Environment Plan

Stromlo-1 exploration drilling program

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Environment plan summary statement

EP summary material requirement	Relevant section of EP containing EP summary material
The location of the activity	Section 2.0
A description of the receiving environment	Section 4.0 Appendix 7-3
A description of the activity	Section 2.0
Details of the environmental impacts and risks	Sections 6.0, 7.0, 8.0 Appendix 7-5
The control measures for planned and unplanned activities	Sections 6.0, 7.0, 8.0, 9.0 Appendix 9-1
The arrangements for ongoing monitoring of the titleholder's environmental performance	Sections 9.0
Response arrangements in the oil pollution emergency plan	Sections 7.0, 8.0 Appendices 7-4, 9-1, 9-2
Consultation already undertaken and plans for ongoing consultation	Section 3.0, 9.0 Appendices 3-1, 3-2
Details of the titleholders nominated liaison person for the activity	Section 1.0

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1.0 Introduction

1.1 Background

In June 2017, Equinor Australia B.V. became the operator and 100% equity owner of offshore exploration permit EPP 39 located in the Great Australian Bight. The exploration permit obliges the titleholder to complete stages of exploration work in defined periods. In accordance with the permit obligations, Equinor Australia B.V. is planning to drill one exploration well (Stromlo-1).

1.2 Proponent

Equinor Australia B.V. is a subsidiary of Equinor ASA, an international energy company supplying more than 170 million people with energy every day. We are headquartered in Norway and have a presence in more than 30 countries around the world. Since 1972 we have explored, developed and produced oil and gas on the Norwegian continental shelf. From the early 1990s, we have built a global business, with key positions in Europe, Africa, North America and Brazil. Equinor ASA has also developed a portfolio of new energy solutions- currently delivering wind power to 650,000 British households.

At Equinor ASA, the way we deliver is as important as what we deliver. The Equinor ASA Book summarises important aspects of our identity. It is a store of knowledge and learning that we have built up since the early days of our company and is the core of our Management System. It describes the most important requirements for the company and defines a common framework for the way we work. It sets standards for our behaviour, our performance and our leadership, and it points us in the right direction for success tomorrow.

Titleholder	Equinor Australia B.V.
ACN number	165 559 642
Business address	Level 15, 123 St Georges Terrace, Perth, Western Australia 6000, Australia
Liaison person	Audun Sande, Safety and Sustainability Leader gabproject@equinor.com
Liaison person phone number	0413 901 235

Equinor Australia B.V. will notify National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA) in writing in the event of a change of the titleholder, the nominated liaison person and/or contact details of the titleholder or liaison person.

1.3 Scope of this Environment Plan

The project will be conducted in accordance with all applicable legislation and regulations, including the requirements of the *Offshore Petroleum and Greenhouse Gas Storage (OPGGS) Act 2006* and the OPGGS (Environment) Regulations (OPGGS(E)) and the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act); both acts being administered by National Offshore Petroleum Safety and Environmental Management Authority in this context. This Environment plan applies to a defined “petroleum activity”, as defined in the OPGGS(E). For this project, the petroleum activity is defined as:

Any works undertaken within the Operational Area from the time the mobile offshore drilling unit (MODU) arrives at the well location, until the time the mobile offshore drilling unit demobilises from the well location.

Activities associated with the establishment and operation of a shore base to support the project are regulated by the South Australian Government and are being managed by Equinor Australia B.V. accordingly. These activities are outside the scope of the EP.

This Environment Plan has been prepared by Equinor Australia B.V. in accordance with Division 2.3 of the OPGGS(E) for assessment by National Offshore Petroleum Safety and Environmental Management Authority. In brief, the Environment Plan provides a description of:

- the exploration drilling activity
- environmental legislation relevant to the activity
- engagement and consultation
- the environment that may be affected
- environmental impacts and risks
- mitigation and management measures
- environmental objectives and performance standards
- implementation strategy, including emergency response plans.

Once accepted, the Environment Plan will need to be revised if there are any material changes to the context of the accepted EP. Triggers for such a revision are described in Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009 (OPGGS(E) Regulations) 17 and 18.

1.4 Purpose of this Environment Plan

The purpose of this environment plan is to identify our planned petroleum activity's impacts on, and risks to, the receiving environment. The plan also sets out control measures to reduce the identified environmental impacts and risks of the activity and describes how and to what standard of performance those measures will be implemented throughout the life of the activity including in emergency situations.

1.5 Environment Plan approach

Equinor Australia B.V. has approached the Environment Plan in multiple phases to support a rigorous approach to environmental management (Figure 1.1). This approach includes:

- definition of the geographic and activity scope of assessment and identification of scoping factors, including stakeholder concerns and legal requirements.
- a systematic approach to the assessment and management of environmental impacts and risks, including those associated with planned activities and unplanned events.
- development of an implementation strategy to enable the continued and effective delivery of the control measures.

Stakeholder engagement and consultation has been integral to this approach and has been undertaken throughout the development of this EP. Engagement and consultation will continue until the project is complete.

Information about the approach taken for each stage of the Environment Plan is provided in the relevant section of the document as indicated in Figure 1.1.

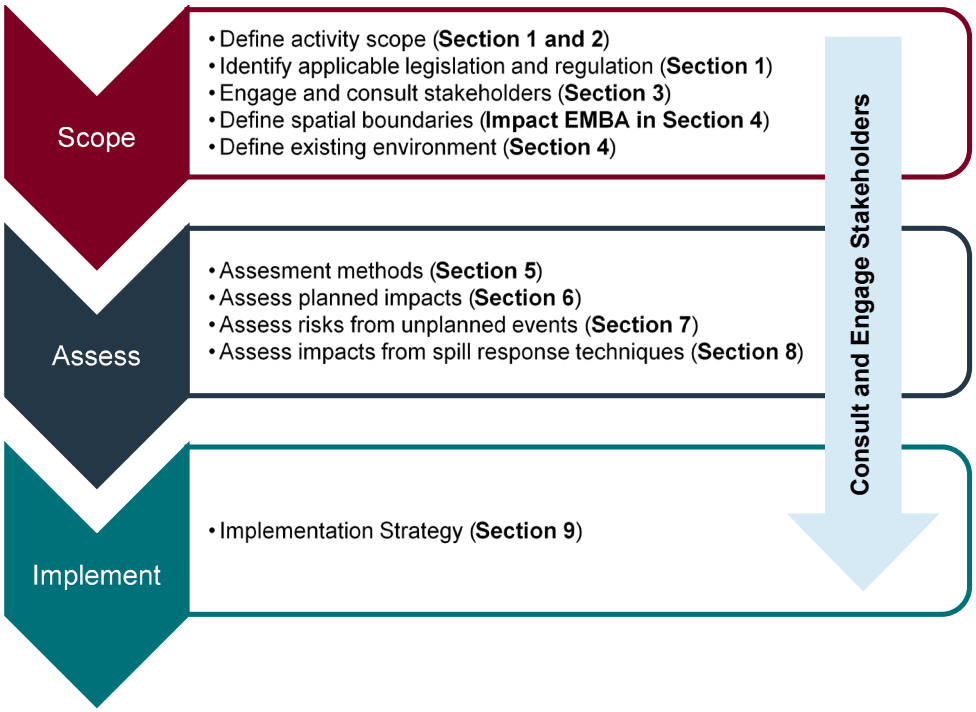


Figure 1.1 Environment Plan approach

1.6 Appropriateness of our approach

Equinor Australia B.V. considers its approach to be appropriate to the nature and scale of the activity because:

- The requirements of relevant legislation and regulations have been met.
- Relevant guidance from National Offshore Petroleum Safety and Environmental Management Authority has been considered.
- The exploration activity is being undertaken in an area identified jointly by the Commonwealth and South Australian governments as appropriate for oil and gas exploration.
- Equinor Australia B.V. has contributed to extensive scientific research studies which have significantly improved the understanding of deep-water environmental values of the Great Australian Bight (GAB) and the findings have been incorporated into the EP.
- Extensive oil spill fate and trajectory modelling, muds and cuttings dispersion modelling and noise modelling was undertaken to better understand the extent of environmental risks and impacts.
- Wherever uncertainty was encountered, for example lack of scientific surety of effect levels, selecting input parameters for modelling, variable occurrence of fauna; this was addressed by using conservative assumptions and assessments which in general overestimates the levels of predicted effect on the environment.
- Extensive and long-term stakeholder engagement and consultation across southern Australia was conducted and is ongoing and the inputs from relevant persons have been given due consideration and where merited have been used to refine the management of environmental and socio-economic impacts and risks.
- A draft of this environment plan was voluntarily published for public comment to improve transparency in the assessment process. This facilitated a broader consideration of stakeholder comments.
- Our extensive work with state emergency response agencies is leading to a more cohesive oil spill response network across Western Australia (WA), South Australia (SA), Victoria (VIC), Tasmania (TAS) and New South Wales (NSW), which will be of lasting benefit to the nation, for example in the event of a vessel grounding or collision.

1.7 Legislative framework

The planned drilling activity is located in Commonwealth waters off the South Australian coast. Petroleum activities undertaken in this area are regulated under Commonwealth legislation; primarily under the *Offshore Petroleum and Greenhouse Gas Storage Act 2006* (OPGGS Act) and associated regulations. In accordance with Regulation 13(4) of the OPGGS(E), this section describes the requirements including Commonwealth and state legislation, international agreements and other relevant guidelines and codes of practice. Applicable legislation is summarised in Appendix 1-1.

1.7.1 Ecologically sustainable development

The Australian Government has affirmed its commitment to sustainable development at United Nations conferences on environment and development; notably via the Rio Declaration and Agenda 21 in 1992 and the Johannesburg Declaration at the United Nations 2002 World Summit. Australia reaffirmed its commitment at the summit to promote the integration of the three components of sustainable development – economic development, social development and environmental protection, as interdependent and mutually reinforcing pillars.

Australia developed the National Strategy for Ecologically Sustainable Development (ESD) identifying four national principles. The strategy also identified ways to apply the principles to a range of industry sectors and issues such as climate change, biodiversity conservation, urban development, employment, economic activity, and economic diversity and resilience. OPGGS(E) Regulation 3 states that the objective is to ensure that any petroleum activity or greenhouse gas activity carried out in an offshore area is carried out in a manner consistent with the principles of Ecologically Sustainable Development.

Assessment of this petroleum activity, its potential impacts (positive and negative) and the management measures used to enhance positive and reduce negative impacts will continue to be undertaken in the context of Ecologically Sustainable Development principles. The assessment provided in Sections 6, 7 and 8 demonstrates Equinor Australia B.V.'s responsible approach and understanding of undertaking activities in this environmental and socio-economic setting.

Table 1.1 describes Equinor Australia B.V.'s strategies to ensure how the Stromlo-1 exploration drilling program will be managed to be consistent with the goals and guiding principles of Ecologically Sustainable Development. Sustainability is embedded in Equinor Australia B.V.'s strategy and our Annual Sustainability Report offers an overview of how Equinor Australia B.V. follows up its ambitious sustainability agenda and performance.

Table 1.1 Stromlo-1 Ecologically Sustainable Development strategies

ESD principle	Definition	Strategy
Precautionary principle	Where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.	Manage the project to avoid, wherever practicable, serious or irreversible damage to the environment (Sections 6.0, 7.0 and 8.0). Adopt conservative approaches where there is scientific uncertainty (throughout). Consult and communicate with relevant government, industry and other stakeholders (Section 3.0).
Inter- and intra-generational equity	The present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of present and future generations.	Minimise footprint, emissions and discharges (Sections 6.0, 7.0 and 8.0). Manage the project to avoid, wherever practicable, serious or irreversible damage to the environment (Sections 6.0, 7.0 and 8.0).
Conservation of biological diversity and ecological integrity	The conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making	Minimise the effect on ecosystems, habitats and species identified within the area of planned impacts and in response to emergencies associated with unplanned events (Sections 6.0, 7.0, 8.0 and 9.0).
Improved valuation, pricing and incentive mechanisms	Should be promoted to ensure that the costs of environmental externalities are internalised, and that the polluter bears the costs.	Maintain financial assurance enough to give Equinor Australia B.V. the capacity to meet costs, expenses and liabilities arising in connection with planned activities or unplanned events.

1.7.2 Commonwealth legislation

Appendix 1-1 presents a comprehensive list of Commonwealth legislation (including legislation adopting international conventions) relevant to the environmental management of the project. A brief overview of the main legislation and regulation applicable to the acceptance of this Environment Plan is provided below.

1.7.2.1 *Offshore Petroleum and Greenhouse Gas Storage (OPGGS) Act 2006*

The Act and the associated OPGGS (Environment) Regulations 2009 specify the requirements to manage the environmental impacts of petroleum activities. The Regulations require that an Environment Plan must be accepted by the regulatory authority (National Offshore Petroleum Safety and Environmental Management Authority) prior to commencing the proposed activities. National Offshore Petroleum Safety and Environmental Management Authority guidelines outline the requirements for the content of EPs.

1.7.2.2 *Environment Protection and Biodiversity Conservation Act 1999*

Under Commonwealth government streamlining arrangements, National Offshore Petroleum Safety and Environmental Management Authority's assessment of this Environment Plan provides an appropriate level of consideration of the impacts to matters of national environmental significance (MNES) protected under Part 3 of the *Environment Protection and Biodiversity Conservation Act 1999*. This obviates the requirement to refer the project to the DoEE.

1.7.3 State legislation

The project is located entirely in Commonwealth waters; however, South Australian, Victorian, New South Wales, Western Australian and Tasmanian legislation relevant to emergency response and the environmental values of areas that may be affected by unplanned events is applicable (Appendix 1-1).

1.7.4 International agreements

Australia is signatory to several international environmental protection agreements and conventions which are relevant to the region, these include conventions for protecting migratory birds and other marine fauna (Japan–Australia Migratory Birds Agreement/China–Australia Migratory Birds Agreement/Republic of Korea and Australia Migratory Birds Agreement/ACAP/Bonn), wetlands (Ramsar) and environmental values (International Convention for the Prevention of Pollution from Ships (MARPOL)).

1.8 Environmental policies, guidelines and codes of practice

This section describes the environmental policies, government guidelines and codes of practice relevant to the exploration activity.

1.8.1 Equinor Australia B.V.'s practices and policies

Equinor Australia B.V. strives to be recognised as an industry leader in safety, security and carbon efficiency, and believes that all accidents related to people, environment and assets can be prevented.

Equinor Australia B.V.'s most important document is The Equinor ASA Book which is the core of its Management System and defines a common framework for the way it works. It sets standards for behaviour, delivery and leadership.

Equinor Australia B.V.'s GL0386 – Guideline for Impact Assessment in Projects offers guidance on how to fulfil the requirements for Impact Assessment (IA) in projects (including exploration drilling), as described in Equinor Australia B.V. governing documents FR11 – Sustainability (SU), the work processes described in GL0635 – Environmental management and RM100 – Manage risk. The purpose of the IA process is to help the project manage its risks and improve its social and environmental performance throughout the project life. Close coordination with other project disciplines is required to ensure project management ownership, right timing, cost efficiency and effective risk management.

Other Equinor Australia B.V. policies, practices and guidance relevant to the management of environmental and social impact and risk in this project are referred to where relevant in the EP.

1.8.2 Government guidelines

This Environment Plan is consistent with National Offshore Petroleum Safety and Environmental Management Authority's content requirements (N04750-GN1344, Rev 3, April 2016), which provides advice on National Offshore Petroleum Safety and Environmental Management Authority's interpretation of the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009, to assist titleholders in preparing environment plans.

In addition, National Offshore Petroleum Safety and Environmental Management Authority has published various other relevant guidance notes and information papers which have been considered in the development of this Environment Plan as listed below:

- policies
  - PL0050 – Assessment – Rev 14 – January 2018
  - PL1347 – Environment plan assessment – Rev 6 – April 2017
- guidance notes
  - GN1343 – Petroleum activity – Rev 2 – April 2016
  - GN1344 – Environment plan content requirements – Rev 3 – April 2016
  - GN0166 – ALARP – Rev 6 – June 2015 (this guidance note has been prepared for safety cases but is included here as it provides valuable information for demonstrating As Low As Reasonably Practicable for EPs)
  - GN1488 – Oil Pollution Risk Management – Rev 2 – February 2018
  - GN1735 – Petroleum Activities and Australian Marine Parks (N-04750-GN 1785) – Rev 0 – July 2018
  - GN0926 – Notification and reporting of environmental incidents – Rev 4 – February 2014.
- guidelines
  - GL1721 – Environment plan decision making – Rev 5 – June 2018
  - GL1566 – Environment plan summaries – Rev 1 – July 2016
  - GL1691 – End of the operation of an environment plan – Regulation 25A – Rev 1 – October 2016
  - GL1705 – When to submit a proposed revision of an environment plan – Rev 1 – January 2017
  - GL1629 – Decision-making guideline – Criterion-10A(g) Consultation requirements (Draft for Consultation) – Rev 1 – November 2016
  - GL1381 – Financial Assurance for Petroleum Titles (N-04750) – Rev 6 – September 2017
- information papers
  - IP1349 – Operational and scientific monitoring programs – Rev 2 – March 2016
  - IP1411 – Consultation requirements under the OPGGS Environment Regulations 2009 – Rev 2 – December 2014.
- regulatory bulletins
  - Regulatory bulletin #2 – Clarifying statutory requirements and good practice consultation – November 2019.

1.8.3 Industry codes of practice

In Australia, the petroleum exploration and production industry operates within an industry code of practice developed by the Australian Petroleum Production and Exploration Association (APPEA) – the APPEA Code of Environmental Practice 2008 (CoEP). This code provides guidelines for activities that are not formally regulated and have evolved from the collective knowledge and experience of the oil and gas industry, both nationally and internationally.

As an Australian Petroleum Production and Exploration Association member, Equinor Australia B.V. adheres to the APPEA Code of Environmental Practice when undertaking petroleum exploration and production activities in Australia and keeps abreast of up-to-date government and industry environmental policies and regulation through its active participation in the Australian Petroleum Production and Exploration Association Environmental Affairs Committee.

Several other industry codes of practice are used to guide various planning aspects of the project, such as the drilling program itself and oil spill response strategies. Equinor Australia B.V. has considered environmental and social standards and practices generally accepted in the international oil and gas industry – including those from the:

- American Petroleum Institute (API)
- International Association of Oil & Gas Producers (IOGP) Environmental Management in Oil and Gas Exploration and Production 1997
- Global oil and gas industry association for environmental and social issues (IPIECA)
- International Association of Drilling Contractors (IADC)
- International Well Control Forum (IWCF).

Standards and guidelines specific to management of various drilling issues are referenced throughout Sections 6, 7 and 8. Table 1.2 summarises the industry codes of practice or guidelines regarding environmental management for offshore drilling. None of these codes of practice or guidelines have legislative force in Australia, but are considered to represent environmental best practice and have been considered in the preparation of this EP.

Table 1.2 Guidelines, Standards and Codes of Practice

Organisation (date)	Document
Australian Maritime Safety Authority (2013)	Technical Guideline for the Preparation of Marine Pollution Contingency Plans for Marine and Coastal Facilities, March 2013
Australian Maritime Safety Authority (2019)	National Plan for Maritime Environmental Emergencies (National Plan)
Standards Australia/ Standards New Zealand (2006)	Handbook on Environmental Risk Management – Principles and Process. Third edition. Standards Australia/Standards New Zealand (HB 203:2006)
Australian Petroleum Production and Exploration Association (2008)	Code of Environmental Practice (CoEP)
Australian Petroleum Production and Exploration Association (2017)	Australian Petroleum Production and Exploration Association Stakeholder Consultation and Engagement Principles and Methodology – Working Draft
Commonwealth of Australia (2009)	The National Biofouling Management Guidance for the Petroleum Production and Exploration Industry (DAFF, 2009) provides a generic approach to a biofouling risk assessment and practical information on managing biofouling on hulls and niche areas.
Commonwealth of Australia (2013)	EPBC Act Significant Impact Guidelines 1.1 – Matters of National Environmental Significance
Department of the Environment, Water, Heritage and the Arts (DEWHA) (2005)	Australian National Guidelines for Whale and Dolphin Watching
Department of the Environment, Water, Heritage and the Arts (2008)	EPBC Act Policy statement 2.1 – Interaction between offshore seismic exploration and whales

Organisation (date)	Document
Department of Environment and Energy (2016)	Australian Ballast Water Management Requirements (version 6) provide the mandatory ballast water management requirements and provide information on ballast water pump tests, reporting and exchange calculations.
ESDSC (1992)	National Strategy for Ecologically Sustainable Development
International Standards Organization (ISO)	31000:2009 Risk Management – Principles and Guidelines

1.9 Environmental emergencies

A brief description of the National Plan and state oil spill response plans is provided below, with details in the Oil Pollution Emergency Plan (OPEP).

1.9.1 National Plan

The National Plan for Maritime Environmental Emergencies 2017 (the National Plan) is managed by Australian Maritime Safety Authority and sets out national arrangements, policies and principles for the management of maritime environmental emergencies. It gives administrative effect to Australia's emergency response obligations relating to the:

- International Convention on Oil Pollution Preparedness, Response and Co-operation, 1990 (OPRC)
- Protocol on Preparedness, Response and Co-operation to Pollution Incidents by Hazardous and Noxious Substances, 2000 (OPRC-HNS Protocol)
- International Convention Relating to Intervention on the High Seas in Cases of Oil Pollution Casualties, 1969 (Intervention Convention)
- Articles 198 and 221 of the United Nations Convention on the Law of the Sea, 1982.

1.9.2 State spill response plans

State emergency management plans are largely based on the National Plan and set out local arrangements, policies and principles for the management of maritime environmental emergencies in state waters.

- South Australian Marine Spill Contingency Action Plan (SAMSCAP) – under revision
- Western Australian state Hazard Plan – Marine Environmental Emergencies (MEE)
- Victorian state Maritime Emergencies (non-search and rescue) Plan Part A and B (VSMEP)
- Tasmanian Marine Oil Spill Contingency Plan (TasPlan)
- New South Wales state Waters Marine Oil and Chemical Spill Contingency Plan.

2.0 Activity description

2.1 Activity definition

Equinor Australia B.V. is the sole titleholder of exploration permit 39 (EPP39), located in the Ceduna Sub-basin in Commonwealth waters off southern Australia (Figure 2.1). The figure also shows exploration wells drilled since 1960.

In accordance with the exploration work commitment set out in exploration permit 39, Equinor Australia B.V. plans to spud the Stromlo-1 exploration well in late 2020. The well will be drilled using a mobile offshore drilling unit. The planned duration of the drilling is approximately 60 days. The preferred drilling period is between November and February when weather conditions are more conducive to fast and efficient drilling. A broader activity period has been selected to provide contingency for unexpected delays.

The Environment Plan (EP) validity period for drilling the Stromlo-1 well is between 1 November 2020 and 30 April 2022. Once accepted, Equinor Australia B.V. will be permitted to drill the Stromlo-1 well at any time during this period other than from 1 May to 31 October inclusive, in any year.

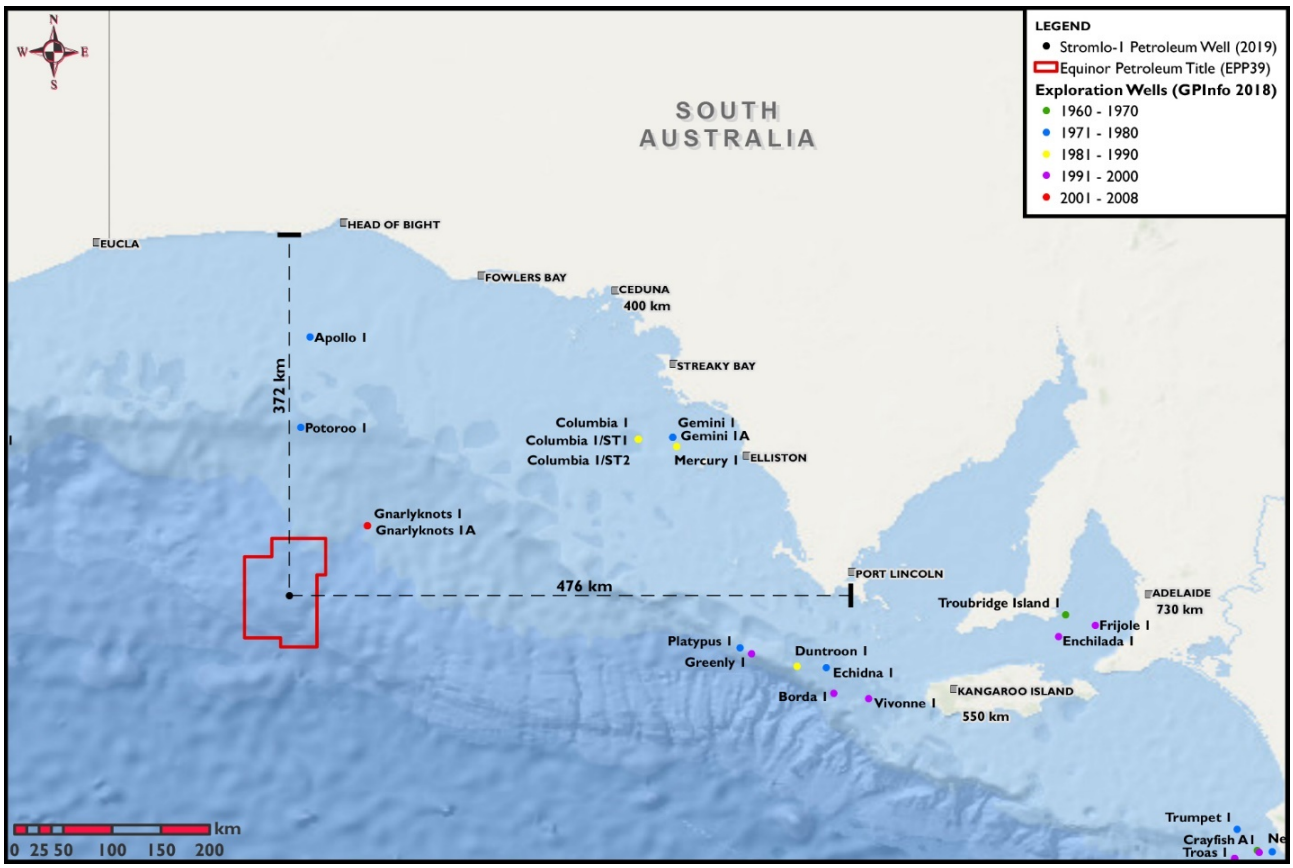


Figure 2.1 Exploration permit 39 and Stromlo-1 well location

A mobile offshore drilling unit (MODU) will be used to drill the well and the drilling program will be supported by three vessels and two helicopters. The support vessels will resupply the mobile offshore drilling unit via a supply base in Port Adelaide and will be refuelled in port. The helicopter base will be at the Ceduna airport.

After all the permits, regulatory approvals and authorisations have been obtained, and contracts are in place, the mobile offshore drilling unit will be mobilised to the drilling location. A 500 m radius Petroleum Safety Zone (PSZ) will be gazetted around the mobile offshore drilling unit after it reaches location and will be formally advised to mariners. Once the mobile offshore drilling unit is in place, it will take on ballast to increase its stability and will use Dynamic Positioning (DP) to maintain a fixed position at the drilling location.

2.1.1 Operational area

The mobile offshore drilling unit, support vessels and helicopters will be conducting a “petroleum activity” for the purposes of the Environment Plan whilst within the Operational Area which is defined by a 2 NM radius around the mobile offshore drilling unit location. This area encompasses the 500 m Petroleum Safety Zone and the surrounding area where support vessels engaged in the activity may be present during the activity.

When the mobile offshore drilling unit and vessels are outside the Operational Area (e.g. transiting to or from location) and remain within Australian waters, they come under the regulatory jurisdiction of Australian Maritime Safety Authority under the *Navigation Act 2012* (Cth). Accordingly, this Environment Plan (and associated Oil pollution emergency plan) does not cover activities performed by the support vessels while outside the Operational Area. The Environment Plan and OPEP does cover oil spill response activities outside the Operational Area.

At all times, helicopter operations come under the regulatory jurisdiction of the Civil Aviation Safety Authority (CASA) under the *Air Navigation Act 1920* (Cth), Civil Aviation Safety Regulations 1998 and the Federal Aviation Regulations.

2.2 Location

The Stromlo-1 well location lies approximately 730 km west of Adelaide, 400 km south-west of Ceduna and 372 km from the Australian coast at its closest point (Figure 2.1). The water depth at the location is approximately 2240 m, and the current plan is to drill through around 2700 m of sediments before reaching the target depth. The notional coordinates of the well are shown in Table 2.1.

Table 2.1 Stromlo-1 location

Coordinate system information	
Datum	WGS 84
Projection	UTM zone: 52S
Surface location	
Latitude	34° 56′ 21.47″ S
Longitude	130° 39′ 44.61″ E
Northing	6132427.1 m
Easting	651815.4 m

2.3 Prospectivity

Equinor Australia B.V.’s understanding of the hydrocarbon prospectivity of Stromlo prospect is based on geological records from approximately 50 years of exploration in the area, including multiple 2D and 3D seismic surveys and 13 exploration wells drilled safely in the Great Australian Bight (Figure 2.1, Table 2.2 and Table 2.3). The closest well, Gnarlyknots-1, was drilled by Woodside in 2003 in a water depth of 1316 m. No significant hydrocarbon reserves have yet been discovered in the Ceduna Sub-basin; however, geological modelling indicates a petroleum system being present further offshore in the Stromlo area. The most probable source rock for hydrocarbons will be the Cenomanian-Turonian marine shale at the base Tiger sequence at the Stromlo-1 location, as encountered by dredge samples further west in the neighbouring Eyre Sub-basin.

Table 2.2 Stromlo prospect details

Well name	Stromlo-1
Permit	exploration permit 39
Basin	Ceduna Sub-basin
Operator	Equinor Australia B.V.
Water depth (m MSL)	2239
Top reservoir depth (m TVD MSL)	4941
Base reservoir depth (m TVD MSL)	5086
Planned TD depth (m TVD MSL)	5186

Table 2.3 Great Australian Bight offshore exploration wells

Well (year and operator)	Distance from Stromlo-1
Gnarlyknots-1/1A (2003, Woodside Energy)	98 km north-east
Borda-1 (1993, BHP)	468 km south-east
Greenly-1 (1993, BHP)	394 km south-east
Vivonne-1 (1993, BHP)	498 km south-east
Duntroon-1 (1986, Outback Oil and BP p.l.c.)	433 km south-east
Colombia-1/ST1/ST2 (1982, Occidental)	339 km north-east
Mercury-1 (1982, Occidental)	366 km north-east
Jerboa-1 (1980, Esso Expl. and Production Australia and Hematite Petroleum)	323 km north-west
Apollo-1 (1975, Outback Oil)	267 km north
Gemini-1/1A (1975, Outback Oil)	356 km north-east
Potoroo-1 (1975, Shell)	172 km north
Echidna-1 (1972, Shell)	456 km south-east
Platypus-1 (1972, Shell)	383 km south-east

Given that Stromlo-1 is an exploratory well, the exact nature of the hydrocarbons that may be encountered is unknown. As none of the wells drilled previously in the area encountered hydrocarbons, there are no hydrocarbons to be assayed to determine likely oil characteristics of this well. Therefore, petroleum fluid properties have been predicted using Equinor Australia B.V.'s petroleum system analysis approach. The oil type is predicted to be similar to the Statfjord C oil in the North Sea (Table 2.4).

Table 2.4 Summary of predicted hydrocarbon properties

Property	Stromlo-1
Hydrocarbon type	Crude Oil (Statfjord C Blend)
Density at 15 °C (g/ccc)	0.830
API (°)	38.8
Viscosity at 20 °C (cSt)	5
Total Sulphur (% wt)	0.19
Aromatics (% wt)	23.3
Asphaltenes (% wt)	0.1

Property	Stromlo-1
Paraffins (% wt)	30.2
Naphthenes (%wt)	46.5
Aromatics (% wt)	23.3
Nickel (ppm)	0.9
Vanadium (ppm)	1.1
Wax (% wt)	4.8

2.4 Metocean conditions

While the Great Australian Bight is a large area extending thousands of kilometres across southern Australia, Equinor Australia B.V. has developed a solid understanding of its oceanographic processes and forces.

Equinor Australia B.V. partnered in an oceanographic measurement program from November 2011 to November 2013 in the Great Australian Bight. The program consisted of installing five moorings (including one in exploration permit 39) to measure oceanographic conditions, sound, waves, currents and meteorological parameters. The results from this survey were later matched with existing meteorological and oceanographic (metocean) databases for the area (e.g. GROW2012, ECMWF, ROMS and WW3) and a predictive model of the meteorological and oceanographic conditions was developed.

In addition, Equinor Australia B.V. part-funded the large Great Australian Bight Research Program from 2013–2017. This was a collaboration between Commonwealth Scientific and Industrial Research Organisation, South Australian Research and Development Institute, BP p.l.c., the University of Adelaide and Flinders University. The program delivered one of the largest whole-of-ecosystem studies ever undertaken in Australia. Part of the project was to develop deep-sea and shelf-focused hydrodynamic models to provide an in-depth understanding of the physical processes which govern the ocean circulation and dynamics. The models were validated using data collected from meteorological and oceanographic measurements in the Great Australian Bight.

The Great Australian Bight area is a mixed wind-wave and oceanic swell-wave environment in which the sea state changes often. The waves are influenced by heavy swell in the region, and there are rarely calm sea states in the region. The annual mean wave height is around 3 m. More details on the meteorological and oceanographic conditions of Ceduna sub-basin are included in Section 4.2.

A summary of the meteorological and oceanographic data for the Ceduna Sub-basin is included in Table 2.5, where a comparison is made to similar settings worldwide where Equinor Australia B.V. has extensive drilling experience. The Norwegian Sea, the Barents Sea and the east coast of Canada are other harsh-environment settings that share some similarities with the Ceduna Sub-basin, and Equinor Australia B.V. will bring its experience in these areas to the Stromlo-1 drilling program.

Table 2.5 Metocean and sea-state data for Ceduna Sub-basin compared with other exploration basins worldwide where Equinor Australia B.V. has drilled successfully

Parameter		Ceduna Sub-basin	Norwegian sea	Barents Sea	Canada east coast	Brazil
Wind speed (m/s)	100-year, 1 hr mean at 10 m	27.5	34	32.5	39	22
	Mean, 1 hr mean at 10 m	7.6	8.7	8.5	9.1	7.3
Significant wave height (m)	100 year	12.2	16.7	15.5	15.5	9.2
	100-year associated Tp (s)	14.9	18.5	18.5	16	16
	Annual mean	3	2.7	2.5	3.1	2
	Monthly mean – winter	3.6	3.9	3.4	4.5	2.3
	Monthly mean – summer	2.5	1.5	1.5	1.8	1.6

Parameter		Ceduna Sub-basin	Norwegian sea	Barents Sea	Canada east coast	Brazil
Extreme wave height (m)	100 year maximum	23	31	28.8	29.7	17.7
	10,000 year maximum	28.7	39.6	36.8	35.4	25.6
Current speed (cm)	100-year surface	113	132	138	35.4	25.6
	100-year mid-water	52	62	75	43	40
	100-year 3 m above seabed	30	57	52	45	30

2.5 Mobile offshore drilling unit

The mobile offshore drilling unit (MODU) will be contracted according to Equinor Australia B.V.'s requirements and guidelines. Equinor Australia B.V.'s rig selection process is defined in governing documents including TR2217 Ship and Maritime Requirements, TR2396 Station Keeping Systems and GL1049 Mobile Offshore Drilling Units, which detail the technical and functional requirements for the mobile offshore drilling unit within Equinor Australia B.V. Rig operations are subject to governing rules and regulations as imposed by the coastal state authorities, the flag state's authorities and classification society. After all the permits, regulatory approvals and authorisations have been obtained, the mobile offshore drilling unit will be mobilised to the drilling location.

Once the mobile offshore drilling unit is in place, positioning and stability operations will occur. This will include ballasting to increase the stability of the mobile offshore drilling unit and implementation of the dynamic positioning system.

The mobile offshore drilling unit will use dynamic positioning to maintain its position over the drilling location. The thrusters allow the mobile offshore drilling unit to maintain a fixed position using a computerised positioning system, to move slightly away from the drilling location during certain operations or propel the mobile offshore drilling unit through the water.

Seabed acoustic transponder arrays (dynamically-positioned acoustic transponders) are required to assist with locating and maintaining the mobile offshore drilling unit's position relative to the well. Transponder arrays are typically secured by concrete mooring weights sitting on the seabed in the vicinity of the well head. They will be removed by the remotely operated vehicle (ROV) at the completion of drilling operations.

Equinor Australia B.V.'s drilling team will bring lessons-learned from previous campaigns and comply with international standards to ensure the Stromlo-1 well is drilled safely. It should be emphasised that Equinor Australia B.V. always requires a thorough understanding of the physical environment prior to planning of offshore activities. Any plan shall always consider the local specific conditions (normal and extreme metocean conditions at the location) and solutions shall be robust in order to ensure safe and efficient operations.

For drilling at Stromlo-1, Equinor Australia B.V. will comply with principles in ISO requirements for offshore structures. General requirements for offshore structures are provided in ISO 19900 /1/ while requirements specific for mobile offshore units are provided in ISO 19905-3 /2/. A key principle in these standards is that all hazardous events that can be reasonably foreseen shall be characterised and evaluated. One type of hazardous event defined in ISO 19900 is an "extreme environmental event" which typically is an event with return period in the order of once per 100 years.

In order to verify the design or suitability of a rig, the ISO standards define four categories of "limit states". A limit state design verification ensures, in terms of reliability, that a structure has adequate structural integrity to operate safely in a region. The four limit states are:

- Ultimate Limit State (ULS)
- Accidental Limit State (ALS)
- Serviceability Limit State (SLS)
- Fatigue Limit State (FLS).

The Ultimate Limit State requirements relate to the mobile offshore drilling unit when in “survival” mode (the marine drilling riser disconnected) and the rig contractor must demonstrate that the rig will not suffer structural failure of components or loss of static equilibrium (overturning, sinking or capsizing) if exposed to a one in hundred years storm event.

The limits of the Serviceability Limit State requirements are often based on the capability of the connected marine drilling riser on drilling units. Activity Specific Operating Guidelines will be prepared prior to the operations to specify when it must disconnect for survival mode. In setting the Serviceability Limit State criteria, Equinor Australia B.V. has analysed statistics for weather downtime for a wide range of drill ships and semi-submersible rigs at the Stromlo-1 location (Figure 2.2) and concluded there are several options that can give satisfactory operability.

For most offshore operations, the main concern relates to the wave conditions since large and uncontrolled wave induced motions can increase safety risks to personnel and equipment. Equinor Australia B.V. has access to locally recorded metocean data and good quality hindcast data (validated against recorded data). The characteristics of the central Great Australian Bight are described statistically in the Metocean Design Basis for Ceduna. Equinor Australia B.V.’s analyses have identified three critical characteristics of the Great Australian Bight which must be addressed in planning for safe drilling at Stromlo-1:

1. Persistent occurrence of swells.
2. Occurrence of long period waves (>20 s).
3. Combinations of swells and wind seas from different directions

The effect of these characteristics on safe drilling relate to rig motions such as surge, roll and heave whereof the heave motions are expected to be the main concern. Figure 2.2 shows expected operability for a range of rigs and drill ships with this requirement.

Equinor Australia B.V.’s evaluation so far shows that drilling ships can experience resonance effects in lower period waves in beam seas. While a drillship usually will vane towards approaching seas, swells and wind seas approaching from different directions may force the drilling ship to allow beam seas. Another resonance effect can be seen for semi-submersible rigs in longer wave period waves in head seas (Figure 2.3 and Figure 2.4). All of this will be evaluated in more detail (modelled) when selecting a rig for the Stromlo-1 well.

Figure 2.5 shows the rig heave motion characteristics plotted with wave data from the Stromlo-1 location. The figure also shows a contour line representing combinations of Hs (significant wave heights) and Tp (spectral peak periods) which statistically are exceeded once per hundred years. Any rig or drill ship considered for Stromlo-1 must document tolerable motions for all wave combinations along the hundred-year contour.

Equinor Australia B.V.’s department for Marine Structures and Hydrodynamic has world-leading experts on structures and marine hydrodynamics and will assist in rig selections. The suitability of a rig for the Stromlo-1 location will be detailed in the mobile offshore drilling unit safety case for Stromlo-1. The same evaluations are also applicable for a relief well rig.

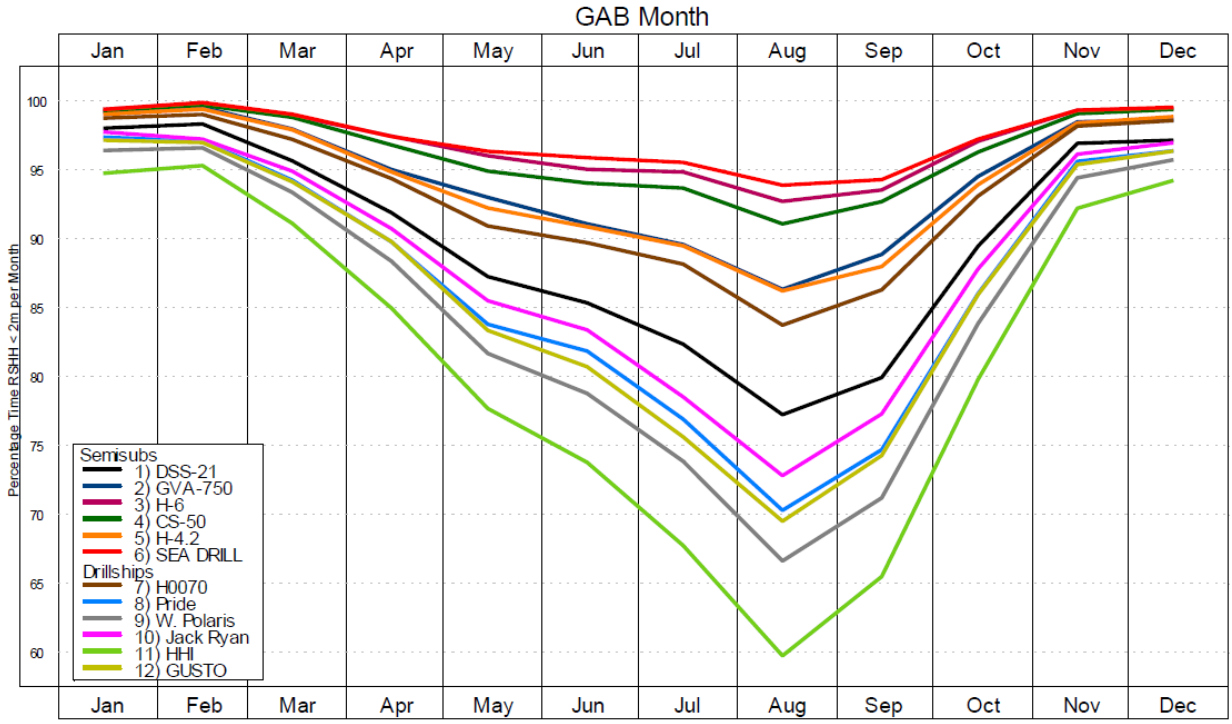


Figure 2.15.2: Average percentage of time each month Rig Significant Heave Height (RSHH) <2m or Rig Most Probable Maximum Heave Height (RMPMHH) < 3.7m

Figure 2.2 Operability of drill ships and semisubmersible rigs at Stromlo-1 with an operational limit in significant heave equal to 2 m based on calculations from Oceanmetrix (BP/Equinor 2012)

For the activity period (November to April), waiting on weather is approximately 20% for the least applicable rigs/ships towards the end of this period (Figure 2.2). Note that significant heave motion depends on both rig-response characteristics and wave spectrum (sea state) and should not be confused with significant wave height.

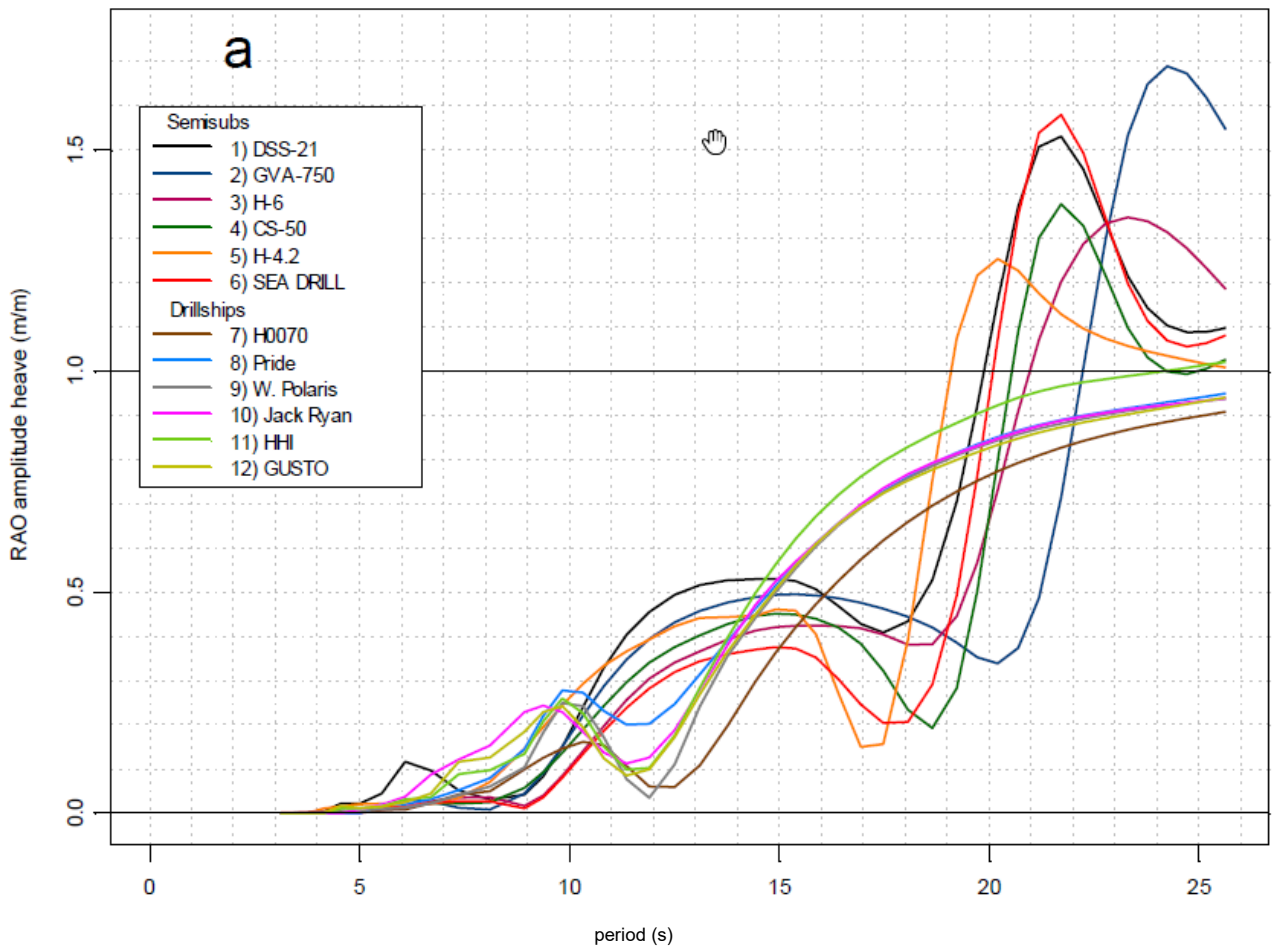


Figure 2.3 Response Amplitude Operators (RAOs) for a wide range of semi-submersible rigs and drill ships (BP 2012) for head seas

The Response Amplitude Operators shows how the heave motion will vary as a function of the wave period (Figure 2.3). A Response Amplitude Operators equal to 1 means that the rig or drill ship will follow the sea surface with the same vertical motions as the sea surface. Response Amplitude Operators closer to zero means that the rig or drill ship will cut through the waves with limited vertical motion. Response Amplitude Operators above 1 means that resonance effect make the rig or drill ship moves more vertically than the surrounding waves. It can be seen that semi-submersible rigs will experience resonance effects for wave periods above 19 to 20 seconds. Drill ships will not experience resonance effects in head seas.

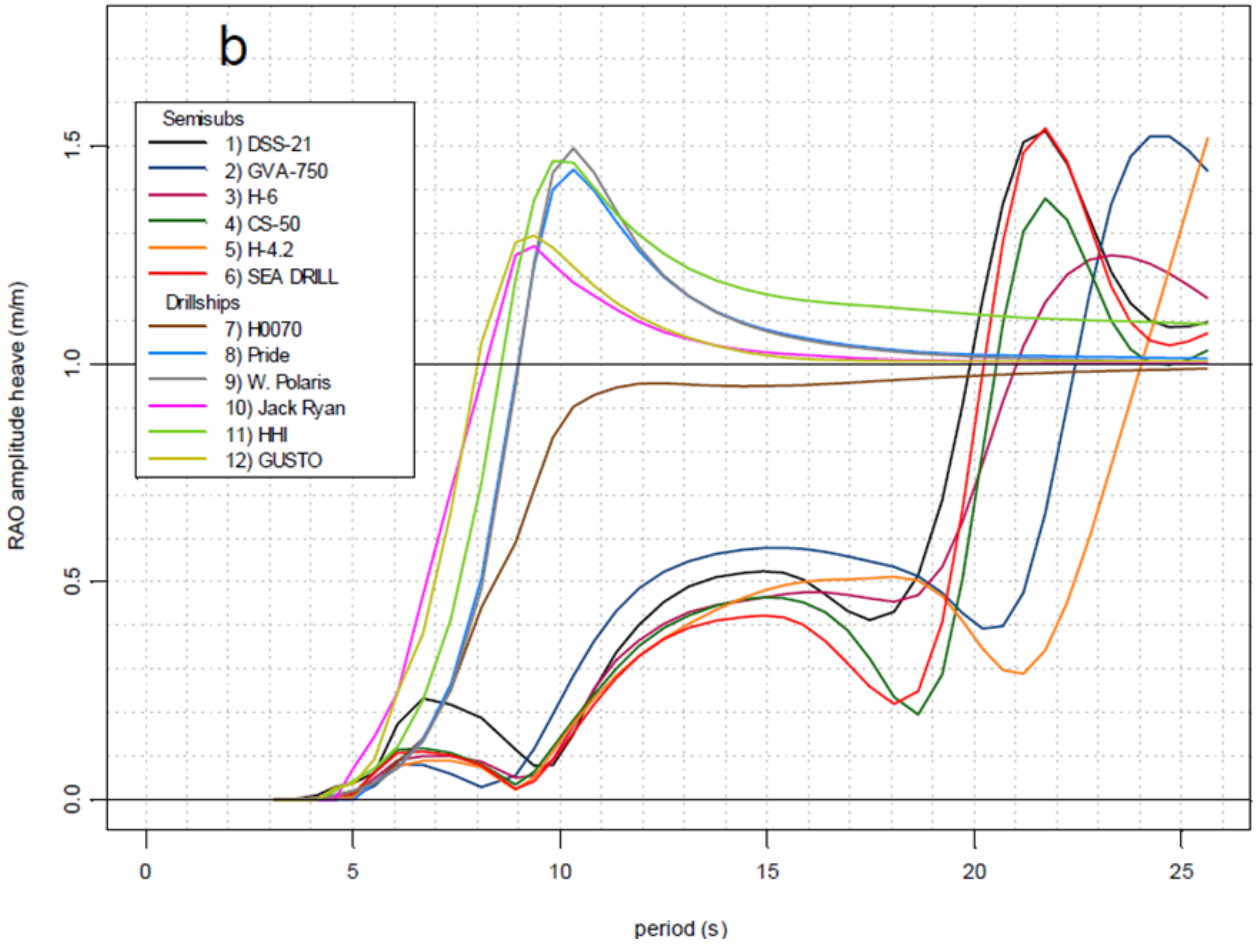


Figure 2.4 Response Amplitude Operators in heave for a wide range of semi-submersible rigs and drill ships when exposed to beam seas (BP 2012)

It can be seen that drill-ships will experience resonance effects for waves perpendicular to the hull with periods in the range 8–12 seconds in Figure 2.4. A drill ship will usually operate with the bow against incoming seas but simultaneous occurrence of swells from one direction and wind seas from another can potentially cause large heave motions. For semi-submersible rigs Response Amplitude Operators in beam seas are similar to Response Amplitude Operators in head seas (Figure 2.3).

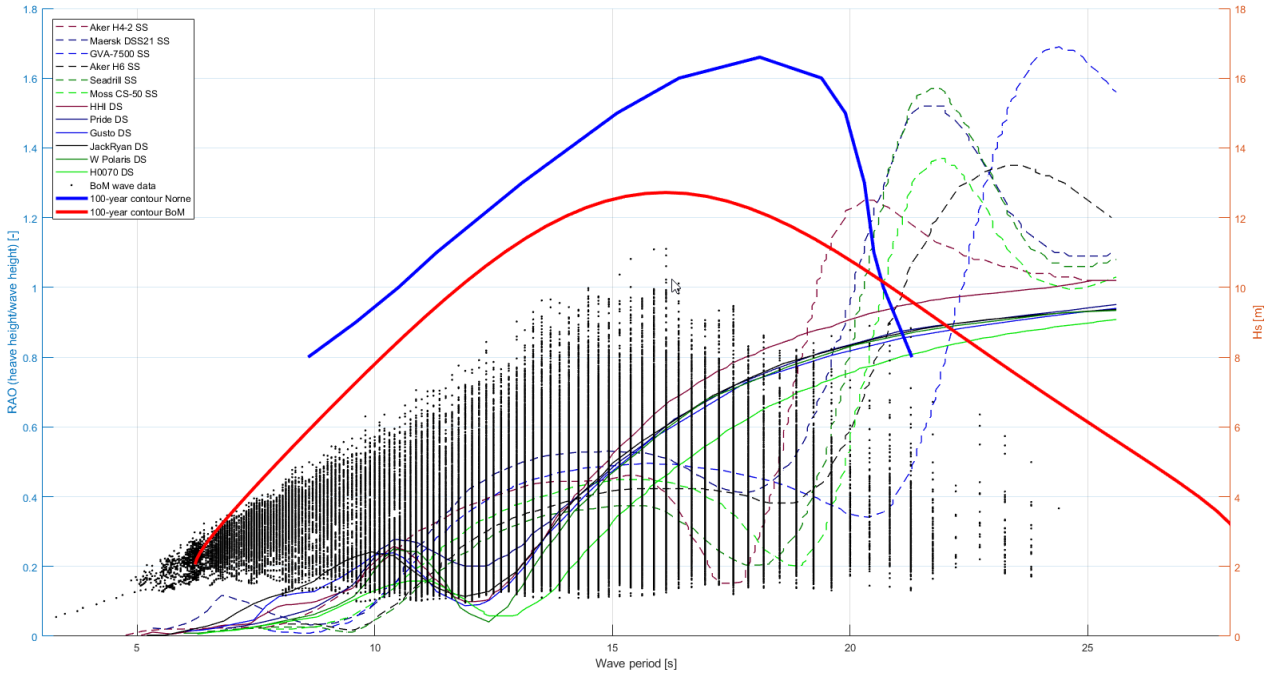


Figure 2.5 Response Amplitude Operators for drill ships and semi-submersible rigs in head seas plotted on top of wave data from the Stromlo-1 location support operations

The data points, shown as black dots in Figure 2.5, shows combinations of significant wave height (Hs) and Spectral Peak period (Tp) that has occurred within the time frame 1979 to 2018. The red solid line is a hundred year contour line calculated by Equinor Australia B.V. based on the Bureau of Metrology (BoM) dataset for the Stromlo-1 location. The contour line represents combinations of Hs and Tp that statistically are exceeded once per hundred years. Offshore structures are typically required to resist actions and actions effects (e.g. motions) that may occur in the 100-year sea states. As a comparison, a hundred-year contour line (solid blue) from one of the most severe locations in the Norwegian Sea (Norne) is added to the plot. While extreme wave heights are much higher in the Norwegian Sea than in GAB, there are occurrence of long period waves in the Great Australian Bight outside the hundred-year compared to the Norwegian Sea.

2.6 Support operations

2.6.1 Support vessels

Three dynamically positioned support vessels will be used throughout the drilling program, with a maximum of two support vessels present near the mobile offshore drilling unit throughout the drilling. In general, one will be on standby within 500 m of the mobile offshore drilling unit, one will be transiting to Port Adelaide, and one will be alongside or returning from Port Adelaide.

The fleet will be dimensioned and selected to ensure they can efficiently fulfil the following functions:

- supply food, fuel and bulk powders, drilling fluid and drilling materials
- collect waste
- assist in emergency response situations
- monitor the 500 m radius Petroleum Safety Zone around the mobile offshore drilling unit and intercept errant vessels.

Initial mobilisation of crew to the support vessels will be via port call. Typically, crews will be changed every 28 days and will be carried out alongside in port. The support vessel fleet will refuel in port.

Table 2.6 Summary details of typical support vessels

Feature	Particulars
Dimensions	
Length	Three support vessels of 60–120 m
DP system	Class 2 with two main thrusters, one bow-thruster and one azimuthal thruster
Power generation	2–4 main engines, with a total power in the range of 15–25 MW
Transit speed	10–16 knots
Persons on board	10–30 personnel
Storage (typical example)	
Cargo deck area	1000 m^2
Fuel oil	1350 m^3
Ballast Water	2737 m^3
Drill water	2065 m^3
Dry bulk tanks	300 m^3
Freshwater	893 m^3
Liquid mud	1050 m^3
Brine	1050 m^3
Base oil	140 m^3
Pumping rates (typical example)	
Fuel oil	2 × 100 m^3/hr at 9 bar, approx.
Drill water	2 × 100 m^3/hr at 9.25 bar, approx.
Liquid mud	2 × 75 m^3/hr at 24 bar approx.
Base oil	2 × 100 m^3/hr at 90 m, approx.
Environmental equipment (typical example)	
Oily water separator	1 × 1 m^3/hr c/w 15 ppm alarm
Water maker	1 × 10 m^3/day, approx., reverse osmosis
Sewage treatment plant	1 × 60 men, evac or equal

2.6.2 Helicopters

Ceduna will be the main base for Equinor Australia B.V.'s helicopter operations in support of the Stromlo-1 drilling program. The type of helicopter to service the mobile offshore drilling unit will be the Sikorsky S-92 or similar. There will usually be one return flight each day with extra flights as required to support the activity.

In addition to the existing helicopter refuelling facilities in Ceduna, helicopter refuelling will take place on the mobile offshore drilling unit. Refuelling will be undertaken in accordance with mobile offshore drilling unit-specific procedures. The mobile offshore drilling unit will have a weather monitoring station on board to enable a forecasting service for informing aviation activities.

2.7 Drilling program

2.7.1 Well design and drilling methodology

Several activities were conducted to support a safe and compliant design of the Stromlo-1 well. In 2013, Equinor Australia B.V. funded a geotechnical investigation survey in the deeper waters of the Great Australian Bight (including within exploration permit 39) to investigate the soil and seabed state of the area. A geohazard analysis was performed on a high-resolution 3D seismic dataset, to reduce the risk of shallow gas in the overburden. No anomalies were found at the well location.

The detailed well design will be finalised in the Well Operations Management Plan (WOMP) for the Stromlo-1 well, which is to be accepted by National Offshore Petroleum Safety and Environmental Management Authority prior to spud.

A preliminary well design and casing schematic, showing the interval and casing details for each hole section is shown in Figure 2.6.

The Stromlo-1 well will spud with a 42” diameter hole being drilled riserless with sea water and high-viscosity sweeps (sea water viscosified by the addition of bentonite clay or polymer). Cuttings generated during top hole drilling will be disposed of directly to the seabed. Upon reaching the section Total Depth (TD) of approximately 96 m below the seabed, the contents of the hole will be displaced with a weighted and inhibited mud (containing bentonite or polymer) prior to running a 36” conductor casing and the well head housing. The conductor casing will then be cemented in place as a safety barrier. Some cement may be discharged to the seabed as an overflow from the conductor cementing operations.

After cementing, a 26” surface hole will be drilled riserless using sea water and high-viscosity sweeps, during which cuttings and muds will be discharged directly to the seabed. At this section TD of about 3150 m, a weighted and inhibited mud (containing bentonite or polymer) will be spotted in the open hole. Then, a 20” surface casing string, with high-pressure sub-sea well head, will be run in hole and cemented in place. Again, it is likely that some cement will be discharged to the seabed as an overflow from the surface casing cementing operations. The bottom of the hole will still be approximately 1750 m above the target hydrocarbon bearing zone.

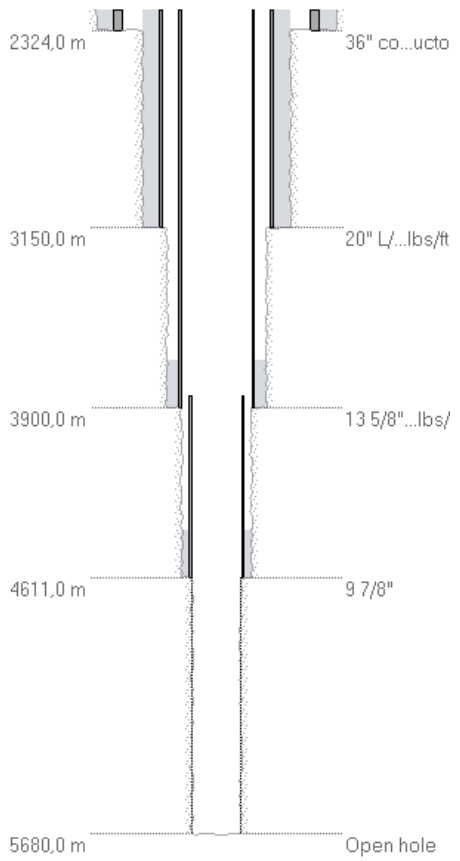
A blowout preventer (BOP) will then be installed on top of the sub-sea well head and a marine riser run from the blowout preventer to the drill floor. The marine riser will provide a closed conduit for the drilling fluid and cuttings to return to the surface while drilling the lower sections of the well. The mud and cuttings return system also allows the effective management and treatment of the cutting and reuse of the muds.

The next section will be a 16” hole. This section will be drilled to the planned section TD using a synthetic-based mud (SBM) system. A 13⅝” casing will then be run to bottom and cemented in place.

A 12¼” hole section will be drilled using the SBM system to the planned section TD. Then, a 9⅞” liner will be run and cemented in place.

Finally, an 8½” hole section will be drilled to the well TD with the SBM system. Open-hole wireline logging will be performed to measure various geological properties of the well bore to confirm the well stratigraphy.

Regardless of the formation evaluation process, the Stromlo-1 well will then be permanently plugged and decommissioned in situ. Cement plugs will be set in the wellbore in line with the accepted Well Operations Management Plan.



42" section

- 36" conductor ~96 m

26" section

- Drill to site survey depth
- Run and cement 20" casing to seabed

16" section

- Drill to 3900 m in K83.5 formation
- Set 13⅝" shoe in competent formation

12¼" section

- Drill to set 9⅞" shoe ×2 uncertainty above K65 reservoir

8½" section

- Drill to TD
- Perform data acquisition

Figure 2.6 Stromlo-1 well casing schematic

2.7.2 Drilling fluids

Drilling fluids (or muds) will be used during the drilling program to:

- control formation pressures
- create a hydrostatic head to maintain overbalance to the reservoir pressure and prevent blowouts
- increase wellbore stability through mud weight and chemical inhibition
- transport drill cuttings out of the hole to the mobile offshore drilling unit treatment system
- maintain the drill bit and assembly (lubrication, cooling and support)
- Seal permeable formations to prevent formation invasion.

Drilling fluids will be selected through evaluation of the technical, safety and environmental attributes of each fluid in relation to the well design and site conditions. The environmental aspects of assessing various drilling fluids, including muds and additives, will be managed in alignment with Equinor Australia B.V.'s chemical management process which is consistent with the Offshore Chemical Notification Scheme (OCNS). The Offshore Chemical Notification Scheme and Equinor Australia B.V.'s Chemicals Management system (SF 601.01 – Chemicals Management) provide a framework and up-to-date register which ranks the environmental performance of chemicals used in offshore petroleum activities.

A well-specific drilling fluid program will be prepared by the drilling fluids contractor, assessed by Equinor Australia B.V. prior to spud and approved if compliant with Equinor Australia B.V.'s standards, the accepted Well Operations Management Plan and the accepted EP. The drilling fluid program will contain details of the planned fluid composition for each section, well data, drilling fluid related risk assessment, execution plan and procedures. This drilling fluid program will be implemented by the wellsite mud engineers on the mobile offshore drilling unit. The drilling method requires the use of a combination of sea water with high-viscosity sweeps and synthetic oil-based mud (SBM) in various sections of the hole.

The drilling method requires the use of a combination of sea water with high viscosity sweeps and SBM in various sections of the hole (see Table 2.7).

Table 2.7 Summary of the base case drilling methodology for the Stromlo-1 well

Hole size	Cuttings discharge location	Fluid type to drill section
42”	Seabed (riserless)	Sea water with high viscosity sweeps
26”	Seabed (riserless)	Sea water with high viscosity sweeps
16"	Sea surface	SBM
12¼"	Sea surface	SBM
8½"	Sea surface	SBM

The riserless top-hole sections (42” and 26”) will be drilled with sea water and sweeps. High-viscosity sweeps consist of approximately 90% sea water, with the remaining 10% made up of drilling fluid additives that are either inert in the marine environment, are naturally occurring benign materials or are organic polymers that are readily biodegradable in the marine environment. Drilling additives typically include sodium chloride, potassium chloride, bentonite (clay), cellulose polymers, guar gum, barite and calcium carbonate.

Below these sections, there is a greater potential for technical challenges during drilling, and an SBM drilling system will be used for the remaining hole sections. The use of SBM provides significant improvement in wellbore stability, in addition to providing better lubrication and stability across large temperature variations. Seabed temperatures are expected to be very low (~3 °C), but the temperature at the expected total well depth could be around 90 °C.

The preferred base oil systems are aerobically degradable in sea water and have low toxicity.

2.7.2.1 Synthetic based mud (SBM) system

The used SBM contains drill cuttings and is pumped back to the solids control equipment (SCE), on the MODU where the drill cuttings are removed before being pumped back to the pits ready for reuse. The SBM drilling fluids that cannot be reused (i.e. do not meet required drilling fluid properties or are mixed in excess of required volumes) are recovered from the mud pits and returned to the shore base for onshore processing, recycling and/or disposal. The mud pits and associated equipment/infrastructure are cleaned when SBM is no longer required, with wastes returned to shore for disposal.

There are typically several mud pits on the MODU to mix, maintain and store fluids required for drilling activities. The mud pits form part of the drilling fluid circulation system. The mud pits and associated equipment/ infrastructure are cleaned out at the completion of drilling and completions operations.

Wash water and mud residue are normally treated in the rig’s bilge water treatment system with an oily water separator. Treated fluid would only be discharged after it is tested and shown to have oil concentrations of less than 15 ppm by volume. Fluid with over 15 ppm oil contamination by volume will be re-treated or sent to shore for disposal at an approved disposal facility. If the selected rig does not have an adequate bilge water treatment system, the wash water and mud residue will be stored on board and sent to shore for appropriate disposal.

2.7.3 Chemical selection

The Drilling Fluid Program will detail the chemical additives that may be used in the various mud mixtures. In the absence of Australian standards regarding the suitability of chemical additives, the selection of chemicals will be guided by the Offshore Chemical Notification System. The Offshore Chemical Notification Scheme and the Equinor Australia B.V. process (SF 601.01 – Chemical Management) provide a framework and updated register which ranks the environmental performance of chemicals used in offshore petroleum activities and discharged to the environment. The chemical selection will be guided by these two processes to ensure environmental impacts and risks associated with chemical use are managed to a level that is As Low As Reasonably Practicable and acceptable.

The Offshore Chemical Notification Scheme uses the Oslo and Paris Conventions (1998) (OSPAR) Harmonised Mandatory Control System to manage chemical use and discharge. The Harmonised Mandatory Control System was introduced with a view to unifying regulations regarding the use and reduction of the discharge of offshore chemicals across the Oslo and Paris Conventions (1998) signatories. The objective of the Harmonised Mandatory Control System is to protect the marine environment by identifying those chemicals used in offshore oil and gas operations with the potential for causing an adverse environmental impact and restricting their use and discharge to the sea. A series of associated recommendations provide guidance on how to compare the potential environmental impact of different chemicals in order to preferentially select those with low potential for impact while fulfilling other (e.g. technical, health, safety and environment and availability) requirements. This involves the generation of an environmental data set (i.e. toxicity, persistence and bioaccumulation potential) and its evaluation using pre-screening criteria and a decision-support tool called the Chemical Hazard Assessment and Risk Management Model.

In cases where the Chemical Hazard Assessment and Risk Management-ranking is not amenable or applicable (e.g. for inorganic substances), equivalent assessments will be done by Equinor Australia B.V.'s in-house chemical centre in accordance with the Offshore Chemical Notification Scheme guidelines: https://www.cefas.co.uk/cefas-data-hub/offshore-chemical-notification-scheme/hazard-assessment-process/.

Environmental data specified in the harmonised offshore chemical notification format (HOCNF) or equivalent (e.g. as per the European Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) format) will be provided by supplier and used as the basis for assessment.

Equinor Australia B.V.'s governing document SF 601.01 – Chemicals management defines the process for the assessment of the offshore operational use and discharge of chemicals for the project. This governing document shall be applied to all "operational" chemicals which, through their mode of use, are expected to be discharged to sea. This includes chemicals discharged during drilling operations and extends to rig washes, pipe dopes and hydraulic fluids used to control well heads and test blowout preventers. The selection process includes classifying chemicals according to the categories in Table 2.8. Only the green ("Chemicals approved for use") and orange categories ("Chemicals not automatically approved", justification requiring approval) of chemicals below in Table 2.8 will be used in the Stromlo-1 drilling program. Written assessments and approvals will be given through Equinor Australia B.V.'s in-house Chemical Centre working with the local Equinor Australia B.V. Health, safety and environment representative prior to the use of chemicals not automatically approved for use.

Chemicals flagged with a "substitution warning" or "product warning" on the product template will be subject to further assessment and consideration of the magnitude of the risk from the presence of hazardous substances. In cases where equivalent chemicals with better health, safety and environment properties are available and feasible, these shall be used. If suitable alternative chemicals are not available or feasible to use, the local health, safety and environment personnel working with Equinor Australia B.V.'s Chemical Centre will assess the risks and develop mitigation measures to reduce risks to as low as reasonably practicable.

Table 2.8 Chemical classifications

Category	Description	Approval for use
Chemicals approved for use	OCNS registered – ranked Gold or Silver (CHARM*), or E or D (non-CHARM#), with no Substitution Warning or Product Warning	All Gold/Silver/D/E and Pose little or no risk to the environment (PLONOR) chemicals will approved with no further assessment.
	Not OCNS registered but are made entirely of PLONOR chemicals	
Chemicals not automatically approved for use, but may be approved with written assessment and justification	Not OCNS registered or PLONOR chemicals	• For non-registered products a pseudo OCNS assessment using the OCSN methodology for non-CHARM products will be performed, using available toxicity, biodegradation and bioaccumulation data for the whole product or constituents. If a D or E is achieved – no further assessment required. • If a product or substitution warning is in place, or D, E cannot be achieved, then the following will be performed:
	Available environmental data is provided demonstrating OCNS "Gold" or "Silver", or CHARMS "E "or "D" but there is a Substitution Warning or Product Warning	
	OCNS Hazard Quotient white, blue, orange, purple, A, B, C or have product/substitution warning, or those that are not on the OCNS Ranked List of Notified Chemicals	

Category	Description	Approval for use
		– investigation of potential alternatives, with preference for options that are on the OCNS Ranked List of Notified Chemicals (Gold, Silver, or are Group E or D with no substitution or product warning). – further written risk assessment (e.g. document alternatives assessment, additional control measures, technical requirements) of the selected chemical with concurrence from the HSE Lead and Drilling Manager that the environmental risk is acceptable and ALARP
Chemicals not approved for use	OCNS registered and not "Gold" or "Silver" ranked (or E or D) which have Substitution Warnings without justification for use	No chemicals from this category will be used
	Provided testing data indicates the chemicals do not rank OCNS Gold or Silver, or E or D, and/or have a substitution warning with no approved demonstration of justification for use	
	Chemical prohibition list (Equinor Australia B.V.'s TR 1668) including those defined as persistent (or very persistent) or bio accumulative (or very bio accumulative) in TR1011	

*CHARM = chemicals with a colour banded ranking using the CHARM model (Chemical Hazard and Risk Management)
#Non-CHARM = chemicals not applicable to the CHARM model (inorganic substances, hydraulic fluids) are assigned an OCNS grouping, A– E
^PLONOR = (Oslo and Paris Conventions (1998) List of) substances which are considered to Pose Little or No Risk to the Environment
†SDS = Safety Data Sheet
<CAS = Chemical Abstracts Service.

2.7.4 Cuttings and fluids treatment

Consistent with industry practice, all cuttings (rock fragments from the hole) generated during riserless drilling of the 42" and 26" holes will be returned directly to the seabed, where they will be deposited in the vicinity of the well head. The lower hole sections of Stromlo-1, comprising the 16", 12¼" and 8½" sections (plus contingent sections), will be drilled with a marine riser and an SBM recirculating drilling fluid system. Cuttings returns will be treated on board the mobile offshore drilling unit prior to discharge to the sea to minimise environmental harm.

Drill cuttings generated from the well are expected to range from very fine sediments to very coarse particles. Cuttings will be separated from the drilling fluids by the solids control equipment (SCE). The SCE will include shale shakers, cuttings dryers and possibly centrifuges to enable most of the muds to be separated from the drill cuttings.

The fluids returned with the drilled cuttings will initially pass through a shale shaker where most of the mud will be separated from the coarse cuttings. The cuttings with then will be passed through a cuttings dryer, which will further remove SBM residue from the cuttings and possibly centrifuge which remove fine solids. The cuttings are usually discharged below the water line and the recovered mud is recirculated into the fluid system The target during drilling will be to reduce retained oil on cuttings (ROC) to as low as reasonably practicable. Retained Oil on Cuttings will be monitored and not allowed to exceed a running average of 6.9% (by weight on wet cuttings), averaged over the SBM hole sections. In most cases the oil on cuttings level will be considerably less than 6.9%, but this will depend on cuttings' size and formation rock quality. If an average of <6.9% dry wt basis averaged over each section is not achieved, the rate of penetration will be decreased to allow a wider margin of cuttings through the drier.

Samples of SBM being discharged from the cuttings dryer will be taken by the sample catcher and tested by the mud engineer so the quality of overboard discharges is known. If there is an issue with the operational dryer, processing will be switched to the back-up dryer.

No bulk SBM discharges (e.g. tank dumps) will be permitted, with dump valves being locked closed while SBM is in use. Any unused or recovered SBM will be shipped back to port and inspected by the mud systems contractor. If it is subsequently determined that the recovered back-loaded SBM cannot be reconditioned at an onshore treatment facility, the SBM will be disposed of at an authorised, onshore waste management facility.

Table 2.9 represents indicative cuttings and fluid volumes based on the well design for Stromlo-1.

Table 2.9 Estimated volumes of drill cuttings and fluids discharged for Stromlo-1 well

Bore diameter (inches)	Well interval	Cuttings	Mud				Discharge point
		Approximate volume discharged (m^3)	Type	Volume liquids and solids discharged (m^3)	Volume of solids discharged		
					%	m^3	
42	Conductor	91.9	Sea water and sweeps	263.91	3.6	9.54	Seabed
26	Surface hole	266.5	Sea water and sweeps	1193.96	3.1	37.04	Seabed
16*	Intermediate hole	203.4	Synthetic based muds	12.72	17.5	2.23	Sea surface
12.25	Intermediate hole	69.0	Synthetic based muds	3.02	7.9	0.24	Sea surface
8.5	Reservoir section	17.1	Synthetic based muds	0.32	50	0.16	Sea surface
Total		647.9				49.2	

2.7.5 Cementing operations

After the casing has been run, cement will be pumped into the annular space between the casing and the borehole wall to secure the casing and isolate the borehole. Cement will also be used for setting abandonment plugs on completion of drilling.

Cementing chemicals will be selected according to Equinor Australia B.V.'s governing document SF 601.01 – Chemicals Management. The processes for selection and assessment of chemical additives are discussed in Section 2.7.3.

Cement will be mixed as required to ensure minimal wastage. All excess dry cement will be brought onshore for disposal.

Some cement may also be discharged at the seabed during the cementing of the conductor and surface casing strings. The well will use about 200% excess cement when pumping for the conductor and surface casing jobs to account for losses and over-gauge hole conditions and thereby to ensure a good seal.

2.7.6 Well evaluation

To reduce operational risks, no conventional coring, drill stem testing, production testing or flow testing will be performed.

The well will be evaluated using Logging While Drilling (LWD) techniques and mud logging. Additional wireline logging and sampling may be performed based on the results of the LWD evaluations.

2.7.6.1 Wireline logging

Optional wireline evaluation will be undertaken to determine rock and fluid properties of the target zones. A suite of standard wireline logs may be run, including gamma ray, neutron-density, resistivity, sonic, acquisition of pressures and samples, vertical seismic profiling (VSP) and sidewall coring.

2.7.6.2 Vertical seismic profiling

Vertical seismic profiling is typically undertaken over a short duration at the completion of drilling the well as part of the well evaluation program. Vertical seismic profiling sound source arrays are typically smaller (fewer airgun elements) than those used for conventional marine seismic surveys. The vertical seismic profiling source array will comprise up to three air guns with a maximum total volume of 750 cui. It will be positioned at about 5–10 m below water surface. Vertical seismic profiling operations are expected to take 4–8 hours to complete, with 7–9 shots being fired in rapid succession (5–10 seconds between shots); with five to 10-minute breaks between levels. A total of 460 shots may be fired in a 24-hour period.

2.7.7 Plugging and decommissioning the well in situ

After drilling and completion of data acquisition and evaluation programs, the well will be permanently plugged and decommissioned in situ, in accordance with Equinor Australia B.V. practices and the National Offshore Petroleum Safety and Environmental Management Authority-accepted Well Operations Management Plan that will be in place prior to drilling. Plugging and decommissioning procedures will isolate the well and mitigate the risk of a potential release of wellbore fluids (including oil) to the marine environment.

Plugging and decommissioning operations will involve setting a series of cement and mechanical plugs within the wellbore, including plugs above and between any hydrocarbon-bearing intervals, at appropriate barrier depths in the well and at the seabed. These plugs will be tested to confirm their integrity.

Section 572 (3) of the *Offshore Petroleum and Greenhouse Gas Storage Act 2006* relating to removal of property states that a titleholder must remove from the title area all structures, equipment and other property that is not to be used in connection with the operations. This relates to removal of seabed infrastructure at the end of exploration programs, which is considered the “base case”. The ALARP assessment did not support well head removal at the end of the drilling program in such deep water well beyond the areas which are actively trawled and where there is negligible benefit in removing a small piece of hard substrate from an area of soft sediment (Table 6.6).

Given the deep water in the area (>2000 m), Equinor Australia B.V. intends to leave the well head permanently in place after setting the plugs. Cutting and removing the well head is undertaken in some areas to prevent the well head interfering with other maritime activities, particularly commercial trawl fishing; however, the fisheries in this region are limited to depths of <800 m. Leaving the well head in place in >2200 m water depth will not impact other marine users, including trawl fishers. Further, there is negligible benefit in removing the wellhead from an environmental perspective because the area affected is very small in comparison with the area of similar habitat in the Great Australian Bight Marine Park and its presence will not compromise any values of the marine park.

The high cost of removing the wellhead relates to the extra vessel time required for the cutting and removal operations. Equinor Australia B.V. has confirmed with a potential contractor that it would take up to three days to safely remove a wellhead (P90 timing) at this water depth. The additional time and specialist cutting equipment hire would add approximately US$3.5m to the program cost. This is considered grossly disproportionate to the minimal environmental and social benefit to be gained from removal of the wellhead.

A remotely operated vehicle will then be used to retrieve the seabed transponders and associated equipment. The remotely operated vehicle will be equipped with 2D sonar and cameras and will provide a record of the seabed at the drill site before and after operations.

All plugging and decommissioning operations will be conducted in accordance with the Well Operations Management Plan.

2.8 References

BP, 2012. Rig Heave Statistics, Blocks EPP37, 38, 39 and 40, Great Australian Bight – OceanMetriX Ltd.

Equinor, 2017. Ceduna – Great Australian Bight – Metocean Design Basis, MAD-RE2017-012.

ISO 19900. Petroleum and natural gas industries – general requirements for offshore structures (ISO/DIS 19900:2017).

ISO 19905-3. Petroleum and natural gas industries – Site specific assessment of mobile offshore units – Part 3: Floating unit (First edition 2017-10).

3.0 Engagement and consultation

3.1 Community engagement and public comment

This section provides additional context on the extent of our community engagement. It is not assessable and describes a level of engagement going beyond the regulatory consultation with Relevant Persons that is required under the OPGGS(E) Regulations and described in Section 3.2 of this Environment Plan.

3.1.1 Background

Since becoming titleholder and operator of EPP39, we have carried out broad community engagement, which led to the decision to voluntarily publish our draft environment plan for public comment. Detailed information on the public comment process is included in the separate report on Equinor Australia B.V.'s website, Statement of response to public comment. This document has been published on our website along with this Environment Plan. The Statement of response to public comment is not part of this Environment Plan.

In addition to publishing the Environment Plan, we also developed an Environment-Plan-in-brief to offer a more digestible, "plain English" summary of our environment plan which is a 1,500-page scientific technical document. The Environment-Plan-in-brief remains on our website for public access and serves as a tool to better navigate the full EP suite of documents. During the public comment period we also held public drop-in sessions to engage further with the community (described below).

The Regulations governing our industry stipulate a very targeted definition of "Relevant Persons" with whom we must consult. This ensures deep and focussed consultation can be managed with those who might be affected by the planned drilling activities. However, given the broader public interest in exploration in the Great Australian Bight, we have gone significantly further in our engagement than the regulations require, which we have described below. Through broad community engagement, including drop-in sessions and public comment, the group of designated "Relevant Persons" becomes a small subset of the total community able to provide input into our Environment Plan to ensure it would at least meet, and more likely exceed, expectations (Figure 3.1).

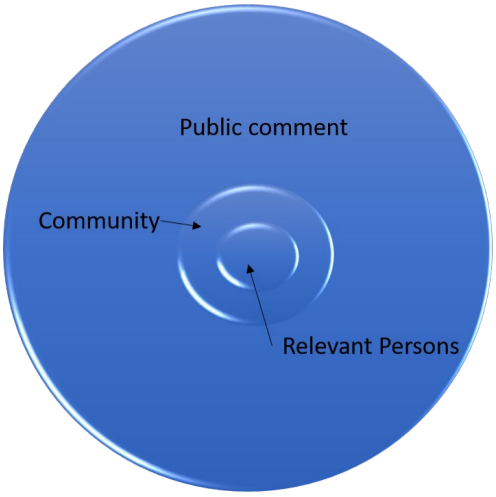


Figure 3.1 Visual representation of broad community engagement

3.1.2 Beyond regulatory consultation

Our community engagement has been broad given the level of community interest in our project and our commitment to working with the communities in which we operate. We have gone beyond the requirements of the OPGGS(E) Regulations for regulatory consultation with Relevant Persons (Section 3.2). Community engagement has taken us from Torquay in Victoria to Albany in Western Australia. We have also hosted some state politicians from South Australia and Victoria at our facilities in Norway.

Since taking up 100 per cent equity in EPP39 in 2017, we have met over 400 people representing 200 businesses and organisations, which is in addition to those we met during the drop-in sessions.

The primary focus of our engagement has been along the Eyre Peninsula and in Kangaroo Island (Figure 3.2). Although these communities are hundreds of kilometres from the project, they are the closest communities to it. This region forms the primary base for fishers, tourism operators and other businesses that operate in the coastal communities from the shoreline of the Great Australian Bight, so there is a natural interest in our operations even though there is no current active fishing or tourism around the drilling location.

Our community engagement provided us with a range of views, including strong interest in the potential economic benefits in the event of a commercial discovery. We discussed the value and importance of co-existence between the oil and gas sector and local businesses, including tourism and fishing. We found strong concerns about what could happen in the unlikely event of an incident and how well we were prepared to respond to such an event. There was also a strong overarching message about the need for transparency.

Figure 3.2 Primary locations of stakeholder meetings

With this understanding, it was important for us to look at how we could best mitigate concerns through genuine and transparent interactive engagement, information sharing, and bringing potential improvements to how we operate.

3.1.3 Meeting broadly across the community since 2017

Since taking ownership of EPP 39 in mid-2017, we have met individuals and members from the fishing, aquaculture, First Nations, conservation, tourism, business and academic communities along with members of sporting clubs, activist groups, charities, government (local, state and federal), NGOs and the general community (Figure 3.3). We will continue to engage broadly with the community throughout the project.

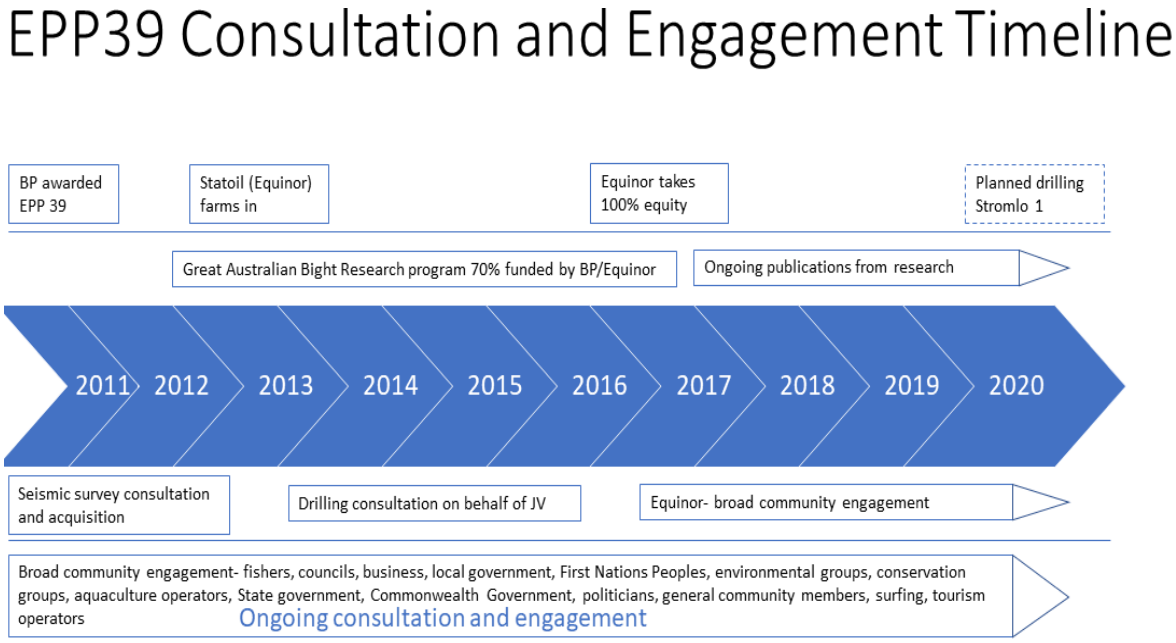


Figure 3.3 Consultation and engagement timeline

Staff in our Australian office have met community members both broadly and regularly over the last two years. We have gone on tours with a passionate dolphin conservation group, taken punts out to oyster beds with growers, visited aquaculture facilities, observed the endangered southern right whales with calves at Head of Bight, taken a formal tour with a knowledgeable DEW ranger to see the endangered Australian sea lions on Kangaroo Island and sighted them again at Point Labatt.

On a number of these occasions we were joined by senior management from Norway who were keen to gain a personal understanding of the environmental values and sensitivities in the Great Australian Bight.

This insight is very important to our senior management, and the understanding of the passion held for this part of the Australian coastline is well understood and appreciated. It is a coastline that we intend to protect during all our operations.

Community Engagement

Meetings		**NGOs**		**States**	
400	More than 400 meetings held to discuss the Environment Plan	15	Engagements with key NGOs- Greenpeace, The Wilderness Society, Sea Shepherd, ACCR- in Norway and Australia	5	Consultation with five state agencies on project planning and response requirements
Organisations		**Public Information Sessions**		**Community Meeting Places**	
200	Met with more than 200 separate organizations to discuss the Environment Plan	170	More than 170 participants met with subject matter experts during public information sessions.	37	Meetings have been held in more than 37 communities across Southern Australia
Nations Covered		**First Nations Peoples**		**3 Tiers of Government**	
2	Meetings have been held with stakeholders in both Norway and Australia	5	Met members and/or Boards of five South Australian Native Title groups & other individuals and organisations	>100	We've met elected members of 35 municipalities, and all major parties at a Federal and State level

Figure 3.4 Community engagement

3.1.4 Public comment and drop-in sessions

Equinor Australia B.V. took an early decision to publish its Environment Plan and was the only company to voluntarily do so prior to it recently becoming mandatory. It was clear from our early engagement that community members wanted to see our full plans, and this fitted in well with our values. Our environment plan was published on our website for 30 days, and over 30,000 entries submitted to us via NOPSEMA's portal. This included input from some Relevant Persons who were previously consulted on the potential impacts of the drilling activity on their interests. A report outlining changes to the Environment Plan as a result of the public comment is published on our website.

We invited a broad cross-section of community members in Port Adelaide, Kangaroo Island, Port Lincoln, Streaky Bay and Ceduna to drop-in sessions while our draft Environment Plan was open for public comment (Figure 3.5). Public notices were placed in the local newspapers the week prior to the drop-in sessions and we provided copies of the advertisements to local councils who committed to posting them on noticeboards and council websites. All the public sessions were open to everyone. Based on feedback from previous engagement, we ensured there were subject matter experts in drilling, environmental science, oil spill response, marine biology and stakeholder engagement present at the sessions to discuss any specific questions from community members.

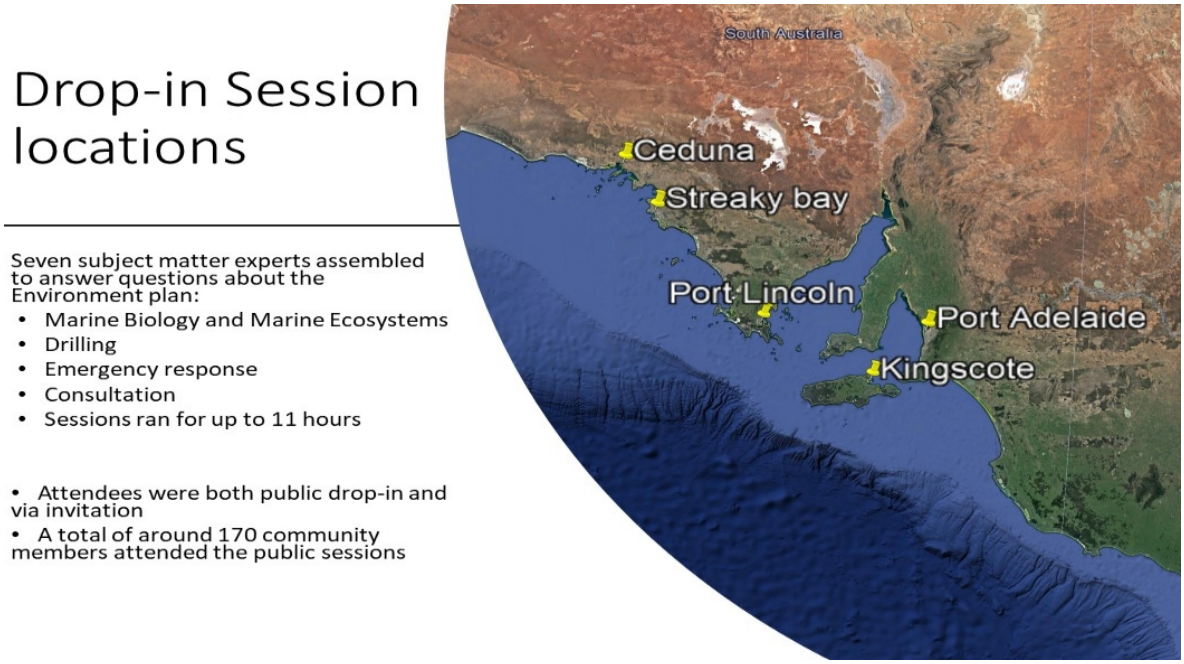


Figure 3.5 Locations of public drop-in sessions

We found themes from the drop-in sessions were very consistent with those that had emerged during our ongoing community engagement activities. We provided people with the opportunity to voice their concerns, and discussed opportunities, listened to all views presented and gave clarifications to questions about our draft Environment Plan. Overall, we believe concerns expressed were genuine. In fact, these concerns are in many ways the same as those held by Equinor Australia B.V., which is why we go to extraordinary lengths to ensure our operations can be carried out safely. Preventing incidents is always our key focus and we will not conduct this activity if we cannot do it safely.

Several other questions and concerns were raised, such as our position on climate change, the need for more exploration, how we invested in local communities, our investments in marine research, seismic exploration, met-ocean conditions and our drilling experience and expertise.

Most of the people who attended, including many who opposed our project, appreciated these drop-in sessions. They were grateful for the opportunity to engage face-to-face, and the multiple desks staffed by the various subject matter experts allowing for meaningful exchanges within their areas of interest. During the Kangaroo Island drop-in session, one community member identified that we had not included the output from sea floor mobile operational diving unit positioning transponders in our sound emissions analysis. This has now been considered in the environment plan.

Equinor Australia B.V.'s drop-in sessions complemented the previous Commonwealth and state government drop-in sessions held in similar locations staffed by the Department of Industry Innovation and Science, NOPSEMA, NOPTA, Parks Australia, SA Department for Energy and Mining and the SA Department of Planning, Transport and Infrastructure.

During these multiple drop-in sessions, people were provided the opportunity to gain a strong understanding of the governing processes behind offshore oil and gas exploration in Commonwealth waters, the stringent requirements placed upon title holders regarding the environmental management of offshore projects, and emergency preparedness requirements.

3.1.5 Environmental NGOs

Equinor Australia B.V. has engaged with key environmental NGOs for some years. We meet with global NGOs regularly in Norway and other countries where we operate. In 2016, 2018 and 2019 at least one Australian representative from an environmental NGO has been provided with an opportunity to present their views about our project in the Great Australian Bight to our shareholders and has met senior management in Norway. During Equinor Australia B.V.'s Annual General Meeting in Norway in May 2019, Greenpeace Australia Pacific and The Wilderness Society Ltd were offered a platform to address senior management and shareholders. A shareholder proposal to "refrain from oil and gas exploration in certain sensitive areas" was considered and voted on.

Submissions were made by environmental NGOs during the public comment period and assessed in the same manner as all submissions we received. More recently, we have met or offered to meet Greenpeace Australia Pacific Australia, Sea Shepherd Australia Limited Australia and The Wilderness Society Ltd. These three key groups and others have received regular updates on our plans via email since we took over the ownership of EPP39. We reached out to these three groups during the public comment period to facilitate an informed discussion on the published environment plan, but our offers to meet during this period were not accepted. No staff were noted attending any of the drop-in sessions held during the public comment period, although individual members may have attended.

Input from environmental NGOs has been received from multiple sources, consisting of face to face meetings in Norway and Australia, presentations to Equinor Australia B.V.'s Annual General Meetings, via public comment, direct correspondence, and indirectly via media releases. All input was considered in the preparation of our Environment Plan.

Since the end of the public comment period, we have met with The Wilderness Society Ltd in Adelaide twice (once with a senior executive team from Norway), Sea Shepherd Australia Limited once and have an outstanding offer to meet Greenpeace Australia Pacific. All meetings in Norway and Australia have been held respectfully and clear philosophical differences have been acknowledged.

Since 2016, we have had over 15 meetings with key environmental and climate NGOs such as Greenpeace Australia Pacific, The Wilderness Society Ltd, Sea Shepherd Australia Limited and Australian Centre for Corporate Responsibility including presentations at shareholder annual general meetings (AGM) in Stavanger, and face-to-face meetings in Australia and Norway.

We have also met with smaller conservation groups in Kangaroo Island with specific interests around marine life and gained insights into key local conservation issues from these groups who voluntarily donate significant hours into raising awareness around those interests.

Everyone gets to review all elements of our EP

Group	Review and comment on all activities	Detailed consultation on planned activities	Detailed consultation on emergency response activities
Relevant Persons - Government State and Federal governments receive input from multiple departments and agencies, communities, and businesses such as fishing, and provide important input into our environment plan and emergency response plans	✓	✓	✓
Relevant persons- other Consult on planned drilling activities with fishers and researchers with interests proximate to our drilling. Understand how drilling may have impacts on these interests	✓	✓	
Local communities Topics at meetings and drop-in sessions cover all elements of our plan.	✓		
Broader Community Everyone gets to provide input via public comment, with many having multiple opportunities.	✓		

Figure 3.6 Review process for the Environmental Plan

3.1.6 Engagement with First Nations Peoples

We have met with, and presented to, the Barngarla, Narungga and Nauo Native Titleholders and claimant boards respectively. We also have meetings pending with the Wirangu 2 claimants and the Far West Coast Aboriginal Corporation following meetings we have had with individual members of these groups. We have met twice with the Alinytjara Wilurara Natural Resources Management (NRM) board, which is the only all Aboriginal NRM board in Australia. During a visit from our Norwegian senior management, we also met with members of an Eyre Peninsula based Aboriginal sporting club who described the importance of the role the club plays with Aboriginal youth. It was important to us to understand this context as we look at how we can better support the communities within which we operate.

For us, it was important to be honest with respect to the limited opportunities that would be available in the early short-term exploration phase. The five Native Title Claimants and Holders we are engaging with represent First Nations peoples covering an area approximately twice the size of Tasmania.

During our drop-in sessions, both the Barngarla Determination Aboriginal Corporation (BDAC) and the Far West Coast Aboriginal Corporation (FWCAC) were offered specific time slots to meet with our subject matter experts, with members of the BDAC attending.

3.1.7 Fishers and aquaculture

Through ongoing engagement with people from the broader fishing, seafood and aquaculture sectors since mid-2017, we have gained a good understanding of their perspectives and insights. We understand their concerns about potential impacts on their businesses in the event of an oil spill and discussed the fact we share the same concerns, which is why we would not undertake the activity unless it could be done safely. Other local issues raised by members of this sector included power reliability and costs given the energy-dependent nature of their processing facilities and the concerns about the reliability of electricity supply in the region. Some saw the potential benefits improved infrastructure could bring in the success case. For example, improved airport connections could result in fresh produce being shipped versus frozen, significantly improving margins.

3.1.8 Tourism, surfing and coastal businesses

It was important for us to engage with marine-dependent tourism operators including eco-tourism, conservation and other marine tourism operators, along with the broader coastal community. Tourism is an important regional economic driver. A wide variety of views were canvassed. We discussed oil spill risk,

consequence and management and the opportunity for co-existence. We looked at examples from the North West Shelf of Western Australia including the World Heritage listed Ningaloo Reef's co-existence with the nearby oil industry. Another example raised was Esso and BHP's Bass Strait 50 year plus operations in Victoria and other oil and gas operators in the Otway Basin, which shares the tourism values of Victoria's Great Ocean Road, the 12 Apostles and Bells Beach where an internationally significant surfing event is held. We also discussed Equinor Australia B.V.'s co-existence with tourism in Norway, including sharing seas with cruise liners and coastal ports with tourism operators.

A representative from the surfing community was also provided an opportunity to speak during the 2019 Annual General Meeting and present a petition from the surfing and broader community to our senior management.

3.1.9 Compensation scheme

Most people we spoke with had a clear understanding that an oil spill was a very unlikely event, and trusted Equinor Australia B.V.'s record of applying the most stringent safety standards to all our operations. Nevertheless, it was reasonable for people to still be concerned about how they might be compensated should they suffer a financial loss as a result of any major oil spill from our drilling operation, and the concept of taking an oil company to court to assess any claim seemed overly burdensome. Many small family businesses were keen to understand how they could keep their businesses operating during such an event.

We are confident in our ability to drill safely without impacting the economic interests of others in the area.

However, we acknowledged these concerns and have established a process to compensate anyone in the unlikely event that they suffer a financial loss caused by our operations. In developing this scheme, we looked locally and internationally for comparable arrangements to inform our approach. However, there was no existing scheme that met the specific needs of our stakeholders.

We invested time and resources to design a bespoke arrangement (Figure 3.7). The scheme has been developed in collaboration with Australian legal experts to ensure it is fit for purpose. We have worked hard to ensure the process is easy to understand. It is designed to be fast, transparent and independent from Equinor Australia B.V. The scheme effectively clarifies how the risk shifts from the stakeholder to Equinor Australia B.V. and was well received by most of those who raised such concerns.

Principle	Detail
Independent	Claims will be assessed by an independent panel.
Simple	The model is a clear process that is easily understood.
Fast	The model allows for immediate funding to meet the applicant's financial commitments, for example mortgage repayments, employee wages and rental payments.
No Cost	There will be no out of pocket cost for lodging a claim.
Accessible	The scheme is open to anyone who believes they have suffered a financial loss caused by our operations.
No limit	There is no limit to the amount that can be claimed. Claims can be made for losses including past and future incomes. There is also no limit on the number of claims that can be made.

Figure 3.7 Equinor Australia B.V. compensation scheme principles

3.1.10 Collaboration

Equinor Australia B.V. looks for opportunities for collaboration wherever we operate. Being a positive contributor to the local and broader community is important to us. Over the years we have invested significant sums into marine research, and we have also worked hard to promote science, technology, engineering and mathematics (STEM) amongst community members where we operate.

The science, technology, engineering and mathematics investments would be a core area for future community investments in the success case, and early engagement with the local community has generated interest in this area.

We have already invested as partners in the Great Australian Bight Research Program. This collaboration in partnership with BP was with CSIRO, the Government of South Australia, the South Australian Research and Development Institute (SARDI), the University of Adelaide and Flinders University (Figure 3.8). This was a five-year project that ended in 2018. More details are on http://www.misa.net.au/GAB.

Figure 3.8 Local partners to Great Australian Bight Research Program

The Great Australian Bight Research Program comprised of 16 inter-related projects covering seven research themes: physical oceanography, open water (pelagic) research; sea floor (benthic) biodiversity; apex predators; petroleum systems; socio-economic analysis; and integration and modelling. The project generated significant quantities of data, which is publicly available and has driven, and will continue to drive, published scientific papers that improve our understanding of the Great Australian Bight.

APPEA members are some of the largest contributors to the marine sciences in Australia. For example, other Great Australian Bight operators have been long terms sponsors of research into southern right whales in the Great Australian Bight.

During the exploration phase we will continue to explore modest opportunities for collaboration and community investment, with the potential for these to grow significantly in the success case. We believe success is something to be shared.

3.1.11 Community engagement outcomes

We have engaged broadly with the community and this engagement goes beyond the requirements of the OPGGS(E) Regulations for regulatory consultation with Relevant Persons. We took what we learned and identified how we could ease any concerns related to our activities, while acknowledging some areas were beyond the project scope (e.g. seismic exploration) or more a matter of public policy (Australia's need for exploration).

We have been very appreciative of the public input into the preparation of our environment plan. The result of this broad dialogue and public comment process was significant, and resulted in the following combined outcomes:

- the full publication of our draft Environment Plan for public comment
- the commitment to publish the full final Environment Plan after acceptance by NOPSEMA
- the improvement of our draft Environment Plan following the public comment process
- the publication of a report highlighting the public comments trends
- the organisation of drop-in sessions with subject matter experts to better inform the public during the public comment period
- the inclusion of sound emissions emanating from the seafloor transponders in our noise analysis – arising out of a drop-in session
- the recognition that we needed to further assess the ALARP process on capping stack deployment

- the further consideration of operating months with respect to noise and southern right whales. October and May have now been removed from the operations window
- the development of a compensation scheme that would provide a simple process for independent and timely compensation for anyone suffering a financial loss as the result of a major spill from our well.

3.2 Consultation with relevant persons

3.2.1 Purpose

Consultation with relevant persons was completed as required under Regulation 11A of the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009. All relevant persons were provided enough information to allow them to make an informed assessment of any possible consequences of the activity on their functions, interests or activities and a reasonable period of time was allowed for them to respond and for consultation to occur.

3.2.2 Definitions and identification

Regulation 11A (1) of the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009 identifies five groups as relevant persons who must be consulted with in the course of preparing an environment plan.

For the purpose of convenience, we have grouped the relevant persons into three categories:

Category 1 – Relevant government departments – 11A (1) (a), (b), (c)

The purpose of the first category is to ensure that we have developed our plan in consultation with each relevant government department and agency (state and federal). The regulation ensures that governmental bodies with jurisdiction or authority over areas that may be affected by both planned and unplanned events have been provided with an opportunity to raise objections or claims, which are reviewed, responded to, and resolved as far as possible by Equinor Australia B.V.

The first category includes the following, each a relevant government department or agency:

- each department or agency of the Commonwealth to which the activities to be carried out under the environment plan may be relevant
- each state department or agency to which the activities to be carried out under the environment plan may be relevant
- the South Australian Department for Energy and Mining.

Process undertaken by Equinor Australia B.V. to identify and consult with relevant government departments included we:

1. Identified the environment that may be affected by unplanned events; the Risk Environment that May Be Affected (Risk EMBA). This is defined by an unmitigated worst-case discharge oil spill simulation using stochastic modelling (i.e. one hundred simulations of an oil spill in different met ocean conditions).
2. Identified the states with shorelines in the Risk Environment that May Be Affected.
3. Consulted with federal and state agencies who would have a role in the event of marine pollution in waters under their respective jurisdiction.
4. Consulted with all other state and federal agencies who have, or would have, a function or jurisdiction in respect of matters that had a sufficient link to the drilling activity or the emergency response arrangements.

The following tables (Table 3.1 and Table 3.2) list all relevant persons consulted under Category 1.

Table 3.1 Category 1 – state relevant persons

State	Department or agency and function			
	Emergency response and monitoring	Oil and gas regulator or central agency	Fisheries resources management	Environmental management
NSW	Roads and Maritime Services Environmental Protection Authority (EPA)	Department of Planning and Environment (DPE)	Department of Primary Industries (DPI)	Department of Planning and Environment (DPE)
SA	Department of Planning, Transport and Infrastructure Environment Protection Authority (EPA) Police (SAPOL)	Department for Energy and Mining (DEM) Department of the Premier and Cabinet (DPC)	Department of Primary Industries and Regions (PIRSA)	Department for Environment and Water (DEW)
Tas	Environment Protection Authority (EPA) Department of Primary Industries, Parks, Water and Environment (DPIPWE)	Department of state Growth (DSG)	Department of Primary Industries, Parks, Water and Environment	Department of Primary Industries, Parks, Water and Environment
Vic	Department of Jobs, Precincts and Regions (DJPR), Department of Transport Environment Protection Authority (EPA)	Earth Resources (ER) (DJPR)	Victorian Fisheries Authority (VFA)	Department of Environment, Land, Water and Planning
WA	Department of Transport (DoT) Environment Protection Authority (EPA)	Department of Mines, Industry Regulation and Safety (DMIRS)	Department of Primary Industries and Regional Development (DPIRD)	Department of Biodiversity, Conservation and Attractions (DBCA) Department of Water and Environmental Regulation

Table 3.2 Category 1 – Commonwealth relevant persons

Function	Department or agency
Maritime Safety	Australian Maritime Safety Authority
Fisheries management	Australian Fisheries Management Authority (AFMA)
Environmental management	Department of the Environment and Energy (DEE) Director of National Parks (DNP) Australian Antarctic Division (AAD)
Industry regulator	Department of Industry Innovation and Science
Defence	Department of Defence (DoD)
Research	Commonwealth Scientific and Industrial Research Organisation Fisheries Research and Development Authority (FRDC)
Biosecurity	Department of Environment and Energy (DAWR)

Category 2 – People and organisations whose functions, interests or activities may be affected by planned activities – 11A (1) (d)

The purpose of Category 2 is to ensure that Equinor Australia B.V. effectively communicates and consults with persons and organisations whose functions, interests or activities may be affected by activities to be carried out under the environment plan, that is, the activities under the environment plan have the potential

to impact or make a change to that person or organisation's functions, interests or activities. Our aim is to foster positive coexistence of multiple organisations operating in the same area. Once identified as a Relevant Person, Category 2 persons are provided an opportunity to raise objections or claims about the activities that will be evaluated, responded to, and resolved as far as possible by Equinor Australia B.V.

The regulation uses three terms that Equinor Australia B.V. has defined having regard to the objectives of the *Offshore Petroleum and Greenhouse Gas Storage Act 2006*, Section 280(2) of the Act, the regulations and Environmental plan decision making guideline (NOPSEMA 2018) (Table 3.3).

Table 3.3 Definition of functions, interests and activities

Functions	A person or organisation's power, duty, authority or responsibilities
Interests	A person or organisation's rights, advantages, duties and liabilities; or a group or organisation having a common concern
Activities	A thing or things that a person or group does or has done

Process undertaken by Equinor Australia B.V. to identify and consult with this category of Relevant Persons where we:

1. Identified the area that may be impacted by the drilling activity.

Equinor Australia B.V. assessed the geographic footprint of each activity that will occur during the drilling operations. Underwater noise will affect the greatest area of the environment around the well-site. All other aspects of the activity such as discharge of drilling muds and cuttings will affect a much more localised area as shown in Figure 3.9. The figure is also showing past exploration wells drilled since 1960. The environment that may be affected by planned activities (Impact Environment that May Be Affected) is represented by the yellow circle which has a 40 km radius.

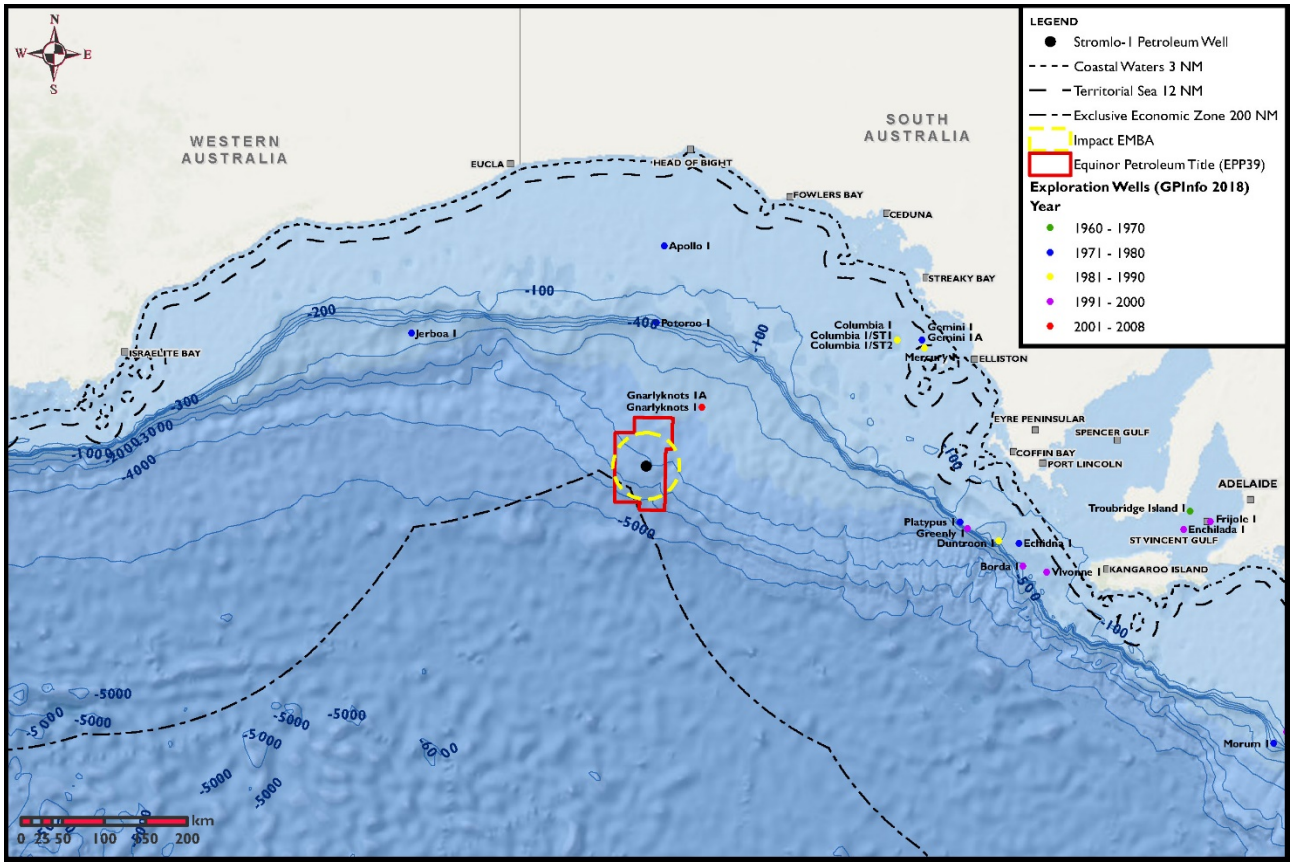


Figure 3.9 Stromlo-1 well Impact Environment that May Be Affected

2. Identified persons who have functions, interests and activities within the Impact Environment that May Be Affected.

Equinor Australia B.V. carried out the following steps to identify this category of relevant persons:

- reviewed BP p.l.c.'s consultation logs
- reviewed Australian Fisheries Management Authority data to determine Commonwealth fisheries areas that partially or wholly overlap with the Impact Environment that May Be Affected
- reviewed Department of Primary Industries and Regions data to determine state fisheries areas that partially or wholly overlap with the Impact Environment that May Be Affected
- confirmed Department of Primary Industries and Regions data with Wildcatch Fisheries South Australia (WFSA)
- undertook online searches for local businesses and operators who may operate in the Impact Environment that May Be Affected
- sought and considered the recommendations and referrals of existing relevant stakeholders for as to which, if any, other persons we should consider.
- Relevant Persons identified in Category 2 are listed in Appendix 3-1.

3. In determining whether a person, organisation or group was potentially impacted by the planned activities, a careful assessment and determination was made of whether the identified function, interest or activity may be actually affected by Equinor Australia B.V.'s planned activity. 'Affected by' considers any change, whether adverse or beneficial, that wholly or partially results from the planned activities. It is considered that functions, interests and activities are not affected by an activity if they cannot be changed by the activity.

Equinor Australia B.V. has engaged in an extensive, wide ranging and lengthy process of public consultation. Equinor Australia B.V.'s objective in so doing was to ensure transparency, and a significant and real opportunity was afforded to both relevant persons under the Act, and persons who do not qualify as "relevant persons", of providing input into Equinor Australia B.V.'s plans. In order to encourage and facilitate such genuine broad community engagement and consultation, Equinor Australia B.V. took a number of measures which were well in excess of its regulatory requirements. Those measures included (but were not limited to publishing a "plain English" summary of its draft EP – the objective was to make the information concerning Equinor Australia B.V.'s plans more accessible and readily comprehensible by all members of the public. This summary publication was in addition to Equinor Australia B.V.'s voluntary publication of its entire draft EP and inviting public comment on it. The summary remains on Equinor Australia B.V.'s website and continues to be used as a tool to effectively navigate and understand the full draft EP.

Again, with the objective of facilitating broad public consultation, Equinor Australia B.V. also conducted public drop in sessions (advertised in advance). Experts in the relevant disciplines attended those sessions to address queries from and to interactively engage with members of the public, and to discuss any issues raised with interested community members.

Category 3 – Any other people or organisations we consider relevant – 11A(1)(e)

The purpose of Category 3 is to enable us to identify and include in the consultation process any other people or organisations that do not satisfy the definition in Category 2, but that we nevertheless consider to be relevant on the basis that they could materially contribute to improving the environment plan.

The draft environment plan was published in full on 19 February 2019 and the public had the opportunity to review and provide relevant comments on it for a 30-day period. This process did not result in the identification of any relevant persons under Category 3.

Equinor Australia B.V. is committed to transparency and public consultation and engagement in respect of its project. In furtherance of this commitment, and as part of its measures beyond its regulatory requirements, Equinor Australia B.V. has in the past offered a platform to a number of NGOs to meet and address senior management and shareholders. Most recently, Equinor Australia B.V. has also offered to meet a number of environmental NGOs in Norway and in Australia, including Greenpeace Australia Pacific Australia, Sea Shepherd Australia Limited Australia and The Wilderness Society, to encourage and facilitate an informed discussion on the draft EP. Submissions were made by a number of environmental NGOs during Equinor Australia B.V.'s extensive consultation process, and were duly considered by Equinor Australia B.V. Equinor Australia B.V.'s consultation process has been fulsome and effective, including (but not limited to) environmental NGOs, despite those organisations not falling within the definition of "relevant persons" for the purposes of the OPGGS(E). Equinor Australia B.V. has continued to maintain an open and transparent dialogue with these groups and other community members to ensure the best outcomes for the project.

3.2.3 Methods

3.2.3.1 Emails

Formal consultation with relevant persons commenced with the distribution of invitations to comment. Each email included an activity description and an offer to meet, and other relevant information where appropriate.

3.2.3.2 Meetings

We met with government agencies and departments, including response agencies from Western Australia, South Australia, Victoria, Tasmania and New South Wales. We also met with fishing associations and a research group.

3.2.4 Outcomes

Outcomes from regulatory consultation are contained in Appendices 3-1 and 3-2. Equinor Australia B.V.'s approach to relevant persons consultation reporting is as follows:

(i) A list of each response by a relevant person (Appendix 3-1).

(ii) A list of each objection or claim about the adverse impact of our planned activities to which the environment plan relates, as relevant to the relevant person or organisation (Appendix 3-1).

(ii) a) An assessment of merit of objections or claims identified in (ii) above (Appendix 3-1), noting new control measures to be implemented where applicable.

(iii) A copy of the titleholder's response, or proposed response, if any, to each objection or claim identified in (ii) above (Appendix 3-1), or to each issue raised in (i) above that was not identified as claim or objection.

(iv) A copy of the full text of any response by a Relevant Person (Appendix 3-2). Note that this appendix has not been published for stakeholder privacy reasons.

3.2.5 Ongoing consultation

We will continue to consult with relevant Commonwealth and state authorities, and other relevant interested persons and organisations. We define relevant interested persons and organisations as all relevant persons from Categories 2 and 3 except those that have advised Equinor Australia B.V. they are not interested in being consulted about the project. The ongoing consultation plan is covered under Section 9.0, Implementation Strategy.

3.3 References

National Offshore Petroleum Safety and Environmental Management Authority, 2018. "Environment plan decision making guideline". Available from https://www.nopsema.gov.au/assets/Guidelines/A524696.pdf.

4.0 Existing environment of the Impact Environment that May Be Affected

This section addresses OPGGS(E) Regulation 13(2), which requires an environment plan to include a description of the environment that may be affected by the petroleum activity (Environment that May Be Affected) and to detail particular relevant values and sensitivities of that Environment that May Be Affected. For the purposes of managing the impacts associated with the planned petroleum activity and risks associated with unplanned events, Equinor Australia B.V. has established two Environments that May Be Affected, as follow:

1. Impact Environment that May Be Affected: the geographical area encompassing the environment that may be affected by the planned activities in the Operational Area. The maximum extent of underwater noise effects (with a conservative buffer allowance) is the dimensioning factor for this area. The Impact Environment that May Be Affected has been used to identify relevant stakeholders whose interests, activities or functions may be affected by the activity and to support the assessment of impacts from the project and is described in this section.
2. Risk Environment that May Be Affected: the geographical area encompassing the environment that may be affected by the unplanned events associated with the planned activities within the Operational Area. The maximum extent of an oil spill due to a loss of well control (LOWC) resulting in a major blowout is the dimensioning factor for this area. The Risk Environment that May Be Affected has been used to inform the oil spill response planning and oil spill risk assessment (Section 7.0) and is addressed in Appendix 7.3, and not discussed any further here.

4.1 Defining the Impact Environment that May Be Affected

Of the aspects of the planned activities that will occur during the drilling program at Stromlo-1, those that will affect the greatest area of the environment around the well site are underwater noise emissions from vertical seismic profiling of the well and mobile offshore drilling unit thruster operation. All other aspects of the activity such as light emissions, discharge of drilling muds and cuttings will affect a much more localised area. Section 6.3 provides a description and assessment of the impacts associated with sound, discharge of muds and cuttings, cementing, seabed disturbance, light and the other aspects and shows that sound impacts affect the broadest area. Therefore, the geographic extent relates to the environment that may be affected by underwater sound during drilling and is hereafter referred to as the Impact Environment that May Be Affected. Details of the underwater sound assessment, including full definition of all terms are included in the sound modelling report (Appendix 6-1) and discussed in terms of environmental impacts in Section 6.3.

Sound propagates better through water than air, and low frequency sounds may travel long distances, however, the potential for environmental effects (impact on receptors) decreases rapidly with distance from the source as the sound levels attenuate through spreading, refraction, reflection and absorption. The underwater environment is naturally noisy with ambient underwater sound from waves, wind, swell, lightning and biological sound. Existing anthropogenic use of the deep offshore waters for commercial shipping also contributes to the ambient sound levels with which the marine biota co-exists. A measurement program in the deep offshore waters of the Ceduna Sub-basin measured ambient noise levels up to 144 dB re 1 µPa (SPLrms) and attributed them to distant blue whale vocalisations and vessel noise (McCauley et al. 2012). Whale migration and commercial shipping across the Bight are regular sources of underwater sound in the Stromlo-1 area. Being offshore near the main shipping lane, the Impact Environment that May Be Affected is subject to existing high levels of ambient sound. Migrating whales, tuna and other oceanic species encounter and are known to co-exist with anthropogenic sounds associated with shipping with no indication of adverse impact on biology or ecology.

Equinor Australia B.V. has completed underwater sound propagation modelling on the loudest sources of underwater sound associated with the activity – thruster (propeller) sound from the mobile offshore drilling unit dynamic positioning system and acoustic source discharge during vertical seismic profiling. The Equinor Australia B.V. modelling team selected relevant generic acoustic source levels, based on previous studies and industry knowledge, and modelled 3D propagation of the expected sound emissions; considering water depth, source power, seabed types, water sound speed profiles and other factors known to affect sound propagation underwater.

The underwater sound propagation modelling examined sound levels at distance from the well site and mobile offshore drilling unit in terms of threshold values, which are generally accepted by underwater acoustic scientists (as detailed in Appendix 6-1) and in terms of background (ambient) sound levels recorded in the central Great Australian Bight. Where the effects on biota are uncertain, a highly conservative approach to setting the thresholds was adopted based on information published in peer-reviewed literature. The threshold values comprise the range of sound levels which may have different effects (behavioural disturbance with no impact on movements, disturbance leading to avoidance of the area, injury / physiological damage) on the range of receptors in the area to be ensonified. The modelling results in relation to thresholds for impacts on plankton, larger invertebrates, fish and marine mammals, are described in the underwater sound modelling report (Appendix 6-1).

The Impact Environment that May Be Affected (Figure 4.1) was based on the greatest distance from the greatest sound sources (vertical seismic profiling and mobile offshore drilling unit thrusters and transponders), beyond which no effects are predicted for the most sensitive receptors; with a conservative buffer area added to allow for uncertainties in the levels of predicted impact. The Impact Environment that May Be Affected encompasses the:

- zone of behavioural disturbance of cetaceans; set by a root mean square sound pressure level (SPLrms) threshold of 160 dB re 1 µPa (National Marine Fisheries Service (NMFS) 2018), which extends for a maximum of 9 km from the well site
- National Marine Fisheries Service (NMFS) (2018) cumulative sound threshold (179 dB Sound Exposure Level (SEL) 24hr) for a continuous sound source effects on low-frequency sound (140 dB SPL), which equates to a maximum of 25 km
- conservative Southall et al. (2007) thresholds for behavioural effects due to impulsive sound (140 dB SPL) which equates to a maximum of 17 km
- spatial extent of acoustic impacts from all sources of high- and low-frequency sound and, all other biological and ecological receptors
- distance to the point where sound levels would fall to within the upper range of ambient sound levels (<140 dB re1µPa SPLrms) in the Ceduna Sub-basin was approximately 12.5 km.

The size of the Impact Environment that May Be Affected for the activity was conservatively set at a radius of 40 km around the well site to allow for any uncertainty in predicting the exposure and sensitivity of marine biota to underwater sound. This means that beyond the Impact Environment that May Be Affected, it is highly unlikely that any marine mammal, fish or invertebrate would be adversely affected by the underwater sound levels generated by the activity.

The physical, biological and socio-economic environment in and around the Stromlo-1 well site, and the regional setting of the Impact Environment that May Be Affected, are described in this section, together with the particular values and sensitivities of the area.

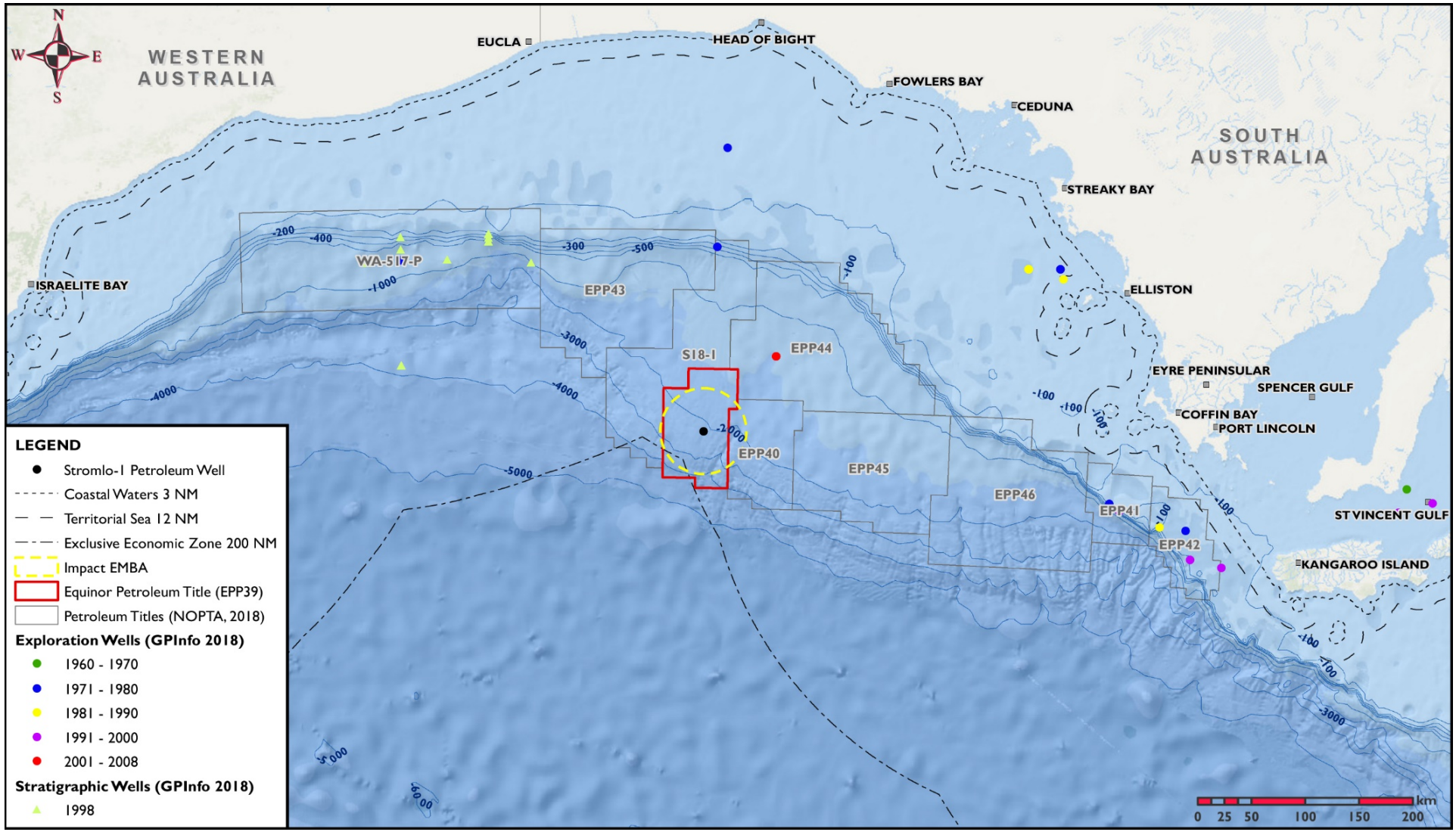


Figure 4.1 Stromlo-1 exploration drilling program Impact Environment that May Be Affected

4.2 Sources of data

A search using the *Environment Protection and Biodiversity Conservation Act 1999* Protected Matters Search Tool (PMST) was conducted in April 2018 for the Impact Environment that May Be Affected. The Protected Matters Search Tool report (Appendix 4-1) was used to identify matters of national environmental significance and other matters protected under the *Environment Protection and Biodiversity Conservation Act 1999*. The Protected Matters Search Tool report was reviewed in order to identify and remove Threatened and Migratory species that do not occur within the Impact Environment that May Be Affected, such as shallow water or coastal species and protected areas.

Species-specific information was gathered using the Department of Environment and Energy Species Profile and Threats (SPRAT) database, species recovery plans, published conservation advice and peer-reviewed scientific publications. A key source of relevant baseline information was the Great Australian Bight Research Program (GABRP) which led to the publication of series of reports and scientific publications, many of which are currently under peer-review by scientific journals.

Information of the seabed and sea floor state was gathered during a geotechnical survey in 2013 and augmented by information and findings from the recent Great Australian Bight Research Program and Great Australian Bight Deepwater Marine Program (GABDMP). Metocean data was derived from collected raw data in the Great Australian Bight (2012) and historical databases.

Information on fisheries was derived from state and Commonwealth online and published fishery reports and personal communication with government fishery experts. It should be noted that there is often a lag of several years in publishing fishing catch statistics and in some cases data on recent catch and effort is not available

4.2.1 Great Australian Bight Research Program

The Great Australian Bight Research Program was a four-year, $20 million research program funded by Joint Venture partners Equinor Australia B.V. (then Statoil Australia Theta B.V.) and BP p.l.c., the Commonwealth Scientific and Industrial Research Organisation and Marine Innovation Southern Australia partners – the South Australian Research and Development Institute, University of Adelaide and Flinders University. The overall aim of the Great Australian Bight Research Program was to improve understanding of the environmental, economic and social values of the Great Australian Bight. It was undertaken between April 2013 and September 2017 by multi-disciplinary research teams from Commonwealth Scientific and Industrial Research Organisation, South Australian Research and Development Institute (SARDI), the University of Adelaide and Flinders University. More than 100 scientists were involved in the Great Australian Bight Research Program, which comprised seven themes including five with an ecological focus:

- Oceanography – collection and analysis of data to develop ocean models to better understand the connections between deep, off-shelf regions on the continental shelf and coastal regions, and the dynamic effect of the ocean on sea floor and pelagic biodiversity.
- Open water (pelagic) ecosystem and environmental drivers – collection of information on the community structure, dynamics and biodiversity of microbes, plankton and micronekton in the Great Australian Bight. Research included assessing food web structure in relation to currents, turbidity, light levels, stratification, nutrient concentrations and turbulence.
- Sea floor (benthic) biodiversity – studies of the abundance and distribution of faunal biodiversity on and in the seabed.
- Ecology of iconic species and apex predators – studies of the status, distribution and abundance of key iconic species such as whales, sea lions, dolphins and apex predators such as southern bluefin tuna (SBT) and sharks. This included developing species distribution models that have been used to inform the full descriptions of all Threatened and Migratory species protected under the *Environment Protection and Biodiversity Conservation Act 1999* identified as potentially occurring within the Impact Environment that May Be Affected.
- Petroleum geology and geochemistry – identification and characterisation of possible natural petroleum seepage in specific areas of the Great Australian Bight.

- Socio-economic analysis – development of a socio-economic profile of communities potentially affected by petroleum activities. Through consultation, community concerns and perceptions of key issues regarding likely future activities were examined, along with the economic dependence of individual regional communities on activities related to the Great Australian Bight.
- Integration and modelling – development of a quantitative model of the structure and dynamics of the Bight's ecosystem, which could be integrated into ecosystem models that can be used to conduct more informed and refined ecological risk assessments for future development activities that may be conducted in the Great Australian Bight.

Information obtained by the Great Australian Bight Research Program will be publicly available for use by all stakeholders interested in the region, including Commonwealth and state government regulators, other commercial operators, academics, environmental groups and the general community.

4.2.2 Great Australian Bight Deepwater Marine Program

The most recent research program in the area is the Great Australian Bight Deepwater Marine Program, which included multiple surveys led by Commonwealth Scientific and Industrial Research Organisation in partnership with Chevron Australia. The program was completed in 2018 and the objectives were to:

- Increase the knowledge of the sedimentary evolution of the Bight Basin.
- Characterise the volcanic seamounts, canyons and potential hydrocarbon seeps on the sea floor.
- Conduct an environmental and biological assessment of the benthic biota.

Some of the findings from the Great Australian Bight Deepwater Marine Program (summarised in Ross et al. (2017)) are included in this section, in particular the description of the seabed in the area and around the drill site. There were multiple surveys associated with this research program.

In addition to the research projects outlined above, additional information has been included from various science symposia and associated journal papers. Results from internal studies on seismic 3D data and Equinor Australia B.V. sponsored geotechnical/meteorological surveys has been included where relevant

4.3 South-west Marine Region physical setting

The area of the activity lies within the South-west Marine Region. The bioregional plan for the region describes the marine environment and the conservation values of the region, sets out broad biodiversity objectives, identifies regional priorities and outlines strategies and actions to address these priorities (DSEWPaC 2012a).

The main physical features of the South-west Marine Region are:

- a narrow continental shelf on the west coast from the subtropics to temperate waters off south-west Western Australia
- a wide continental shelf dominated by sandy carbonate sediments of marine origin
- high wave energy on the continental shelf around the whole region
- a steep, muddy continental slope which include many canyons; the most significant being the Perth Canyon, the Albany canyon group and the canyons in the vicinity of Kangaroo Island
- large tracts of poorly understood abyssal plains at depths greater than 4000 m
- the Diamantina Fracture Zone, a rugged area of steep mountains and troughs off south-west Australia at depths greater than 4000 m
- the Naturaliste Plateau, an extension of Australia's continental mass that provides deep-water habitat at depths of 2000–5000 m
- islands and reefs in both subtropical (Houtman Abrolhos Islands) and temperate waters (e.g. Recherche Archipelago)
- complex and unusual oceanographic patterns, driven largely by the Leeuwin Current and its associated currents that have a significant influence on biodiversity distribution and abundance.

4.4 Conservation values and sensitivities

Conservation values and sensitivities listed and protected under the *Environment Protection and Biodiversity Conservation Act 1999* include Matters of Environmental Significance and Other Protected Matters. matters of national environmental significance occurring, or potentially occurring, within the Impact Environment that May Be Affected include:

- two Commonwealth Marine Areas
- 23 Listed Threatened Species
- 28 Listed Migratory Species.

Other Matters protected by the *Environment Protection and Biodiversity Conservation Act 1999* include:

- 20 Listed Marine Species
- 31 whales and other cetaceans (many of which are also Listed Threatened or Migratory Species)
- one Australian Marine Park.

The full *Environment Protection and Biodiversity Conservation Act 1999* Protected Matters report is provided in Appendix 4-1. The results generated from the protected matters search tool for the Impact Environment that May Be Affected are summarised in the following sections.

4.4.1 Matters of National Environmental Significance

4.4.1.1 Commonwealth marine areas

Two Commonwealth Marine Areas intersect the Impact Environment that May Be Affected: the Australian Exclusive Economic Zone (EEZ) and Territorial Sea; and the Extended Continental Shelf. The activity area is not of particular relevance with respect to these extensive marine areas.

4.4.1.2 Listed Threatened species

A total of 23 Listed Threatened species are either likely to, or may, occur within the Impact Environment that May Be Affected, including:

- 14 seabird species (Section 4.6.7.1)
- five marine mammal species (Section 4.6.6)
- three marine reptile species (Section 4.6.5)
- one shark species (Section 4.6.3.2).

The relevant sections of this Environment Plan discuss the likelihood of these species and their biologically important areas occurring within the Impact Environment that May Be Affected.

4.4.1.3 Listed Migratory species

A total of 28 Listed Migratory species are either likely to or may occur within, the Impact Environment that May Be Affected. Twenty of these are also Listed Threatened Species. Listed Migratory Species include:

- 12 migratory bird species (Section 4.6.7)
- 16 migratory marine species (mammals, sharks and reptiles) (Sections 4.6.6, 4.6.3.2, 4.6.5 respectively).

4.4.1.4 Matters of national environmental significance not present in the Impact Environment that May Be Affected

Matters of national environmental significance which are not represented in the Impact Environment that May Be Affected are:

- World Heritage Properties

- National Heritage Places
- Wetlands of International Importance
- the Great Barrier Reef Marine Park
- Listed Threatened Ecological Communities
- Nuclear actions and water resources, in relation to coal seam gas or coal mining, are matters of national environmental significance, but do not form part of the activity and are not discussed further.

4.4.2 Other matters protected by the *Environment Protection and Biodiversity Conservation Act 1999*

4.4.2.1 Listed marine species

A total of 20 Listed Marine Species are either likely to, or may, occur within the Impact Environment that May Be Affected, including 17 bird species (Section 4.6.7) and three reptile species (Section 4.6.5). Sixteen of these species are also Listed Threatened Species.

4.4.2.2 Whales and other cetaceans

The Protected Matters search determined that 31 cetacean species or their habitat, may occur within the Impact Environment that May Be Affected. Five of these species are also Listed Threatened Species. These species are listed and discussed in Section 4.6.6.1.

4.4.3 Australian Marine Parks (Commonwealth Marine Reserves)

One Australian marine park, the Great Australian Bight Marine Park, intersects the Impact Environment that May Be Affected (Figure 4.2; EMBA - Underwater Sound). The Impact Environment that May Be Affected partially overlaps a Multiple Use Zone (International Union for Conservation of Nature (IUCN) VI) of the marine park which is managed under the South-west Marine Parks Network Management Plan 2018 (DNP 2018) (Table 4.1).

The Great Australian Bight marine park comprises a zone declared prior to 2012 (the former Great Australian Bight Commonwealth Marine Reserve) and a new zone declared in 2012. The Great Australian Bight Marine Park therefore requires the following considerations (National Offshore Petroleum Safety and Environmental Management Authority 2015):

- Former Great Australian Bight Commonwealth Marine Reserve (includes location of proposed Stromlo-1 exploration well) – general approval has been issued by the Director of National Parks (DNP) allowing mining operations in these areas, including petroleum exploration drilling.
- New marine park zone – individual approval required in Benthic Protection Zone. Mining activities prohibited in the area corresponding to the former Marine Mammal Protection Zone. Commercial vessel transit (continuous passage of a vessel by the shortest direct route without any other activity being conducted, e.g. discharge of waste is prohibited) is an approved action, but the Marine Mammal Protection Zone is closed to all access from 1 May to 31 October. The Marine Mammal Protection Zone is more than 250 km from the Impact Environment that May Be Affected. The Impact Environment that May Be Affected is located in the Multiple Use Zone where mining (including exploration drilling) is permissible, given National Offshore Petroleum Safety and Environmental Management Authority approval.

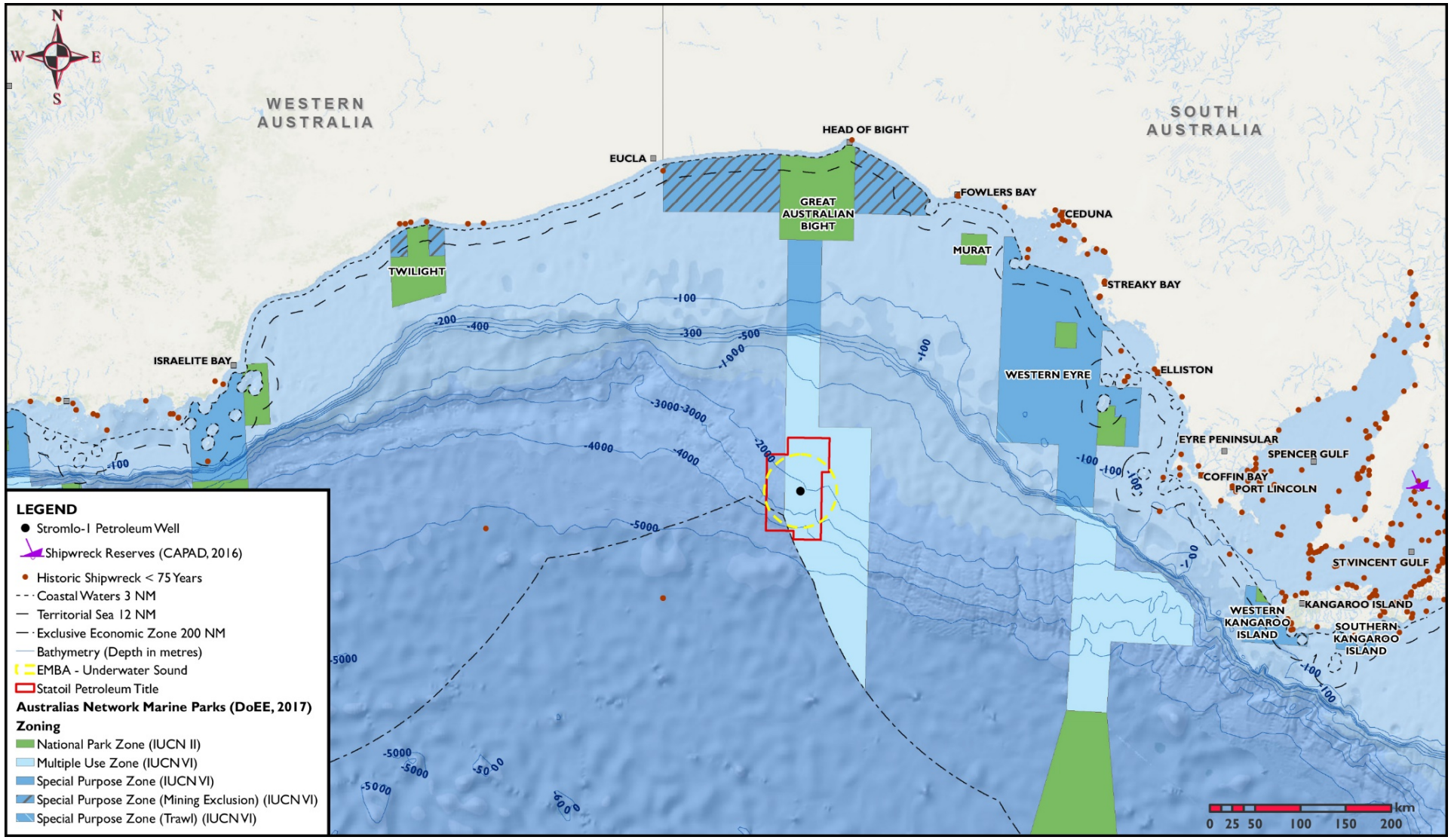


Figure 4.2 Commonwealth protected areas in the vicinity of the Impact Environment that May Be Affected

Table 4.1 Australian Marine Parks within the Impact Environment that May Be Affected

Marine park	Major conservation values	Relevant IUCN management principles
Great Australian Bight Marine Park – Multiple Use Zone (Australian Marine Parks, Dept of the Environment, https://parks australia.gov.au)	Globally important seasonal calving habitat for threatened southern right whales Important foraging areas for threatened Australian sea lions, threatened white sharks, migratory sperm whales, migratory short-tailed shearwaters Examples of the western ecosystems of the Great Australian Bight Shelf Transition and the easternmost ecosystems of the Southern Province Three Key Ecological Features (KEFs): • ancient coastline 90–120 m depth (high productivity) • benthic invertebrate communities of the eastern Great Australian Bight (communities with high species diversity) • areas important for small pelagic fish (species group with an important ecological role)	Multiple Use Zone – IUCN Category VI (22,682 km^2) – managed to ensure long-term protection and maintenance of biological diversity with a sustainable flow of natural products and services to meet community needs. Some commercial fishing is permissible and petroleum exploration and development is permissible. The project area occurs entirely within this zone.

Source: Australian Marine Parks (2018)

4.4.4 Threatened ecological communities

No threatened ecological communities (TECs) listed as matters of national environmental significance under the *Environment Protection and Biodiversity Conservation Act 1999* were identified within the Impact Environment that May Be Affected in the Protected Matters Search Tool report (Appendix 4-1).

4.4.5 Terrestrial values

The Impact Environment that May Be Affected is over 350 km from the closest landfall and therefore does not contain any terrestrial sensitivities or values. Specifically, the following terrestrial values are not represented within the Impact Environment that May Be Affected:

- Ramsar wetland sites
- state protected wetlands
- marine and coastal zone
- nationally important wetlands
- state protected terrestrial areas.

4.4.6 Key ecological features

Key ecological features are the parts of the marine ecosystem that Department of Environment and Energy considers to be important for the biodiversity or ecosystem functioning and integrity of the Commonwealth Marine Area. The Impact Environment that May Be Affected does not include any Key Ecological Features for which Department of Environment and Energy has published a map. The nearest of the spatially defined Key Ecological Features is the Ancient Coastline Key Ecological Feature at approximately 150 km from the Impact Environment that May Be Affected at its closest point (Figure 4.3). The “Small pelagic fish of the South-west Marine Region” Key Ecological Feature and the “Benthic invertebrate communities of the eastern Great Australian Bight” Key Ecological Feature have not been spatially defined but may be considered to intersect with the Impact Environment that May Be Affected and the deeper areas of the Great Australian Bight.

4.4.6.1 Small pelagic fish of the South-west Marine Region

Small pelagic fish are an important component of pelagic ecosystems in southern Australia; providing a link between primary production and higher predators, such as other fish, sharks, seabirds, seals and cetaceans. In the South-west Marine Region Key Ecological Feature, the Department of Environment and Energy lists 10 small pelagic fish species, sardine, scaly mackerel, Australian anchovy, round herring, sandy sprat, blue sprat, jack mackerel, blue (slimy) mackerel, red bait and saury (DSEWPaC 2012a). Small pelagic fish are distributed in pelagic habitats throughout the South-west Marine Region with the abundance of species determined by their individual ecologies. Small pelagic fish are known to occur in all Commonwealth Marine Reserves in the South-west Marine Region, including the Great Australian Bight Commonwealth Marine Reserve (DSEWPaC 2012a).

4.4.6.2 Benthic invertebrate communities of the eastern Great Australian Bight

Soft-sediment benthic invertebrate communities of the eastern Great Australian Bight are diverse and productive due to the influence of upwellings. The Great Australian Bight Research Program and Great Australian Bight Deepwater Marine Program studies have greatly improved the understanding of benthic invertebrate communities within the Impact Environment that May Be Affected and the deeper waters areas of the Great Australian Bight (Sections 4.6.2 and 4.6.3).

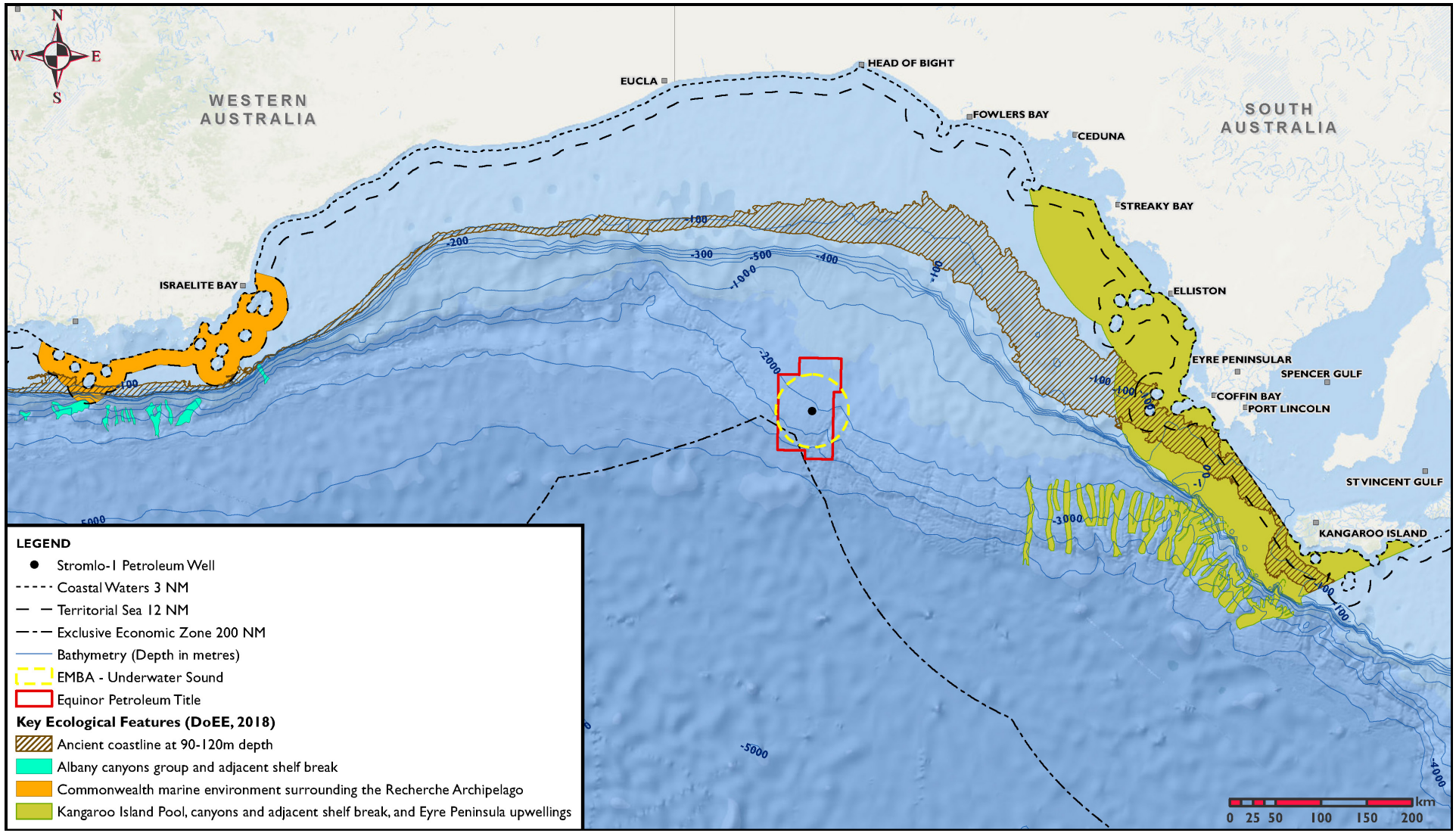


Figure 4.3 Commonwealth-listed Key Ecological Features in the Great Australian Bight

4.5 Physico-chemical environment

4.5.1 Bathymetry

Bathymetric features of the seabed in the Great Australian Bight have been analysed in several studies (e.g. Scholfield & Totterdel 2008) including recent studies by Equinor Australia B.V./BP p.l.c. as part of studies of the Ceduna seismic survey and geotechnical and geophysical investigations.

Rogers et al. (2013) state that about 70% of the seabed in the Great Australian Bight is composed of soft unconsolidated sediments. Due to large variations in bathymetry however, there are marked differences in sedimentary composition and benthic assemblage structure across the region.

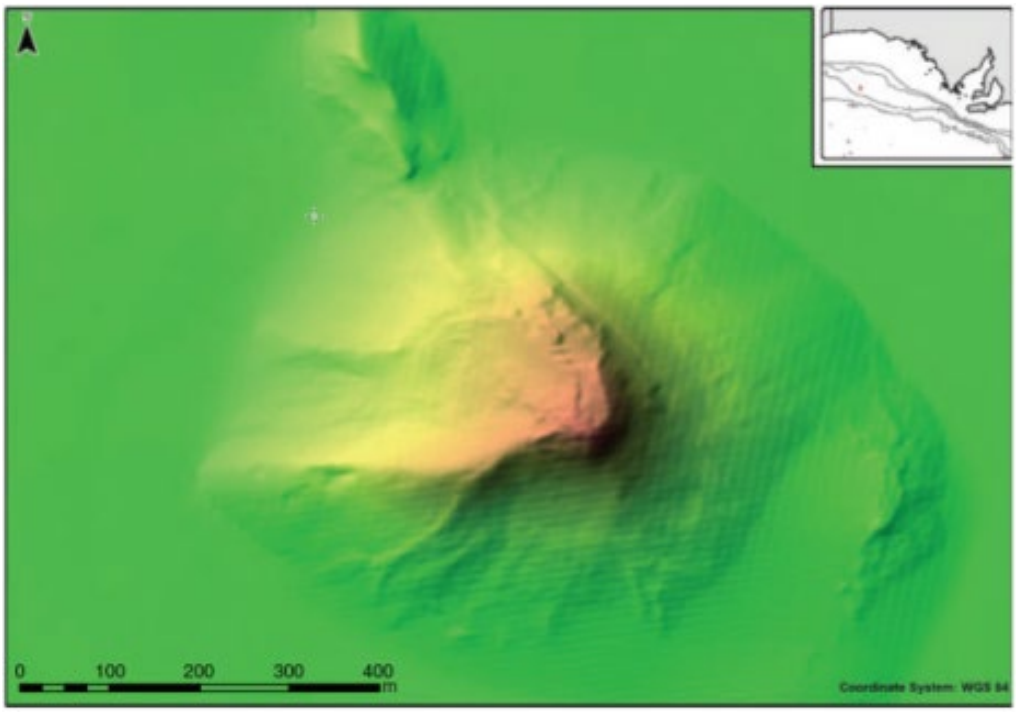
Seabed information previously gathered by Equinor Australia B.V. during the Ceduna seismic survey and geotechnical and geophysical investigation indicated that there are few seabed features in the Impact Environment that May Be Affected, which ranges from approximately 1500 to 4000 m water depth. The sea floor sediments found from the 2013 site investigation survey closest to the location all reports pelagic carbonates in a silty / sandy setting.

Two conical, volcanic seamounts have been mapped in the northern half of exploration permit 39 within the Impact Environment that May Be Affected; colloquially known as Anna's Pimple (Figure 4.4) and Murray's Mount. These seamounts are approximately 800 m in diameter and 200 m high (Currie & Sorokin 2011) and lie in water depths of about 1800 m. At their closest, they are approximately 20 km from the Stromlo-1 well location. Recent research from the Great Australian Bight Deepwater Marine Program indicates that there are around ten other similar volcanic seamounts in the greater Great Australian Bight area.

The Stromlo-1 well location lies on the abyssal slope, and it features slope terraces and deep submarine slope canyons.

To the north-west of the well location are mass wastage features, where soft sediments have been shed off the slope to reveal underlying harder seabed. To the east of the Stromlo well location is the headwall of an incised canyon that cross-cuts the abyssal slope, above which is a striated channel which has been formed by the movement of shelf sediments across the continental slope (Figure 4.5 and Figure 4.6). Another two incised canyons are visible further north.

The Stromlo-1 well location lies in a water depth of ~2239 m (+/-3 m), with a general seabed dip of around 3–4 degrees to the south.



Source: Ross et al. (2017)

Figure 4.4 High-resolution bathymetric map of Anna's Pimple volcanic seamount

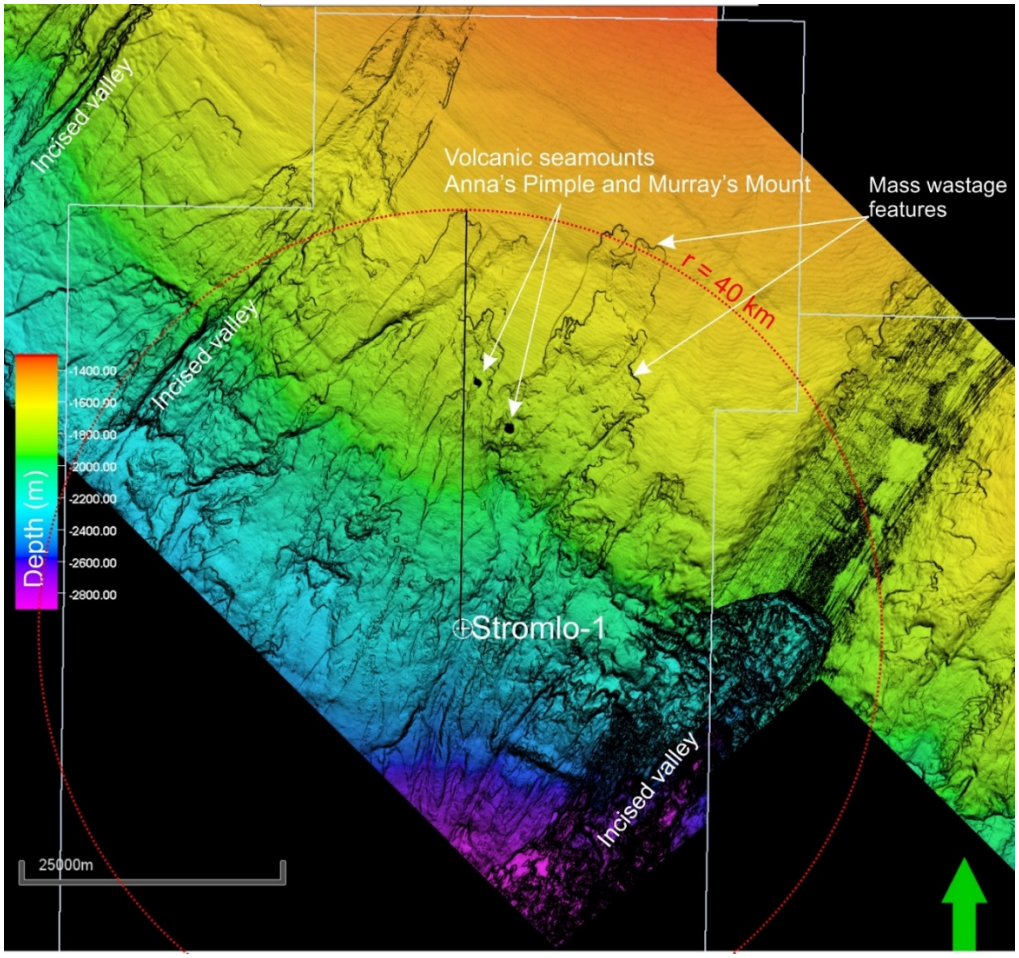


Figure 4.5 Bathymetric map with variance from 3D seismic showing volcanic seamounts, incised valleys and mass wastage features in exploration permit 39

Figure 4.6 Great Australian Bight Site Investigation Programme 2013 showing piston core locations (with Stromlo location in red)

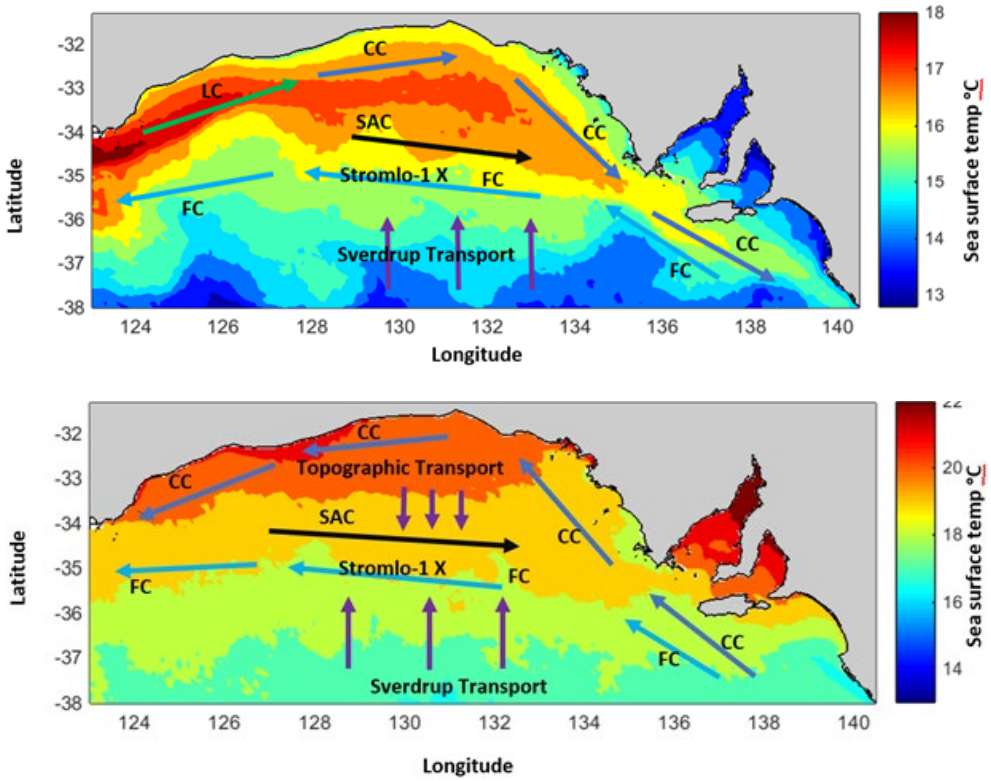
4.5.2 Slope sediments (including the well site)

Slope sediments (from 200 m to 3000 m depths) tend to be muddy and largely biogenic foraminiferal, spicule and pteropod oozes, also comprising fragments and skeletal remains of scaphopods, gastropods, echinoids, spherical and vagrant bryozoans, ostracods, echinoderms, micromolluscs and angular clasts transported downslope from the adjacent shelf (James et al. 2001; James & Bone 2011; McLeay et al. 2003). The muds are a mixture of approximately 66% fine biofragments and 33% fine pelagic components (McLeay et al. 2003). Sediment samples were part of both the Great Australian Bight research and the geotechnical survey performed by Fugro (2013). These were typically very dense clays at 1500–2000 m sites. A broad continental rise flanks the foot of the slope and extends towards the abyssal plain. Here the seabed is soft and muddy, and the surficial sediments are characterised by foraminiferal and coccolith oozes (Williams et al. 2013).

4.5.3 Currents

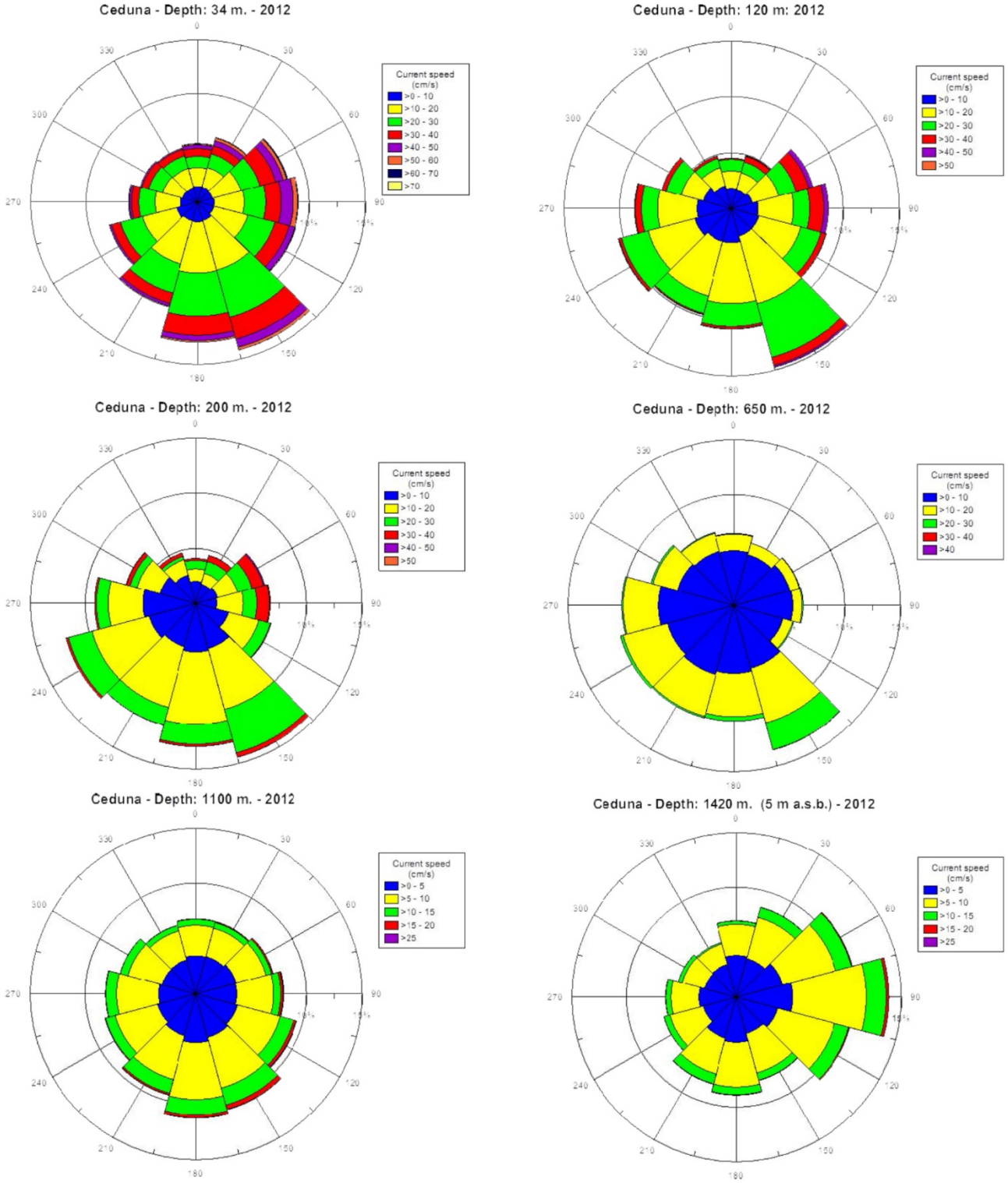
Four distinct oceanic currents occur within the Great Australian Bight: the Leeuwin Current (LC / LUC), the Flinders Current (FC), the South Australian Current (S.A. Current) and the Coastal Current (CC) (Figure 4.7). The LC is a seasonal surface layer current, being strongest in March to November, with current speeds typically reaching around 0.5 m/s. There are also two main wind-driven water circulation mechanisms – Sverdrup transport and topographic transport (Figure 4.7). The CC is a mixed-surface layer flow which in summer is sometimes arrested by the north-westerly flow of the FC. (IMOS 2014a). The FC is a deep underlying current occurring at depths of 400–700 m (Middleton et al. 2017), while the SAC is a surface current and thought to be associated with the LC and wind-forced currents (IMOS 2014b).

Figure 4.8 shows the current strengths and directions at various depths through the water column; from 34 m to 1420 m from the sea surface, as measured by current meters in the offshore Ceduna Sub-basin in 2012–2013 (Mathiesen 2017). The current roses show the prevailing directions towards which the currents flow. The currents decrease with depth, e.g. at 34 m the mean currents are 20 cm/s, decreasing to around 6 cm/s at 1420 m depth. Current speeds at the seabed below these depths are expected to be very low (Figure 4.9).



(LC: Leeuwin Current, FC: Flinders Current, SAC: South Australian Current, CC: Coastal Current) Source: modified Middleton et al. (2017)

Figure 4.7 Mean circulation and major currents in the Great Australian Bight in winter (top) and in summer (bottom)



Source: Mathiesen (2017)

Figure 4.8 Currents through the water column in the Ceduna Sub-basin in 2012

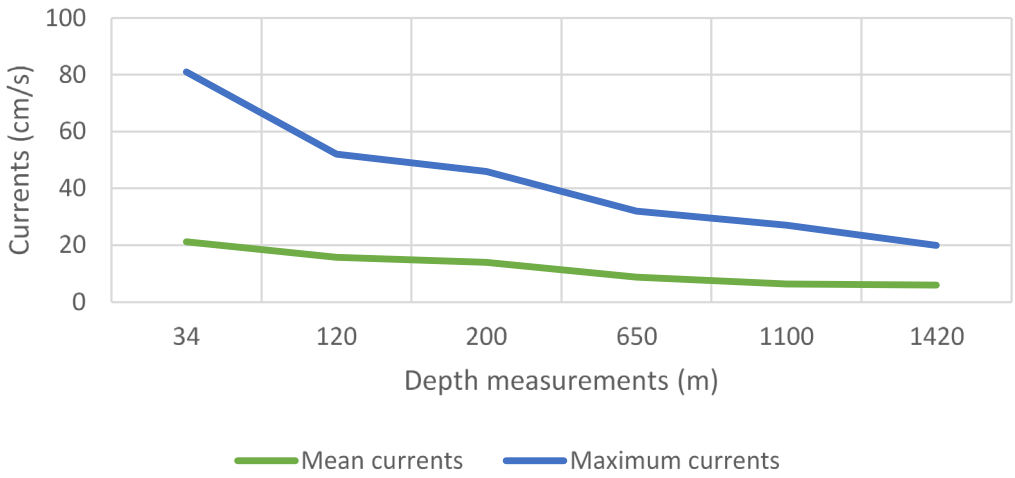


Figure 4.9 Currents through the water column in the Ceduna Sub-basin from local measurements in 2012

4.5.4 Climate and meteorology

Australia's size and geography gives rise to a diverse range of climate patterns across the continent and offshore islands. The southern and south-east coasts of Australia are primarily described as being a temperate climate. There is still variation present within this temperate belt, with south-western Western Australia to south-eastern South Australia typically having mild wet winters and hot dry summers compared with Victoria and New South Wales coasts, which experience year-round rainfall.

In summer, the Great Australian Bight is influenced by high pressure systems that move from west to east across the region. During winter, the land surface temperatures are cooler than the ocean, and the high pressure migrates to the north allowing for greater passage of cold fronts near the coast and primarily eastward winds (Rogers et al. 2013). Mean monthly air temperatures in Great Australian Bight (at a point 54 km from the Stromlo-1 well location) range average around 19 °C in February to 14 °C in July and August (Mathiesen 2017), with a maximum around 26 °C (January, March) to a minimum of 9 °C (August, September).

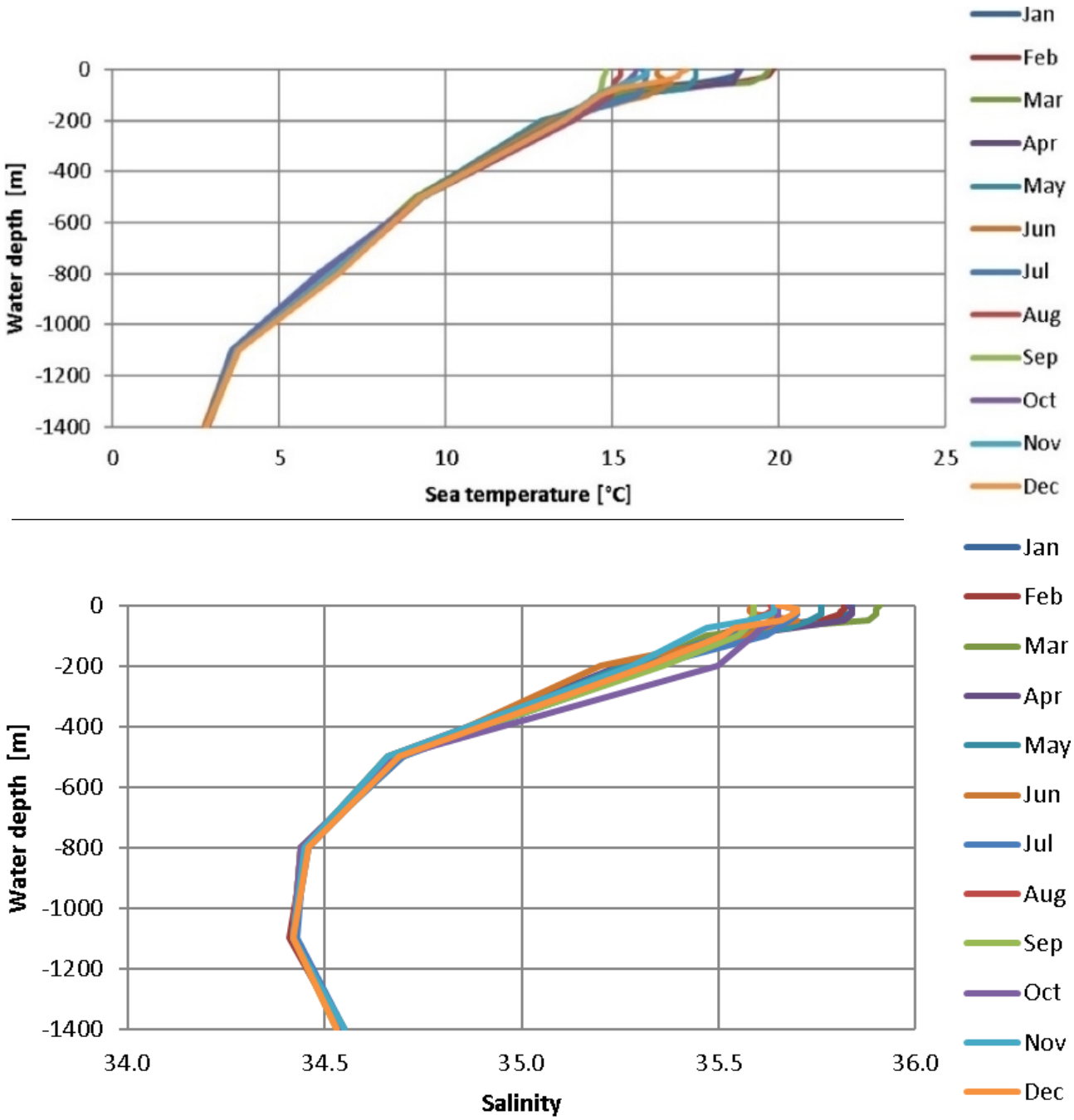
The majority of annual rainfall in the region occurs during the autumn and winter months (April to August), with an annual average of 272 mm at Eucla (90 km north-west of the Stromlo-1 well location) and 296 mm at Ceduna (415 km north-east of the Stromlo-1 well location) (BOM 2012). Rainfall increases to the west, with average annual rainfall along the Gippsland coast ranging from approximately 500 to >1000 mm. Evaporation exceeds precipitation all round and during summer; coastal waters are subject to intense heating (Rogers et al. 2013).

4.5.5 Temperature and salinity

Mean sea surface temperatures of the Great Australian Bight vary from 14.8 °C September to 19.8 °C in February (Figure 4.10; Mathiesen 2017), across the year. This variation is controlled by cross-shelf sea water exchange, and influenced by the combined effects of complex bathymetry, broadscale and local currents, wind and wave action and upwelling and downwelling events (Middleton et al. 2014, and see Sections 4.5.8, and 4.5.9.

During summer and autumn, upwellings produce patches of cool surface water along the coast of the southern Eyre Peninsula, in the eastern Great Australian Bight region. Year-round shelf downwelling caused by atmospheric cooling occurs in in the central Great Australian Bight. There is less seasonal variation in water temperature in depths below 200 m. From 200 m, temperatures drop from approximately 15 °C to 3 °C at 1400 m deep (Mathiesen 2017).

Salinity in the Great Australian Bight is more stable than temperature, across season, depth and distance from shore (Middleton et al. 2014). During both winter (June to August) and summer (January to March), mean salinity values range from 36.6 to 35.4 psu in water depths of 0–50 m, increasing with distance from shore. The saltiest water is found near the coast suggesting dense water formation due to evaporation. Offshore, mean values range from approximately 35.5 psu at the surface to 34.6 at 400 m deep.



Source: Mathiesen (2017)

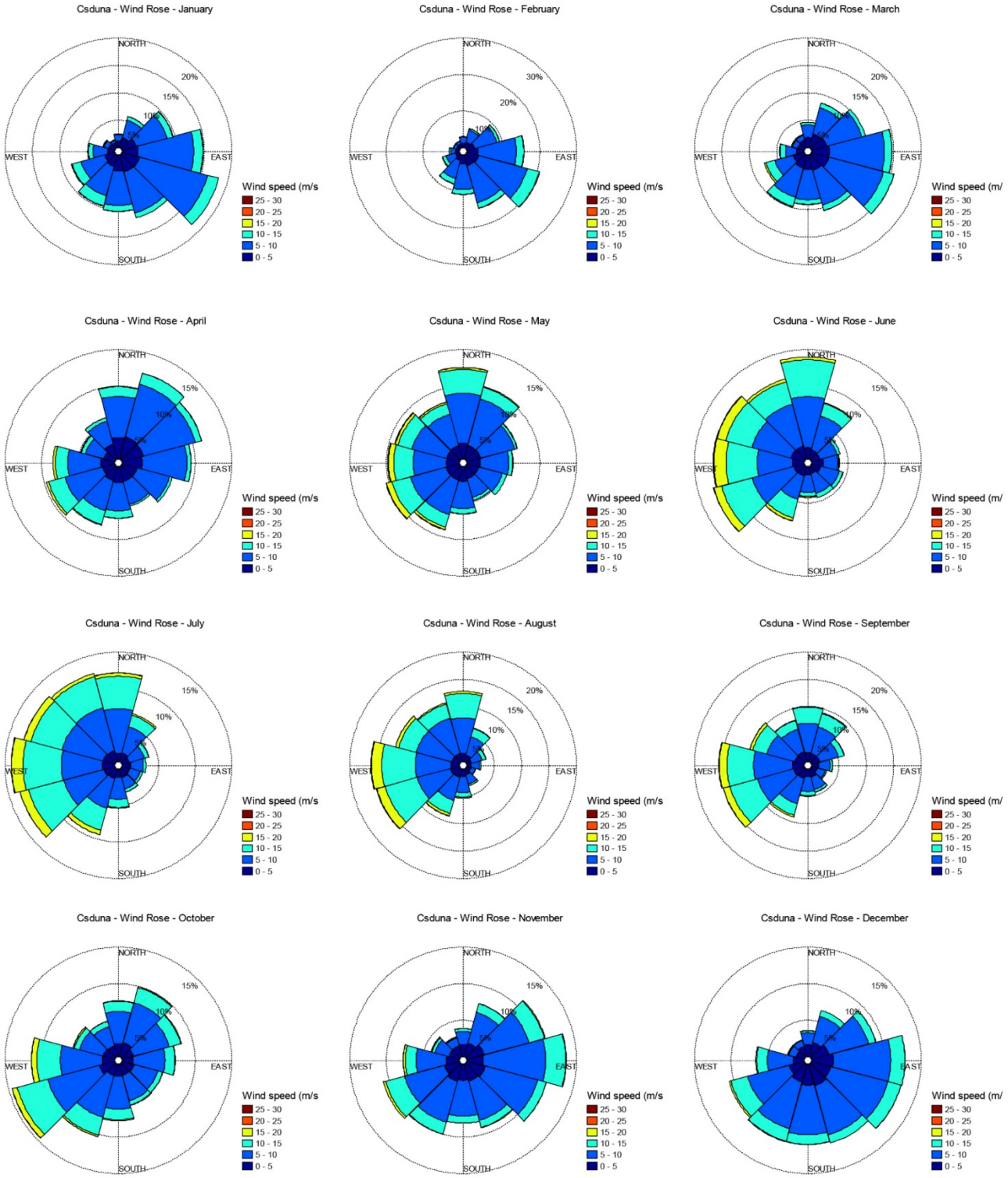
Figure 4.10 Mean monthly sea temperature and salinity profiles in the Great Australian Bight from 2005 to 2013

4.5.6 Winds

Wind data is available for the Stromlo area from a hindcast archive covering the period 1979–2013 with three-hour sampling. The quality of the model data has been verified by comparison with simultaneous local measurements over a period of one year within the Great Australian Bight. While wind velocities are of good quality some uncertainties related to directionality remains.

During November to March, the Great Australian Bight region is dominated by large atmospheric high-pressure systems which direct winds to the west and lower coastal sea levels (Middleton et al. 2017).

In the title area, the strongest winds are predominantly from the west and south-west. Monthly wind roses indicate that the strongest winds (>15 m/s) are experienced between June and September (Figure 4.11). Winds are weaker in November to February, when winds from the east and south-east dominate.



Source: Mathiesen (2017)

Figure 4.11 Monthly wind roses in the title area for 1979–2013

4.5.7 Tides

Tides at the Stromlo-1 well location are semi-diurnal; characterised by two daily high tides of different heights. Tidal elevations at the well location were estimated using the NAO.99b tidal prediction system, which predicted highest tides of +75 cm (Highest Astronomical Tide (HAT)) and lowest tides of -47 cm (Lowest Astronomical Tide (LAT)) relative to the mean sea level (MSL).

4.5.8 Upwelling

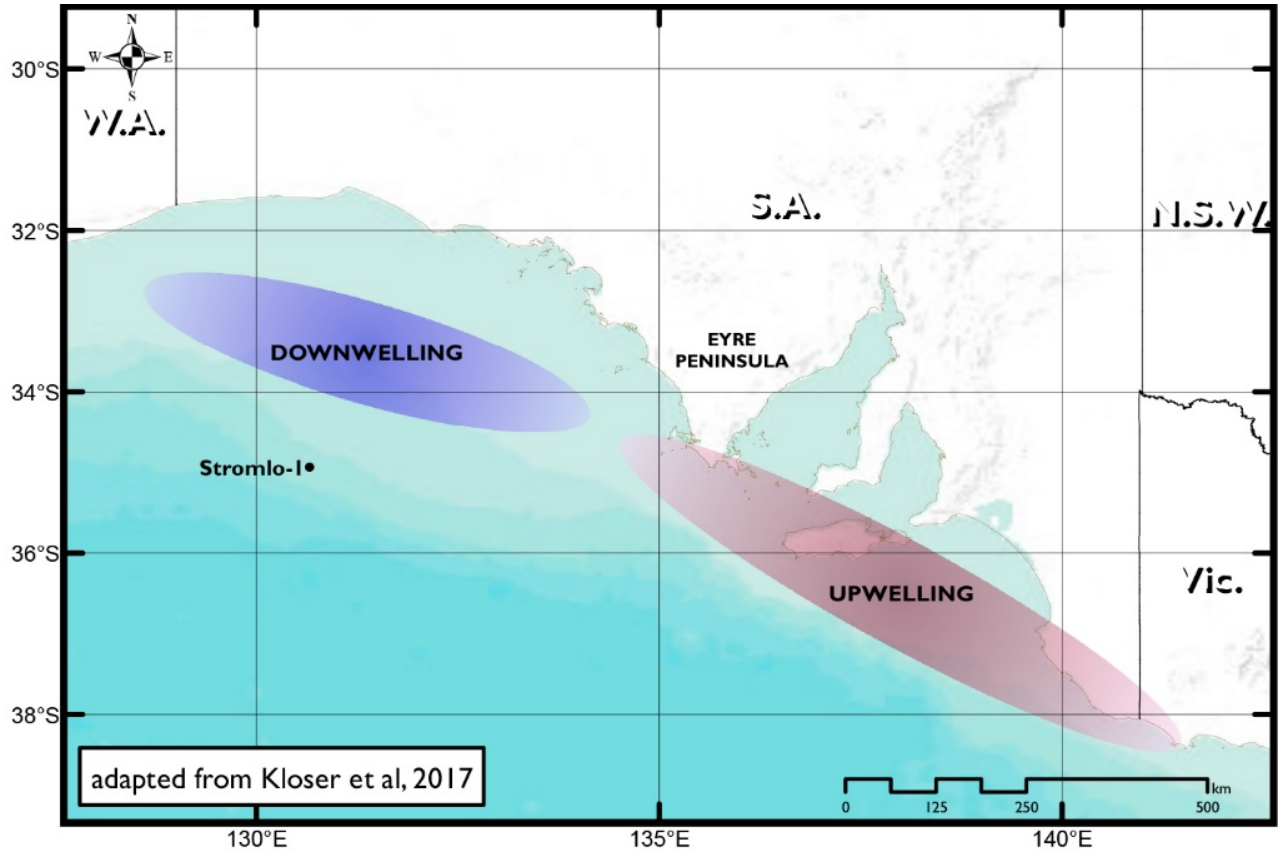
The dominant south-easterly winds during summer favour upwelling of deep oceanic water and assist the movement of water from the slope onto and across the shelf (McLeay et al. 2003). Summer upwelling occurs in the western and eastern Great Australian Bight regions; forced by winds and enhanced by the presence of submarine valleys and headlands (Ward et al. 2017). The eastern upwellings are thought to be linked to mesoscale eddies that form off the Eyre Peninsula, which play a role in lifting cold (14–18 °C), nutrient-rich water from depths of >150 m along the Bonney Coast and Kangaroo Island regions toward the surface in the direction of the Eyre Peninsula and in turn enhance the productivity of plankton communities (Rogers et al. 2013, Ward et al. 2017). Significant upwelling is only observed where the shelf is narrow (Middleton et al, 2017). Surface waters move offshore, and colder water moves up the slope of the coastal shelf with this water tending to be drawn from the depth of the shelf edge (200–300 m) in the case of the Bonney Upwelling, and potentially from deeper canyons downslope from the shelf edge in the case of the Kangaroo Island Upwelling. Both these upwellings are spatially defined as KEFs in Section 4.3. Vertical currents associated with episodic upwelling (and downwelling events) are relatively small (3–30 cm/s; Kampf et. Al. 2004) compared to horizontal currents represented in the tidal and non-tidal current data (0.5–2 m/s).

These seasonal upwellings may occur 4–5 times during each summer (Ward et al. 2017). Hydrodynamic models developed by Middleton et al. (2017) to describe oceanographic circulation within the Great Australian Bight demonstrated that reversal of the nearshore coastal current in summer leads to upwelling in the eastern Great Australian Bight, including the Bonney Upwelling (Figure 4.12). This is a seasonal phenomenon comprised of regular cold-water upwelling plumes that occur along the Bonney Coast (between Robe, South Australia and Portland, Victoria) from November to March (CoA 2015).

4.5.9 Downwelling

Recent research in the Great Australian Bight has confirmed that weak downwelling occurs year-round in the central Great Australian Bight, driven by atmospheric cooling and evaporation in winter, and by the collision of the Sverdrup transports in summer (Ward et al. 2017). However, downwelling favourable winds are dominant from May to October (Kloser & van Ruth 2017). Downwelling is enhanced through the outflow of cold, dense water flows off the coast and out of the gulfs and down the coastal shelf to depths of around 250 m.

Cross-shelf exchange is influenced by downwelling in the north of the central Great Australian Bight (Figure 4.12). Summer westward winds driven by large high-pressure systems drive coastal upwelling and a westward coastal current in the central to eastern Great Australian Bight, leading to a topographic southward transport in the central Great Australian Bight region (Figure 4.7). This transport is important as it collides with the equatorward deep ocean transport, leading to year-round downwelling at the shelf edge, and drives the S.A. Current to the east, even against prevailing westward winds (Ward et al. 2017). During summer, weak coastal currents (<10 cm/s) lead to downwelling in the central Great Australian Bight to depths of 250 m at the shelf slope (Rogers et al. 2013). Mesoscale eddies and internal waves are expected to modulate upwelling and downwelling processes in the epipelagic zone over the Great Australian Bight (Rogers et al. 2013).



Source: Middleton et al. (2017), modified

Figure 4.12 Indicative areas of downwelling and upwelling in the Great Australian Bight region

4.5.10 Waves

The wave climate in Great Australian Bight is dominated by long period swells and the area is therefore affected by persistent presence of swells.

Accurate information on the wave field has been collected over the past few years as a crucial step in simulating the impact of waves on ocean circulation. Equinor Australia B.V. has access to local recordings and long-term quality checked model data for this region. The final wave models have also been compared with independent datasets to determine the models' accuracy. The Great Australian Bight Research Project showed that wave models can confidently be used to predict wave energy across the whole Great Australian Bight, including in areas where there are no observations (Middleton et al. 2017).

Monthly mean and maximum significant wave heights for the offshore Ceduna Sub-basin are presented in Table 4.2. The wave climate in the Great Australian Bight region is mildest in November to March and most extreme in May to October. The annualised wave roses in Figure 4.13 show the prevailing direction from which the waves originate, and the colours indicate the wave heights. The two roses show concordance between the two studies and regions in the predominance of waves from the south-west. These unimpeded south-westerly waves and swells create a high energy near-shore environment resulting in wave abrasion down to 60 m depth (Hayes et al. 2012).

The term "maximum wave height" often refers to the highest individual wave within a sea state (a description of the sea for a three-hour period and is usually characterised by the significant wave height (Hs) and the spectral peak period (Tp)). The highest individual wave within a sea state can be almost twice as high as the significant wave height. The metocean design basis for Ceduna, which is used for planning of offshore operations, includes statistics both for significant wave height (Hs) and maximum individual wave heights.

A rogue wave (sometimes called a monster wave) can occur in most seas around the world. The phenomenon however is simply an event where one wave grows significantly higher than normal by drawing on the energy from surrounding waves. In general, any "normal" wave within a sea state is smaller than twice the significant wave height, whereas a rogue wave can be higher than twice the significant wave height.

There is no known upper limit regarding how high a rogue wave can be relative to significant wave height before it decays but most numbers found in literature are between twice and three times. A rogue wave is therefore not necessarily a very high wave, it is only high relative to the other waves in the sea state. Historically, Equinor Australia B.V. has only experienced one event with damage caused by a rogue wave.

Equinor Australia B.V. commissioned RPS Australia West Pty Ltd to study one year wave statistics with Great Australian Bight wave recordings with the objective to estimate frequency and severity of rogue waves. Preliminary results show that Great Australian Bight waves are not steep and individual wave heights are within the limits of traditional wave statistics.

The main concern with rogue waves is that they cannot be predicted. In order to avoid damage during installation activities all operations have a certain margin between the design limit and the operations limit. This margin shall, amongst other things, ensure that in the unlikely event that a rogue wave occurs at the time and place of the installation, and no harm is caused.

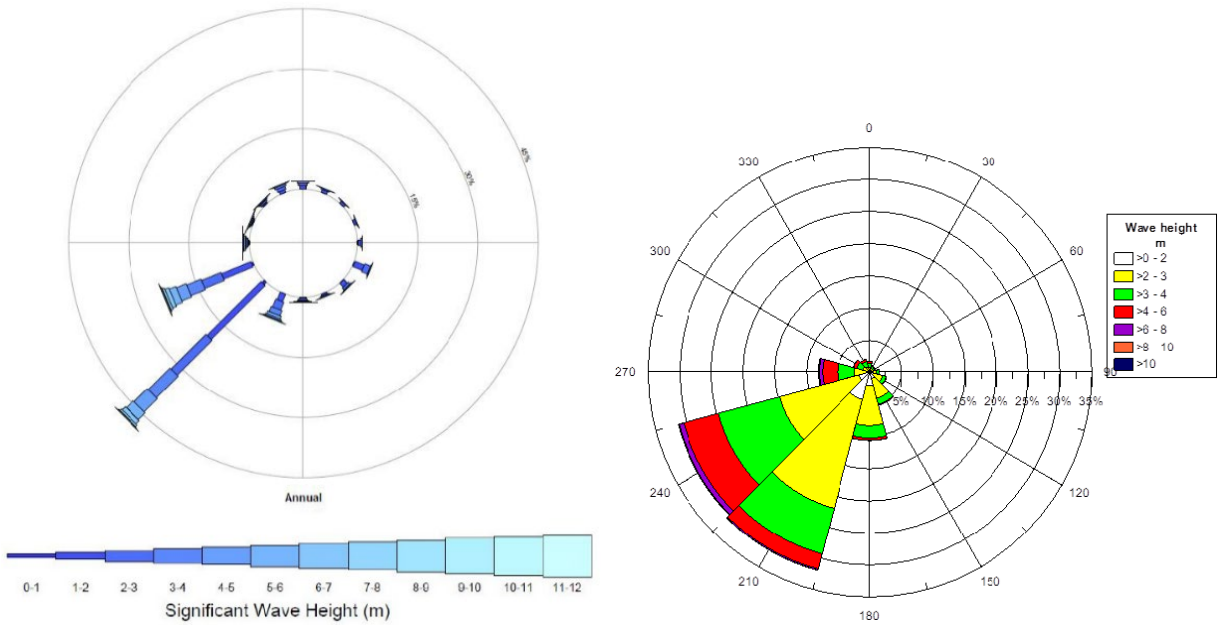
For all offshore operations, waves may cause unacceptable motions to vessels and rigs. To reduce both risks and waiting time, Equinor Australia B.V. actively uses weather and wave forecasts together with wave and motion monitoring. This ensures that operations are stopped safely before any operations limit is exceeded. Wave monitoring is of importance both for offshore personnel to identify weaknesses in forecasting services and for forecasters to correct and improve their forecasts.

Within recent years, Equinor Australia B.V. has collaborated with the forecasting agency StormGeo to developed procedures for “response forecasting”. In addition to forecasting the weather, forecasts will also predict how the vessel/rig motions will be within the upcoming days. Use of response forecasting is expected to be an important supplement to the traditional forecasts when operating in the Great Australian Bight.

Table 4.2 Monthly mean and maximum wave heights for the Ceduna Sub-basin

Significant wave height (m)	Month												Annual
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Mean	2.5	2.5	2.6	2.8	3.1	3.5	3.6	3.7	3.6	3.1	2.7	2.6	3.0
Maximum	7.6	6.3	7.2	9.3	11.0	11.0	9.8	11.0	11.3	10.0	10.7	7.3	11.3

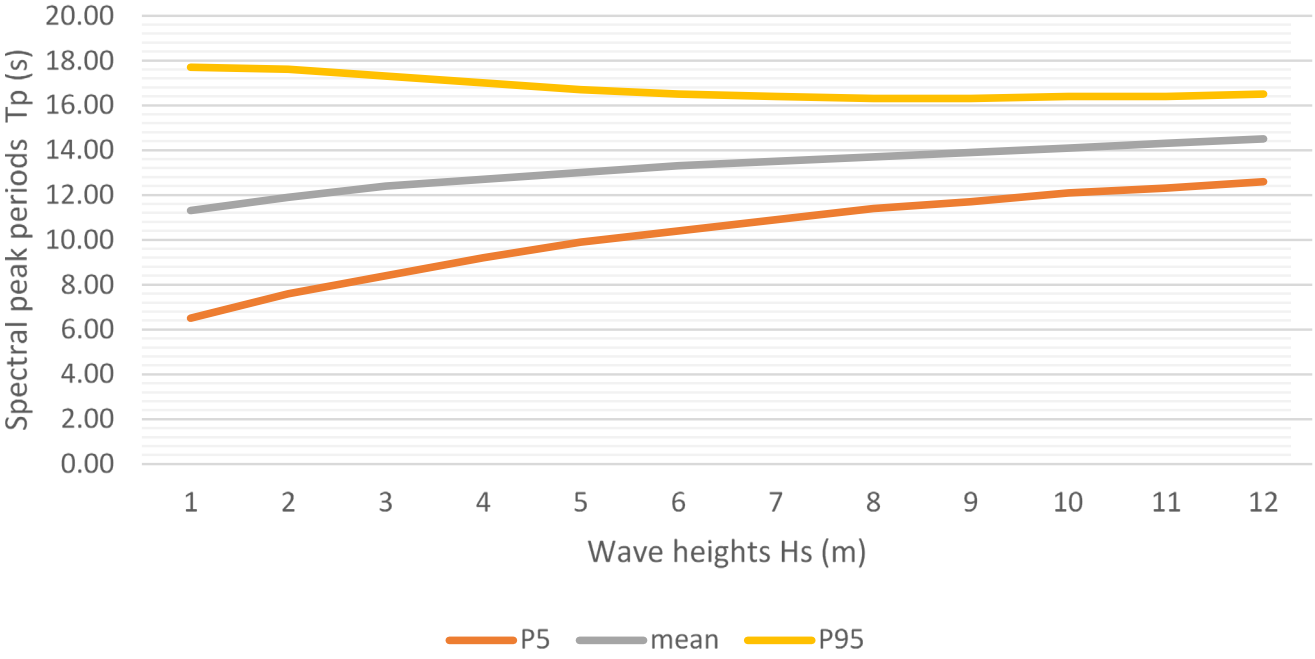
Source: Mathiesen (2017)



Source: Mathiesen (2017), Rogers et al. (2013)

Figure 4.13 Annualised wave roses for the wider Great Australian Bight region from 1993 to 2008 (left) and for the Stromlo area (Ceduna Sub-basin) from 1979 to 2013 (right)

The spectral peak period (the time between consecutive wave crests) shows swells with relatively long inter-peak periods (Figure 4.14). Note there are no data points from the model with wave heights below 1 m (Hs <1 m), reflecting the sea in this area is rarely flat. The mean wave periods indicate 10–14 s periods, and wave heights between 1–12 m. Mean wave height is 3.0 m, with a corresponding wave period of 12 s.



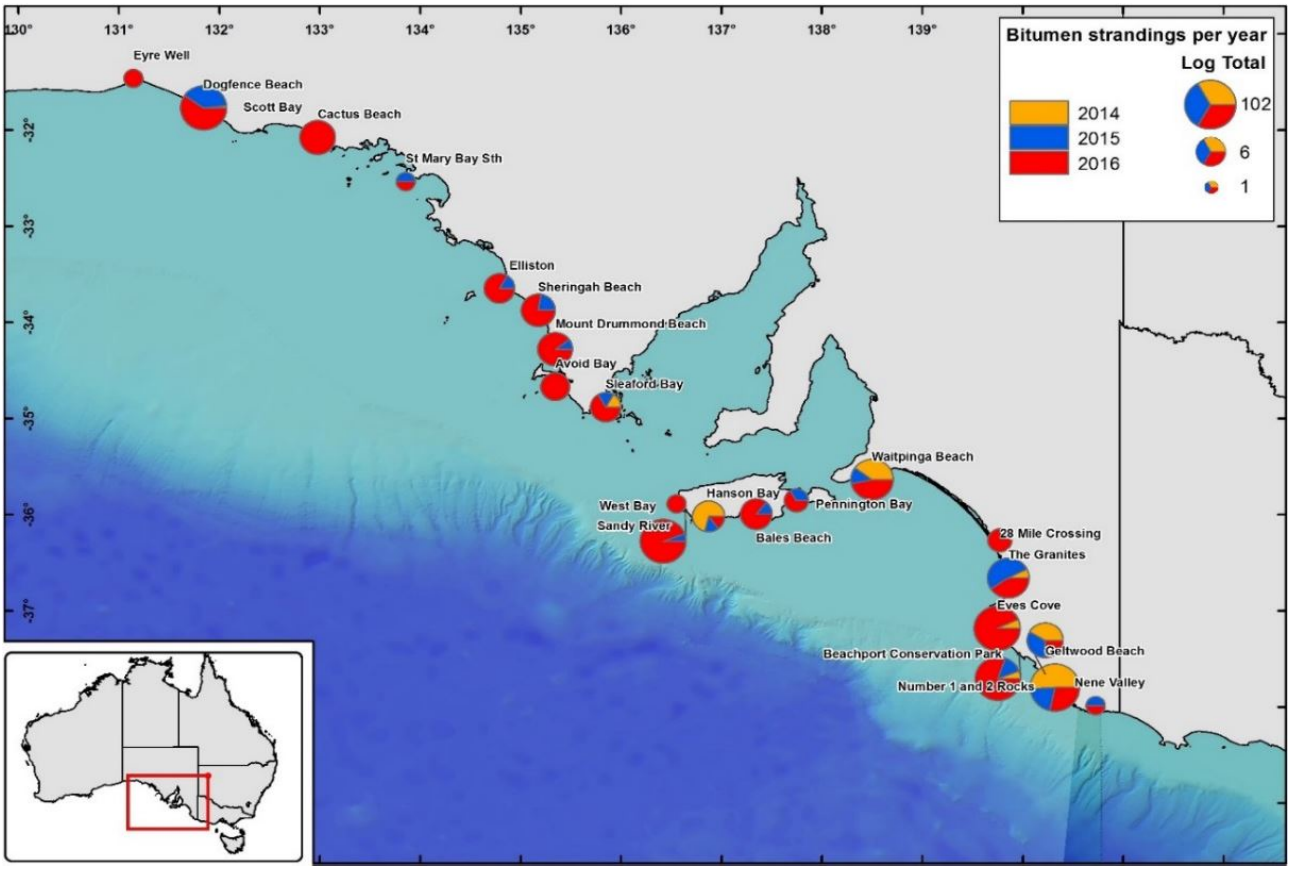
Source: Mathiesen 2017

Figure 4.14 Mean spectral peak periods for given significant wave heights with fifth and 95th percentiles in Ceduna Sub-basin

4.5.11 Natural hydrocarbons in the Great Australian Bight

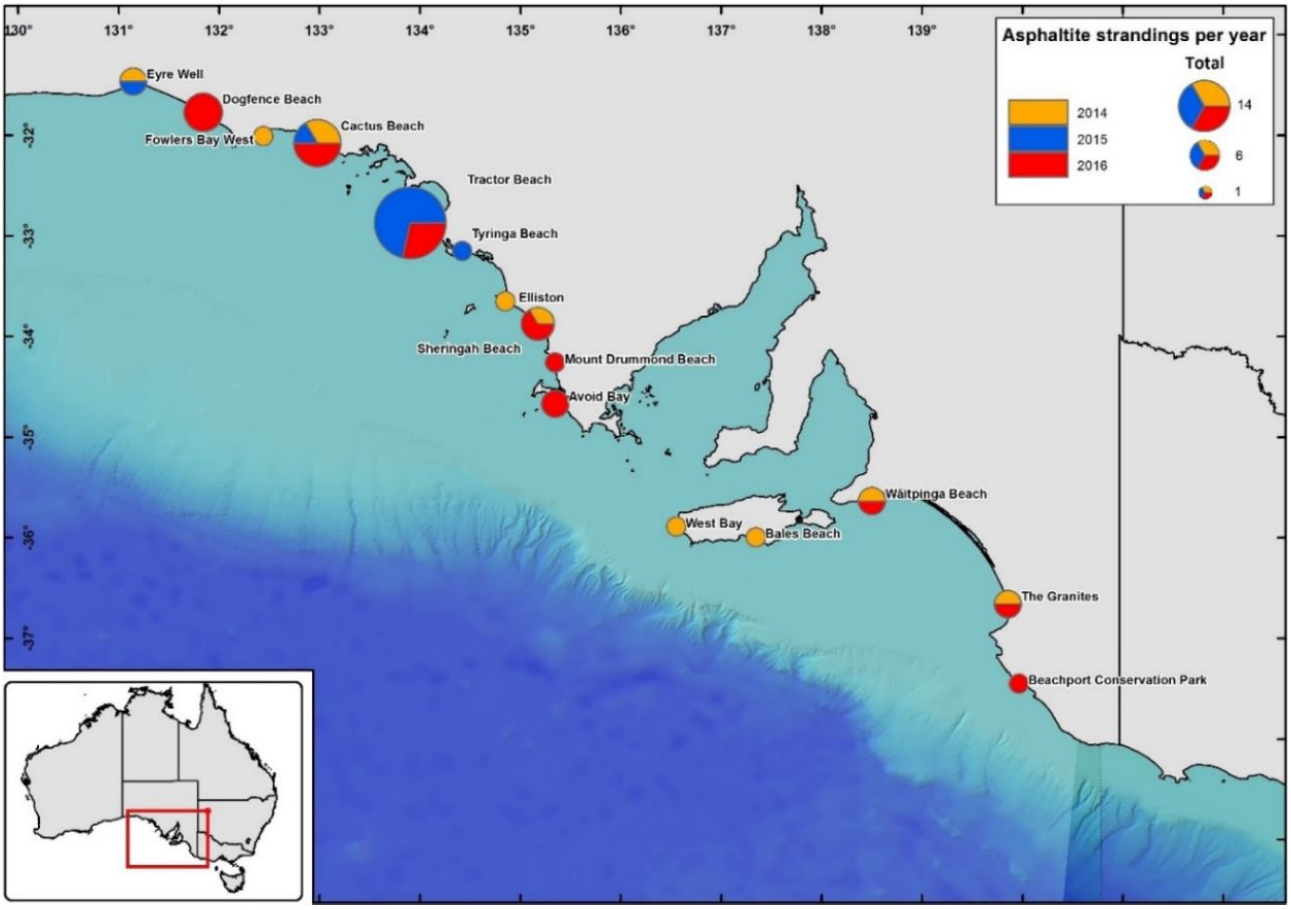
Hydrocarbons are a natural part of the Great Australian Bight environment and highly weathered forms frequently wash ashore along the southern Australian coastline. The Great Australian Bight Research Program has built on historical observations and provided a more detailed understanding of the geographical distribution of modern asphaltite strandings (a jet-black bitumen with a petroliferous odour) along the South Australian coastline which most likely originated from natural hydrocarbon seeps (Ross et al. 2017b). Surveys for asphaltite and waxy bitumens occurred along the coastline during 2014, 2015 and 2016. Tar balls (waxy bitumens) tend to strand in the upper intertidal to supratidal zones of south-west facing ocean beaches, whereas the less common denser asphaltites tend to accumulate on beaches with a north-west aspect (Ross et al. 2017c). Waxy bitumens, possibly originating from Indonesian waters, are the most prevalent types of bitumen stranding on South Australian beaches; particularly on the Limestone Coast (Figure 4.15). Asphaltites are more common along the west coast of the Eyre Peninsula, which suggests a different point of origin (Figure 4.16) (Ross et al. 2017c).

Historical (satellite-mounted) synthetic aperture radar images indicate some hydrocarbon seepage (Figure 4.17), but it is difficult to determine the origin and quality of these signals. Hydrocarbons were not detected in baseline water and sediment samples in the offshore areas of the Great Australian Bight, suggesting any natural seeps would be intermittent or not expressed in the surveyed areas (Ross et al. 2017b).



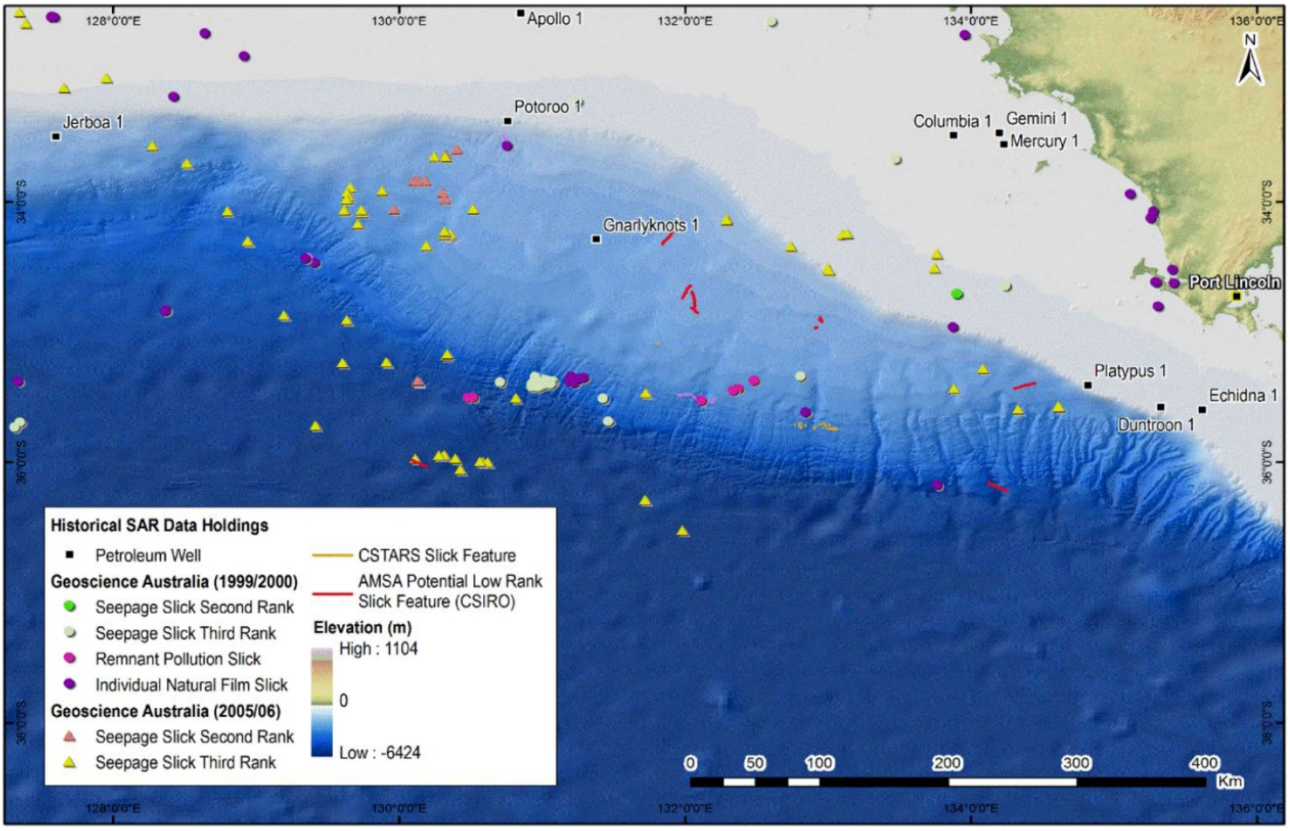
Source: Ross & Kempton (2017)

Figure 4.15 Natural tar ball strandings per year along the South Australian coast (on a log scale)



Source: Ross & Kempton (2017)

Figure 4.16 Asphaltite strandings per year along the South Australian coast



Source: Ross & Kempton (2017)

Figure 4.17 Synthetic aperture radar seepage indications (on the sea surface)

4.5.12 Hydrocarbon degrading bacteria

The Great Australian Bight Research Program revealed the presence of microbial communities capable of degrading hydrocarbons in surficial deep-water sediments down to 2800 m (van de Kamp et al. In Review). These oil-degrading microbes have been shown in various studies, including monitoring after the Macondo oil spill in the Gulf of Mexico in 2010 (Deepwater Horizon), to bloom in the presence of elevated hydrocarbon concentrations, and play an important role in natural bioremediation of oil spills (van de Kamp et al. In Review).

Water and sediment samples taken from different depths show a resident microorganism community that includes a host of known hydrocarbon biodegraders, both bacteria and archaea, which have been shown to increase in abundance in response to previous spills in other basins (Hook et al. 2016; Techtmann et al. 2015). There are several biochemical pathways for biodegradation of hydrocarbons and the key genes for these pathways have been identified in sediment and water microbes in the Great Australian Bight (Tanner et al. 2017). This supports the assumption that hydrocarbon degrading microbes are present and, in the presence of a hydrocarbon food source, would respond with a rapid population increase to be able to biodegrade oil entrained in the water column and sedimented on the seabed.

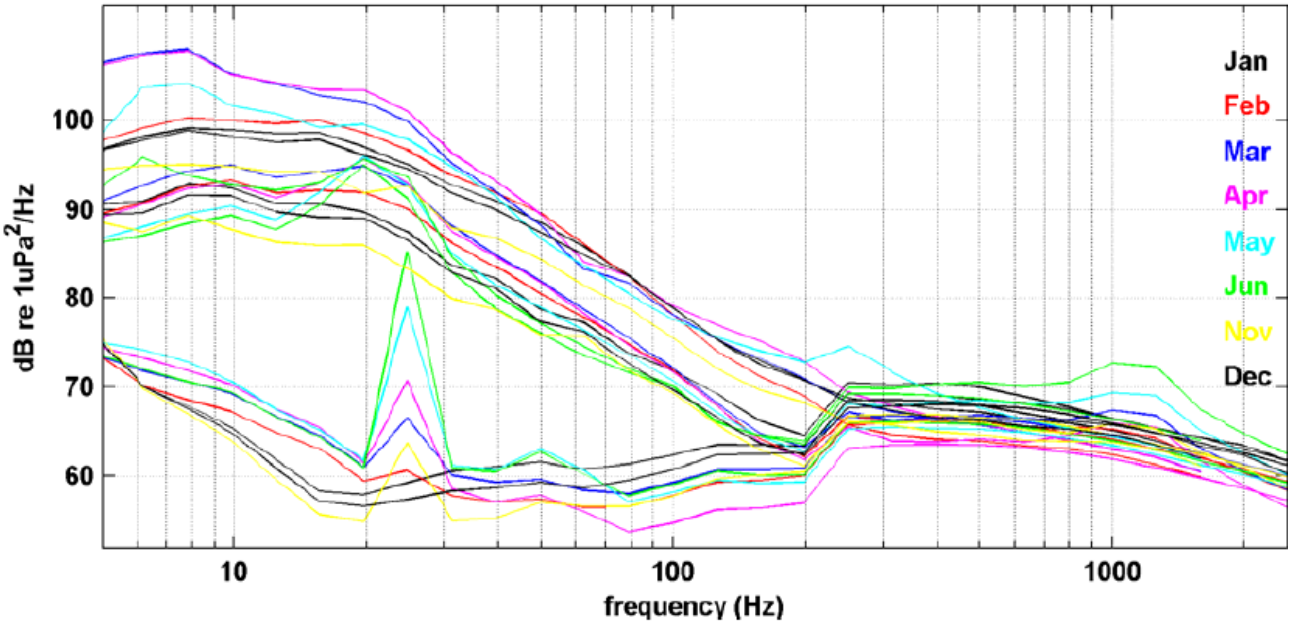
4.5.13 Ambient underwater sound levels

Ambient sound levels in the Great Australian Bight were recorded from late 2011 to mid-2012 by sound loggers that were deployed in the Great Australian Bight as part of BP p.l.c./Equinor Australia B.V.'s efforts to investigate underwater sound characteristics of the area. Three sound loggers were deployed:

- one near the Head of Bight (approximately 335 km north of the Stromlo-1 well) in 50 m of water
- two along the shelf break (approximately 175 km north and 250 km east of the Stromlo-1 well) in water depths of approximately 190 m.

Ambient sound was higher at the shelf break sites compared with the Head of Bight, and the two shelf break sites showed a steady increase in ambient noise over summer and into early winter (McCauley et al. 2012). McCauley et al. (2012) found that ambient sound levels at the Head of Bight ranged from 73.5 to 131.9 dB re 1 µPa root mean squared (SPLrms), with an average of 97.1 dB re 1 µPa (SPLrms); and at the shelf break ranged from 74.5 to 144.9 dB re 1 µPa (SPLrms), with an average of 111.7 dB re 1 µPa (SPLrms).

Figure 4.18 illustrates the mean monthly ambient noise spectral level curves, calculated at ⅓ octave centre frequencies for the three sound loggers. The lower curves are from the Head of Bight, the upper sets of curves are from the shelf break sites. The Head of Bight clearly differentiates as having much lower ambient noise levels from the shelf break sites, principally below 200–300 Hz. The spikes in ambient noise in the 20–30 Hz bands at all sites were due to whale calling, either nearby as at the Head of Bight or via long range energy reaching the receivers via the deep sound channel at the shelf sites (McCauley et al. 2012). Shelf break sites received significantly more energy from distant natural sources below 300 Hz via ducting from the deep (1000 m) sound channel compared to the Head of Bight (McCauley et al. 2012).



Source: (McCauley et al. 2012)

Figure 4.18 Mean monthly ambient noise levels at the three sites in the central Great Australian Bight

4.6 Biological environment – species and communities

4.6.1 Plankton

The central Great Australian Bight slope and offshore waters were sampled during the Great Australian Bight Research Program in April 2013 and in 2015. These were conducted along a series of transects, including one representing the central Great Australian Bight and another in the eastern CAB (Figure 4.19). The surface waters of the central Great Australian Bight are oligotrophic (nutrient poor), affected by year-round downwelling (Figure 4.12; Kloser et al. 2017). The influence of these dynamic conditions along the slope is the subject of new research.

The 2015 survey for the Great Australian Bight Research Program investigated the importance of upwelling events in the central and eastern Great Australian Bight. The survey results indicated that the upwelled water mass, and therefore significant enrichment of waters in the euphotic zone, was restricted to the eastern Great Australian Bight, and that there was no evidence of upwelled water on the central Great Australian Bight shelf (van Ruth & Redriguez 2017).

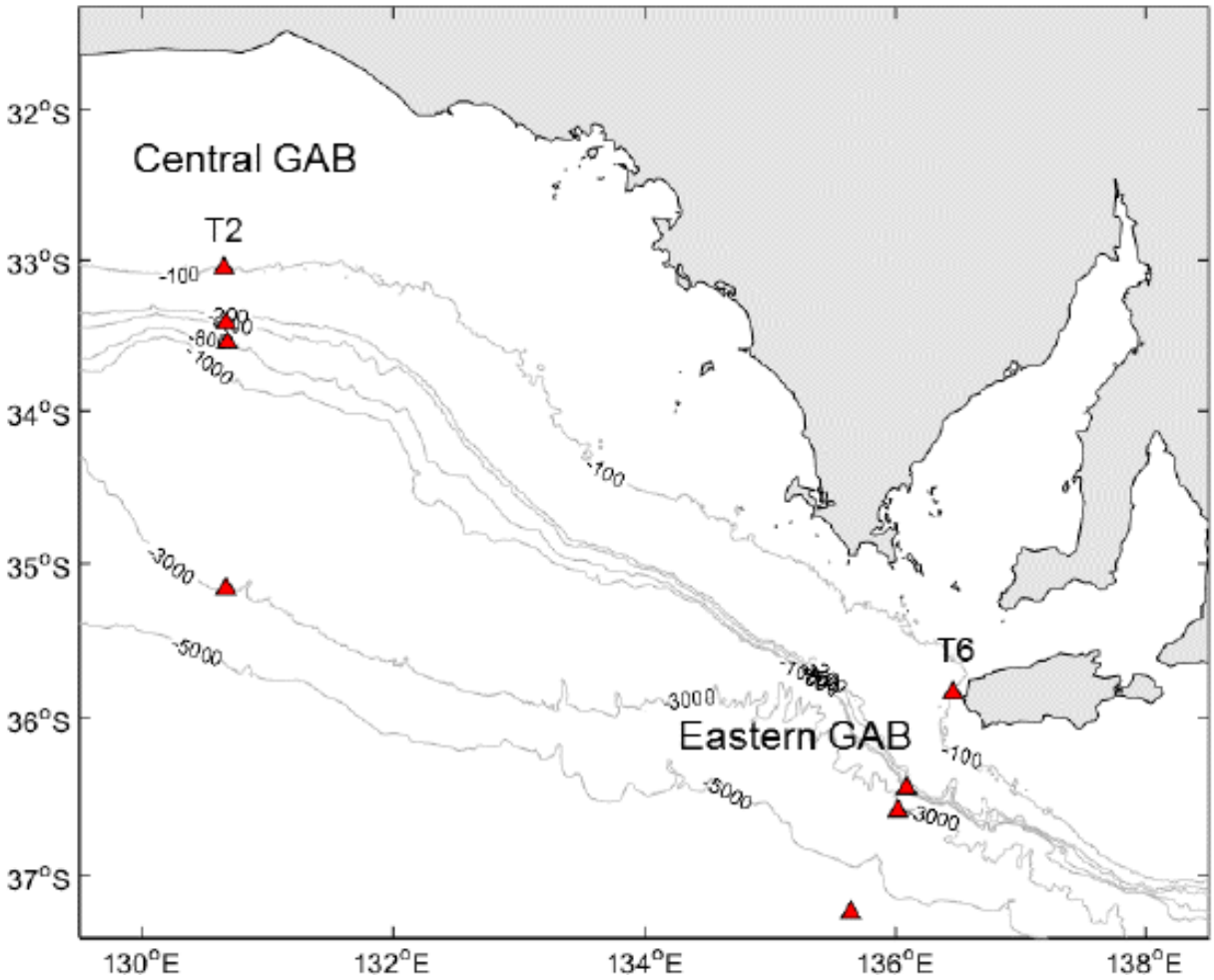


Figure 4.19 Central Great Australian Bight and eastern Great Australian Bight sample sites along transects representing shelf, upper slope, mid slope and offshore stations

Highest concentrations of chlorophyll-a (a photosynthetic pigment used as an indicator of phytoplankton abundance) occurred at depths of 60 m (0.43 µg/L) at the 200 m and 400 m isobaths. Chlorophyll-a declined with distance from the shelf edge to low concentrations (0.19 µg/L) in the water column at the 1000 m and 2000 m isobaths. Upper slope waters in the central Great Australian Bight were dominated by abundant phytoplankton (>94% of Chl a) with picoplankton (e.g. *Synechococcus* and *Prochlorococcus*) well represented. Dinoflagellates generally contributed more than 40% of the phytoplankton community; flagellates were the next most abundant.

Total chlorophyll-a concentrations were 1.7-fold higher in the eastern Great Australian Bight than in the central Great Australian Bight, with the highest concentrations approximately 70–90 m below the surface in the central Great Australian Bight (Kloser et al. 2017). A study of the western Great Australian Bight during summer found that zooplankton biomass was only 2% of that in the Gulf of Carpentaria (McLeay et al. 2003).

Data on zooplankton distributions were collected from the Great Australian Bight during a voyage in April 2013 by the Commonwealth Scientific and Industrial Research Organisation and South Australian Research and Development Institute (Williams et al. 2013). Depth-integrated and duplicate larger surface water samples of mesozooplankton were taken at each station and a range of crustaceans, siphonophores, jellyfish and larval fish were collected (Williams et al. 2013). Deeper water zooplankton sampling was also undertaken to collect zooplankton and micronekton from the surface to 1000 m water depth during the downcast, and then in five discrete depth intervals (1000–800 m, 800–600 m, 600–400 m, 400–200 m, and between 200 m and the surface) during the up-cast (Williams et al. 2013).

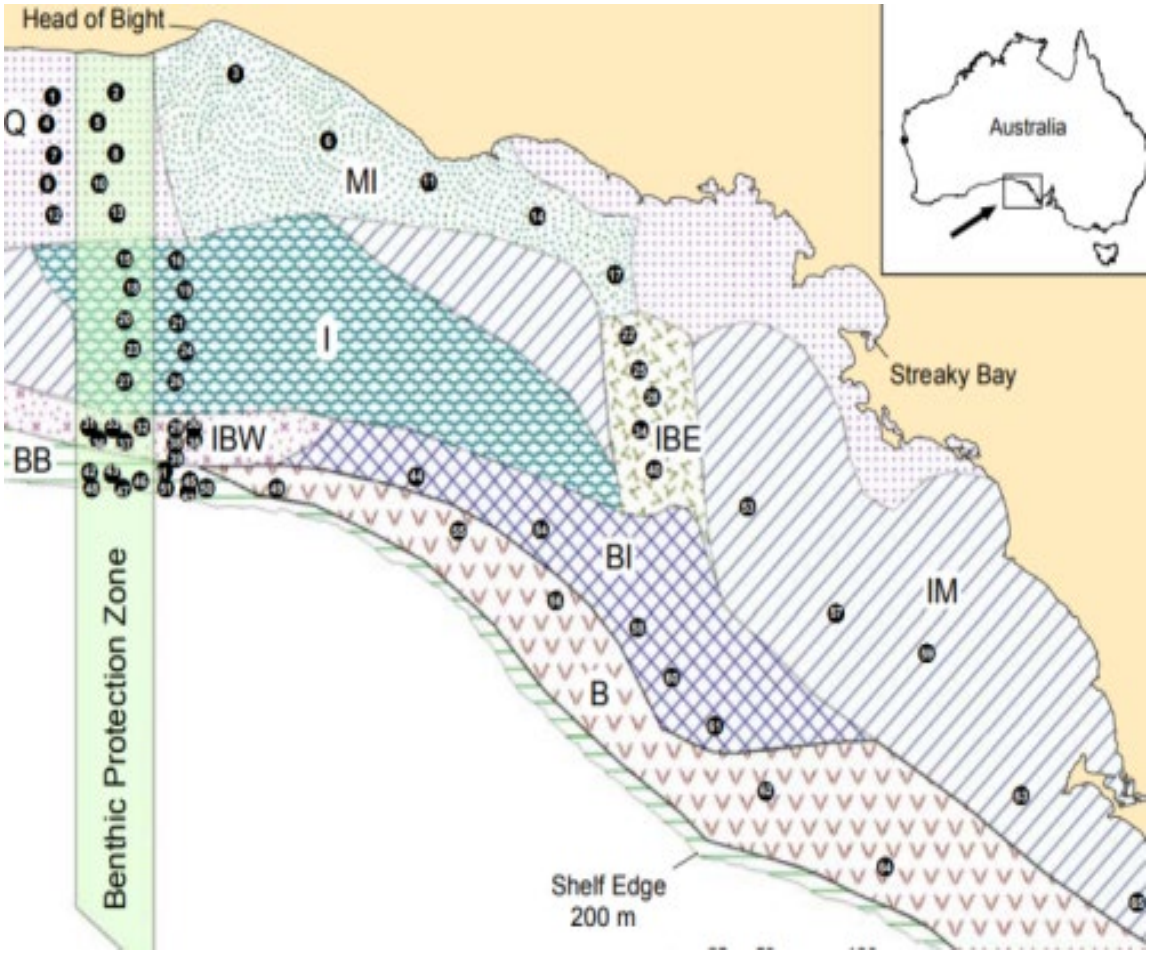
Copepods were the dominant taxonomic group in surface waters of the eastern Great Australian Bight whereas copepods, Appendicularia and thaliaceans were dominant in shelf and offshore waters in the central Great Australian Bight (Kloser et al. 2017). The density of copepods was marginally greater in the

eastern Great Australian Bight (mean 14.25 individuals/m^3) compared to the central Great Australian Bight (mean 3.44 individuals/m^3) (Kloser et al. 2015). Copepods were the dominant taxon at all depths in the central and eastern Great Australian Bight (Kloser et al. 2017). The mean body volume of the copepods increased with depth in both the eastern and central Great Australian Bight (Kloser et al. 2017).

Overall zooplankton biomass was ~ 2-fold higher with the number of individuals ~5 fold higher in the eastern Great Australian Bight compared to the central Great Australian Bight (Kloser et al. 2017) with less abundant meso-zooplankton community with lower grazing rates. Long term patterns in primary productivity are similar between the eastern and central Great Australian Bight (Kloser et al. 2017), particularly on the upper slope. While primary productivity in the east can be high, it is intermittent and highly variable, with the highest rates linked to periods of upwelling. In the central Great Australian Bight primary productivity is more moderate, but linked to a more constant, biologically mediated supply of nitrogen (high nitrification rates) which ensures that these moderate rates can be maintained over longer periods of time.

4.6.2 Benthic infauna

Historically, few infauna samples have been taken in the Great Australian Bight, especially in deep offshore waters. During October 2006, quantitative samples of infauna were collected from 65 sites across the continental shelf in the eastern Great Australian Bight, comprising the first comprehensive collection of the benthic infaunal communities in the Great Australian Bight (Figure 4.20). The infaunal diversity was low compared with other areas, with 240 taxa species from 11 phyla identified from 65 samples and most taxa were represented by few individuals (Currie et al. 2008). The infauna assemblage was most diverse near the Head of Bight and inner-shelf waters (Currie et al. 2008).



B: Bryozoan, BB: Branching Bryozoan, BI: Bryozoan Intraclast, IBE: Intraclast Bryozoan East, IBW: Intraclast Bryozoan West, IM: Intraclast Mollusc, MI: Molusc Intraclast, Q: Quartzose Skeletal
Source: Currie, Sorokin & Ward (2008)

Figure 4.20 Great Australian Bight continental shelf survey sites sampled by South Australian Research and Development Institute during 2006

In 2013, the Great Australian Bight Research Program extended benthic infaunal community surveys into the deep waters off the shelf. This was the first systematic and wide-ranging collection of macroinfauna in the deep parts of the Great Australian Bight and was made during a major field survey aboard the RV *Southern Surveyor*. The field survey in 2013 covered 25 sites along five transects in the eastern and central Great Australian Bight; in water depths of 200 m, 500 m, 1000 m, 1500 m and 2000 m (Williams, Stalvies & Ross 2017).

This survey uncovered 128 distinct species across 72 families in eight major taxonomic groups. Reflecting the very low previous survey effort in the region, roughly half of all identifiable species were new to science. It was noted that the proportion of undescribed species in the deep waters of the Great Australian Bight was consistent with data from similar depths along the Western Australian shelf (Poore et al. 2014). Williams et al. (2017) also suggest that the Great Australian Bight is a single provincial-scale bioregion, with no longitudinal pattern in assemblage, biomass or density distribution. Species richness was not correlated with depth, though species composition changes were partially explained by changes in depth (Williams, Stalvies & Ross 2017).

The overall structure of the macrofaunal assemblage was largely consistent with previous deep-water sampling from Australia (Poore et al. 2014), with 94% of all species and 96% of identified specimens being polychaetes or infaunal crustaceans.

The crustacean assemblage was dominated by amphipods which comprised the majority (~60%) of the diversity. Within the Amphipoda, 37 different taxa were identified, including 13 undescribed species. Isopods were less abundant but still diverse (16 species), with 15 of these species being undescribed. The most abundant amphipod and isopod families are associated with the deep-sea and their compositions were generally consistent with surveys in other regions (Brandt et al. 2012; Knox et al. 2012). Decapods (crabs and shrimps) were less diverse, with only ten specimens collected, with only two new species uncovered by the survey. Nebaliacea were represented by only one undescribed species (which had been recorded elsewhere in southern Australia).

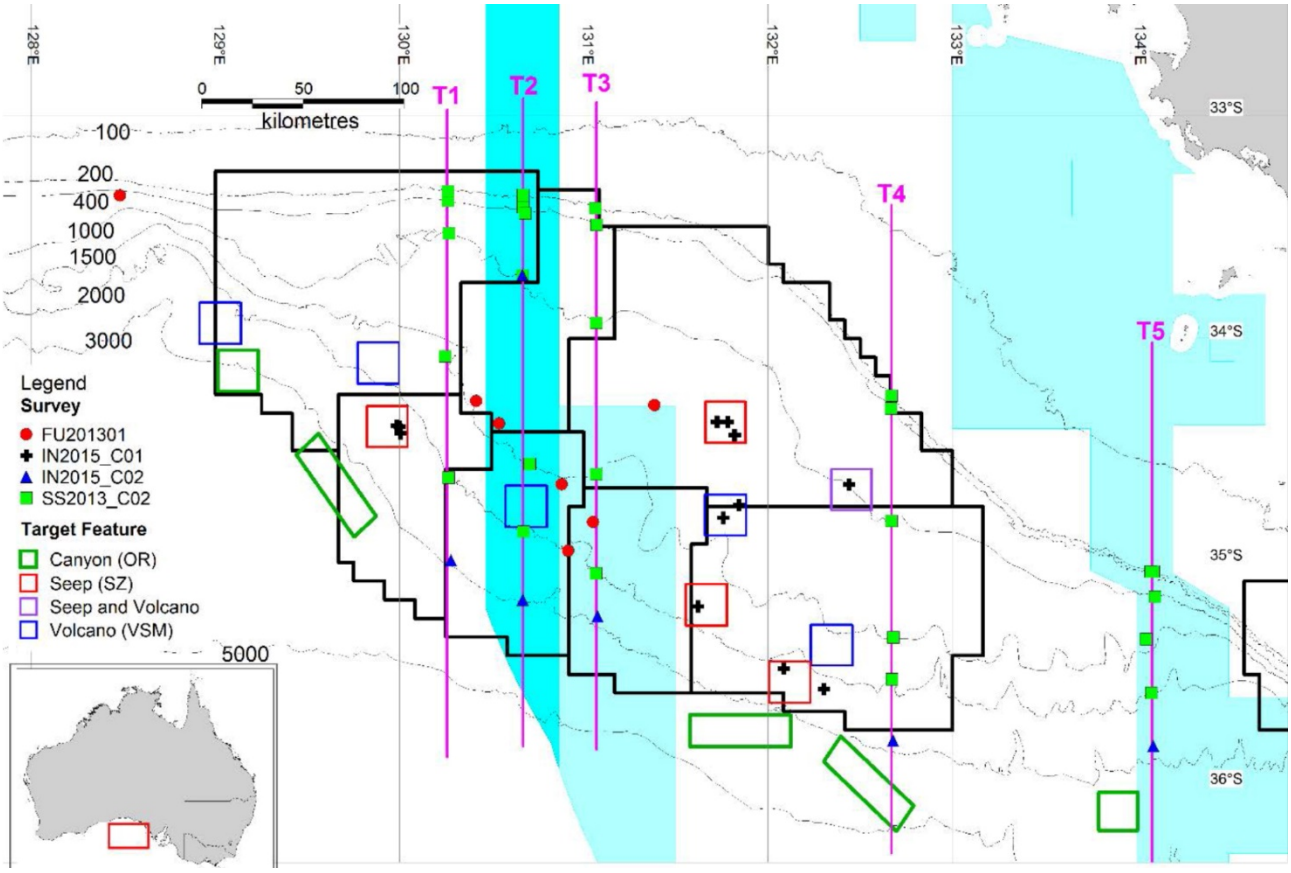
The echinoderm assemblage was dominated by ophiuroids (brittle stars), with three species collected. The annelid assemblage was represented by 59 species from 31 families, with 58 species being polychaetes and one being an oligochaete (Williams et al. 2017a); 29 species were new to science. The composition of the polychaete fauna is typical of studies elsewhere at comparable depths (Alalykina 2013; Shields & Blanco-Perez 2013), with most abundant families including Cirratulidae, Spionidae, Glyceridae and Opheliidae. Only 26% of species identified in this survey have been recorded elsewhere, with little species overlap found between the Great Australian Bight and other temperate regions of Australia. This suggests that the deep waters of the Great Australian Bight host an invertebrate fauna that is regionally endemic (Williams et al. 2017a).

The majority (59–100%) of species or morphospecies were rare, known only from single individuals, and across the whole study 73% of species were recorded only from one site. A rarefaction curve showed steady accumulation of species with continued sampling – indicating that the rate of macrofaunal species accumulation will remain high in further sampling of sediments in the deep Great Australian Bight (Williams et al. 2017a).

A second benthic survey was conducted by the RV *Investigator* in December 2015 as part of the Great Australian Bight Research Program (Williams et al. 2017a). A total of 1303 macroinfaunal invertebrates representing 258 species were collected from 200 multi-corer samples from 30 stations equally distributed between five transects over a 200–3000 m depth range. The Great Australian Bight Research Program sampling sites were arranged along the five north–south transects running across the outer shelf and slope, with sampling at 200 m, 400, 1000 m, 1500 m, 2000 m and 3000 m and transects 1 to 3 running adjacent to or through the Stromlo-1 drilling location. A depth-related pattern in infaunal assemblage structure was identified in the data from this survey.

There was a clear peak in abundance of infauna at intermediate depth (400 m) and very low abundance in deep waters; the Great Australian Bight appears to have relatively low infaunal abundance compared to other areas in this depth range (Tanner et al. 2018). Most species were represented in only a few samples. Infaunal densities peaked at 400 m depth (1320 ± 175 (se) m^2) and declined consistently to 2800 m (268 ± 55 (se) m^2) and were low compared to densities documented elsewhere (Tanner et al. 2018). A survey undertaken in 2010 of benthic macrofauna in deep offshore waters of the Great Australian Bight Marine Park reported considerably lower densities with 50–450 individuals/m^2 at 500–2000 m (Currie & Sorokin 2011).

Assemblage level patterns were less distinct, although shallow sites (200 and 400 m) differed from deeper sites (1000–2800 m). No effects due to differences in upwelling or downwelling regimes between the eastern and western transects could be detected in the infaunal communities, but the shallow eastern sediments were coarser than their western counterparts (Tanner et al. 2017).



Source: (Williams et al. 2017b)

Figure 4.21 Locations of benthic survey transects and sites within the Great Australian Bight in 2013 and 2015

4.6.3 Benthic epifauna

Benthic fauna inhabiting deep-water sediments between 200 m and 5000 m water depth across the Ceduna Sub-basin were sampled several times as part of the Great Australian Bight Research Program and Great Australian Bight Deepwater Marine Program during multiple surveys (2013, 2015 and 2017). The full description and analysis of the results of these surveys are currently in review prior to publication in scientific journals and a special Great Australian Bight edition of Deep-Sea Research II (Williams et al. 2017a).

Analysis of the 2015 survey indicates a diverse assemblage of fauna, including deep-water coral-associated communities on some of the volcanic seamounts (Williams, Stalvies & Ross 2017). A total of 376 species of invertebrates and 54 species of fish were collected (Williams, Stalvies & Ross 2017). This included at least 124 likely new species, although further taxonomic work is required. The epifauna assemblage (fauna living on sediments) was dominated by ophiuroids (brittle stars), holothurians (sea cucumbers) and stony coral, and individuals were typically small (Williams, Stalvies & Ross 2017). The rate of accumulation of different species with additional samples indicated the total benthic diversity was only partly characterised (Williams, Stalvies & Ross 2017).

In the April 2017 survey, over 200 benthic megafauna taxa (invertebrates and demersal fishes) were collected from 10 beam trawls in depths from 2750 to 5030 m. In addition, seabed video imagery was collected along three transects over two volcanic seamounts in the Great Australian Bight Marine Park.

More than 600 species of megafaunal invertebrate epibiota were collected by beam trawl at 30 sampling locations (Figure 4.23) during the 2015 survey by the RV *Investigator* (Williams et al. 2017a). Approximately 25% of these were previously undescribed taxa and 77 were previously unrecorded in Australian waters. All represented families and genera are known to occur in temperate deep-water areas. Diversity was greatest within the Demospongiae, Decapoda, Gastropoda and Echinodermata. Assemblage structure was found to change with depth, with sponges dominating at shallower depths (with respect to biomass and density), whereas both sponges and echinoderms were dominant overall. No longitudinal change in assemblages

were noted (in composition, biomass or density), inferring a single provincial-scale Great Australian Bight bioregion for megafaunal invertebrate epibiota. Figure 4.22 provides benthic images from the GABRP sites closest to the Stromlo-1 location, on the flat seabed surrounding the pinnacles and on the flat seabed near the mud slope to the south-east of the well location. These show homogeneous habitat types across the area which encompasses the well location (note the Great Australian Bight Research Program did not photograph the seabed at Stromlo-1). Potential endemism is low in this assemblage type, with only two species of crustacean recorded that are known only from the Great Australian Bight (the majid crab *Choniognathus granulosus* and the pedunculate barnacle *Arcoscalpellum inum*).

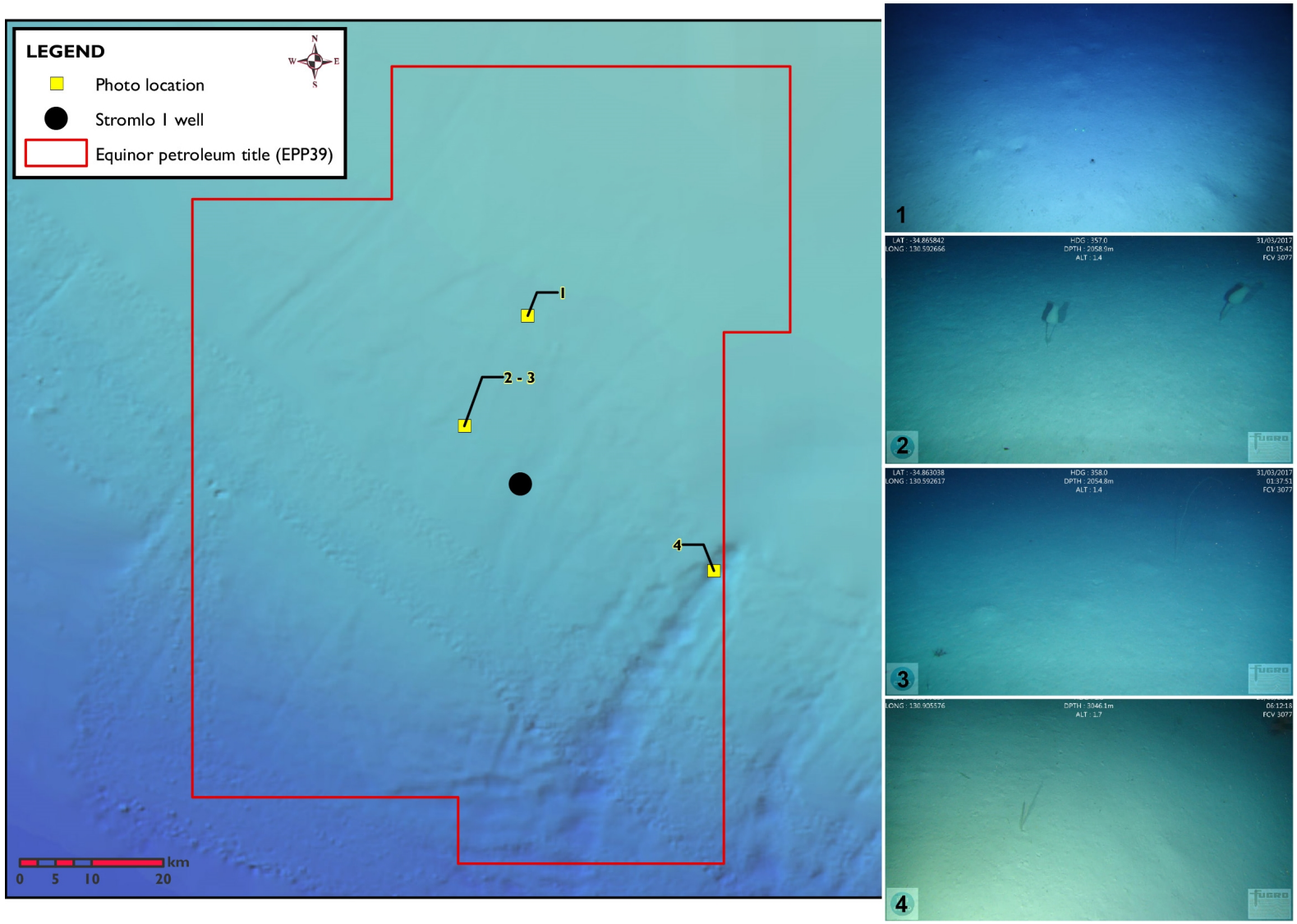
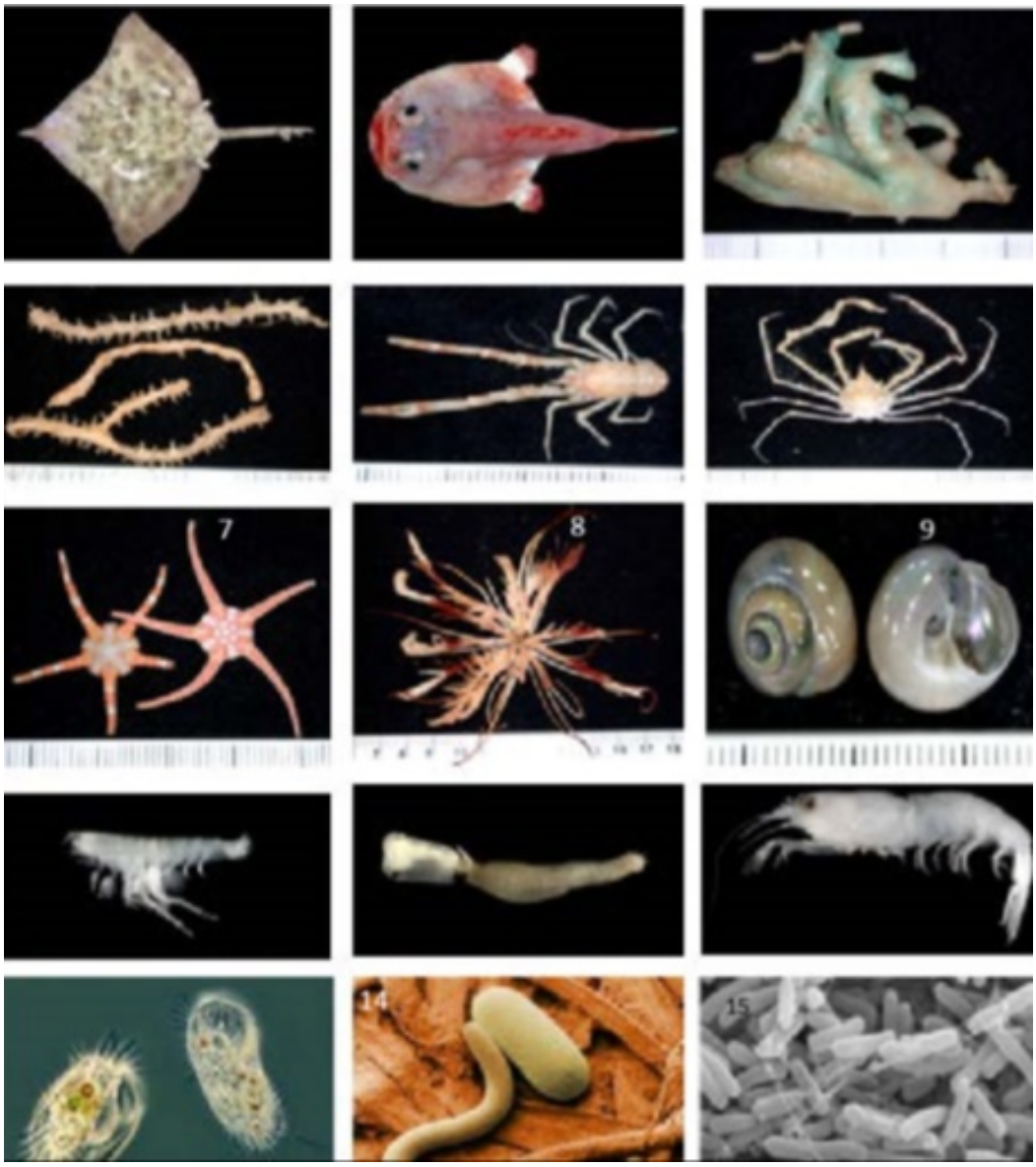


Figure 4.22 ROV photographs from the GABRP within the Stromlo-1 well vicinity



Source: Williams and Tanner (2017)

Figure 4.23 Deep-water benthic biota from the Great Australian Bight, including epifauna, macrofauna and microfauna

Examples of deep-water benthic biota from the Great Australian Bight, including epifauna (living freely on, or attached to, the sea floor – including demersal fishes), macrofauna (exist within or closely associated with marine sediments) and microfauna (e.g. microbes), are shown in Figure 4.23 (Williams & Tanner 2017). Cnidarian corals can be found in deep, dark, cold waters globally, including species such as *Solenosmilia variabilis*, which has a worldwide distribution and may form dense aggregations in depths of 1000 m to 1400 m in waters of southern Australia (Freiwald et al. 2004). These deep-water hard coral species lack symbiotic microalgae (zooxanthellae), and therefore must live at water depths where environmental conditions (such as water pressure) mean that the deposition of the coral skeleton requires a lower energetic cost.

Deep-water corals have been collected from seamounts in the western Great Australian Bight so it is possible the central Great Australian Bight may hold suitable habitats (Williams 2015). Information available on the National Oceanic and Atmospheric Administration DSCRTP National Deep-Sea Coral and Sponge Database 1842-Present (National Oceanic and Atmospheric Administration 2015) shows that the location of deep-water black and gorgonian corals (Subclass Octocorallia) within the Great Australian Bight are well inshore of the Impact Environment that May Be Affected (Figure 4.26). Thresher et al. (2015) also note that extensive coral reefs dominated by the scleractinian coral *Solenosmilia variabilis* are found on seamounts at depths ranging from 1000 m to 1300 m in the South-east Marine Parks Network. As such deep-water corals are unlikely to be present in the Impact Environment that May Be Affected.

4.6.3.1 Seamount habitats

During the Great Australian Bight Deepwater Marine Program, the Commonwealth Scientific and Industrial Research Organisation (CSIRO) surveyed the seamounts to the north of the Stromlo-1 location using a towed underwater camera and recorded images of the seabed which show clearly the habitat types in these areas. Both seamounts are characterised by exposed hard volcanic materials variably overlain by a veneer of mud that supports low densities of epifauna. These two seamounts do not appear to represent regionally significant “biodiversity hot spots” unlike some other seamounts in the region; however, they provide locally important hard substrate in an otherwise barren muddy plain.

Figure 4.24 and Figure 4.25 show the bathymetric character of the Anna’s Pimple and Murray’s Mount respectively. The figures also show the towed camera transects flown at these sites and typical benthic habitat photographs along these transects. These data were sourced by personal communication from Commonwealth Scientific and Industrial Research Organisation in 2018.

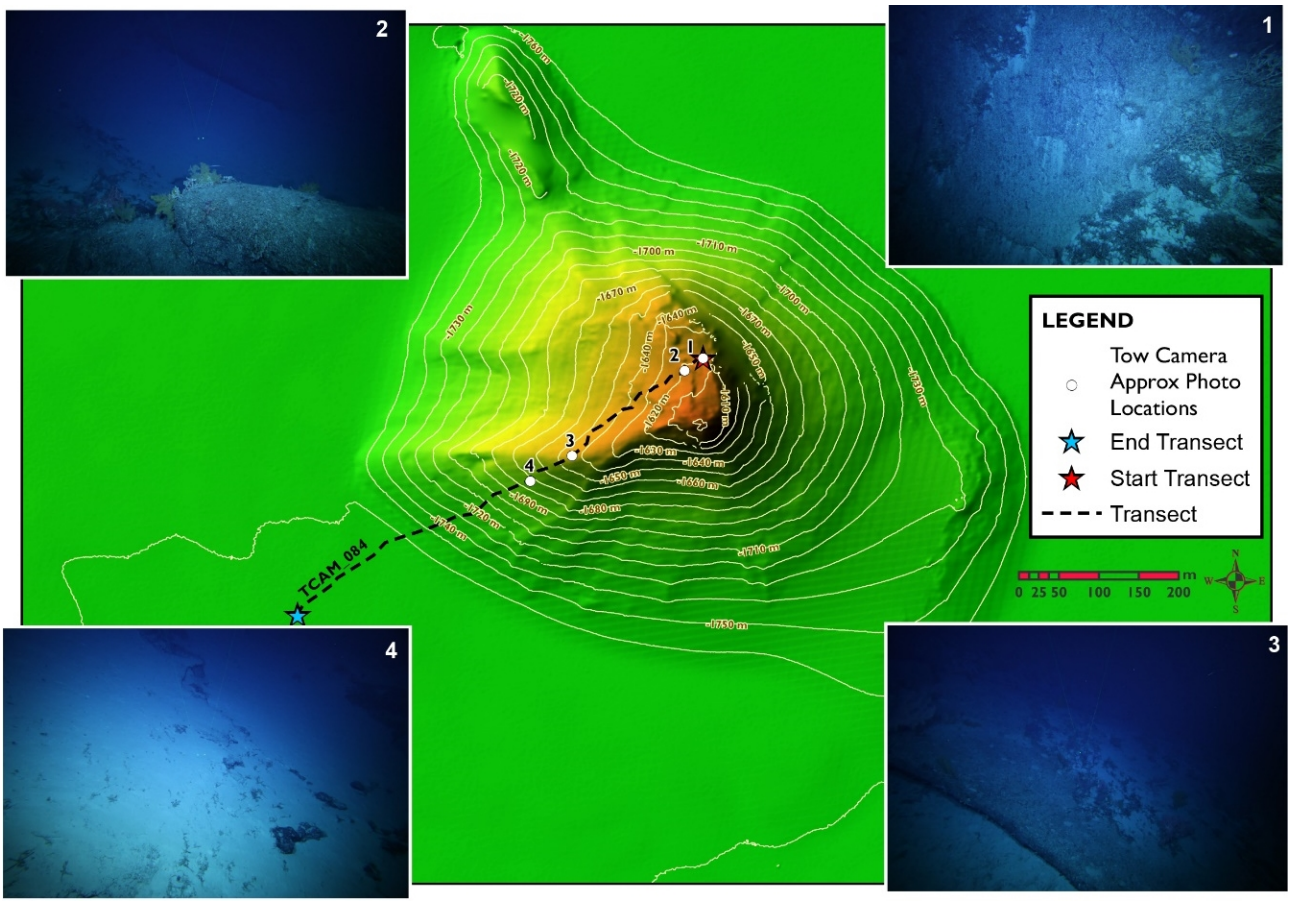


Figure 4.24 Bathymetry and tow video photographs of the seabed at Anna’s Pimple

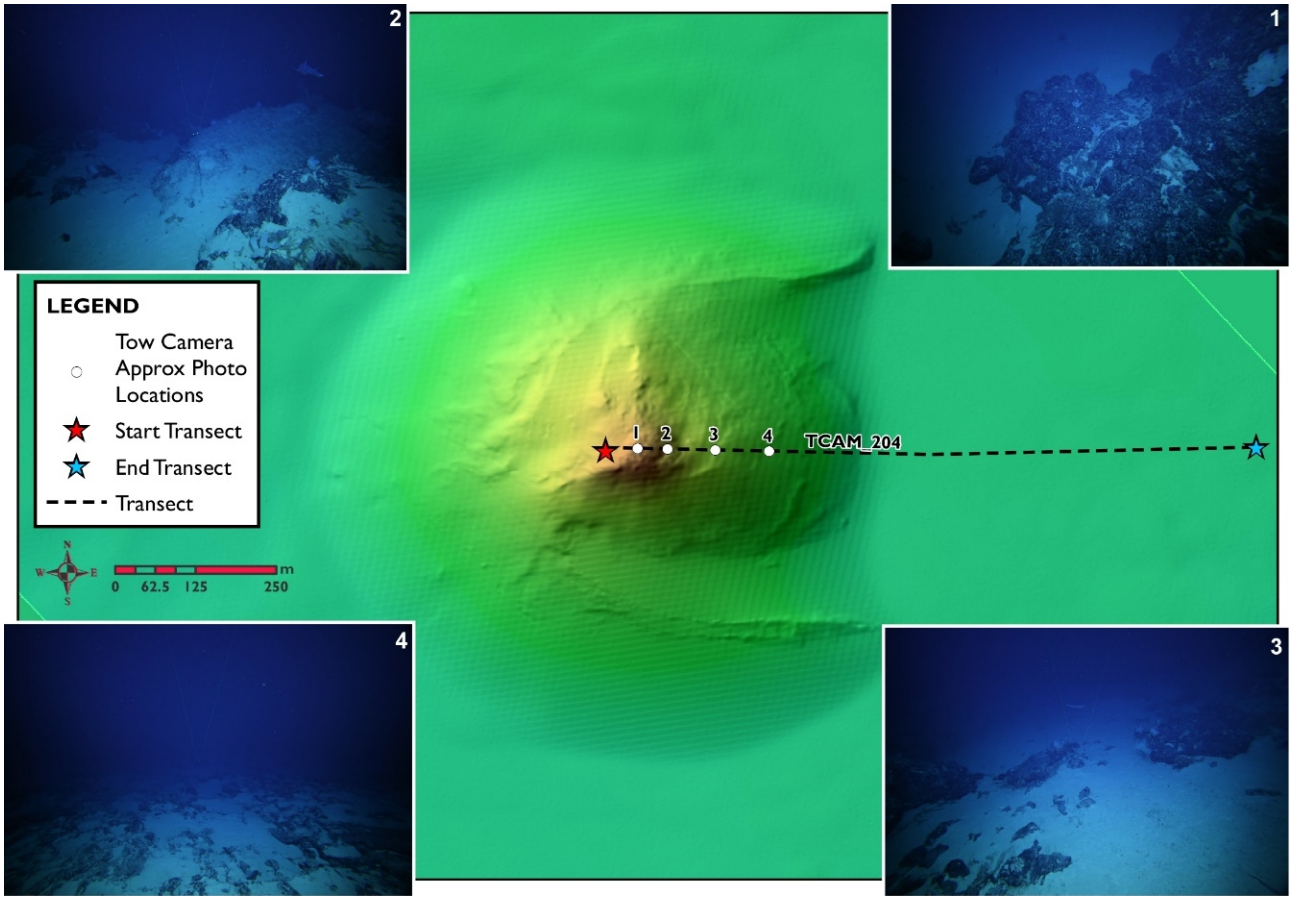
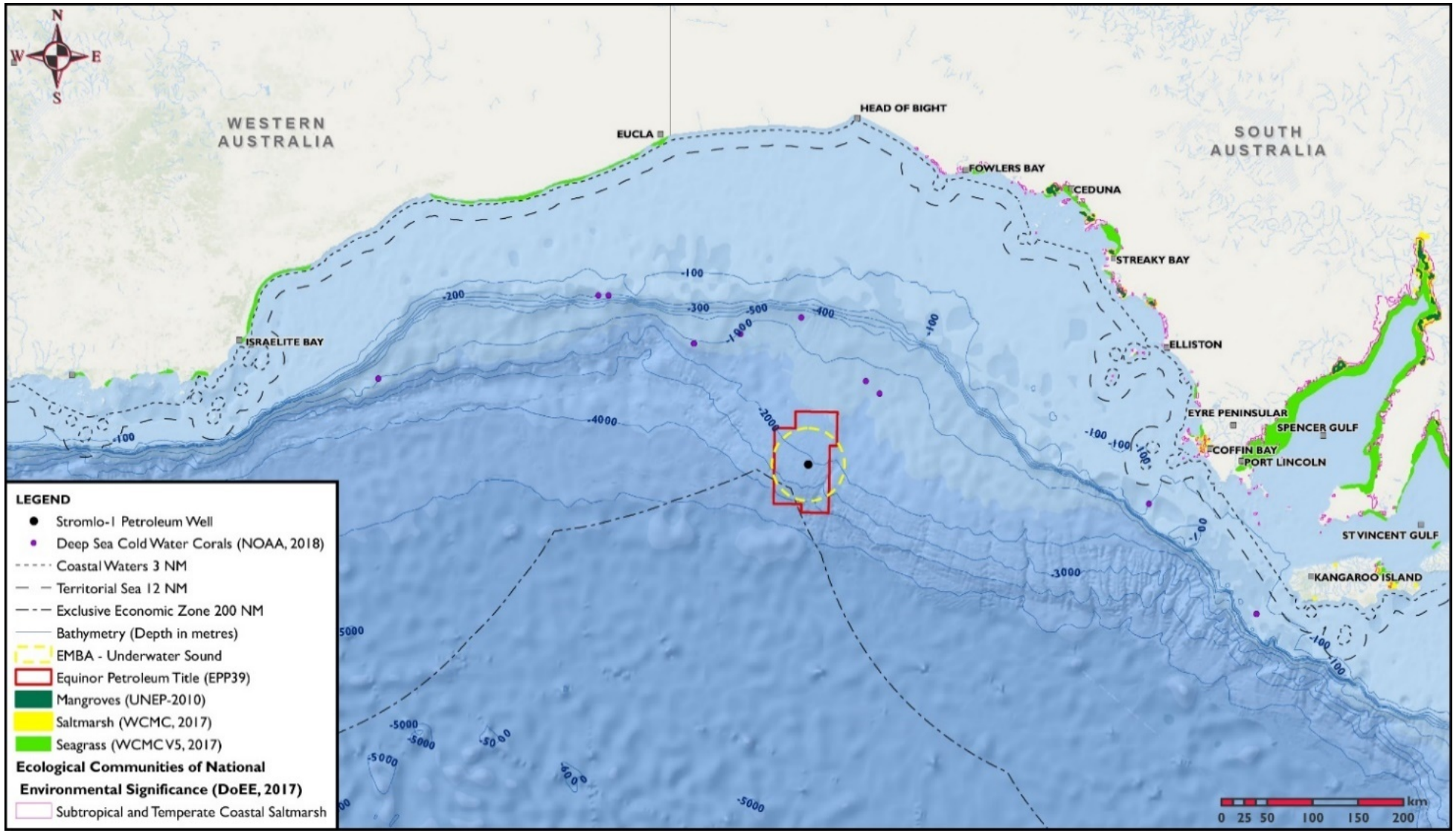


Figure 4.25 Bathymetry and tow video photographs of the seabed at Murray's Mount



Source: National Oceanic and Atmospheric Administration (2015)

Figure 4.26 Potential distribution of deep-water coral across the GAB

4.6.3.2 Benthos of the well location and surrounding seabed

Samples and ROV imagery collected by CSIRO and SARDI during the GAB Research Project provide robust information from which the benthic habitat of the well location can be described (Williams et al. 2017). Confidence in this assessment is relatively high as the closest survey data was collected within 10 km of the proposed well location in similar water depth and seabed imagery shows homogeneous habitat types across broad areas of the central GAB. Collections of sediment macroinvertebrates (> 10 mm in length) from sampling sites along transects at a range of depths across the central and eastern GAB, indicated that there was little difference between the five longitudinal transects and there was little difference in the assemblages found at ≥1000 m water depth. The macroinvertebrate assemblages were dominated by echinoderms (predominantly ophiuroids and holothurians, asteroids and echinoids), decapod crustaceans, gastropods and bivalves (See Rev 3 Appendix 7-3). The infaunal diversity was low compared with other areas, with 240 taxa species from 11 phyla identified from 65 samples.

CSIRO ROV surveys also indicated the presence of epibiota and bioturbation features not captured in trawl sampling. Epibiotic taxa were generally observed at low densities or in patches and included brittle stars, sea pens (including *Umbellula* sp.), branched and whip corals, tulip sponges and other sponges (such as *Hyalonema* sp.), burrowing anemones, the deep-sea asteroid *Hymanaster* sp., long-spined urchins and decapod crustaceans (e.g. squat lobsters). Bioturbation features included burrows, mounds, tracks and depressions caused by macroinvertebrates burrowing into the substrate. The biota described from trawl and ROV studies are characteristic of deep-water soft sediment habitats and are likely to be well represented in the deep waters across the central GAB. Figure 4.22 provides benthic images from the GABRP sites closest to the Stromlo-1 location, on the flat seabed surrounding the pinnacles and on the flat seabed near the mud slope to the south-east of the well location. These show homogeneous habitat types across the area which encompasses the well location (note: GABRP did not photograph the seabed at Stromlo-1). The assemblage structure within the deeper waters of the GAB (200–3000 m) indicate it is a single provincial-scale bioregion, with no longitudinal pattern in assemblage, biomass or density distribution. (Williams et al. 2017).

The deep-water studies discovered new species to science, which is expected for a survey in a new area with very little prior sampling effort. They were represented by low abundances of organisms. It does not necessarily infer high conservation significance; whereas by comparison the shallower waters of the eastern GAB have been recognised as having conservation value due to high levels of biodiversity in shelf benthic communities.

4.6.3.3 Conservation significance of the well location in comparison with the eastern GAB

Three key sources of information, considered in the description of the conservation significance of the area surrounding the proposed Stromlo-1 location, are discussed below.

South-west Marine Parks Network Management Plan 2018

This plan refers to the key ecological feature (KEF) of benthic invertebrate communities of the eastern GAB; valued as a species group or community that is nationally and regionally important to biodiversity and specifically of significance to the Western Eyre Marine Park, Murat Marine Park, and the Great Australian Bight Marine Park.

The KEF of benthic invertebrate communities of the eastern GAB is described as being located in the 0 to 200 m depth range of the GAB Shelf Transition bioregion of the Western Eyre, Murat and GAB Marine Parks (https://parksaustralia.gov.au/marine/pub/scientific-publications/archive/south-west-marine-bioregional-plan.pdf). This description of continental shelf assemblages is not directly comparable to the benthic community in 2239 m water depth at the Stromlo-1 well location.

The differing values of the eastern GAB benthic KEF to that of the central GAB is reflected within the latest revision of the South-west Marine Parks Network Management Plan. The Benthic Protection Zone of the GAB Marine Park enacted in the 2005-2012 plan (https://www.environment.gov.au/system/files/resources/9b53d4e7-9a12-4354-9588-163933b2cbd4/files/gab-plan.pdf) extends seaward from mean low water to the 200 NM limit, and is cited as “reasonably well placed to represent the biodiversity of the Bight, as 53% of the species collected were obtained there” even though the plan also stated “little is known of the composition of the benthic fauna of the Great Australian Bight” (https://www.environment.gov.au/system/files/resources/0ad236e7-3655-422c-b2c2-c3ba2638acdd/files/gab-values.pdf). A new management plan was prepared for the GAB Marine Park, and it no longer included a benthic protection zone. This suggests the importance of the benthic communities there, upon review, was not considered to be significant. But the benthic protection zone was retained in the other Marine Parks to the east.

MacIntosh et al. (2018) Invertebrate diversity in the deep Great Australian Bight 200–5000 m

The paper describes 401 new species being identified and a high degree of rarity (i.e. number of species only recorded once) in the deep Great Australian Bight. The high degree of apparent rarity probably reflects the relatively low sampling effort compared with well-studied regions elsewhere, and this effect has been seen in exploratory deep water sampling elsewhere in Australia and overseas. The number of undescribed species was not surprising, given the depths sampled and general lack of exploration in the region. The result closely matches the proportion of undescribed species in other recent Australian deep sea surveys.

Deep ocean seabed habitats generally support lower densities of organisms in sparsely distributed assemblages, which means many species are only represented by one or few individuals in a sample. The MacIntosh paper reviews and compares data from a wide range of sampling methods targeting different biota in different depths. The statement of rarity originates from the high proportion of species represented by a single individual (31%) and Ward et al. (2006) and a study comparing epifaunal assemblages from three very different ecosystems - the Gulf of Carpentaria (Australia), North Sea (UK) and the Antarctic Shelf. That study only considered one component of the soft-bottom assemblage - sedentary or slow-moving epifauna >50 mm.

A total of 108 deep-sea benthic fish species from 49 families were collected by Williams et al. (2018). Spatial patterns in fish assemblages were evident with species richness, abundance and biomass changing markedly with depth but insignificantly across the Great Australian Bight (Williams et al. 2017a). Benthic fish assemblages were most strongly structured by depth and there was no consistent pattern discernible between the longitudinally separated transects within depth strata (refer Figure 4.27 and Figure 4.28 in Section 4.6.4 of the EP). Catches were dominated by deep-sea families, including *Macrouridae* (rattails), *Synaphobranchidae* (cut-throat eels), *Moridae* (morid cods), *Oreosomatidae* (oreo dories), *Alepocephalidae* (slickheads), *Ophidiidae* (cusk eels) and *Halosauridae* (halosaurs). Greatest species diversity was recorded within the *Macrouridae*, which was also the most frequently recorded family. *Macrouridae* were found abundantly at water depths of ≥400 m (ranked highest by biomass and density when data were standardised by area). Species considered endemic to the Great Australian Bight were most commonly recorded at the shelf break and upper-to-mid continental slope, declining with increased depth. Fish biomass increased between 200 and 400 m water depth (from approximately 0.5 g/m^2 to 3.4 g/m^2, respectively), then declined with increasing depth to ~0.4 g/m^2 at 3000 m. There was little difference in fish assemblage structure noted between 1500, 2000 and 3000 m water depths.

The Great Australian Bight Research Program was the first comprehensive study of the benthic communities in the deeper parts of the Bight and while it remains as one of the most comprehensive studies of these communities, it could only sample a small proportion of the total soft sediment habitat available. Given the novelty of such a deep-water survey, the sampling method used (including effective area sampled) and the relatively low density of individuals and colonies, it is unsurprising that many new species and species represented by single specimens were collected. The species accumulation curves of Williams et al. (2017, 2018) indicate that the deep-water benthic communities will require significantly more sampling before the full range of species are collected. The new and apparently uncommon species are expected to be widely represented in similar habitats at similar depths across the entire central Great Australian Bight.

Director of National Parks

Input provided by the Director of National Parks during consultation (Rev 3 Appendix 3-2) included the statement that the 'benthic invertebrate communities of the eastern GAB are among the world's most diverse soft-sediment ecosystems'. This statement is consistent with the description of the eastern GAB benthic communities discussed above within the South West Marine Parks Management Plan 2018. However, the statement largely relates to the 'benthic invertebrate communities of the eastern GAB' Key Ecological Feature (KEF), rather than the central GAB where the well location lies. This differentiation is supported by the descriptions of the values of the eastern GAB in the:

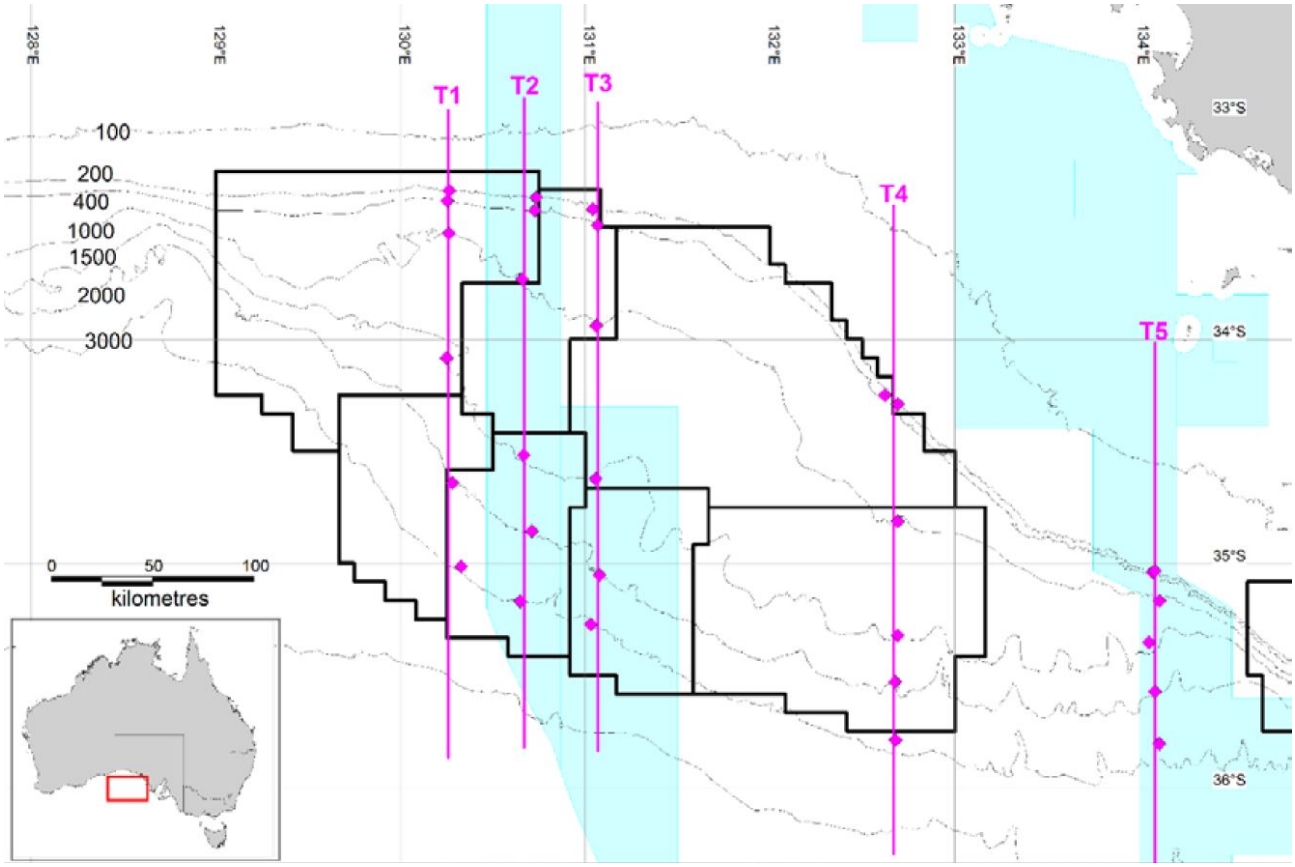
- Department of Environment and Energy (DoEE) Species Profile and Threats database
- marine bioregional plan for the south-west marine region (http://www.environment.gov.au/system/files/pages/a73fb726-8572-4d64-9e33-1d320dd6109c/files/south-west-marine-plan.pdf)
- Parks Australia website (https://parksaustralia.gov.au/marine/management/values/values-of-the-south-west-network/).

The description of this KEF (as described in the three references above) states that the KEF is found on the shelf of the Great Australian Bight, which is located in the 0–200 m depth range. As such, the statement regarding 'benthic communities in the eastern GAB' has been taken as not relating to the deep waters of the central GAB (and the impact EMBA) but to the areas further east where it remains a stated value of the marine management plans for those areas.

4.6.4 Fish

4.6.4.1 Benthic fish

The composition, diversity and biogeographic affinities of the deep-sea benthic fish assemblages in the GAB were studied as part of the Great Australian Bight Research Program and Great Australian Bight Deepwater Marine Program (Williams et al. 2018) to 3000 m using a beam trawl. Samples were collected from soft substrate habitats (with some sites near emergent features) at six depth horizons along five north to south transects. These were positioned to achieve a relatively high density of sampling in the Great Australian Bight Marine Park and the oil and gas permit areas (Figure 4.27).



Source: (Williams & Tanner 2017)

Figure 4.27 Benthic fish transects in the Great Australian Bight Research Program study area

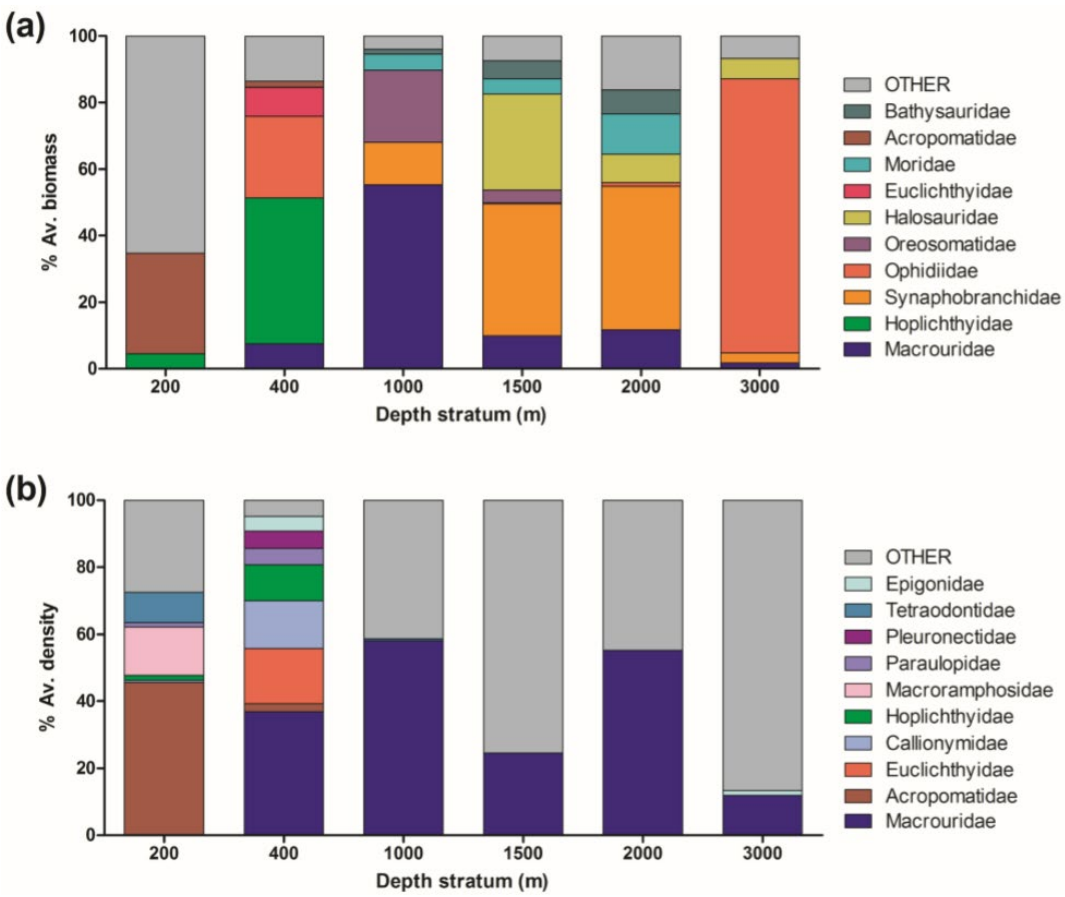
A total of 108 deep-sea benthic fish species from 49 families were collected by Williams et al. (2018). Spatial patterns in fish assemblages were evident with species richness, abundance and biomass changing markedly with depth but insignificantly across the Great Australian Bight (Williams et al. 2017a). Benthic fish assemblages were most strongly structured by depth, there was no consistent pattern discernible between the longitudinally separated transects, within depth strata (Figure 4.29, Figure 4.28).

Catches were dominated by deep-sea families, including Macrouridae (rattails), Synaphobranchidae (cut-throat eels), Moridae (morid cods), Oreosomatidae (oreo dories), Alepocephalidae (slickheads), Ophidiidae (cusk eels) and Halosauridae (halosaurs). Greatest species diversity was recorded within the Macrouridae, which was also the most frequently recorded family. Macrouridae were found abundantly at water depths of ≥400 m (ranked highest by biomass and density when data were standardised by area). Species that considered endemic to the Great Australian Bight were most commonly recorded at depths associated with the shelf break and upper-to-mid slope, declining with increased depth. Fish biomass increased between 200 and 400 m water depth (from approximately 0.5 g/m^2 to 3.4 g/m^2, respectively), then declined with increasing depth to ~0.4 g/m^2 at 3000 m. There was little difference in fish assemblage structure noted between 1500, 2000 and 3000 m water depths. The proximity of emergent hard substrates (e.g. volcanic seamounts, rocky outcroppings in submarine canyons) did not appear to affect the structure of fish assemblages sampled,

though seasonal upwellings in the eastern part of the survey area may have increased productivity at eastern survey locations. The benthic fish assemblages recorded from depths relevant to the permit area (1500–3000 m) showed substantial variation in composition based on biomass, but less in density (Figure 4.29, Figure 4.28)

Family-level composition at the shelf break (200 m) sites stood out from all other depths in having the majority of biomass and density made up by "Other" families, i.e. relatively high diversity, and only two conspicuously dominant families: temperate seabasses (Acropomatidae) (biomass and density), and bellowfishes (Macroramphosidae) (density). In contrast, the dominant families in the upper slope (400 m) stratum, where biomass and density were highest overall, were ghost flatheads (Hoplichthyidae) (biomass) and Macrouridae (mostly species of Coelorinchus) (density). Two other families were also prominent at 400 m depth: cusk eels (Ophidiidae) (biomass, based on two large specimens) and Eucla cod (Euclichthyidae) (density). There were similarities in dominance at the mid-continental slope sites (1000, 1500 and 2000 m depths) where rattails (Macrouridae) (biomass and density) and basketwork eels (Synaphobranchidae) (biomass) were dominant. In this depth range, oreo dories (Oreosomatidae), morid cods (Moridae) and halosaurs (Halosauridae) were all prominent (biomass); the latter two families more so in 1500–2000 m depths. At 3000 m deep the cusk eels (Ophidiidae) were the overwhelmingly dominant family by biomass. Density was relatively very low at all sites >1000 m and entirely dominated by rattails (Macrouridae) and a mix of "other" species. The pattern of relatively lower density than biomass in depths >1000 m indicated a generally larger body size of individuals compared to the upper slope and shelf break, especially for cusk eels (Ophidiidae). The overall trend was for species ranked highly by density to be small-bodied fishes and relatively shallow (<400 m depth) and for species ranked highly by biomass to be larger-bodied and deeper (>1000 m) (Figure 4.28).

The majority of fishes collected were previously recorded from Australian waters (90%) and the Great Australian Bight (75%) (Williams et al. 2017a). The proportions of recorded species were broadly similar between shelf break (~200–240 m depths), upper slope (280–600 m) and mid-slope depths (950–1550 m); (91–100% in Australian waters, 86–89% in Great Australian Bight waters).



Source: Williams et al. (2018)

Figure 4.28 Percentage of (a) biomass and (b) density distribution in the transect samples of the 10 top ranked fish families by depth

4.6.4.2 Conservation significant fish

The Protected Matters Search Tool report (Appendix 4-1) identified three Migratory shark species listed under the *Environment Protection and Biodiversity Conservation Act 1999* as potentially occurring within the Impact Environment that May Be Affected Table 4.3). Biologically Important Areas (BIA) for these sharks are shown in Figure 4.31. One Conservation Dependent species, the southern bluefin tuna, listed under Section 178 of the *Environment Protection and Biodiversity Conservation Act 1999*, was also identified as potentially occurring within the Impact Environment that May Be Affected. The Protected Matters Search Tool did not identify the shortfin mako as potentially occurring within the Impact Environment that May Be Affected; however, the species is listed as Migratory under the *Environment Protection and Biodiversity Conservation Act 1999* and may occur in the vicinity of the Impact Environment that May Be Affected, so it has been included and is described in further detail below.

Table 4.3 Protected fish species which may occur in the Impact Environment that May Be Affected

Scientific name	Common name	EPBC Act status		Bias within Impact EMBA	Relevant plan
		Listed threatened species*	Listed migratory marine species†		
Carcharodon carcharias	Great white shark	Vulnerable	Yes	No	Recovery Plan for the White Shark (*Carcharodon carcharias*) (DSEWPaC 2013a)
Isurus oxyrinchus	Shortfin mako shark	–	Yes	No	–
Lamna nasus	Porbeagle	–	Yes	No	–

* Listed threatened species: A native species listed in Section 178 of the EPBC Act as either extinct, extinct in the wild, critically endangered, endangered, vulnerable or conservation dependent.
† Listed migratory species: A native species that from time to time are included in the appendices to the Bonn Convention and the annexes of Japan–Australia Migratory Birds Agreement, China–Australia Migratory Birds Agreement and Republic of Korea and Australia Migratory Birds Agreement, as listed in Section 209 of the EPBC Act.

4.6.4.3 Great white shark

The great white shark (*Carcharodon carcharias*), listed as Vulnerable and Migratory under the *Environment Protection and Biodiversity Conservation Act 1999*, is widely but sparsely distributed throughout temperate and sub-tropical regions of the world (DSEWPaC 2013a). The species is managed under the Recovery Plan for the White Shark (*Carcharodon carcharias*) (DSEWPaC 2013a), which supports the recovery and long-term survival of the species. In Australia, great white sharks occur from close inshore rocky reefs, surf beaches and shallow coastal bays to the outer continental shelf and slope waters out to 1000 m depth with a range that extends from north-western Western Australia around the southern coastline (including Tasmanian waters) to central Queensland (DSEWPaC 2013a). Figure 4.31 shows the broad distribution of great white sharks across southern Australia, including biologically important areas (Biologically Important Areas) where higher density areas south of Western Australia and South Australia have been identified as foraging sites (the nearest being <200 km north of the well location), as well as where juvenile nursery areas have been identified in eastern Victorian waters (~ 1500 km east of the well location).

Genetic evidence suggests that this distribution includes two separate populations: a western population that ranges from north-western Western Australia to western Victoria; and an eastern population that ranges along the east coast from Tasmania to central Queensland (Blower et al. 2012). There is currently no reliable estimate of the total size of the Australian great white shark populations and therefore no robust measure of population trends or status (DSEWPaC 2013b). However, there is clear evidence from a range of sources of a decline in the relative abundance of the great white sharks in Australian waters over the last 60 years (DSEWPaC 2013a). Preliminary results of a Commonwealth Scientific and Industrial Research Organisation study of great white shark numbers undertaken under the National Environmental Science Program estimates that the population (i.e. east coast of Australia and New Zealand) comprises between 2500–6750 adults, with an adult survival rate of over 90% year to year (Hillary et al. 2018). By collecting DNA from juveniles, scientists estimate the total size of adult populations based on how many individuals in a population share parents. The results to date suggest that there are considerably fewer adults in the eastern

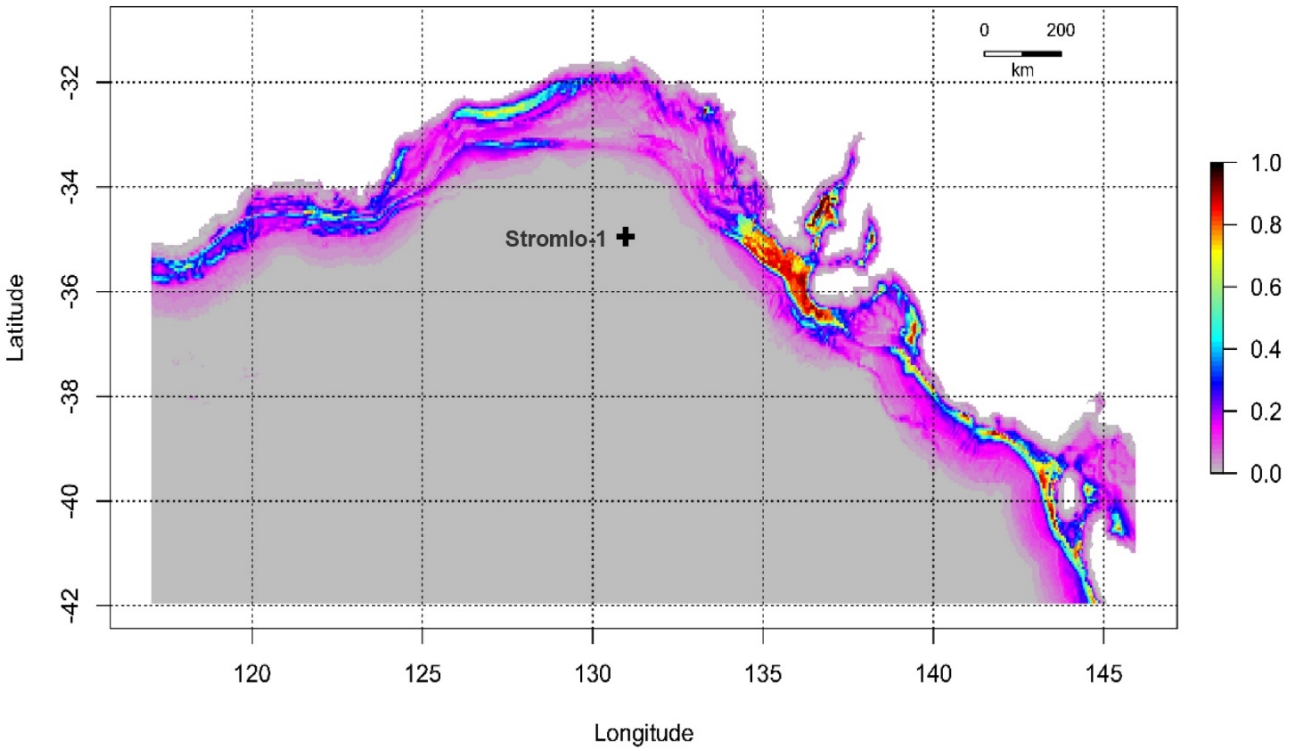
population, although it has a slightly improved survival rate of 93% year to year. A recovery plan (DSEWPaC 2013a) has been developed that sets out the research and management actions necessary to support the recovery and long-term survival of great white sharks in Australian waters.

Adult and sub-adult great white sharks are most commonly observed in Australian waters foraging in coastal waters off pinniped colonies at several locations throughout the South-west Marine Region (DSEWPaC 2013a). This includes the Recherche Archipelago and other islands off the lower west coast of Western Australia, in central South Australia around Fowlers Bay, off the Eyre Peninsula, the Neptune Islands, the southern and eastern coasts of Kangaroo Island, and within Spencer Gulf. Males are observed in these waters year-round in relatively consistent numbers, with data collected at the Neptune Islands over 14 years demonstrating that the abundance of great white sharks is greatest overall from winter to spring, when the occurrence of females is focussed (Bruce & Bradford 2015). Observations of sex-specific patterns in seasonal occurrence (Bruce & Bradford 2015), as well as acoustic telemetry (McAuley et al. 2017) and satellite tracking data (Rogers et al. 2016), show that great white sharks only visit these foraging areas temporarily. Great white shark movements indicate a pattern of temporary residency at favoured sites intermixed with periods of long-distance travel between these sites, undertaking large-scale migrations where they spend most of their time in continental shelf habitats often travelling at depths between 400 and 700 m (Rogers et al. 2016). Individual great white sharks may, however, also show a high diversity of movement strategies and there is limited evidence of predictable return behaviour, seasonal movement patterns or coordination of the direction and timing of individual shark's movements. The observed diversity of movement patterns is hypothesised to relate to patterns of distribution and abundance of suitable prey, reproductive cycling and oceanographic clues, yet the relative importance of each of these drivers is unknown.

Juvenile great white sharks spend a considerable amount of time in the nearshore environment where they feed on finfish, rays and other sharks until they reach approximately 3.4 m in length (generally at around five years of age) and shift to include marine mammals in their diet (Estrada et al. 2006). Satellite and acoustic tracking of great white sharks in eastern Australia have shown that juveniles also intersperse broad-scale movements with periods of temporary residency (both generally occurring shoreward of the 120 m depth contour). However, individual juveniles have shown preferred habitat areas and annual patterns of residency in two discrete coastal nursery areas in waters surrounding Port Stephens in central New South Wales and the southern section of 90 Mile Beach (Corner Inlet) in south-east Victoria (Bruce & Bradford 2012). A recent study (Harasti et al. 2017) using acoustic telemetry demonstrated that juvenile great white sharks use also use the large estuarine systems adjoining the known nursery areas in eastern Australia (Harasti et al. 2017). No juvenile nursery sites have been identified in the south-west region and pupping locations for white sharks remain unknown (DSEWPaC 2013a).

Habitat modelling undertaken by Bailleul et al. (2017) based on tracking data collected from pop-up archival tags deployed on five great white sharks by Rogers et al. (2016) as part of the Great Australian Bight Research Program found that habitats where great white shark foraging habitats have a higher probability of potential occurrence are located on the continental shelf and shelf break in the eastern and western Great Australian Bight and in Spencer and St Vincent Gulfs as well as around the Bonney Coast. The Stromlo-1 well-site is shown as a cross symbol in Figure 4.29 in an area of low probability of occurrence (warm colours represent areas of high probability).

No foraging, breeding or aggregation Biologically Important Areas for great white sharks are present within the Impact Environment that May Be Affected and the species is considered unlikely to occur in abundance within the Impact Environment that May Be Affected.



Source: Bailleul et al. (2017)

Figure 4.29 Standardised probability of potential occurrence of foraging habitats of great white sharks

4.6.4.4 Porbeagle shark

The porbeagle shark (*Lamna nasus*), listed as Migratory under the *Environment Protection and Biodiversity Conservation Act 1999*, is widely distributed through temperate and cold-temperate waters of the north Atlantic Ocean and southern hemisphere (Cavanaugh et al. 2003; International Union for Conservation of Nature 2010). In Australia, porbeagle sharks are typically found in oceanic waters on the continental shelf and are distributed from south-western Australia throughout the South-east Marine Region to southern Queensland (DoE 2015a). The species preys on bony fishes and cephalopods and is an opportunistic hunter that regularly moves up and down in the water column, catching prey in mid-water as well as at the sea floor. It is most commonly found over food-rich banks on the outer continental shelf but does make occasional forays close to shore or into the open ocean, down to depths of approximately 1300 m (Department of Environment and Energy 2017a). It also undertakes long-distance seasonal migrations, although the timing and details of migratory movements are not well understood for Australian populations (Department of Environment and Energy 2017a).

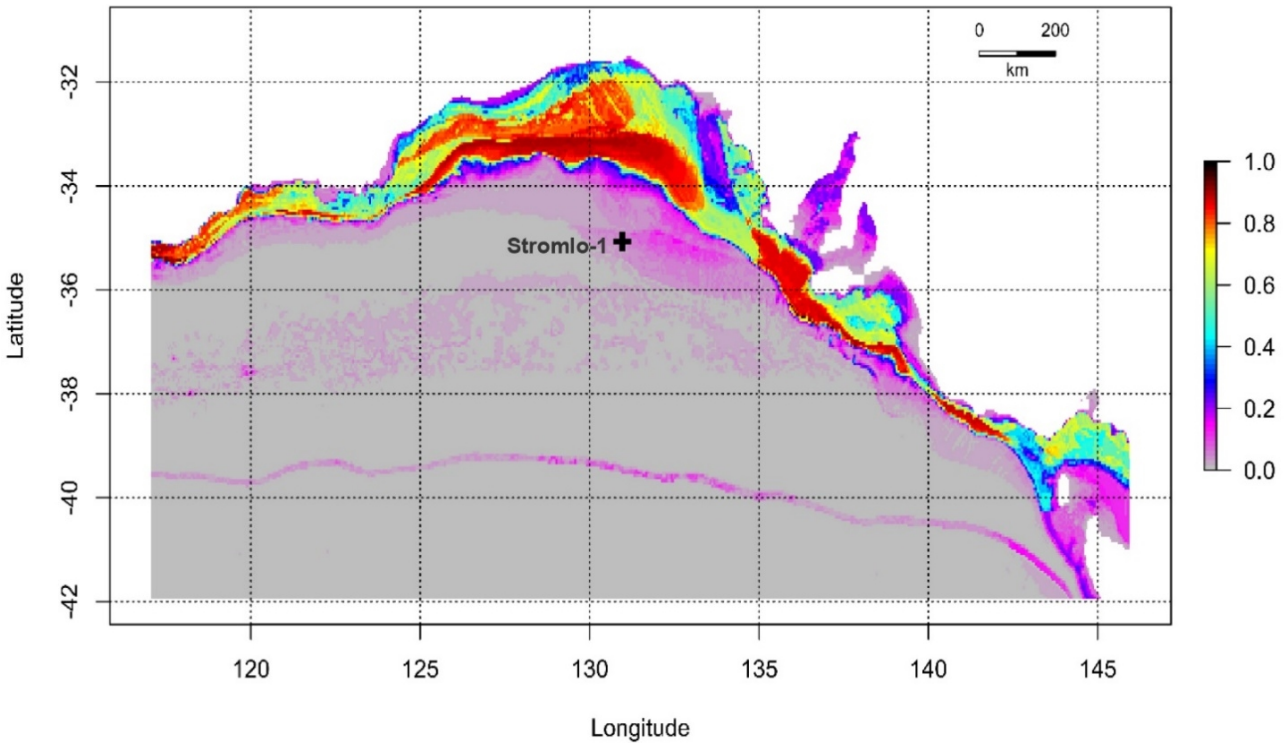
The Protected Matters search determined that the species, or species habitat is likely to occur in the vicinity of the Impact Environment that May Be Affected.

4.6.4.5 Shortfin mako

The shortfin mako (*Isurus oxyrinchus*), listed as a migratory species under the *Environment Protection and Biodiversity Conservation Act 1999*, is a pelagic shark with a circumglobal oceanic distribution in tropical and temperate seas that grows to maximum length of 4 m (TSSC 2014). The species is widespread in offshore waters around Australia (other than the Arafura Sea, Gulf of Carpentaria and Torres Strait) and is known to travel large distances to areas well beyond the Exclusive Economic Zone (TSSC 2014).

Habitat modelling undertaken by Bailleul et al. (2017a) as part of the Great Australian Bight Research Program (Section 1.2.2), based on tracking data collected from pop-up archival tags deployed on 18 mako sharks, demonstrates that suitable foraging habitats in the Great Australian Bight are mainly over the continental shelf and shelf break (Figure 4.30). It is apparent that the well location is well outside the inner shelf areas in which the sharks prefer to forage, with only a low probability of occurrence in the Impact Environment that May Be Affected.

Given the widespread distribution and large distances travelled by the shortfin mako, transient individuals may occur in the Impact Environment that May Be Affected, but densities in this area will be very low (the warmer colours in Figure 4.30 indicate a higher probability of occurrence of foraging).



Source: Bailleul et al. (2017)

Figure 4.30 Standardised probability of potential occurrence of foraging habitats of shortfin mako sharks

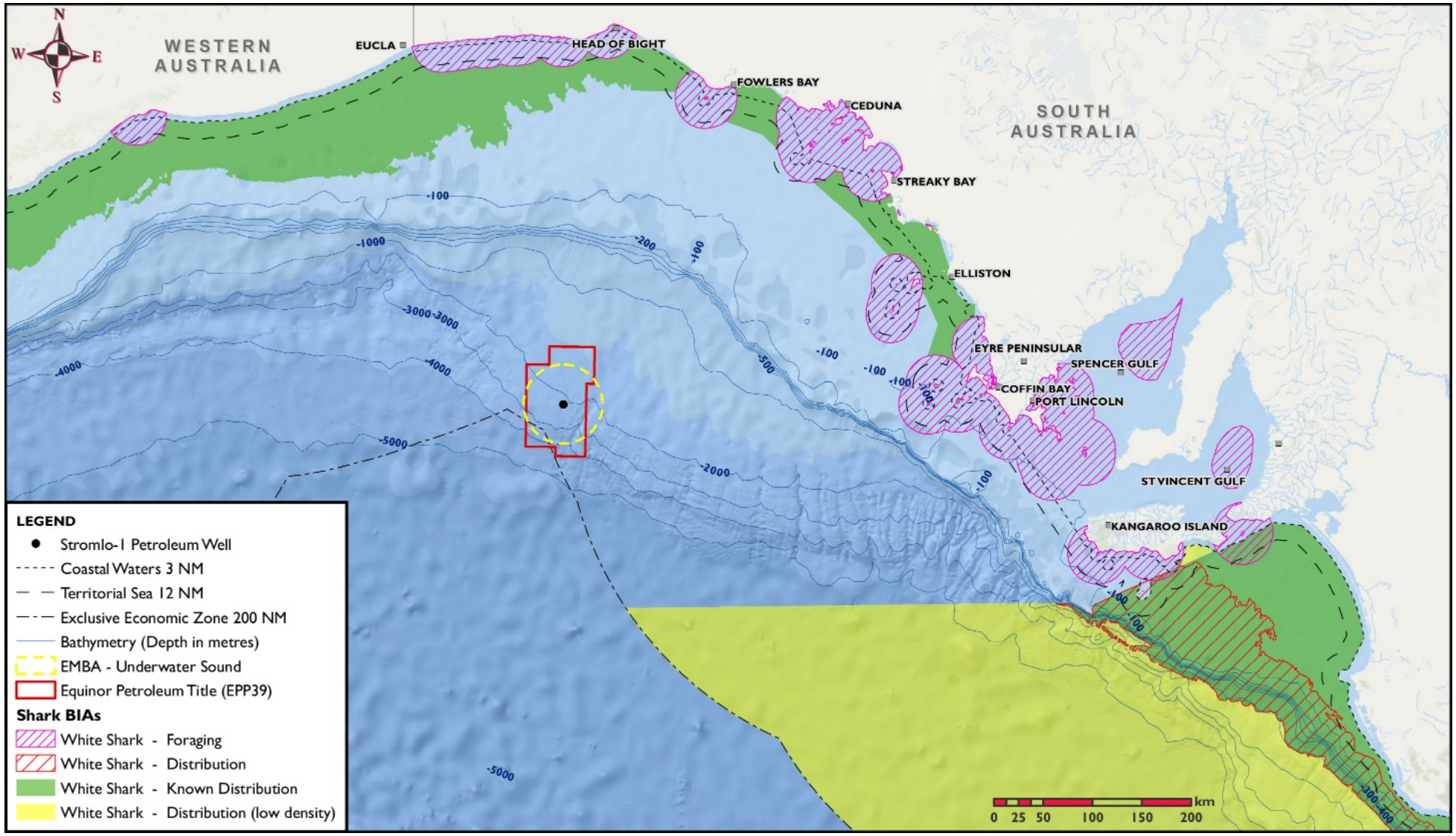


Figure 4.31 Biologically important areas for EPBC-listed sharks

4.6.4.6 Southern bluefin tuna

The southern bluefin tuna (*Thunnus maccoyii*) is a large pelagic fish species that occurs throughout the southern hemisphere in waters between 30°S and 50°S but is mainly found in the eastern Indian Ocean and in the south-western Pacific Ocean (TSSC 2010). The southern bluefin tuna off southern Australia is part of a single, highly migratory biological stock that spawns in the north-east Indian Ocean from September to April and migrates throughout the temperate southern oceans, supporting several international, Commonwealth and state-managed fisheries (Ellis & Kiessling 2016; Honda et al. 2010). The southern bluefin tuna is listed as conservation dependent and is managed in Australian waters according to the Commonwealth Listing Advice on *Thunnus maccoyii* (Southern Bluefin Tuna) (TSSC 2010).

The southern bluefin tuna is a long-lived species (maximum age ~40 years) and is highly fecund. southern bluefin tuna feed rapaciously in the epipelagic layers of oceans, opportunistically targeting fish, crustaceans, cephalopods, salps, and other marine animals (Ellis & Kiessling 2016). Within Australian waters, southern bluefin tuna range from northern Western Australia, around the southern region of the continent, to northern New South Wales (Figure 4.32).

The migratory movements of southern bluefin tuna are complex and vary among life history stages. It is proposed that larvae follow the Leeuwin Current south from the spawning grounds shortly after hatching in the spring months, reaching the waters off south-west Australia in early summer (Rogers et al. 2013). Most of these young-of-the-year southern bluefin tuna are thought move into the continental shelf waters off southern Western Australia and gradually move eastwards into the Great Australian Bight (Rogers et al. 2013). An unknown proportion of this age class remains in the Great Australian Bight throughout the winter while others move into the Indian Ocean (Rogers et al. 2013).

Juvenile southern bluefin tuna (1–4 years old) undertake seasonal large-scale migrations, typically departing the Great Australian Bight between March and July once seasonal upwelling and associated enhanced productivity declines (Evans et al. 2017a). They then move to major feeding grounds, either westward into the central Indian Ocean or eastward into the Tasman Sea, before returning between November and March to use the Great Australian Bight during the summer and autumn, highlighting the global importance of the region for this species (Figure 4.33) (Evans et al. 2017a; Rogers et al. 2013).

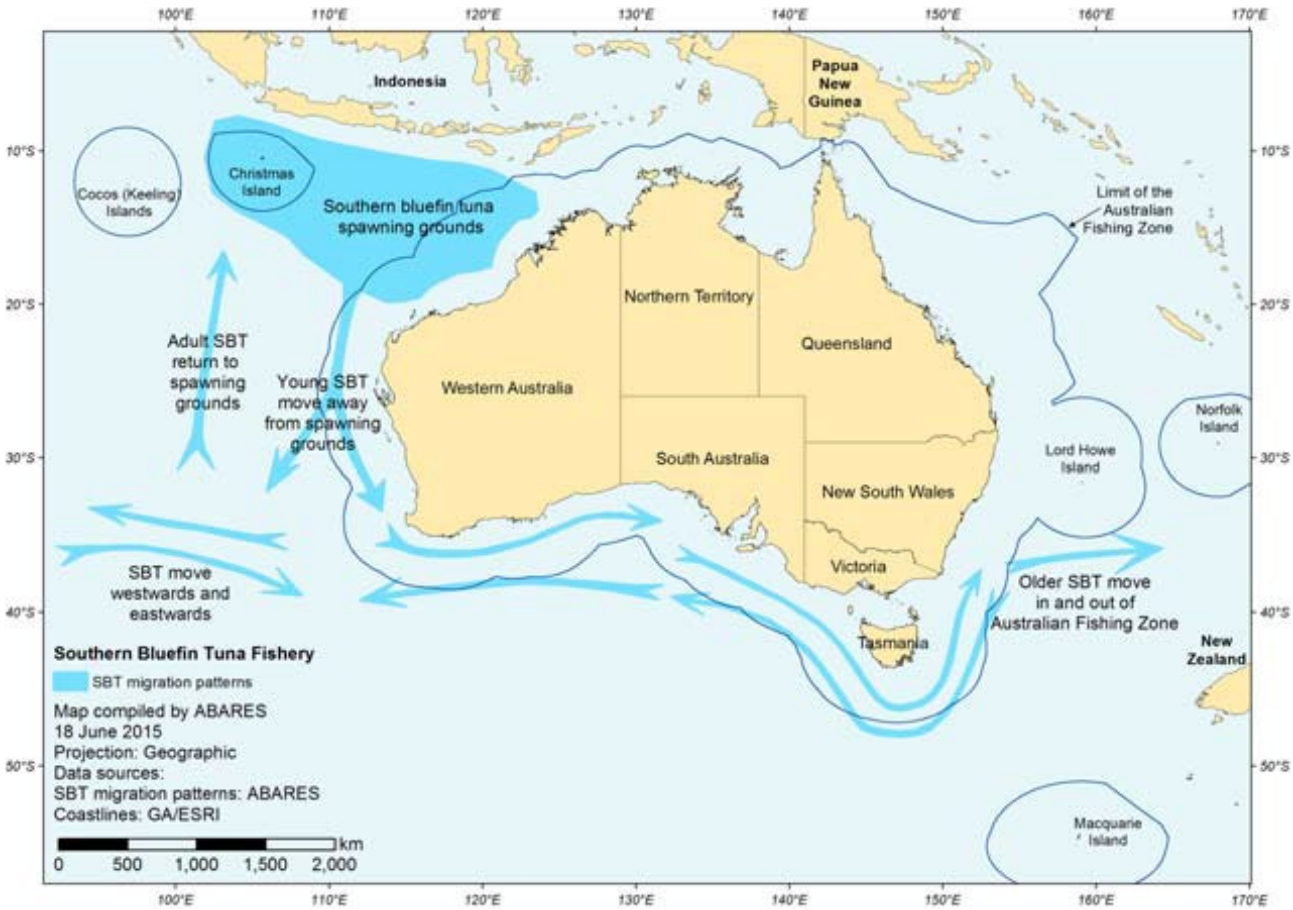
In summer the Great Australian Bight is one of the few locations where southern bluefin tuna form aggregated schools near the sea surface (<200 m deep) during the day. From December to February juvenile southern bluefin tuna largely concentrate in inshore shelf waters or around the shelf break in the western and central Great Australian Bight and tend to shift towards the eastern Great Australian Bight from March to May (Evans et al. 2017b). A large proportion of the annual growth increment of southern bluefin tuna is achieved during this summer and autumn period, with juvenile southern bluefin tuna frequently feeding on relatively small prey, predominantly sardines (Evans et al. 2017b). Increased time spent in warm surface waters over summer may be a form of behavioural thermoregulation, allowing them to increase their body temperature, increasing digestion and growth rates above levels that could be achieved in other coastal or oceanic environments (Evans et al. 2017b). Outside the summer and autumn period, juvenile southern bluefin tuna do not appear to have preferred depth or temperature habitats, instead demonstrating highly plastic behaviours in response to their environment; consequently, feeding is more sporadic and consists of larger prey such as fish, squid and krill. The limited number of southern bluefin tuna that remain in the Great Australian Bight during winter tend to concentrate around the shelf break (Evans et al. 2017b).

Little is known of the movement patterns of sub-adult southern bluefin tuna (>5 years old) but commercial catch data suggest these animals disperse throughout southern temperate waters. Figure 4.34 shows the tracks of over 120 tagged juvenile southern bluefin tuna which dispersed widely across the Great Australian Bight region. Both sub-adult and adult southern bluefin tuna occur seasonally during the winter throughout the Tasman Sea. Adults migrate south around Tasmania towards the end of spring/beginning of summer, moving across the south of Australia and then north along the western coastline of Australia to the spawning ground in the north-east Indian Ocean (Patterson et al. 2008). Similar to juveniles, migration schedules are highly variable with individuals departing the Tasman Sea from September to December (Patterson et al. 2008). Adults demonstrate temperature preferences for waters of 18–20 °C and waters <250 m although spend time at depths >600 m and demonstrate diel variation in diving behaviour for periods of time (Patterson et al. 2008).

Fishery independent aerial surveys have been used to derive an index of relative abundance of 2–4-year-old southern bluefin tuna in the Great Australian Bight between January and March for most years from 1992 to 2016 (Everson & Farley 2016). This data shows a temporal contraction in the distribution of juveniles within the Great Australian Bight to shelf waters and away from the western Great Australian Bight (Figure 4.33 and

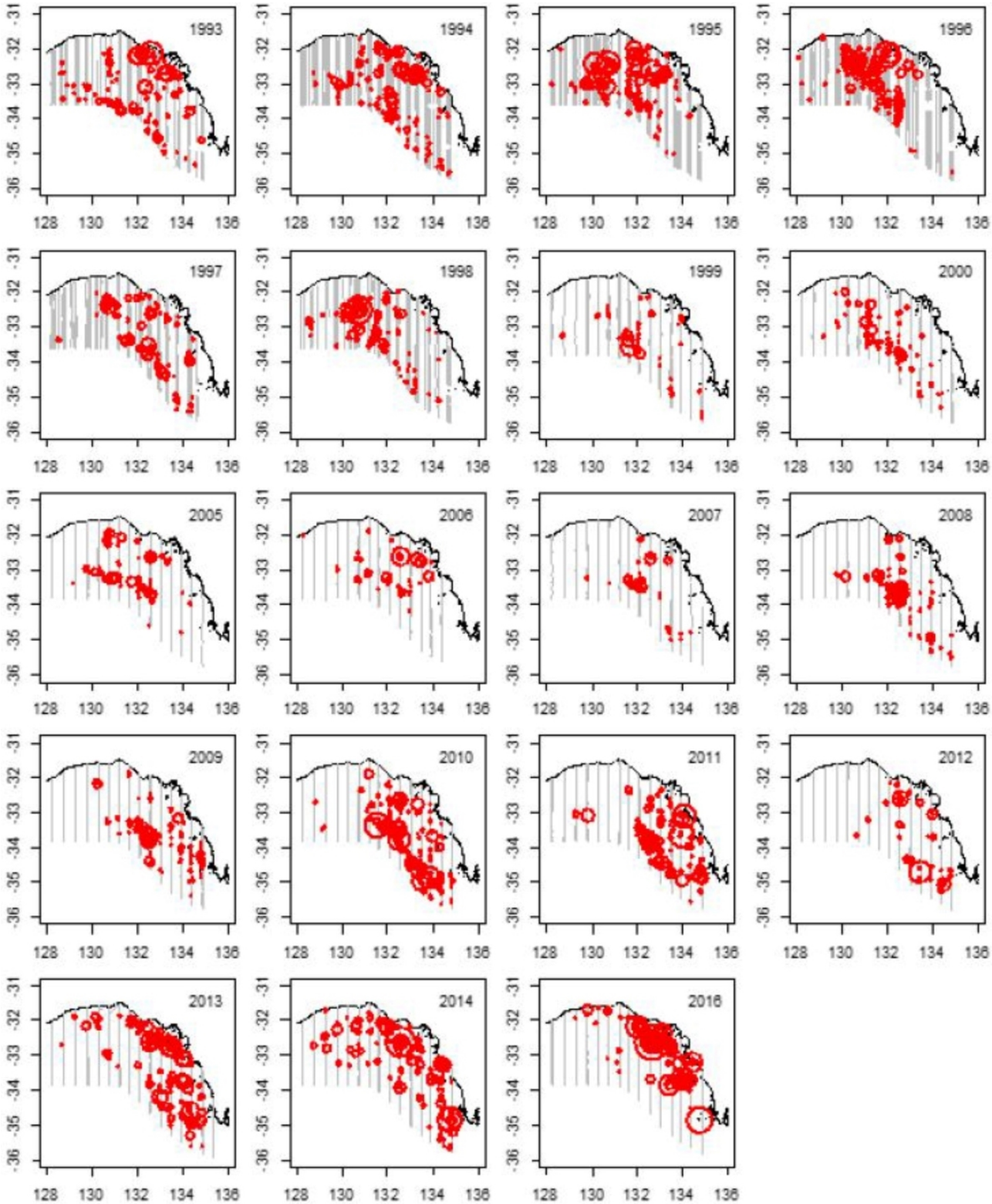
Figure 4.34; Evans et al. 2017a). Electronic tagging of juvenile southern bluefin tuna contributes to current understanding of southern bluefin tuna dynamics and abundance (Commonwealth Scientific and Industrial Research Organisation 2018). Current estimates of absolute abundance of juvenile southern bluefin tuna are conducted using genetic mark-recapture (gene-tagging) methods (Preece et al. 2014).

Southern bluefin tuna are likely (70%–80% probability) to be present within the Impact Environment that May Be Affected during summer, as they regularly forage in the area of the exploration lease (Evans et al. 2017a; Evans et al. 2017b), but in relatively low numbers compared to the continental shelf and areas nearer the shelf break and upwelling areas (Figure 4.32, Ellis & Kiessling 2016).



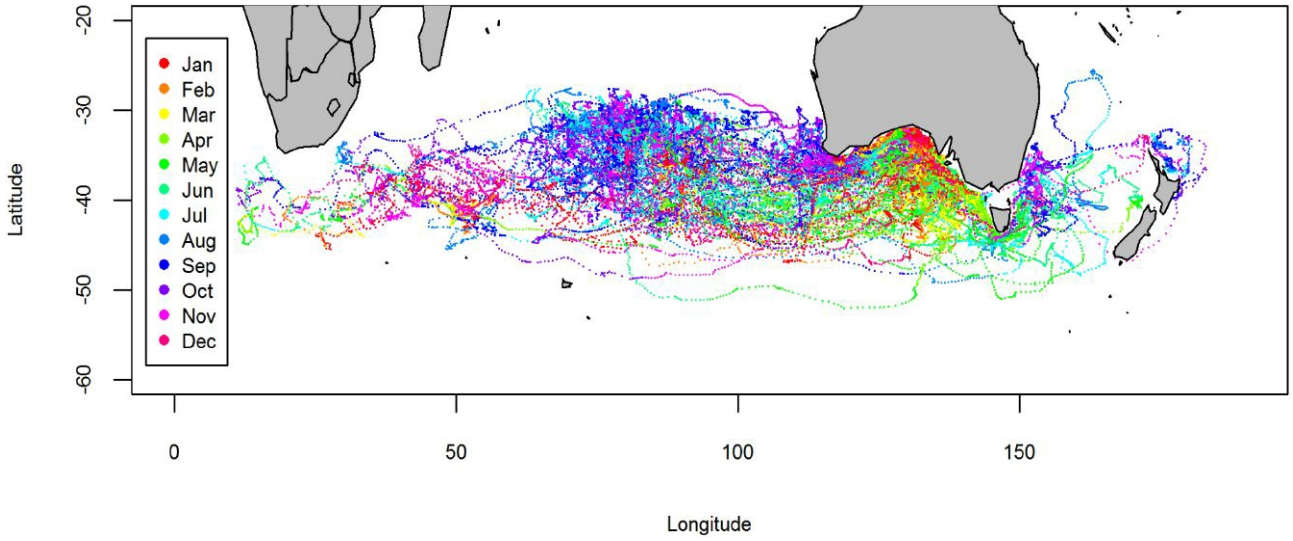
Source: ABARES in Ellis & Kiessling (2016)

Figure 4.32 Generalised southern bluefin tuna migration patterns



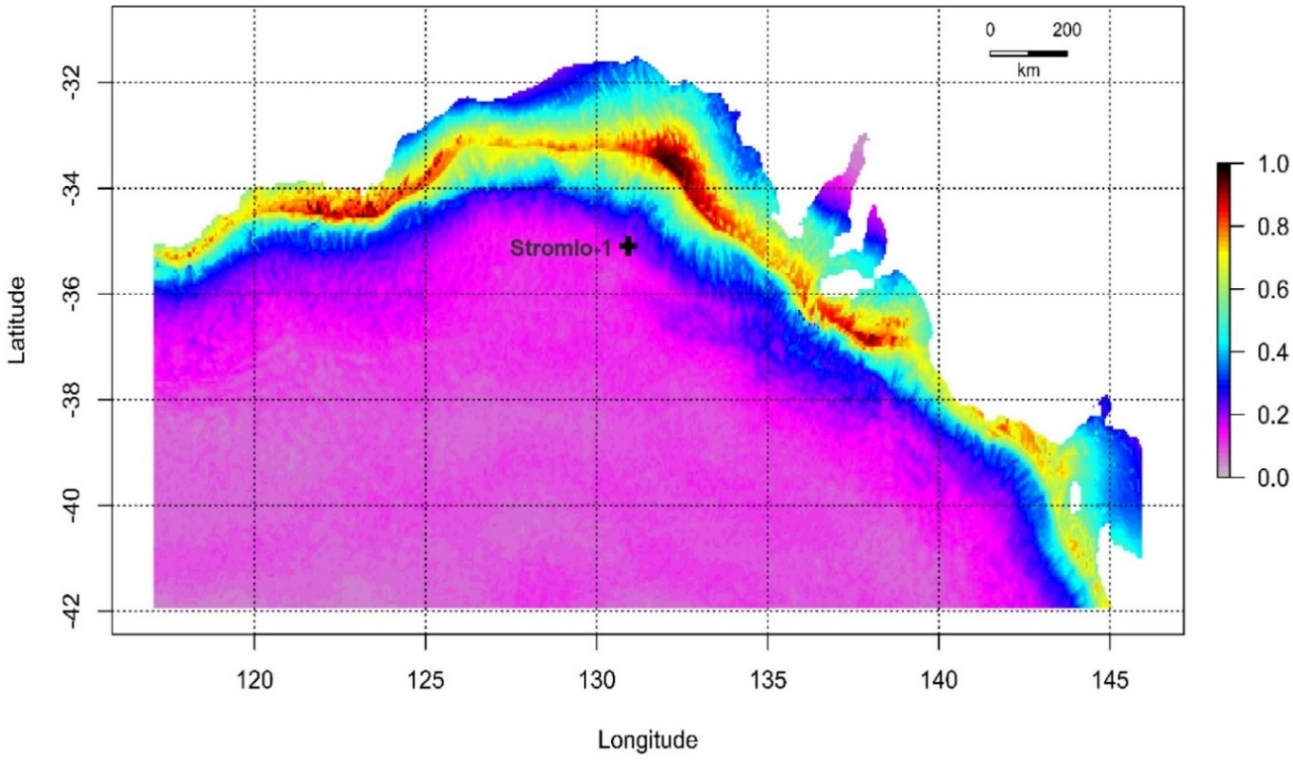
Source: Evans et al. (2017a)

Figure 4.33 Distribution of southern bluefin tuna during aerial census surveys 1992–2016



Source: Evans et al. (2017a)

Figure 4.34 Movements of juvenile southern bluefin tuna derived from archival tag deployments 1998–2011



Source: Bailleul et al. (2017)

Figure 4.35 Standardised probability of potential occurrence of foraging habitats of southern bluefin tuna

4.6.4.7 Pelagic fishes

The small pelagic fish assemblage is considered a Key Ecological Feature (KEF) of the South-west Marine Region because it is believed to provide an important trophic link between the upwelling-driven primary and secondary production and high level predators. The assemblage includes sardine, scaly mackerel, Australian anchovy, round herring, sandy sprat, blue sprat, jack mackerel, blue or slimy mackerel, red bait and saury (DEWPC 2012). This group of fish supports Australia's largest fishery (by weight)—the South Australian Sardine Fishery—as well as a diverse range of large pelagic, predatory fish including southern bluefin tuna, samson fish and kingfish (DEWPC 2012).

The small pelagic fish assemblage KEF is not mapped but was originally included, as described in the South-west Marine Bioregional Plan (DEWHA 2007), to include small pelagic fish assemblages from the following IMCRA bioregions: Southwest Shelf Transition, Southwest Shelf Province, Great Australian Bight Shelf Transition, Spencer Gulf Shelf Province. The Impact EMBA lies within the Southern Province which is entirely off the continental shelf and outside the IMCRA regions with significant small pelagic fish assemblages. The spatial separation between the KEF and the offshore Impact EMBA is further supported by the assessment of threatening processes, which predominantly relate to shelf and slope fisheries. The sardine is the dominant clupeoid off South Australia and occurs in the southern portions of Gulf St Vincent and Spencer Gulf and over the continental shelf. All effort in the South Australian Sardine Fishery occurs exclusively within and adjacent to the Spencer Gulf in coastal waters and waters shoreward of the continental shelf break (Stock assessment of Australian Sardine of South Australia 2017). The stock and the fishery are hundreds of kilometres from the Stromlo well location and are highly unlikely to be impacted by underwater sound emissions from the drilling activity. In reviewing the literature for this environment plan the authors were unable to find any documented cases of actively fished small pelagic fish beyond the shelf break in the Great Australian Bight.

No studies have mapped the distribution and abundances of small pelagic fish across the broader Great Australian Bight; however, knowledge of their food source and movements and foraging patterns of their predators has been used to infer their probable distribution and abundances outside the fishery. The Flinders current is the dominant driver of nutrient rich upwelling which occurs predominantly in the eastern Great Australian Bight during the summer and autumn months. This is a known source of food for small pelagic fish with krill making up some 65% of the sardine diet (Ward et al. 2008). Therefore, it would be expected that small pelagic fish aggregate around these upwelling events due to the importance of this food source. (Ward et al. 2008, Ecological importance of small pelagic fishes in the Flinders current system).

It is well documented that small pelagic fish dominate the diets of juvenile southern bluefin tuna in the Great Australian Bight. Evans et al. (2017) reported that southern bluefin tuna caught closer to the coastline had stomach contents dominated by sardines, while southern bluefin tuna caught closer to the shelf edge had stomach contents dominated by jack mackerel. Evans et al (2017) also showed that during the proposed summer months of the drilling activity that tagged southern bluefin tuna are aggregated around shallower shelf waters and around the shelf break. Marine mammals, also known predators of small pelagic fish, have also been shown to have similar spatial and temporal aggregation patterns in the Great Australian Bight.

It is unlikely that significant numbers of small pelagic fishes would ever occur in the deep, offshore waters of the Impact Environment that May Be Affected. There are sufficient data to confirm their preferred habitats are on the continental shelf and in nearshore waters, some 150 to 200 km from the Stromlo well location. Given the maximum range of underwater sound impacts to fish is less than the established Impact EMBA (40 km), no impacts on small pelagic fish are predicted. Impacts to larger pelagic fishes such as southern bluefin tuna are already addressed in Section 6.3.

4.6.4.8 Squid

Gould's squid (*Nototodarus gouldi*) inhabit temperate and subtropical waters of Australia and New Zealand. Individuals can be found in estuaries and pelagic environments to depths of 825 m but are most abundant over the continental shelf between depths of 50–200 m. Genetic studies indicate a single biological stock of Gould's squid throughout south-eastern Australian waters (Patterson et al. 2018). The genetic homogeneity of the species is thought to be a function of broad dispersal of juveniles on seasonal longitudinal ocean currents (Patterson et al. 2018). Individuals aggregate near the seabed during the day and move into the water column at night to feed. They reach reproductive maturity at an age of 6–9 months and spawn throughout the year (Table 4.4), dying shortly after spawning (AFMA 2019). Larvae and juveniles are often found in shallow coastal waters. The adults are not expected to visit the Impact EMBA given they are predominantly in less than 200 m water depth and Stromlo-1 is approximately 2240 m deep.

Southern calamari (*Sepioteuthis australis*) inhabits temperate and subtropical waters of Australia and New Zealand. Individuals are common over reefs, sand and seagrass beds in shallow, inshore waters in depths less than 70 m depth. Females are serial spawners and spawn throughout the year. Fertilised eggs are laid in clumps at the base of macroalgae and seagrass. Juveniles are generally found in the deeper areas such as the middle of the gulfs. As they grow, the subadults move inshore where they reach maturity and aggregate to commence spawning on shallow seagrass habitats and low profile rocky reefs. (PIRSA 2013, Runck 2018). They are not expected to visit the Impact EMBA.

4.6.4.9 Fish spawning

Information regarding fish spawning in offshore regions of the Great Australian Bight is generally limited. Spawning aggregation areas are not known to occur within the Impact Environment that May Be Affected and consultation with relevant fishing industry authorities (i.e. Australian Fisheries Management Authority and Department of Primary Industries and Regions) and commercial fishing associations (i.e. GABIA, WFSA) for fisheries permitted to operate in the survey area did not identify concerns over fish spawning in the vicinity of the Impact Environment that May Be Affected.

Spawning periods for key species of Commonwealth and South Australian fisheries with a jurisdictional area that includes the Impact Environment that May Be Affected are shown in Table 4.4 and

Table 4.5. Some commercially important species able to be fished in the vicinity of the Impact Environment that May Be Affected are not shown in Table 4.4 as they spawn outside of the Great Australian Bight, most notedly southern bluefin tuna – Australia's most valuable pelagic fish stock. The spread of fish spawning periods throughout the year (Table 4.4) indicates that there are no specific periods of higher sensitivity with respect to fish spawning for key fisheries species which may potentially spawn within the Impact Environment that May Be Affected.

Table 4.4 Spawning periods for key species of Commonwealth fisheries with a jurisdictional area that includes the Impact Environment that May Be Affected

Fishery	Key species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Additional information
Western Tuna and Billfish Fishery	Yellowfin tuna													Spawn throughout the tropical and equatorial waters of the major oceans. Spawning is seasonal at higher latitudes with peaks in summer – Spawning does not occur within the Impact EMBA
	Bigeye tuna													Spawning occurs throughout the year in tropical waters, mostly occurring in the eastern Pacific Ocean. Peak spawning periods in the southern hemisphere are between summer and autumn – Spawning does not occur within the Impact EMBA
	Skipjack tuna													Spawn throughout the year in tropical waters and during summer and early autumn in subtropical waters. The spawning season becomes shorter as distance from the equator increases – Spawning does not occur within the Impact EMBA
	Albacore													Spawning occurs in small aggregations during the summer. The peak spawning period in the southern hemisphere occurs in summer
	Broadbill swordfish													Spawning appears to occur throughout the year in tropical waters but is restricted to spring and summer at higher latitudes – Spawning does not occur within the Impact EMBA
Southern and Eastern Scalefish and Shark Fishery (SESSF)	SESSF – Commonwealth trawl sector													
	Blue grenadier													Spawning occurs in winter and early spring. The main spawning ground for blue grenadier is on the west coast of Tasmania (Australian Fisheries Management Authority, 2017) – Spawning unlikely to occur within the Impact EMBA
	Tiger flathead													Spawning occurs over an extended period from spring to autumn, with some variation on the timing of spawning depending on location
	Silver warehou													Spawning occurs in late winter-early spring, with some variation in timing depending on location
	Pink ling													Spawning occurs over an extended period during late winter and spring. May move into deeper water to spawn

Fishery	Key species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Additional information
	SESSF – Gillnet, hook and trap sector													
	Blue-eye trevalla													Thought to move into shallower waters and aggregate over specific areas for spawning. Most spawning activity occurs in waters from central New South Wales to north-eastern Tasmania – Spawning does not occur within the Impact EMBA
	Pink ling						See above							See above
	SESSF – Great Australian Bight trawl sector													
	Deepwater flathead													Spawning activity in the western central GAB peaks in late summer – Spawning may occur within the Impact EMBA
	Bight redfish													Form spawning aggregations above “lumps” on the seabed during summer and early autumn
	Orange roughy													Migrate to form dense spawning aggregations usually associated with submerged hills or seamounts generally at depths of 700–1000 m – Spawning unlikely to occur within the Impact EMBA
Small Pelagic Fishery	Jack mackerel													Spawning begins off the south-east coast of Australia and moves progressively southwards over the summer. Eggs and sperm are released among schooling fish, possibly deep in the water column near the edge of the continental shelf – Spawning unlikely to occur within the Impact EMBA
	Redbait													Spawning occurs over 2–3 months during spring
	Australian sardine													Spawning occurs during spring summer in the southern part of the species range, and in summer autumn in the northern part
Southern Squid Jig Fishery	Gould’s squid													Spawn continuously throughout the year, possibly with 2–3 peaks in spawning activity

Table 4.5 Spawning periods for key species of South Australian fisheries with a jurisdictional area that includes the Impact Environment that May Be Affected

Fishery	Key species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Additional information
Sardine (pilchard) Fishery	Australian sardine	See above												See above
Rock Lobster Fishery	Southern rock lobster													Hatching occurs in early spring, phyllosoma then spend 8–23 months at sea during which time they become widely distributed in the Southern Ocean
Marine Scalefish Fishery	King George whiting													Spawn in offshore waters from late summer to winter

Fishery	Key species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Additional information
	Southern garfish													Spawning occurs in close association to seagrass beds with peak spawning activity occurring from Oct to Nov
	Australasian snapper													Aggregate outside harbours, bays and estuaries to spawn, usually from Nov to Dec. South Australia state-wide snapper spawning closure between midday 1 Nov and midday 15 Dec each year. Additional closure areas are in place in the gulfs from 15 Dec to 31 Jan – Spawning does not occur within the Impact EMBA
	Southern calamari													Spawning occurs in shallow inshore waters, with egg mass deposits attached to seagrass, macroalgae and reef substrates – Spawning does not occur within the Impact EMBA
Miscellaneous Fishery (specialised fisheries)	Scallop													Spawning occurs over an extended period during winter and spring
	Giant crab													Closures previously existed in South Australia waters from May to Oct

Source: Australian Fisheries Management Authority (2017); Collette & Nauen (1983); DEWR (2006); Dredge et al. 2016); Ewing & Lyle (2009); (Food and Agriculture Organization of the United Nations 2005); (Kailola et al. 1993); (Marshall et al. 1993); (Pecl 2000); Department of Primary Industries and Regions (2007, 2017); Poisson & Fauvel (2009); Wild (1994)

4.6.5 Marine reptiles

Three widely distributed species of marine turtles listed as Threatened and Migratory under the *Environment Protection and Biodiversity Conservation Act 1999* were identified as potentially occurring within the Impact Environment that May Be Affected (Table 4.6). The Protected Matters Search Tool report (Appendix 4-1) did not identify any other matters of national environmental significance listed marine reptile species or species habitat as potentially occurring in the Impact Environment that May Be Affected. All species of marine turtles in Australian waters are managed under the Recovery Plan for Marine Turtles in Australia (Department of Environment and Energy 2017b). The species of marine turtles identified as potentially occurring within the Impact Environment that May Be Affected do not have Biologically Important Areas or habitats critical to their survival within the Great Australian Bight.

Table 4.6 EPBC listed marine reptile species or habitat within the Impact Environment that May Be Affected

Scientific name	Common name	EPBC Act status			BIA within Impact EMBA	Relevant plan
		Listed threatened species*	Listed migratory marine species†	Type of presence		
Caretta	Loggerhead turtle	Endangered	Yes	Species or species habitat likely to occur within area	No	Recovery Plan for Marine Turtles in Australia (2017b)
Chelonia mydas	Green turtle	Vulnerable	Yes	Species or species habitat likely to occur within area	No	
Dermochelys coriacea	Leatherback turtle	Endangered	Yes	Species or species habitat likely to occur within area	No	

* Listed threatened species: A native species listed in Section 178 of the EPBC Act as either extinct, extinct in the wild, critically endangered, endangered, vulnerable or conservation dependent.
† Listed migratory species: A native species that from time to time are included in the appendices to the Bonn Convention and the annexes of Japan–Australia Migratory Birds Agreement, China–Australia Migratory Birds Agreement and Republic of Korea and Australia Migratory Birds Agreement, as listed in Section 209 of the EPBC Act.

4.6.5.1 Loggerhead turtle

The Endangered loggerhead turtle (*Caretta caretta*) is globally distributed in tropical, subtropical waters and temperate waters (Limpus 2008a). Loggerhead turtles show a strong fidelity to their breeding and feeding areas (Limpus 2008a).

The main Australian breeding areas for loggerhead turtles are generally confined to the southern Queensland and north-western Western Australian coasts (Limpus 2008a). Hatchlings disperse into oceanic currents and gyres and remain in pelagic environments until large enough to settle in coastal feeding habitats (Department of Environment and Energy 2017b). Pelagic juveniles from eastern Australian rookeries are known to travel as far as South America (Department of Environment and Energy 2017b). Following this, loggerhead turtles take up residency nearshore and forage in depths up to 55 m, feeding primarily on benthic invertebrates such as molluscs and crabs (Department of Environment and Energy 2017b). Loggerhead turtles forage in the waters of all coastal states and the Northern Territory (NT), but are uncommon in South Australia, Tasmania and Victoria (Department of Environment and Energy 2017b). Most migrate less than 1000 km between their feeding and breeding areas (Limpus 2008a), although individuals have been infrequently recorded in waters north-east of Kangaroo Island and Spencer Gulf (DENR 2004).

The Protected Matters search determined that the species or species habitat is likely to occur within the Impact Environment that May Be Affected, however the species is likely to be only a very infrequent visitor to the area.

4.6.5.2 Green turtle

The Vulnerable green turtle (*Chelonia mydas*) is distributed in subtropical and tropical waters around the world (Limpus 2008b). Green turtles show a strong fidelity to their breeding and feeding areas (Limpus 2008b). Nine genetically distinct Australian green turtle stocks are recognised with breeding areas across northern Australian waters including the Cocos Keeling, North West Shelf, Ashmore Reef, Scott Reef-Browse Island, Cobourg, Gulf of Carpentaria, northern Great Barrier Reef and Torres Strait, Coral Sea and southern Great Barrier Reef (Department of Environment and Energy 2017b). Green turtle hatchlings spend their first 5–10 years drifting on ocean currents until they settle in tidal and subtidal coastal habitats such as reefs, bays and seagrass beds where they feed on seagrass and algae (Department of Environment and Energy 2017b; Limpus 2008b). Green turtles are predominantly found in Australian waters off the Northern Territory, Queensland and Western Australian coastlines, with limited numbers in New South Wales, Victoria and South Australia (Department of Environment and Energy 2017b). Most migrate less than 1000 km between feeding and breeding areas (Limpus 2008b), although individuals have been infrequently recorded in waters north-east of Kangaroo Island and Spencer Gulf (DENR 2004).

The Protected Matters search determined that the species or species habitat is likely to occur within the Impact Environment that May Be Affected, however it is likely to be only a very infrequent visitor to the area.

4.6.5.3 Leatherback turtle

The Endangered leatherback turtle (*Dermochelys coriacea*) is distributed throughout tropical, sub-tropical and temperate waters around the world (Limpus 2009). Unlike other marine turtles, leatherback turtles do not take up residency in continental shelf waters but instead spend most of their life travelling vast distances and foraging in temperate coastal and open ocean areas. As the species is largely pelagic, leatherback turtles also differ in that they remain planktivorous throughout their life, feeding on jellyfish and large planktonic ascidians in the upper 300 m of the water column (Limpus 2009). Within Australia, the species is most commonly reported from coastal waters in central-eastern Australia (southern Queensland to central New South Wales); south-east Australia (from Tasmania, Victoria and eastern South Australia) and in south-western Western Australia (Limpus 2009). The central-eastern to south-eastern Australian region is one of five identified foraging sites (where area restricted behaviour is known to occur) for the leatherback turtles (Bailey et al. 2012; Department of Environment and Energy 2017b). Tracks from individuals fitted with satellite tags indicate that they forage in warmer waters further north in autumn and spring and only forage at higher southerly latitudes in south-east Australian waters during summer (November to February) (Bailey et al. 2012). This is consistent with reports that the species has been observed in the Bass Strait during summer (Limpus 2009). Away from their feeding grounds leatherback turtles are rarely found nearshore (Department of Environment and Energy 2017b). Records available from the Atlas of Living Australia (Commonwealth Scientific and Industrial Research Organisation 2017) suggest that the species is a rare but occasional visitor to the Great Australian Bight; between 2006 and 2016 there were eight sightings (including

strandings) in the Great Australian Bight and 10 in the Bass Strait, compared to over 40 in waters off the coast of New South Wales.

No major leatherback turtle rookeries have been recorded in Australia. Most leatherback turtles in Australian waters migrate to breed in neighbouring countries including Indonesia, north-west Papua, northern Papua New Guinea, the Solomon Islands and Vanuatu. However, nesting is known to occur in the NT during December-January as well as occasionally along parts of southern Queensland and northern New South Wales (last reported in 1996) (Department of Environment and Energy 2017b).

The Protected Matters search determined that the species or species habitat is likely to occur within the Impact Environment that May Be Affected, however it is likely to be only an infrequent visitor to the area.

4.6.6 Marine mammals

The Protected Matters Search Tool report (Appendix 4-1) identified the marine mammal species, listed as Threatened and/or Migratory under the *Environment Protection and Biodiversity Conservation Act 1999*, that may occur within the Impact Environment that May Be Affected. This included mysticete (baleen) whale species and odontocete (toothed) whale species (including one dolphin species). These are listed in Table 4.7 and described in the following sections. The New Zealand fur seal was not included in the Protected Matters Search Tool report but is an EPBC-listed marine species and may occur in the area; it is discussed below with the Australian Sea lion (Section 4.6.6.2). Regionally significant species identified from Marine Bioregional Plans that may occur within the Impact Environment that May Be Affected are also described below.

4.6.6.1 Cetaceans

Thirty-five cetacean species have been recorded in the Great Australian Bight, comprising 11 baleen (mysticete) whales and 24 toothed (odontocete) whale species (Fulton et al. 2017). The National Conservation Values Atlas (Department of Environment and Energy 2015) showed that the only Biologically Important Area that overlaps the Impact Environment that May Be Affected is the pygmy blue whale's distribution Biologically Important Area. Biologically Important Areas for cetaceans in the Great Australian Bight are shown in Figure 4.36.

Until recently, information on cetaceans in the Great Australian Bight has largely been restricted to sightings or stranding records, with little information about the population status, population dynamics, foraging ecology and habitat utilisation of most species (Rogers et al. 2013). However, studies by Goldsworthy et al. (2017) as part of the Great Australian Bight Research Program have explicitly addressed the paucity of baseline information on cetaceans and other iconic species. These studies included aerial surveys to assess the occurrence and distribution of dolphins and other cetaceans using inshore habitats, and offshore ship-based acoustic and visual surveys to assess the occurrence and distribution of baleen and toothed whales in offshore shelf, shelf-break and slope habitats (Goldsworthy et al. 2017). In addition, Fulton et al. (2017) have also used information available from a range of sources to establish trophodynamic and whole-of-system models of the structure and function of socio-ecological systems of the Great Australian Bight that included cetaceans. This work was also undertaken as part of the Great Australian Bight Research Program (Fulton et al. 2017).

Pilot whales

Pilot whales are included in the South-east Marine Region Profile (DoEE 2015) as "species or habitat may occur in the area" and are further described in Appendix 7-3. The Marine Bioregional Plan for the South-west Marine Region (DEWPC 2012) states that long finned pilot whales are known to occur in the region. More recently, Gill et al (2015) and Goldsworthy et al (2017) undertook visual and acoustic surveys for cetaceans and confirmed the distribution of long finned pilot whales in the waters of the Great Australian Bight. Short finned pilot whales were not recorded; however, they are known in the bight from stranding records (Segawa and Kemper 2015, In: Goldsworthy et al. (2017)).

Goldsworthy et al (2017) conducted aerial surveys in December 2015, January to February 2016, and April 2016 as part of the Great Australian Bight Research Program. Long finned pilot whales were only sighted in April 2016 with 646 individuals counted in a mean water depth of 515 m. Pilot whales were generally spotted in large groups with a mean number of 58 individuals, with all size classes observed in these groups. Gill et al. (2015) recorded pilot whales with calves in the upwelling areas from west Kangaroo Island to Victoria. These studies found that pilot whales tend to occupy the upper slope of the shelf break and suggested they

are likely to feed primarily on squid and, therefore, their presence is likely to be influenced by upwelling along the shelf break. The observed behaviours of pilot whales during the aerial surveys included milling and traveling. No critical foraging, aggregation, resting or breeding sites were identified. All available evidence indicates that the main habitat of the long-finned pilot whales is inshore of the Impact EMBA and therefore, they have not been specifically addressed in the underwater sound impact assessment.

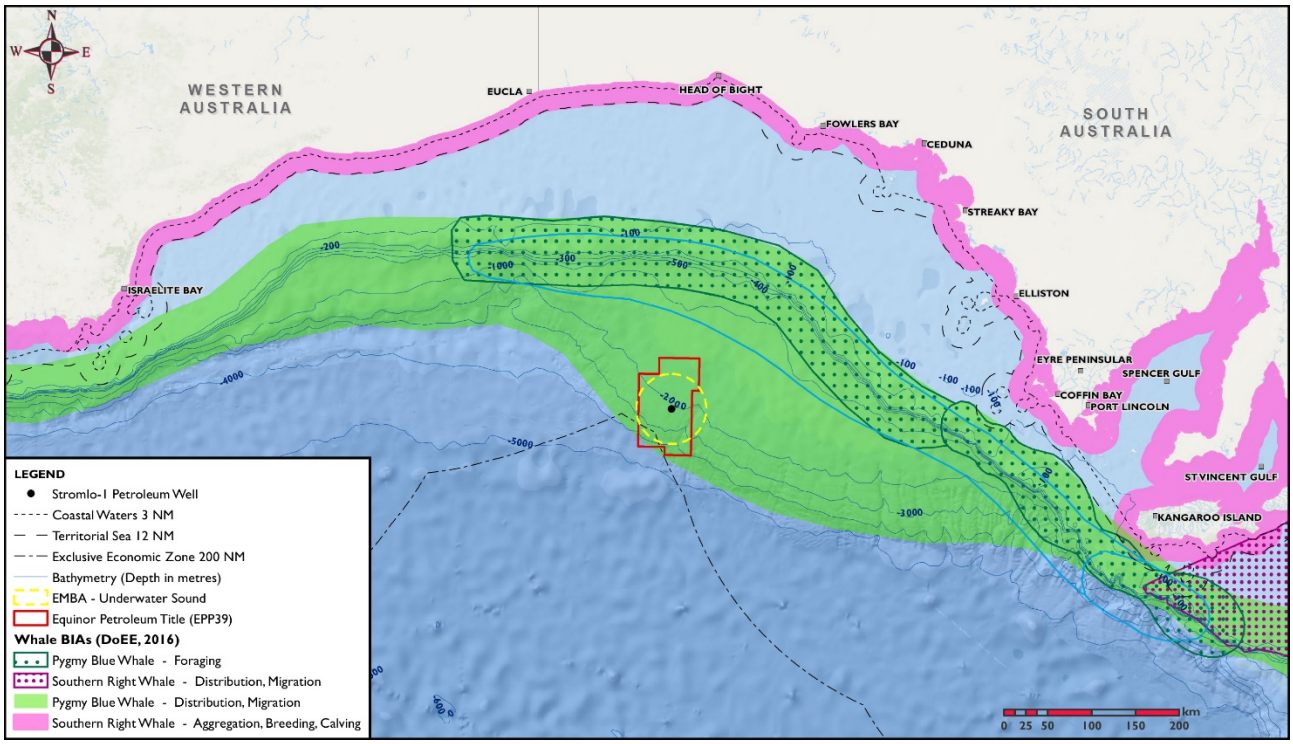


Figure 4.36 Cetacean biologically important areas in the Great Australian Bight

Table 4.7 Likely occurrence and conservation status of EPBC listed cetaceans in the Great Australian Bight

Scientific name	Common name	EPBC Act status			BIA within Impact EMBA	Relevant plan
		Listed threatened species	Listed migratory marine species	Type of presence		
Cetaceans (whales and dolphins)						
Balaenoptera bonaerensis	Antarctic minke whale	–	Yes	Species or species habitat likely to occur within area	No	–
Balaenoptera borealis	Sei whale	Vulnerable	Yes	Species or species habitat likely to occur within area	No	*Balaenoptera borealis* (sei whale) conservation advice (TSSC 2015a)
Balaenoptera edeni	Bryde's whale	–	Yes	Species or species habitat may occur within area	No	–
*Balaenoptera musculus**	Blue whale	Endangered	Yes	Species or species habitat likely to occur within area	Distribution/ Migration	Blue Whale Conservation Management Plan (DoE 2015b)
Balaenoptera physalus	Fin whale	Vulnerable	Yes	Species or species habitat likely to occur within area	No	*Balaenoptera physalus* (fin whale) conservation advice (TSSC 2015b)

Scientific name	Common name	EPBC Act status			BIA within Impact EMBA	Relevant plan
		Listed threatened species	Listed migratory marine species	Type of presence		
Caperea marginata	Pygmy right whale	–	Yes	Species or species habitat may occur within area	No	–
Eubalaena australis	Southern right whale	Endangered	Yes	Species or species habitat may occur within area	No	Conservation Management Plan for the Southern Right Whale (DSEWPaC 2012b)
Lagenorhynchus obscurus	Dusky dolphin	–	Yes	Species or species habitat likely to occur within area	No	–
Megaptera novaeangliae	Humpback whale	Vulnerable	Yes	Species or species habitat may occur within area	No	Conservation Advice *Megaptera novaeangliae* humpback whale (TSSC 2015c)
Orcinus orca	Killer whale	–	Yes	Species or species habitat may occur within area	No	–
Physeter macrocephalus	Sperm whale	–	Yes	Species or species habitat may occur within area	No	–

*Two blue whale (*Balaenoptera musculus*) subspecies occur within Australian waters – the Antarctic blue whale (*B. m. intermedia*) and the pygmy blue whale (*B. m. brevicauda*)

Antarctic minke whale

Antarctic minke whales (*Balaenoptera bonaerensis*), listed as Migratory under the *Environment Protection and Biodiversity Conservation Act 1999*, have been recorded from all Australian states except the NT (Bannister et al. 1996), though population estimates in Australia are not available (DoE 2018a). This species is known to occur north to 21°S off the east coast, with distribution along the west coast of Australia unknown. The southern distribution of Antarctic minke whales extends south to approximately 65°S in the Australian Antarctic Territory (DoE 2018a). Extensive migration occurs between their summer feeding grounds in Antarctic waters and winter subtropical or tropical breeding grounds (DoE 2018a).

Mating occurs from June to December, with calving peaking during late May–early June in warmer waters north of the Antarctic convergence, with a 14-month calving cycle (DoE 2015a).

Antarctic minke whales are known to feed on Antarctic krill (*Euphausia superba*) and other smaller krill species. In the high latitudinal winter breeding grounds in other regions, Antarctic minke whales appear to be distributed off the continental shelf edge, suggesting a similar winter distribution could be expected for Australian Antarctic waters (DoE 2018a).

Minke whales have occasionally been encountered during systematic surveys in the Great Australian Bight. Only one animal was recorded during systematic aerial surveys for inshore cetaceans (<100 m water depth) between Ceduna and Coffin Bay during July and August 2013 (Bilgmann et al. 2014). Similarly, one minke whale was also recorded during the offshore aerial cetacean survey (100–200 m water depth) between south-west Kangaroo Island to south of the Head of the Bight during December 2015 and April 2016 as part of the Great Australian Bight Research Program (Gill 2016).

There were no minke whales recorded during the 2011–2012 Ceduna 3D seismic survey of the Ceduna sub-basin (inclusive of the exploration permit 39 permit area), which was in water depths of approximately 1000–3000 m.

As uncertainties surround exact migration corridors and where foraging and breeding areas are, there is a possibility that the Antarctic minke could be encountered within the Impact Environment that May Be Affected at some time.

Sei whale

The sei whale (*Balaenoptera borealis*), listed as Vulnerable and Migratory under the *Environment Protection and Biodiversity Conservation Act 1999*, is a wide-ranging baleen whale species with a global distribution that primarily resides in deep-water oceanic habitats (TSSC 2015a). Guidance on the recovery of sei whale populations using Australian waters is provided in the Conservation Advice *Balaenoptera borealis* sei whale (TSSC 2015a) developed under the *Environment Protection and Biodiversity Conservation Act 1999*.

The distribution, abundance and latitudinal migrations of sei whales are thought to be largely determined by seasonal feeding and breeding cycles, although the spatial and temporal distribution of sei whales and areas where biologically important behaviours are displayed (Biologically Important Areas) are poorly defined in the Australian region (TSSC 2015a). Most sightings occur within Australian Antarctic Territory waters but sei whales have infrequently been recorded in Commonwealth waters off all states as well as the Northern Territory (TSSC 2015a).

It is thought that the sei whale has a similar migration pattern to other baleen whale species, completing long annual seasonal migrations from subpolar summer feeding grounds to lower latitude winter breeding grounds, but details of this migration, and whether it involves the entire population, are unknown (TSSC 2015a).

Recent sightings of sei whales in the Great Australian Bight include in the Bonney Upwelling region off South Australia (approximately 300 km east of the well location) (Miller et al. 2012), where opportunistic feeding has been observed between November and May (Gill et al. 2015), as well as a small number of females and calves sighted about 40 km south of Hobart, Tasmania (approximately 1700 km south-east of the well location) (Ensor et al. 2002 in TSSC 2015a). No sei whales were observed during 2011–2012 Ceduna 3D seismic survey of the Ceduna sub-basin (inclusive of the Impact Environment that May Be Affected) in depths ranging from approximately 1000 to 3000 m (BP p.l.c. 2016).

This species is likely to be present within the Impact Environment that May Be Affected infrequently.

Bryde´s whale

Bryde's whale (*Balaenoptera edeni*), listed as Migratory under the *Environment Protection and Biodiversity Conservation Act 1999*, is restricted to tropical and temperate waters (generally found between latitudes of about 40°N and 40°S) and has been recorded off all Australian states (Bannister et al. 1996). Bryde's whales can be found in both oceanic and inshore waters with the only key localities recognised in Australia being in the northern parts of the continent (Department of Environment and Energy 2018).

Population estimates are not available for Bryde's whales, globally or in Australia, and no migration patterns have been documented in Australian waters (Department of Environment and Energy 2018). Offshore populations have been recorded in depths of between 500 m and 1000 m.

Due to the uncertainties associated with the exact migratory paths, foraging and breeding areas, there is the potential that the Bryde's whale may be encountered within the Impact Environment that May Be Affected; however, the likelihood is low given their preference for shallower waters.

Blue whale

The blue whale (*Balaenoptera musculus*) is listed as Endangered and Migratory under the *Environment Protection and Biodiversity Conservation Act 1999*. There are two recognised subspecies of blue whale in Australian waters; the Antarctic blue whale (*B. m. intermedia*) and the pygmy blue whale (*B. m. brevicauda*) (DoE 2015b). Both subspecies are found in all Australian waters, with the Antarctic blue whale primarily found in waters south of 60°S and pygmy blues found in waters north of 55°S (DSEWPC 2012c). Given that both species may be found in Australian waters, reference to blue whale unless otherwise specified is synonymous to both species.

The Conservation Management Plan for the Blue Whale identifies threats and establishes actions for assisting the recovery of blue whale populations using Australian waters (DoE 2015b).

Biologically Important Areas for the pygmy blue whale have been identified around Australia and one, a distribution Biologically Important Area, overlaps the Impact Environment that May Be Affected, as shown in Figure 4.36. This Biologically Important Area extends along the south coast and up the west coast of Australia. The nearest foraging pygmy blue whale Biologically Important Area is located approximately 140 km north of the Stromlo-1 well location, and along the shelf break to the west and south of Kangaroo Island, extending north-west along the 200 m isobath (DEWHA 2007; DSEWPaC 2012a; Morrice et al. 2004).

Both subspecies feed on krill (euphausiids *Nyctiphane australis*). The area between Cape Otway and Robe, which includes the Bonney Upwelling, has been identified as having high annual use due to an abundance of food (DoE 2015a).

They are thought to remain in the upwelling system for up to approximately six months of the year (P. Gill pers. comm. in Fulton et al. 2017). Antarctic blue whales feed mainly during summer-autumn, while pygmy blues feed during spring–autumn in a regional upwelling system; the Eastern Great Australian Bight Upwelling/Kangaroo Island canyons (DSEWPaC 2012c; Gill et al. 2011), approximately 350 km south-east of the well location.

Most sightings that occur between late spring to autumn to the east of the well location are believed to be pygmy blue whales (Department of the Environment, Water, Heritage and the Arts 2007, though aerial surveys indicate that their abundance in the eastern Great Australian Bight is highly variable between and within seasons (DSEWPaC 2012c).

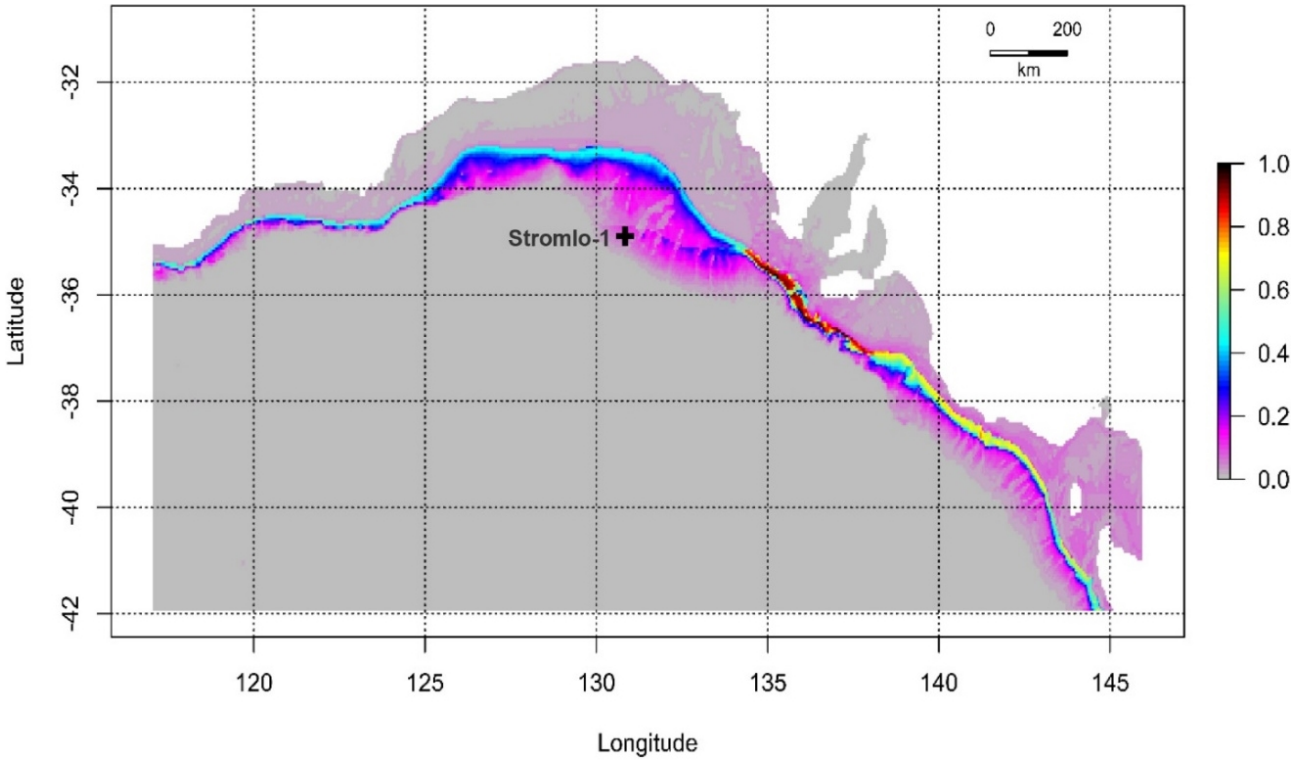
Noise loggers deployed at the shelf break and at the Head of Bight in late 2011 by McCauley et al. (2012) for BP p.l.c.'s Ceduna 3D seismic survey, recorded pygmy blue whale vocalisations. Antarctic blue whales were detected from the shelf break during winter; their calls were thought to have originated in deeper southern waters (McCauley et al. 2012).

Blue whale migration patterns are similar to those of the humpback whale, with the species feeding in mid to high latitudes (south of Australia) during the summer months and moving to temperate–tropical waters near Indonesia in the winter for breeding and calving. Blue whale migration is oceanic and no specific migration routes have been identified in the Australasian region (Department of the Environment, Water, Heritage and the Arts 2007).

Up to 40 photo-identified individuals have been recorded in the Great Australian Bight, but no formal assessments of abundance have been undertaken in Australia (Rogers et al. 2013). During the 2011–2012 Ceduna 3D seismic survey of the Ceduna Sub-basin (inclusive of the Impact Environment that May Be Affected) in depths ranging from approximately 1000 m to 3000 m, a total of 12 blue whales were observed,10 in the central Great Australian Bight and two during transit. Ten of these sightings occurred during November. Pygmy blue whales were also detected at the Head of Bight by sound loggers deployed from November 2011 to June 2012, with no detection of pygmy blue whales from late January to May 2012 at the Head of Bight (McCauley et al. 2012). Six blue whales were recorded during an aerial survey of waters between 100 m and 200 m deep, from south-west Kangaroo Island to south of the Head of the Bight, during December 2015 and April 2016 (Gill 2016).

Habitat modelling undertaken by Bailleul et al. (2017) as part of the Great Australian Bight Research Program, based on aerial survey observations of 119 pygmy blue whales, indicates that the subspecies has the highest probability of occurrence over the continental shelf break between 134°E and 138°E but may be found along the entire continental shelf break within the Great Australian Bight. The Impact Environment that May Be Affected lies in an area of relatively low suitability for pygmy blue whales (Figure 4.37).

Given the overlap of the blue whale distribution and migration Biologically Important Area with the Impact Environment that May Be Affected, it must be assumed that pygmy blue whales may be present within the Impact Environment that May Be Affected during November–May but are likely to be in transit to upwelling areas outside the Impact Environment that May Be Affected.



Source: Bailleul et al. (2017)

Figure 4.37 Standardised probability of potential occurrence of at-sea pygmy blue whales across the Great Australian Bight

Fin whale

The fin whale (*Balaenoptera physalus*) is listed as Vulnerable and Migratory under the *Environment Protection and Biodiversity Conservation Act 1999*. It is a cosmopolitan species and occurs from polar to tropical offshore waters but is rarely seen in inshore waters (TSSC 2015b). The extent of their distribution in Australian waters is uncertain, but they occur within Commonwealth waters and have been recorded in most state waters and from Australian Antarctic Territory waters (Bannister et al. 1996; Bannister 2008; Thiele et al. 2000).

The fin whale's inclusion on the *Environment Protection and Biodiversity Conservation Act 1999* threatened species list is primarily due to its small population size (TSSC 2015b); however, the abundance and population trends of fin whales in Australian waters are unknown. The Conservation Advice *Balaenoptera physalus* fin whale (TSSC 2015b) has been developed to provide guidance on the recovery of fin whales in Australian waters.

These whales are generally thought to undertake long annual migrations from higher latitude summer feeding grounds to lower latitude winter breeding grounds (Aguilar 2009). It is likely that fin whales migrate between Australian waters and Antarctic feeding areas (the Southern Ocean); subantarctic feeding areas (the Southern subtropical front); and tropical breeding areas in Indonesia, the northern Indian Ocean and south-west South Pacific Ocean (D. Thiele 2004, pers. comm. in (TSSC 2015b). Their oceanic migratory routes and dispersal to winter breeding grounds are largely unknown (TSSC 2015b).

Fin whales are generalist feeders, preying on schooling krill, fish and squid (TSSC 2015b). Fin whales have been sighted inshore over the southern Australian continental shelf and slope between western Bass Strait and the eastern Great Australian Bight, corresponding to the known extent of the broad-scale upwelling system, including the predictable and intense Bonney Upwelling. They have been observed during the summer upwelling season between November and May (Gill et al. 2015). This includes one of the first documented records of these whales feeding in Australian waters, suggesting that the southern Australian coastal upwelling zone may be used as an opportunistic foraging ground (Gill et al. 2015).

The sighting of a fin whale cow and calf in the Bonney Upwelling in April 2000 and the stranding of two fin whale calves in South Australia suggest that the inshore area could play a role in the species breeding, perhaps as a provisioning area for cows with calves (TSSC 2015b). However, there are no defined mating or calving areas in Australia waters.

During the 2011–2012 Ceduna 3D seismic survey, a total of nine fin whales were observed (in the central Great Australian Bight over the shelf break and slope) during November, April and May. Gill (2016) only observed one individual fin whale during the offshore aerial survey between south-west Kangaroo Island to south of the Head of the Bight, during December 2015 and April 2016. This whale was observed over the upper slope in the eastern Great Australian Bight.

The species may occur within the Impact Environment that May Be Affected but as the Stromlo-1 well location is more than 500 km west of the nearest upwelling zone south of Kangaroo Island its presence is likely to be limited to a small number of individuals passing through the area.

Pygmy right whale

The pygmy right whale (*Caperea marginata*) is a baleen whale found in temperate and sub-Antarctic waters in oceanic and inshore locations and is thought to have a circumpolar distribution in the southern hemisphere between about 30°S and 55°S. It is listed as Migratory / Marine under the *Environment Protection and Biodiversity Conservation Act 1999* and listed as Rare in South Australia under the *National Parks and Wildlife Act 1972*.

It has been recorded from the edge of the South Australian gulfs, around Tasmania, at Stewart Island, in Cook Strait, and in the Auckland area (Kemper 2002). While there are few confirmed sightings of pygmy right whales at sea (Reilly et al. 2008), Gill et al. (2008) reported a large group (100+) near Portland in June 2007.

The species or species habitat may occur within the Impact Environment that May Be Affected; however, their important habitats appear to be areas of coastal upwelling and the Subtropical Convergence (DoE 2018b). There is no Recovery Plan for this species.

Southern right whale

The southern right whale (*Eubalaena australis*) (SRW) is listed as Endangered and Migratory under the *Environment Protection and Biodiversity Conservation Act 1999*. Critical habitat has not been identified for the southern right whale under the *Environment Protection and Biodiversity Conservation Act 1999*; however, the Conservation Management Plan for the Southern Right Whale 2011–2021 (DSEWPC 2012a) provides information on Biologically Important Areas necessary for maintaining essential life functions (Figure 4.37).

The species only occurs in the southern hemisphere where it has a circumpolar distribution between latitudes of 16°S and 65°S (DSEWPaC 2012b). The Australian southern right whale population migrates annually from southern feeding grounds (below 40°S) to breed, calve and rest in coastal waters (mostly in shallow waters within 2 km of the shoreline) between Perth and Sydney (including off Tasmania) between May and October (DSEWPaC 2012b).

The Australian population of southern right whales was estimated at 2500 in 2017 (Charlton 2017) and thought to comprise two genetically differentiated sub-populations; the western sub-population and the eastern sub-population (Jackson et al. 2016; Mackay & Goldsworthy, 2015). The western sub-population occupies areas between Cape Leeuwin in Western Australia and Ceduna in South Australia (Bannister 2017). The smaller eastern sub-population occupies the south-eastern Australian coast, including Tasmania, but is rarely seen further north than Sydney. The western population is showing signs of recovery at a rate of approximately 5.55% per year while the eastern subpopulation is not showing signs of recovery (Bannister 2017; Mackay & Goldsworthy, 2015).

In Australia, the main calving and nursing grounds are off southern Western Australia and off the far west of South Australia. Less than 10% of reproductively mature females calving on the Australian coast appear to use the coastal waters off Tasmania, Victoria, New South Wales or eastern South Australia. The most important aggregation, wintering and calving areas in Australia are: Head of Bight in South Australia (~375 km from the well location), and Doubtful Island Bay (~1020 km from the well location) and Israelite Bay in Western Australia (~650 km from the well location). Lesser aggregation and calving areas include Fowlers Bay, Encounter Bay, Warrnambool, Port Campbell, Portland and Port Fairy in South Australia; and Twilight Cove, Yokinup Bay, Hassell Beach, Bremer Bay and Flinders Bay in Western Australia (Figure 4.38).

The closest aggregation area to the Impact Environment that May Be Affected is the Head of Bight; a significant aggregation area which is located in the Commonwealth Great Australian Bight Marine Reserve and where 25–45% of the south-western population gathers between May and October to calve in waters less than 20 m deep (Charlton 2017). Mother and calf pairs generally stay within the calving grounds for 2–3 months (DSEWPaC 2012b), with abundance at the Head of Bight peaking between June and September (DSEWPaC 2012c).

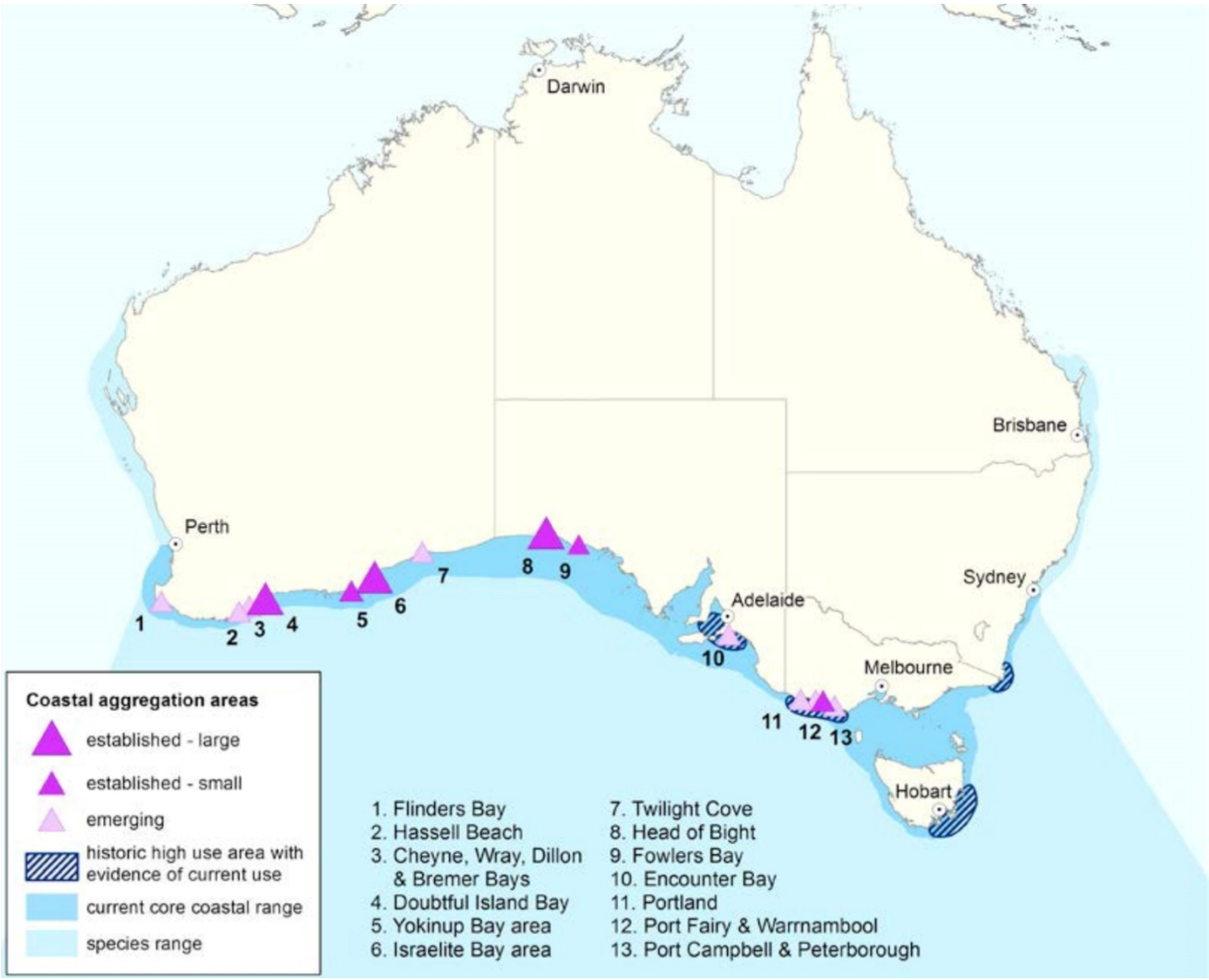
The National Conservation Values Atlas (Department of Environment and Energy 2015) identifies other breeding, calving, migration, resting and aggregation habitat Biologically Important Areas for southern right whales throughout the South-east Marine Region and the South-west Marine Region (Figure 4.36). The calving habitat Biologically Important Area encompasses all coastal waters from Victor Harbour, east of Kangaroo Island to southern Western Australia. At its closest point this Biologically Important Area is approximately 320 km north of the Impact Environment that May Be Affected (Figure 4.36). The other mapped Biologically Important Areas are further from the Impact Environment that May Be Affected.

Southern right whales move offshore from the Great Australian Bight to higher latitude areas, including the Antarctic ice edge, to feed on crustaceans in the spring months (September to November) (Rogers et al. 2013). Limited information is available on migration paths away from the coast. A defined nearshore coastal migration corridor is considered unlikely given the absence of any predictable directional movement of southern right whales along the coast (DSEWPC 2012a). The entire coastline from Kangaroo Island west to the Perth Canyon may be part of the migratory pathway for the southern right whale (DSEWPC 2012d). From photo identification data, it is thought that relatively direct approaches and departures to the coast are likely, and there is a seasonal westward movement (DSEWPC 2012a).

Information obtained from underwater sound loggers deployed in the Great Australian Bight indicates that southern right whales move to the Head of Bight from the south and possibly from the west (McCauley et al. 2012). Satellite tracking of three adult females (each accompanied by a calf) undertaken by South Australian Research and Development Institute in September 2014 at the Head of Bight showed that when they departed approximately a month later, two of the whales travelled south-west across the shelf without following the coastline (Figure 4.39) (Mackay & Goldsworthy 2015). Therefore, it is likely that some southern right whales will travel through the Impact Environment that May Be Affected in spring as the leave the Great Australian Bight. The tag on the other whale only began to transmit data 30 days after it was deployed but showed that the whale followed the coast westward before departing to the south-west (Mackay & Goldsworthy 2015).

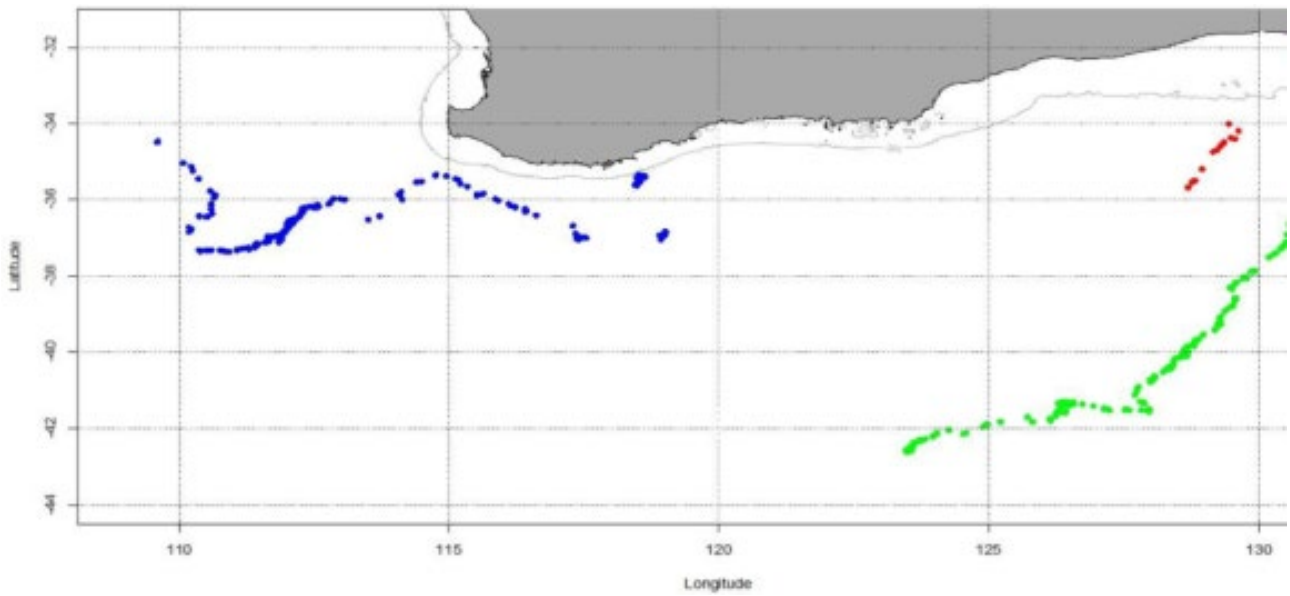
Aerial surveys for inshore cetaceans undertaken across coastal waters (<100 m water depth) of the Great Australian Bight between Ceduna and Coffin Bay during July and August 2013 detected seven southern right whales (Bilgmann et al. 2014). None were observed in the vicinity of the well location during the Ceduna 3D seismic survey undertaken between November 2011 and May 2012.

Southern right whales may be present within the Impact Environment that May Be Affected between May and October when the Australian population migrates to the south coast of Australia to breed. Given the Head of Bight is a particularly important calving area, individuals may traverse the Impact Environment that May Be Affected as they move to or from breeding areas, but the lack of defined migration pathways and survey observations suggest a diffuse migration and indicates that large numbers of individuals are unlikely to be present in the Impact Environment that May Be Affected.



Source: DSEWPaC (2012b)

Figure 4.38 Coastal aggregation areas for southern right whales



Source: Mackay et al. (2015)

Figure 4.39 Tracks of tagged southern right whales leaving the Head of Bight aggregation site in September–October 2014

Killer whale

The killer whale (*Orcinus orca*), listed as Migratory under the *Environment Protection and Biodiversity Conservation Act 1999*, is the most cosmopolitan of all cetaceans and may be seen in any marine region. However, the species is most numerous in coastal waters and cooler regions where productivity is high (Department of Environment and Energy 2017c). Killer whales are most abundant in the Antarctic south of 60°S and are regularly reported from Australian waters surrounding the Heard and Macquarie islands, which appear to be a key locality (Department of Environment and Energy 2017c). There has been limited study of killer whales in Australian waters with most of the information on their distribution and occurrence obtained from incidental sightings. The species has been recorded around the Australian continent, with sightings concentrated off southern Western Australia, Victoria and Tasmania (Department of Environment and Energy 2017c). No important breeding or resting grounds have been identified in Australia (Department of Environment and Energy 2017c).

Killer whales are the dominant oceanic apex predator and generally feed on a variety of vertebrate and invertebrate species. Observed killer whale movements are thought to be mainly related to foraging opportunities (Bannister et al. 1996; Morrice 2004; Morrice et al. 2004) and their movements probably reflect the distribution of their prey. The diet of Australian killer whales is not well known but there are reports of attacks on dolphins, young humpback whales, blue whales, sperm whales, beaked whales, dugongs, Australian sea lions and sun fish (Bannister et al. 1996; Wellard et al. 2016).

Within the last decade, large numbers of killer whales have been discovered to congregate around a group of canyons on the continental slope of the Bremer sub-basin; 70 km south-east of the Bremer Bay in Western Australia from January to March each year (Totterdell 2014). Other pelagic megafauna, including various squid, sharks, cetaceans and seabirds, also aggregate in the area and the biodiversity “hot spot”, which is within the area designated as the Bremer Canyon AMP. The killer whales probably visit the area to forage on a variety of locally abundant prey. The marine park is over 1000 km from the Impact Environment that May Be Affected.

Satellite telemetry data suggest that killer whales travel along the continental slope; beyond the shelf break in water depths around 1000 m (Totterdell 2014).

This species may occur within the Impact Environment that May Be Affected, but it does not overlap any important habitats for the whales.

Sperm whale

The sperm whale (*Physeter macrocephalus*) is listed as Migratory under the *Environment Protection and Biodiversity Conservation Act 1999* and is found in all oceans and confluent seas but tends to inhabit offshore areas more than 600 m deep and is uncommon in waters less than 300 m deep (Department of Environment and Energy 2017d). Sperm whales have been recorded off all Australian states with a portion of the population present in Australian waters year-round (Department of Environment and Energy 2017d). Female and young male sperm whales remain in tropical and subtropical waters year-round, whereas older males are usually found in waters from 45°S to the Antarctic but travel to lower latitudes occasionally (Department of Environment and Energy 2017d). Both sexes are gregarious, tending to live in groups of up to 50 individuals. Sperm whales are deep divers and forage for oceanic cephalopods, as well as medium and large demersal fish including rays, sharks and teleosts (Department of Environment and Energy 2017d).

The submarine canyons (steep-sided valleys on the continental slope) off south-western and south-eastern Australia have been identified as a key ecological feature as they are linked to localised, periodic upwellings that enhance productivity and attract aggregations of marine life including large cetaceans (Hooker et al. 1999; Moors-Murphy 2014). Submarine canyons have been identified as preferred habitat for sperm whales in south-west Australia, specifically in the Albany Canyon group and the Perth Canyon.

Key locations for sperm whales include the area between Cape Leeuwin and Esperance, Western Australia, close to the edge of the continental shelf; south-west of Kangaroo Island, South Australia; off the Tasmania west and south coasts; off New South Wales, including Wollongong; and off Stradbroke Island, Queensland (Bannister et al. 1996). The National Conservation Values Atlas (Department of Environment and Energy 2015) identifies a Biologically Important Area for sperm whale foraging along the shelf break of the Great Australian Bight and waters south of Kangaroo Island. This Biologically Important Area is approximately 95 km from the well location at the nearest point.

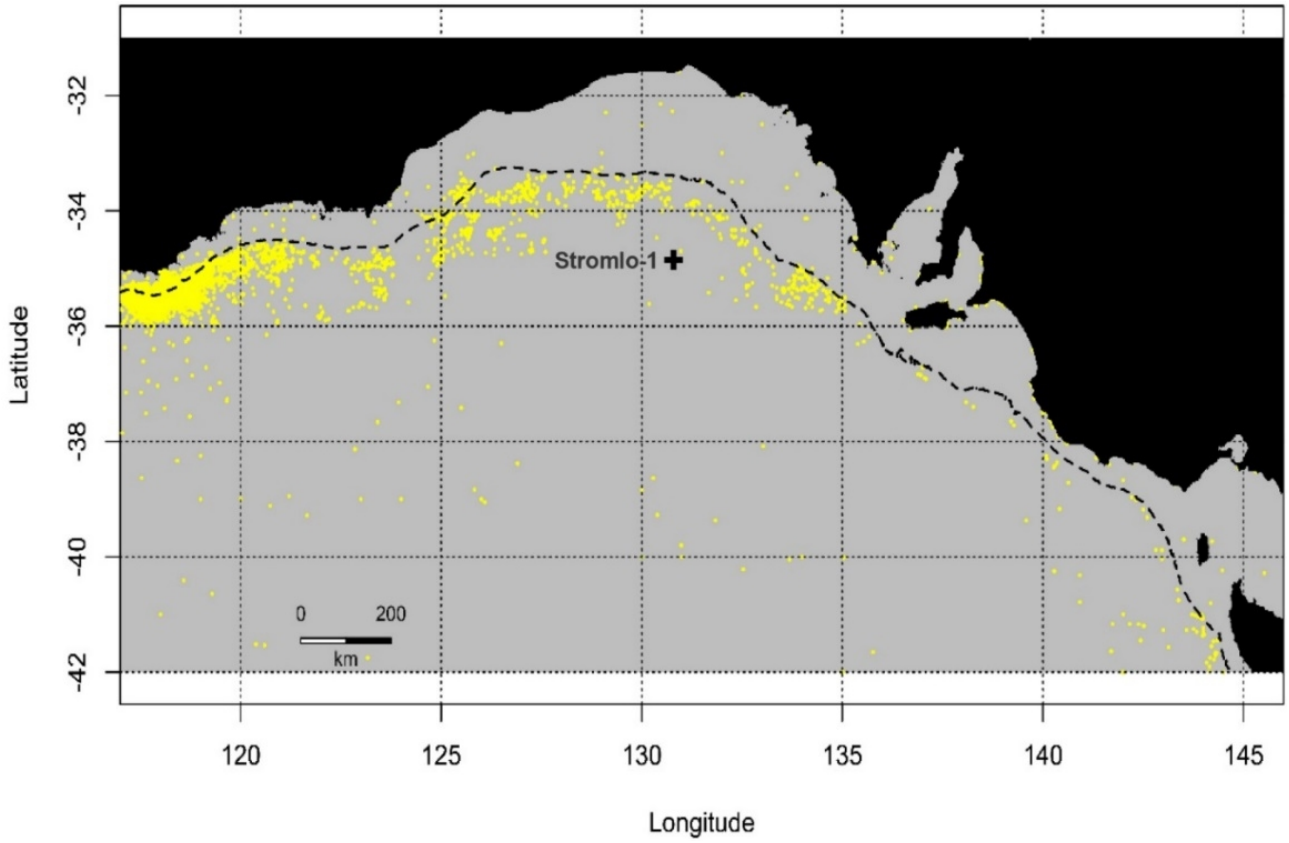
Aerial cetacean surveys over the outer shelf, between the 100 and 200 m depth contours, in the eastern and central Great Australian Bight in December 2015 and April 2016 by Gill (2016) as part of the Great Australian Bight Research Program recorded sperm whales during each of the three transects flown. Gill et al. (2015)

had previously also observed sperm whales during aerial surveys over shelf and slope waters in the eastern Great Australian Bight in 2002–2013. Sperm whales were observed in November, December and April of these years but were absent from a number of surveys as well. Sixty-eight per cent of sperm whale sightings during these surveys were of solitary mature males, and the remainder were groups of 2–12 similarly sized animals (possibly bachelor schools; (Gill et al. 2015).

No sperm whale feeding sounds were detected by sound loggers deployed from November 2011 to June 2012 at the Head of Bight and along the shelf break in the Great Australian Bight (McCauley et al. 2012). During the 2011–2012 Ceduna 3D seismic survey over the central Great Australian Bight area, 25 sperm whales were observed in December, April and May.

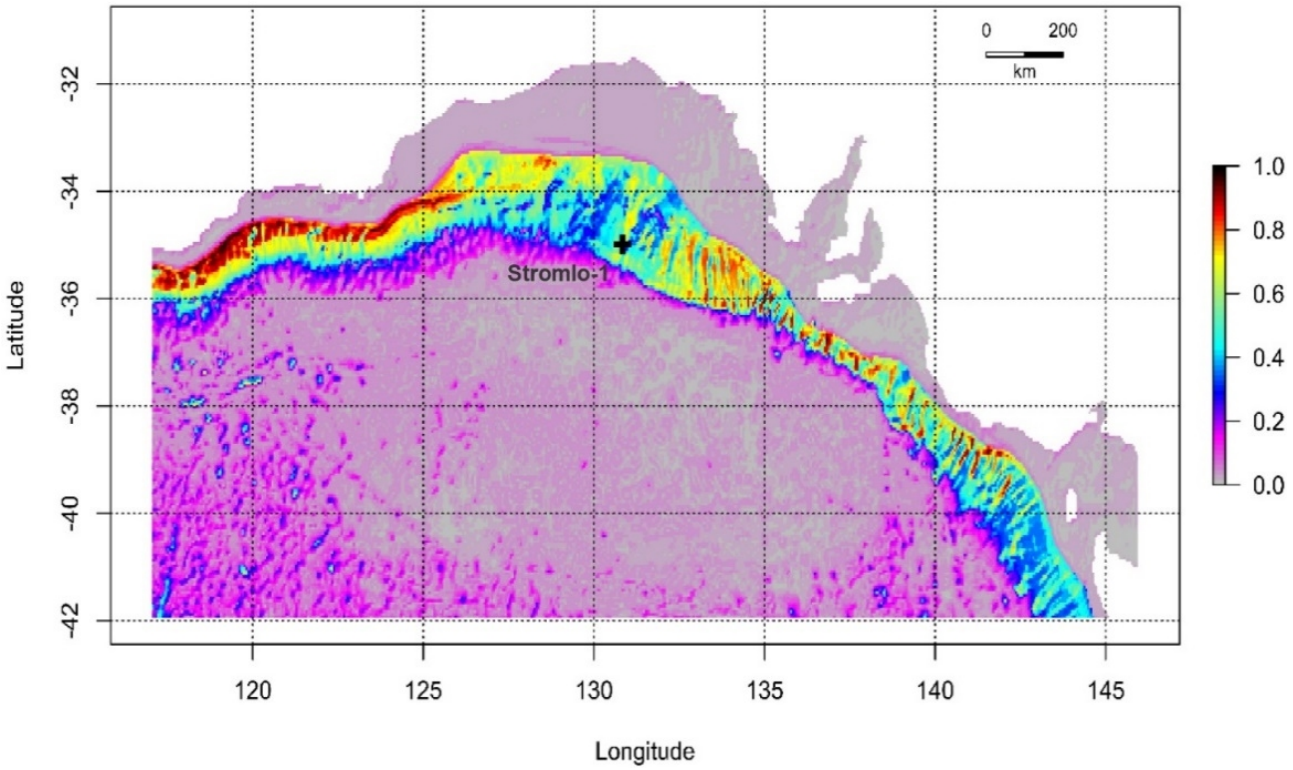
A foraging Biologically Important Area for sperm whales has been identified along the continental shelf break; approximately 70 km north-east of the Impact Environment that May Be Affected at the nearest points (Figure 4.36). Habitat modelling undertaken by Bailleul et al. (2017) as part of the Great Australian Bight Research Program based on more than 15,500 records of the locations of sperm whales (Figure 4.40) demonstrates the importance of the sub-marine canyons of the continental shelf break, for sperm whales in the Great Australian Bight (Figure 4.41).

The Impact Environment that May Be Affected does not overlap with the sperm whale foraging Biologically Important Area which is around the continental slope canyons. Based on the distribution model, sperm whale occurrence near the Impact Environment that May Be Affected is likely to be low.



Source: Bailleul et al. (2017)

Figure 4.40 Sperm whale records from aerial surveys, opportunistic sightings and historical whaling data in the Great Australian Bight



Source: Bailleul et al. (2017)

Figure 4.41 Standardised probability of potential occurrence at-sea of sperm whales in the Great Australian Bight

Humpback whale

The humpback whale (*Megaptera novaeangliae*), listed as Migratory and Vulnerable under the *Environment Protection and Biodiversity Conservation Act 1999*, is a baleen whale that has a global distribution. Due to their recovery since the cessation of whaling, the global population is now categorised on the International Union for Conservation of Nature Red List as Least Concern. To provide guidance on the ongoing conservation of humpback whales in Australian waters, the Conservation Advice *Megaptera novaeangliae* humpback whale (TSSC 2015c) has been developed under the *Environment Protection and Biodiversity Conservation Act 1999*.

Humpback whales are found in Australian offshore and Antarctic waters, undertaking an annual migration between summer feeding grounds in Antarctic waters and winter breeding and calving grounds in subtropical and tropical inshore waters on both the east and west coast of Australia (Jenner et al. 2001). They primarily feed on krill in Antarctic waters south of 55°S.

Humpback whales migrate up the eastern and western coasts of Australia and do not often travel into the Great Australian Bight (DEH 2005; Vang 2002). The northern migration of the south-east coast starts in April and May, while on the west coast it occurs towards early June. The west coast southern migration then peaks around November and December, while the east coast southern migration peaks in October and November.

The nearest known humpback whale resting area is in Flinders Bay on the south coast of Western Australia, approximately 1400 km west of the Impact Environment that May Be Affected. Small numbers of humpback whales have been observed at the Head of Bight and near Kangaroo Island in early winter. Aerial surveys for inshore cetaceans undertaken across coastal waters (<100 m water depth) of the Great Australian Bight between Ceduna and Coffin Bay during July and August 2013 detected three humpback whales (Bilgmann et al. 2014). No humpback whales were observed during the 2011–2012 Ceduna 3D seismic survey nor were they detected by sound loggers deployed from November 2011 to June 2012 at three locations in the Great Australian Bight (McCauley et al. 2013).

Given this species known feeding and breeding areas and migration routes, it may occur infrequently within the Impact Environment that May Be Affected.

Dusky dolphin

The dusky dolphin (*Lagenorhynchus obscures*), listed as Migratory under the *Environment Protection and Biodiversity Conservation Act 1999*, is mostly found from 55°S to 26°S, though sometimes further north in association with cold currents. They generally an inshore species but can also be oceanic when cold currents are present (Gill et al. 2000). Only 13 reports of the dusky dolphin have been made in Australia since 1828, and key locations are yet to be identified (Bannister et al. 1996). They occur across southern Australia from Western Australia to Tasmania, with confirmed sightings near Kangaroo Island and off Tasmania.

Given the lack of sightings in Australian waters, it is unlikely that significant numbers of dusky dolphins would be present in the Impact Environment that May Be Affected.

4.6.6.2 Pinnipeds

The Protected Matters Search Tool report (Appendix 4-1) did not identify any pinniped species protected as Threatened or Migratory under the *Environment Protection and Biodiversity Conservation Act 1999* as potentially occurring within the Impact Environment that May Be Affected. The Protected Matters Search Tool did not identify the New Zealand fur seal (*Arctocephalus forsteri*) as potentially occurring within the Impact Environment that May Be Affected; however, the New Zealand fur seal is listed as a protected marine species under the *Environment Protection and Biodiversity Conservation Act 1999* and recent evidence from the Great Australian Bight Research Program suggests foraging habitats may occur in the vicinity of the Impact Environment that May Be Affected. The habitat modelling in the Great Australian Bight Research Program showed the other two pinnipeds studied – the Australian sea lion and the Australian fur seal are not likely to occur in the Impact Environment that May Be Affected (Bailleul et al. 2017).

Australian sea lion

The Australian sea lion (*Neophoca cinerea*) is listed Vulnerable under the *Environment Protection and Biodiversity Conservation Act 1999*. The TSSC has published the Commonwealth Listing Advice on *Neophoca cinerea* (Australian sea lion) to guide conservation of the species in Australian waters. Given the high mortality through bycatch especially in demersal gillnet fisheries (Goldsworthy et al. 2017) and small population sizes over a few colonies, populations in South Australia were surveyed by Goldsworthy et al. (2017) at a colony level. The survey counted the South Australia population across 83 sites to be around 9652 individuals with a decline (of about 2.9% per year) since equivalent survey periods. Most populous breeding sites were noted at Bunda cliffs, Nuyts reef, Purdie Island, West Island, Fenelon Island, Lounds Island, Breakwater Island, Blefuscu Island, Lilliput Island, Olive Island, Nicholas Baudin Island, Ward Island, Pearson Island, Jones Island, West Waldegrave Island, Cap Island, North Rocky Island and Rocky Island (south), Four Hummock Islands, Price Island, Liguanea Island, Lewis Island, Dangerous Reef, English Island, Albatross Island North Islet, Peaked rocks, Seal Slide, and North Page and South Page islands (Figure 4.42).

The Impact Environment that May Be Affected is more than 100 km away from any Australian sea lion foraging Biologically Important Area.

Habitat mapping undertaken by Bailleul et al. (2017) as part of the Great Australian Bight Research Program based on tracking data from satellite tags deployed on 196 individuals (148 female, 48 male) from 34 sites across the Great Australian Bight (Figure 4.43) demonstrated that suitable realised habitats for females are located along the coast east of 133°E, south-east to Kangaroo Island, and in southern Spencer and St Vincent gulfs. Suitable habitats for males are mainly located east of 132°E, further away from the coast and nearer the shelf break. No habitat suitable for the occurrence of either sex was shown to exist within more than 200 km of the well location. Standardised probability of occurrence is shown in Figure 4.44.

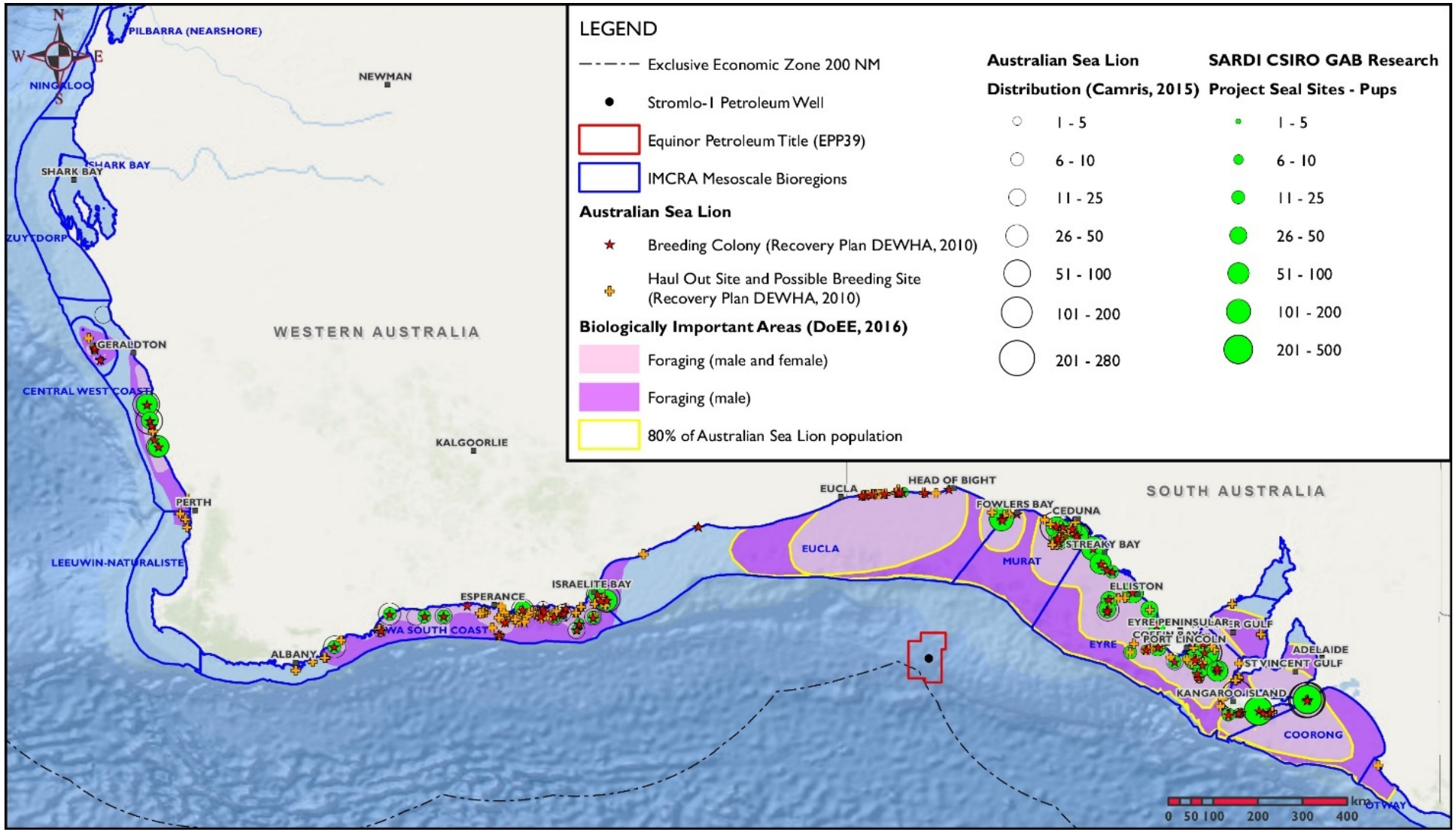
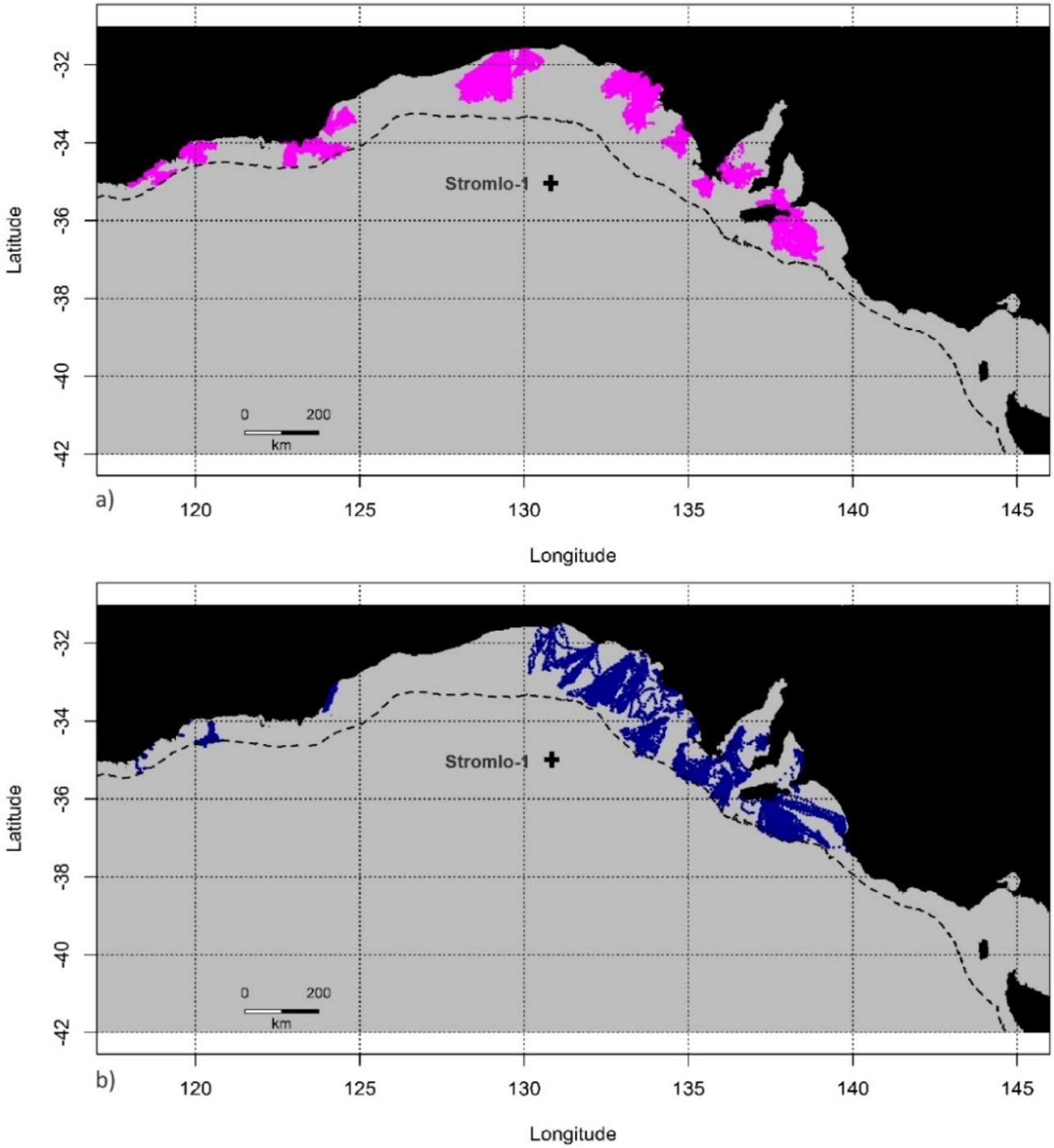
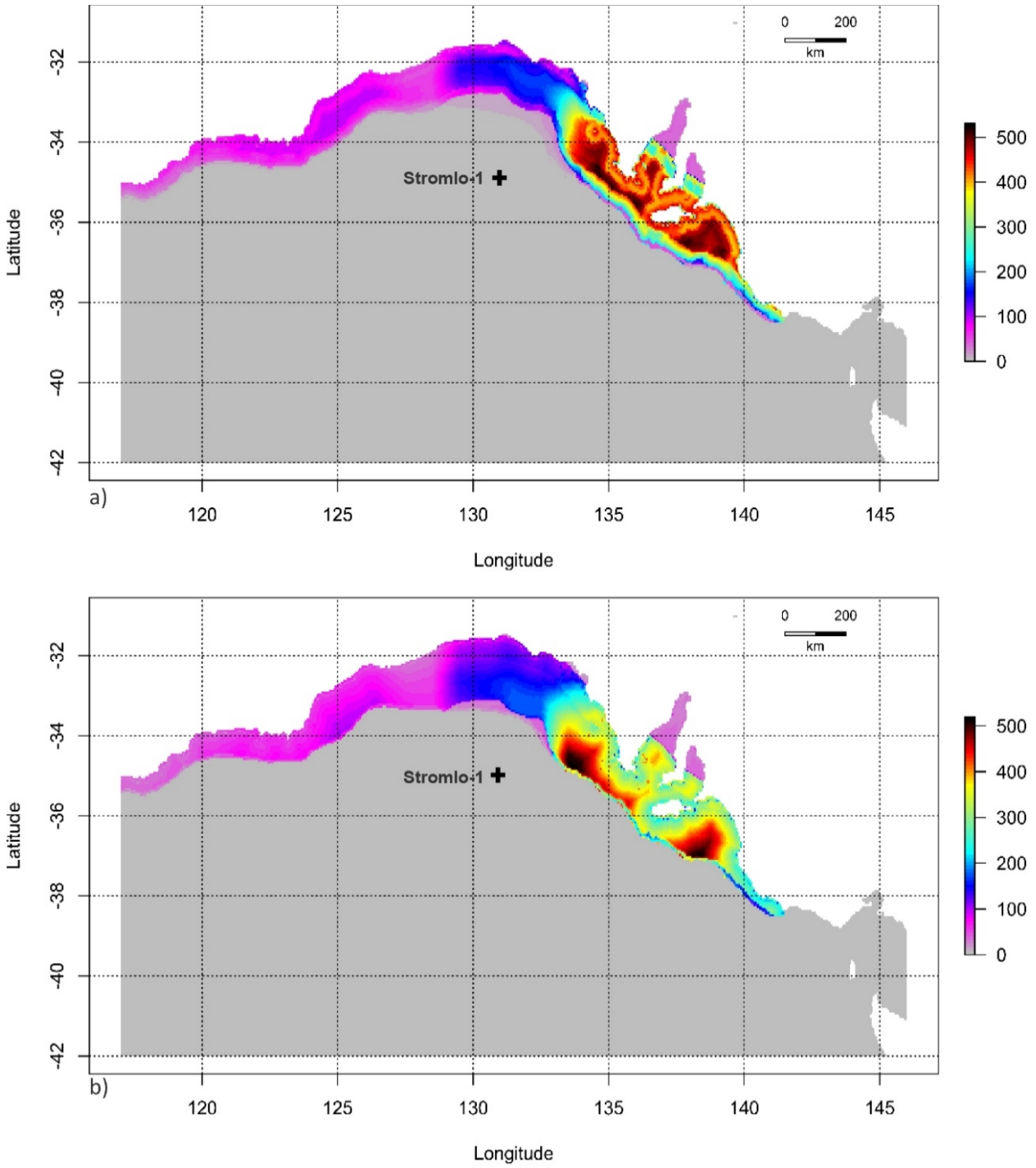


Figure 4.42 Biologically Important Area, haul out and pupping sites for Australian sea lions



Source: Bailleul et al. (2017)

Figure 4.43 Tracking data for female (top) and male Australian sea lions (bottom) (dashed line represents 250 m isobath and extent of the continental shelf)



Source: Bailleul et al. (2017)

Figure 4.44 Standardised probability of occurrence of realised foraging habitats (weighted by abundance) of female (top) and male (bottom) adult Australian sea lions

New Zealand fur seal

The New Zealand fur seal or long nose fur seal (*Arctocephalus forsteri*), a listed marine species under the *Environment Protection and Biodiversity Conservation Act 1999*, is the most abundant pinniped in the Great Australian Bight. It is also known as the long-nosed fur seal, Australasian fur seal and South Australian fur seal. New Zealand fur seals are native to Australia but also occur at several other islands in the Southern Ocean and around the South Island of New Zealand, where they were first described. In Australia, they are found in the coastal waters and on offshore islands off south-west Western Australia, South Australia, Victoria and New South Wales. Biologically Important Areas have not been defined for the New Zealand fur seal.

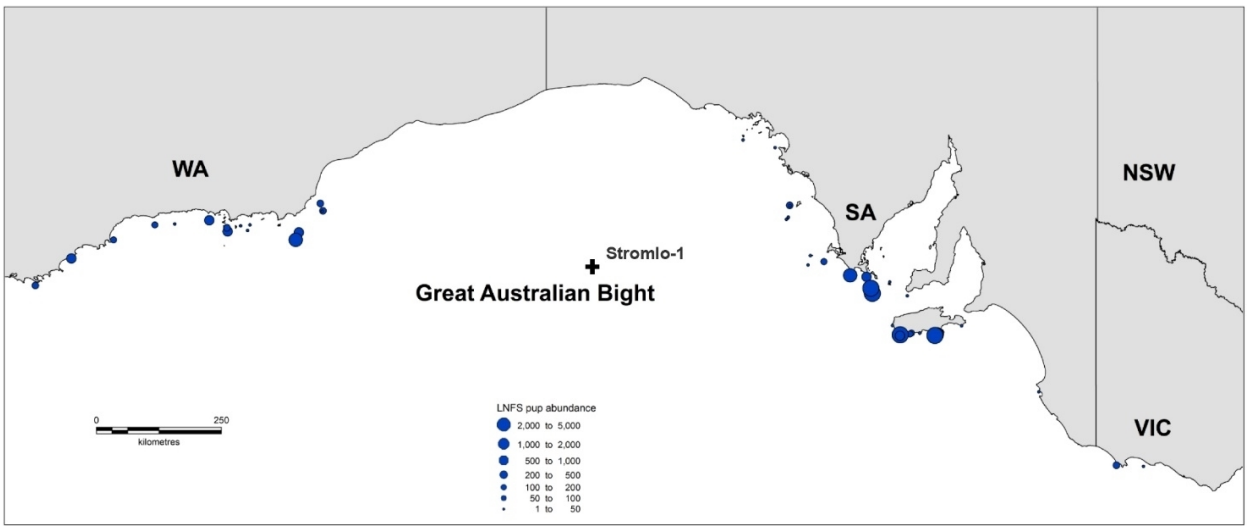
As part of the Great Australian Bight Research Program, Goldsworthy et al. (2017) compiled a comprehensive synthesis of recent and historic data on fur seal populations at 33 breeding colonies in South Australia, 16 breeding colonies in Western Australia and two breeding colonies in Victoria (Bass Strait Islands). Smaller breeding colonies are also found on remote islands off the south coast of Tasmania (DEHWA 2007). The largest breeding sites are at the Neptune Islands at the mouth of Spencer Gulf, with 7870 individuals estimated during the 2013–2014 breeding season (Shaughnessy et al. 2015). The Neptune Islands and Kangaroo Island (southern coast) and Liguanea Island, collectively account for ~80% of the national annual pup production for the species (Department of the Environment, Water, Heritage and the Arts 2007). Smaller breeding populations are also found at islands off the Eyre Peninsula, the Nuyts Archipelago, Head of Bight, Recherche Archipelago and Cape Leeuwin (Department of the Environment, Water, Heritage and the Arts 2007). Other important areas along the Great Australian Bight coast include haul-out and basking sites at Cape Rock, Rocky Islands, Curta Rocks, William Island, Low Rocks and Albatross Island (Edyvane 1999). A total of 56 breeding colonies were surveyed in the eastern and western Great Australian Bight by Bailleul et al. (2017) with the central Great Australian Bight noted as not suitable habitat for NZ fur seals and having no known breeding colonies.

New Zealand fur seals feed on small pelagic fish such as redbait (*Emmelichthys nitidus*) and jack mackerel (*Trachurus declivis*), cephalopods, benthic fish species and seabirds, primarily little penguins (Rogers et al. 2013). Male adult New Zealand fur seals forage widely over the continental shelf and continental slope habitats (Goldsworthy et al. 2017; Rogers et al. 2013). Female adult New Zealand fur seals forage over the shelf, along the shelf break and in the oceanic waters, especially in the eastern Great Australian Bight. Nursing females tend to feed in mid-outer shelf waters, within 50–100 km of the colony (Rogers et al. 2013). Juvenile seals feed primarily in oceanic waters beyond the continental shelf (Rogers et al. 2013).

Eight New Zealand fur seals were observed during 2011–2012 Ceduna 3D seismic survey of the Ceduna Sub-basin (inclusive of the exploration permit 39 permit area) in depths ranging from approximately 1000 to 3000 m. As part of the Great Australian Bight Research Program, Bailleul et al. (2017) modelled satellite tracking data from previous studies for 87 individuals (62 female, 25 male) from six sites in the Great Australian Bight. The tracking data show the importance of both continental shelf and oceanic waters for females and continental shelf waters for males in the Great Australian Bight.

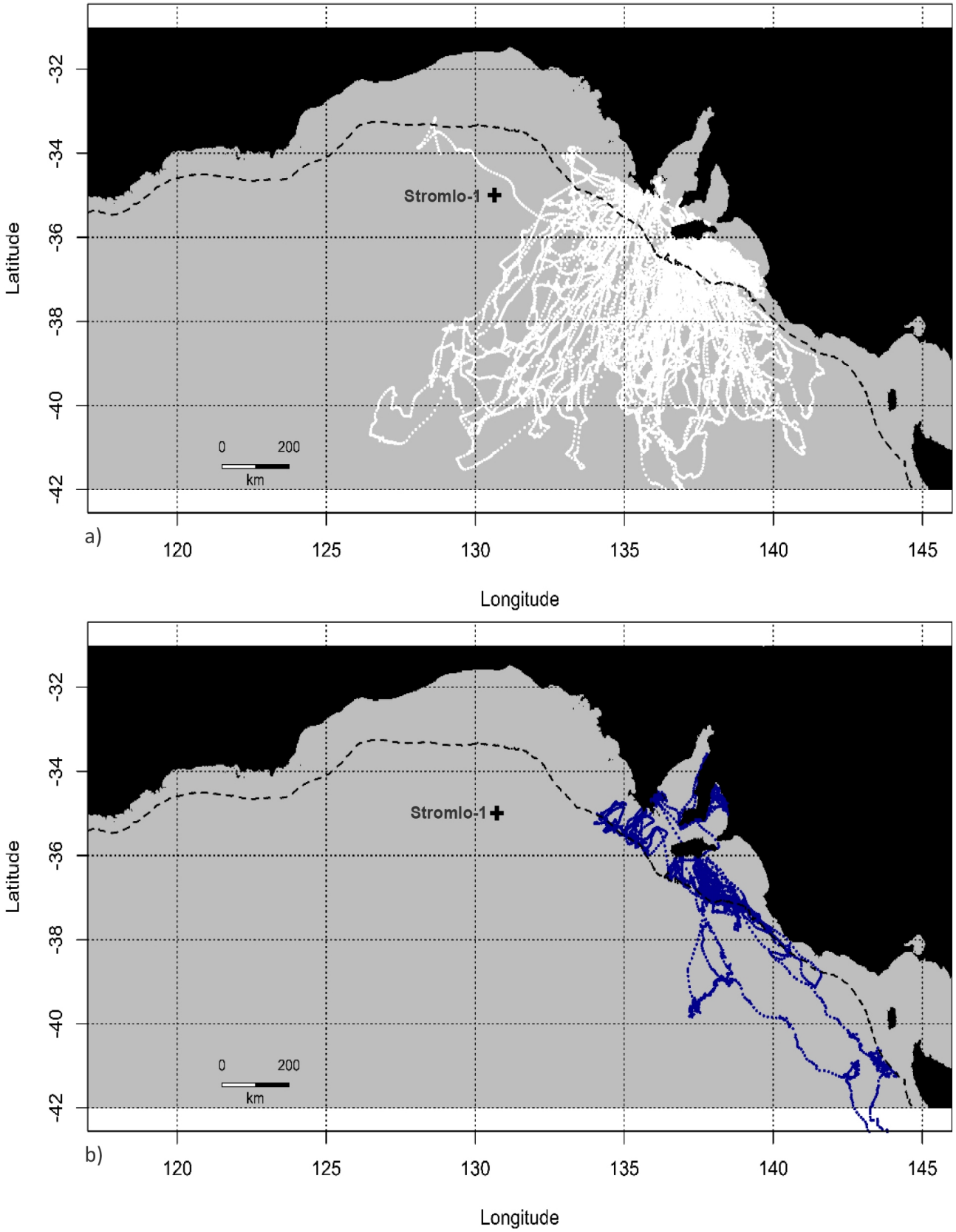
The habitat modelling undertaken by Bailleul et al. (2017) as part of the Great Australian Bight Research Program, based on these tracking data, looked at seasonal use of the shelf and offshore waters. In summer, females foraged over a more restricted area of the continental shelf in the western Great Australian Bight and the eastern Great Australian Bight, north-west and south-east to Kangaroo Island and along the Bonney coast. In winter, females foraged over the continental shelf in the western Great Australian Bight and over the continental shelf, along the shelf break and in the oceanic waters in the eastern Great Australian Bight (Figure 4.46). Standardised probabilities of males and females are shown in Figure 4.47.

Foraging New Zealand fur seals from South Australian colonies may occur within the Impact Environment that May Be Affected but are unlikely to visit the area in summer.



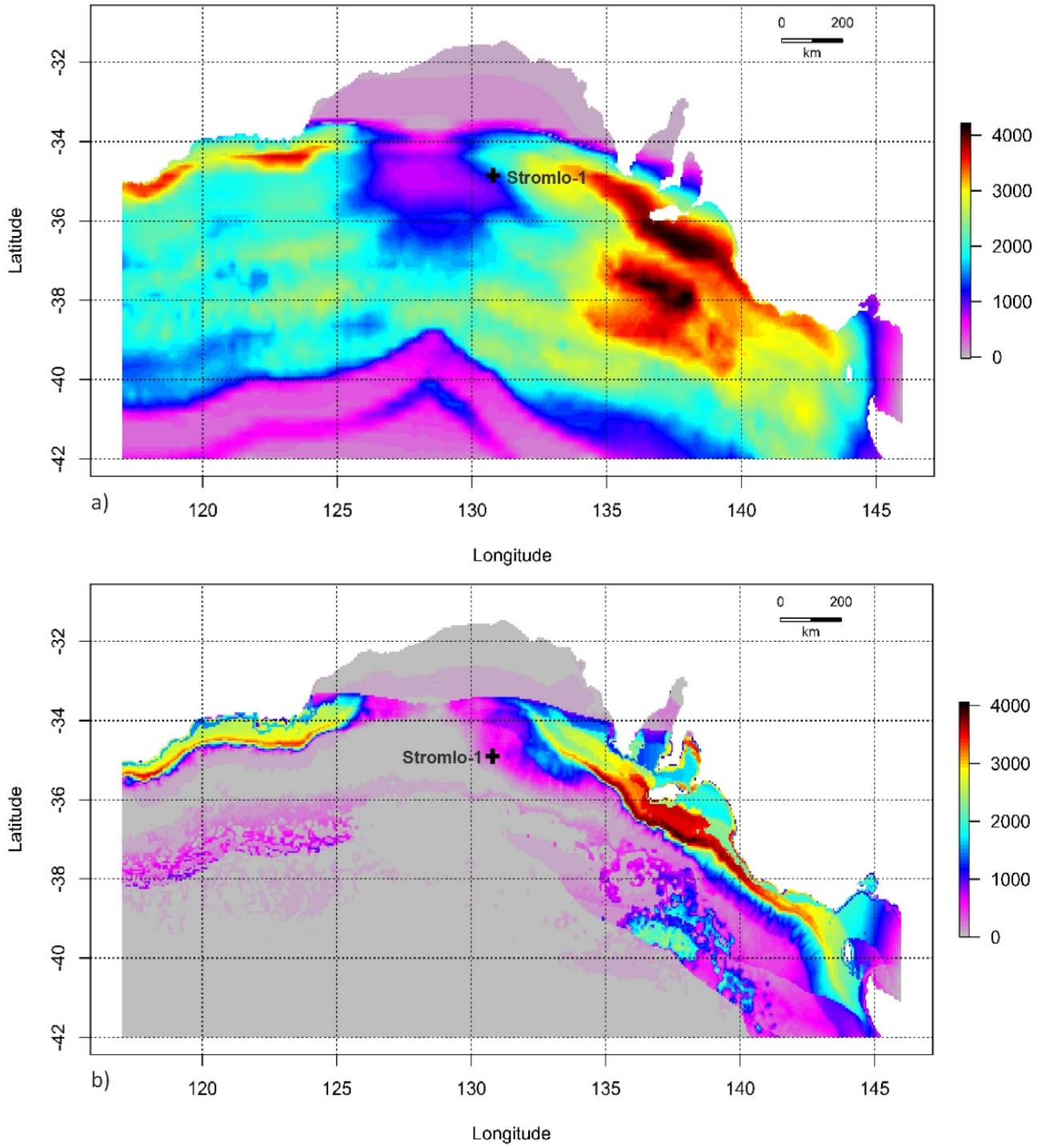
Source: Bailleul et al. (2017)

Figure 4.45 Location and size (based on pup abundance) of New Zealand fur seal breeding sites in the Great Australian Bight



Source: Bailleul et al. (2017)

Figure 4.46 Satellite tracking data for female (top) and male (bottom) New Zealand fur seals in the Great Australian Bight



Warmer colours indicate a higher probability of occurrence. The well location is indicated by the "+" symbol

Source: Bailleul et al. (2017)

Figure 4.47 Standardised probability of potential occurrence of realised foraging habitats of female (top) and male (bottom) adult New Zealand fur seals

4.6.7 Birds

4.6.7.1 Seabirds

Continental shelf waters, inshore coastal waters, inshore and offshore islands, and embayments of southern Australia provide regionally and nationally important seabird habitats. These include roosting, foraging or breeding habitats for a diverse array of seabirds, including a number of highly migratory species which are

protected under international agreements. Oceanic features, such as seasonal upwellings in the east of the Great Australian Bight, increase biological productivity thereby creating a significant foraging habitat for both resident and migratory species. Some of the oceanic foragers such as sooty terns are thought to have foraging ranges of several hundred kilometres while rearing chicks (DSEWPC 2012f) which could take them into the area of the Impact Environment that May Be Affected.

No Biologically Important Areas or critical habitats for seabirds occur within the Impact Environment that May Be Affected; however, seabirds may travel long distances from breeding and roosting areas to preferred foraging areas (Elliot et al. 2009) and may occasionally transit through the Impact Environment that May Be Affected. Threatened or Migratory seabird species listed in Protected Matters Search Tool Report as potentially occurring in the Impact Environment that May Be Affected (Appendix 4-1) are included in Table 4.8; those with Biologically Important Areas closest to the Impact Environment that May Be Affected are shown in Figure 4.48.

Table 4.8 Matters of national environmental significance listed seabird species that may occur within the Impact Environment that May Be Affected

Scientific name	Common name	EPBC Act status			BIA within Impact EMBA	Relevant plan
		Listed threatened species*	Listed migratory marine species†	Type of presence		
Albatrosses (family Diomedeidae)						
Diomedea antipodensis	Antipodean albatross	Vulnerable	–	Species or species habitat likely to occur within area	No	National recovery plan for threatened albatrosses and giant petrels 2011–2016 (DSEWPaC 2011)
Diomedea epomophora	Southern royal albatross	Vulnerable	Yes		No	
Diomedea exulans	Wandering albatross	Vulnerable	Yes		No	
Diomedea sanfordi	Northern royal albatross	Endangered	–		No	
Phoebetria fusca	Sooty albatross	Vulnerable	Yes		No	
Thalassarche cauta	Shy albatross	Vulnerable	Yes		No	
Thalassarche cauta steadi	White-capped albatross	Vulnerable	Yes		No	
Thalassarche impavida	Campbell albatross	Vulnerable	–		No	
Thalassarche melanophris	Black-browed albatross	Vulnerable	Yes		No	
Petrels, prions and shearwaters (family Procellariidae)						
Ardenna carneipes	Flesh-footed shearwater	–	Yes	Foraging, feeding or related behaviour likely to occur within area	No	–
Ardenna tenuirostris	Short-tailed shearwater	–	Yes	Foraging, feeding or related behaviour likely to occur within area‡	Yes‡	–

Scientific name	Common name	EPBC Act status			BIA within Impact EMBA	Relevant plan
		Listed threatened species*	Listed migratory marine species†	Type of presence		
Halobaena caerulea	Blue petrel	Vulnerable	–	Species or species habitat may occur within area	No	Conservation Advice *Halobaena caerulea* blue petrel (TSSC 2015d)
Macronectes giganteus	Southern giant petrel	Endangered	Yes	Species or species habitat may occur within area	No	National recovery plan for threatened albatrosses and giant petrels 2011–2016 (DSEWPaC 2011)
Macronectes halli	Northern giant petrel	Vulnerable	Yes	Species or species habitat may occur within area	No	
Pachyptila turtur subantarctica	Southern fairy prion	Vulnerable	–	Species or species habitat may occur within area	No	Conservation Advice *Pachyptila turtur subantarctica* fairy prion (southern) (TSSC 2015e)
Pterodroma mollis	Soft-plumaged petrel	Vulnerable	–	Foraging, feeding or related behaviour likely to occur within area	No	Conservation Advice *Pterodroma mollis* soft-plumaged petrel (TSSC 2015f)

*listed threatened species: A native species listed in Section 178 of the EPBC Act as either extinct, extinct in the wild, critically endangered, endangered, vulnerable or conservation dependent.
† Listed migratory species: A native species that from time to time are included in the appendices to the Bonn Convention and the annexes of Japan–Australia Migratory Birds Agreement, China–Australia Migratory Birds Agreement and Republic of Korea and Australia Migratory Birds Agreement, as listed in Section 209 of the EPBC Act.
‡Not listed in Protected Matters Search Tool report, Biologically Important Area shown in National Conservation Values Atlas (Department of Environment and Energy, 2015.

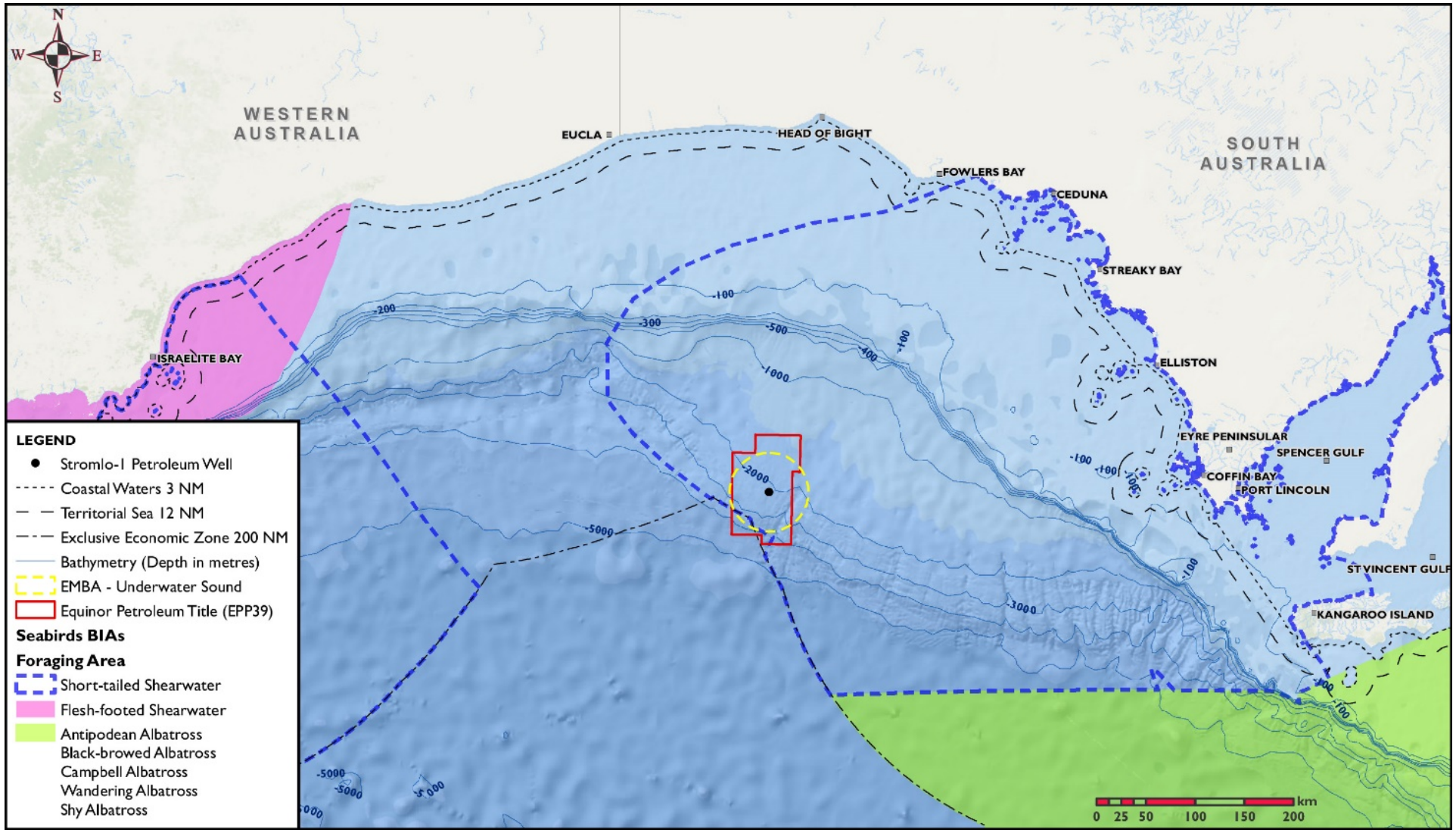
Albatrosses

Albatrosses are among the most widely dispersed and oceanic of all birds, spending more than 95% of their time foraging at sea and usually only returning to remote islands to breed. The Protected Matters Search Tool report identified nine Threatened albatross species, listed under the *Environment Protection and Biodiversity Conservation Act 1999*, as potentially occurring within the Impact Environment that May Be Affected (Impact EMBA). All nine species are additionally listed as Migratory species (Table 4.8) and are managed under the National Recovery Plan for Threatened Albatrosses and Giant Petrels 2011–2016 (DSEWPaC 2011). Given that these albatrosses are all widespread across the southern hemisphere, face similar conservation threats and require the same conservation actions, reference to albatross below applies to all species unless otherwise specified.

Albatrosses have a broad range of diets and foraging behaviours, and hence their at-sea distributions are diverse (DSEWPaC 2011). They can cover vast distances and all Australian waters can be considered foraging habitat. The most critical foraging habitat is the waters south of 25°S where most species spend the majority of their foraging time (DSEWPaC 2011). Albatrosses usually forage in offshore areas during winter, particularly along the continental shelf edge, with cephalopods, fish and crustaceans caught while diving generally forming the basis of their diet (DSEWPaC 2011). (Figure 4.49, see www.birdlifeorg.au for improved resolution).

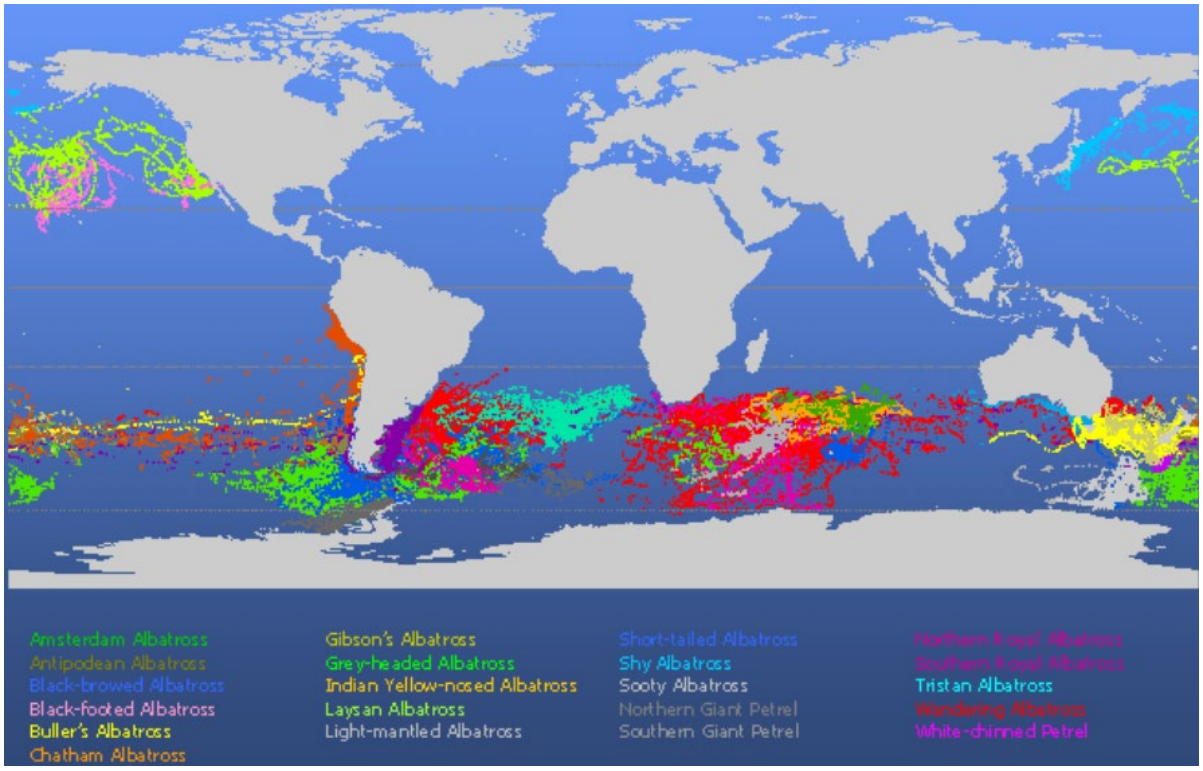
Albatrosses breed at only six localities under Australian jurisdiction: Macquarie Island (including Bishop and Clerk islets); Albatross Island; Pedra Branca; the Mewstone; Heard and McDonald islands and the Australian Antarctic Territory (Giganteus Island, Hawker Island and the Frazier Islands) (DSEWPaC 2011). These remote islands constitute the only suitable breeding habitat under Australian jurisdiction and are regarded as habitat that is critical to the survival of albatrosses in Australian waters under the DSEWPaC (2011) National Recovery Plan for Threatened Albatrosses and Giant Petrels 2011–2016. None of these sites is in the Impact EMBA; Albatross Island is the nearest breeding site at ~1375 km east-south-east.

No breeding or foraging Biologically Important Area for any of the nine albatross species identified in the Protected Matters search occurs within the Impact EMBA, however given the large, pelagic distribution of albatrosses, individuals may fly over the Impact EMBA in transit or while foraging. Some species have been observed in the central Great Australian Bight region (Figure 4.48).



Source: Bailleul et al. (2017)

Figure 4.48 Seabird Biologically Important Areas in the Great Australian Bight region



Source: DSEWPaC (2011)

Figure 4.49 Extract from Birdlife International's global procellariiform tracking database

Petrels

Four Threatened petrel species were listed in the Protected Matters Search Tool report as potentially occurring within the Impact Environment that May Be Affected (Table 4.8). Two of these species are additionally listed as Migratory. Petrels range widely throughout certain regions of the Great Australian Bight, foraging on small fish, cephalopods (octopus, squid and cuttlefish) and crustaceans along the edge of the continental shelf and over open waters.

The blue petrel (*Halobaena caerulea*), listed as Vulnerable under the *Environment Protection and Biodiversity Conservation Act 1999*, is found throughout the Southern Ocean and breeds on sub-Antarctic islands including offshore stacks near Macquarie Island (DoE 2015a). The blue petrel breeds in colonies, laying eggs in mid to late October and fledging in January–February. The birds occur predominantly between July and September in Australian waters, throughout the South-east Marine Region (DoE 2015a). They forage for pelagic crustaceans, fish, cephalopods and insects (DoE 2015a). Conservation advice (TSSC 2015d) has been developed for the blue petrel that provides guidance on immediate recovery and threat abatement activities that can be undertaken to ensure the conservation of the species.

The northern giant petrel (*Macronectes halli*), listed as Vulnerable and Migratory under the *Environment Protection and Biodiversity Conservation Act 1999*, and the southern giant petrel (*M. giganteus*, Endangered and Migratory), resemble albatrosses in that they cover vast oceanic distances throughout the southern hemisphere and breed on isolated islands in Australian jurisdiction (Figure 4.49). Both are managed under the National recovery plan for threatened albatrosses and giant petrels 2011–2016 (DSEWPaC 2011). All waters within Australian jurisdiction can be considered foraging habitat but the most critical foraging habitat is the waters south of 25°S where most species spend the majority of their foraging time (DSEWPaC 2011). Macquarie Island, Heard Island and McDonald Islands, Giganteus Island, Hawker Island and the Frazier Islands habitat critical to the survival of giant petrels (DSEWPaC, (2011) but are all outside of the Impact Environment that May Be Affected in waters south of 50°S, with Macquarie Island the closest at ~3100 km south-east of the Impact Environment that May Be Affected.

The soft-plumaged petrel (*Pterodroma mollis*) is listed as Vulnerable under the *Environment Protection and Biodiversity Conservation Act 1999*, and conservation advice has been issued for the species (TSSC 2015f). Within Australia its distribution covers temperate and sub-Antarctic waters in the South Atlantic, southern Indian and western South Pacific oceans. The species is a regular visitor to southern Australian seas being most abundant between 30°S and 50°S from South Africa to Australia (DoE 2015a).

The soft-plumaged petrel feeds predominantly on cephalopods, fish and crustaceans and forages by surface seizing. The species breeds at two sites in Australian waters: on Maatsuyker Island off Tasmania and on Macquarie Island.

No Biologically Important Areas for the blue petrel, southern giant petrel, northern giant petrel or soft-plumaged petrel overlap the Impact Environment that May Be Affected however the blue petrel, southern giant petrel and northern giant petrel may occur within the Impact Environment that May Be Affected. The Protected Matters search determined that the soft-plumaged petrel may forage in the vicinity of the Impact Environment that May Be Affected although the nearest known foraging Biologically Important Areas lie approximately 1000 km to the west.

Shearwaters and prions

The Protected Matters Search Tool report identified one Threatened prion species, and one Migratory shearwater species as potentially occurring within the Impact Environment that May Be Affected.

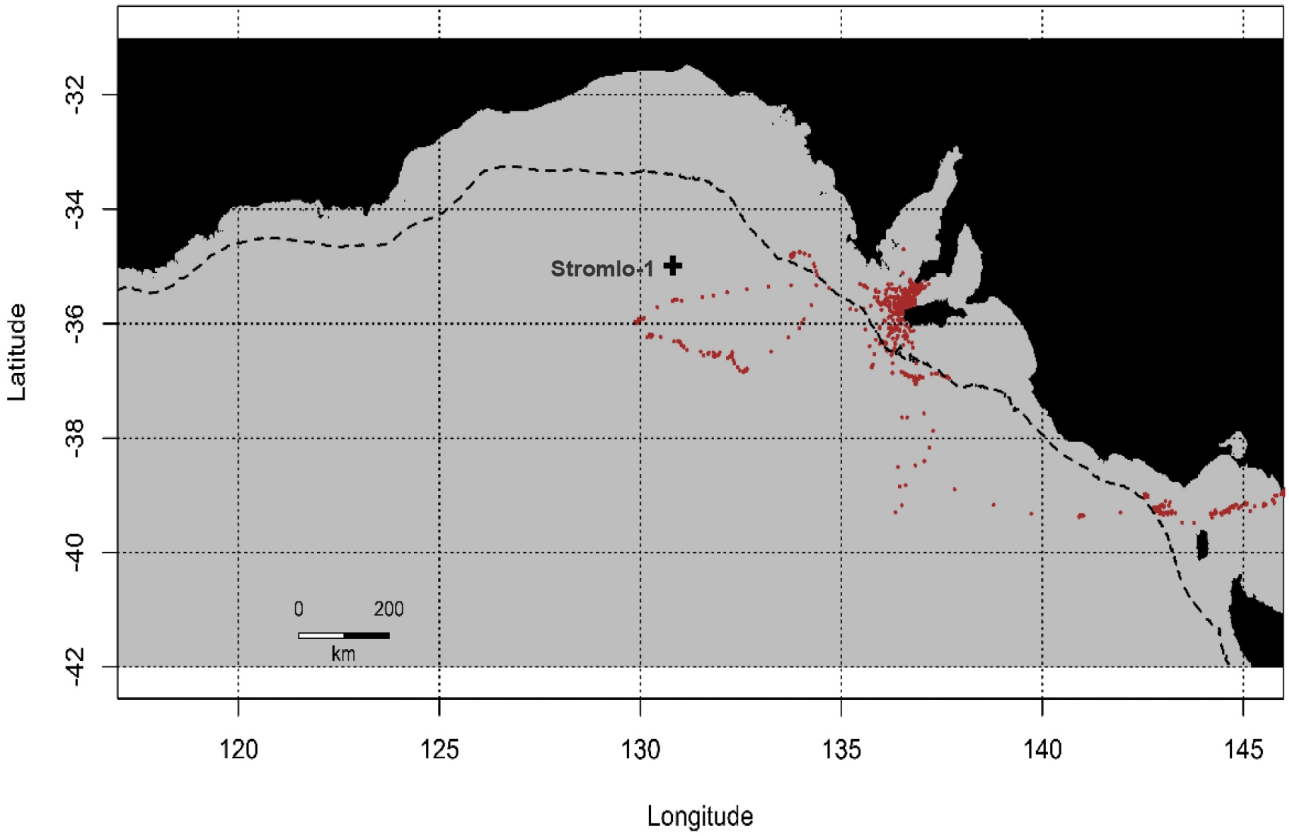
The flesh-footed shearwater (*Ardenna carneipes*), listed as Migratory under the *Environment Protection and Biodiversity Conservation Act 1999*, is a locally common visitor to waters of the continental shelf and continental slope off southern Australia and around Lord Howe Island. Pairs breed on 41 islands off the coast of south-western Western Australia, on Smith and Lewis Island off the south-eastern coast of Eyre Peninsula in South Australia and on Lord Howe Island (DEWR 2006).

The flesh-footed shearwater undertakes trans-equatorial migrations between non-breeding foraging grounds and breeding colonies. The breeding range extends from St Paul Island (mid-southern Indian Ocean), across offshore islands of Western Australia and South Australia, Lord Howe Island in the Tasman Sea, and islands off the North Island of New Zealand. Flesh-footed shearwaters forage in high numbers in nearshore areas of the south-west Western Australian coast as far east as the eastern Recherche Archipelago, and in low numbers for a short distance east of the archipelago (Goldsworthy et al. 2017). They are the most abundant shearwater species in the Great Australian Bight (Goldsworthy et al. 2017). About 104,000 pairs of flesh-footed shearwaters breed on islands between Eucla and Cape Leeuwin and from early September to late May, the species forages up to 100 km offshore along the south and extreme south-west coasts (DSEWPaC 2012a). From late April to late June, and again from late August to early November, they migrate over offshore waters off the south-west coast of Western Australia (DSEWPaC 2012a).

As part of the Great Australian Bight Research Program by Goldsworthy et al. (2017) surveyed flesh-footed shearwaters at their only known breeding sites in the eastern Great Australian Bight (Lewis and Smith Island in the Spencer Gulf) and estimated that there were approximately 728 and 5785 pairs breeding on the two islands respectively.

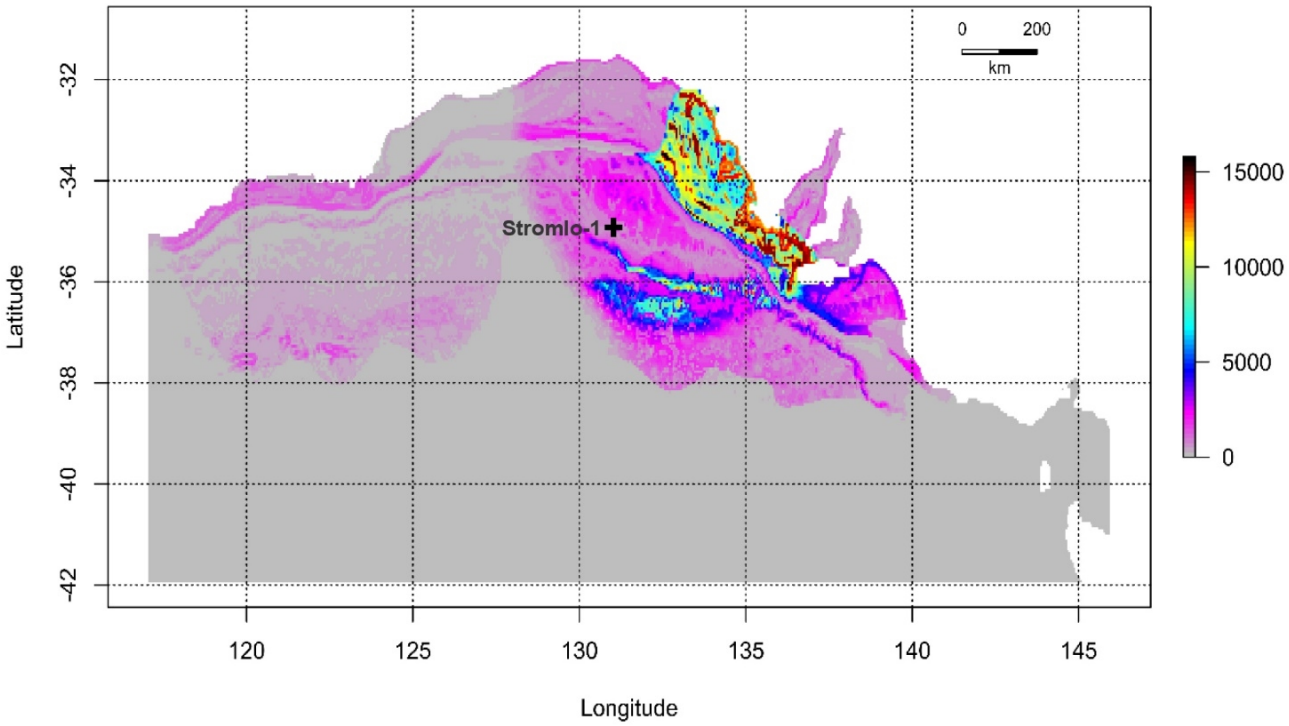
The National Conservation Values Atlas (Department of Environment and Energy 2015) identifies known foraging Biologically Important Areas for the flesh-footed shearwater approximately 500 km west north-west of the Impact Environment that May Be Affected (Figure 4.48, DSEWPaC 2011). The species may forage in the Impact Environment that May Be Affected.

Short-tailed shearwaters are listed as Migratory under the *Environment Protection and Biodiversity Conservation Act 1999*; however, the Protected Matters Search Tool report did not predict their presence in the Impact Environment that May Be Affected. The foraging Biologically Important Area is shown in the National Conservation Values Atlas (Department of Environment and Energy 2015) as overlapping the Impact Environment that May Be Affected and over the central and the western Great Australian Bight. Birds tracked from Kangaroo Island (Figure 4.50) ranged over open ocean and they are likely to be transient visitors to the offshore Impact Environment that May Be Affected. The Great Australian Bight Research Program modelling of foraging habitats of short-tailed shearwaters indicated they mostly forage over waters to the west and north-west of Kangaroo Island and along the west shore of the Eyre Peninsula but may venture across the central Great Australian Bight. The standardise probability map of occurrence is shown in Figure 4.51.



Source: Bailleul et al. (2017)

Figure 4.50 Shearwater tracked from Kangaroo Island



Source: Bailleul et al. (2017)

Figure 4.51 Standardised probability of occurrence (weighted by abundance) of short-tailed shearwaters across the Great Australian Bight

The southern fairy prion (*Pachyptila turtur subantarctica*) is listed as Vulnerable under the *Environment Protection and Biodiversity Conservation Act 1999* and managed under the Conservation Advice *Pachyptila turtur subantarctica* fairy prion (southern) (TSSC 2015e). The species breeds on two rock stacks off Macquarie Island. The Protected Matters search identified that southern fairy prion habitat may occur within the Impact Environment that May Be Affected. Individuals may infrequently fly over the Impact Environment that May Be Affected in transit or while foraging.

4.6.7.2 Shorebirds

No shorebird species were identified in the *Environment Protection and Biodiversity Conservation Act 1999* Protected Matters Search Tool report (Appendix 4-1). This is due to the Impact Environment that May Be Affected being over 350 km offshore; beyond the normal range of shorebirds while nesting, breeding and feeding.

4.6.7.3 Terrestrial birds

No terrestrial bird species listed as Threatened or Migratory under the *Environment Protection and Biodiversity Conservation Act 1999* were identified in the Protected Matters Search Tool report (Appendix 4-1). This is due to the Impact Environment that May Be Affected being over 350 km offshore; beyond the normal range of terrestrial birds.

4.7 Socio-economic environment

4.7.1 Commonwealth managed fisheries

The Australian Fisheries Management Authority manages all Commonwealth fisheries under the *Fisheries Management Act 1991*. Six Commonwealth-managed commercial fisheries intersect the Impact Environment that May Be Affected and the jurisdictional area of each fishery is shown in Figure 4.52. The areas fished and relative catch levels of all Commonwealth-managed fisheries in 2014–2016 are presented in Table 4.9 and Figure 4.53. Commonwealth-managed fisheries are restricted to shallower Great Australian Bight shelf waters; there is no current or expected fishing effort in or near the Impact Environment that May Be Affected. In the fishery maps below, the well location is indicated by the “+” symbol.

4.7.1.1 Western skipjack tuna fishery

The Western Skipjack Tuna Fishery overlaps with the Impact Environment that May Be Affected but has not been active since 2008–2009 and management arrangements for the fishery are under review. Fishing is unlikely to occur within the Impact Environment that May Be Affected.

4.7.1.2 Southern bluefin tuna fishery

Juvenile southern bluefin tuna are fished commercially by purse seine vessels in the continental shelf waters of the Great Australian Bight and a longline fishery for sub-adult and adult southern bluefin tuna operates from New South Wales to Tasmania during the winter and spring months. Each summer the purse seine fishery harvests about 98% of the national allocation of southern bluefin tuna, transporting them to inshore ranching operations based off Port Lincoln where juveniles are grown out over a period of 4–5 months for the export market.

The southern bluefin tuna is listed as conservation dependent on the basis that it is subject to a formal rebuilding strategy overseen by a regional Fisheries Management Organisation, the Commission for the Conservation of Southern Bluefin Tuna (CCSBT).

The Fishery Status Report 2019 (https://www.agriculture.gov.au/abares/research-topics/fisheries/fishery-status/southern-bluefin-tuna-fishery#233-economic-status) describes the management of the southern bluefin tuna take under the 1994 Convention for the Conservation of Southern Bluefin Tuna:

In 2011, the Commission for the Conservation of Southern Bluefin Tuna (CCSBT) adopted a management procedure (the Bali Procedure) that is analogous to a harvest strategy, and this has been used to set the global total allowable catch (TAC) since 2012. The global TAC is allocated to members and cooperating non-members as agreed by the CCSBT under the 2011 CCSBT Resolution on the Allocation of the Global Total Allowable Catch. The Australian Fisheries Management Authority (AFMA) sets the TAC for the SBTF in accordance with Australia's allocation. A new management procedure is currently being developed.

The Australian TAC is allocated primarily to holders of statutory fishing rights in the fishery through individual transferable quotas (ITQs). The ITQs give fishers flexibility to use input combinations that result in the most efficient operation. Theoretically, transferability of ITQs between fishers also allows the catch to be taken by the most efficient operators in the fishery, since quota is expected to gravitate to the most efficient operators. However, other factors are often considered by quota holders when deciding to lease or sell quota, sometimes resulting in quota not being allocated to the most efficient user. This may limit quota transaction activity between the purse-seine operators and longline operators in some years.

The geographic extent of the southern bluefin tuna fishery overlaps the Impact Environment that May Be Affected (Figure 4.54) however, fishing effort in 2018 for the Southern bluefin tuna fishery, indicates no fishing effort in the Impact Environment that May Be Affected or adjacent waters.

4.7.1.3 Western tuna and billfish fishery

Maps of fishing effort in 2016 for the Western Tuna and Billfish Fishery, which is entitled to fish in the Impact Environment that May Be Affected, are presented in Figure 4.53. Fishing is unlikely to occur within the Impact Environment that May Be Affected.

4.7.1.4 Southern and eastern scalefish and shark fishery

The Impact Environment that May Be Affected lies within area closures for certain sectors of the Southern and Eastern Scalefish and Shark Fishery (SESSF) which are expected to be in place until at least May 2021 (Table 4.9; Figure 4.54). Constraints on fishing methods in the Great Australian Bight Marine Park restrict other SESSF sectors from fishing within the part of the Impact Environment that May Be Affected included within the Great Australian Bight Marine Park area. Fishing is unlikely to occur within the Impact Environment that May Be Affected.

4.7.1.5 Small pelagic fishery

The Small Pelagic Fishery is entitled to fish within the Impact Environment that May Be Affected although fishing effort is concentrated around the shelf break and historic fishing effort shows the fishery is not operating within the Impact Environment that May Be Affected (Figure 4.54). Fishing is unlikely to occur within the Impact Environment that May Be Affected.

4.7.1.6 Southern squid jig fishery

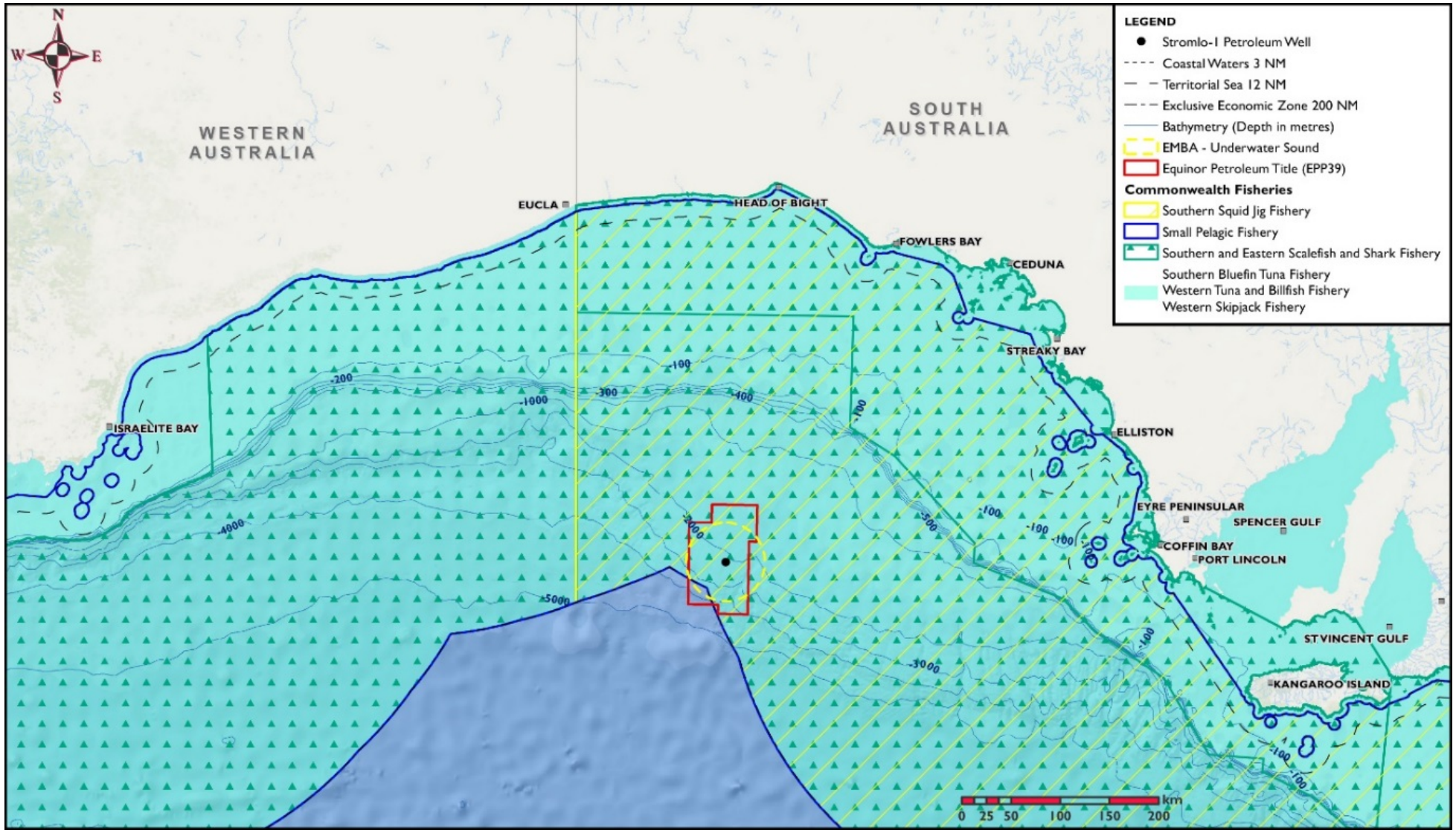
The Southern Squid Jig Fishery (SSJF) targets Gould's squid using squid jigs in waters across South Australia, Tasmania, New South Wales, Victoria and southern Queensland. The fishery operates at night in depths between 60–120 m. Squid are also caught in the Commonwealth Trawl Sector. Jurisdiction of the Southern Squid Jig Fishery overlaps, although fishing effort for the Southern Squid Jig Fishery confirms that there is no overlap between the active area of this fishery and the Impact Environment that May Be Affected, and the target species (Gould's squid) is not known to occur in areas as deep as the Impact Environment that May Be Affected (Australian Fisheries Management Authority 2017). Fishing is therefore unlikely to occur within the Impact Environment that May Be Affected.

Table 4.9 Commonwealth-managed fisheries which overlap the Impact Environment that May Be Affected

Fishery	Geographic extent	Target species	Season	Method	Catch and value	Fishery jurisdiction intersects the Impact EMBA?	Fishing occurs within the Impact EMBA?
Western Skipjack Tuna Fishery	All external Commonwealth and state waters out to 200 NM	Skipjack tuna	Year-round	Purse seine and pole	Not active	Yes	No – licence holders have not participated in the fishery since 2008-2009 and management arrangements for the fishery are under review
Southern Bluefin Tuna Fishery	All AFZ waters (3–200 nm). Most of the Australian catch is taken in the GAB, with small amounts taken off south-east Australia. Fishing in the GAB occurs around the 200 m isobath near King Island and Port Lincoln, towed alive to grow-out cages off Port Lincoln for South Australia state-managed aquaculture production (Section 4.8.2)	Juvenile southern bluefin tuna (2–4 years)	Fishing occurs from the start of Dec to the end of Mar. After feeding in the grow-out cages, fish are generally harvested in Aug	Purse seine (in the GAB), pole and line, longline and trolling (off south-east Australia)	5636 t valued at $35.8M in 2015–2016 (based on the catch prior to transfer to grow-out cages) 2017–18: gross value of production for the Southern Bluefin Tuna Fishery; combined value of catch at the point of transfer to farming pens and catch sold direct into global markets estimated as $39.7 million*. 8,102 tonnes valued at $123 million based on post-ranching exports**. ABSTIA estimates the value at $120-280 million (refer to ABSTIA consultation on 20 March 2019 in Section 3.3.1 of Appendix 3 1).	Yes	Unlikely – purse seine fishing is permitted in the Impact EMBA but historical catch and effort data show that it does not occur there
Western Tuna and Billfish Fishery	All AFZ waters (3–200 nm) from Cape York (Queensland) to the Victoria–South Australia border. In recent years, effort has concentrated off south-west Western Australia and South Australia	Yellowfin tuna, bigeye tuna, skipjack tuna, albacore, billfish	Year-round	Pole and line, purse seine, pelagic longline, troll, rod and reel, handline	320 t in 2015–2016. Value not reported	Yes	Unlikely – fishing is permitted and occurs similar distances off of south-west Western Australia, but historical fishing effort data shows that fishing has not occurred within the Impact EMBA for at least a decade
Southern and Eastern Scalefish and Shark Fishery (SESSF)	Comprises three main sectors, two of which intersect with the Impact EMBA. The sectors (and subsectors) that overlap with the Impact EMBA are described in the rows below	Multi-species (refer to SESSF rows below)	Year-round	Multi-gear (refer to SESSF rows below)	15,612 t valued at $68M in 2015–2016 (overall)	Yes (refer to SESSF rows below)	No (refer to SESSF rows below)
	SESSF – Gillnet, hook and trap sector (GHTS)						
	Comprises four subsectors: Scalefish Hook Subsector – extends from Sydney southwards around Tasmania to the South Australia–Western Australia border, excluding 80 NM from the coast offshore of New South Wales Shark Gillnet Subsector – extends from the New South Wales–Victoria border to the South Australia–Western Australia border Shark Hook Subsector – extends from the New South Wales–Victoria border to the South Australia–Western Australia border Trap Subsector – within the Shark Hook Subsector, in waters north of 42°20″S	Mixed fish species particularly pink ling, blue-eye trevalla, gummy shark	Year-round	Demersal gillnet, demersal longline, dropline, trotline, trap, purse seine	3596 t valued at $20.9M in 2015–2016	Restrictions are in place for fishing near the well other than by the Trap subsector Scalefish Hook Subsector: Partially – methods excluded the part of the Impact EMBA that lies within the GAB Marine Reserve area Shark Gillnet Subsector and Shark Hook Subsector: No – area closures prohibit fishing until at least May 2021	Trap Subsector: Unlikely – no to low historical effort and fishery landings, fishers set traps at depths between 300 m and 700 m Scalefish Hook Subsector: Unlikely – historical fishing effort shows that activity is limited to depths <800 m
	SESSF – Great Australian Bight trawl sector						
	Extends from Cape Jervis South Australia westward to Cape Leeuwin, Western Australia. Excludes shelf waters to the extreme east and west fished by Western Australia and South Australia managed trawlers	Deepwater flathead, Bight redfish and orange roughy	Year-round	Demersal otter trawl, limited midwater trawl	1794 t valued at $8.5M in 2015–2016	Partially – methods excluded the part of the Impact EMBA that lies within the GAB Marine Reserve area	Unlikely – fishing is permitted within part of the Impact EMBA but historical catch and effort data show that it does not occur there
Small Pelagic Fishery	AFZ waters extending from the Queensland–New South Wales border around southern Australia to Lancelin, Western Australia	Blue mackerel, jack mackerel, redbait, Australian sardine	Year-round	Purse seine and mid-water trawl	8038 t in 2016–2017. Value not reported	Yes	–
Southern Squid Jig Fishery	AFZ waters adjacent to South Australia, Tasmania, New South Wales, Victoria and southern Queensland up to Sandy Cape. The major fishing ground is continental shelf waters around Portland, Victoria	Gould's squid	Year-round, although fishing usually takes place from Jan to Jun	Jig	981 t valued at $2.57M in 2015–2016	Yes	Unlikely – historical fishing effort data shows that activity is limited to waters off south-eastern Australia and depths <200 m.

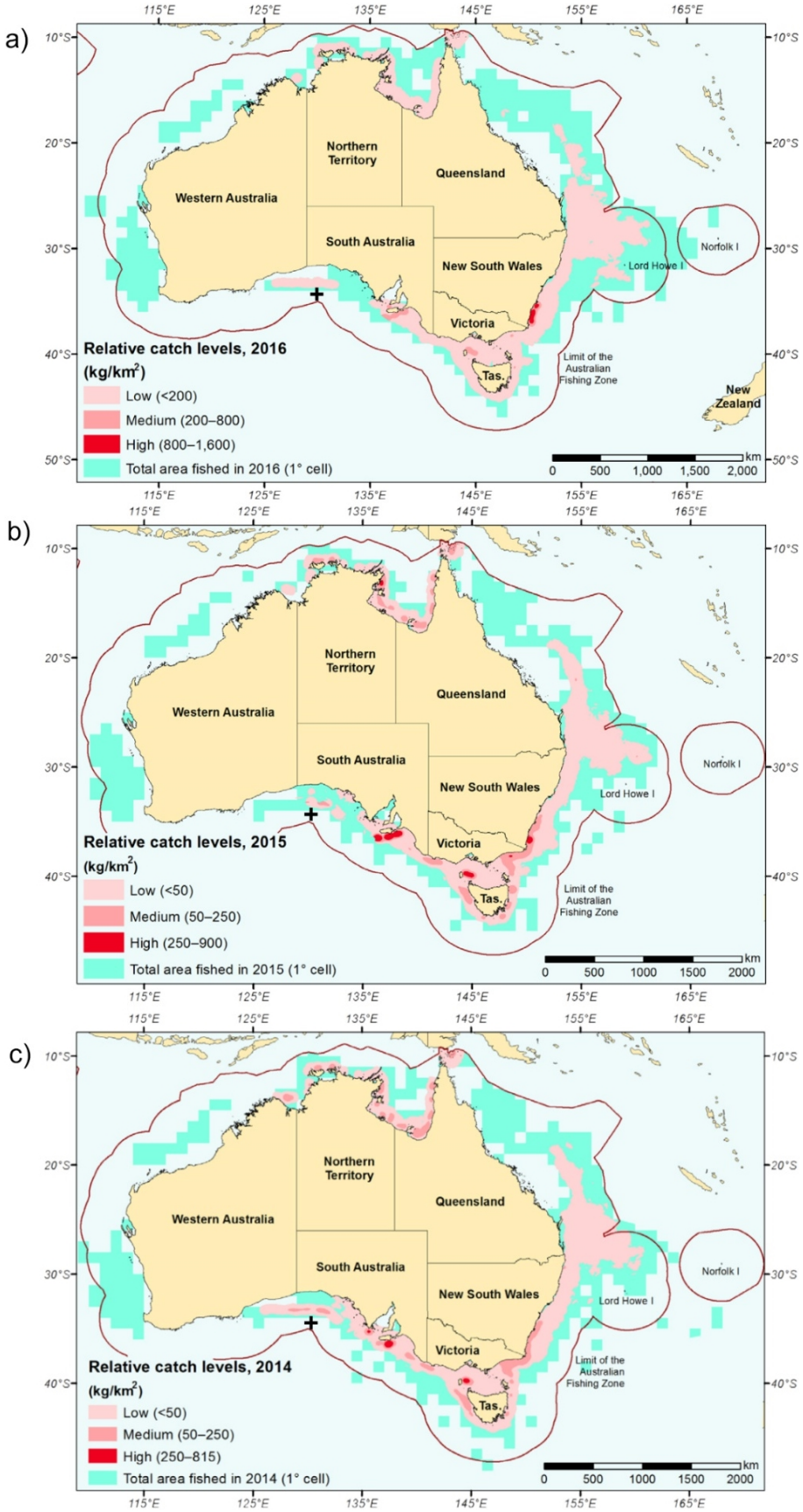
Information sourced from (Savage 2016) and (ABARES 2017)

*https://www.agriculture.gov.au/abares/research-topics/fisheries/fishery-status/southern-bluefin-tuna-fishery#233-economic-status
**http://www.agriculture.gov.au/SiteCollectionDocuments/abares/publications/fsr2018.pdf



Source: Australian Fisheries Management Authority (2017)

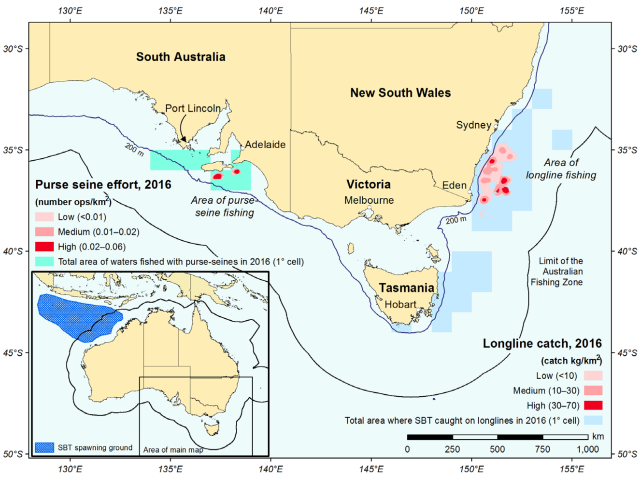
Figure 4.52 Commonwealth-managed fisheries in the Great Australian Bight



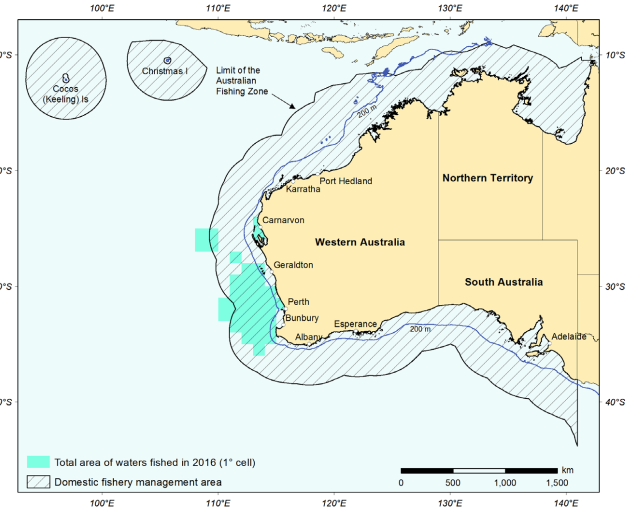
Source: Australian Fisheries Management Authority / ABARES Reports

Figure 4.53 Comparison of the area fished across all Commonwealth-managed fisheries in a) 2016, b) 2015 and c) 2014

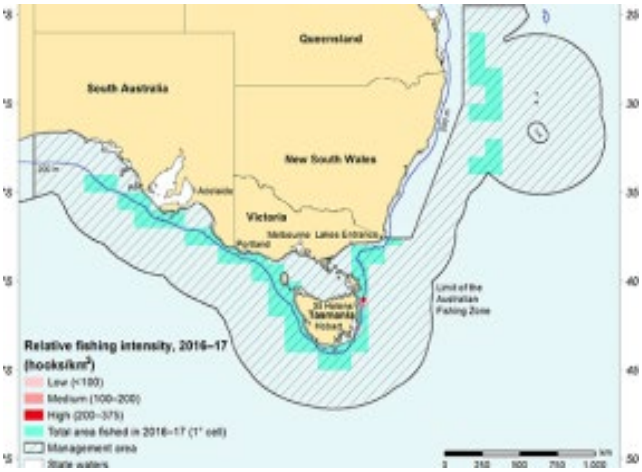
a) Southern Bluefin Tuna Fishery



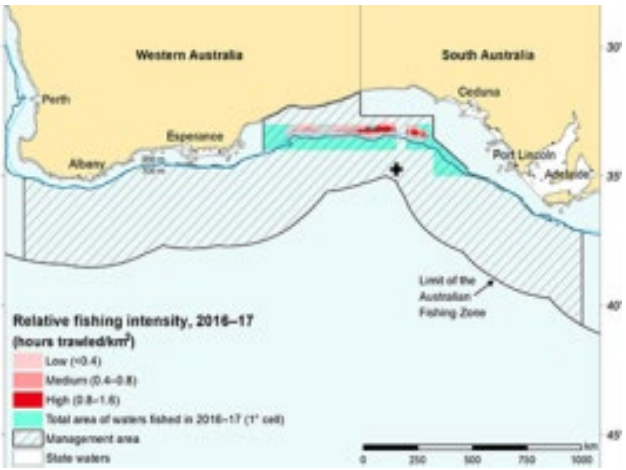
b) Western Tuna and Billfish Fishery



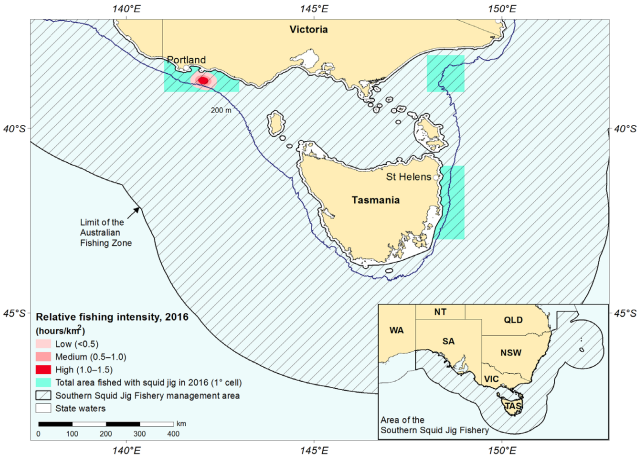
c) SESSF GHTS – Scalefish Hook Subsector



d) SESSF – Great Australian Bight Trawl Sector



e) Southern Squid Jig Fishery

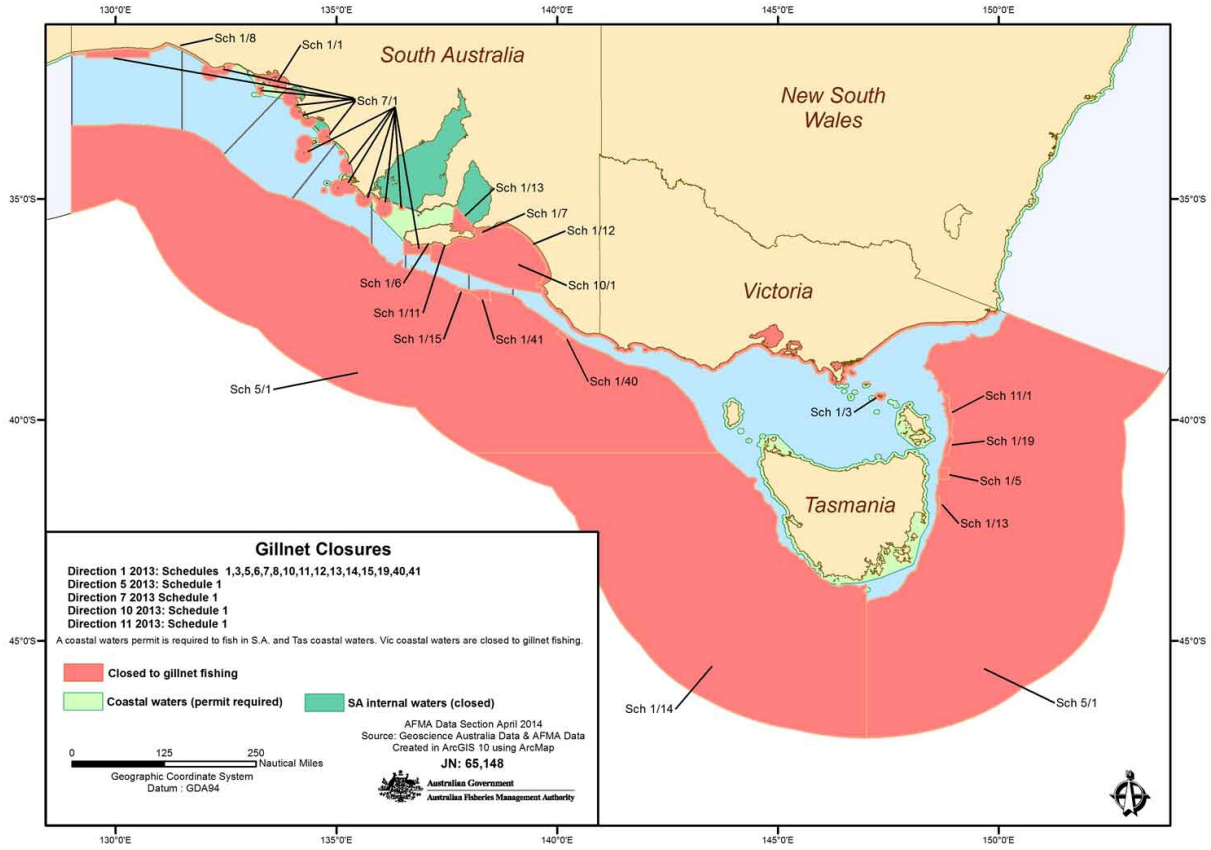


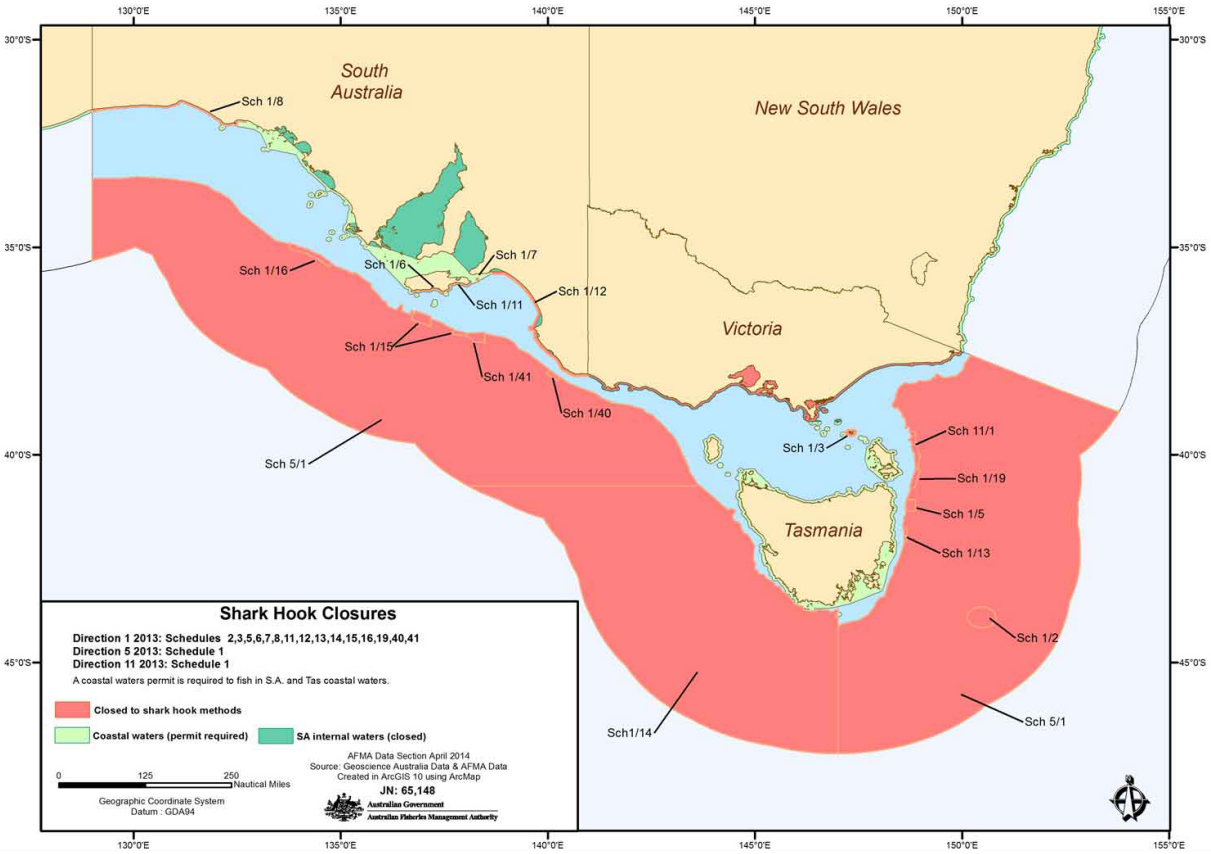
f) Small Pelagic Fishery

Stromlo-1 well location is indicated by the "+" symbol

Source: Australian Fisheries Management Authority / ABARES reports

Figure 4.54 Commonwealth-managed fisheries fishing effort/catch (2016) for fisheries overlapping the Impact Environment that May Be Affected





Stromlo-1 well location is indicated by the "+" symbol

Source: Australian Fisheries Management Authority 2017

Figure 4.55 Southern and Eastern Scalefish and Shark Fishery – gillnet, hook and trap sector area closures

4.7.2 South Australian state-managed fisheries

Department of Primary Industries and Regions manages commercial South Australian fisheries under the under the *Fisheries Management Act 2007* (South Australia) and aquaculture production under the *Aquaculture Act 2001* (South Australia). The gross value of production of South Australian commercial fisheries was $468 million in 2014–2015 (52% wild-catch, 48% aquaculture), accounting for 17% of Australia's total fisheries and aquaculture production. Key South Australian fisheries species include southern bluefin tuna (aquaculture), southern rock lobster (wild-catch), prawns (wild-catch), abalone (wild-catch) and oysters (aquaculture) (Savage 2016). None of the aquaculture areas overlap the Impact Environment that May Be Affected.

Three South Australian wild-catch commercial fisheries intersect with the Impact Environment that May Be Affected:

1. Miscellaneous fisheries.
2. Rock lobster fishery.
3. Sardine fishery.

The location and extent of these fisheries is shown in Figure 4.56. Information on the geographic extent, target species, season, method, catch, value and the likelihood of fishing occurring in the vicinity of the Impact Environment that May Be Affected is included in Table 4.10. The state fisheries extend to the limit of the Australian Fishing Zone (AFZ) which coincides with the offshore Exclusive Economic Zone boundary and overlap the Impact Environment that May Be Affected; however there no fishing effort for any fishery within the Impact Environment that May Be Affected.

4.7.3 Other state-managed fisheries

No Victorian, Tasmanian or Western Australian state-managed fisheries overlap the Impact Environment that May Be Affected. They are not considered further herein.

Table 4.10 South Australian state-managed fisheries in the Impact Environment that May Be Affected

Fishery	Geographic extent	Target species	Season	Method	Catch and value	Fishery jurisdiction intersects Impact EMBA?	Fishing in Impact EMBA?
Sardine (Pilchard) Fishery	All South Australia waters out to the edge of the 200 NM AFZ	Australian sardine. Majority of catch used as fodder for the SBT aquaculture sector	Year-round	Purse-seine nets	36,020 t in 2014–2015, valued at $22 million	Yes	No
Rock Lobster Fishery	All South Australia waters out to the edge of the 200 NM AFZ although fishing only occurs in depths <200 m. Fishery split into a Northern Zone and Southern Zone either side of the Murray River	Southern rock lobster	Nov to May for the Northern Zone. Oct to May for the Southern Zone	Pots	1622 t in 2014–2015, valued at $125M (321 t from the Northern Zone and 1238 t from the Southern Zone)	Yes	No
Miscellaneous fishery (specialised fisheries)	All South Australia waters out to the edge of the 200 NM AFZ	Sea urchins, scallop, native oyster, giant crab, Western Australian salmon, beach cast seagrass and macroalgae, Eyre golden perch, Welch's grunter and Barcoo grunter	Subject to a range of seasonal spatial closures	Multiple types of fishing gear	Information not available	Yes	No

Source: (Savage 2016), EconSearch (2016), (Fowler et al. 2015)

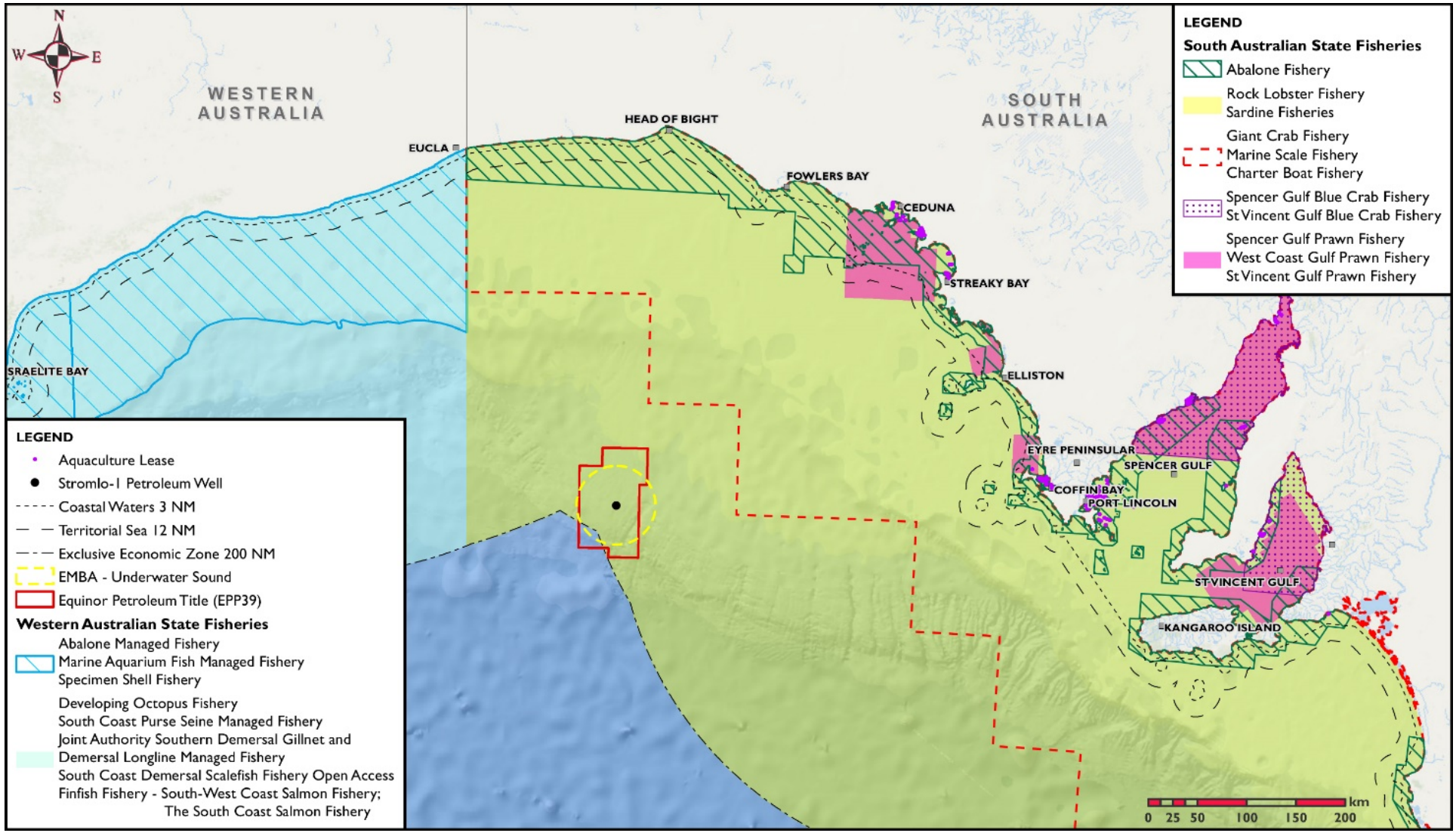


Figure 4.56 South Australian state-managed fisheries in the Great Australian Bight

4.7.4 Heritage places

No national heritage places listed as matters of national environmental significance under the *Environment Protection and Biodiversity Conservation Act 1999* are situated within the Impact Environment that May Be Affected. All national heritage places are over 350 km from the Impact Environment that May Be Affected.

Coastal Native Title claims often extend offshore but there are no sea claims currently lodged over the Impact Environment that May Be Affected.

The documented traditional Indigenous connection with the waters of the Great Australian Bight are those of the Mirning, Wirangu, Narangga, Kaurna and Ngarrindjeri (Appendix 7-3, Section 5.3.2) who identify as having Dreamtime connections to marine fauna such as whales and sea lions (totems) and/or responsibility over the "Sea Country" of the Great Australian Bight. The Dreaming is the worldview that structures Aboriginal culture and provides Aboriginal peoples with a framework for understanding and interpreting each person's place in the world. The Dreaming describes the strong physical, cultural and spiritual connection that Aboriginal Australians have to the land and all living beings.

The Mirning and Ngarrindjeri peoples described via the public comment process their connection to Land and Sea Country. A Ngarrindjeri Elder explained that whales are important to their culture and all of the fish, birds and animals, insects and plants are their 'ngartji' (our best friend). The Ngarrindjeri have a Dreamtime story of Kondoli the whale, which is a creation story of all the marine life, plants, animals and birds around the Ngarrindjeri Sea Country. They noted they have a responsibility and duty to be the voice for the whales, just like their ancestors for the past 60,000 years.

Representatives of the Mirning People explained via the public comment process that they "have cared for the land and sea for many of Dreamtime" and that the whales and waters of the Great Australian Bight are spiritual grounds. The Mirning People have the responsibility of caring for the 'munda and wanna mar' – their Land and Sea Country. The biological status of these totems is described in Section 4.6 (e.g. under cetaceans) and Appendix 7-3 (Section 5.3 Native Title and Heritage) and potential impacts to their spiritual connection is described in the impact and risk assessment sections of this EP.

A Mirning Elder spoke at Equinor's 2019 Annual General Meeting and highlighted his people have cared for the Bight for 120,000 years, that the Mirning came from the ocean in the whale Dreamtime, and the whales and the ocean were part of the Mirning family.

4.7.5 Historic shipwrecks

A search of the Australian National Shipwreck Database (Department of Environment and Energy 2017e) identified no historic shipwrecks within the Impact Environment that May Be Affected.

4.7.6 Tourism and recreation

No recreational or tourist activities are based within the vicinity of the permit area due to the remoteness and inaccessibility of the well location. Oceanic sailing craft may navigate through the area in transit across the Great Australian Bight.

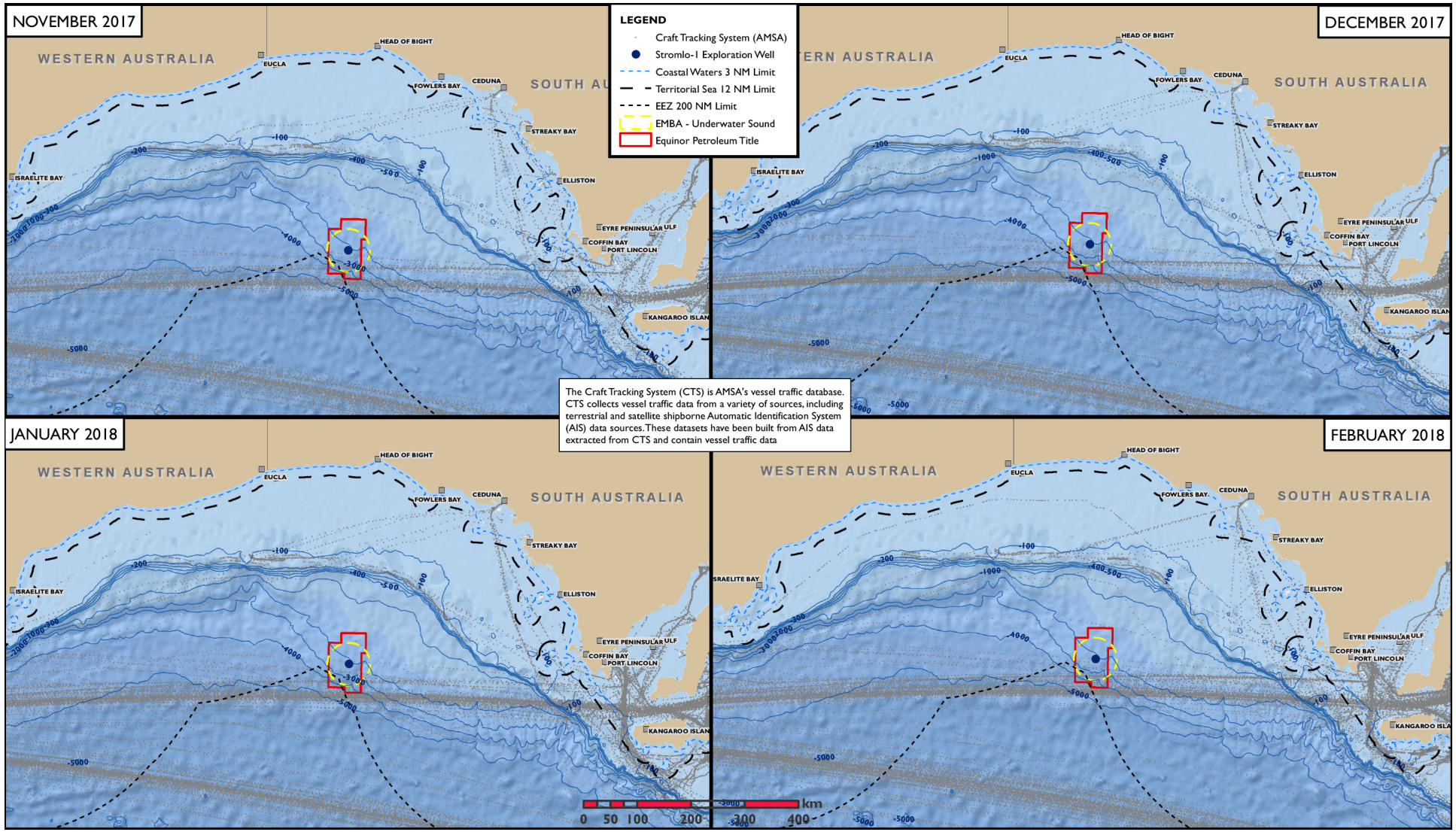
4.7.6.1 Recreational fishing

Recreational fishing is an important activity for many Australians and contributes substantially to the Australian economy (Evans, Bax & Smith 2017). At a national level, recreational fishing (including freshwater and marine) was estimated to have an annual economic value of $2.56 billion in 2013, based on an expenditure evaluation approach (Evans, Bax & Smith 2017).

Access to offshore areas in the Great Australian Bight is limited for small vessels (<8 m) due to the inaccessible coastline and exposed waters (Rogers et al. 2013). Some fishing occurs offshore for pelagic and deeper-water species, but recreational fishing is unlikely to occur within the Impact Environment that May Be Affected given that it is 400 km offshore from the closest population centres.

4.7.7 Shipping

Vessel traffic associated with commercial and recreational fishing, tourism, international shipping, and oil and gas operations is focussed around coastal ports with generally low traffic across the central the Great Australian Bight. Vessel traffic densities derived from automatic identification system (AIS) data provided by Australian Maritime Safety Authority for November 2017 to February 2018, show low density shipping traffic through the southern part of the Impact Environment that May Be Affected as ships travel between Adelaide and south-west Western Australia (Figure 4.57). The other main shipping route across the Great Australian Bight is approximately 200 km south of the Impact Environment that May Be Affected. This runs in a straight line between Albany and Cape Otway and is used by most vessels crossing the Great Australian Bight from Victoria.



Source: Australian Maritime Safety Authority (2107)

Figure 4.57 Shipping routes across the Great Australian Bight

4.7.8 Infrastructure and industry

4.7.8.1 Petroleum exploration and production

A search of the National Offshore Petroleum Titles Administrator (NOPTA 2017) National Offshore Petroleum Information Management System identified nine existing petroleum titles in the Bight Basin, all of which are Exploration Permits (Table 4.11). Another exploration permit adjacent exploration permit 39 in the Bight Basin was released for bidding in the 2018 Offshore Petroleum Exploration Acreage Release. Petroleum exploration permits, and wells previously drilled in the Great Australian Bight, in relation to the Stromlo well site and the Impact Environment that May Be Affected, are shown in Figure 4.1.

Table 4.11 Great Australian Bight petroleum titles

Petroleum titles	Titleholder
EPP39 and EPP40	Equinor Australia B.V.
EPP41 and EPP42	Bight Petroleum
EPP43	Murphy Australia EPP43 Oil and Santos Offshore
EPP44 and EPP45	Chevron Australia
EPP46	Karoon Gas
WA-517-P	Santos Offshore Pty Ltd and JX Nippon Oil and Gas Exploration (Australia)
S18-1	Pending 2019 award

4.7.9 Defence

No Department of Defence (DoD) restricted areas occur within the Impact Environment that May Be Affected.

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5.0 Impact and risk assessment methodology

5.1 Impact and risk management process

As required by Offshore Petroleum Greenhouse Gas Storage Environment Regulations 2009 10A(b), 10A(c), 13(5) and 13(6), Equinor Australia B.V. has undertaken an assessment of the planned environmental impacts and unplanned environmental risks associated with the petroleum activity. The impact and risk management process is shown in Figure 5.1. This process aligns with Equinor Australia B.V.'s Manage Risk process (RM100) (Equinor Australia B.V. 2016a) and International Standards Organization 31000:2018 Risk Management – Guidelines (International Standards Organization 2018). Figure 5.1 includes references to the major sections of this Environment Plan that cover the outcomes of each step in the process.

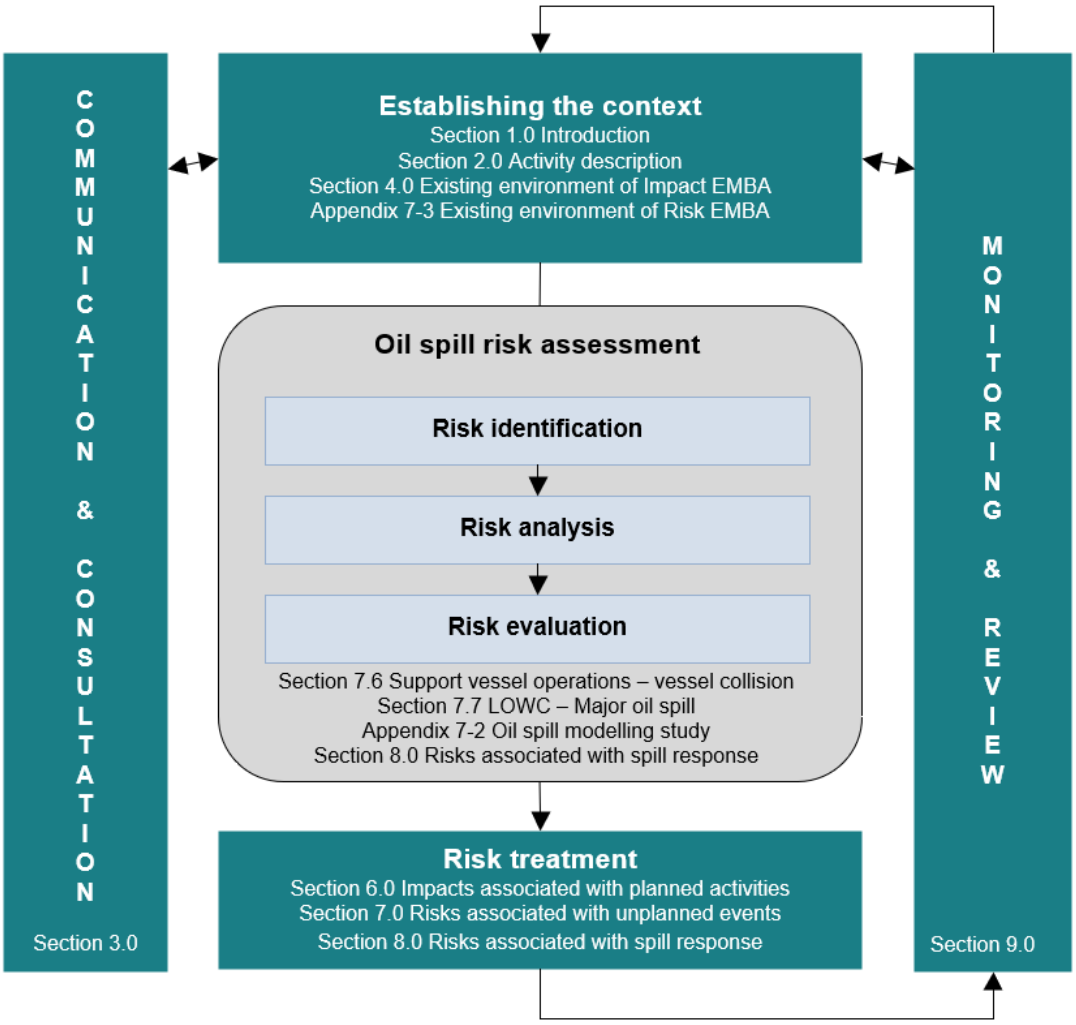


Figure 5.1 Impact and risk management process

Equinor Australia B.V. has followed the process in Figure 5.1, continually reviewing, analysing, evaluating and treating the impacts and risks, in response to new or updated information gained from, for example, further literature reviews, modelling and ongoing stakeholder feedback.

A series of Environmental Hazard Identification workshops were held to identify, analyse, evaluate and treat planned impacts and unplanned risks. The scope of the workshops was:

- Mobile Offshore Drilling Unit (MODU) Operations Environmental Hazard Identification
  - mobile offshore drilling unit and supply vessel planned impacts (physical interaction, presence and discharges)

- mobile offshore drilling unit and supply vessel unplanned impacts (unplanned overboard releases and vessel collision).
- Drilling Operations Environmental Hazard Identification
  - Drilling planned impacts (drilling muds, cement, cuttings and blowout preventer fluid)
  - Drilling unplanned discharges (unplanned overboard releases from riser disconnect and well blowout).
- Spill Response Environmental Hazard Identification
  - Impacts caused by spill response techniques (shoreline clean-up, dispersant application).

ALARP workshops have also been held to review additional or alternative control measures to apply.

5.2 Definitions

The definitions that were applied for the impact and risk management process (and that are used in Sections 5.0 to 8.0 of this EP) are in Table 5.1.

Table 5.1 Environmental impact and risk assessment definitions

Term	Definition
Acceptable level[1]	An "acceptable level" is the level of impact or risk to the environment that may be considered broadly acceptable with regard to all relevant considerations including, but not limited to: • principles of ecologically sustainable development (ESD) • legislative and other requirements (including laws, policies, standards, conventions) • internal context (e.g. consistent with titleholder policy, culture and company standards) • external context (the existing environment and stakeholder expectations).
As Low As Reasonably Practicable[1]	Reducing impacts and risks based on the concept of reasonable practicability; the weighing up of the magnitude of impact or risk reduction against the cost of that reduction. In this context, a titleholder is required to implement all available control measures where the cost is not grossly disproportionate to the environmental benefit gained from implementing the control measure.
As Low As Reasonably Practicable assessment[2]	Process by which Equinor Australia B.V. demonstrates, through reasoned and supported arguments, that there are no other practical measures that could reasonably be taken to reduce risks further.
Consequence[1,3]	The outcome of an event. The consequence considers extent, duration, severity and certainty of what would happen should prevention control measures fail. Equinor Australia B.V.'s Manage Risk process (RM100) uses the term "impact" rather than "consequence". The term consequence has been adopted for this EP.
Control measure[3,4]	A system, an item of equipment, a person or a procedure, that is used as a basis for managing environmental impacts and risks. Control measures maintain and/or modify risk.
Cost[5]	The sacrifice required for implementing a control measure, which includes an impost such as the money, time, and/or trouble required to implement a particular control measure. Environmental cost may also be a cost in some circumstances (e.g. dispersant use on an oil spill).
Environmental aspect[6]	Element of an organisation's activities or products or services that interacts or can interact with the environment.
Environmental impact[1,4]	Any change to the environment, whether adverse or beneficial, that wholly or partially results from an activity of a titleholder. Environmental impacts result from planned events as they are an inherent part of the activity.
Environmental performance outcome[4]	An environmental performance outcome is the measurable level of performance required for the management of an environmental aspect of an activity to ensure that environmental impacts and risks will be of an acceptable level.

Term	Definition
Environmental performance standard[4]	An environmental performance standard is a statement of the performance required of a control measure
Environmental risk[3]	Risk is a deviation (positive or negative) from what is expected and reflects the uncertainty associated with unexpected events. A combination of the consequences of an event occurring and the likelihood of its occurrence. Environmental risks result from unplanned events that may occur as a result of the activity.
Event[3]	The occurrence or change of a particular set of circumstances. Events can have one or more consequences and causes, can be expected or unexpected, and can be a risk source.
Likelihood[3]	The chance that an event may happen. Equinor Australia B.V.'s Manage Risk process (RM100) uses the term "probability" rather than "likelihood". Both terms have been adopted for this EP. The likelihood may be determined using via quantitative means (where data are available), or via qualitative means based on oil and gas industry performance.
Measurement criteria[1]	Measurement criteria define how environmental performance will be measured and are used to determine whether the outcomes have been met during the activity.
Predicted impact	The level of environmental impact associated with planned activities, with control measures implemented.
Probability	Probability is a measure of the likelihood that an event will occur and is represented as a number between 0 and 1. Probability has been applied in risk assessment of a LOWC.
Residual risk	The level of environmental risk associated with unplanned events after risk treatment (with control measures implemented).

Source of definitions:
1. National Offshore Petroleum Safety and Environmental Management Authority Guidance Note N04750-GN1344 Environment plan content requirements (Revision 3, April 2016) (National Offshore Petroleum Safety and Environmental Management Authority 2016).
2. National Offshore Petroleum Safety and Environmental Management Authority Guidance Note N-04300-GN0166 ALARP (Revision 6, June 2015) (National Offshore Petroleum Safety and Environmental Management Authority 2015).
3. International Standard 31000:2018 Risk Management – Guidelines (International Standards Organization 2018).
4. Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009.
5. National Offshore Petroleum Safety and Environmental Management Authority Guidance Note GL1721 Environment plan decision making (Revision 5, June 2018) (National Offshore Petroleum Safety and Environmental Management Authority 2018).
6. Australian/New Zealand Standard 14001:2016 Environmental management systems – Requirements with guidance for use (Standards Australia/ Standards New Zealand 2016).
7. Matters of national environmental significance – Significant impact guidelines 1.1 EPBC Act 1999 (Department of Environment and Energy 2013).

5.3 Communication and consultation

Communication and consultation with internal and external stakeholders has been undertaken throughout the development of this EP. The following stakeholders have been involved in identifying, reviewing and providing feedback on impacts and risks (see Section 3.0 for further details on consultation):

1. Equinor Australia B.V. and RPS Australia West Pty Ltd (RPS) environmental, health and safety, emergency response (including oil spill response), and project management personnel.
2. Equinor Australia B.V. geologists, reservoir engineers, petroleum engineers, sub-sea engineers, drilling supervisors.
3. Equinor Australia B.V. asset management.
4. Equinor Australia B.V. and RPS consultation and communications personnel, and commercial advisors.
5. Commonwealth and state government agencies and authorities with expertise in environmental management, maritime operations, emergency response, oil spill response and local community issues.
6. Relevant stakeholders (i.e. fishers and fisheries groups, community groups, titleholders and organisations such as Australian Marine Oil Spill Centre and Oil Spill Response Limited (OSRL).
7. Other stakeholders interested in the activity who provided relevant feedback on impacts and risks.

The impacts and risks identified have been communicated within Equinor Australia B.V. to ensure key personnel understand the impacts and risks, the basis on which decisions have been made and the reasons why certain control measures are required. As contractors are engaged for the activity, they will be made familiar with the impacts and risks associated with the activity, and importantly the control measures that must be implemented.

Relevant stakeholders have been engaged or consulted on environmental impacts and risks via multiple communication methods (i.e. meetings, letters, emails, etc). Invitation-to-comment requests with information packages attached have also been sent to stakeholders covering topics such as discharges, underwater noise, oil spill, etc. The public comment period will result in further stakeholder input on impacts and risks. Equinor Australia B.V. has considered (and responded to) all feedback received from stakeholders to date on the environmental impacts and risks assessed. Where Equinor Australia B.V. has deemed it necessary, the feedback has been incorporated into the risk management process in this EP. Further details on stakeholder feedback and our responses are in Section 3.0.

5.4 Establishing the context

The following information was considered when establishing the context for the impact and risk management process:

- description of the activity, including an understanding of the nature and scale compared to similar exploration drilling activities (Section 2.0), e.g. well design, equipment types, location, timing and duration, and vessel activities
- objections or claims of relevant persons (Section 3.0)
- understanding of the physical, biological and socio-economic receptors in the area (Section 4.0), e.g. environmental values and the sensitivity of the receiving environment with respect to species, habitat distribution and location of environmentally sensitive areas (breeding, migration, resting areas); and with respect to other marine users (fishers, vessel traffic)
- the nature and scale of potential effects on valued ecosystem components associated with each impact and risk were reflected in the level of detail presented in the descriptions of impacts and risks in Sections 6.0, 7.0 and 8.0. For example, through its natural properties, underwater sound has a greater impact range than other impacts and therefore was assessed in more detail – dedicated modelling and more detailed impact descriptions by key receptors. Similarly, the risk associated with a major oil spill resulting from a loss of well control, may adversely affect biota and other environmental values over a broad area and result in population level effects. This required dedicated modelling of a number of different scenarios, including mitigation measures, a dedicated As Low As Reasonably Practicable appendix and very detailed assessment of residual risks. Therefore, Section 7.7 is structured differently to other subsections, to accommodate the much more in-depth assessment and treatment.
- applicable state, Commonwealth and international legislation, standards and guidelines, including species action plans and marine reserves management plans (Appendix 1-1 and Section 4.0)
- Equinor Australia B.V.'s internal policies, standards and procedures (referred to in Sections 6.0 to 9.0).

5.5 Impact and risk assessment

5.5.1 Impact and risk criteria

Environmental impacts and risks associated with the activities proposed under this Environment Plan have been assessed via a process consistent with the ISO31000:2018 Risk Management – Guidelines (International Standards Organization 2018) and Equinor Australia B.V.'s risk management process (RM100 Manage Risk). Identified impacts and risks associated with the activity were evaluated using Equinor Australia B.V.'s risk matrix (Table 5.2). Likelihood definitions are shown in Table 5.2, environmental consequence definitions are shown in Table 5.2 and qualitative and quantitative risk levels Table 5.4.

The shaded regions in the risk matrix indicate the tolerability of risks as broadly described in Table 5.4. Environmental risks ranked as Low (green) or Medium (yellow) are considered ALARP. Risks ranked High (orange) or Very High (red) are undesirable or unacceptable and require additional control measures to reduce the level of risk.

Table 5.2 Quantitative and qualitative risk matrix

Consequence category	Probability							
	< 1×10^{-5}	1×10^{-5}–1×10^{-4}	1×10^{-4}–1×10^{-3}	1×10^{-3}–1×10^{-2}	1×10^{-2}–0.05	0.05–0.25	0.25–0.50	> 0.50
	Likelihood (relative frequency)							
	Unknown in the Industry	Very rare but known in the industry	Has rarely occurred in the industry	Has occurred several times in the industry	Has occurred in the region/ company	Has occurred more than once in the company	Has occurred locally/in facility	Occurs frequently
1-3								
4								
5								
6								
7								
8								
9								

Source: RM100, Manage Risk (Equinor Australia B.V. 2016a)

Table 5.3 Environmental consequence definitions

Category	Definitions
1-3	Very limited impacts (restitution time < 1 month) on populations (local), ecosystems or environmentally sensitive areas of local importance Local impact on individual organism level
4	Short term impacts (restitution time <1 year) on populations (local), ecosystems or environmentally sensitive areas of local importance
5	Short term impacts (restitution time <1 year) on populations (national or regional), ecosystems or environmentally sensitive areas of national or regional importance Medium term impacts (restitution time 1-3 years) on populations (local), ecosystems or environmentally sensitive areas of local importance
6	Medium term impacts (restitution time 1-3 years) on populations (national or regional), ecosystems or environmentally sensitive areas of national or regional importance Long term impacts (restitution time 3-10 years) on populations (local), ecosystems or environmentally sensitive areas of national importance
7	Large oil spill in populated area Long term impacts (restitution time 3-10 years) on populations (global or national), ecosystems or environmentally sensitive areas of international or national importance Very long or permanent impacts (restitution time > 10 years) on populations (regional), ecosystems or environmentally sensitive areas of regional importance
8	Large oil spill in densely populated area Very long or permanent impacts (restitution time >10 years) on populations (global or national), ecosystems or environmentally sensitive areas of international or national importance
9	Long lasting oil blow-out that cannot be killed with a relief well

Source: RM100 Manage Risk (Equinor Australia B.V. 2016a).

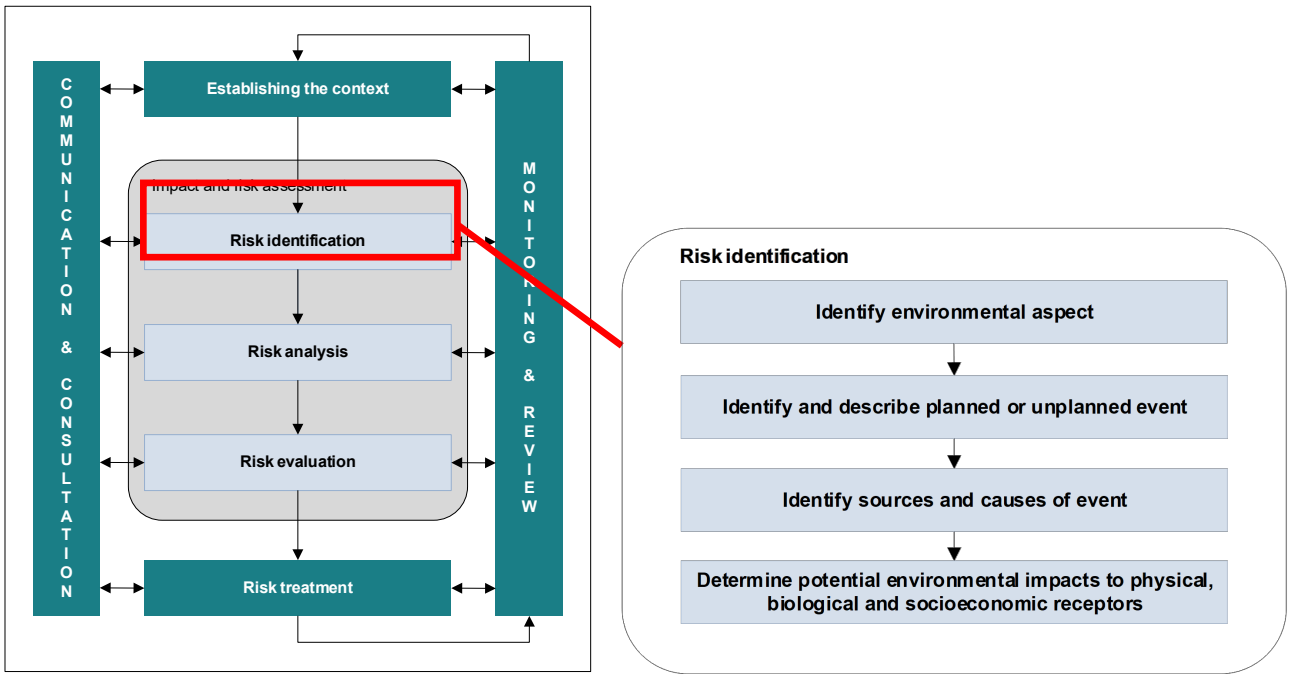
Table 5.4 Quantitative and qualitative risk levels

Risk level	Description
Very High	Risk is unacceptable (intolerable) and may require re-design of project and/or its parameters; additional control measures are required to be implemented (regardless of cost) to prevent or reduce the risk to As Low As Reasonably Practicable and an acceptable residual risk level Single red risks shall without delay be lifted from Business Area to corporate level risk register with appropriate description of the risk and its further handling, unless immediate risk reduction is implemented. The Corporate Executive Committee shall be informed if the risk has relevance for other Business Areas or Corporate Staff functions.
High	Risk is undesirable; Upper Management decision required to accept risks and proceed. Additional control measures are required to be considered and implemented, if the cost is not grossly disproportionate to the environmental benefit gained, to prevent or reduce the risk to As Low As Reasonably Practicable and an acceptable residual risk level. You shall lift the risk to the organizational level above with information on further handling, unless short term risk reduction is implemented. Medium term actions shall be identified based on the As Low As Reasonably Practicable principle or other applicable principles subject to relevant jurisdiction (s).
Medium	Risk that is acceptable (tolerable), providing that it can be shown that all practicable control measures have been implemented, with continual review of these measures and any potential new ones. The risk is deemed to be “As low as reasonably practical” and acceptable. Lifting not required. Medium term actions shall be identified based on the As Low As Reasonably Practicable principle or other applicable principles subject to relevant jurisdiction (s).
Low	No effects or those that are beneath levels of perception, within normal bounds of variation. Risk is low and acceptable without further reduction measures being required. Lifting not required. Actions generally not required.

Source: RM100 Manage Risk (Equinor Australia B.V. 2016a).

5.5.2 Impact and risk identification

Impact and risk identification involves identifying environmental aspects, planned and unplanned events, sources and causes of events, the potential impacts and risks, affected receptors and potentially affected stakeholders. The information used to establish the context of the assessment (Section 5.4) is the basis for impact and risk identification.



5.5.2.1 Environmental aspects

Environmental aspects relevant to planned activities, unplanned events were identified using professional judgement and following industry practice, as listed in Table 5.5.

5.5.2.2 Planned and unplanned events

The various planned activities and unplanned events relevant to the environmental aspects were identified and described on the basis of the activity description (Section 2.0) for planned activities and on the basis of known incidents, accidents or accident potentials for unplanned events.

5.5.2.3 Sources and causes of events

Anticipated causes of unplanned events were identified on the same basis as the events were identified, to assist in the development of preventative control measures.

5.5.2.4 Impacts and risks, affected receptors and potentially affected persons.

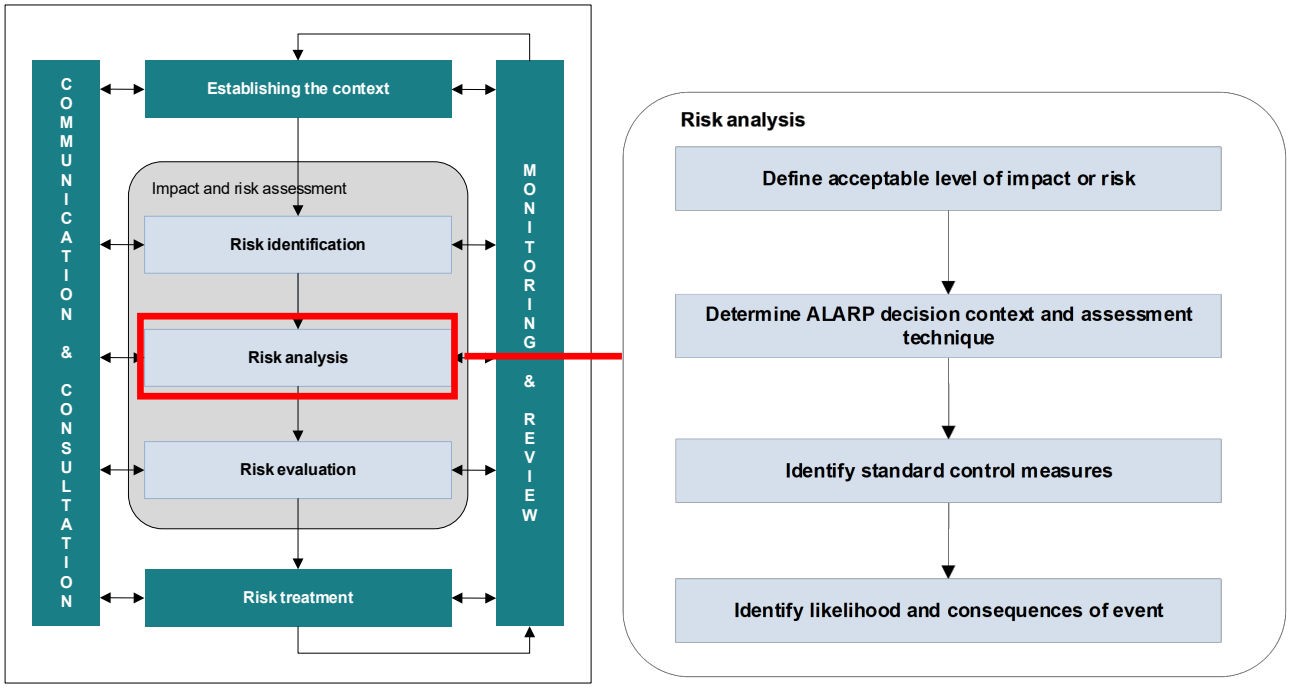
The spatial and temporal characteristics of the impacts and risk were used to predict potential effects on the environmental receptors, including socio-economic receptors. This was guided also by inputs from relevant persons during consultation.

5.5.3 Impact and risk analysis

Identified impacts and risks were analysed, taking into consideration the extent, duration, severity of consequences and the certainty around understanding of the identified impact or risk. Analysis first involved defining criteria for an acceptable level of impact or risk and determining the As Low As Reasonably Practicable decision context and assessment technique. Following that, the consequence was determined using the environmental consequence definitions (Table 5.3) assuming standard control measures are in place.

For the impacts from each planned activity, the likelihood was assumed to be certain (probability of 1) as the predicted impact will occur. For risks from unplanned events, the likelihood was determined assuming that control measures designed to prevent the incident are in place. Likelihoods for most risks were based on relative frequency judgement; how many times the event had occurred previously; whereas for oil spill risks where there are data available, probabilities were used.

Consistent with National Offshore Petroleum Safety and Environmental Management Authority's guideline on Environment Plan decision-making, we use the terms "predicted impacts" and "residual risks" herein to describe the level of impact or risk remaining after risk treatment (the control measures are implemented, including those identified through the As Low As Reasonably Practicable process).



5.5.3.1 Defining an acceptable level of impact or risk

OPGGS(E) Sub-regulation 10A(c) requires that an Environment Plan demonstrate that the environmental impacts and risks of the activity will be of an acceptable level. An "acceptable level" is the level of impact or risk to the environment that may be considered broadly acceptable with regard to all relevant considerations including, but not limited to (National Offshore Petroleum Safety and Environmental Management Authority 2016):

- relevant principles of ecologically sustainable development
- legislative and other requirements (including laws, policies, standards, conventions)
- internal context (consistent with titleholder policy, culture and company standards)
- external context (the existing environment and stakeholder expectations).

As part of the impact and risk analysis process, we set criteria for acceptable levels of each impact and risk identified. Following risk evaluation and treatment, when impacts and risks were considered As Low As Reasonably Practicable, the predicted impacts and risks were compared against the acceptable level criteria. If the criteria were met, the environmental impacts and risks of the activity were considered acceptable.

Our approach to assessing and mitigating environmental impacts and risks means this Environment Plan is consistent with the core objectives and principles of Ecologically Sustainable Development as defined in the National Strategy for Ecologically Sustainable Development (1992), which are relevant to petroleum exploration activities. Equinor Australia B.V. considers the residual risks and predicted impact described herein are acceptable in terms of following the objectives and principles of Ecologically Sustainable Development because their management and mitigation have followed a process consistent with relevant parts of the national strategy for Ecologically Sustainable Development.

The relevant core objective of Australia's Ecologically Sustainable Development strategy which has been incorporated into this impact and risk assessment process, is:

- to protect biological diversity and maintain essential ecological processes and life-support systems.

Equinor Australia B.V. has followed the As Low As Reasonably Practicable process to reduce impacts and risks as far as practicable with an objective to protect biodiversity and ecological function; these are central tenets of the RM100 risk management process.

The relevant principles of Australia's Ecologically Sustainable Development strategy that have been incorporated into this impact and risk assessment process, are:

- decision-making processes should effectively integrate both long and short-term economic, environmental, social and equity considerations
- where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation
- decisions and actions should provide for broad community involvement on issues which affect them.

The risk management process is consistent with these principles because it is based on consequence categories reflecting and appropriately weighting short-term vs long-term effects; where there is the potential to significantly affect the biological diversity and ecological integrity and/or the operations result in serious or irreversible environmental damage, a conservative approach has been applied; extensive effort has been taken to reduce scientific uncertainty (Great Australian Bight Research Program); and the Environment Plan is being published for broad community engagement.

The following were considered when setting criteria for levels of acceptability against which the impacts and risk described, analysed and treated in Sections 6.0, 7.0 and 8.0, were compared:

- legislative and other requirements – control measures are consistent with state, Commonwealth and international laws, widely adopted industry standards and best practices, and requirements identified in relevant state and Commonwealth species recovery plans or approved conservation advices
- internal context – Equinor Australia B.V. policies, standards and procedures have been identified and implemented
- external context – societal values and relevant stakeholder objections and claims have been considered and addressed.

5.5.3.2 As Low As Reasonably Practicable decision context

OPGGS(E) Sub-regulation 10A(b) requires that an Environment Plan demonstrate that the environmental impacts and risks of the activity are reduced to As Low As Reasonably Practicable. The United Kingdom (UK) offshore oil and gas industry has developed a framework to assist risk-related decision making ("Oil and Gas UK", formerly UKOOA 2014). This framework and Equinor Australia B.V.'s ALARP Principles guideline (GL0139) (Equinor Australia B.V. 2016b) were followed as part of the impact and risk assessment process. The As Low As Reasonably Practicable assessment process is covered in Section 5.6 (Risk treatment).

The framework takes the form of three different decision contexts (A, B and C). The decision type is selected based on an informed discussion around the uncertainty of the risk, and it is agreed by workshop participants and documented in worksheets. Factors including activity type, risk and uncertainty, and stakeholder influence are considered in determining the decision context. The decision contexts are shown in Figure 5.2 defined as follows:

- Context A decisions –where the risk is relatively well understood, the potential impacts are low, activities are well practiced and there is no significant stakeholder interest. It is noted however, that where good practice may not be sufficiently well-defined, additional assessment may be required
- Context B decisions – where there is greater uncertainty or complexity around the activity and/or risk, the potential impact is moderate, and the risk is generating a number of concerns from stakeholders. In this instance established good practice is not considered sufficient, and further assessment is required to support the decision and ensure that the risk is As Low As Reasonably Practicable.
- Context C decisions – typically involve sufficient complexity, high potential impact, uncertainty or stakeholder interest to require a precautionary approach. In this case, relevant good practice will still have to be met, additional assessment will be required, and the precautionary approach applied for those controls that only have a marginal cost benefit.

	Factor	A	B	C
Decision Context	Type of Activity	Nothing new or unusual Represents normal business Well understood activity Good practice well-defined	New to the organisation or geographical area Infrequent or non-standard activity Good practice not well defined or met by more than one option	New and unproven invention, design, development or application Prototype or first use No established good practice for whole activity
Decision Context	Risk & Uncertainty	Risks are well understood Uncertainty is minimal	Risk amenable to assessment using well-established data and methods Some uncertainty	Significant uncertainty in risk Data or assessment methodologies unproven No consensus amongst subject matter experts
Decision Context	Stakeholder Influence	No conflict with Company values No partner interest No significant media interest	No conflict with company values Some partner interest Some persons may object May attract local media attention	Potential conflict with company values Significant partner interest Pressure groups likely to object Likelihood of adverse attention from national or international media
Assessment Technique	Good Practice			
Assessment Technique	Engineering Risk Assessment			
Assessment Technique	Precautionary Approach			

Figure 5.2 Oil and Gas UK decision support framework

5.5.3.3 As Low As Reasonably Practicable assessment technique

The chevrons in Figure 5.2 show the assessment techniques required to demonstrate that potential impacts and risks are As Low As Reasonably Practicable. The decision context provides a means to assess the relative importance of adherence to, and reliance on, Good Practice, Engineering Risk Assessment and Precautionary Approach when making decisions either to accept risk rankings or to continue to treat risks. The assessment techniques are defined as followed:

Good practice

The risk assessment considers compliance with requirements of the relevant Codes or Standards. The management of risk was benchmarked against good practice measures based on the industry experience, knowledge and judgement of the As Low As Reasonably Practicable study team and determined to be "Good Practice" or not. Guidance on current industry practices was also taken from reference cases provided by National Offshore Petroleum Safety and Environmental Management Authority and National Energy Resources Australia (NERA, https://referencecases.nera.org.au/).

Engineering risk assessment

The engineering risk assessment considers the recognition of what is good practice, and an understanding and application of sound engineering and scientific principles and methods. This includes engineering analysis, consequence modelling, deterministic cases for hazard management as well as competent judgement and interpretation of these and other information. Control measures were introduced where they may significantly reduce the risk.

Precautionary approach

Where extensive scientific knowledge is lacking and there is a risk of a high consequence, the risk assessment takes a more conservative approach, including consideration of the views, concerns and perceptions of stakeholders.

The Environmental Hazard Identification workshops examined the environmental impacts and risks with reference to the "decision context" and "assessment technique" for the identified aspects. The decision context and assessment technique to be applied to ensure the residual impacts and risks have been reduced to As Low As Reasonably Practicable, are summarised in Table 5.5.

Table 5.5 As Low As Reasonably Practicable assessment techniques

#	Environmental aspect	Decision context	Assessment technique
A. Impacts associated with planned activities (Section 6.0)			
A.1	Physical interaction – displacement of other marine users	A	Good practice
A.2	Physical presence – seabed disturbance	A	Good practice
A.3	Underwater sound	A	Good practice
A.4	Light emissions	A	Good practice
A.5	Atmospheric emissions	A	Good practice
A.6	Planned discharges – drilling fluids and cuttings	B	Engineering risk assessment
A.7	Planned discharges – cement	B	Engineering risk assessment
A.8	Planned discharges – cooling and brine water	A	Good practice
A.9	Planned discharges – sewage, grey water and putrescible	A	Good practice
A.10	Planned discharges – deck and bilge waters	A	Good practice
A.11	Planned discharges – BOP fluid	A	Good practice
B. Risks associated with unplanned events (Section 7.0)			
B.1	Physical presence – introduction of a marine pest	A	Good practice
B.2	Physical interaction – collision with marine fauna	A	Good practice
B.3	Loss of solid waste materials overboard	A	Good practice
B.4	Loss of containment of hazardous materials	A	Good practice
B.5	Vessel collision fuel spill	A	Good practice
B.6	Loss of well control and Level 3 oil spill	C	Precautionary approach
C. Risks associated with spill response (Section 8.0)			
C.1	Source control -seabed disturbance, physical interaction and presence	B	Engineering risk assessment
C.2	Dispersant application – effects on oil plume	C	Precautionary approach
C.3	Containment and recovery – minor spills, fauna entanglement	A	Good practice
C.4	Shoreline protection/clean-up – secondary contamination, physical effects	A	Good practice
C.5	Oiled wildlife response – behavioural disturbance, fauna injury	A	Good practice
C.6	Monitoring – seabed disturbance, biota disturbance and injury	A	Good practice

5.5.3.4 Standard control measures

Equinor Australia B.V. identified appropriate, standard control measures by applying the hierarchy of controls. The effectiveness of control measures was considered when determining the likelihood of events with control measures in place (i.e. factors such as functionality, availability, reliability, survivability, independence and compatibility of control measures). (Table 5.6).

Existing control measures were identified for each impact and risk taking into consideration the context of the activity and the effectiveness of the controls in reducing risk. Measures were drawn from a range of sources, including (but not limited to):

- Equinor Australia B.V.'s environmental management system and associated policies, standards and procedures
- relevant persons consultation
- mobile offshore drilling unit/vessel plans and procedures
- industry practices, codes and standards
- applicable state, Commonwealth and international legislation, standards and guidelines.

The effectiveness of control measures was considered when determining the likelihood of events with control measures in place (i.e. factors such as functionality, availability, reliability, survivability, independence and compatibility of control measures).

Table 5.6 Hierarchy of control measures

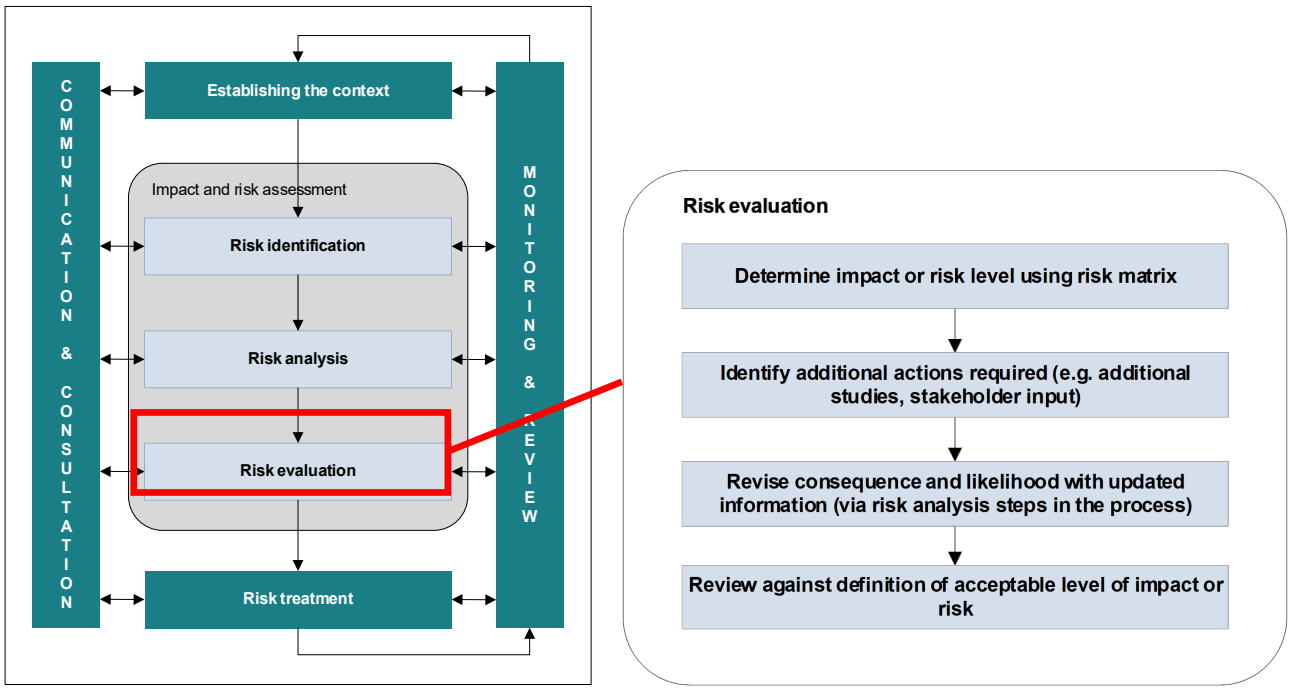
Control type	Description
Eliminate	Completely remove the hazard
Substitute	Replace the material or process with a less hazardous one
Engineering/isolation	Provide engineering solutions to control the hazard / isolate the hazard from the environment
Administration	Use administrative procedures to control the hazard
Protective	Use appropriate protective equipment, (including emergency response and contingency planning), when other control measures are not practical or have not totally removed the hazard

5.5.4 Impact and risk evaluation

The evaluation of impacts and risks involved comparing the results of the risk analysis with the risk matrix to determine the risk level. Depending on the risk level and considering the As Low As Reasonably Practicable decision context and assessment technique, further actions were considered. Further action primarily included undertaking further analysis and reviews to better understand the impact or risk (e.g. additional modelling, literature reviews, data assessments, engineering assessments), considering additional risk treatment options and conducting further consultation with stakeholders. When further actions were completed, the impact and risk analysis part of the process was revisited (with the updated studies, stakeholder input or additional controls).

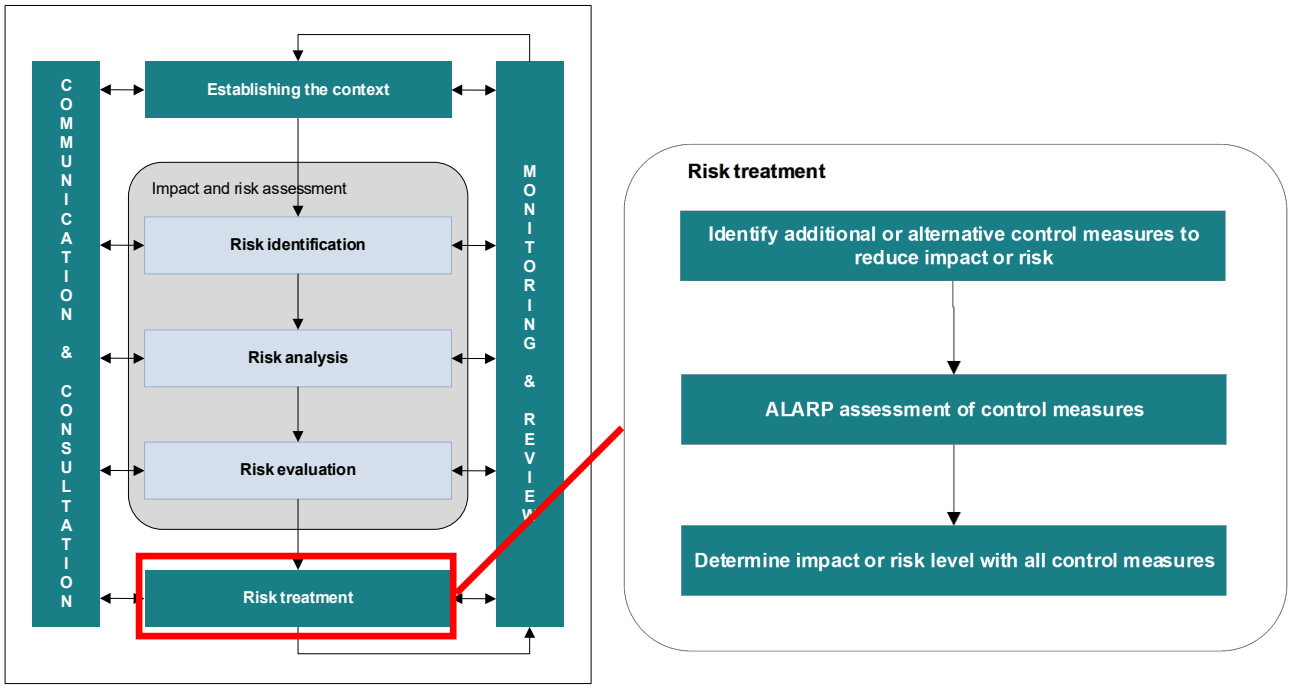
The evaluation of impacts and risks included consideration of the existing control measures in place and an evaluation to determine if an impact or risk requires further treatment (e.g. elimination, prevention, reduction and mitigation) to meet the defined acceptable level.

Impact and risk evaluation was completed with an assessment against the defined level of acceptable impact or risk criteria that were set earlier in the process. If the acceptable level criteria were not met, the impact and risk management process was continued until Equinor Australia B.V. could demonstrate the criteria had been met.



5.6 Risk treatment

Risk treatment involved determining whether an impact or risk requires further treatment to meet the definition of acceptable level of impact or risk, to mitigate any potentially undesirable consequence, and to reach As Low As Reasonably Practicable. Additional or alternative control measures were proposed and evaluated using As Low As Reasonably Practicable principles. If an adopted control measure had the potential to result in additional or modified impacts and risks, those impacts, and risks were also assessed via the same process.



5.6.1 Control measures

Once the predicted impact or residual risk level was determined, additional control measures were identified by applying the hierarchy of controls (Table 5.6). The effectiveness of control measures was considered when determining the likelihood of events with control measures in place, i.e. factors such as functionality, availability, reliability, survivability, independence and compatibility of control measures, were considered.

5.6.2 Potential for Significant Impact

Following the identification of additional or alternative control measures, the consequence of the impacts and risks were reviewed to identify any potentially Significant Impacts to Matters of National Environmental Significance. Consequence values of 4 (Moderate) to 9 (Extreme) according to Equinor Australia B.V.'s environmental consequence definitions were deemed to indicate a potentially Significant Impact. This is considered conservative since it represents any impacts and risks that are not rated as having a Minor consequence (rating of 1–3).

If a potentially Significant Impact was identified, a review was undertaken to determine if it was likely or unlikely (based on the information from the impact and risk analysis, evaluation and treatment steps in the process). This provided an additional prompt to review the impact and risk assessment part of the process and identify if further analysis, evaluation or treatment was required to demonstrate that Significant Impact to matters of national environmental significance was unlikely.

5.6.3 As Low As Reasonably Practicable

OPGGS(E) Sub-regulation 10A(b) requires that an Environment Plan demonstrate that the impacts and risks of the activity will be reduced to As Low As Reasonably Practicable. Reducing impacts and risks to As Low As Reasonably Practicable centres on the construct of reasonable practicability; the weighing up of the magnitude of the impact or risk against the cost of reduction. Additional control measures were considered reasonably practicable if the costs to implement them are not grossly disproportionate to the reduction in risk achieved.

In accordance with Equinor Australia B.V.'s risk matrix (Table 5.2), a predicted environmental impact or risk was demonstrated to be As Low As Reasonably Practicable when:

- Low risk – all practical measures have been taken and no further reduction measures are considered without implementation costs being grossly disproportionate to the risk reduction achieved
- Medium risks – all practicable control measures have been implemented, with continual review of these measures and any potential new ones
- High risks – good industry practice has been applied and additional control measures have been considered and implemented to reduce the risk. This may require assessment of Equinor Australia B.V. and industry benchmarking, review of local and international codes and standards, consultation with stakeholders etc.
- Very High risks – alternatives and additional control measures have been considered and implemented. Very High risks are lifted from the business area to the corporate level risk register to ensure risk reduction is implemented.

To evaluate and rate the estimated cost impact of the additional or alternative management measures the cost/benefit evaluation was based on the:

- cost of the control or mitigation measure as a percentage of the total drilling campaign project cost (over 10%, between 5–10%, 2–5%, 0.5–2% and less than 0.5%), based on professional judgement
- environmental benefit: derived from how much the control or mitigation measure will reduce the adverse environmental effect, reduce the amount of oil released (reduction in number of days of discharge) or reduce the adverse effects of the spill (reduction in shoreline loading or reduction in amount of oil surfacing.

The environmental benefit criteria are defined in Table 5.7.

Table 5.7 Environmental benefit scale

Scale	Environmental benefit (quantitative percentages applies for oil spill to sea)
Negligible	Control measure reduces the adverse environmental effect by <1%
Minor	Control measure reduces the adverse environmental effect by 1–3%
Moderate	Control measure reduces the adverse environmental effect by 3–10%
Significant	Control measure reduces the adverse environmental effect by 10–50%
Major	Control measure reduces the adverse environmental effect by >50%

The estimated cost criterion was qualitatively assessed by Equinor Australia B.V. personnel familiar with the practicalities of implementing the management measures. The expected net benefit of the management alternative in reducing the likelihood or the consequence, beyond that achieved by the previously identified management measures was evaluated. Personnel assessed whether each additional control measure would result in a real reduction of risk. If a control measure reduced the potential risk significantly, but did not change the risk level, it was still considered as a net benefit and contribution to reaching As Low As Reasonably Practicable.

The potential for each new control to generate negative environmental impacts, health and safety issues or operational hazards was also considered. Where effects were considered to negate the potential benefit partially or fully, the control measure was not adopted, as it had no net benefit and contribution to reaching As Low As Reasonably Practicable.

Where the cost of implementation was considered grossly disproportionate to the potential environmental, socio-economic or reputational benefit of a control, the control was not adopted. As such, the controls presented in the risk assessment constitute only those that were deemed to result in a reasonable, practicable reduction in environmental harm while achieving the objectives of the activity. The control measures considered as part of As Low As Reasonably Practicable assessment are documented in Sections 6.0 to 8.0. Additional or alternative control measures evaluated for the oil spill risk assessment are in Appendix 7-4.

5.7 Monitoring and review

It is imperative that once environmental impacts and risks have been identified, assessed and reduced to As Low As Reasonably Practicable and to an acceptable level, that performance monitoring and review arrangements are in place to ensure the adopted control measures are implemented and effective.

Regulation 4 of the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009 defines environmental performance as the performance of a titleholder in relation to the environmental performance outcomes and standards, defined as follows:

- an environmental performance outcome is the measurable level of performance required for the management of an environmental aspect of an activity to ensure that environmental impacts and risks will be of an acceptable level
- an environmental performance standard is a statement of the performance required of a control measure
- measurement criteria define how environmental performance standards will be measured and are used to determine whether the outcomes have been met during the activity. Measurement criteria are preferably quantitative, however where no practicable quantitative target exists, qualitative targets are set and used to measure whether an outcome or standard has been met.

The environmental performance outcomes, performance standards and measurement criteria that have been set require review and external reporting under the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009.

Review of the impacts and risks assessed has been undertaken throughout the environmental impact and risk management process (Figure 5.1). This included planning, gathering and analysing information, recording results and providing feedback. Performance monitoring and review of impacts and risks will continue for the duration of the activity if impacts and risks change, or new impacts and risks are identified. If the outcomes of monitoring and review prompt changes to this EP, or Equinor Australia B.V.'s internal management system, the changes will be undertaken via Equinor Australia B.V.'s management of change process. Monitoring and review, reporting and management of change is described in Section 9.0 of this EP.

6.0 Impacts associated with planned activities

An “environmental impact” is defined as any adverse or beneficial change to the environment that results from a planned activity. Environmental impacts are a fundamental part of undertaking specific activities due to the unavoidable nature of the operations. The acceptability of such impacts is assessed in terms of the consequences or level of environmental effects, as their likelihood is considered certain (they are necessary aspects of the planned activity). The process for identifying environmental impacts is described in Section 5.0 and the planned events that are predicted to result in impacts during the activity are listed in Table 6.1.

A discussion of the environmental impacts associated with the activity to be carried out under this EP, the predicted environmental effects and the control measures that will be implemented to reduce impacts to As Low As Reasonably Practicable, are presented in this section. Alternative controls identified and considered to ensure residual impacts are As Low As Reasonably Practicable and comply with the pre-set acceptability criteria of the residual impacts are also covered. The As Low As Reasonably Practicable process is described in Section 5.0. Environmental performance outcomes, controls, standards and measurement criteria are provided for each type of impact.

Table 6.1 Summary of planned impacts

No.	Source of impact (event)	Potential environmental effects	Predicted level of impact (consequence category)	ALARP	Acceptable
6.1	Exclusion of other marine users due to physical presence of MODU and vessels within the Petroleum Safety Zone and the plugged and abandoned well head	Localised and temporary displacement of other marine users around the well location during drilling Long-term, localised displacement from seabed hazard exclusion zone set up for abandoned well head	1–3	Yes	Yes
6.2	Seabed disturbance from MODU transponders, drilling, cementing, ROV operations and well head installation	Localised and temporary disturbance to benthic habitat Localised alteration of benthic habitat close to the well site Long-term, localised modification of soft-sediment seabed habitats due to presence of abandoned well head	1–3	Yes	Yes
6.3.1	Underwater sound from drilling, thrusters and engines on the MODU, support vessels and helicopters in PSZ	Localised and temporary behavioural disturbance to noise sensitive marine fauna, including small numbers of protected cetaceans	1–3	Yes	Yes
6.3.2	Underwater sound from intermittent or impulsive sources – MODU transponder and Vertical Seismic Profiling	Localised and temporary behavioural disturbance to noise sensitive marine fauna, including protected cetacean species Potential for auditory impairment (Temporary Threshold Shift or Permanent Threshold Shift) in noise sensitive marine fauna, including protected species, in close proximity to the sound source	1–3	Yes	Yes
6.4	Artificial lighting on MODU and vessels for navigational and operational safety	Localised and temporary behavioural disturbance of light-sensitive marine fauna, including protected species (ocean-foraging birds and cetaceans)	1–3	Yes	Yes
6.5	Fuel combustion by MODU, helicopter and vessel engines	Reduced local air quality from atmospheric emissions and negligible contribution to national greenhouse gas emissions	1–3	Yes	Yes
6.6	Discharge of drilling fluids (SBM) and cuttings	Localised burial and smothering of benthic habitats in the GAB Marine Park by drill cuttings Localised and temporary effects to water quality (e.g. turbidity increase) and marine biota Potential localised chemical toxicity and oxygen depletion impacts to fauna in the water column and sediment from drilling fluids	1–3	Yes	Yes
6.7	Discharge of cement	Localised modification of marine benthic habitats around well head Localised and temporary effects to water quality (e.g. turbidity increase)	1–3	Yes	Yes

No.	Source of impact (event)	Potential environmental effects	Predicted level of impact (consequence category)	ALARP	Acceptable
6.8	Discharge of cooling and brine water from MODU and support vessel	Localised adverse effects on marine biota due to increase in temperature, salinity and potential chemical toxicity, minor behavioural response from protected species avoiding heated plume	1–3	Yes	Yes
6.9	Discharge of sewage, grey water and putrescible wastewater from MODU and support vessels	Localised effects on marine biota due to increase in turbidity and nutrient concentrations	1–3	Yes	Yes
6.10	Discharge of deck and bilge waters from MODU and support vessels	Localised adverse turbidity and chemical effects on water quality and marine fauna	1–3	Yes	Yes
6.11	BOP fluid discharge during BOP installation and function testing	Localised adverse chemical effects on water quality and marine fauna	1–3	Yes	Yes

6.1 Displacement of other marine users

6.1.1 Impact description

The 500 m radius Petroleum Safety Zone established around the drilling location to safeguard the mobile offshore drilling unit while it is unable to manoeuvre during the drilling activity may exclude shipping traffic and fishers from a small area of deep offshore waters. The impacts considered are:

- loss of access to the Petroleum Safety Zone area (exclusion from fishing grounds or deviation to shipping route)
- ongoing obstacle to deep-water demersal trawling (presence of well head).

The most credible impact to other marine users will be their exclusion from about 0.79 km^2 of waters within the Petroleum Safety Zone. The Petroleum Safety Zone overlaps 10 state-managed or Commonwealth-managed fisheries and is in proximity of a commercial shipping route across the central Great Australian Bight.

The exclusion of fishers from the Petroleum Safety Zone would only affect individuals who actively fish in the area. Commercial ships in transit across the central Great Australian Bight will need to deviate around the Petroleum Safety Zone if it lies on their plotted course.

Following plugging and abandonment of the well head in situ, it will remain on the seabed permanently. The well head location will be marked on navigation charts (in the short term via a chart correction in Notice to Mariners) as an isolated seabed hazard for marine users.

6.1.2 Levels of acceptable impact

The impact caused by physical presence of the mobile offshore drilling unit on location will be acceptable if:

a. Establishing the Petroleum Safety Zone is consistent with the activities allowable under the management plan for the Great Australian Bight Australian Marine Park.

b. All activities are carried out “in a manner that does not interfere to a greater extent than is necessary for the reasonable exercise of the rights and performance of the duties” as per Section 280 (2) of the *Offshore Petroleum and Greenhouse Gas Storage Act 2006*.

c. The Stromlo-1 exploration drilling program does not pose an unreasonable risk to, or burden on, users of the main shipping routes.

d. There will be negligible overlap with fishing zones (spatial and temporal) and the abandoned well head does not affect the activities of fishing licence holders.

e. There are no unresolved relevant persons objections regarding exclusion from the Petroleum Safety Zone or the presence of the abandoned well head in deep offshore waters.

6.1.3 Impact prediction

The area of the Petroleum Safety Zone is about 0.79 km^2, which represents a very small proportion of the deep offshore waters of the Great Australian Bight, the areal extent of the relevant fisheries, and the Multiple Use Zone (International Union for Conservation of Nature Category VI) of the Great Australian Bight Marine Park. The Petroleum Safety Zone does not overlap the main shipping routes across the Bight.

There are no Department of Defence restricted areas, Heritage Places, or other petroleum users currently active in the vicinity of, or immediately adjacent to, the Petroleum Safety Zone (Figure 4.1).

State and Commonwealth fisheries generally extend to the outer boundary of the Australian Economic Exclusion Zone, 200 NM from shore. Within the fishery boundaries, the fishers target areas with the best returns for maximising catches while minimising outlay in time and fuel costs. Therefore, actively fished areas are generally limited to waters in closer proximity to home ports. The Petroleum Safety Zone is overlapped by the offshore boundaries of six Commonwealth and four state-managed fisheries, but information obtained during consultation (Section 3.0) and from fishing management authority records indicates there is no active commercial fishing in the area around the drilling location. The Stromlo-1 location is too far offshore and too deep to be fished commercially by these fishers.

No objections were received during consultation with relevant persons with respect to plugging and abandoning the well head. The well head in >2200 m water depth will be too deep to interfere with traps, nets or trawl nets used by fishers and in waters too deep for vessels to anchor. Demersal trawling is prohibited in the immediate area of the Marine Park.

Purse seine, pole and line and long-line fishing by the Southern Bluefin Tuna Fishery and Western Tuna and Billfish Fishery and the South Australian Miscellaneous Fisheries (variety of techniques) are permitted in the Petroleum Safety Zone area but no commercial activity extends beyond a maximum of around 800 m water depth. No fishing effort has been recorded in the past decade within the Petroleum Safety Zone.

Impacts to commercial fishers are considered minor because the activity is not predicted to interfere with commercial fishing (via loss of catches or damage to fishing equipment), so impacts are limited to temporary displacement from the Petroleum Safety Zone.

The nearest commercial ports to the Stromlo-1 location are Ceduna, Port Lincoln and Port Adelaide at approximately 400–700 km away. Australian Maritime Safety Authority records show that the majority of vessels traversing the Great Australian Bight from these ports and smaller ports follow two main routes (Section 4.7.5); neither of these intercepts the Stromlo-1 location. The closest shipping route across the Great Australian Bight is approximately 10 km south of the Petroleum Safety Zone. Impact to commercial shipping is considered minor as the Stromlo-1 well location is outside the shipping routes and shipping densities are very low within the Petroleum Safety Zone area.

Interruptions to other marine users not following the standard routes will be limited to minor track deviations around the Petroleum Safety Zone exclusion area.

The predicted impacts on other marine users are considered to be Category 1–3, because the presence of the mobile offshore drilling unit and the abandoned well head will cause negligible disruption to commercial or recreational vessel users, including fishers.

6.1.4 Impact treatment

6.1.4.1 Environmental performance outcomes (EPO 6.1)

The disruption to other marine users due to the activity is limited to the Petroleum Safety Zone exclusion area and the physical presence of the mobile offshore drilling unit and support vessels on location does not interfere to a greater extent than necessary for our reasonable exercise of rights and performance of duties.

6.1.4.2 Context for assessment

Table 6.2 Context for mitigating impacts on other marine users

Legislative and other requirements	The Australian Maritime Safety Authority is responsible for maritime safety in Australian waters including the maintenance of aids to navigation, ship routing, ship reporting and Vessel Traffic Services. International and national conventions and regulatory frameworks provide the standards enforced by Australian Maritime Safety Authority, including: • *Navigation Act 2012* • Marine Orders 30 (Prevention of Collisions) 2009 • Marine Order 21 (Safety of navigation and emergency procedures) 2012. This legislation and associated orders require the use and maintenance of appropriate lights and communications to minimise interference between marine users. NOPSEMA prohibits vessels from entering the PSZ.
Equinor Australia B.V. standards	Activities will be undertaken in line with the principles stated in: RM100 – Manage Risk which “requires consideration of relevant external stakeholders and their concerns, the regulatory framework and the use of the risk matrix to determine the required control measures” TR1011 – Environmental requirements for offshore installations requires compliance with applicable laws and regulations (as per “Legislative and other requirements” above).

Table 6.3 Control measures and performance standards for mitigating impacts on other marine users

Control measures	Performance standards	Measurement criteria	Responsibility
Notice to Mariners of drilling activity informs other users of presence and movements	EPS 6.1.1: Notice to Mariners information provided to the Australian Hydrographic Service delineating the PSZ and schedule of MODU movements at least four working weeks prior to MODU arrival on site and on completion of program.	Record of information to support a Notice to Mariners sent to the Australian Hydrographic Service via email: datacentre@hydro.gov.au	Equinor Australia B.V. Drilling Manager
Relevant person notification informs relevant persons of presence	EPS 6.1.2: Notification providing the PSZ location, is issued to relevant persons four weeks prior to MODU arrival on location and on the cessation of the operation	Consultation database and emails confirm that notifications were issued four weeks prior to the MODU arriving on location.	Equinor Australia B.V. Country Manager
Notice to Mariners informs other users of the well head location	EPS 6.1.3: Notice to Mariners information provided to the Australian Hydrographic Service detailing well head location prior to MODU leaving site.	Record of information to support a Notice to Mariners sent to the Australian Hydrographic Service via email: datacentre@hydro.gov.au.	Equinor Australia B.V. Drilling Superintendent
All necessary permits are in place for in situ abandonment of wellhead	EPS 6.1.4: Equinor will engage with DoEE regarding requirements for a permit under the *Dumping at Sea Act 1996* If a Sea Dumping permit is required it will be applied for and in place prior to commencement of the drilling activities	Records of consultation with DoEE regarding wellhead abandonment in situ Permit date confirms it was in place (if required) prior to commencement of the drilling activities	Equinor Australia B.V. Drilling Manager

6.1.5 Demonstration of acceptability

The level of impact that the physical presence of the mobile offshore drilling unit, vessels and well head will have on other marine users is acceptable because it meets the a priori acceptability criteria as described below.

Table 6.4 Acceptability evaluation for displacement of other marine users

Acceptability criteria	Evaluation against acceptability criteria
a. Establishing the PSZ is consistent with the activities allowable under the management plan for the Commonwealth Marine Park	The exploration drilling activity requires the presence of the MODU and associated support vessels and is permitted within the Great Australian Bight Marine Park Multi Use Zone (International Union for Conservation of Nature Category VI).
b. All activities are carried out “in a manner that does not interfere…to a greater extent than is necessary for the reasonable exercise of the rights and performance of the duties” as per Section 280 (2d) of the OPGGSA.	The 500 m radius PSZ exclusion area is industry standard (maximum) and no objections received from relevant persons. The PSZ exclusion area will be very localised (<0.79 km^2)
c. The Stromlo-1 exploration drilling program does not pose an unreasonable risk to, or burden on, users of the main shipping routes	The PSZ is located outside main shipping routes (approximately 10 km north of closest shipping route) with any required deviations minimal for vessels that might otherwise plot a track through the PSZ. Shipping density is very low in the area and ships mainly passing >10 km to the south of the PSZ
d. There will be negligible overlap with fishing zones (spatial and temporal) and the abandoned well head does not affect the activities of fishing licence holders	The PSZ overlaps with a negligible area (<0.8 km^2) of state and Commonwealth fishing zones. However, there is no commercial or recreational fishing activity in the PSZ. As such, exclusion for up to eight months and the permanent presence of the well head does not interfere with fishing activities. The permanent presence of the plugged well head does not present a credible risk to fishers or vessels given the water depth (>2200 m) and absence of fishing in the area

Acceptability criteria	Evaluation against acceptability criteria
e. The operations will be compliant with all applicable maritime law regarding establishing and maintaining safety zones	The establishment of the exclusive PSZ and the notification of the presence and movements of the vessels and MODU to other marine users is compliant with maritime law:
f. There are no unresolved relevant person objections regarding exclusion from the PSZ during drilling or the presence of the abandoned well head in deep offshore waters	Before operations – Equinor Australia B.V. engaged with relevant persons and addressed any issues relating to potential effects arising from the presence of the MODU, vessels and well head.

6.1.6 Demonstration of As Low As Reasonably Practicable

The decision context and assessment technique for the As Low As Reasonably Practicable assessment are provided in Table 6.5. Additional controls which have been considered in reaching As Low As Reasonably Practicable are listed in Table 6.5. Equinor Australia B.V. considers the impacts of the presence of the mobile offshore drilling unit, vessels and well head are As Low As Reasonably Practicable because:

- the number of vessels, the duration of activities, and the dimensions of the Petroleum Safety Zone are already at minimal levels and further reduction would compromise ability to conduct activity safely
- the communication of the presence of the mobile offshore drilling unit and well head to other users is considered a highly effective control for avoiding impacts
- impact level is already Category 1–3 with standard practices and controls
- no additional control measures have been identified to further reduce the impact of physical displacement of other marine users, apart from not conducting the drilling activity which is not acceptable.

Table 6.5 As Low As Reasonably Practicable decision context and assessment technique for displacement of other marine users

As Low As Reasonably Practicable decision context	This is a well understood activity and it is expected that there will be limited interactions with other marine users due to the very low densities of shipping traffic and the remote deep-water location of the well precluding fishing. No relevant persons raised objections or claims over displacement from the PSZ. There are no unresolved relevant persons objections or claims over the presence of the abandoned well head. Taking this into consideration Decision Context A should be applied to demonstrate impacts are As Low As Reasonably Practicable.
Assessment technique	Good Practice – Identified industry good practices adopted to reach As Low As Reasonably Practicable

Table 6.6 Assessment of additional controls to mitigate impacts on other marine users

Additional capability	Hierarchy	Environmental benefit	Env benefit %	Cost	Rationale	Outcome
Cut and retrieve the well head	Elimination	The environmental benefits of removing the well head to below surface would be limited to eliminating a remote chance of physical interaction with other marine users. Removing the well head will not affect fishing activity in the area because no trawlers operate that deep. Exclusion from the small area of seabed around the well head is not predicted to affect future activity in the area. There would be a minor benefit in removing the wellhead structure from the benthic setting of the GABMP; however this would be negligible given the cuttings pile will change the seabed habitat type over the long-term, so it would not be returning to pre-drilling status. The change from soft sediment habitat to hard upstanding seabed feature will affect the immediate vicinity only Compliance with base case under OPGGS Act	Negligible (<1%)	1–2% of project cost	The negligible environmental benefits associated with removing the well head after plugging are grossly outweighed by the costs of leaving it in situ. The integrity of the design when not removing the well head is no different to the design for removal of the well head and there is negligible increase in risk to the marine environment over the longer-term. The removal of the well head is neutral with respect to removing physical obstructions for the fishing industry because demersal trawling is prohibited in the marine park area and the seabed is too deep for typical trap, trawl-board and net techniques. The costs are approximately US$3.5m, which is disproportionately high given there is negligible environmental or socio-economic benefit in well head removal.	Not adopted

6.2 Seabed disturbance

6.2.1 Impact description

While positioning the mobile offshore drilling unit in preparation to drill, the seabed within the Commonwealth Marine Park will be disturbed through the placement of transponder weights, remotely operated vehicle operations near the seabed, and active water jetting if required.

Seabed transponder arrays are required to assist with locating and maintaining the mobile offshore drilling unit's position relative to the well. Transponder arrays are typically secured by concrete mooring weights sitting on the seabed in the vicinity of the well head. The mooring weights are expected be in place temporarily; and will be removed by the remotely operated vehicle at the completion of drilling operations. The installation of the well casing and the blow out preventer will directly disturb the seabed. Following plugging and abandonment, the blowout preventer will be removed but the well head will remain in situ and this will cause a permanent change in seabed type from soft mud to hard substrate (steel).

A remotely operated vehicle will be used to assess the seabed prior to drilling and may also be used to relocate small amounts of sediment material (to create a stable, level surface and reduce the potential for scouring under sub-sea equipment. The remotely operated vehicle operations would disturb the surface sediments which will then settle back to the seabed in surrounding areas.

Impacts from drill cuttings, muds and cement are discussed in Section 6.6 and Section 6.7.

The impacts are considered to be:

- localised and temporary increase in suspended sediments, reducing water quality near the seabed
- disturbance of soft sediment benthic habitats due to localised sediment relocation
- alteration of habitat caused by the placement of the transponder mooring weights and by the well head remaining in situ.

The seabed disturbance will be limited to a few square metres around the well head and mooring blocks. The mobile offshore drilling unit transponder clump weights are expected to occupy an area of approximately 2 m^2 and the 42" (1067 mm) surface hole will occupy an area of about 0.9 m^2.

Seabed disturbance resulting from disturbance by mobile offshore drilling unit transponders will be temporary because the depressions will gradually fill in through the re-deposition of suspended material in the area (including outputs from the activity, e.g. cuttings).

The well head will remain in situ and will modify the benthic habitat type from soft sediment to hard substrate. Disturbance impacts from the well bore will be permanent, but the footprint is less than 1 m^2.

6.2.2 Levels of acceptable impact

The seabed disturbance caused by installing the well head and blowout preventer, the footprint of the transponder mooring weights and any sediment resuspension due to remotely operated vehicle activities will be acceptable if:

a. The area of seabed disturbed is in a habitat type widely represented within the local area and within the Great Australian Bight Marine Park.

b. The well head does not contain any hazardous materials.

c. There will be no direct effect on EBPC Act listed matters of national environmental significance or Great Australian Bight Marine Park Management values.

d. The activity is permitted within the Marine Park Multiple Use Zone.

e. The plugging and abandonment of the well is compliant with industry and Equinor Australia B.V. standards.

6.2.3 Impact prediction

The Stromlo-1 well location is located within a Multiple Use Zone (International Union for Conservation of Nature category VI) of the Great Australian Bight Marine Park and the Benthic Protection Zone. The seabed disturbance associated with the drilling activity is predicted to affect less than 100 m^2 of soft sediment that is well represented in the areas surveyed and which is a negligible proportion of the Marine Park and the Benthic Protection Zone.

There are two areas of higher biodiversity value in the general area – Anna's Pimple and Murray's Mount; both of which are approximately 20 km from the Stromlo-1 well location. Recent Great Australian Bight studies have identified a number of additional seamounts in the broader region. The "ancient coastline at 90–120 m depth" Key Ecological Feature occurs about 190 km north of the well location.

Sections 4.6.2 and 4.6.3 summarise the benthic habitats and communities in the area of Stromlo-1. The Great Australian Bight Research Program included infaunal investigations of deep-sea benthic habitats in depths of 200–3000 m (Rogers et al. 2013; Tanner et al. 2017). The Great Australian Bight Research Program sampling had three transects running adjacent to or through exploration permit 39 area (see Section 4.7.2 – Figure 4.21). Infaunal densities in the Great Australian Bight over a depth range of 200–2800 m sampled were relatively low (268–1320 individuals/m^2) compared to densities documented elsewhere (Tanner et al. 2018). The two Great Australian Bight Research Program studies examining infauna densities reported considerably lower densities – 50–450 individuals/m^2 at 500–2000 m (Currie & Sorokin 2011). The 2013 studies noted the large number of new fauna species was not surprising given there have been relatively few surveys of deep-water infauna in Australia. It was noted that the proportion of undescribed species in the deep waters of the Great Australian Bight was consistent with data from similar depths along the Western Australian shelf (Poore 2004), suggesting these species may be abundant and widespread throughout similar depth environments of the Great Australian Bight. Benthic invertebrate fauna was predominantly Crustacea and Annelida (worms), accounting for 94% of all species and 96% of identified specimens.

Deep-water corals (Cnidaria) are largely found in less than 1000 m water depth, although patches of communities have been found beyond 2000 m (National Oceanic and Atmospheric Administration 2018) and as such, are unlikely to be a dominant habitat type in the Impact Environment that May Be Affected at depths of over 2200 m. Chlorophyll-a concentrations (an indicator of phytoplankton biomass) declined with distance from the shelf edge to low concentrations (0.19 µg/L) at stations at the 1000 m and 2000 m isobaths. Benthic fauna surveys in late 2015 (depths 200–5000 m, Section 4.7) indicated a diverse assemblage of fauna including several new species patchily distributed over the survey area. Catches of epifauna were dominated by ophiuroids (brittle stars), holothurians (sea cucumbers) and stony coral, and were typically small (Williams et al. 2017, 2018).

The Protected Matters Search Tool database (Appendix 7-2) suggests conservation-significant fish species that may be present within the Impact Environment that May Be Affected include the great white shark (*Carcharodon carcharias*), porbeagle (*Lamna nasus*) and southern bluefin tuna (Conservation Dependent). Other than habitat and migration areas for pygmy blue whales (*Balaenoptera musculus brevicauda*), there are no adjacent or nearby Biological Important Area for matters of national environmental significance cetaceans – with pygmy blue and sperm (*Physeter macrocephalus*) whale foraging grounds lying about 100 km north. However, the southern right (*Eubalaena australis*), humpback (*Megaptera novaeangliae*) and sei (*Balaenoptera borealis*) whales may still traverse the area, as may the fin (*Balaenoptera physalus*), and various other beaked and baleen whales. Likewise, toothed whales including the killer whale (*Orcinus orca*) and dolphins may be found in the Impact Environment that May Be Affected at some point in time. The foraging areas of various threatened and vulnerable seabirds such as shearwaters, albatrosses and petrels will not be impacted by seabed disturbances.

There are no known sensitive seabed features in the immediate vicinity of the proposed well site at risk of impact due to the loss of habitat or smothering. The likelihood of such a small affected area being of relevance suffice to impact matters of national environmental significance is very low given it is less than 100 m^2 of widespread habitat typical of the surveyed areas of the Great Australian Bight deep-water region. The area that will be disturbed is very small compared with the overall extent of the habitat in the region and, consequently, there will be no long-term impacts to the diversity and abundance of matters of national environmental significance.

Benthic flora, fauna and habitats may be affected by the physical presence of the infrastructure (including transponders) and the temporary increase in suspended sediment near the sea floor. The area of seabed disturbance and the area of increased turbidity will be highly localised around the disturbance point and as

such is unlikely to result in any significant impact to the diversity and abundance of benthic flora and fauna in the area.

It is expected that areas of seabed disturbed by the mobile offshore drilling unit transponders will rapidly return to the original state through natural recruitment. Habitat loss at the well head may be considered as potential long term to permanent, but the spatial scale of the impact is negligible at a local scale (less than 100 m^2 is potentially disturbed by transponders and well head placement, which is <0.01% of the Petroleum Safety Zone area of 785,400 m^2).

Remotely operated vehicle activities near the sea floor and small amounts of sediment relocation may result in slight and short-term impacts to deep-water biota as a result of elevated turbidity and the clogging of respiratory and feeding parts of filter feeding organisms. However, elevated turbidity is expected to be very short term and temporary and is therefore not expected to have any significant impact to environment receptors, particularly given the low densities of benthic organisms and plankton in the deep-water environment of Stromlo-1.

Colonisation of the well head is highly likely as it presents a hard structure. Given its size and isolation, impacts will be localised. Over time, the cement surrounding the well head will likely become partly buried in sediment as a result of prevailing ocean currents. Over time, the steel well head structure will corrode, and marine fouling is expected to accumulate, whereby a marine life structure may remain above the sea floor. The well head remaining in situ is expected to have a localised impact that is not significant to environmental receptors.

Given the water depth of the Stromlo-1 well and prohibition of demersal trawling (Multiple Use Zone – International Union for Conservation of Nature VI) at the well location, impacts to commercial fishing as a result of the well head remaining in situ are unlikely.

The predicted impacts resulting from of seabed disturbance are considered to be Category 1–3, because the area of disturbance is small and the habitats around the Stromlo-1 drilling site are typical of those in areas surveyed in similar deep water in the Great Australian Bight. Given that only the well head (and associated cuttings mound) will remain long term without negative effects, the seabed disturbance impact is localised.

6.2.4 Impact treatment

6.2.4.1 Environmental performance outcomes (EPO 6.2)

The seabed disturbance1 will be limited to the immediate footprint of the well bore, abandoned well head, the mobile offshore drilling unit transponders – an area contained wholly within the Petroleum Safety Zone.

6.2.4.2 Context for assessment

Table 6.7 Context for mitigating impacts from seabed disturbance

Legislative and other requirements	The *Environment Protection (Sea Dumping) Act 1982* (Cth) only applies to intentional sea dumping operations.
Industry standards	Australian Petroleum Production and Exploration Association CoEP (2008): Objectives regarding seabed disturbance from offshore exploration drilling are to: • Reduce the risk of release of substances into the marine environment to As Low As Reasonably Practicable and to an acceptable level. • Reduce the impacts from events such as spills and loss of equipment to an acceptable level and reduce the risk to As Low As Reasonably Practicable. • Reduce the impacts to benthic communities to acceptable levels and to As Low As Reasonably Practicable.
Equinor Australia B.V. standards	Activities will be undertaken in line with the principles stated in: TR1011 – Environmental requirements for offshore installations requires compliance with applicable laws and regulations (as per “Legislative and other requirements” above).

1 Excluding that from muds and cuttings and cement discharges discussed in Sections 6.6 and 6.7.

6.2.4.3 Control measures and performance standards

Table 6.8 Control measures and performance standards for mitigating impacts from seabed disturbance

Control measures	Performance standards	Measurement criteria	Responsibility
Recover equipment	EPS 6.2.1: The ROV will recover the acoustic transponders	ROV operator logs verify recovery of the transponders and weights	MODU Offshore Installation Manager
Pre-spud ROV survey	EPS 6.2.2: ROV survey of footprint area undertaken to document the baseline condition of benthic habitats	ROV operator logs confirm benthos surveyed prior to spud	MODU Offshore Installation Manager
Monitor seabed impact using ROV	EPS 6.2.3: ROV surveys post-drilling will be undertaken to determine any visible impacts on benthic habitats	ROV operator logs and Daily Drilling Reports (DDRs) verify the extent of benthic impacts	Equinor Australia B.V. Drilling Supervisor
Following well abandonment, notify marine users the well head will remain in situ	EPS 6.2.4: Notice to Mariners reported to the Australian Hydrographic Service detailing well head location	Inspection of information to communicate a Notice to Mariners is provided to the Australian Hydrographic Service via email: datacentre@hydro.gov.au	Equinor Australia B.V. Drilling Superintendent

6.2.5 Demonstration of acceptability

The level of impact that seabed disturbance will have on marine biota and other marine users is acceptable because it meets the a priori acceptability criteria as described below.

Table 6.9 Acceptability evaluation for seabed disturbance

Acceptability criteria	Evaluation against acceptability criteria
a. The area of seabed disturbed is in a habitat type widely represented within the local area and Great Australian Bight Marine Park	The area of disturbance is small (direct footprint <100 m^2; <0.0002% of the Operational Area which itself is <0.19% of the Multiple Use Zone of the Great Australian Bight Marine Park (GABMP). A small area (<100 m^2) of seabed will be disturbed with the loss of some benthic invertebrates likely but much of it is expected to recover rapidly (the lightly sedimented habitats). The GABRP has confirmed that soft sediment habitats are homogeneous and widespread across the GAB, with no measurable longitudinal variation. The benthic habitats affected around the well site are widely represented across the central GAB.
b. The abandoned well head does not contain hazardous materials	Abandoned items have negligible risk of any hazardous substances.
c. There will be no direct effect on EBPC Act listed MNES or GAB Marine Park management values	Given that the Impact EMBA does not support notable densities of MNES, and that receptors (e.g. fish, reptiles and cetaceans) are likely to be highly mobile, impacts will be limited to an individual (not population) level and immobile species such as plankton and benthic invertebrates within the 100 m^2 of disturbed seabed. The impacts are assessed as too localised and temporary to directly affect any of the GAB marine park values (e.g. pygmy blue, sperm and southern right whale migrating or calving habitats, foraging areas for threatened great white shark and specific KEFs such as areas important to small pelagic fish with important ecological roles). No impacts on the local seamounts or the Ancient Coastline or the diversity of the Benthic Protection Zone are predicted.

Acceptability criteria	Evaluation against acceptability criteria
d. The activity is permitted within the Marine Park Multiple Use Zone	The activity will not affect the Marine Mammal Protection Zone adjacent to the South Australian coast and "mining" is permitted in the Multiple Use Zone of the GABMP subject to assessment by NOPSEMA (and acceptance of this EP). It is consistent with the intent of the current Management Plan because the operations are not likely to compromise the protection of biological diversity or the park's conservation values, alone or in combination with other natural or human influences. In complying with the OPGGS Act and the EPBC Act, as assessed by NOPSEMA under delegated authority and in accepting this EP, all other requirements of regulations and legislation relevant to the GABMP are also met.
e. The plugging and abandonment of the well is aligned with industry and Equinor Australia B.V. standards and guidelines	The plugging and abandonment of the well is compliant with industry (American Petroleum Institute and NORSOK) and Equinor Australia B.V.'s practice GL3588 as provided in the WOMP and the well design includes P&A considerations. Associated activities are undertaken in alignment with Equinor Australia B.V.'s technical and working requirements described in TR3501, TR3507 and associated guidelines for well construction, integrity, abandonment design, permanent plugging, abandonment and slot recovery operations. As such impacts are within those described in this EP

6.2.6 Demonstration of As Low As Reasonably Practicable

The decision context and assessment technique for the As Low As Reasonably Practicable assessment are provided in Table 6.10.

Equinor Australia B.V. considers the impacts on seabed disturbance are As Low As Reasonably Practicable because:

- the area and duration of disturbance is already at minimal levels and further reduction would compromise the activity
- impact level is already Category 1–3 with standard practices and controls
- no additional control measures have been identified to further reduce the impacts of seabed disturbance, apart from not conducting the drilling activity, which is not acceptable.
- the option of removing the well head is listed in Table 6.6.

Table 6.10 As Low As Reasonably Practicable decision context and assessment technique for impacts from seabed disturbance

As Low As Reasonably Practicable decision context	Seabed disturbance is of a very restricted spatial scale (total less than 100 m^2) and falls within a Multiple Use Zone (IUCN category VI) and the management arrangements contained in the former Great Australian Bight Marine Park (Commonwealth Waters) Management Plan (Director of National Parks 2005). The Stromlo-1 well location is more than 20 km from the isolated seabed features of Anna's Pimple and Murray's Mount. No additional control measures are required to continue to reduce impacts to As Low As Reasonably Practicable. No relevant persons raised objections or claims regarding seabed disturbance Taking this in consideration Decision Context A should be applied to demonstrate impacts are As Low As Reasonably Practicable.
Assessment technique	Good Practice – Identified industry good practices adopted to reach As Low As Reasonably Practicable

6.3 Underwater sound

6.3.1 Impact description

Sources of anthropogenic sound associated with the Stromlo-1 drilling program include sources of continuous sound (e.g. thruster sound from continually operating propellers), intermittent sound (e.g. sound from helicopter passing overhead) and impulsive sound (e.g. infrequent vertical seismic profiling). Continuous or non-pulsed sounds can be broadband or tonal, and do not have the rapid rise in pressure that characterise impulsive sounds such as acoustic sources used for vertical seismic profiling. Impulsive sounds are typically broadband and transient (Richardson et al. 1995). Marine biota in an area of ensonification will be exposed to different levels of sound energy, depending on the strength of the sound output, the type of sound source, their behaviour, physiology and where they are in relation to the source (distance, depth, bearing). For a given sound source, proximity is the most important factor affecting potential impacts on marine fauna. Near-field (close to the sound source) and far-field (at distance from the sound source) received sound levels are influenced by several factors including the overall size (capacity) of the acoustic source, the array configuration, water depths in the area, position in the water column, distance from the source and geo-acoustic properties of the seabed. Sound tends to propagate further in deeper water due to reduced interference from the seabed.

6.3.1.1 Mobile offshore drilling unit

Underwater sound will be created by the mobile offshore drilling unit's thruster propellers during dynamic positioning to get the rig on location and to maintain its position during drilling. Sound will also be created by the dynamic positioning of the support vessels, by the action of the drill string in the hole, and to a lesser extent machinery, pumps and generators on the mobile offshore drilling unit and vessels (Erbe et al. 2013). Only a few studies have been published on the underwater sound emitted from drill ships or other drill rigs (Austin & Hannay 2018; Greene 1987; Kyhn et al. 2014; McCauley 1998; Richardson et al. 1990). The most recent measurements were by Austin and Hannay (2018) who measured broadband drilling source levels for the Kulluk drilling unit (168.6 dB re 1 µPa m, the drillship Noble Discoverer (174.9 dB re 1 µPa m), and the semi-submersible Polar Pioneer (170.1 dB re 1 µPa m).

Greene (1987) measured sound from two drill ships in shallow waters (<50 m), the Canmar Explorer I and II and a drilling barge, the Kulluk. Most of the sound energy was below 1–2 kHz with sound pressure levels of 122–125 dB re 1 µPa (SPLrms) at 170 m from the Canmar Explorer I and 134 dB re 1 µPa (root mean squared (rms)) at 200 m from the Canmar Explorer II during drilling. Sound from the drilling barge Kulluk was higher at approximately 143 dB re 1 µPa (SPLrms) at 1 km from the barge during drilling. Received sound levels were above ambient at 10 km from all three vessels (Green 1987), which was the furthest distance that recordings were made.

More recently, Kyhn et al. (2014) measured sound emitted by an active drill ship, Stena Forth, in 484 m of water in Baffin Bay, western Greenland. Sound levels were recorded during both drilling and maintenance work and were detectable at 500 m to 38 km from the drill ship. The frequency of most of the sound energy was below 3 kHz with the highest source amplitude levels (up to 190 dB re 1 µPa SPLrms) recorded during maintenance work, while during drilling the source level was 184 dB re 1 µPa (SPLrms).

Drill ships are the noisiest method of drilling in water (Richardson et al. 1995), primarily because the hull has good coupling with the water and facilitates effective underwater sound radiation. Other drilling rig types, such as the mobile offshore drilling unit proposed for the Stromlo-1 drilling operations, have most machinery well above the water line and therefore less sound is transmitted to the surrounding water (Salgado Kent et al. 2016).

McCauley (1998) measured sound levels from a drilling rig on the North West Shelf (Australia) during drilling operations and during maintenance (i.e. not drilling) and sound levels were lower than 120 dB re 1 mPa at around 3.5 km from the rig.

Operation of the mobile offshore drilling unit's azimuth thrusters for the Stromlo-1 drilling operations is expected to be the dominant continuous sound source for the mobile offshore drilling unit and drilling activity. The thrusters would be a continuous source of underwater sound for the duration of the drilling whereas support vessel sound will be intermittent and transient in any one area as the vessels move around.

The dynamic positioning system of the MODU uses acoustic signals at high frequencies (main energy above 20 kHz) throughout the operation. This is similar to the sound emitted routinely by commercial vessel echosounders but higher in energy due to the deeper water it operates in. Energy is emitted from a ship mounted transducer and from transceivers at the sea floor. The sound generating equipment is referred to as dynamic-positioning-acoustic-transducers (DP-AT) (referred hereafter as 'transponder'). Sound emitted by the transponder is considered an intermittent and impulsive source of underwater sound.

The mobile offshore drilling unit for the Stromlo-1 drilling operations has not been selected yet but will have similar specifications to Seadrill Limited's West Sirius semi-submersible mobile offshore drilling unit (Figure 6.1).

Figure 6.1 Typical MODU, Seadrill's Limited's West Sirius

6.3.1.2 Support vessels

Support vessels will maintain position by dynamic operation of multiple thrusters. Sound source levels from the thrusters and propellers of support vessels when holding position at a drill site on the North West Shelf were measured at up to 182 dB re 1µPa and dropped to around 120 dB re 1µPa at 3.5 km from the rig. (McCauley 1998). This sound level will be higher than for any machinery on the vessels. The support vessels will ensonify the waters surrounding them most whenever they are holding position near the mobile offshore drilling unit and it assumed that one vessel will be present in the Petroleum Safety Zone at all times throughout the program, but not always on the same location.

6.3.1.3 Helicopter transfers

Crew changes for personnel on board the mobile offshore drilling unit will involve transfer by helicopter between the mobile offshore drilling unit and the nearest airport (Ceduna). Flights will occur at least four times a week depending on the progress of the drilling operations and logistical constraints. The presence of the helicopter and its associated sound field will be highly transient. On approach to the mobile offshore drilling unit, the helicopter will descend to the helideck where there is greatest potential to ensonify the water column. Sound pressure will be greatest at the sea surface and rapidly diminish with increasing depth.

Helicopter engine sound is emitted at a range of frequencies generally, below 500 Hz (Richardson et al. 1995). Richardson et al. (1995) reported helicopter sound (for Bell 214 type) being audible in air for four minutes before it passed over receivers, but only detectable underwater for 38 seconds at 3 m depth and for 11 seconds at 18 m depth for the same flight path. Such short-term, intermittent sound is not considered further in the impact assessment.

6.3.1.4 Vertical seismic profiling

Vertical seismic profiling will involve placing a string of hydrophones in the well borehole and transmitting impulsive sound energy to them from a sound source. Vertical seismic profiling operations are typically of short duration; normally taking less than a day to complete. One vertical seismic profiling operation is planned for the Stromlo-1 well, with a source test at least 12 hours before vertical seismic profiling operations commence. The operation is planned to take less than 4–8 hours. The source will be positioned 5–10 m below water surface and will generate sets of 7–9 acoustic pulses in rapid succession (every 5–10 seconds) with a 5–10-minute interval between each set of pulses. A total of 460 shots may be fired in a 24-hour period.

Vertical seismic profiling uses highly directional sound energy; it is focussed towards the seabed but will also ensonify the surrounding water column. The underwater sound generated by the array will be strongest directly under the source and will rapidly decrease with distance from the mobile offshore drilling unit. The propagation of sound from the vertical seismic profiling to surrounding waters has been modelled by Equinor Australia B.V.'s acoustics specialist to support prediction of impacts to marine fauna in the area (Appendix 6-1).

6.3.1.5 Potential impacts to marine receptors

Of the environmental receptors, sensitivities and values described in Section 4.0, underwater sound associated with the mobile offshore drilling unit thrusters and vertical seismic profiling operations has the potential to adversely affect the following, to varying degrees:

- plankton (general open-ocean communities)
- deep-sea invertebrate species (including benthic crustaceans)
- deep-sea fish (e.g. rattails, cusk eels, morid cods, halosaurs)
- transient pelagic fish species (southern bluefin tuna, blue sharks, great white sharks)
- migrating and transient whales (pygmy blue whales, southern right whales, sei whales, fin whales, humpback whales, sperm whales, beaked whales)
- transient pinnipeds (New Zealand fur seal)
- transient marine turtles (loggerhead turtles, leatherback turtles, green turtles)
- Great Australian Bight Marine Park Multiple Use Zone.

The potential for impacts depends on a number of factors, including the presence of the animals during the survey period, their proximity to the sound source, behavioural ability to avoid the sound field generated by the mobile offshore drilling unit/vertical seismic profiling, specific physiological tolerance and the overlap between their hearing range and the seismic frequency range. The marine species most at risk from the acoustic emissions from vertical seismic profiling (<200 Hz) and mobile offshore drilling unit (<3 kHz) operations within the Impact Environment that May Be Affected are cetaceans, particularly baleen whale species that hear and communicate in similar low frequency ranges to the vertical seismic profiling and mobile offshore drilling unit sound sources. Impacts to marine fauna could include:

- physical injury to auditory tissues or other air-filled organs
- hearing loss; either temporary threshold shift (TTS) or permanent threshold shift (PTS)
- direct behavioural effects through disturbance or displacement and consequent disruption of natural behaviours, such as migration, feeding, resting, calving
- indirect behavioural effects by impairing or masking their ability to navigate, communicate or find food, as well as affecting the distribution or abundance of prey species
- indirect effects on the recruitment via planktonic phases to commercial fish stocks.

6.3.2 Levels of acceptable impact

Sound is a natural component of the underwater environment and marine fauna co-exist with current levels of ambient sound, some of which is of high amplitude, such as lightning strikes, storm waves, wind and cetacean vocalisations. The offshore environment is also subject to frequent anthropogenic sound; mostly from passing ships. Sound generated by the operation of the mobile offshore drilling unit and vertical seismic profiling will add to the ambient soundscape and will affect some marine fauna. vertical seismic profiling and mobile offshore drilling unit sound are necessary components of the petroleum activity and the unavoidable impact on marine receptors caused by underwater sound will be acceptable when it falls below the levels described below. Relevant person objections or claims have been considered in assessing the acceptability.

Table 6.11 Acceptability criteria for receptors

Plankton (incl. Fish larvae, eggs)	Effects on plankton communities will be localised and short-term No lasting population-level or ecosystem-level effects
Fish (incl. Spawning)	Activity is not carried out in a spawning area for commercial fish species. No displacement of white shark from important foraging or distribution BIAs No broad-scale disruption of southern bluefin tuna migration through the GAB No population-level or ecosystem-level effects
Invertebrates (incl. spawning)	No population-level or ecosystem-level effects
Marine turtles	Predicted effects limited to behavioural disturbance of a small number of individuals No population-level or ecosystem-level effects No displacement from key foraging, nesting or inter-nesting habitats
Cetaceans	No displacement from key foraging, aggregating or calving habitats Minor displacement of individuals from migratory pathway Aligns with the relevant management actions from the Conservation Management Plan for the Blue Whale by • no injury to pygmy blue whales • no disturbance to foraging pygmy blue whales in foraging areas, including displacement from foraging area Aligns with the relevant management actions from the Recovery Plan for the Southern Right Whale by • no injury to southern right whales • no disturbance to southern right whales in coastal aggregating and calving BIAs Aligns with the management actions of the Conservation Advice Notes for humpback, sei and fin whale for the assessment of sound impacts No population-level or ecosystem-level effects
New Zealand fur seal	Predicted effects limited to behavioural disturbance of a small number of individuals No population-level or ecosystem-level effects
Fisheries	No displacement of fishers from known fishing grounds No population-level impacts on commercially fished stocks No reduction in catchability or catch as a result of VSP or MODU operations
Protected areas	No predicted long-term impacts on the conservation values of the GAB Marine Park No predicted long-term impacts on the values of the Kangaroo Island Pool, Canyons and Adjacent Shelf Break No predicted long-term impacts on the values of the Eyre Peninsula Upwellings KEF No predicted long-term impacts on the values of the Small Pelagic Fish of the South-west Marine Region KEF

6.3.3 Impact prediction

6.3.3.1 Underwater sound modelling

Equinor Australia B.V. carried out underwater sound propagation modelling for the sound generated by the mobile offshore drilling unit thrusters and vertical seismic profiling operations at the Stromlo-1 well location to enable prediction of the spatial extent of the underwater sound impacts on marine fauna (Appendix 6-1). These sound sources represent the worst-case sound impacts from impulsive and continuous sound and their zones of effect encompass the zones of effect for all other sound sources.

The sound propagation model used was dB Sea v2.1, which has been extensively validated against measured data (http://www.dbsea.co.uk/validation/). Input parameters for seabed properties and the sound speed profile were based on the sound exposure modelling report for the Ceduna 3D Seismic Survey carried out by Curtin University (Maggi & Duncan 2011). Bathymetry data for the region was taken from the GEBCO2014 database.

The mobile offshore drilling unit has not been selected yet, so the source sound level and frequency spectra used as inputs for the modelling study were based on measured data from the Seadrill West Sirius semi-submersible mobile offshore drilling unit (Figure 6.1), which is similar to, or larger than, the mobile offshore drilling unit that will be contracted for the Stromlo-1 exploration well. For modelling, all eight thrusters were assumed to operate at nominal speed and the vertical position of the thrusters was assumed to be a maximum depth of 18 m below the sea surface. The combined source sound pressure level (SPL) assumed for the mobile offshore drilling unit thrusters, based on the measured maximum Seadrill West Sirius sound data, is 196.9 dB re 1 µPa at 1 m.

Details of the Stromlo-1 vertical seismic profiling source array will be finalised after mobile offshore drilling unit contractor selection, but the most likely configuration is three 150 in^3 acoustic elements (maximum total volume of 450 in^3). Given the uncertainty in the final configuration, a worst-case scenario assessment has been modelled using a source array of three 250 in^3 elements (maximum total volume of 750 in^3). The modelled source level for the vertical seismic profiling to be used during the Stromlo-1 drilling operations is 238 dB re 1 µPa SPLpeak.

The full Underwater sound modelling report is provided in Appendix 6-1.

Conservatism in model assumptions

Although there is considerable uncertainty in the relationship between sound levels and impacts on aquatic species, the science underlying sound modelling is well understood (Farcas et al. 2016). The process involves application of quantitative sound exposure thresholds/criteria for particular species and modelling predicted sound levels over a particular area. The accuracy of model predictions depends both on employing an appropriate model and on the quality of the input data (Farcas et al. 2016). Sound propagation models require assumptions regarding the marine environment in which they are based.

Seismic sound from an acoustic source array is highly directional, especially at low frequencies (<200 Hz), in the vertical (downward) direction for optimum penetration of the seabed. A single acoustic source element produces an acoustic signal that is non-directional and is unsuitable for penetrating the seabed. Directionality is achieved by forming an array of several acoustic elements, and to stagger the times at which each element is used. In this way, a highly directional, acoustic signal is produced that has the potential to penetrate the sub-sea geology to a depth of several kilometres.

The impact assessment is based on modelled isopleths (lines of equally high sound energy) which are based on the maximum sound levels through the water column. This over-estimates sound levels in the upper water column where the whales (and other receptors) occur. Therefore, even though a whale or pelagic fish is within the boundary of a given threshold, it would most likely be exposed to sound energy levels well below that threshold (see Figure 6.2). The approach of overlaying isopleths on the distribution of biota therefore overestimates exposure of the receptors and the effect sizes are expected to be considerably smaller.

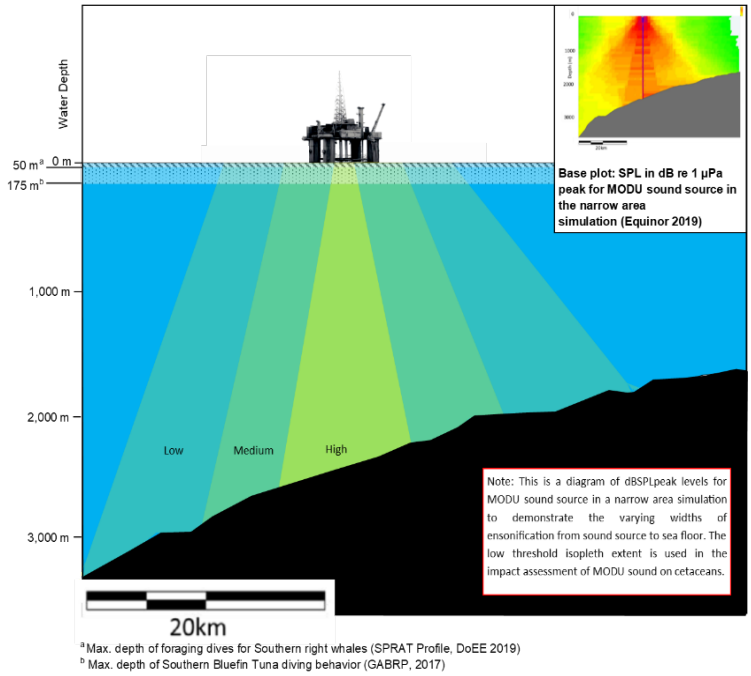


Figure 6.2 Spreading patterns of ensonification under the mobile offshore drilling unit showing how vertical sound level maxima overestimate levels near the sea surface

There is additional conservatism in the modelling prediction which is evident from an in-field validation of a similar size and type of mobile offshore drilling unit to that proposed for the Stromlo-1 activity and drilling in similar depths adjacent to a shelf break (Martin et al 2019). This study showed that at 20 km from the mobile offshore drilling unit, received sound levels were <160 dB SELcum and <168 SPLpeak, and below background levels (i.e. similar to the control location), with the soundscape at this distance determined primarily by wind. At 2 km from the source, received sound levels from the mobile offshore drilling unit were <168 dB SELcum (only approximately 8 dB higher than at 20 km). This confirms that the sound level predictions modelled for the Stromlo-1 impact assessment are highly conservative and gives high confidence in the assessment outcomes.

The modelling predictions are also considered conservative when considering measured received levels from mobile offshore drilling units. Evidence to support this comes from an in-field validation of a similar size and type of MODU to that proposed for the Stromlo-1 activity, and drilling in similar depths adjacent to a shelf break (Martin et al. 2019). This study showed that at 20 km from the mobile offshore drilling unit, This evidence suggests strongly that the predictions generated for this impact assessment are highly conservative.

Marine fauna impact criteria adopted

The underwater sound impact criteria that have been used to predict the impact ranges (distances from the source) for injury or disturbance to marine fauna, include peer-reviewed and accepted thresholds and guideline levels based on the best available science for received sound levels. These criteria cover a range of effects from behavioural disturbance to injury or physiological damage. In the absence of peer-reviewed or recognised criteria, such as for plankton and invertebrates, the modelling has used reported effects levels from recent publications. In the absence of directly relevant criteria for some taxa, conservative criteria have been adopted on the basis of international convention and from pile-driving impact studies, which are based on extended exposure to high intensity sound pulses and make no allowance for the receptor to leave the area if the sound level becomes uncomfortable. This is a highly conservative approach to underwater sound impact assessment.

Plankton

Guideline thresholds for mortality to eggs and larvae have been proposed based on the sound exposure guidelines by the ANSI-Accredited Standards Committee S3/SC 1, Animal Bioacoustics Working Group (Popper et al. 2014). These guidelines represent the Working Group's efforts to establish broadly applicable

guidelines for ichthyoplankton (fish eggs and larvae). The criteria that Popper et al. (2014) suggest for mortality in eggs and larvae are based on levels measured in the study by Bolle et al. (2012) that indicated no damage was caused by simulated repeated pile driving at 210 dB re 1 μPa^2.s SELcum.

Invertebrates

There are no peer-reviewed or recognised sound exposure criteria for invertebrates. Day et al. (2016) assessed the impact of seismic sound on rock lobsters, scallops and their larvae. Day et al. (2016) concluded in their paper that the results of their study were broadly applicable to spiny lobster and scallop fisheries throughout the world, and to crustaceans and bivalves in general. The outcomes of that study have been used to develop a comparative sound exposure level for benthic invertebrates.

Exposure to the maximum measured sound pressure level (SPL) of 209–212 dB re 1μPa (peak to peak) did not result in mortality of any adult lobsters or a reduction in the quantity or quality of larvae; but a range of sub-lethal effects to adults were observed (Day et al. 2016). For the assessment of impacts to benthic invertebrates, an sound pressure level of 209 dB re 1 μPa (peak to peak) has been adopted as the exposure level at which a range of sub-lethal to behavioural or catchability effects may be experienced. Exposure to air gun signals did not result in any lobster mortality in any of the experiments on lobsters and scallops conducted by Day et al. (2016); therefore, benthic invertebrates are not expected to be killed at these sound levels.

Fish

The thresholds for harm to fish species have been based on the sound exposure guidelines for fish proposed by the ANSI-Accredited Standards Committee S3/SC 1, Animal Bioacoustics Working Group (Popper et al. 2014). The guidelines represent the Working Group's consensus efforts to establish broadly applicable guidelines for fish and sea turtles, with specific criteria relating to mortality and potential mortal injury, recoverable injury and temporary threshold shift (Table 6.12). The Working Group defines the criteria for injury and temporary threshold shift as follows:

- mortality and potential mortal injury – immediate or delayed death
- impairment
  - recoverable injury – injuries, including hair cell damage, minor internal or external haematoma, etc (none of these injuries are likely to result in mortality)
  - temporary threshold shift – short or long-term changes in hearing sensitivity that may or may not reduce fitness (defined as any persistent change in hearing of 6 dB or greater).

Table 6.12 Summary of fish injury exposure guidelines for vertical seismic profiling and mobile offshore drilling unit operations

Source	Type of fish	Mortality and potential mortal injury (dB re1 μpa)	Impairment (dB re1 μpa)	
			Recoverable injury	Tts
VSP and MODU Transponder Thresholds	Fish: no swim bladder (particle motion detection)	>213 dB SPL peak	>213 dB SPL peak	>186 dB SELcum
	Fish: swim bladder is not involved in hearing (particle motion detection)	>207 dB SPL peak	>207 dB SPL peak	>186 dB SELcum
	Fish: swim bladder involved in hearing (primarily pressure detection)	>207 dB SPL peak	>207 dB SPL peak	186 dB SELcum
MODU Threshold	Fish: swim bladder involved in hearing (primarily pressure detection)	N/A	170 dB SPLrms	158 dB SPLrms

Sound pressure level exposure guidelines are peak levels, i.e. zero to peak or "rms" (root mean squared) Source: Popper et al. (2014);

Injury

The guideline levels for each of the criteria above have been derived from a number of sources. The mortality and recoverable injury guidelines are based on predictions derived from effects of impulsive sounds from piling (Halvorsen et al. 2011), since there are no quantified data for acoustic sources. Halvorsen et al. (2011, 2012) measured the "response severity index (RSI)" of fish species exposed to pile driving. From this

study, the authors identified that a response severity index of 2 would be an acceptable level of physiological injury for the fish exposed to pile driving, which corresponded to a peak sound pressure level of 207 dB re 1 µPa. It should be noted that the response severity index ranking of 2 relates to "mild" and "non-life threatening" injuries.

There are few data on the physical effects of seismic acoustic sources (e.g. mortality, barotrauma) on fish, and of these none have shown mortality (Carroll et al. 2017; Popper et al. 2014). Popper et al. (2014) cite studies on seismic sound effects on fish and state that no studies have linked mortality of fish, with or without swim bladders, to seismic sound from acoustic sources or in experimental studies replicating seismic sound fields (Boeger et al. 2006; Casper et al. 2012; Halvorsen et al. 2012; McCauley & Kent 2012; Miller & Cripps 2013; Popper et al. 2005, 2007). Empirical evidence comes from a study by Wagner et al. (2015), in which gobies were exposed to seismic sound at a level greater than the mortality and potential mortality threshold proposed by the Popper et al. (2014). The fish were exposed to six discharges at an average peak sound pressure level of 229 dB re 1 µPa. Fish were monitored for 60 hours after exposure and no mortality or significant physiological damage (hair cell loss or otolith damage) was observed.

In the absence of such data, the guidelines for "mortality and potential mortality" and for "recoverable injury" have been extrapolated from piling studies and are therefore conservative in nature (Halvorsen et al. 2011; Popper et al. 2014). An additional layer of conservatism is included in the tentative thresholds proposed by Popper et al. (2014) as they propose that in the absence of data on mortality levels, the recoverable injury guideline level also be used for the mortality/potential mortality guideline level.

Both cumulative sound exposure level and peak sound pressure level guideline levels were proposed, but the Working Group stated that the direct application of cumulative criteria adopted for pile driving to other acoustic sources (including seismic acoustic sources) is not appropriate. Calculation of the cumulative sound exposure from a stationary sound source (i.e. pile driving) to a stationary receptor is less relevant for moving sources and receptors because the levels of received sound change as a function of the separation distance between the source and the receptor. For a situation with variable separation distances, the received peak sound exposure level (or "single strike" sound exposure level) changes from shot to shot as the source moves away and as the fish swims away. The Working Group concluded that it is better to use a guideline based on the closest peak level for seismic acoustic sources than one based on a cumulative sound exposure (Popper et al. 2014). The Stromlo-1 modelling and assessment of the acoustic source (vertical seismic profiling) within this Environment Plan therefore uses the peak (or single strike) sound pressure level thresholds as recommended by Popper et al. (2014).

Casper et al. (2012) further investigated the response severity index for several fish species representative of the three fish groups identified by Popper et al. (2014):

- Group1: fish without swim bladders (sharks, rays, flatfish)
- Group 2: fish with swim bladders not involved in hearing (salmonids, sturgeons, jewfish, snapper)
- Group 3: fish with swim bladders involved in hearing and structurally connected to the inner ear, (herring, perch, bass, rockfish).

The study did not identify any mortal or potentially mortal injuries in the four fish species exposed to piling sound levels above a sound exposure level of 177 dB re 1 µPa^2.s (or 207 dB re 1 µPa sound pressure level peak). This level was concluded by the authors as being the potential onset of physiologically significant injuries (Casper et al. 2012) rather than mortality, highlighting the highly conservative and conservative nature of the guideline levels proposed by Popper et al. (2014). It is, however, important to note that the intent of authors in proposing these thresholds was as "a first step in setting guidelines that may lead to the establishment of exposure standards for fish (and sea turtles)" (Popper et al. 2014).

The actual impacts associated with sound levels for the tentative thresholds for mortality/potential mortal injury and recoverable injury proposed by Popper et al. (2014) are therefore deemed to represent the level of possible onset of physiological damage may start to occur, as evidenced in the studies by Halvorsen et al. (2011, 2012) and Casper et al. (2012). They do not represent a likely mortal impact zone and empirical field data indicates mortality will not occur at these levels (Section 2.0).

Impairment – mobile offshore drilling unit operations

Popper et al. (2014) reported that there is no direct evidence of mortality or potential mortal injury to fish from ship noise. Evidence for recoverable or temporary threshold shift effects from continuous sound has been reported for several pressure sensitive fish species, but partial recovery was observed within 48 hours and full recovery occurred between three and 14 days following exposure (Amoser & Ladich 2003; Smith et al.

2006). Conversely, species lacking specialisations for sound pressure detection showed no temporary threshold shift despite long-term exposure to continuous sound sources (Scholik & Yan 2002; Smith 2004; Wysocki et al. 2007).

Based on these studies, Popper et al. (2014) proposed thresholds for recoverable injury and temporary threshold shift for pressure sensitive fish species (hearing specialists), i.e. "fish with swim bladders involved in hearing (primarily pressure detection" (see Table 6.12). Equinor Australia B.V. has adopted these thresholds for the assessment within this EP.

Impairment – vertical seismic profiling operations

Temporary threshold shift thresholds for fish have been proposed for exposure of fish to a seismic source by Popper et al. (2014), based on data from Popper et al. (2005). The fish were exposed to a sound level of 186 dB re 1μPa^2.s accumulated over five seismic pulses (SELcum) and provide the most relevant cumulative exposure guideline specific to a seismic study. In the Popper et al. (2005) study, the experimental design was based on five exposures to the acoustic source at 40 second intervals so that the fish were exposed to a steady sound level. The authors note that, in contrast, a normal seismic survey might present signals as often as every 10 seconds, but they describe several contributing factors that led them to conclude that although these factors do not compensate for the more frequent exposure in an actual seismic survey, their experiments exposed fish with an approximate "worst case" with regard to seismic stimulation (Popper et al. 2005). One such factor is that as the survey vessel is moving away, a stationary fish would be exposed to the maximum level only once in a sequence of exposures. Further, the majority of exposed fishes during a seismic survey are likely to be at greater distances from the source than those in the Popper et al. (2005) study (i.e. 13 and 17 m) and would therefore receive a lower sound level. The guideline level for temporary threshold shift proposed by Popper et al. (2014) derived from the results of the experiments conducted by Popper et al. (2005) are based on temporary threshold shift responses from a hearing specialist fish species (i.e. those with the highest sensitivity to sound). This guideline level can also be considered worst case in this respect for the fish species assessed within this EP.

An independent peer review was conducted by Popper (2018) for the Bethany MSS Environment Plan (https://www.nopsema.gov.au/assets/epdocuments/A601445-EP-Summary-redacted.pdf). Popper (2018) explained in his review that the effects of temporary threshold shift are unlikely to show up in fishes until the intensity of the sound is well above the fish's hearing threshold. He went on to state that for fish species that are free swimming (which include key commercially targeted species) it is likely that there would be no temporary threshold shift effect whatsoever since fish will likely move away from the sound source. The review concluded that if temporary threshold shift is experienced, the level would be low, and recovery would start as soon as the most intense sound ended and would be within 24 hours. Popper (2018) concluded that the time over which energy should be accumulated in each individual fish in the seismic survey area should be limited to the time over which fishes get maximum exposure, and that a period of 24 hours was considered far too long a period for calculating the accumulation of energy when determining potential harm (e.g. injury or temporary threshold shift). Based on Popper's (2018) conclusions, the most likely effect (if any) to fishes resulting from cumulative sound exposure is temporary threshold shift, and that the cumulative sound exposure level 24-hour threshold is appropriate.

Equinor Australia B.V. has adopted cumulative sound exposure level as the temporary threshold shift threshold for exposure in fish, which based on the Popper's (2018) expert review is considered conservative, because temporary threshold shift effects in fish would be temporary, with recovery expected within 24 hours.

Behaviour

There are no peer reviewed published thresholds for comparison of behavioural disturbance effects in fish as a result of exposure to seismic or continuous sound sources. Popper et al. (2014) did not propose specific behavioural guideline values for exposure to sound due to the limited experimental data supporting previously proposed guidelines, and the specific nature of behavioural responses amongst fish species, i.e. one guideline or criterion does not fit all. Instead Popper et al. (2014) recommends a qualitative relative risk of behavioural effects at three distances from the source – near (tens of metres), intermediate (hundreds of metres) and far (thousands of metres). For seismic sources, a high risk of behavioural effects was agreed for all fish groups (with/without swim bladders) within tens of metres from the source (near) and low risk agreed for all fish groups more than thousands of metres (far).

Equinor Australia B.V. has adopted the qualitative relative risk approach proposed by Popper et al. (2014) for the assessment of potential behavioural disturbance to fish as a result of the activity and has further supported the assessment with conclusions and outcomes of various peer-reviewed studies that have reported behavioural effects to fish exposed to seismic sources.

Marine turtles

Popper et al. (2014) proposed a guideline for mortality and potential mortal injury for marine turtles of 207 dB re 1 µPa (peak SPL) based upon piling studies. There have been no studies conducted on hearing loss or the effects of exposure to intense sounds on hearing in any turtles, therefore Popper et al. (2014) have extrapolated from fish, based on the rationale that the hearing range for turtles much more approximates to that of fishes than of any marine mammal.

There are no specific guideline values proposed by the Working Group for behaviour due to the limitations described above (Popper et al. 2014). Therefore, the assessment of the potential effects on behaviour for marine turtles in this Environment Plan is based on a strong avoidance response of 175 dB re 1 µPa (SPLrms) reported by McCauley et al. (2000). Due to the absence of critical habitats or biologically important areas for turtles, and the therefore low likelihood of encounter, (McCauley et al. 2000) exposure level for a strong avoidance response has been used in this assessment.

Cetaceans

Based on current knowledge of functional hearing in marine mammals, NMFS (2018) identify three distinct, functional groups of cetaceans based on the frequency range at which their hearing is most sensitive: a) low frequency (LF) cetaceans (7 Hz–35 kHz); b) mid-frequency (MF) cetaceans (150 Hz–160 kHz); c) high frequency (HF) cetaceans (275 Hz–160 kHz).

Injury and impairment

NMFS (2018) recommends dual marine mammal acoustic thresholds for the prediction of permanent threshold shift and temporary threshold shift from underwater sound modelling for impulsive sounds (see Table 6.13). Southall et al (2019) and NOAA (2018) define TTS as a temporary reduction in hearing sensitivity and it is not considered a form of injury. PTS is defined as a permanent change in hearing and for the purpose of this EP, PTS is considered a form of injury. Equinor Australia B.V. has applied both thresholds in the assessment for marine mammals within this EP. For non-impulsive (continuous) sounds, NMFS (2018) present cumulative sound exposure level acoustic thresholds (see Table 6.3). NMFS (2018) states that if a non-impulsive sound has the potential of exceeding the peak sound pressure level thresholds associated with impulsive sounds, then these thresholds should also be considered in the assessment. Both criteria have been considered for non-impulsive sounds. A recent peer-reviewed scientific publication by Southall et al. (2019) has confirmed the threshold values in NMFS (2018).

In addition, *Environment Protection and Biodiversity Conservation Act 1999* Policy statement 2.1 determines suitable exclusion zones with an unweighted single shot sound exposure level threshold of 160 dB re 1 µPa^2.s (Department of the Environment, Water, Heritage and the Arts 2008). The policy statement is only relevant for baleen and large toothed whales and does not apply to smaller dolphins and porpoises (Department of the Environment, Water, Heritage and the Arts 2008). This threshold has also been applied to the assessment in this EP.

Table 6.13 Summary of injury (permanent threshold shift) and temporary threshold shift thresholds for marine mammals for impulsive and non-impulsive (continuous) sounds

Hearing group	Impulsive sounds (VSP, MODU Transponder)			Non-impulsive sounds (MODU Thrusters		
	Injury (PTS)		TTS	Injury (PTS)		TTS
	SELcum 24	SPL peak	SELcum 24	SPL peak	SELcum 24	SELcum 24
Low-frequency cetaceans (e.g. baleen whales)	183	219	168	213	199	179
Mid-frequency cetaceans (e.g. toothed whales, including beaked whales)	185	230	170	224	198	178
High-frequency cetaceans (*Kogia* spp. (dwarf and pygmy sperm whales)	155	202	140	196	173	153

Hearing group	Impulsive sounds (VSP, MODU Transponder)			Non-impulsive sounds (MODU Thrusters		
	Injury (PTS)		TTS	Injury (PTS)		TTS
	SELcum 24	SPL peak	SELcum 24	SPL peak	SELcum 24	SELcum 24
Phocid pinnipeds in water (e.g. elephant seal)	185	218	170	212	201	181
Otariid pinnipeds in water (e.g. fur seal)	203	232	188	226	219	199

Note: SELcum unit is (dB re 1 μPa^2.s) and is a weighted threshold for an accumulation period of 24 hours; and sound pressure level peak unit is (dB re 1 μPa) and is "flat" or unweighted.

Behaviour

The NMFS (2018) revised acoustic thresholds for permanent threshold shift and temporary threshold shift did not suggest a revised approach to that proposed in Southall et al. (2007) for behavioural disturbance. Behavioural effects are particularly difficult to assess, since they are highly dependent on behavioural context (Ellison et al. 2012; Popper et al. 2014) and responses may not scale with received sound level (Gomez et al. 2016). Southall et al. (2007) performed an extensive review of literature and studies concerned with marine mammal behavioural response to different types of sounds (multiple pulses (impulsive) and non-pulses (non-impulsive)). Their review found that most marine mammals exhibited varying responses between 140 and 180 dB re 1 μPa SPLrms, however inconsistent methods and results between the studies they reviewed makes choosing a single behavioural threshold difficult. Studies varied, and variations included lack of control groups, imprecise measurements, inconsistent metrics, and that animal responses depended on study context, which included the animal's activity state (e.g. migrating, feeding, breeding). To create meaningful quantitative data from the collected information, Southall et al. (2007) proposed a severity scale that increased with increasing sound levels.

Southall's behavioural disturbance criteria are based on a severity scaling system, which ranks the behavioural response from zero for "no response" to 9 for "outright panic, flight, stampede, attack of conspecifics or stranding events" (Southall et al. 2007). No data exist for severity score 9. Severity scales of 4 to 6 are considered to have potential effects on foraging, reproduction, or survival. Specifically, a severity score of 5 indicates a change in swimming behaviour but not avoidance, and 6 indicates minor to moderate (likely) avoidance of the sound source. A combination of both is used in absence of explicit data for either.

For impulsive sounds (e.g. seismic), this assessment has adopted a threshold of 160 dB re 1 μPa SPLrms for pinnipeds and cetaceans, which is also used by the NMFS (2013). For continuous sounds (e.g. vessels, mobile offshore drilling unit), this assessment has adopted a threshold of 140 dB re 1 μPa SPLrms, based on the studies reviewed by Southall et al. (2007) which found the onset of disturbance for low-frequency cetaceans was at received levels of 140 to 160 dB re 1 μPa SPLrms (Ljungblad et al. 1988; Malme & Miles 1983; Malme et al. 1984; McCauley 1998; McCauley et al. 2000; Richardson et al. 1986; Todd et al. 1996) or perhaps higher (Miller et al. 2005). For mid frequency cetaceans, a response score of 3 was encountered for received levels of 110–120 dB re 1 μPa SPLrms, with no higher severity score encountered. A response score of 3 is not considered representative of disturbance to important behaviours as defined by Southall et al. (2007). For high frequency cetaceans, there was a significant increase in the number of mammals responding at a response score of 6 at exposure levels >140 dB re 1 μPa SPLrms.

6.3.3.2 Impacts to plankton (incl. fish and invertebrate larvae and eggs)

Planktonic organisms are transported by prevailing wind- and tide-driven currents and are unable to use evasive behaviour to avoid anthropogenic sound sources. Some forms of phytoplankton and zooplankton are capable of independent movement and can migrate vertically in the water column, but their horizontal position is largely determined by water movements. Zooplankton typically exhibit diel vertical migration whereby they migrate to the water surface at night and return to deeper waters during the day. Certain species (e.g. the copepod *Neocalanus plumchrus*) will also migrate to different depths at different stages of their life cycle (Kobari & Ikeda 2001). Phytoplankton, particularly diatoms and dinoflagellates, also show diel vertical migration (Cullen & Horrigan 1981; Hajdu et al. 2007), triggered by environmental conditions such as irradiance in the photosynthetically active radiation range (400–700 NM wavelengths) (Gerbersdorf & Schubert 2011).

Spatially, phytoplankton will vary according to nutrient concentrations and light availability. Temporally, phytoplankton populations in subtropical oceans drop off in summer as the buoyant warmer water becomes nutrient depleted. Zooplankton growth rates are highly variable among species. Spatially, the abundance and diversity of zooplankton varies significantly at all scales, driven by environmental conditions such as water temperature, depth, season, the availability of food resources and predation.

There have been few studies to date into the effects of marine seismic surveys on plankton. Until recently, studies on the effects of sound from acoustic sources on plankton have indicated that any effect is likely to be highly localised (<10 m from the source and typically within 0.5–5 m) (Table 6.14) (Booman & Foyn 1996; Kostyuchenko 1973; Matishov 1992; Payne et al. 2009). These studies indicated that impacts would be negligible compared with the naturally high turnover rates of zooplankton.

Table 6.14 Observed seismic sound pathological effects on zooplankton

Species	Source	Source level (dB re 1 µpa)	Distance from source	Exposure level (dB re 1 µpa SPL)	Observed effect	Source
Cod (larvae 5 days)	Single acoustic source	250	1 m	250	Delamination of the retina	Matishov (1992)
Cod (larvae 2–10 days)	Single acoustic source	222	1 m	222	No injuries detected	(Dalen & Knutsen 1986)
			10 m	202	No injuries detected	
Fish eggs (anchovy)	Single acoustic source	230 (estimated)	1 m	230	7.8% of eggs injured relative to control	Kostyuchenko (1973)
			10 m	210	No injuries detected	
Fish eggs (red mullet)			1 m	230	No injuries detected	
			10 m	210	No injuries detected	
Dungeness crab (larvae)	Seven acoustic-source arrays	244 (estimated)	1 m	233.5	No significant difference in survival rate relative to control measures	(Pearson et al. 1994)
			3 m	230.9		
			10 m	222.5		
Snow crab (eggs)	Single acoustic source	216	2 m	216	1.6% mortality; 26% delay in development	(Christian et al. 2004)
Spiny lobsters (embryos)	Single acoustic source	223 (estimated)	Run over the pots	200	No differences in the quantity or quality of hatched larvae	(Day et al. 2016)
		224 (estimated)		203		
		227 (estimated)		205		
Zooplankton (incl. krill)	Single acoustic source (150 in^3)	205 (estimated)	1.2 km	178 (SPL) (153 SEL dB re 1 µPa^2.s)	Decreased abundance and increased mortality rate from 19% to 45%	(McCauley et al. 2017)

Day et al. (2016) exposed egg-bearing female spiny lobsters (*V*) to sound from three air gun configurations, all of which exceeded levels of 209 dB re 1 µPa (peak to peak). Overall there were no differences in the quantity or quality of hatched larvae, indicating that the condition and development of spiny lobster embryos were not adversely affected by air gun exposure (Day et al. 2016). Although no apparent morphological abnormalities were observed, exposed larvae from the 45 in^3 experiment were found to be significantly longer than control larvae. However, the size of larvae in this study fell well within the range of natural variation, indicating natural variation in larvae is much greater that the differences observed between treatments in this study. Day et al. (2016a) concluded no effects on embryos early in development within 1 km to 1.5 km of the seismic source.

McCauley et al. (2017) reported zooplankton mortality rates more than two orders of magnitude higher than recorded in earlier studies. They found that exposure to a 150 in^3 acoustic source shot significantly decreased zooplankton abundance and that the mortality rate increased from a natural rate of 19% per day to 45% per day (McCauley et al. 2017). Impacts were detected out to edge of the study area, at 1.2 km from the acoustic source in waters 34 to 36 m deep (McCauley et al. 2017); these water depths are considerably shallower than the majority of seismic surveys in Australia.

In response to the McCauley et al. (2017) study, Commonwealth Scientific and Industrial Research Organisation modelled the impacts on zooplankton from a 35-day seismic survey in 300–800 m deep water in an 80 km × 36 km survey area (Richardson et al. 2017). Within the survey area, the model predicted a 22% reduction in zooplankton biomass, which declined to 14% within 15 km of the survey area (Richardson et al. 2017). They modelled the recovery of the plankton population and found it returned to 95% of the original biomass level within three days after the end of the survey. The rapid recovery was attributed to the fast growth rates of zooplankton and the dispersal and mixing of zooplankton from inside and outside the impacted area (Richardson et al. 2017).

McCauley et al. (2017) reported significant decreases in abundance and increased mortality rates in zooplankton. One large contextual difference that makes this difficult to be applied to the environmental setting of the Impact Environment that May Be Affected is that their study was conducted in very shallow waters (34–36 m depth), whereas the Stromlo-1 well development is located in water depths >2000 m. Richardson et al. (2017) agreed that McCauley et al. (2017) found evidence of some local-scale impact of seismic activity on zooplankton but also noted that their modelled impacts may have been overestimated due to diel vertical migration which was not included in their model. Notwithstanding, they predicted recovery of the zooplankton community within three days after the end of the seismic survey in lower latitude waters. Recovery may be slower in the cool waters of the Great Australian Bight.

The potential impacts of seismic surveys on plankton will depend on the species in question, the life history stages, the specifications of the acoustic source array, the distance between the acoustic source discharge and the plankton, the number of discharges, the water depth and the seabed features. Proximity to the source (i.e. acoustic source array) will also be variable due to diel migration of plankton (including fish larvae) between surface and deep waters. Consequently, predicting impacts is difficult due not only to the diversity of organism in the plankton but to the variation in environmental and physical parameters.

The only peer-reviewed and accepted thresholds for underwater sound effects on plankton relevant to the Stromlo-1 well development is that for mortality as a result of seismic sound proposed by Popper et al. (2014) (Section 1.1). The underwater sound modelling carried out for the vertical seismic profiling activity predicts that this threshold of 210 dB re 1 μPa^2.s SELcum will not be reached during vertical seismic profiling operations. Therefore, there is no predicted mortality or potential mortality to fish eggs and larvae based on this threshold.

The Stromlo-1 modelling predicted received sound levels for vertical seismic profiling (seismic operations) were also compared with the sound level that McCauley et al. (2017) reported mortality of zooplankton (178 dB re 1µPa peak to peak). The modelling predicted that this sound level could be reached out to a median distance of 900 m out to a maximum distance of 1.5 km from the source. It is possible that some mortality of plankton could be expected over this area, but it is not appropriate to conclude complete mortality of plankton over the entire area based on a single study, due to the limitations Richardson et al. (2017) report on the McCauley et al. (2017) survey parameters, i.e. shallow waters and no account of diel vertical migration. Furthermore, the Stromlo-1 well development is located far from any known areas of high primary productivity. The nearest such area is the Kangaroo Island Pool, canyons and adjacent shelf break, and Eyre Peninsula upwellings Key Ecological Feature, lying more than 200 km from the well location.

Based on the research to date, there are not enough data to confidently define zones of impact for planktonic organisms, including the eggs and larvae of fish. Although the recent work by McCauley et al. (2017) and Richardson et al. (2017) suggests that the zone of impact for zooplankton may be higher than previously thought, there is still evidence that for certain components of the plankton effects are likely to be limited to much less than this. Further, for many components of the zooplankton and phytoplankton, recovery is expected to be rapid (in the order of days), so the effects are expected to be limited and to be within the range of natural variability.

The predicted consequence for plankton is Category 1–3 with very limited impacts (restitution time <1 month) on plankton populations and regional Great Australian Bight primary productivity.

6.3.3.3 Impacts to invertebrates and fisheries

Until recently, effects on marine invertebrates were expected to be limited in spatial extent (<10 m) as reported in a study of the effect of seismic explosions on pearl oysters by Le Provost et al. (1986)), as they are considered less sensitive to sound than hearing-specialist fish species, due to the lack of air-filled organs. La Bella et al. (1996) examined biochemical indicators of stress in bivalves exposed to seismic acoustic source sound. They found that hydrocortisone, glucose and lactate levels between test and control animals were significantly different in the venerid clam *Paphia aurea*, showing an evidence of stress caused by acoustic sound (La Bella et al. 1996). This was measured at an exposure distance of 7.5 m. Following on from this a study by Hirst and Rodhouse (2000) suggested that most invertebrates would only detect seismic shots within about 20 m, and that catch levels of shrimp and lobster in areas surveyed with acoustic sources reported no change during the surveys. A study in 2002 examined a number of health, behavioural, and reproductive variables in snow crabs (*Chionoecetes opilio*) before, during, and after, seismic shooting (Christian et al. 2004). Experimental animals were exposed to peak received broadband sound levels of 201 to 237 dB re 1 µPa and the results suggested no obvious effects on crab behaviour, health or catch rates (Christian et al. 2004).

A study by the Tasmanian Aquaculture and Fisheries Institute (TAFI) assessed the immediate impact of seismic surveys on adult commercial scallops (*Pecten fumatus*) in the Bass Strait (Harrington et al. 2010). Participants in the Bass Strait Central Zone Scallop Fishery (BSCZSF) were concerned that the seismic survey may have a negative impact on the commercially important adult scallops within the region. The TAFI study concluded that no short-term (<2 months) impacts on the survival or health of adult commercial scallops were detected after the seismic survey (Harrington et al. 2010). There had been no change in the abundance of live scallops (or related change in dead scallop categories) or macroscopic gonad and meat condition after seismic surveying within either the control, impacted or semi-impacted strata. There was also no observable change in the size frequency distribution of scallops in the impacted and semi-impacted strata following the survey (Harrington et al. 2010).

In response to the lack of discernible results from the 2010 before-and-after study by TAFI discussed above and the concerns from fisheries groups that seismic operations negatively affect catch rates, the Gippsland Marine Environmental Monitoring (GMEM) project was developed (Przeslawski et al. 2016). This study aimed at modelling and measuring sound at various depths before and during a seismic survey in 2015 to quantify potential impacts of seismic surveys on scallops and other benthic organisms. The underwater sound model predicted sound exposure levels of 170 dB re 1 $\mu Pa^2.s$ within 250 m of the source and sound levels exceeding 150 dB re 1 $\mu Pa^2.s$ out to 4 km from the source. However, the highest sound exposure level measured by hydrophones during the survey was 146 dB re 1 $\mu Pa^2.s$ at 51 m depth when the acoustic sources were operating 1.4 km away. As such, the model was shown to be highly conservative, with actual sound levels falling to under 150 dB re 1 $\mu Pa^2.s$ much closer to the seismic source than predicted. There was no evidence of increased scallop mortality, or effects on scallop shell size, adductor muscle diameter, gonad size, or gonad stage due to the seismic sound (Przeslawski et al. 2018). The authors concluded that the GMEM study provided no clear evidence of adverse effects on scallops, fish, or commercial catch rates due to the 2015 seismic survey in the Gippsland Basin.

The Day et al. (2016) study is one of the most recent that has recorded negative effects on commercially important invertebrate species from seismic sound. The study investigated the effects of seismic sound on southern rock lobsters ((*Jasus edwardsii*)) and Australian scallops (*P. fumatus*). Rock lobster experiments consisted of four sampling times between zero and 120 days after exposure, as well as over the longer term of 365 days after exposure. Following exposure, lobsters were sampled and assessed for mortality and a range of sub-lethal effects. The study found that exposure to seismic sound levels up to a maximum sound pressure level of 209 to 212 dB re 1 µPa peak to peak did not result in mortality of any adult lobsters, even at close proximity. However, sub-lethal effects, relating to impairment of reflexes, damage to the statocysts and reduction in numbers of haemocytes (possibly indicative of decreased immune response function), were observed after exposure (Day et al. 2016).

Although the Day et al. (2016) study did not investigate the ecological impacts of the sub-lethal effects, of note is that the lobsters used for the July 2014 standard pressure experiment were collected from a scientific reserve in an area of high ambient levels of anthropogenic sound. These animals were found to have a high level of pre-existing damage to statocysts similar to that induced by acoustic source experiments. When exposed to the seismic acoustic source, these lobsters did not exhibit a significant increase in statocyst damage. The authors suggested this indicated that lobsters can adapt to statocyst damage, as these control lobsters with damaged statocysts did not display impaired righting reflexes (Day et al. 2016).

Seismic sound exposure did not cause mass mortality of scallops during the experiments but repeated exposure (i.e. more than one pass of the acoustic source) where maximum exposure levels were in the range of 212 to 213 dB re 1 µPa sound pressure level peak to peak was considered to possibly increase the risk of mortality (Day et al. 2016). Scallops exposed to repeated seismic sound suffered physiological damage with no signs of recovery over the four-month period, suggesting potentially reduced tolerance to subsequent stressors. In addition, changes in behaviour and reflexes during and following seismic exposure were observed (Day et al. 2016).

Morris et al. (2018) investigated the effects of seismic on the snow crab fishery along the continental slope in Canada in a before-and-after-control-impact study over a period of two years. Crabs were exposed to received levels of 187 dB re 1 $\mu Pa^2.s$ (single shot) and 200 dB re 1 $\mu Pa^2.s$ (cumulative over 24 hours). There were no negative effects on the catch rates in the shorter term (days) or longer term (weeks), and the authors concluded that seismic effects on snow crab harvest (if they do exist) would be smaller than changes related to natural spatial and temporal variation (Morris et al. 2018).

Research on the impacts of low frequency sound to cephalopods is limited (Carroll et al. 2017). There have been no observed cephalopod mortalities directly associated with seismic surveys. Studies exposing cephalopods to near-field low-frequency sound have shown received levels may cause anatomical damage, but research is limited. Anecdotal data from the strandings of giant squid (Architeuthidae) showed tissue, statolith and organ damage after seismic surveys (Guerra et al. 2004). André et al. (2011) demonstrated injury to four species of cephalopod in 200 litre glass tanks from exposure to sweeping waves 50 to 400 Hz at levels of 157 dB sound pressure level produced continuously for up to two hours. However, the exposure experiments in both of these studies are complicated to relate to commercial seismic surveys due to unknown exposure levels for stranded squid, or the duration of the exposure event. Further, researchers have cautioned the extrapolation of conclusions drawn from behavioural studies in artificial tanks due to the wavelengths of sound in water and the practical restrictions of the size of the tanks making it essentially impossible to do meaningful behavioural studies involving the broadcast of sound in a tank (Goodall et al. 1990; Gray et al. 2016; Montgomery et al. 2006; Popper et al. 2001).

McCauley et al. (2000) studied captive squid (*Sepioteuthis australis*) responses during a seismic survey, where squid showed a strong startle response to nearby air gun start up and evidence that they would significantly alter their behaviour at an estimated 2–5 km from an approaching seismic source. Squid showed avoidance of the acoustic source by keeping close to the water surface at the cage end furthest from the acoustic source, appearing to make use of the sound shadow measured near the water surface (an almost 12 dB difference) (McCauley et al. 2000).

Fewtrell and McCauley (2012) studied the behavioural responses of squid to seismic sound levels. In general, squid displayed an increased frequency of alarm responses, particularly at higher sound levels, and increased swimming speed in the direction of the surface as the acoustic source approached and remaining relatively stationary near the water surface as the acoustic source signal became most intense. The authors again suggested that the squid detected the sound shadow (approximate 12 dB decrease in sound levels at the water's surface compared to the levels at depth), and therefore remained at the surface while the acoustic source signals were most intense (i.e. avoidance behaviour) (Fewtrell & McCauley 2012). This behaviour of becoming motionless is a common component of "crypsis" in squid, and one that squid commonly exhibit when threatened (Smith 1997).

Several researchers have noted that squid showed fewer alarm responses with subsequent exposure to the seismic source (Fewtrell & McCauley 2012; McCauley et al. 2000; Mooney et al. 2016). McCauley and Fewtrell (2012) further suggested that a ramped (i.e. gradual increase in signal intensity) acoustic source signal and prior exposure to acoustic source sound decreases the severity of the alarm responses in squid.

Vertical seismic profiling operations

The relevance and implications of the above research has therefore been considered in the context of invertebrates and invertebrate fisheries and stocks in the Stromlo-1 Impact Environment that May Be Affected.

There are no commercially important invertebrate or aquaculture stocks located within the Stromlo-1 Impact Environment that May Be Affected. Although the giant crab, rock lobster and squid fisheries jurisdictions overlap the well location, these species are not fished down to the water depth of the well location as they are biologically restricted to depths of <200 m (rock lobster), <500 m (giant crabs) <70 m (southern calamari) and <800 m (Gould's squid).

Sound modelling results for vertical seismic profiling operations predicted the potential for sub-lethal effects (no mortality) in deep-sea crustaceans and bivalves up to a maximum distance of 1.2 km from the vertical seismic profiling source (Table 6.15). It is therefore possible that deep-sea crustaceans and bivalves (described in Section 4.7.3) could be within 1.2 km of the vertical seismic profiling source and could experience some physiological and behavioural effects, but no mortality is predicted. The vertical seismic profiling activity itself will also be short-term (<24 hours) and so any potential effects would be short term. There are also no biologically or commercially important stocks within this predicted area of effect, and as such there are be no expected population level effects. The area surrounding the well location lies in >2000 m water depth in a sparsely populated benthic environment dominated by sponges and echinoderms, where invertebrate epibiota are well represented in surveyed samples (and literature) at a provincial scale across the Great Australian Bight bioregion and have low endemism (see Section 4.6). Therefore, adult populations of commercially fished invertebrate species will not be affected by the Stromlo-1 well development due to spatial/depth separation.

As indicated in Section 6.3.3.2, the predicted impacts of vertical seismic profiling operations on planktonic life stages of commercially fished invertebrate species will have very limited spatial and temporal consequence. Therefore, for invertebrate species such as Gould's squid and southern calamari that have extensive spawning seasons and broad stock delineation due to expansive larval drift (Section 4.6.4.8), the potential impacts to subsequent recruitment into adult populations of these species, as well as associated catches by fisheries targeting these species, are also expected to be negligible.

Table 6.15 Summary of modelled impact ranges for vertical seismic profiling operations at the seabed for invertebrates

Invertebrate group	Exposure level (SPL peak to peak)	Description	Predicted impact distance	
			Median	Maximum (rmax)
Crustaceans	209 dB re 1µPa	Sub-lethal	Level not reached	Level not reached
Bivalves	191 dB re 1µPa	Sub-lethal	600 m	1.2 km

Source: Day et al. (2016)

Mobile offshore drilling unit operations

There is no direct evidence of mortality to invertebrates from vessel sound, and no thresholds with which to compare modelled received levels at the Stromlo-1 well location. Studies have predominantly focussed on high amplitude (or loud) impulsive, low frequency sound sources such as seismic sound, which are known to be much more harmful than a continuous sound due to the relatively rapid rise from ambient pressure to the maximum pressure value (Hawkins & Popper 2016; Southall et al. 2007). The impact of vessel sound on invertebrates is limited to observations from only a few laboratory studies, which reported behavioural effects following exposure to continuous, low frequency anthropogenic sound in decapods (Solan et al. 2016; Wale et al. 2013). Solan et al. (2016) observed the Norway lobster (*Nephrops norvegicus*) in 2.4 m diameter tubes repress burying, bioregulation and locomotory behaviour when exposed to a continuous sound source, characteristic of shipping (ship recording made at ~100 m); although tissue concentrations of glucose or lactate were reported to be unaffected.

Wale et al. (2013) showed that the metabolic rate of shore crabs (*Carcinus maenas*) placed in holding tanks were affected by exposure to ship playback sound received levels of 148 to155 dB re 1 µPa SPLrms from recordings of container vessels made at ~200 m, with subjects consuming 67% more oxygen than crabs exposed to ambient sound levels (108 to 111 dB re 1 µPa SPLrms). The authors also observed that although there were no effects on the ability of crabs to find food, those undertaking feeding were more likely to suspend feeding activity following exposure. Also, crabs exposed to the former took longer to return to shelter than those experiencing ambient sound playback (Wale et al. 2013).

It is unlikely that deep-sea invertebrates on the seabed at 3000 m water depth will be exposed to sound from the mobile offshore drilling unit causing mortality or physiological effects. It could be possible that behavioural effects could occur, but this is untested in the literature and limited to close range (<200 m) laboratory-based studies. The well location is in an area already used by shipping (including large container vessels with source levels similar to that of the mobile offshore drilling unit (>190 dB re 1 µPa at 1 m, Popper et al. 2014), albeit at lower shipping densities than the shallower waters of the Great Australian Bight. The deep-sea invertebrate populations known to be found in the vicinity of the well location occur at low densities and are well represented in surveys and literature across the Great Australian Bight provincial bioregion.

The predicted consequence for invertebrate species (including commercially important species) from vertical seismic profiling and mobile offshore drilling unit operations is Category 1–3 with very limited impacts (restitution time <1 month) on deep-sea invertebrate populations and the local ecosystem.

6.3.3.4 Impacts to fish and fisheries

Fish species that may occur in the vicinity of the well location comprise deep-sea species (e.g. rattails, cusk eels, morid cods, halosaurs) and transient pelagic fish species (southern bluefin tuna, blue sharks, great white sharks). There are no Biologically Important Areas for fish species that overlap the Impact Environment that May Be Affected, with the closest being the great white shark Biologically Important Areas for distribution and foraging (see Section 4.6.4.3), which are located >200 km from the Stromlo-1 well development.

Of the species of commercial importance caught off southern Australia, only southern bluefin tuna may occur within the Impact Environment that May Be Affected at the time of drilling in significant numbers during their annual migration to the inner shelf waters. Sound pollution is identified as a pressure of "potential concern" for southern bluefin tuna due to potential broad-scale disruption of migratory behaviour. Juvenile (2–4 years old) southern bluefin tuna undertake large seasonal migrations, typically departing the Great Australian Bight between March and July and returning to feed in the Great Australian Bight between November and March (see Figure 4.31). Juvenile southern bluefin tuna are largely concentrated in inshore shelf waters or around the shelf break across the Great Australian Bight (see Figure 4.31), during the period in which the Stromlo-1 drilling activities could occur (between October and May). Outside of this period, juvenile southern bluefin tuna do not appear to have preferred depth/habitat, with the limited number of southern bluefin tuna that remain in the Great Australian Bight during winter tending to concentrate around the shelf break (Evans et al. 2017). It is therefore possible that southern bluefin tuna could be present in the vicinity of the well location during their annual migration to inner Great Australian Bight waters; however, this will be limited to relatively low numbers due to the preference for habitat inshore of the continental shelf break.

Mobile offshore drilling unit operations

Southern bluefin tuna have a swim bladder that is not involved in hearing and so they are less sensitive to underwater sounds than fish with swim bladders connected to their auditory system; they are therefore unlikely to be adversely affected by exposure to the continuous sound source of the mobile offshore drilling unit thrusters (Popper et al. 2014). However, taking a conservative approach to the impact assessment hearing thresholds, for fish species that are considered "pressure sensitive" (i.e. swim bladder is involved in hearing/pressure detection) has been applied to the assessment for southern bluefin tuna. Based on the application of this more conservative assessment, it is therefore possible that migrating fish could experience recoverable injury or temporary threshold shift within 600–1900 m of the mobile offshore drilling unit (Table 6.16). These effects are predicted from an accumulated 24-hour exposure period and is based on the fish not swimming away from the source, which is considered highly conservative (Popper 2018), particularly for a transient species migrating through the Environment that May Be Affected. It is not realistic to assume that fish would remain stationary for the exposure duration (24 hours) and not swim away from the source. In addition, any effects are expected to be fully recoverable. Further, application of the more conservative cumulative sound exposure level temporary threshold shift criteria established by Popper et al. (2014) for fish with swim bladders involved in hearing adds another layer of conservatism to the predicted impact range of 600 m to 1.9 km. Consequently, the resulting recoverable injury and temporary threshold shift impact ranges should be treated as a conservative estimate.

No medium or long-term impacts predicted to fish or fish populations from sound levels associated with the mobile offshore drilling unit. It is possible that there will be a high risk of behavioural disturbance within tens of metres of the mobile offshore drilling unit, some moderate level effects within hundreds of metres and low-level effects >1000 m (Popper et al. (2014)); but the effects will be short term and transitory as fish pass within these distances and recover as soon as they move beyond these ranges. No effects on migration or changes to migratory patterns/routes are predicted because only a very small proportion of the broad migratory pathway will be affected. Once fish have moved >1.9 km away from the mobile offshore drilling unit, fish are likely to resume normal behaviour and distribution within the area.

Impacts of sound on small pelagic fish species

The small pelagic fish species in the Great Australian Bight are aggregated around upwelling areas along the shelf break and shelf and coastal waters. These aggregations and fished areas are hundreds of kilometres from the Stromlo well location and as such sound from the mobile offshore drilling unit will not cause injury, TTS or changes in behaviour of small pelagic fish species. No further assessment is reasonable.

Impact of sound on deep sea fish species

The latest research from the Great Australian Bight Research Program showed that the deep sea fish assemblage was sparse in water depths between 2000 and 3000 m in the central Great Australian Bight where the Stromlo-1 well location lies. The average number of benthic deep sea fish species at each site was between five and eight, and the average biomass of these species was low at just over 1 g/m^2 (Figures 8.4 and 8.5 of Williams et al. 2017).

The sound modelling conducted for the impact assessment (Appendix 6-1 in the EP (Rev 1)) predicted the maximum distance from the source where underwater sound levels would exceed the threshold for recoverable injury to potential mortality to fish is <75 m, and the distance to the threshold for inducing TTS is an average of 1 km and a maximum of 1.9 km (Table 6.3) from the acoustic source. The seabed under the mobile offshore drilling unit is further than these threshold distances and therefore, in the drilling depth of 2240 m adverse effects of underwater sound on benthic fish are not predicted.

Vertical seismic profiling operations

The sound modelling does not predict mortality, potential mortality, recoverable injury or temporary threshold shift as a result of sound from vertical seismic profiling operations in any fish species with or without a swim bladder (Table 6.15). The closest range at which the model calculates distances to thresholds is 150 m due to the scale at which the model was run. It is therefore possible that there could be a range of effects up to 150 m from the vertical seismic profiling source, which could include injury, recoverable injury and temporary threshold shift. However, based on the expert review carried out by Popper (2018), it is highly unlikely that there would be physical damage to fishes as a result of a seismic survey unless the animals are very close to the source (perhaps within a few metres), with temporary threshold shift being the most likely (if any) level of effect.

Popper (2018) further concludes that if temporary threshold shift does take place, the duration of exposure to the most intense sounds that could result in temporary threshold shift will be over just a few hours, and therefore, accumulation of energy over longer periods than a few hours is probably not appropriate. If temporary threshold shift takes place, Popper (2018) concludes that it is likely to be sufficiently low that it will not be possible to easily differentiate it from normal variations in hearing sensitivity, with recovery within 24 hours. Any fish species that occurs with 150 m of the vertical seismic profiling could experience temporary threshold shift, but effects are recoverable as soon as the fish swims away from the stationary vertical seismic profiling source. Further due to the short-term nature of the vertical seismic profiling operation (24 hours), the potential for exposure of migrating fish to levels that could cause temporary threshold shift within 150 m of the source is further reduced.

It is possible that there may be a high risk of behavioural disturbance within tens of metres of the vertical seismic profiling operations and the potential for some moderate level effects within hundreds of metres, with a low risk of disturbance >1000 m (Popper et al. 2014). Any effects are expected to be short-term and limited to duration that the fish is exposed to the source, which for a pelagic (free swimming) species would be limited to the time taken for the fish to swim away from the source. At a distance of >1000 m there is a low risk of behavioural disturbance to fish species. The duration of the vertical seismic profiling activity is <24 hours which again limits the exposure of fish to levels that could cause disturbance. There are no commercially or biologically important demersal fish stocks within 1000 m of the well location.

Modelled vertical seismic profiling received sound levels predict a possible behavioural avoidance response in fish of up to 1.9 km when compared with the level (173 dB sound pressure level peak) at which McCauley et al. (2000) recorded a strong behavioural avoidance response in fish exposed to seismic. This level, while not a threshold, presents a highly conservative predicted distance for behavioural disturbance as the vertical seismic profiling will only be operated for a maximum of 24 hours for each of the two operations, and so any effects on fish behaviour will not only be limited in spatial scale but will also be temporary (short term). No effects on migration or migratory patterns/routes is predicted.

The predicted consequence for fish species (including commercially important species) from vertical seismic profiling and mobile offshore drilling unit operations is Category 1–3 with very limited impacts (restitution time <1 month). No medium or long-term effects are predicted for fish species as a result of vertical seismic profiling operations. No effects on key biological process, e.g. migration patterns, are predicted for commercially important species, such as southern bluefin tuna.

Table 6.16 Summary of modelled impact ranges for vertical seismic profiling and mobile offshore drilling unit operations for fish (including sharks)

Source	Fish group	Exposure level	Description	Predicted impact distance
Mortality, potential mortality, recoverable injury				
VSP	Fish: No swim bladder (also applied to sharks)	213 dB re 1µPa (SPL peak)*	Mortality and potential mortal injury / recoverable injury	Threshold not reached
VSP	Fish: Swim bladder not involved in hearing	207 dB re 1µPa (SPL peak)*	Mortality and potential mortal injury / recoverable injury	Threshold not reached
VSP	Fish: Swim bladder involved in hearing			
MODU	Fish: All groups	207 to 213 dB re 1µPa (SPL peak)*	Mortality and potential mortal injury / recoverable injury	<75 m (max)
MODU	Fish: Swim bladder involved in hearing	170 dB re 1µPa (SPLrms)*	Recoverable injury	600 m (average) 1 km (max)
Impairment: TTS				
VSP	Fish: All groups (no swim bladder, swim bladder not involved in hearing, swim bladder involved in hearing)	186 dB re 1 μPa^2.s (SELcum)*	TTS	Threshold not reached
MODU	Fish: Swim bladder involved in hearing	158 dB re 1µPa (SPLrms)*	TTS	1 km (average) 1.9 km (max)
MODU	Fish: All groups			

*Source: Popper et al. 2014

Impacts to fisheries

Some fishers believe there is a longer-term effect on fish catchability or presence in fished areas; but it is not possible to separate possible seismic survey effects out from confounding factors such as fishing pressure, climatic changes and variation in natural population dynamics. A series of studies have been undertaken to determine the effects of seismic surveys on fish catches and distribution, primarily in the United States and Europe (e.g. California: Greene 1985; Pearson, Skalski & Malme 1992; Norway: Dalen & Knutsen 1986; Løkkeborg & Soldal 1993) and the United Kingdom (Pickett et al. 1994). While the conclusions from these studies are largely ambiguous, due to the inherently high levels of variability in catch statistics, one study noted that pelagic species appear to disperse, resulting in a decrease in reported catches during the surveys (Dalen & Knutsen 1986).

In 2015, the potential impact on the catchability of commercially important fish species was investigated using a 2D seismic survey in the Gippsland Basin, Bass Strait, to quantify fish behaviour and commercial fisheries catch across the region before and after acoustic source operations (Bruce et al. 2018). Acoustically tagged species (gummy shark, swell shark, tiger flathead) were monitored before, during and after the seismic survey and little evidence of consistent behavioural responses was found except for flathead, which increased their swimming speed during the seismic survey period and changed their diel movement patterns after the survey (Bruce et al. 2018). Modelling of logbook data for 15 commercially fished species and two gear types (Danish seine, gillnet) showed that catch rates following the seismic survey were significantly different than predicted in nine out of the 15 species, with six species (tiger flathead, goatfish, elephantfish, boarfish, broadnose shark and school shark) showing increases in catch following the seismic survey, and three species (gummy shark, red gurnard, and sawshark) showing reductions (Bruce et al. 2018).

Of the Commonwealth and state-managed fisheries identified in Section 4.7 with jurisdictions that overlap the Stromlo-1 well location, there are no fisheries known to be actively operating within the Environment that May Be Affected, nor likely to within the time frame of the Stromlo-1 activity (Section 9.0). There are also no aquaculture operations for southern bluefin tuna within the Environment that May Be Affected, with the nearest grow-out cages located offshore of Port Lincoln, >400 km from the well location (see Section 2.0). However, as stated above it is possible that southern bluefin tuna could migrate through waters in the vicinity of the well location, though migration would be limited to relatively low numbers of mostly juveniles due to the preference for habitat inshore of the continental shelf/shelf break.

Mobile offshore drilling unit operations could cause temporary, and recoverable, effects on migrating tuna within 1.9 km of the well location, which is the largest disturbance range predicated by the sound modelling for both mobile offshore drilling unit and vertical seismic profiling operations. However, this is based on an accumulated 24-hour exposure period, which is considered highly conservative and unrealistic. If temporary threshold shift is experienced, the level would be low, and recovery would occur within 24 hours (Popper 2018). Further, it is likely that, being free swimming fish, southern bluefin tuna would swim away from the source. It is unlikely that they would remain stationary for the 24-hour duration of exposure. Consequently, migration pathways for southern bluefin tuna are highly unlikely to be affected by sound levels generated by mobile offshore drilling unit or vertical seismic profiling operations, and while some small deviation may occur of up to 1.9 km from the mobile offshore drilling unit, there is no expected ensuing impact to migration pathways of southern bluefin tuna to and from the Great Australian Bight.

The predicted impact on fish species (including commercially fished species) as a result of both vertical seismic profiling and mobile offshore drilling unit operations is minor and limited to short-term behavioural disturbance impacts to any migrating individuals within 1.9 km of the well location and a restitution (recovery) time commencing within 24 hours for individuals and within days to weeks for fish populations. No population level effects are expected for commercially important fish or invertebrates and no impacts are predicted for the fisheries that overlap the Impact Environment that May Be Affected because any localised effects will be short-term and will not directly or indirectly affect catch rates for commercially important species.

Impacts to spawning

Key target species for commercial fisheries that overlap the Impact Environment that May Be Affected are described in Section 4.7 and their spawning seasons and habitats (and/or depth ranges) for spawning are described in Table 4.4 and Table 4.5. Based on the known seasons and habitats/depths over which commercially important fish species spawn, it is unlikely that there are any species that spawn within the Environment that May Be Affected over the proposed duration of the drilling activity.

It is possible that some deep-sea fish species with no commercial value could spawn in the Impact Environment that May Be Affected at the time of the survey, but it is unlikely that there will be any medium to long-term effects on fish populations. There is no predicted mortality or potential mortality to fish eggs and larvae based on the Popper et al. (2014) threshold (see Section 2.0). It is possible that some mortality of plankton could be expected within an area of 1.5 km of the well location if compared with the received level that caused mortality in the McCauley et al. (2017) study; however, it not appropriate to conclude there will be complete mortality of plankton over the entire area based on a single study, due to the limitations Richardson et al. (2017) report on the McCauley et al. (2017) survey parameters, i.e. shallow waters and no account of diel vertical migration.

Based on the research to date, there are not enough data to confidently define zones of impact for planktonic organisms, including the eggs and larvae of fish and crustaceans. Although McCauley et al. (2017) recently suggested that the zone of impact for zooplankton may be two orders of magnitude higher than previously thought, there is still evidence that for certain components of the plankton effects are likely to be limited to <10 m. Further, for many components of the zooplankton and phytoplankton, recovery is expected to be rapid (in the order of days), so the effects are expected to be limited and to be within the range of natural variability. Richardson et al. (2017) showed that zooplankton communities can begin to recover during the survey period during periods of good oceanic circulation (and periods of upwelling), and therefore a continuous decline is zooplankton throughout the survey period is not anticipated and parts of the survey are would progressively recover during the survey.

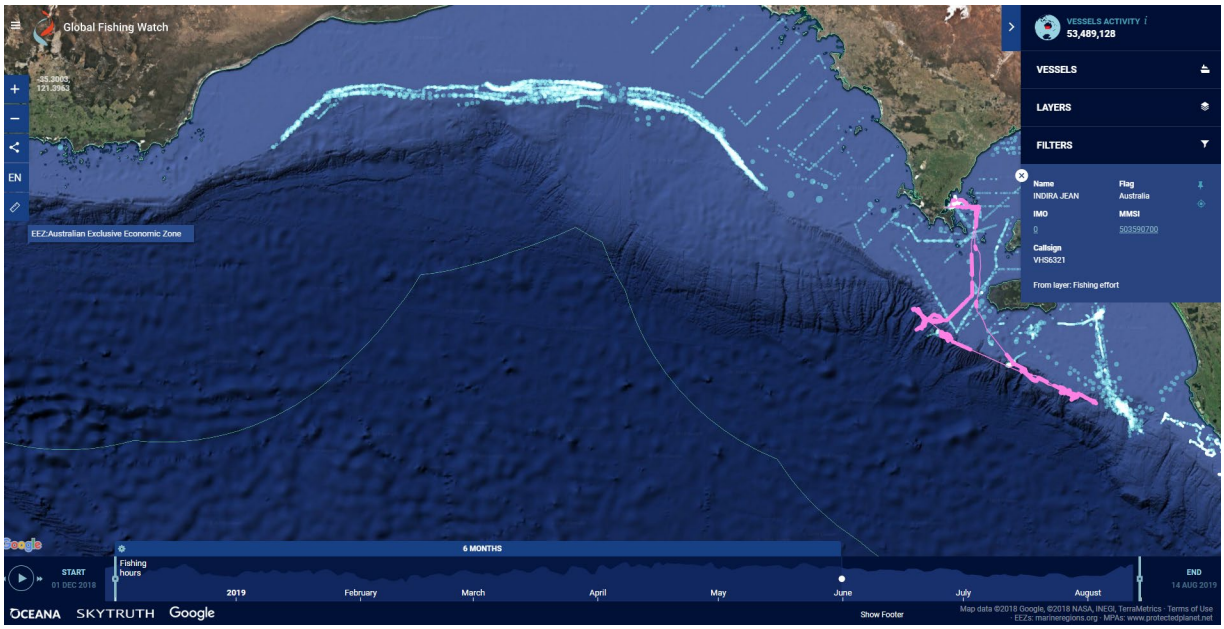
The potential mortality of larval fish that rely on zooplankton for food is difficult to predict but is not expected to affect a significant proportion of larvae based on the assumption that not all zooplankton are killed by exposure to acoustic sources (around 22% to 35%, depending on ocean circulation; Richardson et al. 2017), only a very small proportion of the plankton would be exposed at any one time, and that zooplankton populations are likely to begin to recover rapidly following completion of a seismic survey due to fast growth

rates, combined with dispersal and mixing of zooplankton from both within and without the area of effect. It is unlikely there would be localised patches of reduced food availability for plankton feeders over the period of the survey and during the three-day recovery period as modelled by Richardson et al. (2017).

The predicted consequence for fish spawning as a result of the vertical seismic profiling is Category 1–3 with very limited impacts on fish populations, commercial fisheries and catch rates and a restitution (recovery) time <1 month for fish populations. The densities of commercially important crustacean larvae, particularly lobsters and deep-sea crabs, are expected to be very low in the area of ensonification because the larval populations will be highly dispersed. The sound generating activities are not predicted to have any discernible effect on the populations, stocks, recruitment or catchability of fin fish or crustaceans.

Impacts of sound on southern bluefin tuna in towed pontoons/nets

In order to assess the potential impacts of sound from the mobile offshore drilling unit on tuna towed in cages Equinor Australia B.V. requested the routes along which the cages are towed from fished areas to ranching areas. However, Australian Southern Bluefin Tuna Industry Association did not provide this information and as a result data on vessel movements was sought from the website https://globalfishingwatch.org. Data on fishing vessel movements from 1 December 2018 to June 2019 (Figure 6.3) showed the movements of fishing vessels from Port Lincoln operating along the shelf break in the Great Australian Bight. The actual activities of the fishing vessels are unknown; however, the data coincided with the southern bluefin tuna juvenile tuna catching season which started in December 2018 and pink highlighted vessel below is a southern bluefin tuna boat involved in ranching grow-out and therefore must tow its catch to the holding pens. It is likely this and other vessels were engaged in fishing and towing fish to ranching areas. None of these vessels were recorded within 200 km of the drilling location.



(Global Fishing Watch)

Figure 6.3 Fishing vessel activity 1 December 2018–1 June 2019

At these distances from the mobile offshore drilling unit, sound levels are expected to be well below those capable of inducing a behavioural response in fish. Sound levels reaching tuna towing routes and holding pens, from the distant mobile offshore drilling unit, are predicted to be lower than the sound levels generated by the proximate tuna vessel towing the nets.

Modelling of sound from the mobile offshore drilling unit undertaken for this Environment Plan shows that at 25 km from the mobile offshore drilling unit sound levels are predicted to be around 138 dB re 1µPa^{2}s (Figure 15 sound modelling appendix). In comparison, in-field measurements of whale watching monohull vessels (similar size, class and propulsion source as tuna fishing vessels) have been shown to produce sound levels of 148.6 dB re 1µPa^{2}s (Jasco 2018, Port of Vancouver whale watching study). Therefore, at distances of hundreds of kilometres from the mobile offshore drilling unit, the level of sound experienced by tuna in cages is unlikely to be higher than the sound levels emitted by the tuna vessels towing the cages.

6.3.3.5 Impacts to marine turtles

The Recovery Plan for Marine Turtles identifies sound pollution as a threat of potential concern for green, leatherback and loggerhead turtles, but there are no critical habitats or Biologically Important Areas for these species within the Impact Environment that May Be Affected or the Great Australian Bight and so their presence would only be transient and limited to individuals passing through the area.

The majority of the limited studies looking at the effect of seismic sound on marine turtles have focused on behavioural changes and responses as physiological damage is more difficult to observe in living animals. Studies carried out by (Lenhardt 1994) showed that marine turtles increased their movements after seismic sound emissions and did not return to the depth at which they usually rested. De Ruiter and Doukara (2010) observed turtles during active seismic operations and recorded startle responses (rapid dive) to the seismic emissions; 51% of turtles dived at or before their closest point of approach to a seismic source. However, they could not distinguish the stimulus source of the startle response, as they did not perform a control without the seismic stimulus (De Ruiter & Doukara 2010). McCauley et al. (2000) conducted controlled experiments on a caged loggerhead turtle and a caged green turtle and at exposure to sounds from seismic sources louder than 175 dB re 1 µPa SPLrms the turtles actively swam away from the source.

Modelled received sound levels for the vertical seismic profiling operations were used to predict impact ranges compared with peer-reviewed guidelines and published levels (see Table 6.16). The sound modelling did not predict mortality or potential mortal injury in turtles as a result of vertical seismic profiling operations. Strong avoidance behaviour is predicted up to a maximum of 1.6 km from the well location. Such behavioural changes are expected to be limited to transient individuals only lasting for the duration of the vertical seismic profiling operation (<24 hours) with normal behaviour anticipated to resume when the vertical seismic profiling has ceased. Any disturbance will be limited to avoidance response followed by rapid resumption of normal activity.

There are no thresholds or reported levels to compare sound exposure levels from mobile offshore drilling unit thruster operations, but as turtles hear at low frequency ranges (e.g. 100 Hz to 900 Hz) (Ketten & Bartol 2010), the outcomes of the modelling for vertical seismic profiling have been applied. Any transiting marine turtles may therefore actively avoid the mobile offshore drilling unit/well location by up to 1.6 km for the duration of the drilling campaign. However, given that there are no known areas of importance or critical habitats for marine turtles within the Impact Environment that May Be Affected or within 200 km of the Impact Environment that May Be Affected, there are no predicted population level effects as any localised effects will be limited to transiting individuals and will be short term.

The predicted impact on marine turtle species as a result of both vertical seismic profiling and mobile offshore drilling unit operations is Category 1–3 and limited to short-term behavioural disturbance impacts to any transiting individuals within 1.6 km of the well location and a restitution (recovery) time <1 month for marine turtle populations.

Table 6.17 Summary of modelled vertical seismic profiling impact ranges for marine turtles

Guideline description	Guideline / published comparison level	Impact range (max)
Mortality and potential mortal injury (Popper et al. 2014)	>207 dB peak SPL	No exceedance
Behaviour: strong avoidance (McCauley et al. 2000)	>175 dB SPLrms	1.6 km

6.3.3.6 Impacts to cetaceans

Marine mammals that could be present within the Impact Environment that May Be Affected include migrating and transient baleen whales (pygmy blue, southern right whales) and toothed whales (sperm whales). Species of cetacean that could occur infrequently within the Impact Environment that May Be Affected include humpback, fin and sei whales. There are no critical habitats or Biologically Important Areas for these cetacean species within the Impact Environment that May Be Affected, with the exception of the pygmy blue whale Biologically Important Area for distribution/migration (see Figure 4.35).

Foraging Biologically Important Areas for pygmy blue and sperm whales are based around the continental shelf and slope, associated with upwelling events in the region, and located >100 km from the well location at their closest points. The timing of the upwellings is variable, but pygmy blue whales are known to feed

within their foraging Biologically Important Area (from Robe, South Australia to Cape Otway, Victoria) from November to May, although their presence in the eastern Great Australian Bight is generally around November to December as they move eastwards into the Otway Basin in January (Gill et al. 2011). Sound loggers deployed at the shelf break and at the Head of Bight in late 2011 by McCauley et al. (2012) for BP p.l.c.'s Ceduna 3D seismic survey, recorded pygmy blue whale vocalisations. Antarctic blue whales were detected from the shelf break during winter, but their calls were thought to have originated in deeper southern waters of the Antarctic (McCauley et al. 2012).

Sperm whale presence/feeding is located around the submarine canyons off southern Australia. Although not seasonal in occurrence, observations made during the Great Australian Bight research program studies identified that sperm whale presence was more frequent in August–September. Bailleul et al. (2017) modelled sperm whale observations and identified a strong relationship between submarine canyons and areas of high densities of sperm whales. The results support that the deep waters of the well location and the Impact Environment that May Be Affected are not in an area predicted for high densities of sperm whales (see Figure 4.40).

Southern right whales migrate annually from southern feeding grounds (below 40°S) to breed, calve and rest in coastal waters (mostly within 2 km of the shoreline) in southern Australia from May to October (DSEWPaC 2012; Charlton et al. 2014). In 2017 the Australian population was estimated to be approximately 2500 (Bannister 2018). The closest aggregation and calving location is the Head of the Bight in South Australia, which lies >250 km north of the well location at its closest point, and to which approximately 25%–40% of the south-western population is known to visit (Charlton 2017, Burnell 2001). Although most southern right whale activity occurs in close proximity to the coast, a study by Mackay et al. (2015) has tracked tagged southern right whales leaving the Head of the Bight aggregation site and migrating southwards between September and October 2014 (see Figure 4.38). It is therefore possible that southern rights could travel through the Impact Environment that May Be Affected between their southern foraging grounds and aggregation/calving areas off the southern Australian coast.

It is possible, though unlikely, that two high-frequency cetaceans (*Kogia* spp.), pygmy sperm whales and dwarf sperm whales, could occur in the deep offshore waters off southern Australia over the continental shelf and slope to deeper waters beyond the edge of the continental shelf (see Section 4.6.6.1). However, little is known of their distributions and only one sighting for dwarf sperm whales has been made in Australian waters (Department of Environment and Energy 2018). It is unlikely that these species will be present in the Impact Environment that May Be Affected, and if so, it is reasonable to assume that their occurrence would be limited to transiting individuals on their way to feeding areas over the submarine canyons off the continental shelf/shelf slope.

Table 6.18 summarises the average and maximum impact ranges (distances) predicted by the modelling of mobile offshore drilling unit and vertical seismic profiling sound levels. The average and maximum impact ranges are given as sound field footprints often irregular in shape, i.e. the sound level contour might have small protrusions or isolated fringes, where relatively few points are excluded in any given direction. These are influenced by pockets of coherently focused sound that are not physically expected to occur. In these cases, the maximum distance can misrepresent the extent of the area exposed to such effects (i.e. permanent threshold shift, temporary threshold shift, behavioural disturbance). However, the maximum may better represent an area of effect in specific directions such as for large propagating distances in the offshore direction. In the inshore direction the average is likely more representative of the extent of potential effects, and in the offshore direction the maximum is used to define the extent.

The effect zone for ensonification (i.e. Impact Environment that May Be Affected) is conservatively defined as the area extending a distance of 40 km around the Stromlo-1 well location. Equinor Australia B.V. has taken a conservative approach in defining the Impact Environment that May Be Affected as a 40 km radius which encompasses the largest area of ensonification for marine fauna (i.e. 25 km for temporary threshold shift/recoverable effects in low frequency cetaceans from mobile offshore drilling unit operations). This area of ensonification is considered more than adequate because it encompasses all physiological and behavioural disturbance effects to all marine fauna considered within this Environment Plan assessment, both at the seabed, sea surface and in the water column (Table 6.18).

Mobile offshore drilling unit operations

This assessment of the impacts on blue whales and southern right whales from exposure to sound emissions from the mobile offshore drilling unit is based on the most likely realistic scenario and evidence from peer-reviewed scientific literature that these species will exhibit a behavioural response and move away from the MODU sound source before it reaches injurious levels.

Blue whales are known to migrate through the permit area, but in very low densities (GABRP studies) and the Impact EMBA overlaps with the blue whale distribution BIA. The permit area is not a known resting, calving or feeding ground for either of these species (TSSC 2015a (blue whale conservation management plan) and TSSC 2015b (southern right whale conservation management plan)). Therefore, if they are present during the drilling activity, they will likely be transiting through the Impact EMBA to/from feeding grounds in the Southern Ocean, and are not expected to remain in the Impact EMBA and be exposed to sound from the activity for longer than it takes to migrate through the area. The data from a tagging study of blue whales shows that migrating individuals can travel 50 to 100 km per day (Double et al, 2012). This equates to an average swimming speed of 2-4 km/hr over a 24 hr period. A tagging study of southern right whales found that individuals have a maximum swimming speed of 7.2 km/hr, with one of the individuals studied moving through the GAB region (Childerhouse et al, 2010). Finally, Mate et al (1997) found that tagged northern right whales had a mean migration speed of 3.5 km/hr. Based on this evidence and for the purpose of this impact assessment it is assumed that blue whales and southern right whales migrating through the permit area are reasonably likely to be traveling at a mean speed of 3 km/hr.

Blue whales and southern right whales are expected to respond behaviourally to avoid the MODU once a relevant sound threshold is reached. There is considerable evidence that low frequency hearing cetaceans show avoidance behaviour when exposure to anthropogenic sound. McCauley et al (1998) reported humpback whales began avoidance manoeuvres in response to seismic generated sound at 159 dB re 1µPa2 and general avoidance was observed at 168 dB re 1µPa2. Similarly, humpback whales (adults and calves) exposed to seismic sound (135 dB re 1µPa2) during the Behavioural Response of Australian Humpback whales to Seismic Surveys (BRAHSS) project showed a behavioural response where females and calves slowed speed on their southern migration down the east coast; however the response was also observed in control trials when the seismic source was not operational, suggesting the response was in reaction to the presence of the seismic vessel (Dunlop et al 2015). Goldbogen et al (2013) showed that blue whales changed orientation and horizontal displacement in response to exposure to simulated mid-frequency sonar sound. The study found that blue whales feeding on deep, dispersed prey were more likely to change diving behaviour and avoid sonar sources than whales feeding at shallow depths on highly concentrated prey (Goldbogen et al. 2013). Southall et al (2016) also showed that baleen whales showed directional avoidance of a stationary sonar sound source and were more likely to do this if there was not a concentrated food source present; this is relevant to the central GAB where there are no prey aggregations.

Based on this peer reviewed evidence, it is reasonable to predict that blue whales and southern right whales will respond behaviourally to avoid sound emissions from the mobile offshore drilling unit. A study investigating of the effectiveness of acoustic deterrent devises (ADDs) (as a mitigation tool) demonstrated that the ADDs were effective in changing cetacean swimming direction and speed so that animals avoided the ensonified area (McGarry et al. 2017).

The figure below (Figure 6.4) shows the predicted maximum ensonified field around the mobile offshore drilling unit under maximum operating conditions based on the modelling predictions figures in Table 6.18 for low frequency cetaceans.

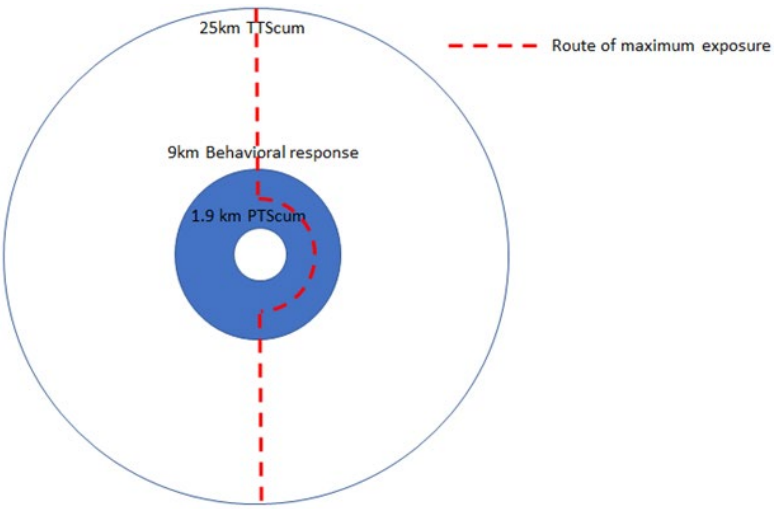


Figure 6.4 Predicted maximum ensonified field around the mobile offshore drilling unit

The red dotted line is the theoretical path of a migrating whale based on the reasonable expected behavioural response and the route that would result in the maximum exposure to sound emitted from the mobile offshore drilling unit. The path conservatively assumes that at the mid-point of the behavioural response zone (which is predicted to extend up to 9 km from the mobile offshore drilling unit sound source), that whales will alter their migratory path to avoid the sound source, swim at this distance around the mobile offshore drilling unit and then continue on; to represent the maximum time spent within the TTScum zone. Based on this maximum theoretical path, the distance travelled while in the TTScum zone is 54.3 km. With a mean migratory travel speed of 3 km/hr, the maximum duration that a whale would be exposed to received sound levels that could cause responses ranging from behavioural avoidance to onset of TTS is 18.1 hrs. An animal moving through the 25 km predicted TTS onset zone would not necessarily receive sound levels causing TTS as the 25 km zone is based on a cumulative dose of TTS over 24 hours. Animals already within the 25 km zone at the commencement of sound exposure (i.e. start-up of mobile offshore drilling unit thrusters) could be exposed to TTS onset levels over a shorter period of time. As such, it is possible that migrating whales passing within 25 km of the mobile offshore drilling unit could develop a temporary shift in hearing ability, however due to the absence of areas that could be important for foraging, breeding or aggregating, and the absence of any constricted migratory corridor, there is no motivation for whales to remain in an area where a behavioural disturbance response or onset of TTS is predicted.

Importantly, PTS injury is highly unlikely to be induced for the following reasons:

1. Based on the literature, a whale is highly unlikely to swim into the PTScum zone because the animal would need to travel a distance of 7.1 km from the edge of the predicted behavioural disturbance zone to the edge of the predicted PTScum zone.
2. At no point around the mobile offshore drilling unit will sound levels be high enough to cause instantaneous PTS.
3. There are no important areas for foraging, breeding, aggregation in the Impact EMBA for any cetacean species (including blue and southern right whales), and therefore there is no motivation for whales to remain in ensonified areas that would otherwise elicit behavioural avoidance of the area.

The energetic cost of avoiding the mobile offshore drilling unit is likely to be small in the context of the greater migratory movements of whales migrating through the area. The radius of the behavioural effect zone is 9 km and a whale avoiding this will only alter its path by a few tens of kilometres at worst over a migration of thousands of kilometres. Further, there is no constriction to the width of the migratory corridor and animals are not confined to migrating through a narrow corridor to reach the Southern Ocean or Australian feeding grounds. Therefore, this level of change is highly unlikely to alter the overall energy budget of whales migrating through the impact EMBA. Importantly, this is highly unlikely to displace blue whales from their distribution BIA due to the very small geographical scale of potential effects on behaviour relative to the broader and very large spatial extent of the BIA.

Goldbogen et al. (2013) and Southall et al. (2016) highlight the importance of behavioural state of an animal in response to acoustic stimuli, where foraging behaviours may motivate an animal to remain in an ensonified area.

Following on from these studies where behavioural responses (avoidance and remaining to feed) have been observed in response to acoustic disturbance, researchers modelled the effects of disturbance in cetaceans to determine if there are impacts at a population level. Pirotta et al. (2019) modelled the population consequence of disturbance for North Pacific blue whales to investigate spatial and temporal patterns of behaviour and reproduction in response to changes in environmental conditions and to anthropogenic disturbance. The study found that disturbance was only predicted in areas that are important to the blue whales for foraging and that animals moving over great distances (migrating) are more resilient to anthropogenic disturbance than those in a small area / habitat footprint (feeding). The Stomlo-1 well and wider Impact EMBA area not in an area of importance for cetaceans (i.e. foraging, breeding, aggregating) and so blue and southern right whales in transit through the Impact EMBA to/from the Southern Ocean transiting are not motivated to stay in the ensonified zone around the mobile offshore drilling unit.

Dynamic-positioning acoustic transducer (DP-AT) operations

Low-frequency cetaceans: The impact assessment of noise emitted from the DP-AT is based on the same logic and supporting literature as that used in the impact assessment of noise from the MODU. Cetaceans which hear best in the low frequency range and which may travel through the ensonified area (particularly pygmy blue whales and southern right whales) are expected to respond behaviourally to sound from the MODU thrusters not to be exposed to injurious sound from the DP-AT. Migrating whales are predicted to avoid the area ensonified by the thrusters at 9 - 17 km (non-impulsive sound exceeding 140 dB re 1 µPa

SPL) around the MODU and therefore avoid exposure to higher levels of sound nearer the DP-AT which may cause PTS (3.6 km) or TTS (6.7 km) if they remain in the area for an extended period.

PTS injury to low-frequency cetaceans from transponder noise emissions is highly unlikely for the following reasons:

1. Based on the literature, a whale is highly unlikely to swim into the zone where it could accumulate sufficient exposure to sound energy to suffer PTS (SELcum24) because the animal would need to travel a distance of approximately 5.4 – 13.4 km into the zone of predicted behavioural disturbance to reach the area where it could accumulate this amount of sound energy and would need to stay there for 24 hrs (Figure 6.5)
2. Even if a migrating whale does not avoid the area around the MODU where sound exceeds the behavioural disturbance threshold, at an average swimming speed of 3 km/hr a whale will spend less than 24 hours transiting the zones where it could accumulate an injurious level of DP-AT sound (inside the 24 hour cumulative exposure threshold isopleth).
3. The DP-AT source is impulsive and non-continuous which means the total accumulated sound energy will be much lower than for a continuous source of the same output
4. At no point around the mobile offshore drilling unit will sound levels from DP-AT be high enough to cause instantaneous PTS
5. There are no important areas for low-frequency cetacean foraging, breeding, aggregation in the Impact EMBA (including blue and southern right whales), and therefore there is no motivation for whales to remain in ensonified areas that would otherwise elicit behavioural avoidance of the area around the MODU.

High- and mid-frequency cetaceans: The DP-AT system emits more sound energy in the higher frequency bands (> 21 kHz) and therefore the effects distances for high and mid-frequency cetaceans can be expected to be greater than in the low frequencies; however high frequency sound attenuates faster, thereby reducing this effect.

For high-frequency hearing cetaceans the distance at which a behavioural effect could occur (9–17 km) overlaps the range at which TTS (max 15.2 km) or PTS (max 11.6 km) could occur from cumulative sound exposure (SELcum24 thresholds). This is most likely an artefact of thresholds being based on different frequency ranges. The TTS and PTS SELcum24 thresholds are weighted for hearing frequency range, while the behavioural threshold is unweighted. It stands to reason that for high and mid-frequency hearing cetaceans, the behavioural threshold also propagates further, however this granularity of thresholds has yet to be developed (NMFS 2018). Nevertheless, PTS or TTS through cumulative exposure to impulsive DP-AT sound, are highly unlikely to occur for the following reasons:

1. A high-frequency cetacean moving through the drilling area at an average speed of 3 km/hr will have moved through the area many hours before the 24 hrs of exposure required to elicit a PTS or TTS response. Even if shorter exposure to higher levels of sound may elicit a PTS or TTS response, a whale migrating through the area within the PTS (SELcum24) zone, at a travel speed of 3 km/hr, will only be within the PTS (SELcum24) zone for 9.45 hrs. Significantly less than the 24 hrs that the threshold is based on (Figure 6.6).
2. A mid-frequency hearing whale is highly unlikely to swim into the zone where it could accumulate sufficient exposure to sound energy to suffer PTS (SELcum24). It would need to travel a distance of approximately 4.1 km into the zone of predicted behavioural disturbance to reach the area where it could accumulate this amount of sound energy to induce PTS and would need to stay there for 24 hrs (Figure 6.7)
3. The DP-AT source is impulsive and non-continuous which means the total accumulated sound energy will be much lower than for a continuous source of the same output
4. At no point around the mobile offshore drilling unit will sound levels from the transponders be high enough to cause instantaneous PTS.
5. The expected densities of high frequency whales such a *Kogia* spp. sperm whales in the area that transponders will ensonify would likely be very low and they may not even be present during the drilling activity because they prefer shelf-edge canyon habitats; hundreds of km from the MODU location.

The expected effects on the energetics for high frequency hearing whales avoiding the transponders is expected to be inconsequential in the context of their broader movement patterns.

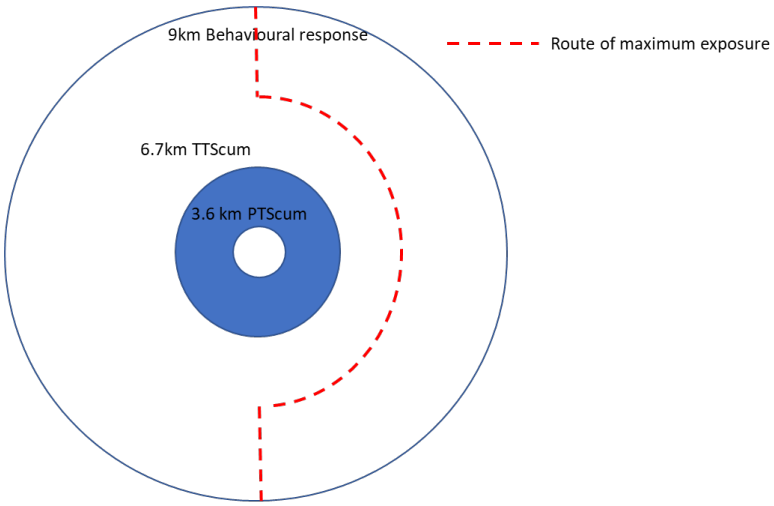


Figure 6.5 Predicted maximum ensonified field emitted by DP-AT beneath the mobile offshore drilling unit for low-frequency hearing cetaceans

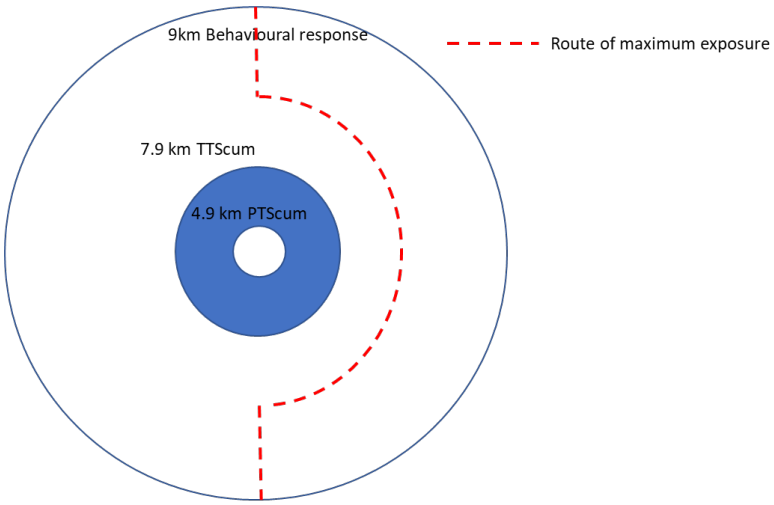


Figure 6.6 Predicted maximum ensonified field emitted by DP-AT beneath the mobile offshore drilling unit for mid-frequency hearing cetaceans

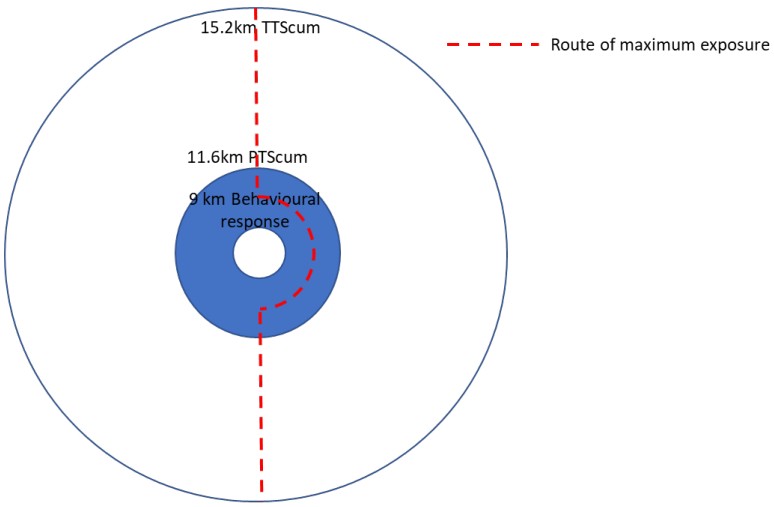


Figure 6.7 Predicted maximum ensonified field emitted by DP-AT beneath the mobile offshore drilling unit for high-frequency hearing cetaceans

Vertical seismic profiling operations

Underwater sounds emitted during the vertical seismic profiling operation are expected to be the most intense sounds generated by the activity. Although vertical seismic profiling sound sources typically use similar equipment that is used in seismic operations (i.e. an array of compressed air source elements), vertical seismic profiling typically uses substantially smaller source array volumes than those used in exploration seismic surveys. The source array for vertical seismic profiling proposed for the activity will comprise three source elements, each with a volume size of 150 in^3.

The pulses of sound generated by the vertical seismic profiling underwater are not predicted to exceed the marine mammal behavioural disturbance threshold for impulsive sounds of 160 dB re1µPa (SPLrms) (NMFS 2013) beyond a maximum distance of 16 km and 160 dB re 1 μPa^2.s (SEL) beyond 9 km around the Stromlo-1 well location (Table 6.18).

The predicted consequence for cetacean species from mobile offshore drilling unit and vertical seismic profiling operations is Category 1–3 with very limited impacts (restitution time <1 month). Underwater noise impacts resulting in effects in cetaceans are predicted to be localised, limited to one or only a few transiting individuals, intermittent, very short-term and recoverable. No impacts at a population level are predicted.

Table 6.18 Summary of modelled impact ranges for mobile offshore drilling unit and vertical seismic profiling operations for cetaceans

Marine mammal group	Exposure level	Predicted impact distance (km)	
		MODU	VSP
PTS (SELcum24)*			
Low-frequency cetaceans (baleen whales)	183 dB re 1 μPa^2.s (impulsive)	3.6 km (max) DP-AT	NE
	199 dB re 1 μPa^2.s (non-impulsive)	1.6 km (average) 1.9 km (max) thrusters	Not Relevant
Mid-frequency cetaceans (toothed whales)	185 dB re 1 μPa^2.s (impulsive)	4.9 km (max) DP-AT	NE
	198 dB re 1 μPa^2.s (non-impulsive)	NE thrusters	Not Relevant
High-frequency cetaceans (*Kogia* spp.)	155 dB re 1 μPa^2.s (impulsive)	11.6 km (max) DP-AT	NE
	173 dB re 1 μPa^2.s (non-impulsive)	0.3 km (max) thrusters	Not Relevant
PTS (SPLpeak)*			
Low-frequency cetaceans (baleen whales)	219 dB re 1 µPa (impulsive)	NE	NE
Mid-frequency cetaceans (toothed whales)	230 dB re 1 µPa (impulsive)	NE	NE
High-frequency cetaceans (*Kogia* spp.)	202 dB re 1 µPa (impulsive)	NE	0.3 km (max)
TTS (SELcum24)*			
Low-frequency cetaceans (baleen whales)	168 dB re 1 μPa^2.s (impulsive)	6.7 km (max) DP-AT	3.3 km (average) 3.5 km (max)
	179 dB re 1 μPa^2.s (non-impulsive)	20 km (average) 25 km (max) thrusters	Not Relevant
Mid-frequency cetaceans (toothed whales)	170 dB re 1 μPa^2.s (impulsive)	8.1 km (max) DP-AT	NE
	178 dB re 1 μPa^2.s (non-impulsive)	4 km (average) 9.8 km (max) thrusters	Not Relevant
High-frequency cetaceans (*Kogia* spp.)	140 dB re 1 μPa^2.s	15.2 km (max)	1.4 km (average)

Marine mammal group	Exposure level	Predicted impact distance (km)	
		MODU	VSP
	(impulsive)	DP-AT	1.6 km (max)
	181 dB re 1 μPa^2.s (non-impulsive)	0.9 km (average) 1.9 km (max) thrusters	Not Relevant
TTS (SPLpeak)*			
Low-frequency cetaceans (baleen whales)	213 dB re 1 μPa (SPL peak) (impulsive)	NE	NE
Mid-frequency cetaceans (toothed whales)	224 dB re 1 μPa (SPL peak) (impulsive)	NE	NE
High-frequency cetaceans (*Kogia* spp.)	196 dB re 1 μPa (SPL peak) (impulsive)	NE	0.58 km (average) 1.0 km (max)
Behaviour (SPLrms)†			
All cetacean groups	140 dB re 1μPa	9 km (average) 17 km (max) thrusters	Not Relevant
	160 dB re 1 μPa	0.6 km DP-AT	14 km (average) 16 km (max)
EPBC Policy statement 2.1 (SEL)			
	160 dB re 1 μPa^2.s	Not Relevant	9 km

Note: * (NMFS 2018), † (NMFS 2013); NE = No exceedance of threshold.

6.3.3.7 Impacts to pinnipeds

The only pinniped species that could be transiently present within the Impact Environment that May Be Affected is the New Zealand fur seal. It is possible that males could occur within the Impact Environment that May Be Affected as they are known to forage over continental shelf and continental slope habitats (Section 2.1) but females are unlikely to occur as they are known to forage in shallow waters. There are no critical habitats for feeding, breeding, haul-outs within the Impact Environment that May Be Affected or within 200 km of the Stromlo-1 well location (Section 4.6.6.2).

Underwater sound modelling for the mobile offshore drilling unit thrusters and vertical seismic profiling predicted no exceedance of thresholds relating to injury (permanent threshold shift) or recoverable injury (temporary threshold shift) for otariid pinnipeds (i.e. fur seals) (Appendix 6.1). Modelling for the transponders on the mobile offshore drilling unit predicts that cumulative sound exposure levels over 24 hours will decrease to below threshold values associated with potential injury (permanent threshold shift) at distances of up to a maximum of 1.4 km, and up to 3.4 km for recoverable injury (temporary threshold shift), for fur seals (Appendix 6-1). However, it is unlikely that fur seals would be remain within either of these distances of the mobile offshore drilling unit over a 24 hour period to receive injurious underwater sound levels. This is further supported by the unlikely presence of New Zealand fur seals in the offshore waters of the Impact Environment that Might Be Affected, particularly during summer when the Stromlo-1 drilling activity is planned, as evidenced by satellite tracking data from the Great Australian Bight Project that showed female New Zealand fur seals foraging tracks over a more restricted area of the continental shelf during summer (Section 4.6.6.2). Finally, interrogation of the underwater sound modelling for peak SPLs based on the NMFS (2018) thresholds for otariid pinnipeds (fur seals) does not predict any exceedance for injury/permanent threshold shift or recoverable injury/temporary threshold shift (Figure 18, Appendix 6-1).

Underwater sound impacts resulting in behavioural effects to the New Zealand fur seal will be limited to 9 km during vertical seismic profiling operations and up to 17 km at all other times, i.e. during mobile offshore drilling unit operations. These effects will be short-term and recoverable with no impacts to breeding success or at a population level predicted.

The predicted impact on pinnipeds as a result of both vertical seismic profiling and mobile offshore drilling unit operations is Category 1–3 and limited to short-term behavioural disturbance impacts to any transiting individuals within 9 km to 17 km of the well location and a restitution (recovery) time <1 month for populations.

6.3.3.8 Impacts to protected area values and management

Equinor Australia B.V. has undertaken the impact assessment in accordance with the management strategies and objectives of the Marine Bioregional Plan for the South-west Marine Region (DSEWPaC 2012), the South-west Marine Reserves Network Management Plan and Australia's International Union for Conservation of Nature Principles. Protected areas that could be affected by sound from the mobile offshore drilling unit thrusters or from vertical seismic profiling operations associated with the Stromlo-1 activity are assessed below. There are no listed cultural heritage properties in the Impact Environment that May Be Affected.

The Stromlo-1 well location and much of the Impact Environment that May Be Affected lie within the Great Australian Bight Marine Park Multiple Use Zone (see Section 4.5.3 – Figure 4.2). There are no Key Ecological Features within the Impact Environment that May Be Affected, but the Kangaroo Island Pool, canyons and adjacent shelf break, and the Eyre Peninsula upwellings Key Ecological Feature are located to the east of the Impact Environment that May Be Affected (see Section 4.5.3 – Figure 4.3) and is it possible that cetaceans potentially present within the Impact Environment that May Be Affected could be transiting to feeding grounds in the upwelling and canyons of the Key Ecological Feature.

The predicted consequence for protected area values and management from mobile offshore drilling unit and vertical seismic profiling operations is Category 1–3 with very limited impacts (restitution time <1 month). The impact assessments for marine fauna provided throughout this section demonstrates that the mobile offshore drilling unit and vertical seismic profiling operations will not have a significant impact on marine fauna in the region. Any effects will be limited to an individual (not population) level and to immobile species such as plankton and deep-sea benthic invertebrates. The predicted impact ranges for fish, turtles and marine mammals are temporary and localised to the area of the Impact Environment that May Be Affected. These ranges are also considered highly conservative as they are based on exposure received by a static (stationary) animal over a period of 24 hours, which is unrealistic given the mobility of these marine fauna groups, and the absence of important habitats within the Impact Environment that May Be Affected. Any disturbance will therefore be temporary, with no direct effects on any of the Great Australian Bight Marine Park or Kangaroo Island Key Ecological Feature values (e.g. pygmy blue and southern right whale migrating and calving habitats, foraging areas for threatened great white shark and migratory sperm whale, foraging areas for New Zealand fur seals.

Sound pollution is not identified as a pressure of concern for the Small Pelagic Fish Key Ecological Feature in the South-west Marine Region and there are no expected disturbance or displacement effects lasting more than 24 hours to areas important to these small pelagic fish species (Section 1.0).

6.3.3.9 Cumulative impacts

All currently submitted and approved EPs have been investigated on the National Offshore Petroleum Safety and Environmental Management Authority website and those with potential spatial and temporal overlap with the Stromlo-1 Environment Plan have been assessed for cumulative sound impacts. There are no other seismic surveys planned (Environment Plan submitted or accepted) that overlap with the Stromlo-1 Operational Area or Impact Environment that May Be Affected.

Potential cumulative impacts associated with the Stromlo-1 exploration drilling activity may occur if:

- mobile offshore drilling unit or vertical seismic profiling operations are undertaken at the same time as another seismic survey or drilling operation within the area, there is an overlap in the predicted ensonified areas by each activity and there are sound sensitive receptors in the overlap zone (concurrent activities); or
- the survey is undertaken within an area where previous seismic surveys have occurred, the affected marine biota are still in the same area and have not fully recovered (sequential activities).

Due to the period of time between the proposed Stromlo-1 Activity and the most recent previous seismic survey conducted by BP p.l.c. in the Ceduna Sub-basin in 2012, it is expected that there has been no lasting impact to the marine fauna receptors in the area and therefore there will be no sequential (or additive) effect as a result of the Stromlo-1 Activity.

Individual recovery times for fish proposed by Stadler and Woodbury (2009) (12 hours) and Popper (2018) (24 hours) indicate that it is highly unlikely that individual fish in an area where a seismic survey was acquired over six years ago (2012) would not have recovered over this time. Populations would be more

resilient due to immigration and recruitment of unaffected individuals. In addition, recent work has shown that fish can recover from the startle response of acoustic disturbance within minutes (Bruintjes et al. 2016) and that repeated exposure can lead to habituation and reduced response within weeks (Nedelec et al. 2016), further substantiated by previous studies investigating the effects of seismic on fish (McCauley et al. 2000; Fewtrell & McCauley 2012).

Following acceptance of this Environment Plan and as part of the pre-survey planning and notification process, the National Offshore Petroleum Safety and Environmental Management Authority website will be monitored for newly accepted EPs for marine seismic surveys and/or drilling activities that could contribute to cumulative sound in the Stromlo-1 Impact Environment that May Be Affected. If seismic activity is permitted within 40 km of the Stromlo-1 Petroleum Safety Zone, and scheduling for both activities may overlap, the relevant titleholder will be contacted, and arrangements made to ensure that the potential cumulative impacts will be reduced to As Low As Reasonably Practicable.

Given the very low likelihood of two activities occurring simultaneously and the control measures that will be implemented to establish and maintain communications prior to and during the Stromlo-1 operations to ensure simultaneous sound producing activities would maintain an adequate separation distance (i.e. 40 km for a seismic survey), there is very little risk of cumulative impacts to marine receptors.

6.3.3.10 Summary of impact predictions

Areas of ensonification predicted by the underwater sound modelling for all marine fauna considered have been based on the largest area of effect modelled at the well location and are summarised as follows:

- mobile offshore drilling unit operations
  - fish (e.g. southern bluefin tuna) – temporary threshold shift effects up to 1.9 km from the mobile offshore drilling unit source (based on accumulated 24-hour exposure scenario and considered highly conservative (see Section 1.2)
  - low-frequency cetaceans (pygmy blue, southern right whales, pilot whales) – temporary threshold shift effects up to a maximum of 25 km from the mobile offshore drilling unit source (based on accumulated 24-hour exposure)
  - mid-frequency cetaceans (sperm whales, beaked whales) – temporary threshold shift effects up to a maximum of 9.8 km from the mobile offshore drilling unit source (based on accumulated 24-hour exposure)
  - high-frequency cetaceans (pygmy or dwarf sperm whales; *Kogia* spp.) – temporary threshold shift effects up to a maximum of 1.9 km (based on accumulated 24-hour exposure)
  - all marine mammal groups (cetaceans and pinnipeds) – behavioural disturbance up to a maximum of 17 km from the mobile offshore drilling unit source (based on threshold of 140 dB re1µPa SPLrms)
- vertical seismic profiling operation
  - plankton (including fish larvae/eggs) – no detectable impact range (based on peer-reviewed mortality threshold in Popper et al. 2014); however potential effects (mortality) could occur 1.5 km of the well location when compared with the received level that caused mortality in the McCauley et al. (2017) study
  - marine invertebrates (deep-sea bivalves) – sub-lethal effects up to 1.1 km from the vertical seismic profiling source (based on recorded by Day et al. 2016)
  - marine invertebrates (deep-sea crustaceans) – no detectable impact range (based on sub-lethal effects recorded by Day et al. 2016)
  - marine turtles – behavioural disturbance effects up to 1.6 km from the vertical seismic profiling source
  - low-frequency cetaceans – up to 9 km from the vertical seismic profiling source (based on temporary threshold shift effects for accumulated 24-hour exposure)
  - high-frequency cetaceans – temporary threshold shift effects up to 750 m in all directions from the vertical seismic profiling source (based on accumulated 24-hour exposure)
  - all marine mammal groups (cetaceans and pinnipeds) – behavioural disturbance up to 9 km in all directions from the vertical seismic profiling source (based on threshold of 160 dB re1µPa SPLrms).

Based on the assessments above in Sections 6.3.3.2 to 6.3.3.9, the predicted impact of underwater sound on marine fauna from mobile offshore drilling unit and vertical seismic profiling operations is considered a Category 1–3 consequence because:

- no predicted injurious effects on listed matters of national environmental significance
- no population level or ecosystem-level effects predicted
- no lasting behavioural changes or redistribution of fish stocks affecting catchability
- no important habitats (Biologically Important Areas or other known areas of importance) for e.g. feeding, breeding/calving, spawning, aggregating for marine fauna in the remote deep-water location of the well
- vertical seismic profiling operations will only be initiated during daylight hours
- relevant person objections or claims regarding underwater sound from sources associated with the activity (vertical seismic profiling, drilling and vessels) have been addressed in the impact assessment and outcomes communicated to relevant persons
- the duration of the drilling activity will be short. Potential effects will be limited to short-term behavioural disturbance impacts to transiting individuals with an expected recovery time of <1 month for all marine fauna populations.

Given the conclusions above regarding the potential biological impacts of underwater sound to marine fauna, it is predicted that the spiritual connection that some Aboriginal communities have with totems such as fish, whales, dolphins and sea lions will not be affected by the petroleum activity. This assessment is based on the minor displacement of a small number of migrating whales, dolphins, sea lions and fish from the Impact Environment that May Be Affected approximately 370 km offshore, no biological effects on whales (any more than current shipping) and no effects on their movements into nearshore areas where Indigenous communities may observe and continue to connect with them.

6.3.4 Impact treatment

6.3.4.1 Environmental performance outcomes (EPO 6.3)

EPO 6.3A

No adverse effects on the ecologically sustainable use or conservation of ecosystems, habitats and native species in the Great Australian Bight Marine Park from sound emissions from the drilling unit or vertical seismic, specifically:

- No mortality or injury to protected marine fauna within the impact EMBA or greater Great Australian Bight Marine Park
- No overlap with southern right whale peak migration period through the impact EMBA or greater Great Australian Bight Marine Park
- No displacement of blue whales from their migratory corridor through the Great Australian Bight Marine Park
- No mortality, injury or displacement of pelagic fish species within the impact EMBA or greater Great Australian Bight Marine Park
- No mortality, injury or displacement of deep-sea benthic fish communities within the impact EMBA or greater Great Australian Bight Marine Park
- No mortality, injury or displacement of southern bluefin tuna from their migratory corridor through the Great Australian Bight Marine Park.

EPO 6.3B

Environmental performance outcomes for impacts associated with underwater sound from mobile offshore drilling unit and/or vertical seismic profiling operations area:

- no mortality or permanent injury to protected marine fauna species due to sound associated with the mobile offshore drilling unit or operation of the vertical seismic profiling
- no displacement of migrating pygmy blue whales and other transient cetaceans beyond 40 km from the mobile offshore drilling unit

- no permanent or temporary displacement of commercially important fish stocks or fisheries, or spawning aggregations
- no long-term effects on the conservation values of the Great Australian Bight Marine Park (see EPO 6.3A)
- no injury (no PTS or physical injury) to migrating whales due to sound emissions associated with the drilling.

6.3.4.2 Context for assessment

Table 6.19 Context for mitigating impacts for underwater sound

Legislative and other requirements	EPBC Act Policy statement 2.1 EPBC Act Species Conservation and Recovery plans: • Conservation Management Plan for the Blue Whale (DoE 2015a) • Humpback Whale Conservation Advice (DoE 2015b) • Sei Whale Conservation Advice (DoE 2015c) • Fin Whale Conservation Advice (DoE 2015d) • Conservation Management Plan for the Southern Right Whale (DSEWPAC 2012) • Recovery Plan for Marine Turtles in Australia (Department of Environment and Energy 2017) NOPSEMA's Information paper: "Acoustic impact evaluation and management", Rev 01 N-04750-IP1765, September 2018
Equinor Australia B.V. standards	N/A

6.3.4.3 Control measures and performance standards

Application of EPBC Policy statement 2.1, Part A Standard Management procedures are considered sufficient in areas where it can be demonstrated, by available evidence, that there is a low likelihood of encountering whales. Despite the Stromlo-1 well location and Impact Environment that May Be Affected having a low likelihood of cetacean presence, Equinor Australia B.V. has taken a conservative approach and considered Part B Additional Management procedures in the As Low As Reasonably Practicable assessment (Section 2.0). Additional management (control) measures have been adopted where the sacrifice/cost is not disproportionate to the environmental benefit gained.

Table 6.20 Control measures and performance standards for mitigating impacts from underwater sound

Control measures	Performance standards	Measurement criteria	Responsibility
VSP operations: application of EPBC Policy statement 2.1 Part A Standard Management Measures			
Marine fauna observer	EPS 6.3.1: Each vessel (MODU and support vessels) will have a crew member trained in marine fauna observation	Training material and attendance records demonstrate selected crew members have received training in commitments under EPBC PS 2.1 in relation to this EP	Drilling Supervisor
	EPS 6.3.2: MFO will undertake pre-start observations preceding VSP and during soft-start of VSP	Marine fauna observer data sheets/report show observations during pre-start and soft-start periods for MODU and support vessel on location at that time	Drilling Supervisor

Control measures	Performance standards	Measurement criteria	Responsibility
Implementation of all relevant management measures described in EPBC PS 2.1 relating to the following: • pre-start-up visual observation • Soft start • Start-up delay • operations • power-down and stop work • during VSP operations	EPS 6.3.3: VSP operations will be conducted in accordance with sections of the EPBC Policy statement 2.1 applicable to a static source. • Implement 30 minute pre-start visual observation and only commence VSP if no whales in 3 km observation zone (pre-start observation) • Ramp up to full VSP power over 20 minutes (soft start) • VSP set to low power if whales sighted in 2 km low-power zone • VSP turned off if whales sighted in 500 m shut-down zone. • VSP source run at low power in period following initial testing and commencement of VSP operations.	Marine fauna observer data sheets/report confirm appropriate pre-start and soft start protocols followed. Seismic log for the VSP operations details all instances the acoustic source was activated, including the acoustic source sequence and confirms ramp up of acoustic power in soft-start for VSP operations and low power maintained between test and VSP	Drilling Supervisor
VSP operations: application of EPBC Policy statement 2.1 Part B Additional Management Measures			
Night-time / poor visibility: VSP source commencement only in day light	EPS 6.3.4 VSP operations will commence during daylight hours only.	Operational report	Drilling supervisor
Remodelling of the MODU thrusters acoustic emissions and revised impact assessment will be carried out in the event that the contracted rig has a more powerful dynamic positioning system that may generate more underwater sound than the modelled MODU.	EPS 6.3.5: Remodelling of the MODU thrusters acoustic emissions will be carried out in the event that any one of the following criteria is met for the selected MODU: • MODU has more than eight thrusters, or • Source (thrusters) are located deeper than the modelled 18 m water depth, or • Propeller diameter 10% greater than 3.5 m, or • Nominal propeller speed 10% greater than 177 rpm, or • Maximum continuous power input 10% greater than 3800 kW. If the modelling comparison and revised	Selected MODU modelled parameters checked and verified against triggers for remodelling and reported under the Management of Change process. Compliance report demonstrates comparison between modelled and selected rig has been completed and actioned as necessary.	Drilling Supervisor

Control measures	Performance standards	Measurement criteria	Responsibility
	impact assessment reveal that the controls in place are no longer effective in managing impacts to ALARP and acceptable levels, an evaluation of additional controls will be undertaken to reduce impact to ALARP and acceptable levels.		
Maintain powered down VSP in operation between test and full power operation	EPS 6.3.6: VSP logs demonstrate low power operation of VSP between source test and full power operation.	VSP log sheet	Drilling Supervisor

6.3.5 Demonstration of acceptability

The level of impact that underwater sound associated with the Stromlo-1 activity is acceptable in accordance with the acceptability criteria as described below.

Table 6.21 Demonstration of acceptability

Acceptability criteria	Evaluation against acceptability criteria
Plankton: • Plankton communities only affected for short time • No lasting population or ecosystem level effects	• Localised impacts on plankton predicted to be fully recoverable within a few days of VSP • No population level or ecosystem-level effects predicted
Fish: • Survey is not carried out during peak periods in key spawning areas for commercially important species • No displacement of white shark from important foraging or distribution BIAs • No broad-scale disruption of southern bluefin tuna migration through the GAB • No population or ecosystem level effects	• No known fish spawning aggregation areas within area ensonified during drilling and VSP operations • No effect on white shark BIA • Displacement of SBT migrating through the offshore waters of the GAB limited to the localised area around the MODU (Impact EMBA) which is a negligible proportion of the migratory pathway; no effect on migrating cohorts' ability to reach inshore areas • No population level or ecosystem-level effects predicted
Marine invertebrates: • No population or ecosystem level effects	• No population level or ecosystem-level effects predicted
Marine turtles: • Predicted effects limited to behavioural disturbance of a small number of individuals • No population or ecosystem level effects • No displacement from key foraging, nesting or inter-nesting habitats	• Only small number of individuals are expected to be present • No population level or ecosystem-level effects predicted • No turtle BIAs within the Impact EMBA
Cetaceans: • No injury (no PTS or physical injury) to migrating blue whales or southern right whales • No more than minor displacement of migrating adult blue whales without affecting migratory success • No displacement of migrating southern right whales with calves	• The impact assessment demonstrates through peer reviewed literature that whales are likely to avoid the sound field around the stationary MODU. The literature supports assumption that migrating whales will avoid the sound source before they reach the PTS_{cum} zone, but if they do, it is even more unlikely that they will stay in the PTS_{cum} zone long enough to induce PTS.

Acceptability criteria	Evaluation against acceptability criteria
• No displacement of migrating pregnant female southern right whales • Consistent with the relevant management actions from the conservation management plan for blue whales. • Consistent with the relevant management actions from the conservation management plan and recovery plan for southern right whales.	• Reducing the Stomlo-1 activity duration to avoid drilling in May and October, a period when pregnant females (May) and cows with calves (October) could migrate through the Impact EMBA, aligns with the southern right whale conservation management plan which requires implementation of management measures to ensure the ongoing recovery of the species. This is achieved by preventing the potential for disturbance to a sensitive life stages that is necessary for the recovery of the population. Further, adoption of this management measure addresses the concerns raised by the Director of National Parks and GAB Right Whale Study and reduces impacts to these sensitive life stages to ALARP. • No disturbance to foraging pygmy blue whales in foraging areas, including displacement from foraging area • No displacement of migrating whales outside the Impact EMBA • Consistent with management plans and advice for pygmy blue whales, southern right whales, humpback, sei and fin whales: because, no injury or displacement from BIAs to pygmy blue, southern right, humpback, sei and fin whales • No population level or ecosystem-level effects predicted
Pinnipeds: • Predicted effects limited to behavioural disturbance of a small number of individuals • No population- or ecosystem-level effects	• Only small number of individuals are expected to be present and no pinniped BIAs within the Impact EMBA • No population level or ecosystem-level effects predicted
Fisheries: • No displacement of fishers from known fishing grounds • No population-level effects on commercially fished stocks • No reduction in catchability or catch as a result of VSP or MODU operations	• No fishing activities within the Impact EMBA • No population level or ecosystem-level effects predicted • No lasting behavioural changes or redistribution of stock affecting catchability
Protected areas: • No predicted long-term impacts on the conservation values of the GAB Marine Park • No predicted long-term impacts on the values of the Kangaroo Island Pool, Canyons and Adjacent Shelf Break KEF Eyre Peninsula Upwellings KEF Small Pelagic Fish of the South-west Marine Region KEF.	• The impacts are assessed as too localised and temporary to directly affect any of the former GAB marine park values (e.g. pygmy blue and southern right whale migrating and calving habitats, foraging areas for threatened great white shark and migratory sperm whale and specific KEFs • No direct effect on EBPC Act listed MNES given lack of known densities of MNES, and receptor (e.g. fish/reptile/cetacean) mobility, any impacts will be limited to an individual (not population) level and immobile species such as plankton and benthic invertebrates.

6.3.6 Demonstration of As Low As Reasonably Practicable

The decision context and assessment technique for the As Low As Reasonably Practicable assessment are provided in Table 6.22.

Equinor Australia B.V. considers the adopted control measures in Table 6.23 to be appropriate in reducing the environmental impacts associated with underwater sound from seismic operations on marine fauna to As Low As Reasonably Practicable

There are no other control measures that may practicably or feasibly be adopted to further reduce the impacts without disproportionate costs compared to the benefit of the potential impact reduction. Equinor Australia B.V. is committed to ensuring continual impact reduction and identifying if additional control measures may be applied that are not disproportionate to the sacrifice (e.g. cost) of implementation. Where the cost of implementing the additional control measures is disproportionate to the benefit gained, they have not been adopted (Table 6.22).

Table 6.22 As Low As Reasonably Practicable decision context and assessment technique for impacts from underwater sound

As Low As Reasonably Practicable decision context	It is expected that there will be limited presence of marine fauna due to the absence of important habitats for e.g. feeding, breeding/calving, spawning, aggregating for marine fauna in the remote deep-water location of the well. Relevant persons objections or claims raised regarding underwater sound from sources associated with the activity (VSP, drilling and vessels) have been addressed in the impact assessment and outcomes communicated to relevant persons. No additional control measures with the exception of those in Table 6.19 are required to continue to reduce impacts to As Low As Reasonably Practicable. Taking this into consideration Decision Context A should be applied to demonstrate impacts are As Low As Reasonably Practicable.
Assessment technique	Engineering Risk Assessment to reach As Low As Reasonably Practicable

Table 6.23 Demonstration of As Low As Reasonably Practicable – underwater sound

Additional capability	Hierarchy	Environmental benefit		Cost	Rationale	Outcome
Avoid VSP initiation at night	Administrate	Given there is some uncertainty in the timing and abundance of whales migrating through the offshore waters of the central GAB, having a management procedure for avoiding start-up of the VSP at night (when visual observations are ineffective) will reduce the disturbance impacts on any migrating animals.	Negligible (<1%)	<0.5% of project cost	Soft start-up will be initiated during daylight, and VSP will be shot every 30 minutes during the night prior to commencing the VSP survey.	Adopted
Reduction of source sound levels from MODU and VSP using bubble curtain technology	Protective	Extent of possible sound reduction varies; depending on physical dimensions of sound generating operations, curtain equipment and bubble size. Historically the "bubbles" are produced by air released from hoses/pipes that are placed on the seabed around the activity so that the bubbles float upwards creating a curtain effect. The curtain would reduce the propagation of sound into surrounding waters and thereby may reduce impacts on marine fauna. Modelling has however shown that the sound emissions will not have a measurable or long-term effect on MNES, important commercial fish stocks or other conservation-significant fauna.	Negligible (<1%)	0.5–2% of project cost	The use of bubble curtain technology has historically been in relation to piling/construction activities in relatively shallow waters. This technology has not been used in a deep open-ocean setting and it is likely that this would present significant operational challenges such as the positioning of the curtain relative to the activity. Furthermore, this technology has not been used for such a large "sound source" as a MODU. The water depth and physical spatial footprint of the MODU would pose significant operational challenges. There would be minimal benefit to be gained and this control is considered impractical and cannot be adopted for this program. The cost of designing and building a system to do this would be disproportionately expensive in consideration of the minor benefit possibly gained.	Not adopted
Additional Marine Fauna Observer (MFO) outside of VSP activities	Administrate	Identification of marine mammals outside of VSP activities is not considered to provide any environmental benefit given that there are no additional control measures that can be implemented to mitigate any potential exposure and the presence of marine mammals is predicted to be infrequent. There will be a dedicated and trained MFO on board the platform supply vessel (PSV) throughout the survey which will allow observations to commence in the day preceding VSP and thereby provide confirmation of whale densities prior to initiating the impulsive sound-generating activity.	Negligible (<1%)	<0.5% of project cost	Given that this resource would only be observing low densities of marine mammals in a non-critical habitat, with the observations not informing anything other than presence, the cost of implementing the control is considered disproportionate to the environmental benefit / level of impact reduction achieved. The current control measures using the trained MFO on the PSV to monitor for whales prior to VSP are considered sufficient to reduce the impacts to As Low As Reasonably Practicable. It is therefore not adopted.	Not adopted

Additional capability	Hierarchy	Environmental benefit		Cost	Rationale	Outcome
Modify activity window to avoid periods when southern right whale cows and calves (October) and pregnant females (May) could migrate through the permit area	Eliminate	The activity window was originally designed to include May and October. However, in October there is the possibility that southern right whales could be migrating south with calves, and in May pregnant females could be migrating to breeding areas (Head of the Bight) on the Australian coast. The likelihood of pregnant females and cow/calf pairs migrating through the Impact EMBA is low as this area does not form part of a constricted migratory corridor between breeding sites on the southern Australian coastline and feeding grounds in the Southern Ocean. Therefore, if whales do pass through the Impact EMBA, they are likely to be widely distributed and the numbers are likely to be low. Despite this, there is potential for exposure to sound levels that could cause behavioural disturbance of sensitive life stages of the whale. These life history stages are vulnerable to disturbance and successful breeding is essential for the recovery of the population. Therefore, avoiding disturbance to these sensitive life stages is consistent with the recovery plan and conservation management plan for southern right whales. There is uncertainty of the actual amount of benefit because of the paucity of knowledge in how southern right whales may use the permit area and Impact EMBA during migration, though these areas are not part of any known confined migratory corridor. However, removal of these shoulder months (May and October) either side of the known period of occurrence for southern right whales in Australian waters will reduce the potential for impacts to pregnant females and/or cow/calf pairs, which is likely to benefit the recovering population.	Moderate (3-10%)	2-5% of the project cost	The cost in reducing operational flexibility is one of increasing commercial risk. Should a rig be contracted in October it may be on standby for days to weeks waiting for mobilisation on 1 November; this would lead to Equinor Australia B.V. having to absorb rig standby costs for this period and could run into millions of dollars being added to the cost of hiring the MODU. Changing the end of activity period to April increases the risk that the drilling activity does not get finished in one year and there would be very significant costs in re-mobilising to complete the well after the EP was revised and the rig re-contracted. The end of the activity period cannot be reduced further without increasing this risk of costs being grossly disproportionate to the benefits. Removing the months is consistent with the conservation objectives of the SRW management plan, and addresses the concerns raised during consultation by the Great Australian Bight Right Whale Study (GABRWS) group who requested removing the months of October and May from the activity period. Thus with the perceived environmental benefit of reducing impacts on a protected species, meeting the recommendations of its management plan and satisfying a merited claim from a relevant person, the cost is not disproportionate to the benefit.	Adopted

Additional capability	Hierarchy	Environmental benefit		Cost	Rationale	Outcome
Hydrophone measurements in situ	Protective	There will be little to no environmental benefit from monitoring sound emissions for the following reasons: The modelling prediction used in this EP is highly conservative, and corroborated by Martin *et al* (2019), therefore in situ verification is unlikely to reveal that sound emissions are greater than predicted; the sound emitted from the thrusters of the MODU cannot be changed if they are greater than predicted (see also control for adaptive management); and based on the current impact assessment and the controls adopted, risks and impacts from sound emissions have been reduced to ALARP and acceptable levels.	Negligible (<1%)	0.5-2% of project cost	A dedicated study by a specialist supplier would be required and in deep waters a long way from shore would cost well over $1 million. The additional cost of implementing in situ measurements would not provide any measurable environmental benefit or benefit in adaptively managing sound emissions from the MODU. Martin et al (2019) showed that sound emissions from a similar rig in similar water and also adjacent to a shelf break emitted significantly low sound levels than those used in the modelling prediction for this EP.	Not adopted
Only operate VSP during daylight hours	Eliminate	Only operating the VSP during daylight hours removes the uncertainty that accompanies the observations of cetaceans at night-time and during periods of low visibility, as the dedicated MFO cannot observe the extent of precaution zones (shut-down, low power, observation zones). However, the extent of the environmental benefit is likely to be very limited given the low densities of whales in the area. Blue whales are the only cetacean of conservation significance known to migrate through the area during the operational window of the drilling activity. The likelihood of encounter is reduced for southern right whales due to the removal of the months of May and October from the Stromlo-1 activity period. The impact thresholds for all cetaceans for injury (cumulative PTS and instantaneous PTS) are not reached in the modelled sound outputs during VSP, for any hearing groups (low, mid or high frequency) and therefore the potential for impacts is low without any additional control measures. Instantaneous TTS is only possible for high frequency cetaceans up to 750 m from the source, which would be managed with the application of EPBC 2.1 PS Part A management measures; particularly the soft-start	Negligible <1%	0.5-2% of project cost	Only operating the VSP during daylight hours could add an additional day to the total drilling campaign because it is a critical path activity. Therefore, the additional MODU and support vessel and crewing costs could exceed $0.5M. The costs associated with extending the time for the rig and support vessels are grossly disproportionate to the minor environmental benefit, given acoustic deterrent effect of the soft-start and MODU sound, and densities of whales in the area are expected to be very low.	Not adopted

Additional capability	Hierarchy	Environmental benefit		Cost	Rationale	Outcome
		procedure and maintaining the VSP array at low power between the source test and full power operation. The model predicts cumulative TTS and behavioural disturbance from impulsive sound up to 9 km from the VSP source if the exposure to the full power source occurred for a period of 24 hours, however the full source power will not be operated for more than 8 hrs and with the application of EPBC 2.1 PS Part A management measures including a low power zone of 1 km (as the EPBC PS 2.1 threshold of 160 dB SEL is not exceeded at 1 km), TTS_{cum} is not predicted to occur. As such, only operating the VSP during daylight hours will not provide additional protection from injury, PTS or a temporary change in hearing threshold in cetaceans. Cetaceans are predicted to actively avoid the MODU thrusters at ~9 km, therefore, only operating the VSP during daylight hours is unlikely to provide any additional benefit in reducing effects on cetacean behaviour.				
Maintain powered down VSP in operation between test and full power operation	Engineering	Powering down the VSP between testing and full operations has the potential to have some benefits at night if cetaceans are present. However, as outlined in the ALARP evaluation of only operating the VSP during daylight hours the additional environmental benefits are likely to be limited due to the nature and scale of the risks from operating the VSP.	Negligible (<1%)	<0.5% of project cost	Powering down the VSP between testing and full operations presents little to no additional cost of the drilling operation and is considered good practice	Adopted

6.4 Light emissions

6.4.1 Impact description

Lighting is required for safe conduct of drilling, emergency response, aviation activities, and collision avoidance. Minimum navigation and obstruction lighting levels are mandated by maritime regulations; these will be specified in the Safety Case for the mobile offshore drilling unit. Navigational and deck lighting on the mobile offshore drilling unit and vessels within the Operational Area will emit light over surrounding waters. Lighting for deck operations typically consists of bright white (metal halide, halogen, fluorescent) lights. Lighting on the helideck is likely to comprise coloured perimeter lights, low flood lights on the deck and high-mounted aviation lights. No flaring will be undertaken.

The impacts from the mobile offshore drilling unit and vessels are considered to be:

- disruption to behaviour and orientation of light sensitive marine fauna, including protected species
- localised light glow may attract light-sensitive species (e.g. seabirds, fish, zooplankton), in turn affecting predator-prey dynamics.

Direct illumination of surface waters is limited to the immediate vicinity of the mobile offshore drilling unit and vessels, typically within 100 m.

External lighting is located over the entire mobile offshore drilling unit or vessel, with most external lighting directed towards working areas such as the main deck, pipe rack and drill floor. These areas are typically lower than 20 m above sea level. The distance to the horizon at which the brighter components of the mobile offshore drilling unit lighting will be directly visible can be estimated using the formula:

- horizontal distance (km) = 3.57 × √ (height (m)).

Using this formula, the main deck (at ~20 m above sea level) would be visible at approximately 16 km from the mobile offshore drilling unit, which is suitable for navigation avoidance. Elevated lights for navigation and aviation are typically must less intense. The light spill will be limited to the drilling period of up to eight months and the area affected will be smaller for vessels with lower decks.

6.4.2 Levels of acceptable impact

The impact on light sensitive marine fauna caused by light emissions of the mobile offshore drilling unit on location will be acceptable when there are:

a. No lasting behavioural effects on marine fauna, with full recovery on cessation of activities.

b. No direct effects on EBPC Act listed matters of national environmental significance at a population level and no direct effects on the Great Australian Bight Marine Park management values.

c. Compliant with legislative requirements and industry practice.

6.4.3 Impact prediction

Monitoring by Woodside (2010) indicates that light density (navigational lighting) attenuated to below 1.00 lux and 0.03 lux at distances of 300 m and 1.4 km from a rig, respectively. Light densities of 1.0 and 0.03 lux are comparable to natural light densities experienced during deep twilight and during a quarter moon. No impacts would be expected at these light levels.

Studies conducted between 1992 and 2002 in the North Sea confirmed that artificial lighting was the reason that birds were attracted to and accumulated around illuminated offshore infrastructure (Marquenie et al. 2008) and that lighting can attract birds from large catchment areas (Wiese et al. 2001). It is noted from these studies that migratory birds are attracted to lights on offshore platforms when travelling within a radius of five km from the light source, and that outside this zone their migratory paths are unaffected (Shell 2009).

Various protected seabirds (described in Section 4.6.7) may traverse through the Stromlo-1 area and may be temporarily attracted to the mobile offshore drilling unit lights. These include albatross, giant petrel and shearwater species, which forage widely over the Great Australian Bight. In the absence of seabed features maintaining a high abundance of resident fish in the Stromlo-1 well site area, the seabirds are not expected to remain in the area.

Fish, squid and zooplankton may be directly or indirectly attracted to the light field in the immediate vicinity of the mobile offshore drilling unit and vessels. Experiments using light traps have found that some fish and zooplankton species are attracted to light sources (Meekan et al. 2001), with traps drawing catches from up to 90 m (Milicich et al. 1992). Lindquist et al. (2005) concluded from a study of larval fish populations around an oil and gas platform in the Gulf of Mexico that an enhanced abundance of clupeids (herring and sardines) and engraulids (anchovies), both of which are highly photopositive, was caused by the platform's light fields. The concentration of organisms attracted to light results in an increase in food for predatory species, and marine predators are known to aggregate at the edges of artificial light halos. In a similar light trap study, juvenile tunas (Scombridae) and jacks (Carangidae), which are highly predatory, were thought to have been preying upon concentrations of zooplankton attracted to the light field of the platforms (Shaw et al. 2003). This could potentially lead to increased predation rates compared to unlit areas. For fish and squid, it is expected that any potential impact of increased predation would be undetectable at a population level, and only affect transient individual fish and squid.

The proportion of zooplankton exposed and subjected to higher predation rates at the platform light fields is negligible due to the size of the area of impact relative to the extent of the central Great Australian Bight oceanic habitat (assuming 100m direct light on the ocean around the mobile offshore drilling unit, affected area would be approximately 4% of the Petroleum Safety Zone which is <0.003% of the Multiple Use Zone). In the event that deck or navigational lighting results as an attractant to an occasional seabird, it is not expected that this will permanently impact on migration or other behaviours.

Artificial lights can also be detrimental to the sea-finding behaviours of marine turtle hatchlings because they can disrupt visual cues. It has also been found that changes in ambient light levels may affect nesting behaviours with artificial lighting potentially deterring mature turtles from emerging from the water to nest. Given the absence of marine turtle nesting and aggregation areas at the Stromlo-1 site, the impact to marine turtles is negligible and limited to temporary behavioural effects on individuals rather than population levels.

Threatened species of fish (such as the great white and porbeagle shark) may benefit from increased congregations of prey around light spilled on the water but this advantage will only present during the drilling activities and be limited to a few hundred metres. Likewise, protected and/or migratory seabirds may be attracted to the light and the increased prey for the duration of the activity.

Ecological impacts are expected to be undetectable at a population level and would be considered as local degradation of the environment, with rapid recovery following completion of the activity.

Given that the lights on the mobile offshore drilling unit will be visible for approximately 16 km with decreasing intensity, they will not affect any other marine users beyond serving as an effective navigation warning.

The predicted impacts on marine life and amenity are considered to be Category 1–3 because light spill on the water with potential to modify behaviour of marine fauna will be limited to within hundreds of metres from the vessels and mobile offshore drilling unit. The impacts are restricted to a small number of individuals that will recover quickly to resume normal behaviours. Cumulative impacts from the vessels and the mobile offshore drilling unit are assessed as Category 1–3 due to the lack of light receptors and location remote from population centres.

6.4.4 Impact treatment

6.4.4.1 Environmental performance outcomes (EPO 6.4)

Artificial lighting during the activity will not result in an impact greater than a localised and temporary disturbance to fauna.

6.4.4.2 Context for assessment

Table 6.24 Context for mitigating impacts from light emissions

Legislative and other requirements	Maritime safety requires external lighting to conform with *Navigation Act 2012* (Cth: • Australian Maritime Safety Authority Marine Orders Part 30 (Prevention of Collisions). • Australian Maritime Safety Authority Marine Orders Part 59 (Offshore Support Vessel Operations).
Industry standards	Environmental, Health and Safety Guidelines for Offshore Oil and Gas Development (World Bank Group, 2015) Guidelines met with regard to: • Ship collision (item 120). To avoid collisions with third-party and support vessels, offshore facilities should be equipped with navigational aids that meet national and international requirements, including navigational lights on support vessels. Australian Petroleum Production and Exploration Association CoEP (2008): • To reduce the risk of collision with other vessels in accordance with maritime standards and to an acceptable level. • To reduce the impact on cetaceans and other marine life to As Low As Reasonably Practicable and an acceptable level.
Equinor Australia B.V. standards	TR1011 – Environmental requirements for offshore installations requires compliance with applicable laws and regulations (as per "Legislative and other requirements" above).

6.4.4.3 Control measures and performance standards

Australian Maritime Safety Authority has requested maximum lighting for navigational safety purposes and there are few light-sensitive receptors in the area. As such, no further control measures have been implemented for reducing lighting levels.

6.4.5 Demonstration of acceptability

The level of impact on light sensitive marine fauna caused by light emissions from the mobile offshore drilling unit and vessels in the Operational Area is acceptable because it meets the a priori acceptability criteria described below.

Table 6.25 Acceptability evaluation for impacts from light

Acceptability criteria	Evaluation against acceptability criteria
a. No lasting behavioural effects on marine fauna, with full recovery on cessation of activities	A full and rapid recovery of localised behavioural impacts is expected after the Stromlo-1 Drilling Program is completed and the MODU is demobilised from the PSZ. After completion, the night light stimulus will be removed, and normal behaviour will return to local plankton and fish communities.
b. There will be no direct effect on EBPC Act listed MNES at a population level or direct effects on the GAB Marine Park management values	The Stromlo-1 location is more than 370 km offshore. Only a small number of oceanic species, including some MNES under the EPBC Act such as protected sharks and seabirds, are likely to be directly impacted with no population-level effects credible. The light emissions will be too far offshore, too localised and temporary to affect any of the GAB Marine Park values such as the Mammal Protection Zone, southern right whale calving areas and pygmy blue migration routes, foraging areas for threatened great white shark and sperm whale, and specific KEFs such as area known to be important to small pelagic fish.
c. Alignment with legislative requirements and industry practice	Performance standards align with Australian Maritime Safety Authority Marine Orders Part 30 (Prevention of Collisions) and Australian Maritime Safety Authority Marine Orders Part 59 (Offshore Support Vessel Operations) as well as with industry guidelines (Australian Petroleum Production and Exploration Association and Environmental, Health and Safety Guidelines for Offshore Oil and Gas Development (World Bank Group, 2015). Maximum lighting levels will be retained for safety as requested by Australian Maritime Safety Authority (Section 3.0).

6.4.6 Demonstration of As Low As Reasonably Practicable

The decision context and assessment technique for the As Low As Reasonably Practicable assessment are provided in Table 6.26. Additional controls which have been considered in reaching As Low As Reasonably Practicable are listed in Table 6.27.

Equinor Australia B.V. considers the impacts from light on the mobile offshore drilling unit and vessels are As Low As Reasonably Practicable because:

- The number of vessels and mobile offshore drilling units and the duration of the activity are already at minimal levels and further reduction would compromise the activity.
- The clear visual communication of the presence of the mobile offshore drilling unit to other vessels is paramount for safety as is the safety of workers at night. The absence of sensitive receptors means the costs of further light reduction outweighs any negligible environmental benefits.
- Impact level is already Category 1–3 with standard practices and controls.
- No additional control measures have been identified to further reduce the impacts of light, apart from not conducting the drilling activity which is not acceptable.

Table 6.26 As Low As Reasonably Practicable decision context and assessment technique for impacts from light

As Low As Reasonably Practicable decision context	The use of lights for navigational purposes and safe work practices is a legislated requirement and is subsequently a well understood impact. Given the distance of the Stromlo-1 location from sensitive shoreline locations and the limited potential for exposing light sensitive marine receptors to changes in ambient light levels, light has a low severity potential at this location. No additional control measures are required to continue to reduce impacts to As Low As Reasonably Practicable. No relevant persons raised objections or claims over lighting. Australian Maritime Safety Authority requested maximum lighting for safety purposes. Taking this into consideration, Decision Context A should be applied to demonstrate impacts are As Low As Reasonably Practicable.
Assessment technique	Good Practice adopted to reach As Low As Reasonably Practicable.

Table 6.27 Assessment of additional controls to mitigate light impacts on marine biota

Additional capability	Hierarchy	Environmental benefit	Env benefit scale	Cost	Rationale	Outcome
Use only long wavelength yellow and red light	Substitute	Typically used for light intensive activities in the vicinity of sensitive receptors (e.g. turtle nesting).	Negligible (<1%)	<0.5% of project cost	Limited benefit due to low likelihood of night-time encounters with sensitive receptors in the Impact EMBA (no BIA sites for light sensitive receptors). Cost of re-fit outweighs environmental benefit.	Not adopted
No night-time operations.	Elimination	Light glow is minimised to no lights in excess of those required under Australian Maritime Safety Authority Marine Orders Part 30 (Prevention of Collisions).and Part 59 (Offshore Support Vessel Operations).	Negligible (<1%)	>10% of project cost	Limiting drilling activities to daylight hours would significantly extend the schedule with major cost impacts. The location is remote from land (closest shoreline is 372 km) and there are no turtle or shorebird nesting BIA in the vicinity of the well site. Negligible environmental benefit in 12-hour operations, but significant increase in MODU and vessel charter costs and length of survey. Sacrifice disproportionately higher than benefit	Not adopted
External lighting will be directed only onto working decks and extensive shrouding installed	Engineering/ Isolation	Overspill to the ocean is reduced where practicable.	Negligible (<1%)	<0.5% of project cost	There are no critical habitats for light-sensitive species around the proposed drilling site that would be disrupted by MODU and vessel light glow. Australian Maritime Safety Authority communications requested maximum lighting for navigational safety purposes	Not adopted

6.5 Atmospheric emissions

6.5.1 Impact description

No drill stem testing or flaring is planned. Atmospheric emissions will be generated by the combustion of fuel (specifically, marine-grade diesel) to power the mobile offshore drilling unit and support vessels' engines, generators and mobile and fixed plant and equipment. The gaseous emissions will comprise greenhouse gases such as carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O), along with non-greenhouse gases such as sulphur oxides (SOx) and nitrogen oxides (NOx). Greenhouse gases and non-greenhouse gases may also be emitted from on-board waste incinerators and helicopter exhaust emissions. The gaseous emissions will be generated by combustion of an average about 40 m^3 of fuel per day.

Vessels and the mobile offshore drilling unit may utilise ozone-depleting substances (ODSs) in closed-system rechargeable refrigeration systems.

The potential impacts for all emissions are considered to be:

- chronic effects to sensitive receptors from localised and temporary decrease in air quality from liquid fuel combustion
- contribution to global greenhouse gas effect
- discharge of ODSs and resultant contribution to the ozone hole.

Atmospheric emissions will cause a local reduction in air quality and negligible contribution to the global greenhouse gas effect. Gaseous emissions will, under normal circumstances, quickly dissipate into the surrounding atmosphere. The reduction in local air quality is limited to the drilling operations period.

Helicopter fuel usage and associated emissions while in the Operational Area were assessed as intermittent, incidental and with no scope for practical reduction given that helicopters are essential for support and safety. Monitoring and minimising usage within the Operational Area is impractical and requirements are managed under aviation legislation. As such, their emissions are not considered further in this EP.

6.5.2 Levels of acceptable impact

The reduced local air quality from atmospheric emissions by the operation will be acceptable when:

a. Potential impacts from emissions from the mobile offshore drilling unit and vessels are limited to a localised and temporary reduction in air quality with no impacts on sensitive receptors or matters of national environmental significance.
b. ODS-containing equipment is maintained in accordance with standard industry practice for avoiding release of ODS to the atmosphere.
c. Compliant with legislative requirements and industry practice.

6.5.3 Impact prediction

Emissions such as NOx, volatile organic compounds (VOCs) and SOx and greenhouse gas emissions can lead to a reduction in local air quality, which can impact humans and other air-breathing organisms, including seabirds and cetaceans in the immediate vicinity, generate dark smoke, and add to the national greenhouse gas loadings. Inhaling particulate matter and pollutants can cause or exacerbate respiratory health impacts to humans (e.g. offshore project personnel or nearby populations, if any) depending on the number of particles inhaled. Similarly, the inhalation of particulate matter may affect the respiratory systems of fauna. In the proposed drilling area, this is limited to seabirds overflying the mobile offshore drilling unit and vessels.

As the Stromlo-1 site is more than 370 km offshore, the combustion of fuels in such a remote location will not impact on air quality in coastal towns, the nearest being Ceduna. The quantities of gaseous emissions are relatively small and will under normal circumstances in the open-ocean environment, quickly dissipate into the surrounding atmosphere. The concentrations of migratory and protected seabirds in the immediate vicinity at any time will be low (Section 4.6.7), with all Biologically Important Area foraging areas for listed albatross, petrel, prion and skua far from the site – typically closer to the mainland shore or islands, within the Bass Straits, around Tasmania and off the Western Australia and Otway coasts. One species, the short-tailed shearwater, has a known Biologically Important Area foraging area which overlaps with the Impact Environment that May Be Affected, and has a low probability of occurrence at the site (Section 4.6.7.1).

As such, the rapidly diffusing atmospheric pollutant emissions to concentrations below impact levels, effects to listed species are predicted to be negligible.

Accidental releases and fugitive emissions of ODSs are not expected to occur during the activity. Refrigeration systems containing ODS typically do not require frequent maintenance and follow well established practices to prevent accidental release of ODS. The short-term nature of the activity reduces the potential for maintenance being required.

Atmospheric emissions will be similar to other vessels operating in the region for both petroleum and non-petroleum activities. While these emissions add to the greenhouse gas load in the atmosphere, they are relatively small and diluted rapidly.

The drilling program is similar to other industrial activities contributing to the accumulation of greenhouse gas in the global atmosphere. With a preventative maintenance system, engines will run efficiently, and the use of low sulphur diesel will minimise the emission of SOx. Given the distance to population centres, visual amenity and the presence of dark smoke have no sensitive receptors. Hydrocarbon combustion may result in a temporary, localised reduction of air quality in the environment immediately surrounding the discharge points.

The predicted impacts of atmospheric emissions are considered to be Category 1–3 because the Stromlo-1 location is remote from sensitive receptors in an open-ocean environment where there will be rapid dispersion of any atmospheric emissions. The decrease in air quality from vessels and mobile offshore drilling unit operation will be temporary and localised. Standard processes outlined under Control measures and Performance Standards will be effective in reducing impacts from gaseous emissions to a Category 1–3 consequence. Cumulative impacts from the vessels and the mobile offshore drilling unit combined are assessed as Category 1–3 due to the location and volumes.

6.5.4 Impact treatment

6.5.4.1 Environmental performance outcomes (EPO 6.5)

Minimise risk to air quality from combustion emissions by keeping impacts localised and temporary.

6.5.4.2 Context for assessment

Table 6.28 Context for mitigating impacts from atmospheric emissions

Legislative and other requirements	• Navigation Act 2012 (Cth): • Chapter 4 (Prevention of Pollution) • Protection of the Sea (Prevention of Pollution from Ships) Act 1983 (Cth): • Part IIID (Prevention of Air Pollution). • Australian Maritime Safety Authority Marine Orders Part 97 (Air Pollution), enacting MARPOL Annex VI (especially Regulations 6, 14, 16)
Industry standards	• Environmental, Health and Safety Guidelines for Offshore Oil and Gas Development (World Bank Group, 2015) • Air emissions (item 11): The overall objective is to reduce air emissions. • Air emissions (item 12): During equipment selection, air emission specifications should be considered, as should the use of very low sulphur content fuels and/or natural gas. • Australian Petroleum Production and Exploration Association CoEP (2008): To reduce GHG emissions to As Low As Reasonably Practicable and an acceptable level
Equinor Australia B.V. standards	Management of emissions from the MODU will be consistent with the principles of TR1011-Environmental Requirements for Offshore Installations that require minimising air emissions through compliance with legal/regulatory requirements and keeping sulphur emissions within limits.

6.5.4.3 Control measures and performance standards

Table 6.29 Control measures and performance standards for mitigating impacts from atmospheric emissions

Control measures	Performance standards	Measurement criteria	Responsibility
Ozone-depleting substance management on-board MODU and vessels	EPS 6.5.1: Ozone-depleting substances (ODS) managed in accordance with Regulation 12 of MARPOL Annex VI, which includes prohibiting the deliberate release of ODS.	Inspection of the ODS Record Book show compliance with Annex VI.	MODU Offshore Installation Manager
Use of low-sulphur fuel only (by MODU and vessels	EPS 6.5.2: To minimise sulphur emissions, the sulphur content of fuel oil will not exceed 3.5% m/m.	Bunker delivery notes confirm the use of low-sulphur marine diesel.	MODU Offshore Installation Manager
Cleaner option marine fuels will be used, recorded and reported for the MODU and vessels	EPS 6.5.3: Only marine gas oil (MGO) and marine diesel oil (MDO) will be used for vessel and MODU power generation	Fuel procurement records or Material Safety Data Sheets show only MGO or MDO is used.	MODU Offshore Installation Manager
Fuel use will be measured, recorded and reported for the MODU and vessels	EPS 6.5.4: Vessel fuel usage will comply with *Protection of the Sea (Prevention of Pollution from Ships) Act 1983* (Commonwealth) and usage recorded.	Fuel procurement records or Material Safety Data Sheets show only low-sulphur fuel is used. Records confirm volume of diesel used on board.	MODU Offshore Installation Manager
Planned Maintenance System (PMS) on the MODU and vessels	EPS 6.5.5: Combustion equipment will be maintained in accordance with the PMS.	PMS records confirm that combustion equipment is maintained to schedule.	MODU Offshore Installation manager Vessel Master
	EPS 6.5.6: The heating, venting and air conditioning (HVAC) system will be maintained to prevent refrigerant gas leaks.	PMS records confirm that HVAC equipment is maintained to schedule.	
International Air Pollution Prevention (IAPP) Certificate (System) for vessels >400 T)	EPS 6.5.1: Support vessels will maintain a current IAPP Certificate in accordance with MARPOL Annex VI, which certifies that measures to prevent ozone-depleting substance (ODS) emissions, and reduce NOx, SOx and incineration emissions during the activity are in place.	IAPP Certificate if required is current certifying that a ship-specific Ship Energy Efficiency Management Plan is on board, where applicable.	MODU Offshore Installation manager Vessel Master

6.5.5 Demonstration of acceptability

The level of impact that the air emissions will have on marine biota, communities and the global airshed is acceptable because it meets the a priori acceptability criteria as described below.

Table 6.30 Acceptability evaluation for impacts from atmospheric emissions

Acceptability criteria	Evaluation against acceptability criteria
a. Potential impacts from emissions from the MODU and vessels result in limited to localised and temporary reduction in air quality and no impacts on sensitive receptors or Matters of National Environmental Significance (M)	Emissions will occur in a location remote from sensitive receptors resulting in localised temporary reductions in air quality with no impact to visual amenity or human health. The use of low-sulphur fuel ensures vessel emissions are typical or less than those from commercial shipping transiting the region using heavier bunker fuels. All MNES that may occur in the plume are highly mobile and transient through the area, unlikely to spend time in the plumes, hence; their exposure would be negligible.

Acceptability criteria	Evaluation against acceptability criteria
b. Equipment containing ozone - depleting substances (ODS)- is maintained in accordance with standard industry practice for avoiding release of ODS to the atmosphere	Standard practices on board the MODU will include routine maintenance of equipment, including any using ODS, in alignment with manufacturers' specifications and maritime legislation
c. Compliant with legislative requirements and industry practice.	Performance standards for vessels are aligned with the Navigation Act 2012 and Protection of the Sea (Prevention of Pollution from Ships) Act 1983 (Cth) In addition, performance standards are aligned with industry guidelines (Australian Petroleum Production and Exploration Association CoEP and Environmental, Health and Safety Guidelines for Offshore Oil and Gas Development (World Bank Group, 2015) and Equinor Australia B.V. standards such as TR1011 Environmental Requirements for Offshore Installations

6.5.6 Demonstration of As Low As Reasonably Practicable

The decision context and assessment technique for the As Low As Reasonably Practicable assessment are provided in Table 6.31. Additional controls which have been considered in reaching As Low As Reasonably Practicable are listed in Table 6.32.

Equinor Australia B.V. considers the impacts from atmospheric emissions are As Low As Reasonably Practicable because:

- impact level is already Category 1–3 with standard practices and controls.
- no additional control measures have been identified to further reduce the impacts of atmospheric emissions, apart from not conducting the drilling activity which is not acceptable.

Table 6.31 As Low As Reasonably Practicable decision context and assessment technique for impacts from atmospheric emissions

As Low As Reasonably Practicable decision context	The operation of diesel generators to power MODU operations and marine vessels is a well-practiced and unavoidable activity in deep offshore waters. Given the remoteness of the activity's location and distance from sensitive receptors, in conjunction with the emissions being constrained to the duration of the Activity with no long-term impacts expected, the likely effects from atmospheric emissions are considered minor. No additional control measures are required to reduce impacts to As Low As Reasonably Practicable. No relevant persons raised objections or claims regarding air emissions. Emissions are regulated and managed under other specific legislation; taking this in consideration, Decision Context A should be applied to demonstrate impacts are As Low As Reasonably Practicable.
Assessment technique	Good Practice adopted to reach As Low As Reasonably Practicable.

Table 6.32 Assessment of additional controls to mitigate impacts of atmospheric emissions

Additional capability	Hierarchy	Environmental benefit	Env benefit scale	Cost	Rationale	Outcome
No incineration on vessels if incineration is possible	Elimination	No air emissions onshore and minimised transport impacts	Negligible <1%	0.5–2%	Incineration of wastes on vessels using MARPOL-certified equipment and procedures is an accepted practice, which avoids potentially greater impact through transport, treatment and disposal onshore	Not adopted
Use a cleaner burning fuel (MDO/MGO)	Elimination	Emissions of particulate matter from MDO and MGO are less than from heavy fuel oil or bunker fuel.	Minor (1–3%) depending on technology	0.5–2%	Approximately 40 m^3 fuel are burned daily by the vessels and MODU. Bunker oil or heavy fuel oil emissions are higher in SOx, particulate matter and other pollutants than the more expensive MDO and MGO.	Adopted

6.6 Drilling fluids and cuttings discharges

6.6.1 Impact description

Unrecoverable drilling fluids, synthetic-based muds (SBM) and cuttings will be discharged to the seabed during the following activities:

- During the conductor and surface hole drilling (riserless, 42" and 26" sections), drill cuttings and unrecoverable, low-toxicity fluids (sea water mixed with fine particles from the drilling, bentonite clay and natural polymers) will be discharged at the seabed; the larger particles forming a cuttings pile in the immediate vicinity of the well, with smaller particles spreading further from the source aided by ocean currents. Sea water will be used for sweeps during the initial phase of drilling.
- Once the riser is installed (intermediate and production hole 16", 12¼" and 8½" sections), treated drill cuttings will be discharged just below the sea surface, resulting in hydrodynamic dispersion of the cuttings and residual muds over a larger area as they sink to the seabed.
- There will be occasional discharges of wash water and mud residue from the mud pits, for example at the end of drilling.

If the mobile offshore drilling unit needs to re-spud, a proportionally small increase in cuttings may be generated.

Table 6.33 summarises the estimated volume of drill cuttings and muds discharged for each well interval.

Table 6.33 Estimate of drilling fluids and cuttings discharged per well interval

Bore diameter (inches)	Well interval	Cuttings	Mud				Discharge point
		Approximate volume discharged (m^3)	Type	Volume liquids and solids discharged (m^3)	Volume of solids discharged		
					%	M^3	
42	Conductor	91.9	Sea water and sweeps	263.91	3.6	9.54	Seabed
26	Surface hole	266.5	Sea water and sweeps	1193.96	3.1	37.04	Seabed
16	Intermediate hole	203.4	Synthetic based muds	12.72	17.5	2.23	Sea surface
12.25	Intermediate hole	69.0	Synthetic based muds	3.02	7.9	0.24	Sea surface
8.5	Reservoir section	17.1	Synthetic based muds	0.32	50	0.16	Sea surface
Total		647.9				49.2	

Note: modelling done for 17.5"bore diameter (hence the greater associated volume of cuttings and mud)

There is a low likelihood that the well will need to be re-spudded during drilling of the top-hole section. This would lead to a small incremental increase in cuttings and mud discharge volumes. The likelihood of re-spudding an exploration well is low (<10% likelihood). As such, these additional volumes are not included in the base case. The environmental aspects of re-spudding are similar to those for top hole drilling as described below with no significant changes to planned environmental impacts. The net environmental effect will be an increase in the volume of cuttings generated (and discharged at the seabed) from the repeated drilling of the top-hole section and minor increases in operational discharges from support vessels and the mobile offshore drilling unit (such as brine, sewage, air emissions etc.) due to an extended drilling program.

Since 1980, around 10% of all the wildcat wells (exploration well where there is less certainty about the subsurface geology) drilled in Australia included side-tracks (SINTEF, 2017). The net environmental effect of a side-track will be limited to an increase in the volume of cuttings generated and discharged, water based mud (WBM) or SBM use and minor increases in operational discharges from support vessels and the mobile offshore drilling unit (e.g. brine, sewage, air emissions, etc.) due to an extended drilling program.

SBM and chemicals will be assessed in accordance with Equinor Australia B.V.'s Chemical Selection and Assessment standard process prior to approval for use in the drilling program. The chemical selection process, aimed at minimising use and discharge of chemicals with potential ecotoxicological effect, is described in Section 2.0.

The planned discharge of drill cuttings and fluids has the potential to affect marine fauna and habitats through:

- burial and smothering of benthic infauna and epifauna (habitats and communities)
- sedimentation leading to the alteration of the seabed sediment quality and physico-chemical composition
- temporary increase in total suspended solids (TSS) concentrations and turbidity in the water column, increasing attenuation of light in the surface waters
- potential chemical toxicity and oxygen depletion impacts to biota in the water column, benthic habitats and sediment (including demersal and pelagic fish, transient marine mammals and reptiles and plankton).

The predicted impacts on other marine users are considered to be Category 1–3 because the presence of the mobile offshore drilling unit and the abandoned well head will cause negligible disruption to commercial or recreational vessel users, including fishers.

6.6.2 Levels of acceptable impact

The impact on fauna caused by the drilling fluids and cuttings discharge will be acceptable when:

a. There are no consequences to marine biota and habitats greater than localised impacts to individual organisms. There are no effects on ecosystem function or population-level effects from discharging drilling cuttings and muds.

b. The turbidity and total suspended solids impacts on water quality are temporary and localised.

c. Only low-toxicity chemicals are selected for use.

d. Potential chemical toxicity impacts to fauna in the water column and benthic habitats are localised.

e. There are no direct effects on matters of national environmental significance and identified seabed features (Anna's Pimple and Murray's Mount) or effects on the Great Australian Bight Marine Park Management values.

f. The drill fluid selection, management and disposal operations are aligned with industry practice and company standards and procedures.

6.6.3 Impact prediction

6.6.3.1 Drill cuttings and muds deposition and suspended solids plumes

The deposition of solids (including muds) on the seabed and the extent of the turbid plume of suspended and dissolved solids have been assessed using plume dispersion and sedimentation modelling. The model provides a conservative approach to assessing the impacts and takes into account differential settling rates, particle sizes and hydrodynamic factors. The muds and cuttings dispersion modelling report (RPS 2018) is included in Appendix 6-2.

The objectives of the dispersion modelling were to:

- Predict the potential sediment deposition (bottom thickness with smothering and toxicity potential) and in-water total suspended solids concentrations and toxicity from the discharge of cuttings and unrecoverable muds.
- Predict the likelihood of contact to the nearest seabed features, Anna's Pimple and Murray's Mount.

The modelling examined discharges under varying current conditions for the start of each calendar month and was carried out in several stages. Firstly, a three-year dataset (2010, 2011 and 2012) of three-dimensional currents that included the combined influence of ocean and tidal currents was established. Secondly, the current data and drill cuttings discharge characteristics were input into the sediment dispersion model (MUDMAP). Thirdly, the movement and initial settlement of the discharged sediments were predicted

for the first day of each calendar month for 2010, 2011 and 2012. The results were combined to provide an overall assessment that shows seasonal differences in the behaviour of muds and cuttings discharges.

The near-seabed discharges totalled 405 m^3 of cuttings and muds. The sea surface discharges totalled 289.5 m^3 of cuttings and 2.6 m^3 of unrecoverable drilling muds. The model was run for 27 days after cessation of drilling to allow finer sediments to settle out of suspension. The densities of the cuttings and drilling muds were assumed at 2600 kg/m^3 and 4200 kg/m^3, respectively. It is important to note that grain size has a greater influence on the rate of settling than density (Neff 2005). Grain size distribution and differential particle settling velocities were accounted for in the model as described in Appendix 6-2.

Sedimentation (deposition on the seabed) thickness thresholds were set at 0.05 mm and 1 mm to represent levels above background and low environmental impact, respectively. The lower end of the high exposure threshold was set at sedimentation above 10 mm thick. The low impact threshold (1 mm) is a very conservative threshold in a depositional sediment ecosystem where the benthic communities are adapted to continual sedimentation from the overlying water column. Kjeilen-Eilertsen et al. (2004) showed that deposition of greater than 9.6 mm may cause smothering impacts on benthic ecosystems. Also, IOGP (2016) had indicated that ecological impacts would only be expected when sediment deposition exceeds 6.5 mm thick. A literature review by Smit et al. (2008) found a 50% hazardous level of sediment burial was 54 mm. Therefore, 10 mm is considered a reasonable thickness threshold above which high-level ecological effects are possible.

The minimum total suspended solids concentration threshold used for the modelling assessment was 5 mg/L, which is considered conservative because Nelson et al. (2016) found that <10 mg/L had no effect or minimal effect. Jenkins and McKinnon (2006) reported that levels of suspended sediments >500 mg/L are likely to produce a measurable impact upon larvae of most fish species, and that levels of 100 mg/L will affect the larvae of some species if exposed for periods greater than 96 hours. IOGP (2016) stated that very high concentrations (>1830 mg/L) of total suspended solids have been shown to result in mortality of pelagic biota.

Table 6.34 Sedimentation and total suspended solids environmental effect thresholds

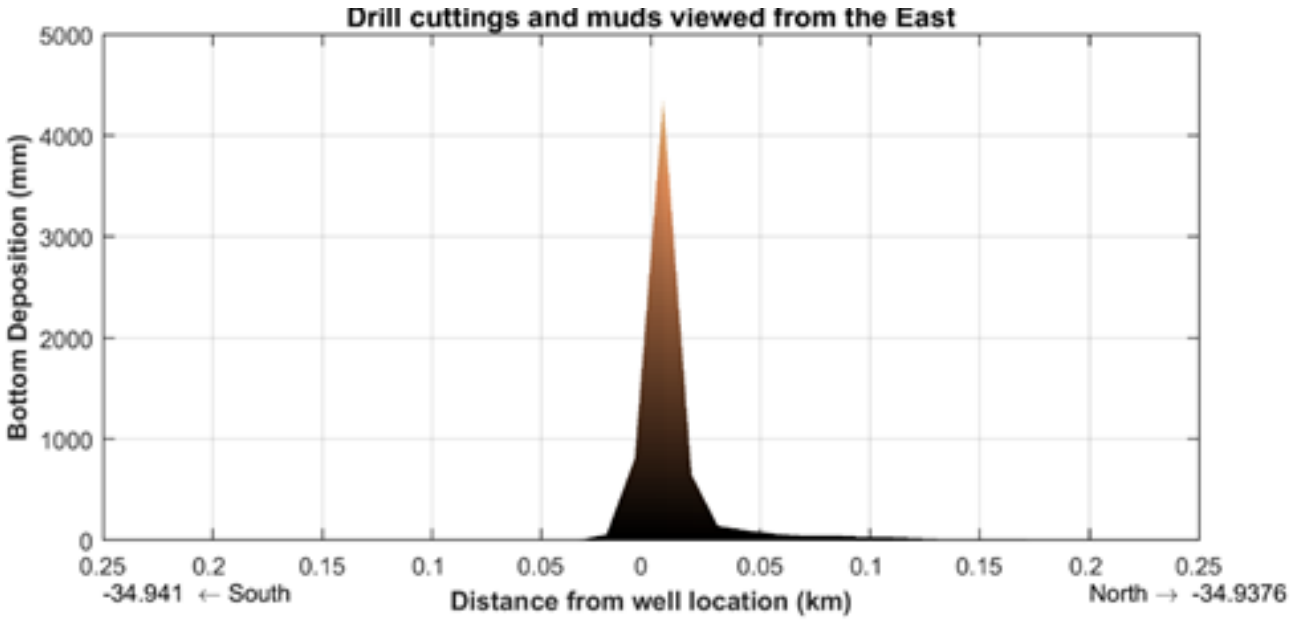
Initial grouping	Unit	Low effect	Medium effect	High effect
Sedimentation	mm	0.05–1	1–10	>10
TSS concentrations	mg/L	5–10	10–25	>25

Seabed deposition

Coarse cuttings (rock fragments) released near the seabed during top-hole drilling will fall immediately to the seabed around the well. Finer cuttings and muds discharged near the seabed will have limited time to be carried by the current and therefore will generally also settle near the well. The larger cuttings (0.45–6 mm diameter) were predicted to settle within 50 m of the discharge point and to form a primary cuttings mound around the well. Under the influence of seabed currents, the cuttings mound extended slightly further to the north-east than in other directions (Figure 6.4). The predicted maximum thickness of this primary cuttings mound around the well-site ranged between 1690 to 4036 mm, depending on the prevailing conditions during each of the simulations. The predicted total area of coverage above the background level (>0.05 mm thick) varied from 3.17 to 3.87 km^2 under different seasonal conditions.

The drill cuttings and muds discharged at the sea surface will drift and disperse with ocean currents much further as they settle through the deep-water column (2239 m water depth). This will lead to a much larger area of deposition from the surface discharges but most of the area affected will only receive a thin veneer of sediments (Figure 6.6).

The modelling predicted that the area of coverage based on low (1–10 mm) and high (>10 mm) thresholds was 1.78 km^2 and 0.17 km^2, respectively. This equates to 7% and 1% of the total area of coverage above background indicating that most of the affected area would receive a very thin coating of particles. The maximum distances from the well to the low and high thresholds were 2.3 km and 0.7 km, respectively. The remainder of the affected area would receive less than 1 mm of sediment deposition.



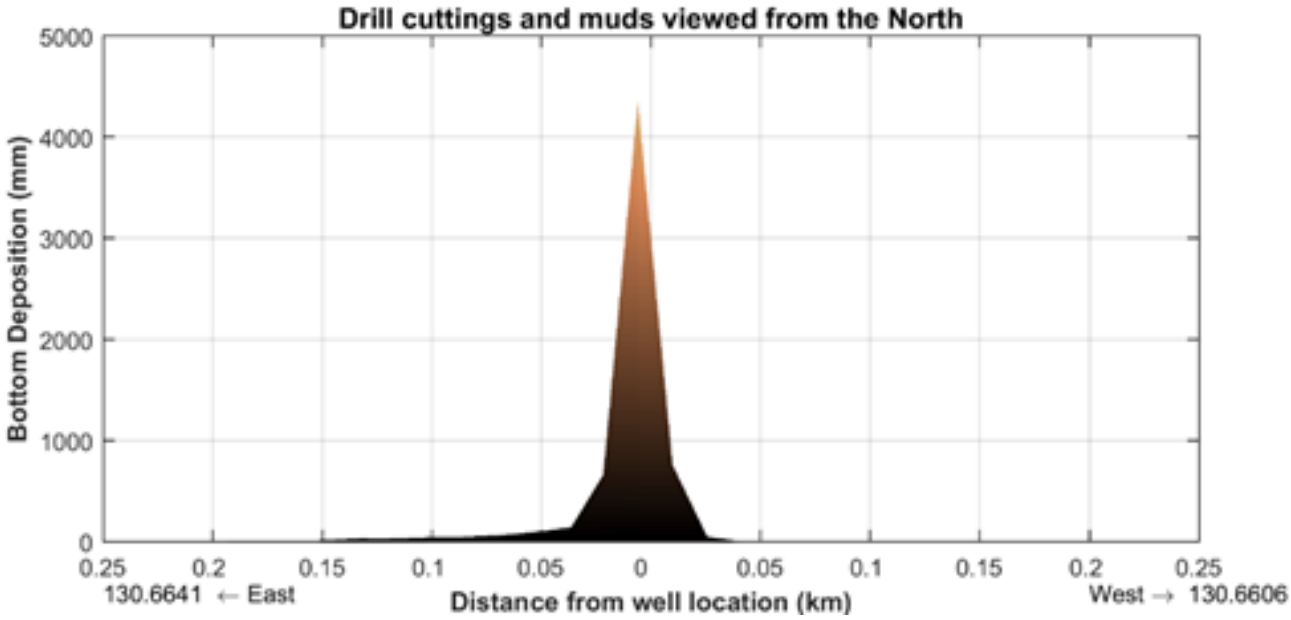
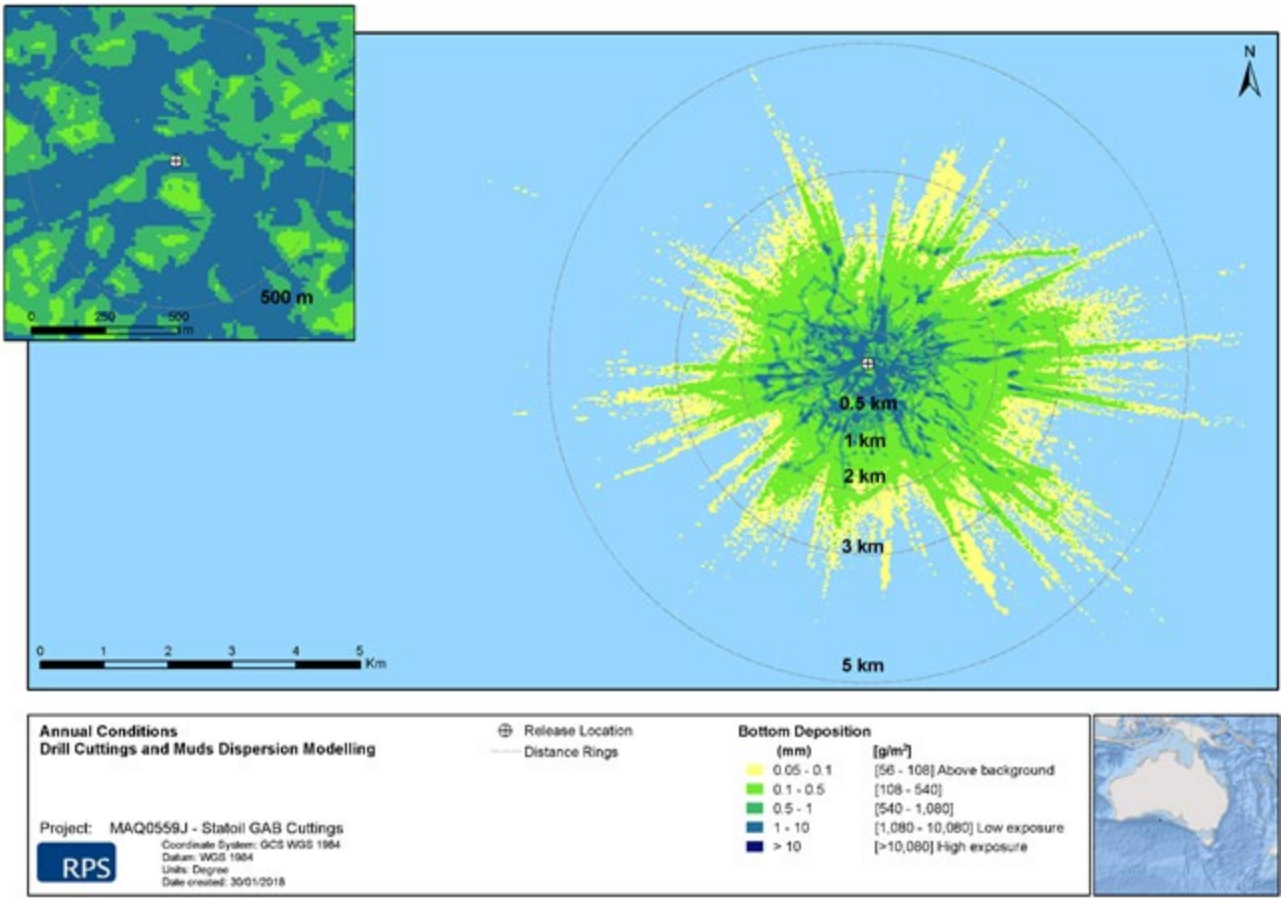


Figure 6.8 Predicted accumulation of cuttings and mud discharges on the seabed during drilling



Note that this is a compilation of 36 runs; not an individual scenario

Figure 6.9 Maximum thickness of seabed deposition combined for all near-seabed and sea surface discharges

Suspended solids plume

The maximum predicted total suspended solids concentration in the turbid plume discharged from the well was 1857 mg/L, which occurred within 0–10 m of the release location and was predicted to persist for only a few hours before settling and being dispersed by water currents. The total suspended solids concentrations fell rapidly to less than 100 mg/L within about 30 m of the discharge point. The area exposed to total suspended solids concentrations greater than 25 mg/L was 0.23 km^2, extending a maximum distance of 870 m north-east of the well site (Figure 6.6). The predicted area exposed to total suspended solids concentrations above background (>5 mg/L) was 4.32 km^2 and the area affected extended a maximum distance of about 4 km north-east from the release location.

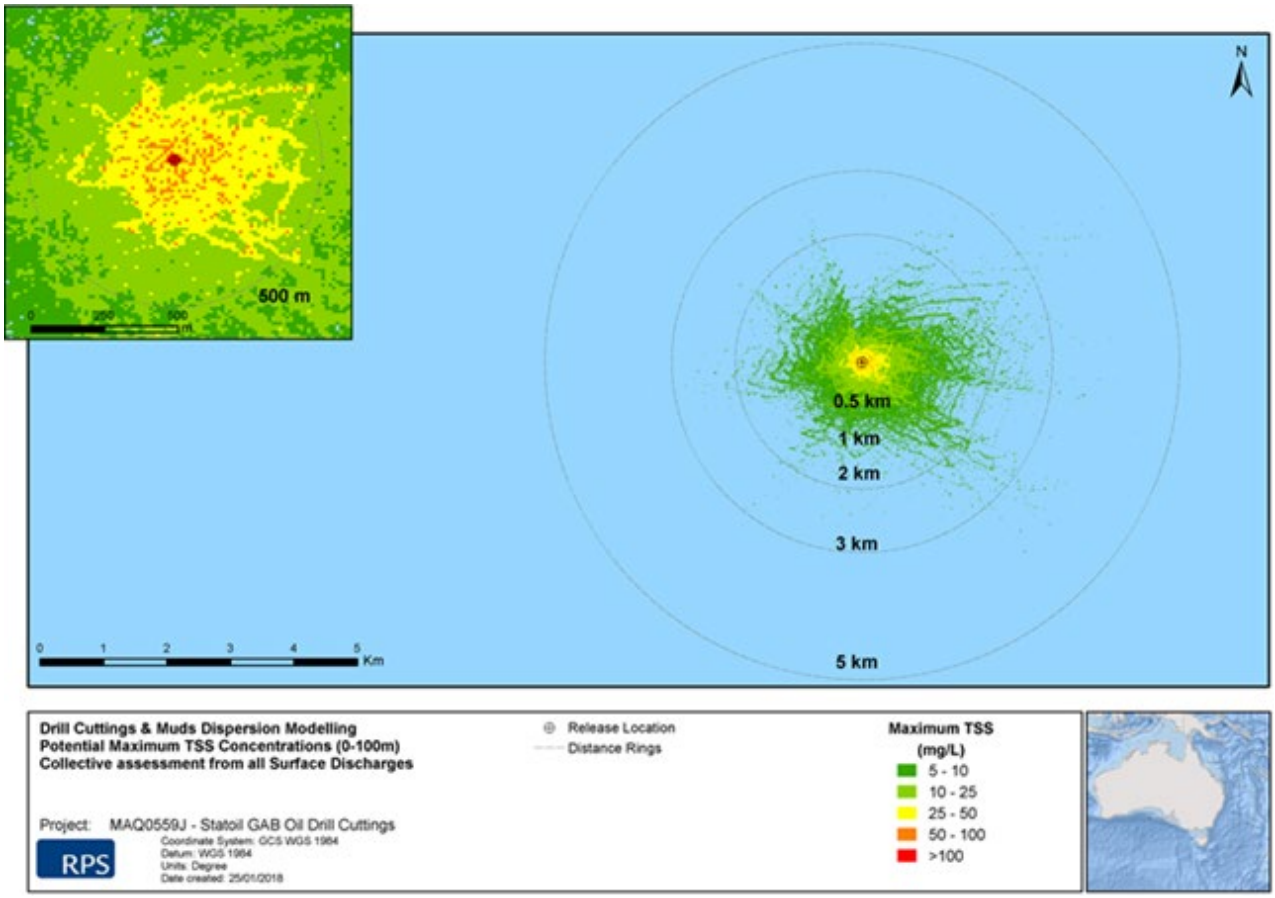


Figure 6.10 Predicted maximum total suspended solids concentrations combined for all near-seabed and sea surface discharges

Release of toxic chemicals

Modern SBM typically have a low toxicity to water column and benthic organisms (IOGP 2016). Equinor Australia B.V. will apply its internal process for selecting lower toxicity chemicals for any drilling fluid additives, to minimise potential for adverse impacts on the environment. The Equinor Australia B.V. process requires that drilling fluids and chemical components are selected on the basis of low toxicity, in accordance with the Offshore Chemical Notification Scheme that is widely used in Europe and other parts of the world. The chemicals used in the program will be Offshore Chemical Notification Scheme rated D or E or ranked Gold or Silver. Chemicals rated D or E will only have toxic effects above 100 ppm in the water column and above 1000 ppm in the sediments (Table 6.35).

Given the low predicted toxicity, modelling predicts that the concentrations of SBM chemicals and chemical additives will be below acute toxicity thresholds beyond the primary cuttings mound around the well and the immediate water column mixing zone. The modelling indicated that exposure to total suspended solids concentrations above 100 ppm (100 mg/L) would be restricted to less than 50 m around the discharge point (Figure 6.4). Considering this as an impact zone is conservative because most of the discharge will be rock cuttings from the well, inert clays, natural polymers and only a small proportion of the total suspended solids plume will comprise low-toxicity chemicals and SBM.

Table 6.35 Ecotoxicity information for Offshore Chemical Notification Scheme fluids

Receptor group	Initial grouping				
	A	B	C	D	E
Aquatic toxicity (ppm)	<1	>1–10	>10–100	>100–1000	>1000
Sediment toxicity (ppm)	<10	>10–100	>100–1000	>1000–10,000	>10,000

Note: Group “A” has the greatest hazard potential and Group “E” the least hazard potential.

Source: https://www.cefas.co.uk/cefas-data-hub/offshore-chemical-notification-scheme/

6.6.3.2 Effect duration

The primary cuttings mound is expected to persist within the 50 m radius around the well site and will gradually be buried by natural sedimentation. The surface of the mound will be bioturbated by benthic fauna as they colonise it, integrating the cuttings with the natural sediments. The burial, smothering and sediment changes in the 50 m zone can be expected to be long term (>5 years) and within a few hundred metres of the well (IOGP 2016).

Water column turbidity and any plume toxicity impacts are limited to the drilling period.

6.6.3.3 Environmental effects of deposition and total suspended solids

Smothering and burial

The primary cuttings mound within 50 m of the well head, where there will be significant accumulation of solids that will smother benthic biota and bury benthic habitats, lies wholly within a flat sparsely featured part of the Multi Use Zone of the Great Australian Bight Marine Park, an area characterised by deep soft sediments. As outlined in Section 4.0, the deep-water sediment habitat is very widely represented across the Great Australian Bight with no discernible spatial patterns within depth zones. The benthic communities at the Stromlo-1 location are typical of similar areas surveyed in the central Great Australian Bight. Infaunal assemblages in the soft sediments are characterised by low abundance of individuals of most species. The loss of a small area of habitat, until it can be re-colonised, will not adversely affect the viability of local populations of infauna or epifauna, the ecology of the local area or the biodiversity of the region.

Mobile benthic fauna such as crabs, shrimps and demersal fish in the area of the primary cuttings mound are expected to be able to largely avoid impacts from the cuttings deposition (IOGP 2016). Mobile megafauna are usually unaffected but sometimes repelled or attracted to changes in topography (Hughes et al. 2010) and their distribution in the local area may be affected by the cuttings mound. Studies have shown increases in populations of some opportunistic species with a resultant decrease in local species diversity but Balcom et al. (2012) concluded such impacts are minimal and highly localised.

Ecotoxicological effects may occur if cuttings and muds contain high concentrations of low-toxicity chemicals or organic matter. Chemical concentrations exceeding 1000 ppm may occur in sediments immediately adjacent the well head and may affect infauna and epifauna colonising the cuttings mound. Microbes biodegrading organic matter in drilling muds may deplete sediment oxygen faster than can be replaced from the overlying water column, causing localised anoxia effects in the sediments (CSA 2006).

The Great Australian Bight Research Program was the first comprehensive study of the benthic communities in the deeper parts of the Great Australian Bight and while it remains as one of the most comprehensive study of these communities, it could only sample a very small proportion of the total soft sediment habitat available. Given the novelty of such a deep-water survey and the sparse nature of the assemblages, it is unsurprising that many new species and species represented by single specimens were collected. The species accumulation curves of Williams et al. (2017, 2018) indicate that the deep-water benthic communities will require significantly more sampling before the full range of species are discovered. The new and apparently uncommon species are expected to be widely represented in similar habitats across the entire central Great Australian Bight.

The only known rare or unusual habitats in the area are scattered seamounts, which provide hard substrate and thereby support local biodiversity hotspots of higher conservation significance. The modelling indicates that no cuttings or muds will be deposited on locally uncommon seabed features such as seamounts. The closest are Anna's Pimple and Murray's Mount (see Section 4.6.2 – Figure 4.6). The minimum distance from the area of cuttings and muds deposition is 16 km to Anna's Pimple and 20 km to Murray's Mount. The biotic assemblages on these seamounts will not be impacted.

The low levels of sediment deposition away from the immediate area of the well site, represented by a thin layer of settled drill cuttings and muds, will be naturally reworked into surface sediment layers through bioturbation (United States Environmental Protection Agency 2000) and will not be of a significant impact potential given the small area affected (<1.78 km^2). The thin veneer of sediment deposition is not predicted to impact on mobile benthic fauna such as crabs and shrimps or pelagic and demersal fish in the broader area affected, given their ability to avoid the area (IOGP 2016).

It is also noted that SBM cuttings from surface discharges tend to clump and settle to the seabed rapidly, adding to the cuttings pile around the well site, and the patchy nature of the more distant depositions allow the recovery and recruitment of new colonising organisms (IOGP 2016, report 543) of sediment re-workers. Figure 6.5 shows the predicted mosaic of sediment deposition around the well.

Benthic communities typically start recovering shortly after drilling finishes, even in areas of thick deposition, and recovery is often well advanced within a year (IOGP 2016, report 543). Full recovery will be delayed until the physical and chemical properties of the sediments return to pre-discharge conditions, which may rely on natural deposition of sediment to bury the cuttings mound and bioturbation to re-oxygenate the surface sediment layers. The vast areas of unaffected soft sediment surrounding the well-site will provide suitable donor populations to enable natural recovery of infaunal and epifaunal communities.

Impacts due to organic enrichment (and consequent anoxia effects) and to a lesser extent chemical toxicity near the well location are highly localised, with short-term recovery that may include changes in community composition with the replacement of infauna species that are hypoxia-tolerant (IOGP 2016). Recovery of affected benthic infauna, epifauna and demersal communities is expected to occur quickly, given the short duration of sediment deposition and the widely represented benthic and demersal community composition.

Suspended solids and turbidity

Conservation-significant fish species that may traverse the plume include the great white shark, and southern bluefin tuna (Conservation Dependent). The pygmy blue whale is the only Protected Matters Search Tool listed whale with a distribution habitat and migration route overlapping the Operational Area. There are no other adjacent or nearby known Biologically Important Areas for protected species – pygmy blue whale and sperm whale foraging grounds lie about 100 km north but a number of species of whales may still seasonally traverse the area such as fin, long finned pilot, pilot, humpback, killer and various beaked whales and others may visit throughout the year (e.g. sperm whale). Likewise, several species of dolphins (such as common short beaked, Risso's and Indo-Pacific bottlenose) may transit the region. The area of the turbidity plumes is regarded as a very small percentage of the foraging grounds of protected seabirds such as shearwaters, albatrosses and petrels. Research data detailing potential impacts from suspended solids and turbidity from drill cuttings to megafauna is scarce, however such megafauna are highly mobile, transitory and able to avoid the plumes.

The environmental receptors that are more likely to be exposed to increased suspended solids and turbidity levels in the water column include motile pelagic invertebrates and fish species, larvae of invertebrates and fish, and zooplankton (Section 4.6) in the immediate vicinity of the well location. Migratory species of some fish are seasonally transient in the immediate area as they pass through between high latitude habitats and the Australian coast, shelf and slope waters.

The high concentrations of total suspended solids in the first tens of metres around the discharge point may affect biota that do not avoid the densest part of the plume, by clogging the gills or digestive tracts of zooplankton (e.g. copepods) and light attenuation may temporarily impact the productivity of phytoplankton. Studies of phytoplankton showed adverse effects from bentonite clay concentrations above 10 mg/L, or from barite in suspension above1000 mg/L (Smit et al. 2008). Garcia et al. (2014) reported that the 72-hour no observed effect concentration (NOEC) for marine phytoplankton of bentonite clay is 1000 mg/L; a concentration not typically found beyond 25 m down-current of a drilling discharge (Smit et al. 2004). This is consistent with the current modelling that predicted total suspended solids concentrations will fall below 100 mg/L within 30 m of the discharge.

Smit et al. (2008) estimated the average lethal median concentration of suspended bentonite and barite to 12–15 species of pelagic biota was 1830 mg/L and 3010 mg/L, respectively. The maximum concentration of total suspended solids for the Stromlo-1 well was predicted to be 1857 mg/L; this was a spike which only lasted a few hours and was limited to within 10 m of the well. This suggests that the range of adverse impacts to water column biota will be limited to tens of metres around the well site.

The suspended solids in the water column will increase the turbidity of the surface waters mainly where the discharge concentrations are highest. Turbid water attenuates photosynthetically active radiation (light) penetration and can reduce the productivity of phytoplankton and benthic primary producers. The water is too deep for high concentrations of benthic primary producers, so impacts are limited to a short-term reduction in plankton productivity and larvae of invertebrates and fish in the immediate area.

The area that will be affected represents a very small proportion of the overall extent of the habitat in the region and given the duration of increased turbidity being short term, there will be no long-term impacts to the diversity and abundance of benthic or pelagic fauna, with impacts being localised limited local degradation of the environment.

Toxicity

The toxicity of chemicals in the muds and cuttings discharge stream will depend on their bioavailability to organisms in the receiving waters and sediments. Non-soluble components are typically more likely to have a smothering or clogging effect, rather than a toxicological one. Most chemicals are not bioavailable unless dissolved or ingested. Dissolved components, particularly salts and water-soluble organic drilling fluid additives, dilute and leach rapidly in the water column. Nedwed et al. (2006) found that water depth is an important factor affecting the concentrations of base fluid on deposited cuttings, where cuttings that had a great distance to reach the seabed had significantly lower concentrations, suggesting that loss of base fluid during settling acted to significantly reduce chemical effects from discharges. This was based on the assessment of discharges in 950 m water depth; the effect will likely be greater at Stromlo-1 in 2239 m water depth.

Most minerals in cuttings are stable and have low solubility in sea water and barite (the most abundant particulate solid in the SBM) has very low solubility in sea water. A high proportion of the chemicals associated with the coarser primary cuttings and aggregates and retained in flocculated clay/barite deposits will settle directly to the seabed (IOGP 2016) and be less available to water column biota, but more available to sediment biota.

The modelling predicted very rapid dispersion of the plume of muds and cuttings, apart from the heavier fractions that will deposit on the seabed around the well. Hinwood et al. (1994) and Neff (2005) note that within 100 m of the discharge point, a drilling cuttings and fluid plume will have diluted by a factor of at least 10000. Neff (2005) also states that in well-mixed oceanic waters (as is the case at the Stromlo-1 drilling area), drilling mud is diluted by more than 100-fold within 10 m of the discharge.

Fluids will only comprise a small percentage of the discharge and prior to discharge they will be treated to reduce residual synthetic oil on cuttings to a maximum of 6.9% by weight (IFC 2015). After release any fluids will be diluted approximately 100-fold within 10 m and 10,000-fold within 100 m of the discharge. As such potential concentrations of fluid chemicals are expected to be reduced to 690 ppm within 10 m of the mobile offshore drilling unit and 6.9 ppm within 100 m of the release location.

Given the relatively low productivity of the area, the absence of abundant features that might lead to aggregations (e.g. compared to upwellings such as the Bonney Upwelling in the region, oceanic convergence zones, islands or reefs) and the localised nature of the plume and deposition areas, only low densities of marine fauna are expected to be exposed to the discharge plume.

As outlined in “Suspended solids and turbidity section above”, protected megafauna that may be present include threatened species such as the pygmy blue whale that has a distribution and migration area within the Impact Environment that May Be Affected, but foraging areas lie well out the plumes about 100 km north. The foraging area for the sperm whale also lies about 100 km north. However, numerous other endangered or vulnerable whale species (see Section 4.6.6.1) may also transit the area and encounter the plume. Seabirds with foraging areas in the region that may overlap the plumes include vulnerable and endangered species of albatross, shearwater, skua and petrels.

High concentrations of protected megafauna are, however, not likely to remain in the plume but transient, mobile individuals may encounter areas of elevated oils/cuttings. As such potential exposure through ingestion (e.g. contaminated prey) or low-level oiling is predicted at worst on an individual level.

The environmental receptors in the water column exposed to discharged cuttings and muds that are most likely to be impacted by chemicals in the discharges include pelagic fish, plankton, eggs/larvae of invertebrates and fish, and transient larger fish.

Benthic infauna and epifauna and demersal fish are most likely to be exposed to any chemicals in the sediments deposited on the seabed around the well. Section 4.6 summarises the benthic habitats and communities in the area of Stromlo-1. In the Great Australian Bight Research Program survey in 2017 survey, over 200 benthic invertebrate and fish taxa were collected from 10 beam trawls in depths from 2750 m to 5030 m. The epifauna assemblage was dominated by ophiuroids (brittle stars), holothurians (sea cucumbers) and stony coral, and individuals were typically small (Williams et al. 2017). The Great Australian Bight Research Program included infaunal investigations of deep-sea benthic habitats in depths of 200–3000 m (Rogers et al. 2013; Tanner et al. 2017). The Great Australian Bight Research Program sampling

had three transects running adjacent to or through exploration permit 39 area (see Section 4.7.3 – Figure 4.21). Infaunal densities in the Great Australian Bight over a depth range of 200–2800 m sampled were relatively low (268–1320 individuals/m^2) compared to densities documented elsewhere (Tanner et al. 2018). The two Great Australian Bight Research Program studies examining infauna densities reported considerably lower densities: 50–450 individuals/m^2 at 500–2000 m (Currie & Sorokin 2011). The 2013 studies noted the large number of new fauna species was not surprising given there have been relatively few surveys of deep-water infauna in Australia. It was noted that the proportion of undescribed species in the deep waters of the Great Australian Bight was consistent with data from similar depths along the Western Australian shelf (Poore et al. 2014), suggesting these species may be abundant and widespread throughout similar depth environments of the Great Australian Bight. Benthic invertebrate fauna were predominantly Crustacea and Annelida (worms), accounting for 94% of all species and 96% of identified specimens. Where seabed samples described in Fugro (2013) comprise very soft to soft sandy clay, the seabed is unlikely to support abundant surface epifauna, which means its less likely there are scallop beds or epifaunal communities to be impacted by smothering.

The composition, diversity and biogeographic affinities of the deep-sea benthic fish assemblages in the Great Australian Bight were studied as part of the Great Australian Bight Research Program (Williams et al. in review). This was the deepest systematic collection of benthic fishes in Australian waters, undertaken across depths ranging from 200 to 3000 m using a beam trawl. A total of 108 deep-sea benthic fish species from 49 families were collected by Williams et al. (in review). Spatial patterns in fish assemblages were evident with species richness, abundance and biomass changing markedly with depth but negligibly across the Great Australian Bight (Williams et al. in review). There was little difference in fish assemblage structure noted between 1500, 2000 and 3000 m water depths. In this depth range, oreo dories (Oreosomatidae), morid cods (Moridae) and halosaurs (Halosauridae) were all prominent (biomass); the latter two families more so in 1500–2000 m depths. At 3000 m deep the cusk eels (Ophidiidae) were the overwhelmingly dominant family by biomass. Density was relatively very low at all sites >1000 m and dominated by rattails (Macrouridae) and a mix of “other” larger bodied species

The low toxicity and low bioaccumulation potential of the drilling muds means that the effects of the discharges are highly localised and are not expected to spread through the food web. The potential for impact is limited to the area around the well location where chemical concentrations will be highest; beyond this area chemical concentrations will be rapidly diluted to levels below acute toxicity thresholds. As such the potential impacts are considered to be limited to local degradation of the environment with minor impacts on small communities.

The primary cuttings mound is expected to persist due to the cohesive nature of the muds and the low energy of bottom waters. Organic compounds will be biodegraded, but more slowly in the anoxic deeper sediment layers within the mound (IOGP 2016). In areas with a thin veneer of sediment deposition, sediment excavation and reworking by benthic fauna will integrate cuttings into the surficial seabed sediments and any chemicals present will be further diluted.

Recovery

The open ocean pelagic assemblages are expected to recover immediately after drilling is completed due to dilution and dispersion of the total suspended solids plume and settlements of heavier components to the seabed. The continual flow of surface waters and the steady supply of new recruits (larvae, migrants, eggs) to the planktonic and macro-pelagic assemblages will enable biotic recovery from any impacts within months to a year, depending on the reproductive cycles of the affected organisms.

Recovery on the seabed will depend on the thickness of the deposition layer; areas with a thin veneer will be largely unaffected and will recover quickly, whereas the localised impact within the primary mound will persist, possibly for decades.

Jones et al. (2012) used remotely operated vehicle surveys of cold deep-water drill cuttings piles to determine megafaunal assemblage recovery at two sites; one 3 years after drilling and one 10 years after drilling. Densities and species richness of motile faunal were significantly elevated immediately after drilling in the area of intermediate disturbance, presumably due to opportunistic fauna being attracted by the drilling disturbance. After three and 10 years, densities of motile organisms were less variable with distance, except very close to the drill site where densities and species richness were still reduced. In the area remaining completely covered by drill cuttings few megafaunas were observed even after 10 years, likely resulting from the change of bottom type from hard substrate supporting a sponge-dominated community to a soft sediment community that was presumably less suitable to the motile megafauna of the area.

The seabed sediments in the Stromlo-1 area are very fine and clayey to depths of at least 4 m below the seabed surface (Fugro 2013) and the deposition of muds will not materially change the habitat type. The solid drill cuttings will, however, create a new habitat type in the local area until such time as they are buried by natural sedimentation. The biota in the area will be able to continue to colonise the broader areas where the cuttings have integrated with the seabed sediments and to colonise the surficial sediment deposits over the cuttings. This may take several years to decades given the very low abundances of epifauna and infauna in the area (Williams et al. in review).

In summary, the impact of the discharge of drilling muds and cuttings on the receiving marine environment, including the Great Australian Bight Marine Park, is considered to result in a Category 1–3 consequence because:

- the primary cuttings mound, where benthic communities and habitats will be lost, is restricted to the immediate vicinity of the well. Even though the pile may remain for a long period, the footprint is small and ongoing impacts are localised
- rated as a Category 1–3 consequence because it is predicted to have only individual level effects and no population level
- the affected habitats and communities are very widely represented across the central Great Australian Bight and across the Benthic Protection Zone of the outer slope waters
- benthic communities in the wider area to be affected by a thin layer of sedimentation are not expected to be adversely impacted in the long term
- all practicable control measures have been implemented in accordance with industry standards
- the plume of turbid water and suspended solids will be localised and rapidly dispersed under oceanic water circulation conditions
- the well- site is in a remote area, over 370 km from the coast and therefore remote from more sensitive shallow-water ecosystems
- no ecosystem- or population-level effects are predicted on any protected marine species or management values of the Great Australian Bight Marine Park.

Given the conclusions above on the potential biological impacts of drilling discharges on marine fauna and the marine ecosystem health, it is predicted that the spiritual connection that Aboriginal communities have with totems such as fish, whales, dolphins and sea lions as well as the health of the marine environment, will not be affected. This assessment is based on the predicted localised seabed disturbance and temporary water quality degradation within the Impact EMBA approximately 370 km from shore. The drilling discharges are not predicted to have any effects on whales or other totems with no effects on their movements into and within important nearshore areas where Aboriginal Peoples may observe and connect with them.

6.6.4 Impact treatment

6.6.4.1 Environmental performance outcomes (EPO 6.6)

Consequences to water quality (from turbidity and TSS) or marine biota (from burial and sedimentation) are not greater than localised impacts on an organism-level. No consequences affecting ecosystem functions and no population-level effects from discharging drilling cuttings or fluids during the activity.

6.6.4.2 Context for assessment

Table 6.36 Context for mitigating impacts from drill fluids and cuttings discharges

Legislative and other requirements	The new Great Australian Bight Marine Park encompasses the former Great Australian Bight Marine Park (Commonwealth waters) which is managed consistent with the arrangements for marine parks proclaimed prior to 2012. The additional areas of the new AMP that were first proclaimed in 2012 are only subject to the transitional arrangements that place no restrictions on mining operations in those areas. Mining operations, including oil and gas exploration in the GAB Marine Park are prohibited in the South-east Marine Reserves Network by the EPBC Act (ss. 355 and 355A) unless done in accordance with the relevant Management Plan. Following proclamation of the network, approval was given under s. 359B of the EPBC Act for the carrying on of oil and gas seismic surveys in Special Purpose zones and Multiple Use zones, and the transit of vessels through the network in connection with mining operations undertaken elsewhere. While approval from the Director of National Parks (DNP) is required for activities in the Benthic Protection Zone of the former Great Australian Bight Marine Park (Commonwealth waters), NOPSEMA is the sole assessor of the titleholder's environmental management arrangements for offshore petroleum and greenhouse gas activities in Commonwealth waters, including in Australian Marine Parks.
Industry standards	The IFC 2015 established a 6.9% by dry weight limit on the quantity of non-aqueous based fluids, including synthetic fluids that could be retained on the cuttings discharged to the marine environment. Elsewhere regulation varies from zero discharge to a 10% maximum of oil on cuttings. The USEPA require the Best Available Technology is applied. Given the internal Equinor Australia B.V. standard aligns with the OCNS process for chemical selection and IFC standards (as described in T1101-Environmntal requirements for Offshore Installations), the 6.9% (dry weight) residual oil on cuttings is deemed the industry standard for this location. • OCNS standards for chemical selection will be followed by selecting only OCNS gold/silver or group D/E chemicals. The following industry standards were considered when drawing up the specific acceptability criteria and when benchmarking Equinor Australia B.V.'s practice against industry practice in the As Low As Reasonably Practicable assessment: • IOGP Drilling fluids and health risk management (Report 396) • IOGP Drilling waste management technology review (Report 557) • IOGP Environmental fates and effect of ocean discharge of drill cuttings (Report 543).
Equinor Australia B.V. standards	Equinor Australia B.V. manages drill cuttings discharges in alignment with the following internal standards to ensure impacts will be minimised: • All chemicals selected and procured as per SF601.01 – Chemicals Management process to ensure selection of low-toxicity chemicals. Chemicals listed for substitution may only be used where these additives have been shown as the only feasible solution due to technical or safety reasons and the impact assessment shows the impacts to be As Low As Reasonably Practicable and Acceptable • TR1011 – Environmental Requirements for Offshore Installations – chemical selection process • Drilling fluids managed in alignment with TR3518 Drilling fluids, completion fluids and total fluid management • Consumption and disposal of muds and cuttings managed as per Stromlo-1 Drilling Fluid and Waste Management Program

6.6.4.3 Control measures and performance standards

Table 6.37 Control measures and performance standards for mitigating impacts from drill fluids and cuttings discharges

Control measures	Performance standards	Measurement criteria	Responsibility
Chemical Selection in accordance with Table 2.8 and aligned with (SF601.01 – Chemicals Management) requires preferential selection of chemicals of lower environmental impact	EPS 6.6.1: All drill fluids and chemicals in the additives planned for discharge are evaluated in accordance with Table 2.8 and aligned with SF601.01 – Chemicals Management and accepted prior to use. The impact assessment process is aligned with the OSPAR-OCNS-CEFAS system. Drilling fluids and chemicals planned for overboard discharge that are ranked using the OSPAR OCNS/ CHARMS system, or are PLONOR substances listed by OSPAR, and do not have substitution warning or product warning will be approved for use and require no further assessment. For non-registered products, a pseudo OCNS assessment using the OCSN methodology for non-CHARM products will be performed, using available toxicity, biodegradation and bioaccumulation data for the whole product or constituents. If a D or E is achieved – no further assessment required. If a product or substitution warning is in place, or D, E cannot be achieved then the following will be performed: • investigation of potential alternatives, with preference for options that are on the OCNS Ranked List of Notified Chemicals (Gold, Silver, or are Group E or D with no substitution or product warning). • further written risk assessment (e.g. document alternatives assessment, additional control measures, technical requirements) of the selected chemical with concurrence from the HSE Lead and Drilling Manager that the environmental risk is acceptable and ALARP Any chemical which does not meet the above requirements or is on the Equinor prohibited chemical list is not acceptable for use.	Records demonstrate the chemical selection, assessment and approval process for chemicals to be discharged overboard is followed.	Equinor Australia B.V. Drilling Manager HSE Lead

Control measures	Performance standards	Measurement criteria	Responsibility
Cuttings are treated by solids control equipment to reduce retained oil on cuttings prior to discharge	EPS 6.6.2: Solids control equipment (shale shakers, cuttings driers and centrifuge) will treat cuttings to a level below 6.9% dry wt retained oil on cuttings (ROC); averaged over each section.	Rig tender specification includes SCE redundancy and cuttings treatment performance standards aligned with this EP. Retort test reports confirm ROC measured and no discharge of SBM with average oil >6.9% dry per section is recorded in the daily drilling report.	Equinor Australia B.V. Contractor: Mud Engineer
	EPS 6.6.3: Frequency of ROC measurements will be • Penetration of 0 ft: no sample • Penetration between 0 and 500 ft: one sample • Penetration between 500 and 1000 ft: two samples • Penetration of more than 1000 ft: three samples.	Inspection of ROC records confirm frequency of measurements	Equinor Australia B.V. Drilling Supervisor Equinor Australia B.V. Contractor: Mud Engineer
	EPS 6.6.4: In the unlikely event that an average of <6.9% dry ROC per interval cannot be achieved then the Rate of Penetration (ROP) is reduced to allow a wider margin of cuttings/hour through the dryer	Retort test reports confirm ROC measured and no discharge of SBM with average oil >6.9% dry per section is recorded in the daily drilling report. Records show if average ROC exceeds specifications, cuttings are stored and/or taken to shore for disposal at appropriate sites.	Equinor Australia B.V. Contractor: Mud Engineer
	EPS 6.6.5: Discharge volumes shall be recorded and reported against planned volumes in the daily well report.	Inspection of the daily well report confirms volumes are recorded and any anomaly is explained.	Equinor Australia B.V. Drilling Supervisor
	EPS 6.6.6: Calibration checks on equipment that measures the ROC and confirmation that the technique followed to measure ROC is compliant with the industry standard.	Calibration records confirm checks on ROC equipment are being undertaken as per the industry standard.	Equinor Australia B.V. Contractor: Mud Engineer
	EPS 6.6.7: Preventative maintenance of solids control equipment is undertaken according to PMS or manufacturers specifications.	Inspection confirms shale shakers and centrifuges are maintained according to the PMS or manufacturers specifications.	Equinor Australia B.V. Contractor: Mud Engineer

Control measures	Performance standards	Measurement criteria	Responsibility
Undertake pre-spud and post-drill surveys to confirm the extent of impacts to benthic communities from primary cuttings deposition	EPS 6.6.8: Pre-Spud and Post-Drill remotely operated vehicle surveys will be undertaken and interrogated to identify and, if possible, quantify primary cuttings deposition within the areas surrounding the well location. ROV transects across PSZ to record visible impacts of discharges.	ROV reports pre- and post-drilling.	Equinor Australia B.V. Contractor: ROV Contractor
In the event of SCE failure (where no redundancy is available) while drilling with SBM, the action is to cease drilling and repair the SCE.	EPS 6.6.9: No overboard disposal of SBM unless otherwise detailed in this EP.	Records show SBM is stored and treated /disposed or returned to shore for disposal if average exceeds 6.9% dry wt basis per interval In the event of auger or cuttings dryer failure (where no redundancy is available), active drilling is initially stopped as soon as safe to do so. Evidence of the decision to drill ahead with failed SCE can be produced. Records confirm the average ROC for intervals) do not exceed limit.	Equinor Australia B.V. Contractor: Mud Engineer
Mud pit wash residue will be measured for oil content before discharge	EPS 6.6.10: Achieves less than 15 ppm oil contamination by volume before discharge	Records after pit clean-out (for pits potentially contaminated with base oil) demonstrate mud pit wash residue was less than (15 ppm) by volume oil content before discharge	Equinor Australia B.V. Contractor: Mud Engineer
Undertake pre-spud and post-drill ROV surveys to confirm the extent of impacts to benthic communities from primary cuttings deposition	EPS 6.6.11: Pre-spud and post-drill ROV surveys interrogated to identify, where possible, the extent of primary cuttings deposition around the well location.	Report of pre-and post-drilling surveys with assessment of size of primary cuttings mound and comparison with modelled mound. Results reported to NOPSEMA in the close of activity report.	Equinor Australia B.V. Contractor-ROV, Equinor Australia B.V. Drilling Manager
Discharge of cuttings below the water line to reduce surface impacts	EPS 6.6.12: Discharge below the water line	Capability for discharge below the water line is included in the rig contract	Equinor Australia B.V. Drilling Manager

6.6.5 Demonstration of acceptability

The level of impact that the drill fluids and cuttings discharges will have on marine biota and marine park values is acceptable because it meets the a priori acceptability criteria as described below.

Table 6.38 Acceptability evaluation for impacts from drill fluid and cuttings discharges

Acceptability criteria	Evaluation against acceptability criteria
The primary cuttings pile will have a long term presence (>10 years) but impacts on seabed biota and habitats are very localised (consequence category 1-3: very limited impacts on individuals, no ecosystem or population level effects),	Modelling from Stromlo-1 and literature from other regions predict the main cuttings pile to lie close to the well – i.e. approximately within 50 m of the well, with a patchy veneer beyond this of decreasing thickness with distance from well. The pile may be present in the long term and will modify an area of seabed habitat, but the affected area is small. The shallow and non-contiguous nature of the drilling mud veneer allows for recovery by recruitment from unimpacted areas and by biodegradation
The cuttings discharge plume will have a short-term local impact to the water column (consequence category 1-3: very limited impacts on individuals or local populations, no ecosystem or population level effects)	The turbidity and TSS impacts on water quality are temporary and localised (i.e. the non-contiguous plume of concentrations above a medium (10-25 mg/L) roughly within 1 km of the well) with rapid and full recovery predicted due to the continual flow of surface waters and steady supply of new recruits. The modelling showed that the highest TSS concentrations were limited to a few hours' duration. The open ocean conditions at the well site facilitate rapid dilution and dispersion of the turbid plume from the drilling discharges. TSS plumes above 10 g/L were predicted to extend non-continuously a maximum distance of approximately 2 km. As such impacts are considered localised (total area of exposure above background is <0.22% of the Multiple Use Zone of the GABMP). The TSS impact threshold of 100 mg/L extends for approximately 50 m from the source. These plumes will be rapidly diluted
Low-toxicity chemicals are selected for use	Low-toxicity drilling fluids and chemical components will be assessed and selected according to the OCNS rating system (D or E; or GOLD/SILVER). This will be managed through Equinor Australia B.V.'s chemical management practices during drilling.
Potential chemical toxicity impacts to fauna in the water column and benthic habitats are localised	High concentrations of TSS and associated chemicals are limited to tens of metres from the discharge point. Concentrations of the OCNS D/E chemicals will be below acute toxicity thresholds (>100 ppm) within 100 m of the discharge. The high mixing rate in the offshore waters will rapidly dilute the discharge and ensure the impacts from the chemical discharges are localised. The toxicity of deposits on the seabed, with potential toxicological effects on sediment biota, will be limited to the primary cuttings mound within 50 m of the well. No impacts to commercial fish stocks are predicted given the short duration and localised nature of the impact as well as the low fishing intensity in the area (Section 4.7).
There will be no direct effect on MNES and identified seabed features (Anna's Pimple and Murray's Mount) or effects on the GAB Marine Park Management values	The transient nature of MNES in the immediate vicinity (including migrating cetaceans protected under the EPBC Act and mobile fish) will reduce exposure to potential effect from the discharge to a level where no impacts are predicted. No local seabed features such as the sea mounts or the Ancient Coastline will be affected as they lie distant of the plumes. Benthos and invertebrate communities of the eastern GAB outside the 50 m radius are not expected to be impacted in the long term or at population levels. The activity is consistent with the allowable activities in the GAB Marine Park. Other values of the GAB Marine Park (such as the Marine Mammal Protection Zone, habitat for migratory cetaceans such as the southern right whale and pygmy blue whale, foraging areas for threatened great white shark and specific KEFs such as areas important to small pelagic fish with important ecological roles will not be affected other than at worst on an individual level.
The drill fluid selection, management and disposal operations will be compliant with industry practice and company standards and procedures	The process used by Equinor Australia B.V. (SF601) to select, manage and dispose of drill fluids and chemicals is based on the OCNS/CHARMs systems, both of which are used extensively by OSPAR signatory countries and by the industry and regulators around the world.

6.6.6 Demonstration of As Low As Reasonably Practicable

The decision context and assessment technique for the As Low As Reasonably Practicable assessment are provided in Table 6.39. Additional controls which have been considered in reaching As Low As Reasonably Practicable are listed in Table 6.40.

Equinor Australia B.V. considers the impacts from drilling cuttings and fluid discharges are As Low As Reasonably Practicable because:

- Drilling fluids are required to undertake drilling activities. Only water based mud will be discharged to the marine environment. All chemicals that may be operationally released or discharged to the marine environment are required to be selected and approved as per SF601.01 – Chemicals Management and well design minimises the generation of cuttings.
- For the well sections where SBM will be used the treatment of returned cuttings reduces the SBM remaining on cuttings to an average of less than 6.9% oil on cuttings (by weight) per section prior to disposal overboard.
- Additional reductions in chemical discharge concentrations and volumes have been assessed above with those being adopted. The impacts are predicted to be Category 1–3 with no population- or ecosystem-level impacts predicted within the AMP.
- No alternative options for SBM and cuttings disposal are considered practical without gross expense for little or negative environmental benefit and no further control measures were identified.
- The identified control measures, including treatment of cuttings and minimisation of cuttings disposal through well design and drilling management, reduce environmental impacts to As Low As Reasonably Practicable.
- New technologies have been considered, but few of these have been approved for deep-water operations.
- The impact level is already Category 1–3 with standard practices and controls.

Table 6.39 As Low As Reasonably Practicable decision context and assessment technique for impacts from drill fluids and cuttings discharges

As Low As Reasonably Practicable decision context	The planned release of drill cuttings and adhered fluids offshore is a well understood and practiced activity both nationally and internationally. Modelling to inform the potential extent of cuttings deposition has been undertaken to remove some of the uncertainty and to understand the potential extent and concentrations that may result in environmental impacts. The localised smothering and alteration of the seabed, which would be expected to occur from petroleum exploration and development activities within a Multiple Use Zone (IUCN category VI) of the GABMP, represents a Category 1–3 consequence because it will lead to localised impacts to individuals rather than population-level effects. There would be highly localised long-term impacts on the benthic ecosystem, but these are considered too small to have an ecological effect on the values of the GABMP and the local biodiversity concentrations on the seamounts will not be impacted. The sustainable management objectives for the GABMP allow for minimal disturbance of the benthos in the Benthic Protection Zone, which was largely established to protect benthic communities from widespread trawling impacts. The DNP has been consulted in preparation of this EP. No issues were raised regarding the discharge of drill fluids and cuttings specifically but advice regarding management values was taken into regard in the risk assessment. The NOPSEMA guidance note N-04750-GN 1785 describes the requirements for petroleum activities in AMPs – notably planning activities such that impacts and risks are As Low As Reasonably Practicable with respect to location, consulting the DNP, describing the environment that may be affected, AMP requirements and how they are met, defining acceptable levels of impact and risk, evaluating impacts and risks, environmental performance and implementation strategy. Taking this into consideration, Decision Context B should be applied to demonstrate impacts and are As Low As Reasonably Practicable.
Assessment technique	Engineering Risk Assessment adopted to reach As Low As Reasonably Practicable

The As Low As Reasonably Practicable assessments are summarised below in Table 6.40.

Table 6.40 Assessment of additional controls to mitigate impacts from drill fluids and cuttings discharges

Additional capability	Hierarchy	Environmental benefit	Env benefit scale	Cost	Rationale	Outcome
Replace conventional drilled/ cemented conductor by a Conductor Anchor Node (CAN) which is a specially designed suction anchor with integrated conductor	Engineering/ Isolation	CAN technology reduces environmental risks by pre-installing conductor support using a DP vessel to install the CAN ahead of rig arrival, thus removing the initial 36" (42") hole drilling, conductor running and cementing operations from the rig drilling schedule. This would reduce discharges of muds and cuttings to the seabed by about 10%; however, it is expected to reduce the thickness of the cuttings pile rather than the spatial extent of it and therefore would have minimal effectiveness in reducing seabed impacts.	Negligible	0.5–2% of project cost	The use of CAN has been evaluated and the seabed at the location may not be suitable for the use of this technology (or suction anchors) and the anchor node would likely need to be cemented anyway. The use of a CAN will add operational risk with negligible environmental benefit. It is not standard equipment in offshore drilling and introducing it would engender significant costs which would be disproportionate to the minor environmental benefit (if any) to be gained. Even if the CAN could be safely deployed, reducing the thickness of the cuttings pile will have a negligible environmental benefit as the risk is already low and the area of effect would not be reduced. The maximum areas above 1 mm thickness (low threshold) are already localised (<0.3 km^2) regardless of the season drilled. Reducing the thickness of deposition over this small area further is not considered a reduction in environmental consequence. The additional vessel costs of a vessel to deploy the CAN is disproportionate to the negligible environmental benefit.	Not adopted
Slim hole / coil tubing drilling	Engineering/ Isolation	This would result in a direct reduction of the volumes of cuttings produced, discharged and therefore deposited, reducing the footprint of area potentially impacted by smothering of benthic habitat.	Negligible	0.5–2% of project cost	There are circulating density, tooling and kick tolerance issues associated with this type of drilling resulting in the risk that the final depth and well objectives will not be achieved (due to safety and well integrity considerations). This type of well would increase exposure for a major accident event given the reduction in kick tolerance and increases the difficulty and reliability of data acquisition. This method is considered to limit the options for using contingency casing strings. This is not a proven technology for deep-water drilling from a MODU in this environment and therefore engenders risk of significant cost blowouts if drilling time is prolonged There are increased HSE risks associated with this form of drilling and there is also an increased potential cost associated with fluid losses given the higher risk of fracturing the formation during drilling. The costs and additional risks are grossly disproportionate to the negligible environmental benefit of a slight reduction in seabed deposition in an area where the impacts are already considered low. This control is considered likely to be impractical and would increase environmental and safety risk with negligible environmental benefit.	Not adopted
Slimming sections	Engineering/ Isolation	This would result in a direct reduction of the volumes of cuttings produced, discharge and therefore deposited. Consequently, reducing the seabed footprint likely to be impacted by smothering.	Minor	<0.5% of project cost	The 17½" section can be reduced to 16" with the application of drilling best practices, and carefully executed casing-running and cementing operations. There is no cost associated with this, and the risks of failure of completing the well section to the planned depth and a casing run with intended integrity can be managed effectively. Environmental benefits outweigh the costs of implementation and this has been adopted within the design.	Adopted
Use WBM fluid systems for entire well (eliminate SBM)	Engineering/ Isolation	WBM fluid systems are generally considered to be less toxic than SBM, as reflected in their lower rankings on the OCNS/CHARMS system. The effect would be limited to a localised decrease in impacts to the low densities of more sensitive marine benthic fauna. However, there is some environmental disbenefit; this would probably increase the volume of deposition on the seabed, and the consumed WBM fluids would need to be disposed of at the end of the program given there is limited ability to recondition used WBM. SBMs reduce the overall waste generated (and discharged) due to better in-hole stability (less wall slumping and therefore less cuttings and fluids).	Minor to moderate depending on systems and volumes selected	<0.5-2% of project cost	SBMs have been selected because they are technically superior for deep sections of holes and increase well safety (reducing LOWC risk). SBM reduces operation risk with resulting higher reliability than WBM as it reduces the risk of stuck pipe, drilling a gauge hole, provides improved lubricity, higher levels of shale inhibition, improves wellbore stability, helps to inhibit hydrates and increases penetration rates. These advantages decrease non-productive time and consequently have a direct cost correlation through reducing drilling time. SBM is suitable for all formations and therefor provides more certainty for an exploration well where information regarding the formations is limited. WBM can be used where additional formation information exists, as the WBM can be engineered to the specific formation. Although the unit cost of WBM is slightly lower than for SBM, a greater the volume of WBM would be required. This would probably also result in greater overall costs. Burke and Viel (1995) compare drilling times for wells drilled with either WBM or SBM. Rates of penetration were substantially faster using SBM, resulting in overall cost savings >50% when compared with drilling using WBM. Cost savings from using SBM are significant as a result of the potential reduction in non-productive time. The environmental benefit is minor and uncertain given the lower toxicity is offset by the greater volume of muds needed. Given the well-integrity and safety concerns this option is not considered practicable and it is therefore not adopted. Given too, only the SBM muds that are ranked Gold/Silver/D or E on the CEFAS OCNS/CHARMS scheme will be used, the toxicity impacts presented by the SBM will be low and localised; and TSS impacts are temporary. The CEFAS OCNS/CHARM system is used widely in the drilling industry across OSPAR signatory countries, taking into account testing results across multiple taxa. As such, when compared to risks associated with extended drilling time frames caused by technical issues, the benefits of WBM do not outweigh the costs. With an ROC of 6.9% dry basis, the Stromlo-1 program equals or exceeds the Industry standard for many of the drilling programs undertaken both in in GAB and the Bass Straits and the NWS.	Not adopted
Riserless Mud Recovery System (RMR)	Engineering/ Isolation	Drilling using RMR in the top-hole sections has the potential to result in the recovery of fluids and cuttings in top-hole sections. Through using an RMR, cuttings piles and consequently deposition within close proximity of the well will be reduced. Based upon the dispersion modelling (Appendix 6-2, RPS 2018), this will mean that the area with a radius of 150 m around the well that would potentially be affected may be reduced. However, as cuttings would still need to be disposed of when bought back to the rig, it is expected that they would be discharged overboard, resulting in prolonged turbidity plume. This would reduce potential impacts from smothering, but this environmental benefit is only small.	Minor	0.5–2% of project cost	RMR is an un-proven technology in deep-water environments such as the GAB. In addition to potential costs associated with non-productive time, it is expected that this would require an additional 2 rig days to rig up and test the equipment (given the additional days have associated emissions/discharges, attendant vessel requirements, HSE risks, increased exposure to drilling risks, exposure to noise etc). This cost is anticipated to be in the order of 2% of the entire well given the additional resources and engineering required. The potentially impacted area (deposition ≥1mm) is already small and with an absence of features that might lead to aggregations or abundance of flora and fauna communities (<0.009% of the Multiple User Zone, <0.026% of the area of the GAB Marine Park National Park Cat II. Given the Stromlo-1 receiving environment is typical of the surveyed deep-water offshore GAB, the environmental benefit of minimising cuttings impacts still further does not justify the cost and risk. It is therefore not adopted.	Not adopted

Additional capability	Hierarchy	Environmental benefit	Env benefit scale	Cost	Rationale	Outcome
Thermal desorption unit (TDU) offshore	Engineering/ Isolation	Thermal desorption can result in very dry solids with residual oil on cuttings to less than 1% with best outcomes less than this. This will reduce the already low potential for toxicity associated with adherent fluids. This is the most viable equipment in reaching this level of performance, and thus is the most viable option in reducing potential toxicity effects. However, given the TDU reduces cuttings particle size, it is expected that using this technology may result in increasing the plume extent potentially increasing turbidity impacts. Given the high dispersion and dilution rates expected at the MODU, reducing ROC further will have negligible effect.	Minor	>10% of project cost	Operational experience with this equipment suggests there are significant issues due to the engineering complexity (rig modifications, power requirements, fuel consumption, CO2 emissions, increased noise and additional personnel). The space required to accommodate the equipment is approximately 20 m × 5 m (approximately 5–6 shipping containers not including any exclusion areas), and additional ISO tanks are required to meet high drilling rates and prevent downtime. The system generally has slow processing rates and is unreliable / prone to shutdowns. In addition to the cost of the unit, approximately 6 to 12 additional personnel would be required on-board the MODU to manage the operations in comparison with running conventional dryers and centrifuges (2–3 people). Other additional costs include overheads and ongoing costs associated with the use and management of on board iso-tank storage systems. To prevent non-productive time, cuttings need to be stored on the rig with processing continuing once cuttings generation is completed. The shortage of space on the MODU could preclude this equipment being operated offshore on an otherwise appropriate rig that we will hire for the work, and it is considered non-feasible for a short exploration program of a single well. It is therefore not adopted. Given too that the potential for toxicity impacts is already low as the muds selected will be CEFAS OCNS/CHARM ranked Gold/Silver/D or E, a further reduction in toxicity does not outweigh the associated risks and costs.	Not adopted
Cuttings re-injection	Engineering/ Isolation	Re-injection has the benefit of preventing the need to discharge cuttings to the marine environment. This would result in reducing the potential smothering of benthic habitats as well as reducing localised potential water column toxicity and turbidity effects.	Negligible	>10% of project cost	Reinjection involves slurrifying cuttings (i.e. mixing them with a liquid) and then pumping them into a separate well, designed for reinjection. Searching for and preparation of an appropriate formation in close proximity has additional costs and significant impacts and risks. Under pressurised conditions, cuttings pass into targeted formations down the well. Offshore injection of cuttings from fixed well head platforms is well proven, but sub-sea injection from mobile drilling units in deep water has not been done. The sub-sea injection equipment involved is very specialised (i.e. it requires a flexible injection riser and a specially designed well head) and has only been developed for water depths of 305 m. Additionally, equipment weight increases considerably with the length of the pipe, so the use of a flexible pipe at deep water depths would be costly and require a large storage capacity on the rig. Therefore, sub-sea cuttings reinjection has never been developed for deep water either by operators or the service sector, because the risked costs are too high especially for exploration drilling. Implementing of sub-sea cutting injection would require the use of unproven technology. It is not considered feasible and is therefore, not adopted.	Not adopted
Drill cuttings returned to the MODU will be discharged below the water line	Engineering	Discharging drill cuttings below the water line will reduce carriage and dispersion of cuttings. thereby reducing the consequence of cuttings discharges during the Stromlo-1 Program	Minor	0.5–2% of project cost	Standard industry practice. At the location depth of >2200m, the discharge height will have little influence on bottom deposition. However, surface slicks may be minimised by below surface discharges and surface impacts minimised e.g. to diving birds.	Adopted
Cuttings centrifugation and drying Reconditioning and storage of SBM before reuse or disposal	Engineering/ Isolation	The ROC is reduced from above 20% to less than 6.9% by using cuttings dryer and centrifuges. This will reduce the amount of SBM on the cuttings SBM is reconditioned offshore and reused where quality allows, with surplus or out of spec fluids stored before re-treatment or returned to shore for storage or disposal, minimising impacts to the marine environment.	Significant (10-50%)	0.5–2% of project cost	Cuttings treatment equipment are commonly used to reduce ROC on exploration wells. It is unlikely that the rig would require major modifications. The cost is hence reasonable and will achieve a reduction of more than 50% SBM disposed. Impacts from the ROC are localised. Limiting the ROC to 6.9 wt % and the use of low toxicity constituents, combined with drilling mud recycling and cutting discharge at sea level to aid dispersion over a wider area, are considered sufficient control measures to reduce the impacts and risks associated with this hazard to ALARP, in accordance with Section 5 as the nature of this risk is well understood, the activity is a well-established practice and the residual risk resulting from this activity is considered to be low. There are no KEFs within the potentially impacted area. The public raised questions regarding at sea disposal of SBM cuttings in general. As such alternative were re-considered and the predicted impact extent and duration re-assessed against ESD principles but no practical alternatives emerged, and no outstanding claims remain. Consequently, no further evaluation against the principles of ESD is required. 6.9% limit for ROC is standard industry practice (based on US EPA statistical analysis of data from 65 wells representing four cuttings drier technologies), including for deep-water drilling. Additional equipment (requiring space, maintenance and trained staff) to further reduce this ROC is not considered ALARP for a single well campaign in this location. The availability of the additional equipment (mobilisation, installation, commissioning and decommissioning) and the utilities and space required, has potential to jeopardise the drilling schedule and costs.	Adopted
Disposal of drilling muds onshore – landfill or use as construction material after suitable treatment	Engineering/ Isolation	Disposal onshore largely eliminates the need to discharge overboard. However, disposal onshore (to landfill) carries additional minor onshore environmental impacts and potentially moves the waste closer to sensitive receptors. However, with additional treatment this material has the potential to be used as a clean fill / construction material, thereby reducing the requirement for waste disposal. Disposal onshore would eliminate cuttings discharge in the marine environment and the associated low level of impact.	Negligible	Potentially >10% depending on onshore destination selected	Drilling mud and cuttings skips (bins) can contain up to about 6.4 m^3 of waste material. Based upon estimated mud and cuttings quantities (total approximately 1426 t / 709 m^3), around 110 skip loads would be required, increasing the number of lifts for the well by an estimated 1100 lifts (assuming 10 lifts per skip load estimated based on each skip being lifted onto a truck, from a truck to the dock, from the dock to a boat, from the boat to the rig deck, from the rig deck to the loading station and then back again). This increases health and safety exposure given the significant increase in the number of lifts required. NOPSEMA's annual offshore performance report that 50% of its high-risk incidents in the year of 2015 were attributed to dropped objects / lifting operations. Beyond relocating the disposal problem from the ocean to landfill, the potential costs of disposal have been estimated at approximately $713,000 based on an indicative cost of $500 per tonne. Further treatment of cuttings onshore may be required to ensure a standard suitable for landfill such as Class II or Class III landfill. To manage the additional skips, it is estimated that at least 2 additional support vessels would be required to support the additional waste generation at an estimated cost of $40,000 x2 per day. Based upon the assumption of a 60-day drilling program, this equates to approximately $4.8 million The increased logistics operations would also increase the risk of having to wait on poor weather, and hence prolonging the time to complete the well.	Not adopted

Additional capability	Hierarchy	Environmental benefit	Env benefit scale	Cost	Rationale	Outcome
					This option was assessed as re-locating the impact of disposal of waste from the ocean (where the location is remote from sensitive shallow water environments) to filling limited landfill sites at a significant cost for little or negative overall environmental benefit. In addition, there is the potential to halt drilling activity if transfer operations are delayed due to weather or operational issues, and increased risk of unplanned vessel collision or loss of cuttings during transfer activities Onshore disposal to landfill would engender significant costs which would be disproportionate to the minor environmental benefit (if any) to be gained. It is therefore not adopted.	
Disposal of drilling muds outside the Marine Park	Engineering/ Isolation	Impacts to the Marine Park are minimised by depositing cuttings beyond the boundaries of the Park. As such potential impacts to values of the Park are minimised.	Negligible (if any)	0.5–2% of project cost	Similar to above – storage, multiple handling including crane lifts and at least 1-2 (depending on destination) additional support vessels are required. The additional vessel will have associated costs, emissions and discharges and risk (collision, loss of loads, marine fauna strike etc). Dumping at Sea has a host of additional approval requirements (e.g. dump permits) which pose a risk of schedule delay, surveys for finding appropriate sites and environmental impacts (suspended sediment/ sedimentation) of discharging cuttings at new location and other regulatory approvals may also be required (e.g. sea dumping permit). This has the potential to halt drilling activities if transfer operations are delayed due to weather or operational issues. Note that the surveys undertaken as part of the GAB studies (Section 4) identified the eastern GAB especially in the region of the Bonney Upwelling as being an area of high biodiversity and sensitivity near the shelf. Studies indicated the deep-water habitats and fauna of the Central GAB displayed decreasing abundance with water depth and the largely soft sediments of the immediate area surveyed were well represented locally and regionally. The impacts occur within the Multiple Use Zone of the GAB Marine Park. Deepwater discharges are likely to have fewer sensitive receptors than shallow water environments. As such, depositing cuttings to the east, closer to upwellings or north near down wellings or in shallower waters may have a higher impact than at the site itself.	Not adopted
Disposal of drilling muds onshore – bio-treatment of muds and cuttings	Engineering/ Isolation	Bioremediation uses controlled processes in which biological, mainly microbiological, methods degrade or transform hydrocarbons on solids to non-toxic or less toxic products. This reduces the toxicity of the waste and therefore reduces potential environmental harm. The toxicity of the SBM is already low, so the benefit would be a minor reduction in effects on sensitive organisms at the localised discharge site.	Negligible	2–5% of project cost	In addition to the logistics of onshore disposal (see above), a large land area is required to manage the volumes of cuttings associated with this program. There would be little overall environmental benefit above those associated with onshore disposal of the cuttings and muds. The logistics from vessel handling, storage and onshore transport all add HSE risks. Onshore disposal with bioremediation would engender significant costs for a single exploration well which would be disproportionate to the minor environmental benefit (if any) to be gained. It is therefore not adopted.	Not adopted
Disposal of drilling muds onshore – incineration of muds and cuttings	Engineering/ Isolation	Incineration technologies oxidize (combust) wastes at high temperatures (typically 1200–1,500 °C) and convert them into less bulky materials that are non-hazardous or less hazardous than they were prior to incineration. Smaller volumes of incineration wastes can then be disposed to landfill. Although there will be a potential environmental benefit through the reduction in the volume of discharges to the marine environment, this is only predicted to be a minor impact reduction. Significant energy is required to incinerate drilling wastes that would be expected to have a high liquid content. This may lead to a net environmental dis-benefit.	Negligible	2–5% of project cost	Incinerators are generally permanent (non-mobile) units and offshore incineration for this volume of waste is not possible. Consequently, this is considered as an onshore disposal option only, with MODUs unlikely to have the space or staff aboard to operate and maintain an incinerator for a single well campaign. There would be little overall environmental benefit above those associated with onshore disposal of the untreated cuttings and muds. In addition to the logistics of onshore disposal an appropriate facility needs to be identified of which Equinor Australia B.V. are only aware of a single facility in Victoria that would engender a significant impost on local communities and an increase in risk associated with road and vessel transport. There would be increased HSE risk, cost, transport emissions and energy consumption. Onshore disposal of cuttings from a single exploration well by incineration would engender significant costs which would be disproportionate to the minor environmental benefit (if any) to be gained. It is therefore not adopted.	Not adopted
Water quality and/or sediment monitoring of drill cuttings or drilling fluids to verify impact during activity	Engineering	Monitoring could be used to inform additional control measures in future drilling activities; however, there is a considerable body of existing scientific literature on potential impacts of drill cuttings and impacts are generally well understood. Furthermore, it is not guaranteed that additional controls would be feasible, or if they would provide any environmental benefit.	Negligible	2–5% of project cost	For in-water sampling using ROV, there are costs around the time and logistics for tool change-out from operational tools to specialised scientific sampling tools. Other considerations include additional personnel on board to operate ROV and coordinate sampling program. It is possible there is low ROV availability due to operations which can limit time to monitor environment. If an additional ROV is required on the MODU, deck space and resources to run/store/service ROV as well as resources for sample processing (space/equipment/ personnel) must be factored against the environmental benefit. Cost/sacrifice outweigh benefit to be gained in the context of existing environment (deep water, open ocean communities with no proximity to sensitive benthic communities or receptors). Although adopting this control could be used to verify EPOs associated with drilling mud and cutting discharge, alternative controls identified achieve an appropriate outcome.	Not adopted
More frequent monitoring of the ROC	Engineering	Adaptive management can be introduced quicker to minimise volumes of SBM overboard.	Negligible	<0.5% of project cost	The frequency of sampling is limited by how long the sampling and measurement process takes and rectification action takes. Mitigation is in place if the ROC >6.9% so just increasing the frequency above that recommended by the industry standard uses valuable resources Additional sampling and measurement equipment requires additional staffing, space, maintenance, etc and is unnecessary as alternative mitigation is available.	Not adopted
Return mud pit wash water to shore for further treatment and disposal	Elimination	Avoiding the discharge of oil-contaminated mud and wash water and disposal onshore will reduce impacts offshore	Negligible	<0.5% of project cost	The wash discharge has a localised, temporary impact on the water column and pelagic biota and is ranked category 1-3 (no impacts beyond on populations or ecosystem functions). Tank cleaning during and after the drilling activities will follow IMO rules on discharging fluids to the sea and this is considered ALARP.	Adopted

6.7 Cement discharges

6.7.1 Impact description

After the casing has been run, cement will be pumped into the annular space between the casing and the borehole wall to secure the casing and isolate the borehole. This ensures the integrity of the well seal around the conductor and surface casings after drilling the top-hole sections. Some cement will be discharged at the seabed during the cementing of the conductor and surface casing strings. The well will use ~200% "excess" cement when pumping for the conductor and surface casing jobs to account for losses and over-gauge hole conditions and thereby to ensure a reliable seal. The use of "excess" cement is considered a safety measure.

Cement will also be used for setting abandonment plugs on completion of drilling.

The cementing process is repeated at key stages in the drilling to ensure the integrity of each successive section, in accordance with the approved Well Operations Management Plan.

Cement will be mixed as required to ensure minimal wastage. Excess cement (dry bulk, after well operations are completed) will be taken ashore for disposal.

The following estimated volumes of cement may be discharged to the environment:

- cement overspill at the seabed during cementing of well structural casing jobs (estimated to be 24 m^3 for the Stromlo-1 well), which will only occur during the top-hole (42" and 28") cement jobs.

A planned discharge of cement has the potential to result in effects to fauna and habitats through:

- burial and smothering of benthic habitats and communities.

Predicted impacts are generally confined to within a few hundred metres of the well location.

6.7.2 Levels of acceptable impact

The environmental impact of the cement discharges will be acceptable when:

a. Chemical toxicity impacts to benthic habitats are temporary and localised, not exceeding a consequence category of 1-3.
b. Burial and smothering of benthic biota (habitats and communities) is localised.
c. There are no direct effects on EBPC Act listed matters of national environmental significance and identified seabed features (Anna's Pimple and Murray's Mount) or long-term ecological effects on Great Australian Bight Marine Park Management values.
d. It is a permissible activity in the Great Australian Bight Marine Park.
e. The cement selection, management and disposal operations are compliant with industry practice and Equinor Australia B.V.'s Chemical Management System.

6.7.3 Impact prediction

6.7.3.1 Potential toxicity and turbidity

Cement sets rapidly underwater and forms an inert hard substrate. It is the most common material currently used in artificial reefs around the world (Oslo and Paris Conventions (1998) 2010) and is not expected to pose any toxicological impacts to receptors from leaching or direct contact. Silicate and haematite are the major components by weight and once the cement has hardened, the chemical constituents are locked into the hardened cement (Terrens et al. 1998). Cement on the seabed does not present a threat of ecotoxicological effects.

The main impact is associated with the surface discharge of cement slurry from washing the cement unit, which typically lasts less than an hour each time. The discharged slurry will mix rapidly with the surrounding sea water with the larger particles settling to the seabed and the fines forming a turbid plume around the discharge point. The modelling of 1.3 m^3/min predicted that after two hours cement concentrations in the plume will fall to 5–50 mg/L. The plume is predicted to extend approximately 150 m horizontally and 10 m

vertically. Four hours after the start of the discharge, modelling indicates that the plume will have completely dispersed to particulate concentrations of <5 mg/l. The modelling also indicated that less than 0.1% of the cement solids would be deposited on the seabed within 1.5 km of the point of discharge, and that no significant seabed deposition would occur at any particular location.

The pygmy blue whale is the only Protected Matters Search Tool listed whale with a distribution habitat and migration route overlapping the Operational Area. There are no other adjacent or nearby known Biologically Important Areas for protected species – blue pygmy and sperm whale foraging grounds lie about 100 km north but a number of species of whales may still seasonally traverse the area such as fin, long-finned pilot, pilot, humpback, killer and various beaked whales and others may visit throughout the year (e.g. sperm whale). Likewise, several species of dolphins (such as common short- beaked, Risso's and Indo-Pacific bottlenose) may transit the region. The area of the turbidity plumes is regarded as a very small percentage of the foraging grounds of protected seabirds such as shearwaters, albatrosses and petrels. Research data detailing potential impacts from suspended solids and turbidity from drill cuttings to megafauna is scarce, however such megafauna is highly mobile, transitory and able to avoid the plumes.

The environmental receptors with the potential for exposure and considered to be most sensitive to either toxicity or an increase in turbidity levels from this release include immobile plankton, pelagic fish (and larvae) and mobile demersal fish communities around the well location. Conservation-significant fish species that may traverse the plume include the great white shark, and southern bluefin tuna (Conservation Dependent).

Given the expected rapid dispersion (<5 mg/L in four hours covering approximately 150 m) based on comparable modelling in the open ocean, there is limited potential for receptors to be exposed to levels above impact thresholds for the duration required to result in an impact. This discharge is expected to result in a localised and short-term exposure or a Category 1–3 consequence. No mass fish spawning is known to occur specifically within the area adjacent to Stromlo-1 hence larval impacts on a population level are not likely. Other than pygmy blue whale distribution and migration routes, there are no known matters of national environmental significance Biologically Important Area or aggregation areas near Stromlo-1. As such any impacts would be localised, temporary and on an individual basis.

Jenkins and McKinnon (2006) reported that levels of suspended sediments >500 mg/L are likely to produce a measurable impact upon larvae of most fish species and that levels of 100 mg/L will affect the larvae of some species if exposed for periods greater than 96 hours. The authors also suggest that levels of 100 mg/L are likely to affect the larvae of several marine invertebrate species and that fish eggs and larvae are more vulnerable to suspended sediments than older life stages (Jenkins & McKinnon 2006). The discharges associated with this activity are expected to be limited to intermittent surface discharge of cement after flushing lines and equipment. Particular values and sensitivities are not expected to be exposed for extended periods of time given their transient nature in the operational area.

Plankton communities have a naturally patchy distribution in both space and time (ITOPF 2011). Due to high natural reproduction, any change in phytoplankton or zooplankton abundance and composition is expected to be localised and short term with the population recovering rapidly through horizontal advection of biota from surrounding areas. Food chain effects (e.g. planktivorous fish) are not expected due to the localised and short-term nature of the discharge.

Jenkins and McKinnon (2006) indicate a total suspended solids of 100 mg/L is likely to affect the larvae of several marine invertebrate species. Modelling of a similar scale cement discharge predicted that after two hours the plume concentrations are in the order of 5–50 mg/L and therefore too low to have a sustained adverse turbidity effect (BP p.l.c. 2013). The horizontal and vertical extents of the plume are localised at approximately 150 m and 10 m, respectively. Four hours after the start of the discharge, modelling indicates that the plume will have completely dispersed to particulate concentrations of <5 mg/L; as such, the consequences are minor, localised and temporary and the discharge represents a minor impact on the environment. Recognising that the modelling was conducted in a different area, we can conservatively multiply the range of effect tenfold and still not have a significant effect on the ecology of the local area.

No impacts on Anna's Pimple or Murray's Mount will occur as the predicted plume lengths are well short of the ~20 km to these features. Given the expected rapid dispersion (<5 mg/L in four hours), there is limited potential for receptors to be exposed to levels above impact thresholds for the duration required to result in an impact. Based on the estimated discharge volumes identified for this program, this discharge is expected to result in a localised and short-term exposure of a Category 1–3 consequence.

6.7.3.2 Bottom deposition – smothering and alteration of the seabed

The potential impacts of smothering from a surface release are expected to be significantly less than from the seabed release due to small volumes, the intermittent nature of these discharges, and the high potential for dispersion via ocean currents given the deep-water location (>2200 m). Comparative modelling (BP p.l.c. 2013) also indicated that less than 0.1% of the cement solids would be deposited on the seabed within 1.5 km of the point of discharge and that no significant seabed deposition would occur at any location from a surface discharge.

The modelling for larger volumes of cement (200 tons) have indicated that cement from top-hole sections displaced to the seabed may affect the seabed around the well to a radius of approximately ~10–20 m (depending on height) from the well, resulting in the potential for disturbance of 0.002 km^2. The cement discharged to the seabed around the well will change the existing soft-sediment seabed habitat to a hard substrate habitat, but the affected area will not extend beyond that already altered by the primary cuttings piles and will therefore not impact any additional area of seabed.

Anna's Pimple and Murray's Mount at ~20 km from the well will not be impacted by the cement discharge plumes or solids. The soft sediment epifauna and infauna in the area surrounding the well will be affected in the long term. Their habitat will change from a soft sediment habitat to a hard substrate habitat and the community structure and abundance is expected to change in response. Eventually the cement collar (and drill cuttings) will be covered by sediment and infauna and epifauna in surrounding areas may recolonise the area; however, this is expected to occur over >5 years and is a considered a long-term impact.

Given the relatively small footprint associated with the sub-sea release of cement, it is predicted to result in localised impact to a small area of a widely represented benthic habitat.

The localised mound of cement that may be formed around the casing will have only very localised effects on individual fauna and benthic communities within the area, without any impact on the values of the marine park or any population- or ecosystem-level effects and as such is ranked Category 1–3.

6.7.4 Impact treatment

6.7.4.1 Environmental performance outcomes (EPO 6.7)

The cement discharge impacts on water quality are limited to localised and short-term effects, not exceeding a consequence category of 1-3.

6.7.4.2 Context for assessment

Table 6.41 Context for mitigating impacts of cement discharges

Equinor Australia B.V. standards	• Chemical additives to the cements are selected and procured as per SF601.01 – Chemicals Management which is aligned with CHARMS and OCNS systems • Drilling managed as per TR3501 Drilling practice • Cement managed as per TR3519 Well cementing

6.7.4.3 Control measures and performance standards

Table 6.42 Control measures and performance standards for mitigating impacts from cement discharges

Control measures	Performance standards	Measurement criteria	Responsibility
Chemical Selection (SF601.01 – Chemicals Management) followed to ensure chemicals of lower toxicity are preferentially selected	ES 6.7.1: Evaluate all cementing products and additives in accordance with SF601.01 – Chemicals Management and approved prior to use.	Inspection of the Cement Chemical Inventory verifies that cement additives conform to As Low As Reasonably Practicable as per the SF601.01 – Chemicals Management with documentation and approvals in place.	Equinor Australia B.V. Drilling Manager
Cementing procedures comply with Equinor Australia B.V. Standard TR3519.	ES 6.7.2: Discharge volumes shall be recorded and reported against planned volumes in the Daily Well Report.	Inspection of Daily Well Reports confirms cement volumes are in accordance with the Cementing Program.	Equinor Australia B.V. Drilling Supervisor

6.7.5 Demonstration of acceptability

The level of impact that the cement discharges will have on marine biota and marine park values is acceptable because it meets the a priori acceptability criteria as described in Table 6.43.

Table 6.43 Acceptability evaluation for impacts from cement discharges

Acceptability criteria	Evaluation against acceptability criteria
a. Turbidity and chemical toxicity impacts to fauna (fish and plankton) in the water column and benthic habitats are temporary and localised, not exceeding a consequence category of 1-3	As the most extensive plumes predicted from comparative modelling are within a few hundred metres from the discharges and the duration of the plumes are predicted to last hours, the impacts from Stromlo-1 cementing are assessed as localised and temporary within the PSZ. No impacts to commercial fish stocks are predicted given the short duration and localised nature of the impact.
b. Burial and smothering of benthic biota (habitats and communities) is localised	The footprint from cement (inert) will cover the drill cuttings already disturbing the area immediate to the well. As such there is no new footprint and the area potentially smothered lies within 50 m of the discharge point; this is considered localised.
c. There will be no direct effect on EBPC Act listed MNES and identified seabed features (Anna's Pimple and Murray's Mount) and no effects on the GAB Marine Park management values	The Impact EMBA does not include any known aggregation areas for any conservation significant species (Marine Mammal Protection Zone more than 250 km north with the PMST report noting that the pygmy blue whales possibly use the Impact EMBA as a distribution area and part of its migration route. Other MNES migratory species may also pass through the area but given the small plume size and duration, any effects will be at an individual level only. The plumes are predicted to be more than 19 km from the locally important seabed seamounts with impacts to the benthos at more than 2 km water depth predicted to be minor with recovery in the short term. The impacts are assessed as too localised and temporary to directly affect any of the GABMP values (e.g. southern right whale calving and pygmy blue whale distribution habitats, foraging areas for threatened great white shark, or sperm whale migratory paths). No specific KEFs such as areas important to small pelagic fish with important ecological roles will be affected on a population level. Hence potential impacts to such receptors are likely to be on individuals rather than populations.
d. It is a permissible activity in the GAB Marine Park	Exploration drilling, of which cementing and cement discharges are an integral component, is a permissible activity in the GAB Marine Park.

Acceptability criteria	Evaluation against acceptability criteria
e. The cement selection, management and disposal operations will be compliant with industry practice and Equinor Australia B.V. standards	Cement additive selection, management and disposal operations will comply with Equinor Australia B.V.'s chemical selection process that aims to select chemicals that are environmentally preferred (low toxicity). Volumes are calculated to minimise excess but still meet technical requirements with a safety factor. Safety is paramount in the prevention of incidents with a higher environmental impact than the discharge of cement.

6.7.6 Demonstration of As Low As Reasonably Practicable

The decision context and assessment technique for the As Low As Reasonably Practicable assessment are provided in Table 6.44. Additional controls which have been considered in reaching As Low As Reasonably Practicable are listed in Table 6.45.

Equinor Australia B.V. considers the impacts from cement discharges are As Low As Reasonably Practicable because:

- Cement is required during drilling and excess must be pumped downhole with potential for some to extrude to the seabed around the well to ensure high certainty in well integrity.
- Chemical management practices will ensure low toxicity of cementing chemicals, which are considered to have a minor effect on the local benthos. Impacts already at Category 1–3 level and no further As Low As Reasonably Practicable consideration mandated.

Table 6.44 As Low As Reasonably Practicable decision context and assessment technique for impacts from cement discharges

As Low As Reasonably Practicable decision context	The necessary discharge of cement during drilling is a well understood and practiced activity both nationally and internationally. Modelling to inform the potential extent of cuttings deposition has been undertaken to remove some of the uncertainty and understand the potential extent and concentrations that may result in environmental impacts. No additional control measures are required to continue to reduce impacts to As Low As Reasonably Practicable No relevant persons raised objections or claims over cement discharges Taking this in consideration, Decision Context B-Engineering Risk Assessment should be applied to demonstrate impacts are As Low As Reasonably Practicable.
Assessment technique	Engineering Risk Assessment

Table 6.45 Assessment of additional controls to mitigate impacts from cement discharges

Additional capability	Hierarchy	Environmental benefits	Env benefit %	Cost	Rationale	Outcome
No discharge of excess cement	Elimination	Using only the exact quantities of cement required to secure casing/liner such that excess cement does not discharge beyond the casing/hole cavity results in a small benefit in potentially eliminating the impacts associated with the formation of the cement collar around the well. This would not reduce the area affected because the cuttings and muds would cover a greater area. The environmental benefit would be negligible even if the muds and cuttings were retained and transported to shore for disposal	Negligible (<1%)	<0.5% of project cost	Using excess cement is necessary to assure that the cavities have been properly filled and pumping excess is necessary to allow for filling voids exposed during drilling and getting a positive signal that sufficient volume (plus a safety margin) has been applied. The WOMP will detail the cementing requirements for the Stromlo-1 well. Not applying excess would be considered outside of best/standard safety practice and cannot be supported from a well integrity standpoint. The minimal environmental benefit associated with avoiding cement discharge to the seabed is outweighed by the safety and risk costs associated with inadequately cementing the well as designed.	Not adopted
No discharge of dry cement into the sea	Elimination	By eliminating the discharge of dry cement, increased turbidity in the pelagic zone can be eliminated. However, given that is a minor volume (estimated at 3 m^3) it is unlikely to cause any impacts, so the environmental benefit is negligible.	Negligible	<0.5% of project cost	The cost of returning dry cement to shore for onshore disposal or reuse is minimal and there will be a small benefit from not disposing offshore.	Adopted
In field monitoring for TSS if surface discharge of dry cement	Administrate	The benefit is limited to having an understanding of the temporary increase in TSS and extent from the point of discharge. However, this is a snapshot only, and is likely to be highly variable based on the currents and winds at the time.	Negligible	0.5–2% of project cost	There are high costs associated with the development and implementation of such a program, particularly if a dedicated monitoring team and vessel needs to be deployed. This exposes additional people to safety risks. The low level of environmental impact does not warrant a monitoring program and there are no effective reactive management actions that could be implemented to affect the outcome. The costs of implementing a monitoring program to assess the dispersion of cement residues is disproportionate to the benefit that may be gained in measuring the plume of cement with no opportunity for reducing impacts.	Not adopted

6.8 Cooling and brine water discharges

6.8.1 Impact description

On the mobile offshore drilling unit and support vessels, sea water is used as a heat exchange medium for cooling machinery engines and other equipment. Sea water is drawn up from the ocean, de-oxygenated and sterilised by electrolysis (typically by the release of chlorine from the salt solution) and then circulated as coolant for various equipment through the heat exchangers (in the process transferring heat from the machinery), prior to being discharged to the ocean. The discharge will be warmer than the ambient water temperature and may contain low concentrations of residual biocide, used to prevent biofouling inside the heat exchangers. The maximum cooling water discharge rate on the mobile offshore drilling unit is typically around 4700 m^3/hr (112,800 m^3/day), with the heat exchangers designed to discharge the cooling water at up to 47 °C (this would be approximately 24–34 °C above ambient sea temperature). The discharge point for cooling water varies depending on the mobile offshore drilling unit and vessel design and can be above or below the sea surface.

After discharge into the marine environment, the heated water plume will be rapidly dispersed and diluted through physical phenomena such as turbulent diffusion, convection in water, flow of fluids of variable density, evaporation, radiation and convection in the air (IPPC 2001). In the sea, the warm water plume is rapidly mixed by currents that prevent any stratification caused by the difference in density between the warm water and cold water; this may be assisted by the rise of the warmer, less dense water from the discharge point. The temperature drop in the warm water plume principally comes from the mixing and not from atmospheric heat losses at the surface of the water (IPPC 2001).

Rapid changes in temperature cause thermal shock to marine organisms and can lead to mortality of individuals in the discharge stream near the source. In an enclosed water body, heated water can lead to a reduction in oxygen saturation capacity of the waters, but this is unlikely in the open ocean.

Brine (hypersaline water) wastewater will be produced by the mobile offshore drilling unit and vessels' reverse osmosis (RO) or distillation desalination processes that are required to supply freshwater for drinking, showers and cooking. The brine wastewater will have elevated salinity (typically ~10–20% more saline than sea water) and will be discharged from the mobile offshore drilling unit's reverse osmosis plant at ~10 m^3/hr. It will probably be mixed with other discharge streams to reduce its salinity.

Elevated salinity over an extended period can lead to community-level effects but in a well-mixed, open-ocean environment with a high mixing rate, these effects are unlikely. Changes in salinity can affect the ecophysiology of marine organisms and larval stages tend to be more susceptible to impacts of increased salinity (Neuparth et al. 2002). However, some marine species are known to be able to tolerate short-term fluctuations in salinity in the order of 20%–30% (Walker & McComb 1990) and it is expected that pelagic megafauna species would be able to tolerate short-term exposure to the slight increase in salinity caused by the discharged brine if they swim through the area.

Scale and rust inhibitors and biocides are likely to be used in both the heat exchange and desalination processes to avoid internal biofouling of pipework. These chemicals may have toxicological effects on marine fauna in high concentrations but are expected to be diluted and dispersed to low concentrations close to the discharge point. Scale inhibitors and biocides used in the heat exchange and desalination process discharges are inherently safe because they are usually largely "consumed" in the inhibition process and there is only a low residual chemical concentration in the discharge stream. These chemicals are mainly of concern in enclosed waters where the discharge occurs over an extended time frame; for example, a power station thermal discharge into a river or lake (IPPC 2001).

The impacts to marine fauna in the water column are considered to be:

- increased temperature (thermal shock)
- increased salinity
- potential toxicity impacts to fauna in the upper water column (biocides, other chemicals).

The environmental receptors with the potential to be exposed to changes in water quality from these discharges include pelagic fauna including cetaceans, pelagic fish, marine turtles and plankton; all of which may occur in surface waters around the mobile offshore drilling unit and throughout the offshore marine environment. Marine fauna may be exposed to increased temperature, salinity and potential toxicity impacts in the surface waters immediately adjacent the discharge pipe, for the duration of the drilling.

6.8.2 Levels of acceptable impact

The impact on fauna caused by the discharge of cooling water and brine will be acceptable when:

a. Ecosystem health (biological diversity, abundance and biomass of marine life and ecological processes) is maintained. Ecosystem health values are protected to a high level beyond 500 m of the mobile offshore drilling unit discharge point. Heat, salinity and toxicity impacts to fauna in the water column are localised and temporary , not exceeding a consequence category of 1-3 and no ongoing impact after drilling.

b. There are no direct effects on EBPC Act listed matters of national environmental significance and identified seabed features (Anna's Pimple and Murray's Mount) and no direct ecological effects on the GAB Marine Park management values.

c. Cooling water and brine wastewater management and disposal operations are consistent with industry practice.

6.8.3 Impact prediction

6.8.3.1 Temperature effects

Heated water from the heat exchangers will be discharged to the sea where it will quickly disperse in local currents and rise to the sea surface, mixing and cooling on the way. A hot water plume quickly loses heat as shown in modelling for the Stybarrow Development for a discharge of 100,000 m^3/day of cooling water at 25 °C above ambient sea water temperature. This modelling showed the likelihood of surface water temperature exceeding ambient temperature by >2 °C was reduced to about 1% within 60 m–85 m of the discharge point (BHP Billiton 2004). Given the Stromlo-1 mobile offshore drilling unit will discharge a similar volume of heated water, the discharge stream is expected to reach background temperatures in a similar distance from the discharge point. It may mix and equilibrate faster at Stromlo-1 given the lower ambient water temperatures in the Southern Ocean.

RPS (2017) modelled the dispersion and mixing of a cooling water stream from an offshore oil and gas installation in northern Australia and showed that the plume of water heated to 45 °C and discharged at a flow rate of 288,000 m^3/day (twice the expected discharge for Stromlo-1) mixed to within 3 °C of ambient temperature within 12 m of the discharge point. The maximum horizontal distance the plume moved was about 65 m.

The predicted impacts are limited to area immediately adjacent the discharge point where plankton would be exposed to thermal shock due to the large differential between the discharge temperature and the ambient water temperature. This localised effect would persist during the drilling period. While the thermal shock zone is likely to be <10 m, this has not been modelled and we have assumed a conservative impact area of up to 100 m around the discharge point where there may be mortality of plankton.

Marine reptiles, cetaceans and fish (including southern bluefin tuna and migratory sharks) passing through the area will be able to actively avoid entrainment in the localised plume of heated water (Langford 1990). There are no known fish spawning areas or mass aggregation areas for any matters of national environmental significance or EPBC listed species adjacent to the Stromlo-1 site though pygmy blue whales may transit the area during migration, so any impacts are predicted to be at an individual level and limited to behavioural effects in the vicinity of the mobile offshore drilling unit and vessel discharges.

The deep oligotrophic waters of the central Great Australian Bight (where there is downwelling of surface waters) support lower plankton population densities than in areas of upwelling in the western and eastern Great Australian Bight, which support high plankton productivity and associated planktivorous fish and predatory megafauna including tuna and whales. Short-term thermal effects on planktonic assemblages in the vicinity of the well site are not predicted to have indirect effects on any higher-order marine biota, including conservation-significant biota. No impacts on benthic habitats or communities are predicted given the open-ocean environment and water depths greater than 2 km.

6.8.3.2 Salinity and toxicity effects

Given that the saline discharge is only elevated by about 10%–20% above ambient salinity in the immediate vicinity of the discharge, that chemical concentrations will be low and that discharges will be rapidly mixed and diluted in the receiving waters, any impacts are expected to be limited to the immediate vicinity of the discharge where concentrations are highest. This is consistent with studies that indicate effects from increased salinity on planktonic communities in areas of high mixing and dispersion are generally limited to the point of discharge (e.g. Azis et al. 2003). Planktonic organisms are most likely to be exposed to the plume of increased salinity downstream of the mobile offshore drilling unit, but the populations are expected to rapidly recover from any impacts once the activity ceases as they are naturally characterised by high population turnover rates and rapid population increases (UNEP 1985). Fish larvae and other larvae and juveniles will depend on future spawning events to recover their place in the plankton community – this may delay recovery of some species. In the absence of spawning aggregation areas in these deep offshore waters, the larval assemblage is expected to be widespread and sparse and any localised decrease in abundance to fall within natural levels of variation in population sizes. The impact area is not predicted to be large enough to have a lasting, population-level effect on any species or an ecosystem-level effect. Localised and short-term effects on planktonic communities are not predicted to result in detectable changes in the ecological function, diversity or productivity within the marine park.

The localised and transient nature of the wastewater plumes is predicted to have no effect on migratory matters of national environmental significance and other key species including the great white shark, porbeagle shark, southern bluefin tuna, marine turtles, seabirds and whales. Being transient species, they are not expected to experience any chronic or acute effects. Megafauna will be able to avoid the saline plume if they experience any physiological stress when swimming through the area.

Given the low concentrations, small volumes and deep, open ocean environment surrounding the mobile offshore drilling unit and vessels, impacts on water quality at the drilling location cumulatively and from each source are expected to be localised, temporary and of Category 1–3 consequence.

In summary, the wastewater discharges from the mobile offshore drilling unit and vessels will be short term (duration of drilling operations) and the impacts will be localised due to rapid dispersion and dilution of the discharge streams. No significant impacts are predicted on local planktonic and pelagic communities, the migratory megafauna that may pass through the area, or the values of the Great Australian Bight Marine Park. Effects on local biota and water quality will rapidly dissipate upon completion of drilling activities. The predicted impact is ranked Category 1–3. Cumulative impacts from the vessels and the mobile offshore drilling unit are considered negligible due to the small volumes, location and short periods when they are alongside.

6.8.4 Impact treatment

6.8.4.1 Environmental performance outcomes (EPO 6.8)

Impacts on water quality limited to localised and short-term effects, not exceeding a consequence category of 1-3.

6.8.4.2 Context for assessment

Table 6.46 Context for mitigating impacts from cooling and brine water discharges

Legislative and other requirements	OPGGSA requires impacts to be reduced to As Low As Reasonably Practicable
Industry standards	IMF (2015) outlines an industry standard for heated water discharges reaching to within 3 °C of ambient water temperatures within 100 m of the discharge site
Equinor Australia B.V. standards	TR1011 Environmental requirements for Offshore Installations – The effluent should result in a temperature increase of no more than 3 °C at the edge of the zone where initial mixing and dilution take place. Where the zone is not defined, use 100 m from point of discharge

6.8.4.3 Control measures and performance standards

Table 6.47 Control measures and performance standards for mitigating impacts from cooling and brine water discharges

Control measures	Performance standards	Measurement criteria	Responsibility
Chemical Selection (SF601.01 – Chemicals Management) followed to ensure chemicals of lower toxicity are preferentially selected	EPS 6.8.1: Evaluate all chemical additives to coolant system and the desalination process, in accordance with SF601.01 – Chemicals Management and approved prior to use. Select low toxicity chemicals for use according to OCNS system, considering discharge concentrations, mixing and potential for impact	Inspection verifies that chemical additives assessed and conform to As Low As Reasonably Practicable as per the SF601.01 – Chemicals Management with documentation All chemical additives used are on the list of approved chemicals (including new chemical following assessment and if approved) and do not exceed required concentrations	Equinor Australia B.V. Drilling Manager
Planned Maintenance System (PMS)	EPS 6.8.2: The RO plant and equipment served by the cooling water system is maintained in accordance with the MODU and vessels' PMS to ensure that equipment is operating efficiently	Site inspections of PMS records verify that the RO plant and cooling system are maintained to schedule	MODU Maintenance Supervisor and Vessel Master

6.8.5 Demonstration of acceptability

The level of impact on water quality and pelagic biota in the water column resulting from the discharge of cooling and brine is acceptable because it meets the a priori acceptability criteria as described below.

Table 6.48 Acceptability evaluation for impacts from cooling and brine water discharges

Acceptability criteria	Evaluation against acceptability criteria
Ecosystem health (biological diversity, abundance and biomass of marine life and ecological processes) is maintained. Ecosystem health values are protected to a high level beyond the predicted mixing zone. Heat, salinity and toxicity impacts to fauna in the water column are localised and temporary (no ongoing impact after drilling)	Heat, salinity and chemical toxicity impacts will be diluted rapidly and locally by prevailing currents/tides, thrusters and winds in the high energy open-ocean environment. The buoyant plumes will not impact benthic and epibenthic communities and habitats or demersal biota. No ecosystem health effects are predicted beyond the primary mixing zone adjacent the discharge point. The dispersive receiving environment and constant vessel and MODU thrusters aids local dilution. Modelling suggests the heat, salinity and toxicity plumes are expected to remain within 100 m from the discharge and potential impacts are temporary with full recovery predicted on completion of the drilling program. No impacts to commercial fish stocks are predicted given the localised nature of the impact.
No direct effect on EBPC Act listed MNES and identified seabed features (Anna's Pimple and Murray's Mount). No direct effect on EBPC Act listed MNES and identified seabed features (Anna's Pimple and Murray's Mount) and no direct effect on the GAB marine park management values	The deep-water environment is typical of the similar surveyed areas of the central GAB. Notable seabed features such as seamounts and the Ancient Coastline are more than 19 km and >150 km (respectively) from the well site and not impacted by the plumes, which will remain within the a few hundred metres of the wellsite as predicted by the modelling. No impacts are predicted to KEFs (such as benthic invertebrate communities of the Eastern GAB which is below 2 km water depth or areas important to small pelagic fish with important ecological roles), Biologically Important Areas or ecologically important habitats for species of conservational significance (e.g. southern right calving and migratory areas). At worst, potential impacts may affect mobile individuals that can take avoidance action while immobile plankton is expected to recovery naturally in the short term through recruitment and reproduction. The impacts are too localised and temporary to directly affect any of the GAB Marine Park values (e.g. Mammal Protection Zone, foraging areas for threatened great white shark and migratory areas for sperm whale) on a population level.

Acceptability criteria	Evaluation against acceptability criteria
Cooling water and brine wastewater management and disposal operations will be compliant with industry practice	Water temperature is predicted to be within 3 °C of ambient within 100 m from the release location, which is a commonly adopted industry standard as defined by the International Finance Corporation (IFC 2015). Implementation of the Equinor Australia B.V. chemical management process, based on the OCNS/CHARMS system, is consistent with industry practice in OSPAR signatory countries with the aim to minimise impacts from wastewater discharges.

6.8.6 Demonstration of As Low As Reasonably Practicable

The decision context and assessment technique for the As Low As Reasonably Practicable assessment are provided in Table 6.49.

Equinor Australia B.V. considers the impacts from cooling and brine water discharges are As Low As Reasonably Practicable because:

- Additional controls have been considered in reaching As Low As Reasonably Practicable. Use of alternative technologies to cool water (e.g. internal cooling loops with fin-fan heat exchangers) are being developed. Typically, such technologies require significant deck space and additional power to run fans and ancillary equipment, leading to more fuel consumption. However, no robust proven technologies for remote applications with significant environmental benefits were identified.
- Further cooling the discharges prior to release were not deemed As Low As Reasonably Practicable, given absence of sensitive receptors, small volumes relative to the open ocean receiving environment and the duration of the activity
- Impacts already at a low level and no further As Low As Reasonably Practicable consideration mandated.

Table 6.49 As Low As Reasonably Practicable decision context and assessment technique for impacts from cooling water and brine discharges

As Low As Reasonably Practicable decision context	Discharge of brine and cooling waters during offshore activities (from vessels and other facilities) is an unavoidable but well understood and practiced activity both nationally and internationally. Given the habitat types at the well location and environment that may be affected are well known, there is little uncertainty associated with this discharge and the potential environmental impacts are low. No relevant persons raised objections or claims regarding cooling water and brine discharges Taking this into consideration, Decision Context A has been applied to demonstrate impacts are As Low As Reasonably Practicable
Assessment technique	Good Practice – Identified industry good practices adopted to reach As Low As Reasonably Practicable

6.9 Sewage, grey water and putrescible waste discharges

6.9.1 Impact description

The daily use of ablution, laundry and galley facilities on the mobile offshore drilling unit will generate sewage, grey water and putrescible waste and will require discharge to the marine environment. The volume of sewage, grey water and food waste generated will be directly proportional to the number of persons on board the mobile offshore drilling unit (typically ~180 persons on board) and support vessels (typically 30 persons on board). As the Operational Area is more than 12 NM from the territorial sea baseline, all of these liquid wastes can be discharged directly to the marine environment in accordance with standard provisions of the International Convention for the Prevention of Pollution from Ships. Food waste is collected, stored, processed (through maceration) and disposed of overboard in accordance with International Convention for the Prevention of Pollution from Ships Annex IV.

Typically, the people on board the mobile offshore drilling unit will generate around 0.01–0.06 m^3 of black water per person per day (EMSA 2016). If the sewage is mixed with grey water (from dishwasher, kitchen, showers, laundry, bath and wash basin drains), the total volumes will be around 0.04–0.45 m^3 per person per day. At the upper end, this equates to an average of around 81 m^3 per day for the mobile offshore drilling unit (with 180 persons on board) and proportionally less for the support vessels.

Typical putrescible waste of 1 2 kg per person per day (EMSA 2016) converts to around 0.001–0.003 m^3 food wastes or a maximum of 360 kg per day (0.6 m^3) for a persons on board of 180. The impacts will be limited to the duration of drilling operations.

Organic waste discharges create plumes with elevated nutrient concentrations and under the action of respiration by microorganisms can lead to greater biological oxygen demand and consequent decrease in dissolved oxygen concentrations in the receiving waters. These effects are weaker in open oceanic waters which are well mixed under natural conditions, even for a sustained discharge over a long period.

Eutrophication occurs when the addition of nutrients such as nitrates and phosphates, causes adverse changes to the ecosystem, such as oxygen depletion and phytoplankton blooms; these effects are most likely in enclosed or semi-enclosed water bodies. Other contaminants of concern occurring in these discharges may include ammonia, faecal coliform bacteria and other micro-organisms, volatile and semi-volatile organic compounds, phenol, hydrogen sulfide and metals. These chemicals may be used to treat wastewater and water systems, or used for general cleaning, and in high concentrations may result in direct and indirect toxicity to marine flora and fauna.

The assessment of impacts to marine fauna herein, considered:

- changes to the water quality through nutrient enrichment and increased biological oxygen demand
- impact of behavioural changes on predator/prey dynamics.

The environmental receptors that may be exposed to changes in water quality from these discharges include pelagic fish, marine turtles, cetaceans, seabirds and plankton in surface waters around the mobile offshore drilling unit and vessels.

6.9.2 Levels of acceptable impact

Using the Australia New Zealand Environment and Conservation Council (ANZECC)/Australian National Health and Medical Research Council (2000)2 guidelines where relevant to the Stromlo-1 location, the acceptable levels have been defined as:

a. Ecosystem health, (biological diversity, abundance and biomass of marine life and ecological processes); is maintained. Ecosystem health values are protected to a high level beyond 500 m of the discharge point. No direct effect on EBPC Act listed matters of national environmental significance and identified seabed features (Anna's Pimple and Murray's Mount) and no direct effects on the Great Australian Bight Marine Park management values.

b. Primary industries values are protected (seafood is safe for human consumption) beyond 500 m of the discharge.

c. Wastewater management and disposal operations are aligned with maritime law. The Permit Area is located more than 12 NM from land, which exceeds the exclusion zones required by Marine Order 96 (Marine pollution prevention – sewage) 2013 and Marine Order 95 (Marine pollution prevention – garbage) 2013.

6.9.3 Impact prediction

The adverse effects on marine biota due to increase in turbidity and nutrient concentrations associated with organic waste discharges, are predicted to be localised and limited to the surface waters (<10 m) in the immediate vicinity of the discharge. The discharges will be dispersed and diluted rapidly and therefore the

2 Australia New Zealand Environment and Conservation Council/Australian National Health and Medical Research Council (2000) guidelines have recently been updated but the 2000 Guidelines are still relevant in this context with negligible effects on acceptability criteria.

concentrations of nutrients and biological oxygen demand will all decrease with increasing distance from the mobile offshore drilling unit; changes to ambient conditions are unlikely to occur outside the Operational Area and are not expected to persist beyond the period of drilling operations.

The discharge will be dispersed by open-ocean winds, currents and tides and dispersion enhanced by the action of the vessel/mobile offshore drilling unit thrusters. Thereafter there will be uptake by primary producers such as phytoplankton and secondary consumers, biodegradation through bacterial action and oxidation. A small proportion may eventually settle to the seabed across a broad area under the action of currents as the plume disperses and heavier particles sink.

RPS (2017b) modelled the dispersion and dilution of wastewater discharges from ConocoPhillips' Barossa facilities. During the highest flow rate conditions (during commissioning) the facility was to discharge 96 m^3/day of water at ambient temperature (approximately 25 °C). The wastewater was diluted by a factor of 100 within 5 m of the discharge point and was diluted to 1:5000 within 55 m. The Stromlo-1 discharge is expected to mix more effectively than the Barossa discharge because it is a smaller volume and will be warmer than the receiving waters, which will enhance density mixing and is in the open ocean in greater than 2 km water depth.

At the Stromlo-1 location, nutrients from discharge of sewage will not accumulate or lead to eutrophication due to the highly dispersive marine environment. As sewage discharges from vessels and facilities are at or near the surface, and are buoyant, the receptors with the potential to be impacted are those within or on surface waters, for example, plankton, pelagic fish, seabirds, transient cetaceans and marine turtles. Any potential change in phytoplankton or zooplankton abundance and composition is expected to be localised, and to be limited to within tens of metres of the discharge location (e.g. Abdellatif et al. 1993; Axelrad et al. 1982; Parnell 2003). Effects to the food web (e.g. to fish, reptiles, birds and cetaceans) are therefore not expected beyond a possible increase in prey abundance on the immediate vicinity of the mobile offshore drilling unit. Given the duration of the drilling program no measurable ecological effects are predicted.

Impacts from vessels within the Operational Area will be proportionally less than the mobile offshore drilling unit due to their smaller volumes of wastewater discharge. The mixing zone around the mobile offshore drilling unit and around the mobile support vessels will be too small for cumulative impacts to be realised during the activity.

Given the small volumes (about 81 m^3 of wastewater per day and 360 kg putrescible waste) to be discharged daily for during operations and the rapid dispersion of the wastewater discharge in the open-ocean deep-water environment, potential impacts from the planned discharges are considered temporary and localised to less than 100 m around the mobile offshore drilling unit and vessels. The impact is considered Category 1–3. Cumulative impacts from the vessels and the mobile offshore drilling unit are considered Category 1–3 due to the small volumes, location and short periods when they are alongside.

6.9.4 Impact treatment

6.9.4.1 Environmental performance outcome (EPO 6.9)

Impacts on water quality limited to localised and short-term effects, not exceeding a consequence category of 1-3.

6.9.4.2 Context for assessment

Table 6.50 Context for mitigating impacts sewage, grey water and putrescible waste

Legislative and other requirements	In Commonwealth waters, the *Protection of the Sea (Prevention of Pollution from Ships) Act 1983* and the *Navigation Act 2012* give authority to make Marine Orders which reflect the international obligations and standards Australia has signed and ratified. Where appropriate for the class of vessels undertaking the activity, proposed control measures to mitigate impacts of sewage, putrescible waste and grey water discharge reflect Marine Order 96 (Marine pollution prevention – sewage) 2013 and Marine Order 95 (Marine pollution prevention – garbage) 2013. Marine Orders 91 – pollution prevention – Oil (as relevant to vessel class)-prohibition of untreated oily waste overboard Marine Orders 95 – pollution prevention – Garbage (as appropriate to vessel class)-food waste macerator Marine Orders 96 – pollution prevention – Sewage (as appropriate to vessel class) MARPOL approved sewage treatment plant

Industry standards	Environmental, Health and Safety Guidelines for Offshore Oil and Gas Development (World Bank Group, 2015) Other waste waters (item 44). Grey and black water should be treated in an appropriate on-site marine sanitary treatment unit in compliance with MARPOL
Equinor Australia B.V. standards	Sewage and Grey water management aligns with TR1011 Environmental requirements for Offshore Installations – which requires compliance with MARPOL 73/78B

6.9.4.3 Control measures and performance standards

Table 6.51 Control measures and performance standards for mitigating impacts from sewage, grey water and putrescible waste

Control measures	Performance standards	Measurement criteria	Responsibility
MARPOL type approved sewage treatment system (STP) is fitted to the MODU and support vessels (class appropriate)	EPS 6.9.1: All MODU and support vessels have a current International Sewage Pollution Prevention (ISPP) Certificate in accordance with MARPOL Annex IV, which certifies that required measures to reduce impacts from sewage disposal are in place.	Valid ISPP Certificates are available on board MODU and vessels	Vessel Master MODU Offshore Installation Manager (OIM)
	EPS 6.9.2: All sewage discharges are treated via an approved and functional STP (prior to overboard discharge in accordance with Regulation 9 of MARPOL Annex IV (enacted by Australian Maritime Safety Authority Marine Orders Part 96, Sewage).	Inspections of discharge records show sewage discharge is treated prior to discharge.	Vessel Master MODU OIM
Sewage from holding tanks on support vessels discharged at a *moderate rate for vessels proceeding en route at >4 kt.	EPS 6.9.3: Marine Order 96 – Sewage (treated or untreated) from holding tanks is discharged at a *moderate rate as approved by the Administration based upon standards approved by the International Maritime Organization (MEPC.157 (55)) *moderate rates specified in Marine Order 96	Inspections of sewage disposal records indicate compliance with *moderate rates when the vessel is en route.	Vessel Master
Vessels and MODU display placards notifying waste disposal requirements	EPS 6.9.4: Marine Order 95 – Notifications to personnel regarding food and waste disposal requirements	Evidence of placards notifying of disposal requirements being displayed on board vessel is sighted.	Vessel Master MODU OIM
MARPOL (Annex V/Marine Order 95) compliant macerator is used on the MODU and support vessels within the Operational Area	EPS 6.9.5: All food waste to be macerated to ≤25 mm in size prior to overboard discharge in accordance with Regulation 8 of MARPOL Annex V (enacted by Australian Maritime Safety Authority Marine Orders Part 95, Garbage) to ensure rapid breakdown upon discharge.	Visual confirmation that macerator is operational, used and MARPOL compliant Garbage Record logs confirm maceration of discharged food wastes.	Vessel Master MODU OIM
	EPS 6.9.6: The macerators are maintained or replaced as per the PMS to ensure they are fully functional.	PMS records confirm that the macerator is maintained to schedule or repaired or replaced as required.	Vessel Master MODU OIM
Vessel/facility will maintain a Garbage Management Plan	EPS 6.9.7: MARPOL Annex V/Marine Order 95 as applicable – Food wastes treated and disposed as per the Garbage Management Plan (MEPC.220 (63)). Plan includes written procedures for minimising, collecting, storing, processing and disposing of garbage, including the use of the equipment on board.	Inspections of waste treatment and disposal records confirm compliance with an up to date Garbage Management Plan	Vessel Master MODU OIM

Control measures	Performance standards	Measurement criteria	Responsibility
Planned Maintenance System (PMS) ensures efficient operation	EPS 6.9.8: The STPs are maintained in accordance with the PMS and/or manufacturer specifications to ensure they are not discharging untreated sewage.	PMS records verify that the STPs are maintained to schedule and/or manufacturer specifications.	Vessel Master MODU OIM
Personnel must be appropriately trained in tasks and aware of requirements relevant to their role	EPS 6.9.9: Personnel are competent and provided with procedures or training that describe the requirements for the management of sewage and putrescible waste.	Records show procedures or training have been given to relevant personnel that includes the requirements for the management of sewage and putrescible waste.	Vessel Master MODU OIM

6.9.5 Demonstration of acceptability

The level of impact sewage, grey water and putrescible waste discharges will have on marine biota and marine park values is acceptable because it meets the a priori acceptability criteria as described below.

Table 6.52 Acceptability evaluation for impacts from sewage, grey water and putrescible waste discharges

Acceptability criteria	Evaluation against acceptability criteria
Ecosystem health, (biological diversity, abundance and biomass of marine life and ecological processes); is maintained and protected to a high level beyond 500 m from discharge. No direct effect on EBPC Act listed MNES and identified seabed features (Anna's Pimple and Murray's Mount) and no direct effects on the GAB Marine Park management values	The impact of nutrients and contaminants is considered acceptable given the assimilative capacity of the deep-water marine environment. No impacts are predicted for any KEF, Biologically Important Area or sensitive features. Similarly, no impacts are predicted for MNES such as migrating pygmy blue whales and other cetaceans, southern bluefin tuna and other fish, and protected seabirds (including petrels, albatross), given their mobility and transience through the area. Plankton communities in the immediate vicinity may be temporarily impacted but no ecosystem-level effects are predicted. The discharge is too localised and temporary to impact the GAB Marine Park values (e.g. Marine Mammal Protection Zone, southern right whale migrating and calving habitats, foraging areas for threatened white shark and migratory sperm whale and specific KEFs such as Ancient Coastline and areas important to small pelagic fish with important ecological roles). Given the water depth at over 2 km, no impacts on benthos are predicted.
Primary industries values are protected (seafood is safe for human consumption) beyond 500 m of the discharge.	For a grey water discharge volume of approximately 81 m^3, the defined mixing zone of 500 m is suitably conservative compared to sewage treatment plants that routinely discharge much larger quantities of residential, industrial and commercial wastewater into the marine environment. Given the expected dilutions beyond 100 m based on comparable modelling, no impacts on commercial fishing are predicted. Southern bluefin tuna migrating through the area are not predicted to suffer any impacts.
Wastewater management and disposal operations is compliant with maritime law and standard industry practice	The Permit Area is located more than 12 NM from land, which exceeds the exclusion zones required by Marine Order 96 (Marine pollution prevention – sewage) 2013 and Marine Order 95 (Marine pollution prevention – garbage) 2013. Where not appropriate for the class of vessel, control measures that reflect "good industry practice" have been proposed to manage impacts to As Low As Reasonably Practicable and acceptable levels. The discharge of sewage, grey water and putrescible waste is standard practice on MODUs and commercial vessels in the GAB, in Australia and around the world.

6.9.6 Demonstration of As Low As Reasonably Practicable

The decision context and assessment technique for the As Low As Reasonably Practicable assessment are provided in Table 6.53. Additional controls which have been considered in reaching As Low As Reasonably Practicable are listed in Table 6.54.

Equinor Australia B.V. considers the impacts from sewage, grey water and putrescible waste are As Low As Reasonably Practicable because:

- Discharge of organic wastes during an offshore exploration program is standard practice in the industry and represents a low impact to the receiving environment.
- The International Convention for the Prevention of Pollution from Ships standard is considered to be the most appropriate standard to adhere to in this environment given the nature and scale of the activity. The International Convention for the Prevention of Pollution from Ships standard is as an internationally accepted standard that is utilised industrywide.
- No additional control measures are required to reduce the environmental impacts associated with planned discharges to As Low As Reasonably Practicable.

Table 6.53 As Low As Reasonably Practicable decision context and assessment technique for impacts from sewage, grey water and putrescible waste

As Low As Reasonably Practicable decision context	Discharge of sewage, grey water and putrescible wastewater offshore (from vessels and the MODU) is a well understood activity that is practiced daily both nationally and internationally. Given the environmental impacts are low with standard management of wastewaters, no additional control measures are required to reach As Low As Reasonably Practicable. No relevant person raised objections or claims regarding sewage and waste. Taking this in consideration Decision Context A should be applied to demonstrate impacts are As Low As Reasonably Practicable.
Assessment technique	Good Practice – Identified industry good practices adopted to reach As Low As Reasonably Practicable

Table 6.54 Assessment of additional controls to mitigate impacts from sewage, grey water and putrescible waste

Additional capabilities	Hierarchy	Environmental benefits	Benefit	Cost	Rationale	Outcome
Storage of sewage and treated water on board for onshore disposal via port facilities.	Elimination	Onshore facilities could treat the sewage to a higher specification prior to discharge	Negligible	0.5–2% of project cost	Disposal via port facilities leads to further impacts associated with air and noise emissions during vessel-to-port and port-to treatment/ disposal, HSE handling risks, costs associated with additional space and impacts from discharges in more sensitive populated areas or shallow water environments	Not adopted
Installation of a higher specification STP	Engineering/ isolation	Further treatment will result in lower potential impacts to surface waters	Negligible	0.5–2% of project cost	Specifying the latest generation STP is likely to require retrofitting and is not justified for a remote deep-water location	Not adopted

6.10 Deck and bilge waters discharges

6.10.1 Impact description

Bilge tanks receive fluids from many parts of the vessel and can contain water, oils from machinery spaces or minor spills, detergents, solvents and other chemicals. There will also be variable water discharges directly overboard or via deck drainage systems arising from rainfall, spray and green water, and deck activities such as cleaning/wash-down and residue from minor spills. Bilge water is typically treated to remove gross contaminants, tested and then discharged if it meets the discharge criteria.

The impact assessment herein considered the following impact from discharge of deck and bilge waters:

- decrease in water quality causing acute and chronic toxicity to marine fauna.

Oily bilge water is typically generated on vessels and mobile offshore drilling units at 0.01–13 m^3 per day (EMSA 2016) depending on vessel size and age, condensation and leakages in the engine room. This volume is reduced prior to discharge by 65–85% by using the oily water separator (OWS), which is designed to reduce concentrations of oil in discharge waters to 15 ppm in accordance with International Convention for the Prevention of Pollution from Ships 73/78 (Annex 1). Even at the maximum rate of 0.5 m^3 per hour (a conservative estimate considering the median in literature is around 0.3 m^3 per day) (EMSA 2016), the maximum oil discharge at 15 ppm equates to <0.008 L oil per hour. This is a negligible loading in an open-ocean setting. This discharge will dilute and disperse rapidly in the open ocean environment, especially given the constant thruster action from the vessels and mobile offshore drilling unit as they hold station. Such small volumes of oil will be rapidly eliminated through microbial degradation, evaporation, photo-oxidation and possibly sedimentation. The potential impacts are limited to the drilling operations period.

The environmental receptors with the potential to be exposed to toxicity impacts from these discharges will be pelagic fauna such as marine cetaceans, pelagic fish and plankton in the surface waters in the immediate vicinity of the discharges from the mobile offshore drilling unit. The most credible mechanism for impact to marine fauna is through ingestion of hydrocarbons and chemicals in the surface waters (<5 m) and direct contact with any surface slicks. Discharges disperse and dilute rapidly with increasing distance from the mobile offshore drilling unit, so the potential for impacts decreases rapidly with increasing distance from the source.

6.10.2 Levels of acceptable impact

The impact on marine fauna caused by the discharge of deck and bilge will be acceptable when:

- Chemical toxicity impacts to fauna in the water column are localised and temporary.
- There will be no direct effect on EBPC Act listed matters of national environmental significance and identified seabed features (Anna's Pimple and Murray's Mount) with no direct effects on the Great Australian Bight Marine Park management values.
- Wastewater management and disposal operations will be compliant with all maritime law and standard industry practice.

6.10.3 Impact prediction

Given the small volumes periodically discharged into the surface waters, only surface biota such as immobile fish embryo, larvae and plankton, and mobile pelagic fish and transient reptiles, cetaceans and seabirds in the immediate vicinity of the discharge point will be exposed. The small volumes and low concentrations of oily water from bilge discharges are not expected to induce acute or chronic toxicity impacts to marine fauna or plankton through ingestion or absorption through the skin. In the event the oily water separator malfunctions and discharges off-specification water, these impacts may occur, though this is only likely in a highly localised area (meaning that few immobile individuals would be exposed).

These discharges are non-continuous and infrequent and in the case of the Stromlo-1 mobile offshore drilling unit and support vessels, discharges are further dispersed by the continuous use of station-holding thrusters and movement thrusters. Modelling by RPS (2017b) indicates that upon discharge, the small volumes of hydrocarbons and other chemical will be diluted by several orders of magnitude within tens of metres from

the discharge point. The worst-case potential impact associated with this discharge is expected to be a local decrease in local water quality without any toxicological effects to marine megafauna and no ecosystem-level effects. The water quality is predicted to rapidly return to original state by natural action after drilling is complete. No cumulative impacts from vessels being alongside are predicted given the open-ocean environment, short periods of being alongside, use of thrusters to maintain position and intermittent nature of small volumes of discharges.

Given the small, intermittent volumes, water depth, constant mixing effects of vessel and mobile offshore drilling unit thruster actions, vessel movements and open-ocean currents, the chemical and oil toxicity impacts to fauna in the water column from deck and bilge discharges are predicted to be localised with no ecosystem-level effects and rapid recovery of any affected communities. The localised and short-term environmental impacts are considered Category 1–3. Cumulative impacts from the vessels and the mobile offshore drilling unit are Category 1–3 due to the small volumes and location.

6.10.4 Impact treatment

6.10.4.1 Environmental performance outcomes (EPO 6.10)

Impacts on water quality limited to localised and short-term effects, not exceeding a consequence category of 1-3.

6.10.4.2 Context for assessment

Table 6.55 Context for mitigating impacts from deck and bilge water discharges

Legislative and other requirements	Australia implements MARPOL through the *Protection of the Sea (Prevention of Pollution from Ships) Act 1983* and the *Navigation Act 2012*. Overboard discharge of oil is managed in accordance with MARPOL Annex I: Regulations for the prevention of pollution by oil. Under the Australian Acts, Australian Maritime Safety Authority implements Marine Order 91 (Marine pollution prevention — oil) 2014, which requires: • Oil (vessels >400T) requirement for an oil in water separator that achieves 15 ppm oil in water (OIW) They are also required to have an oil content monitor (OCM) and a bilge alarm to detect if the treated bilge water meets the discharge requirements.
Industry standards	Compliance with MARPOL 73/78 and Marine Order 91 Environmental, Health and Safety Guidelines for Offshore Oil and Gas Development (World Bank Group, 2015) Guidelines met with regard to: • Other waste waters (item 44): Bilge waters from machinery spaces in support vessels should be routed to the closed drain system or contained and treated before discharge to meet MARPOL requirements. Deck drainage water should be routed to separate drainage systems. This includes drainage water from process and non-process areas.
Equinor Australia B.V. standards	Deck and bilge water management aligns with TR1011 – Environmental Requirements for Offshore Installations which references compliance with MARPOL 73/78b

6.10.4.3 Control measures and performance standards

Table 6.56 Control measures and performance standards for mitigating impacts from deck and bilge water discharges

Control measures	Performance standards	Measurement criteria	Responsibility
Bilge water is treated to reduce hydrocarbon concentrations to an acceptable level prior to overboard discharge	EPS 6.10.1: In accordance with Regulations 12 and 14 of MARPOL Annex I, all bilge water is treated through an oily water separator (OWS) set to prevent the discharge of water with a >15 ppm oil in water (OIW) content.	Inspections of the International Oil Pollution Prevention certificate show it is valid.	MODU OIM Vessel Master

Control measures	Performance standards	Measurement criteria	Responsibility
	EPS 6.10.2 All residual oil from the OWS is pumped to tote tanks and transferred to shore for recycling, reuse or disposal.	The Oil Transfer Book contains details of oily wastes transferred to a support vessel, or to suitable waste disposal facility.	MODU OIM Vessel Master
Oily water separator	EPS 6.10.3: The OWS is maintained in accordance with the PMS to ensure it does not discharge water containing >15 ppm OIW in compliance with MARPOL	Inspections of PMS records verify that the OWS is being maintained to schedule.	MODU OIM Vessel Master
A functional oil content monitor (OCM) and a bilge alarm to detect if the treated bilge water meets the discharge requirements	EPS 6.10.4: MARPOL requires the OWS has an oil content monitor (OCM) and a bilge alarm to detect if the treated bilge water meets the discharge requirements.	Inspections of the MARPOL compliant OWS show the OCM is functional, correctly calibrated and maintained according to schedule or the manufacturer's specifications	MODU OIM Vessel Master
	EPS 6.10.5: OWS alarm system is calibrated and maintained in accordance with the PMS	Inspections confirm the OWS alarm system is calibrated and maintained in accordance with the PMS requirements	MODU OIM Vessel Master
Personnel must be appropriately trained in tasks and aware of requirements relevant to their role	EPS 6.10.6: Personnel are competent and provided with procedures or training that describe the requirements for the operation and maintenance of the OWS, OCM and alarm system.	Records show procedures or training have been given to relevant personnel that includes the requirements for the management of the OWS	MODU OIM Vessel Master
Chemicals are stored long term in chemical storage lockers	EPS 6.10.7: A chemical locker is available, bunded and used for the storage of all non-bulk chemicals so as to prevent accidental discharge overboard.	Inspection verifies that a chemical locker is available and in use.	MODU OIM Vessel Master
Spills on deck will be managed to avoid loss to the sea in accordance with vessel Shipboard Oil Pollution Emergency Plan (SOPEP)	EPS 6.10.8: Relevant deck crews receive Shipboard Marine Pollution Emergency Plan (SMPEP)/ SOPEP training every three months.	Inspection of training records show that relevant crew have current spill response training.	MODU: OIM
	EPS 6.10.9: Minor spill response kits available in relevant locations, are fully stocked and ready for use in the event of a spill to deck to prevent or minimise discharge overboard.	Site inspection verifies that response kits are available in relevant locations and are fully stocked.	MODU OIM Vessel Master

6.10.5 Demonstration of acceptability

The level of impact that deck and bilge water discharges will have on marine biota and marine park values is acceptable because it meets the a priori acceptability criteria as described below.

Table 6.57 Acceptability evaluation for impacts from deck and bilge water discharges

Acceptability criteria	Evaluation against acceptability criteria
a. Chemical and oil toxicity impacts to fauna in the water column are localised and temporary	The small volumes of oil (< 0.008 L/hr) discharged into the open deep-water environment will disperse within tens of metres of the discharge. As such the potential impacts will be localised and temporary. No impacts to commercial fish stocks are predicted.
b. There will be no direct effect on EBPC Act listed MNES and identified seabed features (Anna's	The deck or bilge water discharges will not impact either Anna's Pimple or Murray's Mount, which are more than 20 km distant, nor any KEF (such as the Ancient Coastline which is too distant or benthic biota or communities that are at water depths exceeding 2 km). Given the mobility and transient nature of MNES that could be

Acceptability criteria	Evaluation against acceptability criteria
Pimple and Murray's Mount) and no direct effects on the GAB Marine Park management values	traversing the area (such as the migrating pygmy blue whale), potential impacts at worst will be at an individual level with megafauna able to take avoidance action. Plankton may be temporarily impacted but populations are expected to recover quickly given the duration of activities, small volumes, open-ocean deep-water environment and natural rapid recruitment and reproduction. No ecosystem-level impacts are predicted. The discharge is too surficial, localised and temporary to impact the GAB Marine Park values (e.g. the Mammal Protection Zone, southern right whale calving habitats, foraging areas for threatened white shark and migratory sperm whale and KEFs such as areas important to small pelagic fish with important ecological roles)
c. Wastewater management and disposal operations will be compliant with all maritime law and standard industry practice	Equinor Australia B.V. undertakes wastewater management and disposal operations in alignment with MARPOL Marine Orders 91 – oil (as relevant to vessel class) requirements which include mandatory measures for the processing of oily water prior to discharge as applicable to all commercial vessels in the GAB, Australian waters and around the world. Residual oily waste from OWS and deck clean-up will be returned to shore for disposal at a licensed facility. The performance objectives are aligned with industry standards regarding compliance with Environmental, Health and Safety Guidelines for Offshore Oil and Gas Development (World Bank Group 2015) Guidelines.

6.10.6 Demonstration of As Low As Reasonably Practicable

The decision context and assessment technique for the As Low As Reasonably Practicable assessment are provided in Table 6.58. Additional controls which have been considered in reaching As Low As Reasonably Practicable are listed in Table 6.59.

Equinor Australia B.V. considers the impacts from sewage, grey water and putrescible waste are As Low As Reasonably Practicable because:

- The mobile offshore drilling unit and support vessels will discharge small amounts of bilge and deck run-off water with low concentrations of chemicals including hydrocarbons. The impacts are predicted to be low due to the low concentrations, rapid dilution and dispersion and therefore localised effects.
- Discharging the treated water offshore and disposal of collected oil residues onshore will have negligible environmental impact and comply with International Convention for the Prevention of Pollution from Ships requirements which allow for offshore discharges. The International Convention for the Prevention of Pollution from Ships standard is considered to be the most appropriate industry standard to adhere to in this environment given the nature and scale of the activity. The International Convention for the Prevention of Pollution from Ships standard is an internationally accepted standard that is utilised industry wide. Compliance with relevant and appropriate International Convention for the Prevention of Pollution from Ships requirements and other control measures listed above reduces the environmental impacts associated with planned discharges to As Low As Reasonably Practicable.
- No additional control measures are required to reduce impacts to As Low As Reasonably Practicable.

Table 6.58 As Low As Reasonably Practicable decision context and assessment technique for impacts from deck and bilge water discharges

As Low As Reasonably Practicable decision context	Discharge of deck and bilge waters offshore (from vessels and the MODU) is a well understood and practiced activity both nationally and internationally. There is little uncertainty associated with this discharge, as the environmental interactions associated with this discharge are limited and the potential environmental impacts are small. Implementing standard MARPOL requirements for reducing the concentration of oil in discharge waters eliminates potential for adverse ecological impact. No additional control measures are necessary to reduce impacts to As Low As Reasonably Practicable. No relevant persons raised objections or claims regarding deck and bilge waters. Taking this in consideration Decision Context A should be applied to demonstrate impacts are As Low As Reasonably Practicable.
Assessment technique	Good Practice – Identified industry good practices adopted to reach As Low As Reasonably Practicable

Table 6.59 Assessment of additional controls to mitigate impacts from deck and bilge water discharges

Additional capabilities	Hierarchy	Environmental benefits	Env benefit	Cost	Rationale	Outcome
Treatment system to remove oil to 42 mg/L, 30-day average not exceeding 39 mg/L (United States Environmental Protection Agency (US EPA) Regulatory limit for various discharges).	Engineering/ isolation	OIW treatment systems could treat the oil to a lower concentration prior to overboard discharge	Negligible	0.5–2% of project cost	Given the small quantities of oil, ready dispersion and deep water open-ocean location, the decrease in water quality is negligible. However, there is a small environmental benefit in further treatment down to 15 ppm oil. Should the contracted MODU be unable to reach this, retrofitting costs will be grossly disproportionate to the environmental benefits.	Not adopted
Require all deck wash to be treated in the OWS	Engineering/ isolation	Treat all deck wash to remove oils	Negligible	0.5–2% of project cost	Green water and rain events result in volumes too large to treat practically and to little environmental benefit as after the first wash, the wastewater is mostly sea water or rainwater.	Not adopted

6.11 Blowout preventer fluid discharges

6.11.1 Impact description

Blowout preventer hydraulic fluids will be released during blowout preventer pressure testing every 21 days, before drilling out of the deeper casing/liners, and during pressure function testing every seven days. This equates to a total of approximately 15 tests. These fluids will be released directly to the ocean from the functioning of the hydraulically controlled valves about 8 m above the seabed in water depths around 2230 m.

Each blowout preventer test typically results in the release of about 1500 L of freshwater mixed with a glycol-based detergent or water-based anti-corrosion additives. The discharge typically includes the release of about 43–73 L of active chemical ingredient (based on a 3–5% concentration). The total release over the Stromo-1 drilling program is planned to be in the region of 20–25 m^3 of blowout preventer fluid, including up to 1.25 m^3 of active chemical ingredients.

In addition to this, small volumes of blowout preventer fluids are released whenever the riser is unlatched, resulting in an additional release of fluids to the environment.

The impact assessment herein considered the following impact from discharge of blowout preventer test fluids:

- acute and chronic toxicity to demersal marine biota and benthic habitats
- the environmental receptors that will be exposed to these discharges include demersal fauna such as fish and invertebrates near the seabed in the immediate vicinity of the blowout preventer discharge at the Stromlo-1 well location.

The potential impacts are limited to intermittent discharges during the drilling program.

The most credible impact to marine fauna is localised acute and chronic toxicity limited to the immediate vicinity of the discharge valves. The discharged fluids will be dispersed and diluted rapidly with concentrations of chemicals decreasing with distance from the valves, so that temporary changes to ambient water quality are unlikely beyond the vicinity of the blowout preventer at the well-site.

6.11.2 Levels of acceptable impact

The impact on fauna caused by the discharge of blowout preventer test fluids will be acceptable when:

a. Chemical toxicity impacts to biota and water quality are localised and temporary.

b. Effects on EBPC Act listed matters of national environmental significance and identified seabed features (Anna's Pimple and Murray's Mount or direct effects on any of the Great Australian Bight Marine Park management values are negligible.

c. blowout preventer fluid management and disposal operations will be compliant with Equinor Australia B.V. standards and good industry practice.

6.11.3 Impact prediction

None of the EPBC listed megafauna species, including those whose habitats are protected by the Great Australian Bight Marine Park, occur in the deep waters around the well site. The deep-sea demersal fish, epifaunal and infaunal communities in the vicinity of the well-site have been generally described by Williams et al. (2017, 2018) and are understood to be widely represented across the central Great Australian Bight in similar water depths. These communities will be exposed to the blowout preventer fluid discharge in the area adjacent the blowout preventer, but the concentrations of any chemicals released will rapidly dissipate after each test.

The hydraulic fluid to be used for the blowout preventer testing is a water-based, sea water-soluble product that has a low concentration of active ingredients (3–5% by volume or about 50 ppm by concentration). CEFAS data (2018) indicates that these products have an aquatic toxicity LC50 between 10 and 100 ppm and is inherently biodegradable (20–60% in 28 days). For short-duration discharges, the risk assessment convention is to apply a safety factor of 10 to acute toxicity data, consequently, the blowout preventer fluid no-effect concentration is estimated to be between 1 ppm and 10 ppm. To reach these concentrations, dilutions in the order of 5–50 are required.

BP p.l.c. undertook modelling for similar scale of blowout preventer testing fluid discharge and found the maximum time to a 3000-fold dilution was in the order of 77 minutes for 654 L discharged over three minutes and a maximum plume displacement of 98 m (BP p.l.c. 2013). For a lesser discharge of 70 L over 1.16 minutes, dilutions of 3000-fold were reached in about 15 minutes at a maximum distance of 37 m from the discharge. Therefore, a conservative assumption can be made that the required dilutions of up to 50-fold will be achieved for the Stromlo-1 well within 100 m from the discharge point. With the short periods for discharge and the effective dispersion and dilution after discharge, it is unlikely any biota will be exposed to elevated chemical concentrations for long enough to suffer any impacts.

It is expected that the worst-case potential impact from this discharge may result in a limited local degradation of the water quality and deep-water habitat in the immediate vicinity of discharges rapidly returning to original state through natural flushing.

Fish and invertebrate epifauna and infauna are most likely to be exposed but are only expected to be present in low abundance at the discharge location during the very short period of discharge and plume persistence. Any change in epibenthic, benthic or demersal species abundance and composition is expected to be localised, rapidly returning to background conditions. No ecosystem-level effects are predicted.

In summary, the frequency and requirement for blowout preventer testing at specific intervals is determined by safety criteria. Discharges are intermittent and short-lived; they typically last for minutes and are run approximately every seven days. The blowout preventer test fluids mainly comprise sea water and the chemicals therein are in low concentrations and will be rapidly diluted to harmless concentrations within tens of metres of the discharge point. The potential for exposure of more than a few individuals in the demersal/benthic zone is limited. No ecosystem-level impacts are credible, and the impact is considered Category 1–3.

6.11.4 Impact treatment

6.11.4.1 Environmental performance outcomes (EPO 6.11)

Impacts on water quality limited to localised and short-term effects, not exceeding a consequence category of 1-3.

6.11.4.2 Context for assessment

Table 6.60 Context for mitigating impacts from blowout preventer fluid discharges

Legislative and other requirements	IFC (2015) recommends the BOP system is tested at installation and at regular intervals, including pressure testing at installation, after the disconnection or repair of any pressure containment seal in the BOP system and regular well-control drills should be run. BOP test fluid discharges are a necessary part of these tests and drills
Industry standards	OSPAR signatory countries typically use the OCNS (see below) to rank and assess chemical environmental characteristics
Equinor Australia B.V. standards	Equinor Australia B.V. management of BOP fluid discharges considers that chemicals are selected and procured as per SF601.01 – Chemicals Management which follows the CHARMS/OCNS system of assessing and ranking environmental characteristics of chemical and aims to reduce impacts to As Low As Reasonably Practicable

6.11.4.3 Control measures and performance standards

Table 6.61 Control measures and performance standards for mitigating impacts from blowout preventer fluid discharges

Control measures	Performance standards	Measurement criteria	Responsibility
Equinor Australia B.V.'s Chemical Management process is applied to the selection of chemicals present in BOP discharges	EPS 6.11.1: Evaluate all BOP fluids in accordance with	Chemical assessment records from technical MODU procurement process in HSE Evaluation Report indicate additives are all assessed and approved prior to use	MODU: Sub-sea Engineer Equinor Australia B.V. Drilling Manager
	EPS 6.11.2: Chemicals containing substances of very high concern listed in Prohibited and Restricted Chemicals (TR1668) shall not be used	Chemical assessment records from technical MODU procurement process in HSE Evaluation Report indicate compliance with TR1668	Equinor Australia B.V. Drilling Manager
	EPS 6.11.3: Chemicals are only used in pre-determined volumes to avoid over-dosing	Daily records confirm volumes used do not exceed pre-determined volumes without justification and approval from the Drilling Manager	Equinor Australia B.V. Drilling Manager
Bulk operational discharges conducted under the MODU Permit to Work (PTW) system	EPS 6.11.4: PTW process is undertaken prior to any operation of intake/ discharge valves and pumps. All BOP test fluid discharges to the sea are covered by appropriate PTW approvals	PTW records demonstrate compliance	MODU Offshore installation manager

6.11.5 Demonstration of acceptability

The level of impact that the discharge of the blowout preventer fluids will have on benthic and demersal fauna is acceptable because it meets the a priori acceptability criteria as described below.

Table 6.62 Acceptability evaluation for impacts from blowout preventer discharges

Acceptability criteria	Evaluation against acceptability criteria
Chemical toxicity impacts to biota and water quality are localised and temporary	Modelling of comparative discharges indicated very rapid dilution of the BOP test fluids, which are predominantly sea water. As such, extended exposure to concentrations with the potential to result in an environmental impact would not be experienced. Consequently, the worst-case potential impact may result in a limited local degradation of the deep-water habitat in the immediate vicinity of discharges, with the environment rapidly returning to original state by natural action upon cessation of BOP testing. No impacts to commercial fish stocks are predicted given the short duration and localised nature of the impact.
Effects on EBPC Act listed MNES and identified seamounts (Anna's Pimple and Murray's Mount) will be negligible	Given the low volumes of BOP fluids to be discharged, the low toxicity of the discharge, the rapid dilution and dispersion of the discharge plume and the low densities of conservation significant marine fauna in the area affected; effects on MNES will be negligible. The BOP fluids will not impact the seabed features or benthic habitats given the distance from the discharges (20 km), the small volumes and deep-water open-ocean dispersive environment.
BOP fluid management and disposal operations will be compliant with Equinor Australia B.V. and industry practice	The content of the BOP fluid will not be known until after the drilling contractor is engaged; but Equinor Australia B.V. will ensure the selected contractor applies the Equinor Australia B.V. chemical management process (SF601 Chemical Management). This process is aligned with the industry standard OCNS/CHARMs systems, which are used extensively by the UK and the Netherlands, regarded as good industry practice in the North Sea and adopted by numerous OSPAR signatory countries. The discharge of hydraulic fluid during BOP testing is common practice for open control loops and is a standard safety measure in the offshore industry in Australia and around the world.

6.11.6 Demonstration of As Low As Reasonably Practicable

The decision context and assessment technique for the As Low As Reasonably Practicable assessment are provided below in Table 6.63.

Equinor Australia B.V. considers the impacts from blowout preventer fluid discharges are As Low As Reasonably Practicable because:

- Blowout preventer fluid discharges are expected to result in an undetectable or limited local degradation of the seabed environment, rapidly returning to original state by natural action. As such, it is not expected to affect biological diversity or ecological integrity. The impact level is low, and no additional control measures are required to further reduce impacts to As Low As Reasonably Practicable.
- The discharge of blowout preventer test fluids is common practice in the offshore exploration drilling around the world and is a required safety procedure to minimise the risks of loss of well control. The chemical additives will be selected according to Equinor Australia B.V.'s chemical selection process and low toxicity options will be used to reduce impacts to As Low As Reasonably Practicable.

Table 6.63 As Low As Reasonably Practicable decision context and assessment technique for impacts from blowout preventer fluid discharges

As Low As Reasonably Practicable decision context	The use of BOPs and the discharge of BOP fluids is a well understood and practiced activity both nationally and internationally. There is little uncertainty associated with this discharge as the environmental interactions associated with this discharge are limited and the environmental impacts are low. No additional control measures are required to further reduce impacts to As Low As Reasonably Practicable. No relevant persons raised objections or claims about BOP fluid discharges. Taking this in consideration Decision Context A should be applied to demonstrate impacts are As Low As Reasonably Practicable.
Assessment technique	Good Practice – Identified industry good practices adopted to reach As Low As Reasonably Practicable

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7.0 Risks associated with unplanned events

7.1 Risk assessment summary

This section describes the outcome of the environmental risk assessment of unplanned events associated with activities described in Section 2.0 of this Environment Plan (EP). The risks have been assessed according to the processes described in Section 5.0 and no High or Very High residual risks were identified.

A summary of this assessment is provided in Table 7.1, Table 7.2 and Table 7.3. The risk assessment addresses the levels of predicted risk, with controls in place, to contribute to the process of ensuring risks are reduced As Low As Reasonably Practicable and of an acceptable level. The risk categories below (Low and Medium) encompass a range of environmental consequences and the implementation of controls may reduce the level of consequence within a category, without decreasing the predicted risk level. For example, consequences associated with risks which are inherently Low, may be reduced by implementing controls; however, the risk ranking will remain Low.

The potential environmental effects listed in Tables 7.1 and 7.2 represent the greatest consequence where there is a range of different receptors, with different sensitivities and exposure risks. For example, in Table 7.2 for B6.3 only Australian sea lions and pygmy blue whales are discussed, whereas the risk assessment covers all of the receptors in Section 7.7.12.

For each source of risk (event) described in Table 7.1, further assessment of risks and outlines of the control measures to reduce risks to As Low As Reasonably Practicable is provided in the following sections and Appendix 7-4 for major oil spill risks. Environmental performance outcomes, standards and measurement criteria for this Environment Plan are also presented herein.

Note the likelihood of unplanned events 1 to 5 are reported qualitatively while the probabilities of oil spill events B6.1 to B6.3 are assessed quantitatively.

Table 7.1 Stromlo-1 risk assessment summary (unplanned environmental events)

#	Source of risk (event)	Potential environmental effect	Consequence category	Likelihood description	Risk level
7.2	Introduction leading to establishment of Introduced Marine Pest (IMP) from biofouling or ballast water	Reduction in species biodiversity Displacement or reduction of native marine species	1–3	Has rarely occurred in the industry	Low
7.3	Support vessel(s) collision with marine fauna (including propeller strike)	Injury or death of marine fauna, including protected species	1–3	Very rare but known in the industry	Low
7.4	Accidental release of solid waste from MODU or support vessels	Minor and/or temporary effects to water quality Marine pollution resulting in injury or entanglement of marine fauna, including protected species	1–3	Has occurred several times in the industry	Low
7.5	Accidental release of hazardous substances (bulk chemicals, fuels, muds and other products) due to crane transfers, bunkering operations and Emergency Disconnect Sequence activation	Localised acute and chronic toxicity to marine on marine fauna from a reduction in water quality Localised short-term damage of benthic habitats in the immediate location of the dropped object/ substance	1–3	Has occurred several times in the industry	Low
7.6	Vessel collision with a contracted vessel or MODU that results in fuel tank rupture	Minor and temporary disruption to marine fauna, including protected species Minor and/or temporary effects to water quality	1–3 to 4	Has rarely occurred in the industry	Low

Table 7.2 Stromlo-1 risk assessment summary (unplanned loss of well control and oil spill scenarios)

#	Source of risk (event)	Potential environmental effect	Consequence category	Probability of the whole event occurring i.e. LOWC causing a spill that is halted by the BOP/CS/RW	Residual risk
1	Major oil spill occurring due to a loss of well control (worst credible case discharge, WCCD) – with the spill stopped by the blow out preventer (BOP) and closure on Day 1; offshore aerial dispersant application	Short term effects (restitution time <1 yr) on the southern bluefin tuna fishery, which is of national or regional importance, effects being localised to the central GAB around the MODU.	5	0.000085	Low
2	Major oil spill occurring due to a loss of well control (WCCD) – with the spill stopped by the capping stack implementation by Day 15; offshore aerial and subsurface dispersant injection (SSDI)	A small number of Australian sea lion colonies would be affected if the capping stack implementation was successful on Day 15 with weathered oil patches at moderate and high thresholds contacting the eastern coastline of the Great Australian Bight (Port Lincoln, Eyre Peninsula and Kangaroo island). Colonies in the western Bight and Bass Straits would be unimpacted.	6–7	0.000040	Medium
3	Major oil spill occurring due to a loss of well control (WCCD) – with the spill stopped by relief well (RW) on Day 102; offshore aerial dispersant spraying and subsurface dispersant injection application	The effect of a 102-day release of oil on Australian sea lions could have a very long or permanent impact on a population that is already in decline resulting from the loss of individual. Given the predicted long restitution time (>10 years) and possible population-level effects on pygmy blue whales if the spill was to occur at peak aggregation time and a few individual whales were to die due to oil toxicity; and the affected Bonney Upwelling aggregation is considered of national importance.	8	0.000019	Medium
4	Major oil spill due to a loss of well control (WCD) – unmitigated, unrestricted for 129 days	The worst-case effect of a 129-day release of oil, could be a very long or permanent impact on a population of Australian sea lions that is already in decline; resulting from the loss of individual breeding adults or reduced reproductive success. Given the predicted long restitution time (>10 years) and possible population-level effects on pygmy blue whales and southern right whales if the spill was to occur at peak aggregation time and a few individual whales were to die due to oil toxicity; and the affected Bonney Upwelling aggregation of pygmy blue whales is considered of national importance, as are coastal aggregations of southern right whales	8	<0.000019	Medium

Table 7.3 Receptor consequence category and risk assessment summary (mitigated WCCD oil spill and unmitigated WCD scenarios)

Receptor group	Representative taxa / values	Consequence category[1]			
		Unmitigated	Mitigated		
		WCD[2] Relief well Day-129 (B6.4)	WCCD Relief well Day-102 (B6.3)	WCCD CS installed Day-15 (B6.2)	WCCD BOP closed Day-1 (B6.1)
Offshore air quality	N/A	1–3	1–3 (not all scenarios assessed)		
Seabirds	Little penguin	6	6	5	1–3
	Shy albatross	7	6	5	1–3
	Short tailed shearwater	5	5	4	1–3
Shorebirds	Eastern curlew	6	6	4	1–3
Marine reptiles	Turtles and sea snakes	1-3	1–3	1–3	1–3
Plankton	Plankton	5	5	4	1–3
Bony fishes and sharks	Syngnathids	1-3	Not assessed separately		
	Handfish	1-3	1–3	1–3	1–3
	Southern bluefin tuna	5	Assessed under 'Other values'		
	Other bony fish	4	Not assessed separately		
	Great white shark	5	5	4	1–3
Marine mammals – pinnipeds	Australian sea lion	8	8	6–7	1–3
	New Zealand fur seal	7	7	5–6	1–3
	Australian fur seal	7	Not assessed separately		
Marine mammals – cetaceans (Biologically Important Areas)	Pygmy blue whale	8	8	6	4
	Southern right whale	8	7	6	4
	Sperm whale	7	7	6	4
Benthic invertebrates other than corals	Benthic invertebrates	6	7	6	4
Deepwater and other corals	Deep water coral	6-7	7	5	4
	Other coral	1-3	5	4	4
Benthic habitats	Benthic habitat	6	6	5	4
Mangroves and salt marshes	Mangroves, salt marshes	6	6	4	1–3
Seagrass	Seagrasses	5	4	4	1–3
Macroalgae	Macroalgae - Giant Kelp Marine Forest of south-eastern Australia	1-3	1–3	1–3	1–3
Shorelines	South Australian shorelines	7	7	4–5	1–4
Coastal settlements and infrastructure	Coastal settlements, infrastructure of South Australia and Victoria with a population >10,000	5-6	5–6	4	1–3
Protected areas	Australian Marine Parks	6	6	5	4
	Key Ecological Features	4	5	1–3	1–3

Receptor group	Representative taxa / values	Consequence category[1]			
		Unmitigated	Mitigated		
		WCD[2] Relief well Day-129 (B6.4)	WCCD Relief well Day-102 (B6.3)	WCCD CS installed Day-15 (B6.2)	WCCD BOP closed Day-1 (B6.1)
	Ramsar wetlands, wetlands of national importance	6	6	5	1–3
Socio-economic values	Shipping and Ports	1-3	Assessed under 'Other values'		
	Defence	1-3	Assessed under 'Other values'		
	Commercial fishing - Southern bluefin tuna	7	7[3]	6[3]	5[3]
	Aquaculture	6	Assessed under 'Other values'		
	Coastal tourism	5	Assessed under 'Other values'		
	Heritage and Cultural	4	Assessed under 'Other values'		
	Other values	Assessed separately above	6–7	6	5

1 See Section 5.0 for consequence definitions

Residual risk ranking	Low risk	Medium risk

2: See new Appendix 7-5 for the detailed WCD Risk Assessment
3: SBT Biological assessment and impact to fisheries combined

7.2 Physical presence – introduction of marine pests

7.2.1 Risk description

Non-indigenous marine species are species that have been introduced into an area beyond their natural biogeographic range and are able to survive, reproduce and establish founder populations. Introduced marine pests (termed "pests" hereafter) are a subset of non-indigenous marine species that once established, can result in harmful effects to social/cultural, economic and/or environmental values. Not all pests introduced into new environments will cause demonstrable effects, some are relatively benign, and few have spread widely beyond ports and harbours.

Pests can be introduced into the activity area by support vessels or the mobile offshore drilling unit carrying pests on submerged surfaces such as the hull or submersible equipment such as anchors, within internal niches such as sea chests and sea-water systems, or through ballast water exchange. Cross-contamination between vessels can also occur.

Consequences from the introduction of pests arriving with ballast water, or from biofouling on the mobile offshore drilling unit or support vessels and their possible establishment include:

- reduction in species biodiversity of surrounding environment
- displacement of native marine species
- reduced value of commercial fishing resources.

Environmental receptors with the potential to be affected by introduction of a marine pest include the pelagic and benthic species found around the mobile offshore drilling unit at the Stromlo-1 well location. The assessment of this aspect has considered the "major conservation values" identified for the Great Australian Bight Marine Park (DNP 2013) including the following Key Ecological Features:

- benthic invertebrate communities of the eastern Great Australian Bight (high species diversity)
- areas important for pelagic fish.

7.2.2 Levels of acceptable risk

The risk of introducing pests will be acceptable if:

Factors in determining acceptability	Acceptability criteria
Internal context	No specific criteria identified
External context: Relevant persons expectations Values/sensitivities protected under EPBC Act	There are no unaddressed objections or claims from relevant persons regarding pests introduced by the activity. There will be no direct effects on EBPC Act listed Matters of National Environmental Significance (MNES).
Legislation and conventions	Operations are compliant with relevant maritime and biosecurity laws and legislation listed under Section 7.2.4 – Risk treatment – legislative and other requirements
Industry standards and practices	Operations meet or exceed industry practices listed under Section 7.2.4 – Risk treatment – Industry Standards
Comparisons made between predicted levels and acceptable levels	No specific criteria identified

7.2.3 Risk assessment

Risk description	Potential pests vary between regions depending on environmental factors such as water temperature, salinity, nutrient levels and habitat type, which affect their survival and invasive capabilities. Pests typically require hard substrate in the photic zone such as shallow waters, to become established. The translocation of marine pests through biofouling or ballast water discharge has the potential to result in potential effects to seabed habitat and marine ecosystems due to: • out-competing native species, for food, space or light, and by interbreeding with local species such that endemic species are lost • predation on local species.
Likelihood analysis and Consequence evaluation	Established pests can be economically damaging through effects such as direct damage to assets (fouling of vessel hulls and infrastructure) and depletion of commercial resources. If the introduction is detected early, eradication may be effective but is likely to be expensive, disruptive and, depending on the method of eradication, harmful to other local marine life. The Department of the Environment and Energy website does not list any introduced marine pests for the central deep waters of the GAB or for the port of Ceduna (nearest port mentioned on the site https://www.environment.gov.au/marine/marine-pollution/marine-pests). However, the port of Adelaide has recorded the presence of the Asian date mussel (*Musculista senhousia*) typically found in up to 20 m water depth, the aquarium *Caulerpa* (C. *taxifolia*) found up to 100 m water depth in sheltered estuaries and coastal lagoons), European green shore crab (*Carcinus maenas*) found up to 60 m water depth and European fan worm (*Sabella spallanzanii*) found in sheltered waters up to 60 m deep. Once established, pests can be difficult to eradicate (Hewitt & Hayes 2002)) and consequently there is potential for long-term change in ecosystem structure and potentially to fishing resources.in the GAB. Open-water environments are less susceptible to pests establishing and flourishing than disturbed shallower environments such as marinas, due the high number of dilutions and degree of dispersal (Paulay et al. 2002). The Stromlo-1 well location is thus less susceptible considering the deep (>2200 m), colder, open waters exposed to variable ocean currents (Section 4.0), The remote location (>370 km from nearest shoreline and shallower water environments) and the distances to critical habitats (approximately 20 km from the nearest significant hard substrate at water depths around 1800 m) presents a low likelihood of pests surviving translocation or establishment. The soft sediment around the well site with sparse benthic assemblages suggests a lack of hard substrate potentially suitable for growth of pests (with exception of the well head, all other submerged infrastructure will be removed after drilling activity is completed). Thus, any introduced pests introduced by the MODU and support vessels have the low potential to establish within the Operational Area. Translocation between vessels and the MODU (or vice versa) is likewise unlikely as vessels are not exchanging ballast water close to the MODU, the continual use of thrusters in the open ocean environment, the time vessels spend in close proximity to the MODU and the duration of the drilling program.

	The presence of the risk of the introduction of a pest will be temporary, only while the MODU and vessels are in the Operational Area. Given the above, the introduction and establishment of pests is unlikely at the Stromlo-1 location and fisheries and biodiversity values in the vicinity of the Operational Area are not expected to be affected.
As Low As Reasonably Practicable decision context	The introduction pathways for a pest via ballast water and bio fouling are well understood in the marine industry. Legislation is in place to manage this specific risk, which all vessels are required to comply with prior to entering Commonwealth waters. Given the predominantly soft sandy/clay sediment, isolated deep cold-water environment, the introduction of pests due to the new well head left in situ is not credible. However, the Stromlo-1 site lies in the GAB MP Benthic Protection Zone which recognises the value of the benthic diversity in the region. Translocation from vessel to MODU / other vessels or vice versa may have occurred previously in the region as pests are reported sighted in Port Adelaide more than 730 km distant. In a previous BP proposal to drill in the same area, there was relevant persons' interest in the potential for introducing Pacific Oyster Mortality Syndrome (POMS) into aquaculture leases, as advised by the Department of Primary Industries and Regions South Australia to BP. PIRSA suggested that (for diseases with a poorly understood transmission such as POMS) a buffer of 20 km is enough to prevent transmission of the virus. However, as the Stromlo-1 activity is limited to one well location in Commonwealth waters at a much greater distance from oyster farms located near Ceduna and Coffin Bay, this is not considered to be a relevant concern (under the OPGGS(E) Regulations). Taking this in consideration, Decision Context A should be applied to demonstrate risks are As Low As Reasonably Practicable.
Assessment technique	Good Practice – Identified industry good practices adopted to reach As Low As Reasonably Practicable.

7.2.4 Risk treatment

7.2.4.1 Environmental performance outcomes (EPO 7.2)

Zero occurrence of the introduction of introduced marine pests due to Stromlo-1 drilling activities

7.2.4.2 Context for assessment

Legislative and other requirements	International Convention on the Control of Harmful Anti-fouling Systems on Ships 2008: requires vessels to poses valid International Anti-fouling System Certificates International Convention for the Control and Management of Ships' Ballast Water and Sediments requires vessels to maintain a ballast water plan and ballast water record book Biofouling Guidelines (MPEC.207(62)) 2011: Guidelines for the control and management of ships' biofouling to minimise the transfer of invasive aquatic species. *Biosecurity Act 2015*, Australian Ballast Water Management Requirements Version 7 (DAWR 2017a) and Offshore Installations – Biosecurity Guide (DAWR 2018): aim to minimise the potential risks and effects of introduced marine pests. Requires a pre-arrival report to be submitted to gain approval to enter Australian waters. Prohibition of ballast water discharge within the GAB MP under the EPBC Regs unless authorised or under a management plan
Industry standards	National Biofouling Management Guidance for the Petroleum Production and Exploration Industry (CoA 2009) Anti-fouling and in-water cleaning guidelines (DoENZMPI 2015)

7.2.4.3 Control measures and performance standards

Control measures	Environmental performance standards	Measurement criteria	Responsibility
Department of Agriculture and Water Resources (DAWR) clearance received for all international vessels	EPS 7.2.1: Maritime Arrivals Reporting System (MARS) clearance is obtained in accordance with the Australian Ballast Water Management Requirements Version 7 (DAWR 2017b)	Inspection of Biosecurity Status Document (BSD) demonstrating vessel low risk status	Vessel Master MODU Chief Mate
The MODU and support vessels will possess valid International Anti-fouling System Certificates	EPS 7.2.2: The anti-fouling system certification is current in accordance with Australian Maritime Safety Authority Marine Order Part 98 (Anti-fouling systems)	Inspection of valid International Anti-fouling System Certificates.	Vessel Master MODU Chief Mate
Maintain a Ballast water Plan and Ballast water Record Book in accordance with the Australian Ballast Water Management Requirements Version 7 (DAWR 2017b)	EPS 7.2.3: Ballast Water Management Plan and Ballast Water Record System will be available and maintained throughout the duration of the activity	Inspection of records confirm the Ballast Water Management Plan and Ballast Water Record Book are being maintained	Vessel Master MODU Chief Mate
No discharge of foreign ballast water within the GAB MP (in accordance with the EPBC Regs)	EPS 7.2.4: No ballast water discharge within the GAB MP unless authorised or under a management plan	Inspection of records confirm the Ballast Water is not discharged unauthorised or not under a management plan within the GAB MP	Vessel Master MODU Chief Mate
Biofouling on vessels will be managed in accordance with the requirements of the National Biofouling Management Guidance for the Petroleum Production and Exploration Industry (Commonwealth of Australia 2009)	EPS 7.2.5: • Up to date Biofouling Record Book outlining marine antifouling management actions • Biofouling risk assessment shows low risk of IMS presence prior to entry into Australian waters • Routine immersible equipment (e.g. ROV) cleaning, maintenance, drying and storage requirements are sufficient to maintain a low risk of translocation of marine pests	Biofouling risk assessment report details management actions including cleaning as required, and confirms: • vessel poses low risk of introducing IMS. • immersible equipment poses low risk of introducing biofouling organisms	Vessel Master

7.2.5 Outcome

Residual risk	Consequence category	Likelihood	Risk level
	1–3	Very rare but known in the industry	Low

The residual risk of introducing pests is assessed as acceptable because:

Factors affecting acceptability	Acceptability criteria	Demonstration of acceptability
Internal context	No specific criteria identified	No specific criteria identified
External context	There are no unaddressed objections or claims from relevant persons regarding pests from the activity. There will be no direct effect on EBPC Act listed Matters of National Environmental Significance (MNES).	To address interest by relevant persons in the potential for introducing Pacific Oyster Mortality Syndrome into aquaculture leases, a buffer of 20 km was raised as sufficient to prevent transmission of the virus. As such, the activity being >370 km from any oyster farm presents no credible risk of transmission. There are no EBPC Act listed MNES populations predicted to be affected by the risks of effects from the introduction and establishment of invasive marine species. The location of the well site in a highly dispersive, deep, open ocean environment with no abundant adjacent hard substrates or shallow water environments indicates an unlikely likelihood of pests establishing and flourishing or translocating to another environment. No ballast water may be discharged within the GAB Marine Park under the EPBC Regs (unless authorised or under management plan) in accordance with maintaining the GAB Marine Park management values.
Industry standards and practices	Operations are compliant with practices listed under Section 7.2.4 – Risk treatment – Industry Standards	Obtaining anti-fouling certificates and Maritime Arrivals Reporting System reporting are accepted industry practices for vessels working in Australian waters. Compliance reduces the risk in an industry-accepted manner.
Legislation and conventions	Operations are compliant with relevant maritime and biosecurity laws and legislation listed under Section 7.2.4 – Risk treatment – legislative and other requirements	By the vessels and the MODU complying with all maritime and quarantine law and industry practices regarding ballast water and anti-fouling management, the risk is reduced to Low. Predictions are therefore considered acceptable because the Act and national guidance mandates quarantine requirements for vessels to undertake prior to entering Australian waters.

Demonstration of As Low As Reasonably Practicable	MODUs, vessels and immersible equipment will naturally accumulate organisms from the surrounding environment, and vessels and the MODU require ballast water for safety and stability. The majority of known pests require shallow water environments and/or permanent hard substrates. Given the depth of the Stromlo-I site (>2200 m) and distance to the Australian coast (>370 km), it is unlikely that an IMP would be able to successfully translocate to the Operational Area or translocate to another vessel and flourish. No pests are currently recorded at the Stromlo-1 site or immediate surrounds. The planned activity will preferentially source vessels that have been active within state or Commonwealth waters and hence already have a low biosecurity risk status prior to mobilisation for Stromlo-1 activities. However, exclusively hiring local suitable vessels may limit availability and could affect the schedule – i.e. the cost outweighs the small decrease in risk. It is possible to screen every vessel during the contracting and mobilisation stage and require vessels to be cleaned prior to starting work. However, the cost of potential delays and cleaning vessels at suitable docks in the region would be gross compared to the lessening of the risk which is already low at this location. All vessels used in both planned and unplanned activities will adhere to Commonwealth Government biosecurity requirements and practices consistent with the National Biofouling Management Guidance for Petroleum Production and Exploration Industry (CoA 2009) and the Australian Ballast Water Management Requirements Version 7 (DAWR 2017b). Hence, the risk of introducing a pest is considered As Low As Reasonably Practicable and reducing the risk further will yield negligible benefits.

Options considered in seeking to reduce risks to As Low As Reasonably Practicable include:

Additional capability	Hierarchy	Environmental benefit	Env benefit scale	Cost	Rationale	Outcome
Clean all vessels	Engineering	By dry docking and cleaning all wetted surfaces on all vessels, the likelihood of a pest relocation and establishment is considerably lowered	Negligible	3–10% of project cost	Inspection and cleaning require specialist facilities, sites with no pests immediately prior to the work starting. The risk already has a low likelihood so the substantial cost (and time required) to inspect and clean all vessels outweighs the environmental benefit	Not adopted
Use of freshwater ballast on board the MODU and vessels to inhibit survival of marine species	Elimination	Risk of pests in ballast water removed, however results in a freshwater discharge in saline environment	Negligible	0.5–2% of project cost	While ballast water risks are eliminated, pests may still be present on the hulls and wetted niches. The risk already has a low likelihood, so the incremental costs outweighs the environmental benefit	Not adopted

7.3 Physical interaction – collision with marine fauna

7.3.1 Risk description

There is the potential for the mobile offshore drilling unit and vessels involved in the activity to strike marine fauna such as cetaceans, fish and marine reptiles and including protected and threatened species. The main collision risk associated with the activity is support vessels colliding with large, slow moving cetaceans such as whales.

The effect from vessel interactions with marine fauna can range from fauna behavioural changes to severe effects such as mortality resulting from vessel hull, propeller and thruster strikes. Factors contributing to the frequency and severity of effects from collisions vary greatly due to vessel type, vessel operation (specific activity, speed), physical environment (e.g. water depth) and the type of animal potentially present and their behaviours. The mobile offshore drilling unit and support vessels are stationary or moving at low speeds when supporting drilling operations; with two support vessels typically transiting to and from Port Adelaide when the mobile offshore drilling unit is present in the Petroleum Safety Zone.

Helicopters also pose a risk of seabird and shorebird collision. This would affect individuals but not have population-level effects. Given helicopters are required for safety and support, and practical measures are not available for further reducing the risk, this is not assessed further.

7.3.2 Level of acceptable risk

The risks of vessel interactions with marine fauna will be acceptable if:

Factors in determining acceptability	Acceptability criteria
Internal context	No specific criteria identified
External context: • relevant persons expectations • values/sensitivities protected under EPBC Act	There are no unaddressed objections or claims from relevant persons regarding vessel interactions with marine fauna from the activity. There will be no direct effects on EBPC Act listed Matters of National Environmental Significance and GAB Marine Park values

Factors in determining acceptability	Acceptability criteria
Legislation and conventions	Operations are compliant with relevant legislation listed under Section 7.3.4 – Risk treatment – legislative and other requirements
Industry standards and practices	No specific criteria identified
Comparisons made between predicted levels and acceptable levels	No specific criteria identified

7.3.3 Risk assessment

Risk description	The likelihood of vessel/whale collision causing a fatality is directly related to vessel speed. Vanderlaan and Taggart (2007) found that the chance of lethal injury to a large whale as a result of a vessel strike increases from about 20% probability of a fatality when struck by a vessel travelling at 8.6 knots to 80% at 15 knots. Support vessels within the Operational Area will typically travel at less than 8 knots and the MODU is stationary once ballasted. The noise of the thrusters, DP engines and drilling will assist in risk reduction by scaring off some fauna,
Likelihood analysis and consequence evaluation	Other than habitat and migration areas for pygmy blue whales (*Balaenoptera musculus brevicauda*), there are no adjacent or nearby Biological Important Area for MNES cetaceans – with pygmy blue and sperm (*Physeter macrocephalus*) whale foraging grounds lying about 100 km north. However, the southern right (*Eubalaena australis*), humpback (*Megaptera novaeangliae*) and sei (*Balaenoptera borealis*) whales may still traverse the area as may the fin (*Balaenoptera physalus*), killer (*Orcinus orca*) and various other beaked and baleen whales. Likewise, numerous dolphins such as the common short-beaked (*Delphinus delphis*), Risso's (*Grampus griseus*) and dusky (*Lagenorhynchus obscurus*) may be found in Operational Area. Cetaceans are naturally inquisitive marine mammals that are often attracted to offshore vessels and facilities, with dolphins commonly observed to "bow ride" with offshore vessels. The reaction of whales to the approach of a vessel is anecdotally variable. Some species remain motionless when in the vicinity of a vessel while others are known to be curious and often approach ships that have stopped or are slow moving, although they generally do not approach, and sometimes avoid, faster moving ships (Richardson et al. 1995). The presence of pinnipeds and marine reptiles (sea turtles) was initially identified as a risk. However, given the water depth (>2200 m) and distance to potential haul out, nesting or foraging sites (such as island or emerging reef), the Operational Area is unlikely to represent an important marine habitat for turtles and pinnipeds with the Protected Matters Search Tool report not listing any pinnipeds at the site. Three turtle species are listed in the PMST report (loggerhead, green and leatherback) as possibly being encountered in the GAB; but given the lack of Biologically Important Areas in the region for reptiles, the area is unlikely to support large aggregations. Although these faunas may transit the area, they can display avoidance behaviours around operating thrusters. The low likelihood of encountering these marine species in large concentrations in the Operational Area means they have not been considered further. Collisions between vessels with reduced manoeuvrability and large, slow moving cetaceans occur more frequently where high vessel traffic and cetacean habitat occurs (WDCS 2008). Laist et al. (2001) identified that larger vessels with reduced manoeuvrability moving more than 10 knots may cause fatal or severe injuries to cetaceans, with the most severe injuries caused by vessels travelling faster than 14 knots. Vessels typically used to support drilling activities do not have the same limitations on manoeuvrability nor is the traffic intensive (typically the MODU may have two support vessels in the vicinity at any time). The worst-case is a fatality to marine fauna individuals, including EPBC Act listed species. There have been recorded instances of cetacean deaths in Australian waters (e.g. a Bryde's whale in Bass Strait in 1992) (WDCS 2008), though the data indicates this is more likely to be associated with container ships and fast ferries. The Australian National Marine Safety Committee (NMSC) reports that during 2009, there was one report of a vessel collision with an animal (species not defined) (NMSC 2010). A recent paper by Peel et al. (2018) provides the most up-to-date analysis of whale vessel collisions in Australian waters. A detailed search of online archives the study found reports dating back to 1840, including 74 additional records not in the IWC database, bringing the number of reported vessel collisions in Australian waters to 109 (Evans, Bax & Smith 2016). According to the data of Vanderlaan and Taggart (2007), it is estimated that the risk of fatality is less than 10% at a speed of four knots. Vessel–whale collisions at this speed are uncommon and, based on reported data, there were only two known instances of collisions when the vessel was travelling at less than six knots, both were from whale watching vessels that were deliberately placed amongst whales.

	The MODU and vessels while attending are stationary. The death of individuals will not have a population effect on any MNES cetaceans in the region given the natural mortality that occurs during migrations and calving. It is unlikely that vessel or MODU movements in the PSZ will have an effect on marine fauna populations given (1) the short duration of the activity (around 60 days), (2) the low density of transiting individuals, (3) avoidance behaviour commonly displayed by whales, and (4) low operating speed of the support vessels (generally less than eight knots or stationary, unless operating in an emergency).
As Low As Reasonably Practicable decision context	Offshore commercial vessel operations are widely undertaken locally, nationally and internationally. While, shipping activity in the vicinity of the Stromlo-1 well location is relatively low. Australian Maritime Safety Authority has advised that there is considerable shipping traffic in the southern sections of the exploration permit, as this is a national and international commercial shipping corridor. As such vessel operations are not considered to be an unusual activity within this area. Speeds of support vessels are typically less than eight knots and the risks of cetacean collision are well understood. Australian Guidelines for Whale and Dolphin Watching (DoEE 2017a) for sea-faring activities describes strategies to ensure animals are not harmed during interaction with whales and dolphins. No relevant persons raised objections or claims regarding collisions with marine fauna. Taking this in consideration Decision Context A should be applied to demonstrate the risks are As Low As Reasonably Practicable.
Assessment technique	Good Practice – Identified industry good practices adopted to reach As Low As Reasonably Practicable

7.3.4 Risk treatment

7.3.4.1 Environmental performance outcomes (EPO 7.3)

No marine megafauna death caused by vessel strike in the Operational Area

7.3.4.2 Context for assessment

Legislative and other requirements	Under the EPBC Act, listed threatened species are required to have Conservation Advice or Recovery Plans. There are currently Conservation Management Plans (recovery plans under the EPBC Act) for the southern right whale and blue whale. Both plans identify "minimising vessel collision" as being high priority actions. Minimising vessel collision is also identified as a high priority action in the Conservation Advice for fin, sei and humpback whales none of which have a BIA in the PSZ; but they could be encountered in low densities there. Part 8 of Environment Protection and Biodiversity Conservation Regulations 2000 (EPBC Regulations) interacting with cetaceans and for sea-faring activities Australian Guidelines for Whale and Dolphin Watching (DoEE 2017b)

7.3.4.3 Control measures and performance standards

Control measures	Environmental performance standards	Measurement criteria	Responsibility
Vessel bridge watch maintained by the Officer of the Watch during support vessel movements and caution and "no-approach" zones observed	EPS 7.3.1: Officer of the Watch ensures vessel/MODU operations are in accordance with Part 8.04 of EPBC Regulations 2000 – interacting with cetaceans for sea-faring activities, the following will be implemented for support vessel activities within the Operational Area: • Caution zone (300 m either side of whales and 150 m either side of dolphins unless they approach the vessel) – vessels must operate at no wake speed in this zone • "No-approach" zone (100 m either side of whales and 50 m either side of dolphins) –	Inspection shows support vessels log cetacean sightings and the guidelines and Part 8 were implemented.	Offshore Installation Manager Vessel Master

Control measures	Environmental performance standards	Measurement criteria	Responsibility
	vessels should not enter this zone and should not wait in front of the direction of travel or an animal or pod.		
	EPS 7.3.2: Collisions with cetaceans will be reported by the Officer on watch to the department of Environment and Energy (DEE) via the online National Ship Strike Database (https://data.marinemammals.gov.au/report/shipstrike)	Inspections show the report to the National Ship Strike Database as soon as practical but within seven days after becoming aware of the incident.	Vessel Master MODU Offshore Installation Manager
Environmental inductions for relevant crew address marine fauna interaction procedures	EPS 7.3.3: Relevant vessel and MODU personnel will receive an induction prior to commencement of operations, which will include a component on cetacean avoidance actions, observation and reporting requirements.	Inspection of training records show all relevant personnel have been briefed on caution, "no-approach" zones and marine fauna sighting procedures	Vessel Master MODU Offshore Installation Manager

7.3.5 Outcome

Residual risk	Consequence category	Likelihood	Risk level
	1–3	Has rarely occurred in the industry	Low

The risk of vessel interactions with marine fauna is assessed as acceptable because:

Factors affecting acceptability	Acceptability criteria	Demonstration of acceptability
Internal context	No specific criteria identified	No specific criteria identified
External context	There were no unaddressed objections or claims from relevant persons regarding collisions with marine mammals There will be no direct effect on EBPC Act listed Matters of National Environmental Significance and GAB Marine Park values.	There were no unaddressed objections or claims from relevant persons regarding collisions with marine mammals Vessels avoidance actions being implemented on cetacean sightings, the type of activities of the operational vessels in the Operational Area requiring typically slow speeds, and the likely low concentrations of whales in the Operational Area (of the PMST listed whales and dolphin, only the pygmy blue whale has distribution and migration BIA through the Operational Area), there will be no direct effect on EBPC Act listed MNES at a population level.
Legislation and conventions	Operations are compliant with relevant legislation listed under Section 7.3.4 – Risk treatment – legislative and other requirements	The activities will be undertaken in compliance with all legislation and guidelines relating to cetaceans including taking prescribed avoidance actions where safe. The level of risk remaining following compliance with the Regulations is Low.

Demonstration of As Low As Reasonably Practicable	The risk is low and reducing the risk further will yield marginable and negligible benefits in comparison to the costs of adopting these control measures. The MODU and vessel presence is required in the field during the activity and the number of vessels for the activity is already at a minimum for safety reasons. Application of control measures and training of relevant personnel all contribute to reducing the risk of vessel collision with cetaceans. As such, dedicated observers are not justified given the low speeds of vessels and the likely low concentrations of cetaceans, reptiles or pinnipeds within the Operational Area. Application of all actions required in EPBC Regs 2000 Reg 8.04 (2) for vessels interacting with cetaceans and whale watching within the caution zone are not practical for support vessels. For example, docking alongside the MODU will require bow and stern lateral thrusters to maintain

	position, rescue craft may require sudden or repeated changes of direction. As the vessels will not deliberately enter the "caution zone", further control measures for the Operational Area are not warranted. Reducing the typical operating speeds in the Operational Area, number or size of vessels is possible but would introduce disproportionate operational and safety risks, and support vessels are required for monitoring the Operational Area and provision of supplies throughout the activity. Given the current vessel traffic in the shipping lanes to the south, vessel activity is common in the area with most commercial vessels travelling in excess of the typical speed of the support vessel which is around eight knots. No further measures are considered feasible or necessary. Based on all these factors, the risk is considered As Low As Reasonably Practicable.

Additional capability	Hierarchy	Environmental benefit	Env benefit scale	Cost	Rationale	Outcome
Have MFO on every vessel on watch during daylight and good weather conditions	Engineering	Dedicated MFOs on every vessel may improve whale spotting	Negligible	0.5–2% of project cost	All vessels with dedicated MFOs (shift) for 60 days will cost approximately $300,000. The risk already has a low likelihood (low expected concentrations of whales within the Operational Area), so the cost outweighs the environmental benefit	Not adopted
Application of all actions required in EPBC Regs 2000 Reg 8.04 (2) for interactions with cetaceans and whale watching within the caution zone	Procedure	Avoid disturbing whales by applying all whale watching restrictions described in the Regs, e.g: • avoid sudden or repeated changes in direction or speed • avoiding thruster use	Negligible	<0.5% of project cost	Manoeuvring large vessels to avoid disturbing whales in close proximity to the MODU has safety, environmental (spills from collisions) and practicality implications. The risk already has a low likelihood so the incremental cost (e.g. restricting safety vessels' speed changes) and practicality (e.g. restricting thruster use in open-ocean locations) outweighs the environmental benefit.	Not adopted

7.4 Solid materials – loss overboard

7.4.1 Risk description

It is possible for the occurrence of an accidental release of solid (hazardous or non-hazardous) waste materials from the mobile offshore drilling unit and support vessels to the marine environment.

Non-hazardous solid wastes including paper, plastics and packaging and hazardous solid wastes such as oily and contaminated wastes, batteries, fluorescent tubes, medical wastes and aerosol cans released unintentionally to the marine environment as a result of overfull and/or uncovered bins, incorrectly disposed items or spillage during transfers of waste between the mobile offshore drilling unit and support vessels. Dropped objects are described in Section 7.5.

The effects considered include:

- reduction in local water quality, species
- smothering or toxicity effects to ecosystems/habitats, seabed disturbance.

All non-buoyant waste material is expected to sink to the seabed close to the mobile offshore drilling unit or vessels. Buoyant waste material would potentially move with the tides/wind/currents and may result in injury or entanglement of marine fauna, including protected species.

7.4.2 Level of acceptable risk

The risk of an accidental release of solid (hazardous or non-hazardous) waste materials will be acceptable if:

Factors in determining acceptability	Acceptability criteria
Internal context	No specific criteria identified
External context: • relevant persons expectations • values/sensitivities protected under EPBC Act	There were no unaddressed objections or claims from relevant persons regarding loss of solid objects overboard There will be no direct effect on EBPC Act listed Matters of National Environmental Significance or GAB MP management values.
Legislation and conventions	Operations are compliant with relevant maritime law listed under Section 7.4.4 – Risk treatment – legislative and other requirements
Industry standards and practices	Operations meet or exceed relevant industry standards listed under Section 7.4.4 – Risk treatment – industry standards and practices
Comparisons made between predicted levels and acceptable levels	No specific criteria identified

7.4.3 Risk assessment

Risk description	Marine pollution resulting in smothering and contamination of habitats and/or injury, ingestion and entanglement of marine fauna and seabirds, including protected and migratory species.
Likelihood Analysis and Consequence evaluation	Non-hazardous solid wastes such as plastics have the potential to smother benthic environments and cause harm to marine fauna through entanglement or ingestion. Marine turtles and seabirds are particularly at risk from entanglement or if they mistake accidentally disposed material (e.g. plastics) for food; once ingested it can lead to damage of internal tissues and potentially prevent feeding activities and eventually death. However, given that there are no significant aggregations of marine reptiles, the greater risk is to seabirds that may forage in the vicinity of the well. This extends to various species of petrel, albatross and shearwater where their wide-ranging foraging areas overlap the Stromlo-1 well location. The short-tailed shearwater has a foraging biologically important area overlapping the Impact EMBA (yet this species is not noted in the PMST report as a likely visitor in the area). Given the restricted exposures of fauna to waste lost overboard and the limited volume of marine pollution expected to be generated during this activity, it is expected that any effects from inadvertent marine pollution would not have a detrimental effect on any fauna population levels suggesting this event could, at worst, result in a limited local degradation of the environment with potential individual effects. Likewise, an unplanned release of hazardous solid waste may result in the pollution of the immediate receiving environment, leading to minor and/or temporary effects to water quality. Chemical effects such as physiological damage through ingestion or absorption may affect individual fish, cetaceans, marine reptiles or seabirds depending on volumes and toxicities and persistence of the overboard loss. The temporary or permanent loss of objects or waste materials into the marine environment is not likely to have a significant environmental effect, based on the location of the Operational Area which is remote from shallow water habitats (such as turtle BIA) or nesting/roosting grounds of shorebirds and seabirds), and given the types, size and frequency of wastes that could be accidentally discharged at sea.
As Low As Reasonably Practicable decision context	The management of waste offshore is a well-practiced activity with management practices implemented across the industry, typically via a MARPOL compliant Garbage Management Plan. As such there is a good understanding of the release pathways, and the control measures required to manage these. No relevant persons raised objections or claims regarding accidental loss of solids overboard. Taking this in consideration, Decision Context A should be applied to demonstrate that risks are As Low As Reasonably Practicable.
Assessment technique	Good Practice – Identified industry good practices adopted to reach As Low As Reasonably Practicable

7.4.4 Risk treatment

7.4.4.1 Environmental performance outcomes (EPO 7.4)

No unplanned overboard release or loss of solid non-hazardous or hazardous waste from the MODU or support vessels

7.4.4.2 Context for assessment

Legislative and other requirements	Vessel's garbage management in accordance with MARPOL enacted by Australian Maritime Safety Authority: • Marine Orders 95 – pollution prevention – Garbage (as appropriate to vessel class)
Industry standards	Vessel's garbage management in accordance with MARPOL enacted by Australian Maritime Safety Authority: • Marine Orders 95 – pollution prevention – Garbage (as appropriate to vessel class)

7.4.4.3 Control measures and performance standards

Control measures	Environmental performance standards	Measurement criteria	Responsibility
MODU OIM and Vessel Masters ensure the Waste management plan (OPEP) meets legislative requirements and compliance is as per the implementation strategy	EPS 7.4.1: Compliance with MARPOL 73/78 Annex V as applied in Australia *Protection of the Sea (Prevention of Pollution from Ships) Act 1983* (Part IIIB, Division 2, Section 26FC) requires a vessel Garbage Management Plan (GMP) (Regulation 10.2) that must contain as a minimum: • waste handling equipment, waste storage containers, and closed bins appropriate to the type and volume of waste provided at waste storage areas • hazardous and non-hazardous waste labelled and segregated • all waste bins in locations with potential for loss overboard, are covered with tightly fitting, secure lids or netting to prevent any waste blowing overboard • solid and liquid waste (excluding planned discharges) will be disposed of onshore at a suitable waste facility or to a carrier licensed to receive the waste if required by legislation.	Vessel and MODU inspections and audits confirm: • Vessel Garbage Management Plan (GMP) is carried on board, and complies with MARPOL requirements • Waste is managed in accordance with the GMP • All hazardous waste is labelled and segregated • Waste bins all have secure lids or netting in place for locations with potential for loss overboard • A waste manifest tracks all waste types and volumes transferred to support vessels for onshore disposal.	MODU Offshore Installation Manager Vessel masters
Procedure to recover items undertaken to minimise loss or disturbance to benthic habitats from dropped objects	EPS 7.4.2: Procedure undertaken to recover items lost overboard where practical and safe to do so	Daily records show attempts to recover items lost overboard were undertaken where safe and practical to do so and corrective actions identified and undertaken.	MODU Offshore Installation Manager Vessel masters

7.4.5 Outcome

Residual risk	Consequence category	Likelihood	Risk level
	1–3	Has occurred in the region/company	Low

Demonstration of acceptability: The risk of an accidental release of solid (hazardous or non-hazardous) waste materials is acceptable because the risk is low and reducing the risk further will yield marginal and negligible benefits. Further, the risk is acceptable because:

Factors affecting acceptability	Acceptability criteria	Demonstration of acceptability
Internal context	No specific criteria identified	No specific criteria identified
External context	There were no unaddressed objections or claims from relevant persons regarding the loss of solids overboard There will be no direct effect on EBPC Act listed Matters of National Environmental Significance or GAB MP management values.	There were no unaddressed objections or claims from relevant persons regarding the loss of solids overboard The unplanned release of non-hazardous and hazardous solid wastes through inadequate containment and human error is likely to have minor environmental effects as effects would be temporary and localised. Given the low concentrations of MNES (as the area is not adjacent to any BIA or aggregation areas other than the distribution and migration BIA for the pygmy blue whale and foraging BIA for the short-tailed shearwater) and the short 60-day duration of the activity, risks are at an individual rather than population level.
Legislation and conventions	Operations are compliant with relevant maritime law listed under Section 7.4.4 – Risk treatment – legislative and other requirements	See below for MARPOL Marine Orders -95 legislation enacted by Australian Maritime Safety Authority
Industry standards and practices	Operations meet or exceed relevant industry standards listed under Section 7.4.4 – Risk treatment – industry standards and practices	The operations will be compliant with relevant maritime law. Here MARPOL is as an internationally accepted standard used industry-wide. Compliance with relevant and appropriate MARPOL requirements and other control measures listed above reduces the environmental effects associated with unplanned discharges.

Demonstration of As Low As Reasonably Practicable	Small amounts of solid non-biodegradable and hazardous wastes will be generated during the activity. These will be stored on board in fully enclosed containers in accordance with good practice within the petroleum industry. During the activity, the industry standard management control measures listed above will be adopted. Consequently, it is considered that all practicable measures have been implemented and the likelihood of solid wastes being discharged to the marine environment have been reduced to As Low As Reasonably Practicable. The MODU ROV, crane or support vessel may be used to attempt recovery of hazardous solid wastes lost overboard where practical. No additional practical As Low As Reasonably Practicable options were identified.

7.5 Hazardous substances – loss of containment

7.5.1 Risk description

Accidental releases of hazardous substances from the mobile offshore drilling unit, support vessels and remotely operated vehicle may include leaks from hydraulic lines, bulk chemicals lost overboard during crane transfers, spills during bunkering or decanting, accidental dumps from storage tanks and blowout preventer sub-sea leaks. The main credible causes of these accidental releases are:

- dropped objects from crane/derrick transfers due to human error or equipment failure
- failure or mechanical breakdown of equipment that use, store or transfer hazardous materials
- failure to align valves correctly during transfer to tanks
- overfilling of chemical or mud tanks on mobile offshore drilling unit

- overfilling of aviation fuel tank or fuel bulk storage tanks on the mobile offshore drilling unit
- emergency disconnect sequence (EDS) activation of the riser.

The hazardous materials that could be accidentally released to or physically damage the environment include:

- dropped load – chemicals, fuels, large equipment
- fuel (e.g. diesel, marine gas oil or marine diesel oil)
- helicopter aviation fuel (avgas / aviation gasoline)
- chemicals (e.g. leaks from blowout preventer hydraulic fluids and hydraulic oil from the cranes)
- drilling muds (SBM) and fluids.

As many of these events are subsets of others in terms of potential consequences, they are discussed in three overlapping groups, with the focus on the event with the higher environmental risk:

- dropped objects into the ocean or deck spills washed to ocean
- fuel or chemical leaks and spills (faulty hoses or connections, overfilling, valve misalignment, etc.)
- emergency disconnect sequence – release of muds to ocean.

The likelihood of dropped objects have been assessed as part of describing the risk in the assessment section below. While the likelihoods are regarded as low, dropped loads from cranes and derricks have occurred in the region/company. Effects include seabed disturbance with damage to demersal biota, and benthic communities. Hazardous liquid (e.g. diesel, chemicals) spills that could result are subsets of other events described below.

Leaks from the blowout preventer and remotely operated vehicle hydraulic hoses would comprise smaller volumes of the same or similar types of fluids as released during planned blowout preventer testing (Section 6.0). For short-duration discharges, the risk assessment convention is to apply a safety factor of 10 to acute toxicity data. Consequently, the blowout preventer fluid “no-effect” concentration (for a typical blowout preventer fluid such as StackMagic) is estimated to be between 1500 mg/L and 1800 mg/L. To reach these concentrations, a discharge would require dilution of between 550 and 650-fold. To make allowance for uncertainty in the estimation of toxicity, as a conservative estimate, the required no-effect dilution is assumed to be between 2000- and 3000-fold. BP p.l.c. modelled such a discharge (2013), which is likely to have similar characteristics to the blowout preventer fluids selected for Stromlo-1 and is in the order of magnitude of hydraulic leak volumes before detection by low pressure and low volume alarms). Modelling showed dilutions of 3000-fold were achieved within a maximum distance of 37 m. As such, risks to demersal marine biota and benthic habitats are forecast to be localised and temporary (around 15 minutes) with full recovery forecast in the short term, even if a spill or leak is double the modelled volume.

A mobile offshore drilling unit refuelling hose break or overfill could result in a spill of marine gas oil, marine diesel oil, aviation fuel or diesel to the ocean. The Australian Maritime Safety Authority (2012) suggests the maximum credible spill volume from a refuelling incident with continuous supervision is approximately the transfer rate × 15 minutes. Assuming failure of dry-break couplings and based on the largest typical (hydrocarbon) transfer volume in the order of 250 m^3/h, this equates to an instantaneous spill of ~63 m^3. Risks include oiling and acute toxicity effects to water column biota and possibly seabirds as well as indirect effects such as ingestion of contaminated prey.

The activation of the Emergency Disconnect Sequence can result in the release of the entire volume of muds in the marine riser to the marine environment. (A mud hose failure during bunkering could result in a lesser volume discharged to the surface). An emergency disconnect sequence may be implemented if the mobile offshore drilling unit is required to rapidly disengage from the well e.g. due to loss of position. The probability is historically 3E-2 if the riser is connected for a 50-day operation. The emergency disconnect sequence closes the blowout preventer (shutting in the well) and disconnects the riser to break the conduit between the well head and mobile offshore drilling unit. The emergency disconnect sequence is an emergency system that provides a rapid means of shutting in the well and disconnecting the mobile offshore drilling unit from the blowout preventer. The emergency disconnect sequence aims to leave the well head in a secure condition but will probably result in the loss of the drilling fluids/cuttings contained in the riser to the seabed near the well.

An emergency disconnect sequence is activated under the following circumstances:

- automatic activated emergency disconnect sequence when the movement of the mobile offshore drilling unit outside of its operating circle due to failure of the dynamic position system (for example dynamic positioning run-off or power blackout)
- manually activated emergency disconnect sequence when there is a threat to the safety of the mobile offshore drilling unit (for example a support vessel collision with the mobile offshore drilling unit due to loss of power or a loss of well control).

This could result in a subsurface release of a combination of synthetic based muds (SBM) and cuttings at the seabed which would otherwise have been treated on the mobile offshore drilling unit to reduce oil concentrations prior to discharge. The volume released depends on the drilling progress and hence the length of the riser (the entire riser volume could be lost). For the Stromlo-1 well, the maximum volume that could be released to the environment is 420 m^3. The SBM is likely to sink and then spread over a relatively small area of the seabed around the well location. Consequences are similar to planned mud/cuttings discharges and include burial of benthic habitats, reduction in water quality (turbidity) and toxicity of muds/oils to the marine and benthic biota in the immediate location of the mud discharge. The volume lost would have to be resupplied and would later be discharged as a planned release when/if drilling recommenced.

Muds inadvertently released from a valve misalignment or unintentionally dumped from the mud storage tanks is a subset of the above event and would pose the same or lesser risk. Volumes are likely to be less as the tanks are compartmentalised and have redundant alarms systems. However, the volume released may have to be resupplied in order to complete the drilling program, and hence discharged later.

7.5.2 Level of acceptable risk

The risk of a hazardous substance spill will be acceptable if:

Factors in determining acceptability	Acceptability criteria
Internal context	Operations are compliant with relevant internal standards listed under Section 7.5.4 – Risk treatment – Equinor Australia B.V.'s standards
External context: • relevant persons expectations • values/sensitivities protected under EPBC Act	There were no unaddressed objections or claims from relevant persons regarding loss of containment of hazardous substances Consequences are predicted to have no direct effect on EBPC Act listed Matters of National Environmental Significance or GAB MP management values
Legislation and conventions	Operations are compliant with relevant maritime law listed under Section 7.5.4 – Risk treatment – legislative and other requirements
Industry standards and practices	Operations meet or exceed relevant Equinor Australia B.V. and industry standards listed under Section 7.5.4 – Risk treatment – industry standards and practices
Comparisons made between predicted levels and acceptable levels	The consequences are predicted to be localised, temporary and below any ecosystem-level effects

7.5.3 Risk assessment

Risk description	The environmental receptors with the potential to be exposed to toxicity effects from an unplanned hazardous substance release include pelagic fauna such as protected Threatened and Migratory marine mammals, fish species and plankton (as described in Section 4.6) in the water column immediately around the mobile offshore drilling unit at the Stromlo-1 well location as well as benthic assemblages and epibenthic biota local to the well head. Sensitive values/receptors include: • physical damage to benthic biota and habitats from dropped objects • oiling and acute toxicity to marine fauna from exposure to dissolved, entrained and surface hydrocarbons and chemicals leading to hypothermia, irritation, tissue damage and mortality • localised and temporary increase in turbidity near the seabed, smothering and toxicity risks to benthic habitats from SBM and cuttings deposition

Likelihood analysis and Consequence evaluation – seabed disturbance from dropped objects	Operator error (unbalanced, unsecured loads, etc.) and equipment failure can result in crane and derrick loads falling to the deck and/or ocean. Scandpower assessed statistics for dropped objects (Scandpower 2004) for offshore facilities and determined the likelihood of a dropped object falling in the ocean from a crane as 0.0000011 per lift operation. For derrick hoist operations the likelihood of dropping heavy equipment (such as the blowout preventer) is 0.0008 per operation and dropping a riser/drill string is 0.00034 per operation (based on 125 operations per year). Physical disturbance to the seabed from a dropped load would be limited to the footprint of the load and temporary in nature if the item was retrieved and long term if irretrievable. Both are likely to pose minor environmental risk as the seabed within the Operational Area at >2200 m water depth is largely sandy/clay sediment (Sections 4.6.13 and 4.6.14) with isolated benthic assemblages, typical of similar areas surveyed in the central GAB region. Considering the possible footprint of a dropped object (against the large area of the GAB Marine Park) and frequency of the occurrences of dropped objects, it is highly unlikely that a dropped object would have an effect on any benthic community other than minor and localised.
Consequence evaluation – oiling and acute toxicity from fuel spill	The likelihood of dropped loads are described above with dropped loads causing a chemical spill being a subset event. Loss of containment during bunkering fuels may result in surface and water column exposures of hydrocarbons to pelagic marine biota. Such unplanned events have occurred in the region/company. Based upon the assumption that a worst-case volume release to the environment is in the order of 63 m^3, and on the understanding of the physical environment at the Stromlo-1 well location, modelling of similar scale discharges (RPS 2015) of fuels predict that an accidental release of fuel would be dispersed and diluted rapidly, and the surface slick exposure would be limited to the offshore waters surrounding the well location (tens of kilometres). Approximately 40% by mass of typical marine diesel oil (MDO)/marine gas oil/formulations is predicted to evaporate over the first two days or less, depending on the fuel characteristics and prevailing conditions, with further evaporation slowing over time. The heavier (lower volatility) components of the hydrocarbons tend to entrain into the upper water column due to wind-generated waves but can subsequently resurface if wind–waves abate. In the event of a surface diesel spill, the heavier components can remain entrained or on the sea surface for an extended period. The potential for entrained oil to contact benthic habitats is low given the water depths and typical fuel characteristics. Potential exposure of hydrocarbons to specific receptors is described in detail in Section 7.7. The environmental risks associated with a larger loss of diesel fuel from a vessel collision are assessed in Section 7.6. The environmental risks associated with an accidental release of 63 m^3 of diesel will be less than that associated with a loss of diesel from a vessel collision, and thus have not been evaluated further here. The risks associated with an accidental release of aviation fuel during bunkering are expected to be less than those associated with a loss of diesel from a vessel collision due to the smaller volumes and the higher volatility of aviation fuel leading to very rapid evaporation and have not been evaluated further. Sensitive and protected receptors at risk are likewise described in Section 7.6 albeit for a larger scale event. The nature of such a release is instantaneous and short-lived, and discharges are expected to dilute and disperse rapidly in the open-ocean environment. Sensitive receptors would only be exposed to elevated hydrocarbons for a short time (1–2 days) and to rapidly decreasing concentrations. The consequences are considered Category 1–3; and limited to localised and temporary degradation of the environment, at worst affecting individual megafauna and local populations of plankton; but rapidly returning to original state by natural action.
Consequence Evaluation – burial of benthic habitats, increased turbidity and toxicity of sediments to benthic biota	Mud and cuttings could be discharged during an EDS and muds inadvertently dumped from mud storage tanks. These events have occurred several times in the industry. The Benthic Protection Zone is described in the former GAB MP management plan as a 20 nautical mile-wide representative strip of the ocean floor, intended to protect the unique and diverse plants and animals that live on, and are associated with, the ocean floor. Sampling surveys suggest the Bight "is one of the world's most diverse benthic ecosystems" (DEE 2005). In the deep water at the Stromlo-1 well location, the seabed is dominated by expanses of soft sediments supporting sparse communities of benthic epifauna, infauna and demersal fish and invertebrates (Section 4.5). Effects from the planned discharges of drilling muds and cuttings (~700 m^3) are discussed in detail in Section 6.6. Modelling investigated potential effects from 405 m^3 of cuttings and mud discharged near the seabed discharges and 289.5 m^3 cuttings discharged at the surface with 2.6 m^3 muds. The investigation found the maximum total suspended solids was predicted within 20 m of the release with short lived (hours) elevated turbidity levels. The total predicted area of coverage above the background level (>0.05 mm) from the greater volume of planned releases varied from 3.17 km^2 to 3.87 km^2. Potential exposure to toxic effects in the water column and sediments are limited to within 100 m of the discharge. In the unlikely event of an EDS activation, the entire volumes of the riser at the time (up to approximately 420 m^3 of muds) may be released to the seabed. Modelling predicts this will be deposited over a relatively small area of the seabed around the well that is already modified by the

	planned discharge of muds and cuttings during top-hole drilling. The potential to affect benthic communities is greatly reduced by the prior disturbance of the area by the planned drilling discharges and as such it does not engender an elevated level of risk to the environment. The loss of a small area of habitat, until it can be re-colonised, will not adversely affect the viability of local populations of infauna or epifauna, the ecology of the local area or the biodiversity of the region. The features potentially supporting higher biodiversity in the area (the seamounts are ~20 km distant) would not be affected by an EDS or inadvertent mud tank dump. The incremental increase in consequence is considered Category 1–3 as supported by considering the footprint as a percentage of the area of the GAB Marine Park).		
Consequence	Consequence category	Likelihood	Risk level
	1-3 (seabed disturbance from dropped object)	Has occurred in the region/company	Low
	1-3 (toxicity from fuel spill)	Has occurred in the region/company	Low
	1-3 (smothering, toxicity from muds and cuttings)	Has occurred several times (4–20) in the industry	Low
As Low As Reasonably Practicable decision context	Offshore transfer operations and EDS are well-practiced and implemented offshore activities. As such, there is a good understanding of potential spill sources, and the control measures required to manage these. There is little uncertainty associated with the potential environmental risks associated with these events which were evaluated to have a low severity level. No relevant persons raised objections or claims regarding loss of containment of hazardous substances overboard. Taking this in consideration, Decision Context A should be applied to demonstrate risks are As Low As Reasonably Practicable.		
Assessment technique	Good Practice – Identified industry good practices adopted to reach As Low As Reasonably Practicable		

7.5.4 Risk treatment

7.5.4.1 Environmental performance outcomes (EPO 7.5)

No unplanned release of hazardous substances from the MODU or support vessels

7.5.4.2 Context for assessment

Legislative and other requirements	Overboard discharge in accordance with MARPOL enacted by Australian Maritime Safety Authority • Marine Orders 91 – pollution prevention – Oil 2006, requires SOPEP/ SMPEP (as appropriate to vessel class) • Marine Orders 95 – pollution prevention – Garbage (as appropriate to vessel class)
Industry standards	Bunkering and lifting processes and procedures including PTW systems Equipment maintenance in accordance with industry's preventative maintenance schedules Training requirements for crane operators and crew such as mud engineers
Equinor Australia B.V. standards	Chemical selection will be aligned with SF601.01 – Chemicals Management to ensure preferential use of lower toxicity chemicals and safe storage Consistent with the principles of risk "elimination/substitution" as described in Working Environment TR0926, Equinor Australia B.V. has committed to using MDO and MGO in place of Heavy Fuel Oil, thus lowering the risk profile from spills

7.5.4.3 Control measures and performance standards

Control measures	Environmental performance standards	Measurement criteria	Responsibility
MODU and vessel specific bunkering procedure/SBM and chemical transfer	EPS 7.5.1: Communications between the MODU and the vessels will be tested by the MODU Chief Mate and Vessel	Inspection of the bridge log indicates that communications were tested between both vessels	MODU Offshore Installation Manager / Vessel masters

Control measures	Environmental performance standards	Measurement criteria	Responsibility
procedures reduces the risk of a spill by reducing human error and considers spill response to minimise consequence	Master prior to bunkering commencing		
	EPS 7.5.2: The bunker transfer procedure and associated PTW and JSA procedures undertaken to ensure watch always kept during the transfer, hoses inspected, spill kits on standby, etc.	Inspection of PTW and JSA records for bunkering indicate that spill prevention considerations were taken into account	MODU Offshore Installation Manager / Vessel masters
	EPS 7.5.3: Locked pit dump valve permit to work (PTW) required for muds		
Bulk hydrocarbons stored in designated tanks with real-time volume monitoring and high-level alarms within bunded area	EPS 7.5.4: Bulk hydrocarbons (including aviation fuel) are stored within designated tank with real-time volume monitoring and high-level alarms within a bunded area.	Visual inspection confirms that bulk hydrocarbons are stored in designated storage location with real-time volume monitoring and high-level alarms within a bunded area	MODU Offshore Installation Manager / Vessel masters
Transfer hoses fitted with dry break couplings	EPS 7.5.5: Transfer hoses fitted with dry break couplings,	Inspection confirms evidence of use of dry break couplings on transfer hoses	MODU Offshore Installation Manager / Vessel masters
Transfer hose integrity and bunkering procedures	EPS 7.5.6: Transfer hoses and dry break couplings are inspected prior to each transfer to ensure their integrity	Inspection of the bulk transfer PTW indicates that a pre-transfer hose/pump inspection checked equipment integrity in accordance with bunkering procedures	MODU Offshore Installation Manager / Vessel masters
Selection and assessment of chemicals is aligned with SF601.01 – Chemicals Management	EPS 7.5.7: Lowest toxicity functional chemicals to be discharged to ocean are always selected	Inspection of Chemical inventory reports (e.g. for muds, cements, hydraulic fluids) verifies that only “D”/”E” (non-CHARM) and “Gold”/”Silver” (CHARM) OCNS-rated chemicals are in use, with documentation in place to support additional assessment to show risks are As Low As Reasonably Practicable	Drilling Manager
Planned Maintenance System (PMS) maintains integrity of equipment to prevent spillage	EPS 7.5.8: Planned maintenance is undertaken to the PMS schedule	Inspection of PMS records verify that maintenance work (and repairs where necessary) is undertaken according to schedule	MODU Offshore Installation Manager / Vessel masters
	EPS 7.5.9: The transfer hoses are inspected and replaced in accordance with the PMS or when they are visibly degraded	Inspection of the hose register and PMS indicates regular inspection and replacement of fuel/chemical/mud hoses	MODU Offshore Installation Manager / Vessel masters
	EPS 7.5.10: The integrity of storage systems and other equipment will be assured through undertaking preventative repairs and recording these in the PMS	Inspection of the PMS records verify that inspections (and repairs where necessary) are undertaken	MODU Offshore Installation Manager / Vessel masters
	EPS 7.5.11: Visual inspection of lifting gear is undertaken as specified in the PMS by a qualified competent person and lifting gear is tested in line with the vessel/MODU PMS schedule.	Inspection of PMS records verifies that inspections and testing have been conducted to schedule	MODU Offshore Installation Manager / Vessel masters

Control measures	Environmental performance standards	Measurement criteria	Responsibility
Site induction	EPS 7.5.12: All vessel and MODU crew undertake site inductions which include a component on bunkering and chemical transfers	Inspection of the presentation and attendance sheets verify that personnel received the inductions	MODU Offshore Installation Manager / Vessel masters
Spill kits are available and maintained with crew trained in the correct use	EPS 7.5.13: All crew undertake spill response training every three months in accordance with the Shipboard oil Pollution Emergency Plan/Shipboard Marine Pollution (MPEP) Emergency Plan and training matrix	Inspection of training records show that all crew have spill response training	MODU Offshore Installation Manager / Vessel masters
	EPS 7.5.14: In accordance with the SMPEP/ SOPEP, oil spill response kits are available in relevant locations around the MODU, are fully stocked and are used in the event of a mud, chemical or diesel spill to deck	Inspection confirms that stocked SOPEP kits are readily available on deck at locations where spills may occur	MODU Offshore Installation Manager / Vessel masters
		Incident reports record that the spill is cleaned up using SMPEP/SOPEP resources	MODU Offshore Installation Manager / Vessel masters
Undertake crane transfer procedures	EPS 7.5.15: Lifting procedures are implemented in alignment with and described in the Safety Case	Inspection shows lifting procedures are evident, and procedures are followed	MODU Offshore Installation Manager / Vessel masters
Trained crew	EPS 7.5.16: Crane operators and crew responsible for lifting and bunkering have appropriate current training certification	Training records of crane operators and deck crew show currency of appropriate certification and training	MODU Offshore Installation Manager / Vessel masters
Drilling Superintendent, Offshore Installation Manager and Vessel masters report all incidents and spills and instigate investigation within the Equinor Australia B.V. Synergi tracking register	EPS 7.5.17: Any deck spill, bunkering spill or dump/spill to ocean is reported and investigated in alignment with Equinor Australia B.V.'s Synergi tracking register and governing documentation SF-103 Safety Incidents and WR-0593 Incident reporting, notification and investigation	All incidents are reported, investigated and closed out in alignment with time frames stipulated in Equinor Australia B.V.'s Synergi process	Equinor Australia B.V. Drilling Superintendent / MODU Offshore Installation Manager / Vessel masters
Oil pollution emergency plan (OPEP) available and functionality tested	EPS 7.5.18: A pre-drilling Emergency Response Plan (ERP) desktop exercise is undertaken to test the emergency response mechanisms in place as per OPEP	Emergency Response desktop exercise report	Equinor Australia B.V. Leader Safety & Sustainability

7.5.5 Outcome

Residual risk	Consequence category	Likelihood	Risk level
	1-3	Has occurred several times (4-20) in the industry	Low

The risk of an accidental release of hazardous materials waste materials is assessed as acceptable because the risk is low and reducing the risk further will yield marginal and negligible benefits. Further, the risk is acceptable because:

Factors affecting acceptability	Acceptability criteria	Demonstration of acceptability
Internal context	Operations are compliant with relevant internal standards listed under Section 7.5.4 – Risk treatment – Equinor Australia B.V.'s standards	By selecting chemicals in alignment with SF601.01 – Chemicals Management, the use of lower toxicity chemicals and their safe storage reduces risks to As Low As Reasonably Practicable Consistent with the principles of risk "elimination/substitution" as described in Working Environment TR0926, Equinor Australia B.V. has committed to using MDO and MGO in place of Heavy Fuel Oil, thus lowering the risk exposure from spills.
External context	There were no unaddressed objections or claims from relevant persons regarding loss of containment of hazardous substances Consequences are predicted to have no direct effect on EBPC Act listed Matters of National Environmental Significance or GAB MP management values.	There were no unaddressed objections or claims from relevant persons regarding loss of containment of hazardous substances Of the protected cetaceans, only pygmy blue whales have a distribution and migration BIA within the Operational Area, while foraging grounds for the pygmy blue and sperm whales lie approximately 100 km north and other protected species of marine mammals are known to traverse the area. The large foraging areas for numerous species of petrels, albatrosses and shearwaters may overlap with the Operational Area. While the short-tailed shearwater may have a foraging BIA in the area, the PMST report does not note this species as a possible visitor, so numbers are predicted to be low. Given the low abundance of MNES at the Stromlo-1 site, potential risks are at an individual level rather than regional population or ecosystem level. No effects on management values of the GAB MP are forecast as the Marine Mammal Protection Zone lies more than 300 km north. Local benthic assemblages at the Stromlo-1 site were for the most part well represented in sites surveyed throughout the greater GAB under similar conditions. Adverse effects to the Benthic Protection Zone are forecast to be the same or less than those described in Section 6.6 – Planned Discharges: Cuttings and Mud, hence the predicted risk is low.
Legislation and conventions	Operations are compliant with relevant maritime law listed under Section 7.5.4 – Risk treatment – legislative and other requirements	The operations will be compliant with relevant maritime law. Here MARPOL is as an internationally accepted standard used industry-wide. Compliance with relevant and appropriate MARPOL requirements and other control measures listed above reduces the environmental effects associated with unplanned discharges to As Low As Reasonably Practicable
Industry standards and practices	Operations meet or exceed relevant Equinor Australia B.V. and industry standards listed under Section 7.5.4 – Risk treatment – industry standards and practices	Operations in alignment with the following industry standards ensures risk minimisation through: • bunkering and lifting processes and procedures including PTW systems • equipment maintenance in accordance with industry's preventative maintenance schedules • training requirements for crane operators and crew such as mud engineers The redundancy of power systems and station keeping equipment (e.g. thruster specifications, dynamic positioning systems) are described in the Well Operation Management Plan, Safety Case and MODU/vessel classifications and specifications as per industry standards and the contracting process. Rig specific disconnect/policy plans for the Stromlo-1 location for metocean conditions are likewise described in the WOMP and Safety Case. A support vessel is in the vicinity of the MODU 24/7 providing additional assistance if required.

Demonstration of As Low As Reasonably Practicable	Handling and storage of hazardous substances on board in dedicated storage areas is considered good practice within the petroleum industry. The Chemical Management process (SF601.-1) undertaken when selecting and assessing chemicals is based on the CHARMS/OCHNS system which is widely used by regulators and industries in countries that are signatories to OSPAR. During the activity, given the adoption of the industry standard management control measures listed above and the residual low risk, it is considered that all practicable measures have been implemented and the likelihood of hazardous materials being discharged to the marine environment have been reduced to As Low As Reasonably Practicable. The unplanned release of hazardous substance through inadequate containment and malpractices is unlikely to have any significant environmental effects as effects would be temporary (exception for muds/cuttings piles) and localised. The management control measures are considered effective in reducing the potential environmental effect to the marine environment and the risk control measures for these short duration, localised events are considered environmentally acceptable.

As Low As Reasonably Practicable options considered:

Additional capability	Hierarchy	Environmental benefit	Benefit %	Cost	Rationale	Outcome
Use only water-based muds (see Planned Discharges – Drilling Muds and Cuttings Section 2.0 for detailed As Low As Reasonably Practicable)	Substitute	Minimise environmental effects from muds where water-based muds (WBM) have a lower toxicity than the synthetic based muds (SBM)	Negligible	<0.5% of project cost	A non-WBM may be required for safety and technical reasons. The WBM may be unable to drill the well efficiently (introducing risks of stuck pipe, longer drilling program duration, etc.) and/or safely, hence the cost (risk) is disproportionate to the environmental benefits	Not adopted
Locked pit dump valve permit to work (PTW)	Engineering/ isolation/ administration	Minimises risk of human error resulting in additional effects	Negligible	<0.5% of project cost	Standard practice – benefit outweighs cost	Adopted

7.6 Support vessel operations – vessel collision

7.6.1 Risk description

Support vessel operations have a risk of collision with vessels running concurrent operations in the same area. These risks are higher in restricted navigability such as busy port entrances, harbours and narrow shipping lanes. Collision risks are lower in open oceanic waters, with vessels that are working together and where third-party vessels are infrequently encountered but cannot be discounted. Occasionally, collision between vessels causes sufficient damage to the integrity of one of the vessels. The likelihood of such an event is increased by vessel density, poor visibility, watch-keeping failure, inattention or loss of steering or propulsion. Should this occur the worst consequence would be that a fuel tank is ruptured and could spill fuel to the sea. The greatest collision risk in the Great Australian Bight is between a platform supply vessel and a commercial freighter traversing the area or platform supply vessel colliding with the mobile offshore drilling unit.

In the event of a collision with a third-party vessel or the mobile offshore drilling unit that results in fuel tank rupture, fuel could be lost to the sea until it can be pumped from the damaged tanks. Fuel is typically stored within tanks aft of collision bulkheads on the mobile offshore drilling unit, the rupturing of these as a result of a platform supply vessel collision is not considered credible (slow approach speeds when platform supply vessel moves alongside the mobile offshore drilling unit, standard marine communications, typical mobile offshore drilling unit design, etc) and therefore the credible spill scenarios referred to in this section are related to the release of diesel from vessel fuel tanks only.

Det Norske Veritas (DNV) (Australian Maritime Safety Authority 2011) indicates that for the period 1982–2010, there were no spills over one tonne (1 m^3) for offshore vessels caused by collisions. The same DNV (Australian Maritime Safety Authority 2011) report also states that 24 collisions between vessels and offshore installations were recorded worldwide during 1990–2002, with the total oil spill frequency (per ship year) being 3.1E-6 (0.0000031). One of the shipping routes across the Great Australian Bight crosses within the permit area but lies about 10 km south of Stromlo-1 well-site and outside the Petroleum Safety Zone. The likelihood of two vessels colliding and one of them losing an entire fuel tank's volume of fuel is low given that the incident has occurred rarely in the industry.

The effects of an unplanned release of fuel are:

- temporary and localised reduction in water quality
- oiling, injury and death to marine fauna and seabirds including protected and migratory species. Receptors most at risk include plankton, fish, cetaceans, avifauna and pinnipeds. No shorelines or shallow or coastal habitats will be affected.

This risk will be present for the duration of the activity.

7.6.2 Level of acceptable risk

The risk of a diesel spill following a vessel collision will be acceptable if:

Factors in determining acceptability	Acceptability criteria
Internal context	Operations are compliant with relevant internal standards listed under Section 7.6.4– Risk treatment – Equinor Australia B.V.'s standards
External context: • relevant persons expectations • values/sensitivities protected under EPBC Act	There were no unaddressed objections or claims from relevant persons regarding loss of containment of hazardous substances Consequences are predicted to have no direct effect on EBPC Act listed Matters of National Environmental Significance or GAB MP management values.
Legislation and conventions	Operations are compliant with relevant maritime law listed under Section 7.6.4 – Risk treatment – legislative and other requirements
Industry standards and practices	Operations meet or exceed relevant Equinor Australia B.V. and industry standards listed under Section 7.6.4 – Risk treatment – Equinor Australia B.V. and industry standards and practices
Comparisons made between predicted levels and acceptable levels	The effects on local populations, ecosystems and environmentally sensitive areas of local importance are short term (restitution time less than one year) and below ecosystem level.

7.6.3 Risk assessment

The assessment of environmental risks associated with a credible spill scenario resulting from a vessel collision was based on modelling (APASA 2011) a discharge of 509 m^3 diesel fuel released over 12 hours. The spill location was in shallower waters (1028 m) approximately 100 km north-north-west, i.e. closer to mainland than the Stromlo-1 site (APASA 2011). Modelling results are considered conservative because while the support vessels and the mobile offshore drilling unit are yet to be contracted and the exact volume of their individual fuel cells is unknown, an analysis of the average largest fuel tank for various classes of support vessels (B, C, D, V and W) is around 155 m^3.

Modelling used tidal currents generated by HYDROMAP, the Commonwealth Scientific and Industrial Research Organisation BRAN five-year data set and OILMAP's stochastic module to simulate drift, spread, weathering and fate of the diesel. Two hundred simulations were run under varying meteorological and oceanographic conditions to ensure a range of typical prevailing wind and current conditions were represented (October–May). Each trajectory was tracked to a minimum load of 0.1 g/m^2 (i.e. visible, silvery sheen). This minimum reporting threshold is conservative and effectively 100-fold less than that quoted in the literature as causing environmental harm. For example, French et al. (1996b) and French-McCay (2009) report ecological effect to seabirds from surface oil at 10 g/m^2 (see Section 7.7). As such, these modelling results are used primarily to assess the drift, extent of surface oil and rate of weathering.

Fuels such as marine diesel oil and marine gas oil may vary in the percentages of various constituents. The modelled proxy diesel had a density of 842 kg/m^3 and dynamic viscosity at 40 °C of 4.3 cP, which results in rapid spreading on the sea surface with the prevailing wind. Based on the oil assay, approximately 22.5% would readily evaporate (volatiles and semi-volatiles) and only 3% of the diesel fuel oil is considered persistent or non-volatile (as defined by the IOPC Fund). Low viscosities mean fine droplets can disperse and entrain into the upper layers of the water column, moving with the currents.

Evaporation is the dominant process. Figure 7.1 shows that for the proxy diesel, by Day 5, approximately 55% of the total spill had evaporated, 28% remained on the ocean surface and the remaining volume (17% or 86 m^3) was entrained. By the end of the simulation (day 25), 70% of the diesel had evaporated and 30% was predicted to be entrained. Weathering then proceeds at a slower rate and the longer chain compounds with higher boiling points take longer to disperse.

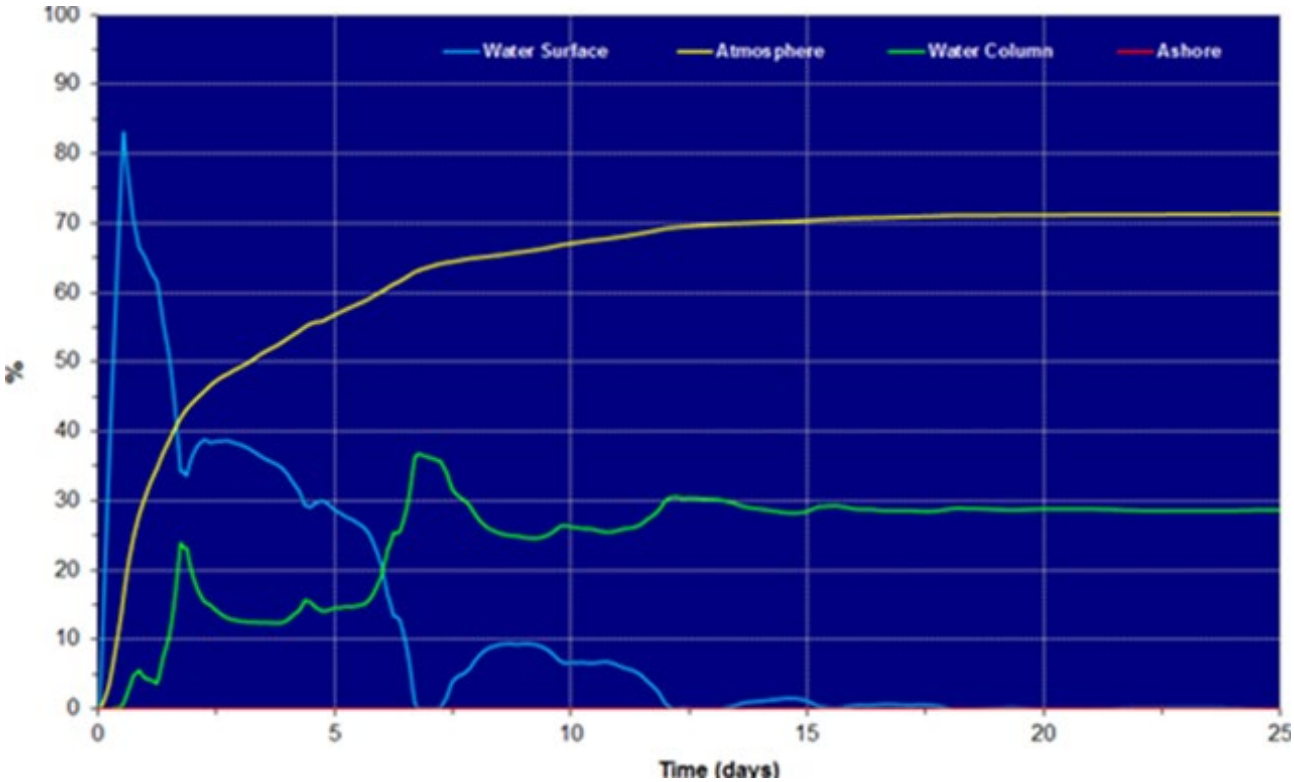


Figure 7.1 Predicted weathering and fates as a function of percentage of the initial volume, for a release over 12 hours of 509 m^3 diesel fuel oil in the central Great Australian Bight

Modelling predicted that up to 20% of the trajectories (or 40 out of 200 trajectories) were predicted to travel in all directions from the release site and up to a maximum of 40 km. The probability of sea surface contact greater than 50% was predicted to be restricted to within 5 km of the release site. The lower probability contour (0–10% probability) of the minimum reporting threshold (i.e. silvery sheen,) stretched up to approximately 310 km in a south-west direction from the release site.

No surface trajectories above the minimum reporting threshold selected for this modelling of 0.1 g/m^2 were predicted to encroach designated marine parks (beyond the Great Australian Bight Marine Park) or shorelines. Note that the minimum reporting threshold used in the 2011 modelling is at least 10-fold less than the minimum reporting threshold used in Stromlo-1 Level 3 modelling (Section 7.7) of 1–10 g/m^3.

There is more detail regarding the thresholds used for consequence determination, the weathering process and the receiving environment in Appendix 7-1.

Risk description	Given the distance from shore and from social or commercial receptors, the primary risk is the potential for toxicity effects and physical oiling of pelagic fauna and seabirds including protected and migratory species from exposure to surface, entrained and dissolved hydrocarbons. No shoreline or shallow water receptors have been considered, given that the extent of exposure to above threshold concentrations is limited to around the Stromlo-1 well location up to approximately 40 km. Given the water depth >2200 m, an MDO/MGO fuel spill will not sink and accumulate on the seabed as pooled or free oil or smother benthic biota or habitats.
Consequence evaluation – potential toxicity	In order to assess potential toxicity effects, the surface oil threshold was set at 0.1 g/m^2 to determine the full extent of a visible surface oil. Based on sensitivities of various receptors as determined from the literature (seabirds) potential for adverse effects can occur at the low effect range of 1–10 g/m^2, depending on duration and receptor. Threshold justifications are discussed in Section 7.8. The lowest thresholds for entrained oil and dissolved oil lie well inside the surface oil boundary of 0.1 g/m^2.
Seabirds	There are listed 15 EPBC-listed seabird species (Section 1.0) with foraging areas likely to occur over a wide geographic area that could potentially be exposed to hydrocarbons, in the event of a large diesel spill. The short-tailed shearwater has a foraging BIA in the area, but numbers are predicted to be low as the Species Profile and Threats Database and PMST reports for the area around Stromlo-1 do not list it as a potential visitor. As the seabird species may vary in distribution, vulnerability and foraging habits, potential effects have been assessed in greater detail in Section 7.7.12. Seabirds rafting, resting, diving and feeding at sea have the potential to contact surface oil at various exposure levels. If seabirds have a long duration of exposure to areas of heavy surface oiling, it is possible that some may suffer chronic effects or mortality, however the duration of the heavy surface oil is in the order of days and limited to a small area around the release. Populations of birds are unlikely to be significantly affected by in-water concentrations of hydrocarbons due to their limited exposure time in the water column but can be at risk of toxic effects from contaminated prey. No large concentrations of threatened or migratory seabirds are expected to be resident in areas of higher hydrocarbon concentrations, but flocks or individual transitory and foraging birds may pass through. Given the extent of exposure is limited to around the well location, and as surface exposures are expected to dissipate within a few days, it is predicted that risks from exposure to surface hydrocarbons that result in acute or chronic effects would be on an individual scale, not affecting population viability or diversity of the region. Given the extent of the spill plume and rapid evaporation and dispersion expected, consequences to seabirds are assessed as Category 4 (restitution <1 year) to account for the low possibility of a species of local importance being affected.
Marine reptiles	While there are three marine turtle species (Section 4.7.5) listed under the EPBC Act as potentially occurring in the exposure zone, they are not noted to reside or aggregate in significant numbers, and there are no recognised BIA in the region. For sea turtles, the main pathways for exposure include ingestion and inhalation of vapours. Diving behaviour may expose them to vapours as they tend to inhale a large volume of air close to the surface prior to submerging. Although the effects of diesel on marine reptiles, specifically turtles can be severe, the low density of turtles expected in the region (due to lack of BIA or aggregations) suggests that few, if any, individuals would be affected. Given the location is remote from shallow foraging waters and that surface exposures are expected to dissipate within a few days, potential consequences to marine reptile populations are assessed as Category 1–3.
Plankton	Sampling surveys and literature suggest plankton found in the open waters around the Stromlo-1 well site is widely represented in the waters sampled within the greater GAB region (Section 4.7.1). It has an important role in the area's food web (e.g. where there are high aggregations of baleen whales). Organisms move through the water column, feeding at night nearer the surface (NRDA 2012). Water column zooplankton can be exposed to diesel through ingestion, inhalation and dermal contact (NRDA 2012), which can cause immediate mortality or declines in egg production and hatching rates along with a decline in swimming speeds (Hook et al. 2016). Phytoplankton is typically not sensitive to the effects of oil, though they do accumulate it rapidly due to their small size and high surface area to volume ratio (Hook et al. 2016). Should surface diesel reduce light for prolonged periods, growth and reproduction of phytoplankton relying on photosynthesis may be reduced (Volkman et al. 1994). Once background water quality conditions are re-established, plankton populations are expected to recover in the short term due to the rapid reproduction of survivors and migration from less affected areas (Dicks 1998; ITOPF 2011). Given the limited extent of a plume and duration associated with this event, the expected abundance in the upper layers of the water column in the region and rapid recolonisation predicted in the literature, the potential consequences of a diesel spill on plankton is assessed as Category 1–3, even considering the role of plankton in the food web (Hook et al. 2016).

Fish (including socio economic effects to fisheries)	Fish and squid nurseries, shallow or inshore species and reef fish are not expected to occur in abundance within the area around Stromlo-1 (Section 4.6.15) where hydrocarbon levels are elevated. Most adult fish in the GAB region are species that largely remain in the mid-pelagic zone, thus are not expected to contact surface hydrocarbons or hydrocarbons entrained within surface waters. Diffusion over the gills and ingestion of entrained and dissolved hydrocarbons in the water column is however possible for many species of adults and juveniles in the mid-pelagic zone, however generally these species are highly mobile and as such are not likely to suffer extended exposure. Sub-lethal effects include altered heart and respiratory rates, enlarged liver, reduced growth, impaired endocrine systems and behaviour changes to feeding, migration, reproduction, etc. (Kennish 1996). Some vertebrates can rapidly metabolise and excrete hydrocarbons (Hook et al. 2016). There is potential exposure to elevated hydrocarbons to several EPBC protected species (e.g. the great white (*Carcharodon carcharias*), short fin mako (*Isurus oxyrinchus*) and porbeagle (*Lamna nasus*) sharks), and other fish species (including "conservation-dependent" species such as the southern bluefin tuna) that are known to occur in the vicinity of a spill plume. However, given the relatively small extent of a plume, the short-lived nature of the diesel plume and the mobile transitory characteristics of many listed species, consequences to fish are assessed as Category 4. The effects of a Level 3 spill on socio-economic activities (such as crustacea and southern bluefin tuna fisheries) are described in the Risk Assessment section below. While the hydrocarbon type may differ, receptor locations and socio-economic effects are similar but correspondingly much smaller in nature and scale, hence not repeated here. Crabs, scallops and rock lobsters are not predicted to be affected as their commercial fishing activity is largely up to the 200 m water depth contour which is remote from modelled spill contours. Should SBT be in the immediate vicinity of the spill, restitution of schools and their prey is predicted in the medium term Given the duration of the effects and relatively small area affected by a vessel collision spill in relation to the areas fished commercially, the exposure risk is assessed as Category 4 to 5, taking into account a restitution time in the medium term of 1–3 years for activities and populations of local importance.
Marine mammals – pinnipeds	Section 4.6.17.2 records three pinniped species protected under the EPBC Act as potentially occurring within the Risk EMBA but none in the Impact EMBA or plume of elevated diesel concentrations, with foraging BIAs identified more than 150 km to the north of the Stromlo-1 location. Diesel can be ingested through contaminated prey. Surfacing within a hydrocarbon slick may lead to a toxic level of exposure where the diesel may stick to the fur and be ingested during grooming. The fur may also become smothered affecting the waterproofing properties and leading to the potential for hypothermia. For surface diesel, inhalation of vapours at the water's surface are also pathways of exposure for pinnipeds. Pinnipeds may come into contact with entrained diesel while diving and foraging However foraging and breeding site BIA are approximately 150 km from the edges of the spill. Although the effects of diesel on pinnipeds can be severe, the very low density of pinnipeds expected in this offshore location suggests that few, if any, individuals would be affected. Given this, the relatively small plume, and that surface exposures are expected to disappear within 1–2 days, potential consequences to pinniped populations from a diesel spill are assessed as Category 1–3.
Marine mammals – cetaceans	Other than distribution and migration areas for pygmy blue whales (*Balaenoptera musculus brevicauda*), there are no adjacent or nearby BIA for MNES cetaceans – with pygmy blue and sperm (*Physeter macrocephalus*) whale foraging grounds lying about 100 km north. However, the southern right (*Eubalaena australis*), humpback (*Megaptera novaeangliae*) and sei (*Balaenoptera borealis*) whales may still traverse the area as may the fin (*Balaenoptera physalus*), killer (*Orcinus orca*) and various other beaked and baleen whales, so high abundance is not predicted. Likewise, numerous dolphins (such as the common short-beaked (*Delphinus delphis*), Risso's (*Grampus griseus*) and dusky (*Lagenorhynchus obscurus*) may cross the diesel spill plume.
ALARP decision context	Operation of a vessel in proximity of other vessels and offshore installations is a well understood and practiced activity. There is a high level of certainty and conservatism around the spill modelling with modelled volumes considerably in excess of those likely (i.e. typical support vessel tanks sizes). There are suitable legislation and marine orders that require the MODU and vessels to be equipped with and maintain sophisticated communication and navigational aids to avoid collisions and to ensure marine crews are competent in navigation and SMPEP requirements. There is little uncertainty associated with this activity and the risk is medium. Cetaceans can be exposed to the chemicals in oil through Internal exposure by consuming oil or contaminated prey, inhaling oil droplets and vapours when surfacing to breathe, dermal contact and from maternal transfer of contaminants to embryos (NRDA 2012; Hook et al. 2016). Effects of exposure include damage of membranes and airways from inhalation, toxic effects from ingestion such as ulceration and haemorrhaging, eye and skin lesions, stress and behavioural changes and clogging of baleen filters.

	Studies by Geraci (1988) and O'Shea and Aguilar (2001) suggest the cetaceans' thickened epidermis greatly reduces the likelihood of hydrocarbon toxicity from skin contact with oil. The physical effects from ingested hydrocarbon with subsequent lethal or sub-lethal effects apply to entrained oil with exposure risk depending on methods of feeding and volumes of contaminated prey. Baleen whales (e.g. blue, southern right and humpback whales) may be susceptible to diesel at the sea surface as they feed by skimming the surface, with oil residues potentially fouling the baleen plates. Toothed whales and dolphins may be susceptible to ingestion of dissolved and entrained oil as they gulp feed at depth. Transient species moving through an area of low exposure makes it unlikely that migratory cetaceans would experience any toxicity effects of the oil. While no relevant persons raised objections or claims regarding vessel collisions, Australian Maritime Safety Authority requested maximum lighting to aid navigational safety. Taking this in consideration Decision Context A should be applied to demonstrate risks are As Low As Reasonably Practicable.
Assessment technique	Good Practice – Identified industry good practices adopted to reach As Low As Reasonably Practicable

7.6.4 Risk treatment

7.6.4.1 Environmental performance outcomes (EPO 7.6)

No loss of fuel to the ocean from collisions of vessels associated with the activity.

7.6.4.2 Context for assessment

Legislative and other requirements	The performance standards outlined in this EP align with the requirements of: • OPGGS Act 2006 (Cth): Section 572A-F (Polluter pays for escape of petroleum) • International Convention of the Safety of Life at Sea 1974 and *Navigation Act 2012* • *Protection of the Sea (Prevention of Pollution from Ships) Act 1983* (Cth) Section 11A (Shipboard oil pollution emergency plan) (for Australian-registered vessels) Australian Maritime Safety Authority Marine Orders Part 91 (Marine pollution prevention – oil). • Australian Maritime Safety Authority Marine Orders Part 30 (Prevention of collisions) 2016 and Marine Order 21 (Safety of navigation and emergency procedures) 2012:
Industry standards	Environmental, Health and Safety Guidelines for Offshore Oil and Gas Development (World Bank Group 2015) Guidelines met with regard to: • Section 75 (Spills): Conducting a spill risk assessment, implementing personnel training and field exercises, ensuring spill response equipment is available • Sections 76-79 (Spill response planning): A spill response plan should be prepared • Australian Petroleum Production and Exploration Association CoEP (2008) Objectives regarding third-party vessel disturbance are To reduce the effects from events such as spills and loss of equipment to As Low As Reasonably Practicable and to an acceptable level.

7.6.4.3 Control measures and performance standards

Control measures	Environmental performance standards	Measurement criteria	Responsibility
Preventative control measures as per "Displacement of Other marine Users" (see Section 6.1.4.2). Additional control measures are provided below.			
Vessels/ MODU and their staff	EPS 7.6.1: Navigation and communication equipment are available and functional for the duration of the activity.	Records show at no time was navigation and communication equipment down without redundancy	Vessel Masters

Control measures	Environmental performance standards	Measurement criteria	Responsibility
	EPS 7.6.2: Navigation equipment and vessel procedures compliant with all marine navigation and vessel safety requirements under the International Convention of the Safety of Life at Sea 1974 and *Navigation Act 2012* (or equivalent) informs other users of presence and movements	Class survey certificate	Vessel Masters
		Logs confirm bridge-watch on all vessels 24 hours per day	Vessel Masters
		Marine Insurance inspection records demonstrate compliance with standard maritime safety procedures and equipment	
	EPS 7.6.3: Anti-collision monitoring equipment e.g. 24-hour radar watch, Global Maritime Distress and Safety System (GMDSS), Automatic Identification System transceiver and satellite reception and radar beacon on the MODU and support vessels is functional and used in accordance with Australian Maritime Safety Authority Marine Orders Part 30 (Prevention of collisions).	Inspection verifies that anti- collision and other navigational and communications equipment is operational and class-certified	MODU Chief Engineer Vessel Masters
	EPS 7.6.4: Lighting on the MODU will be used during hours of darkness or reduced visibility to ensure MODU is visible, with the exception of non-operational lighting such as cabin lights, etc.	Inspection verifies lighting complies with COLREGS, 1972 and full visibility is maintained during periods of restricted visibility	
	EPS 7.6.5: The Vessel Masters/MODU OIM issue warnings (e.g. radio warning, flares, lights/horns) to third-party vessels approaching the Petroleum Safety Zone (PSZ) to prevent a collision.	Radio operations communications log verifies that warnings to third-party vessels approaching the PSZ have been issued when necessary	MODU OIM Vessel Masters
	EPS 7.6.6: MODU OIM to also coordinate with support vessels to avoid a collision with the MODU	Radio operations communications log verifies coordination with vessels approaching the Petroleum Safety Zone have been issued when necessary	
	EPS 7.6.7: MODU and support vessel continually monitor the 500 m exclusion zone to aid detection of other vessels and to provide additional communication with other vessels where necessary.	Radio operation communication logs verifies that the support vessel has communicated with any third-party vessel approaching the Petroleum Safety Zone	MODU OIM Vessel Masters
	EPS 7.6.8: The MODU and vessel watch keepers are appropriately qualified in accordance with Marine Orders Part 3 (Seagoing qualifications) (e.g. International Convention of Standards of Training, Certification and Watch keeping for Seafarers, STCW95, GMDSS Proficiency) to operate radio and navigational equipment.	Training records document relevant crew qualifications	MODU OIM Vessel Masters
	EPS 7.6.9: Crew members are trained to respond to a spill in accordance with the legislative requirements of the Shipboard Marine Pollution Emergency Plan	A current Shipboard Marine Pollution Emergency Plan is available, which includes a Shipboard Oil Pollution Emergency Plan	Vessel Masters
		Spill incident report verifies that the actions taken were in accordance with the Shipboard Oil Pollution Emergency Plan	Vessel Masters

Control measures	Environmental performance standards	Measurement criteria	Responsibility
	EPS 7.6.10: Vessel crew members are inducted into spill response procedures.	Induction and attendance records verify relevant crew have been inducted into spill response	Vessel Masters
	EPS 7.6.11: Vessel crew is trained in spill response techniques in accordance with the SOPEP and vessel training matrix and frequency of exercises in accordance with MARPOL (Annex 1, Reg 37) for vessels >400 gross register tonnage.	Training records verify that relevant marine crew are trained in spill response and exercises have been undertaken on schedule prescribed by MARPOL	Vessel Masters
	EPS 7.6.12: The Vessel Master will authorise actions in accordance with the vessel-specific Shipboard Marine Pollution Emergency Plan (SMPEP, or equivalent according to class) and the specific Shipboard Oil Pollution Emergency Plan to limit the escape of fuel.	Daily operations reports verify that the Shipboard Marine Pollution Emergency Plan and Shipboard Oil Pollution Emergency Plan were implemented.	Vessel Masters
Equinor Australia B.V. Drilling Manager/ Incident Commander	EPS 7.6.13: Inform mariners of the presence of the mandatory Petroleum Safety Zone maintained around MODU The PSZ is gazetted through NOPSEMA effective from the MODU's arrival at the Stromlo-1 well location. Equinor Australia B.V. arranged for Notice to Mariners and AusCoast warnings to be published prior to arrival at the PSZ location	The PSZ gazettal is available on the NOPSEMA website	Equinor Australia B.V. Drilling Manager
		Records of the Notice to Mariners issued demonstrate that the MODU name and location were listed	Equinor Australia B.V. Drilling Manager
		Records of the AusCoast warnings issued demonstrate that the MODU name and location were listed	Equinor Australia B.V. Drilling Manager
	EPS 7.6.14: External agencies will be notified of reportable hydrocarbon spills to the marine environment either verbally or in writing (or both) in the manner and time frames specified in Section 3.2 (diesel spills within the Operational Area) and Section 4.2 (oil spills from the well) of the OPEP	Daily logs, daily incident reports, completed Oil Pollution Reports confirm that verbal and written notifications completed in accordance with Sections 3.2 and 4.2 of the OPEP.	Incident Commander
Operational and Scientific Monitoring Plan (OSMP)	EPS 7.6.15: The OSMP will be initiated in the event of a confirmed Level 2 or 3 spill	Daily incident monitoring and operational reports verify that monitoring is undertaken in accordance with the OSMP.	Incident Management Team (IMT) Planning Section Chief
	EPS 7.6.16: Equinor Australia B.V. ensures that the collection of operational monitoring data takes place in accordance with the OSMP to detect the extent of the diesel spill.		
	EPS 7.6.17: Equinor Australia B.V. will provide the operational monitoring reports to relevant regulatory agencies to characterise environmental effects from a diesel spill.	Correspondence records verify that operational monitoring reports are provided to external agencies.	IMT Planning Section Chief
Oil pollution emergency plan (OPEP)	EPS 7.6.18: A pre-spud ERP desktop exercise is undertaken to test the emergency response mechanisms and interfaces between the Shipboard Marine Pollution Emergency Plan, OPEP, NatPlan and applicable state plans are in place.	Emergency Response / OPEP Exercise Report records verify oil spill response exercise has been undertaken	Equinor Australia B.V. Leader Safety & Sustainability

7.6.5 Outcome

Residual risk	Consequence category	Likelihood	Risk level
	1 to 4	Has rarely occurred in the industry	Low

The risk of a fuel oil spill following a vessel collision event is assessed as of an acceptable level largely because the risk is assessed to be Low and reducing the risk further will yield negligible benefits. Further, the risk is acceptable because:

Factors affecting acceptability	Acceptability criteria	Demonstration of acceptability
Internal context	No specific criteria identified	No specific criteria identified
External context	There were no unaddressed objections or claims from relevant persons regarding loss of containment of hazardous substances Consequences are predicted to have no direct effect on EBPC Act listed Matters of National Environmental Significance or GAB MP management values	There was discussion from relevant persons regarding loss of hydrocarbons, in the context of a Level 2 and level 3 spill. This advice has been used in the development of the spill response actions (Section 8) and the OPEP which will continue to be reviewed.as part of ongoing consultation. The consequences are localised to tens of kilometres around the Stromlo-1 site. Elevated hydrocarbon concentrations remain largely in the upper waters exposed to natural weathering and dissipation. The EBPC Act listed MNES, including migratory cetaceans, fish and seabirds do not have BIA in the immediate vicinity of the well site (with exception of the distribution and migration BIA of the pygmy blue whale and possibly the short-tailed shearwater) and are mobile transients that can avoid spill plumes. There are no forecast effects on the GAB Marine Park management values as hydrocarbons are unlikely to smother or blanket benthic communities within the Benthic Protection Zone or reach the Mammal Protection Zone at concentrations that may result in adverse effects on populations or the biodiversity of the GAB Marine Park. No Key Ecological Features or Threatened Ecological Communities (TECs) would be at risk. Sea lion foraging and breeding sites are remote (more than 150 km) from the nearest areas of elevated hydrocarbons at adverse concentrations so effects would at worst be at individual, not population level. Marine pollution is a threat identified for albatross and giant-petrels in the National recovery plan for threatened albatross and giant petrels 2011–2016 (DSEWPaC 2011a). Population monitoring is the suggested action to deal with marine pollution. The risks posed by response operations do not affect this action The conservation advice and management plans for cetaceans for blue, humpback, sei and fin whales identify hydrocarbon spill as threats, though there are no specific aims to address this. The performance standards listed in this table aim to prevent and minimise effects to cetaceans from such spills.
Legislation and conventions	Operations are compliant with relevant maritime law listed under Section 7.6.4- Risk treatment – legislative and other requirements	The performance standards developed above are consistent with the requirements of maritime law and aligned with the principles of Equinor Australia B.V.'s and the industry standards, particularly as MARPOL is an internationally accepted standard used industry wide. Both the MODU and vessels have and use functional lighting, navigation and communications equipment and procedures in alignment with Australian Maritime Safety Authority Marine Orders Part 30 (Prevention of collisions).
Industry standards and practices	Operations meet or exceed relevant Equinor Australia B.V. and industry standards listed under Section 7.6.4 – Risk treatment – industry standards and practices	As above

Factors affecting acceptability	Acceptability criteria	Demonstration of acceptability
Demonstration of As Low As Reasonably Practicable	Australian Maritime Safety Authority requested the MODU to display full lighting as an aid to collision avoidance. Other lighting options are described in Section 6.0. The presence of the support vessel 24/7 in the immediate vicinity assists in detection and warning third party vessels. MODU and support vessel presence are required in the field during the activity and power substitutes for MDO/MGO (such as solar or biofuels) are not commercially proven. MGO/MDO fuel spills have less stickiness and persistence than heavy fuel oil, hence present a lower environmental risk in the event of a spill. Many modern vessels are "double-skinned", effectively isolating fuel tanks from the hull, making fuel tank damage less likely. While the contracted support vessels may be double-skinned, this cannot be confirmed until a vessel contractor is appointed. In the event of a spill, several control measures are in place to respond to the spill and minimise the effects as much as practical. The predicted risk is low, well understood and no further control measures are required to reduce the likelihood of a vessel collision to As Low As Reasonably Practicable.	

7.7 Loss of well control and major oil spill

This section outlines the risk description, level of acceptable risk, risk assessment, risk treatment and resultant predicted risk, in relation to a loss of well control leading to a major spill of oil to the environment. This focusses on a Level 3 spill, which is the worst-case credible discharge. Level 1 and Level 2 spill risks are discussed in Sections 7.5 and 7.6. Smaller spills associated with loss of well control will have a lower level of residual risk and are considered to be covered under the assessment of a Level 3 oil spill. Further information relating to oil spill prevention, preparedness, response and mitigation activities arising from the implementation of oil spill response measures is provided in the documents are noted below

Barriers that will be implemented to prevent a loss of well control event will be detailed in the well operation management plan. These measures are continually reviewed and improved. The barriers include a series of engineering devices, practices and procedures, each of which can stop or drastically reduce the spill, and these are continually improved, especially as a result of the inquiries into incidents. The barriers are highly effective at preventing oil spills and large oil spills are rare, so for a Level 3 spill (>1000 tonnes or >7000 bbl or >1000 m^3) to occur, all of the barriers have to fail partially or completely.

Since 1980, there have been approximately 59,000 offshore petroleum wells drilled worldwide. In this time there have been only two major spills during drilling (Montara and Macondo), The duration of each spill exceeded 10 weeks (Montara – 74 days in 2009 and Macondo – 87 days in 2010). Only the Macondo spill, which was approximately 70 km from shore, resulted in oil reaching the coast.

The extreme oil spills that resonate with the community and which heighten concerns around drilling safety for oil and gas exploration, include the major spills where there was significant shoreline contact within a relatively short time of the spill starting – meaning that large volumes of fresh oil washed ashore and into sensitive nearshore areas. Most of these have been oil tanker or pipeline accidents involving the loss of oil very close to sensitive areas such as beaches. The risks associated with drilling exploration wells far offshore are lower because any oil spilled would undergo weeks to months of weathering at sea, during which time its toxicity would be greatly reduced, before reaching sensitive coastal areas.

While the preventative barriers will be effective in minimising risks of a spill occurring, in the rare event that there is a spill, there will also be multiple layers of well intervention to stop the flow of oil (blow-out preventers, capping stack and relief well) and a range of mitigative measures to minimise environmental consequences (dispersants, mechanical containment and recovery (CAR), clean-up).

Equinor Australia B.V. has implemented strict barriers to prevent a spill, prepare intervention and mitigation measures as back-up and is confident that the risk has been reduced to As Low As Reasonably Practicable. The risk of a spill from an exploration well is generally considered to be a low likelihood/high consequence event (SINTEF 2001). As described in Section 5.0, the predicted risks associated with a major oil spill have been assessed in terms of the potential environmental consequences of the spill and the likelihood that all the preventative barriers will have failed completely. The risks are further reduced by introducing the intervention and mitigation measures to reduce environmental harm. It is on the basis of the medium level of risk, due to the extremely low probability (less than <10-4) of the major spill occurring, that Equinor Australia B.V. has decided the level of risk is acceptable.

7.7.1 Risk description

The potential oil and natural gas deposits deep below the seabed in the Great Australian Bight are buried kilometres under layers of sediment and rock. When drilling through the layers of sediment to explore for oil and gas, the formation pressure in the well increases with depth. If oil or gas is present, the relative pore pressure is higher and the drilling mud system is used to control this pressure and keep the well fluids in the hole. If there is a sudden unexpected increase in pressure in the well ("kick") due to an unexpected over pressurised layer, the drilling management practice has multiple safeguards to stop hydrocarbons flowing to the surface. These comprise safeguards to control fluid pressure in the well, safeguards to react to unexpected kicks and safeguards to prevent the flow of fluids to the surface by closing the well until the pressure can be controlled and the well is "killed", and the primary barrier is regained. It is important to note that loss of well control has short duration and are resolved in less than a day by crew intervention using the available equipment – normally the blowout preventer. For large volumes of oil to be released to the environment, there needs to be a loss of well control coupled with multiple failures of well safety barriers, followed by failure of the highly effective intervention systems that close the well. Stromlo-1 will have a pre-fitted blowout preventer which, in the event of a loss of well control, will automatically close the well. If the automatic system fails, there is a series of manual systems to close the blowout preventer. Should these all fail, Equinor Australia B.V. will apply a capping stack to stop the flow of oil while a relief well rig can be brought on site to kill the well permanently. The mobile offshore drilling unit would most likely be capable of drilling the relief well or at least starting it by drilling the top-hole section to save time in permanently closing the well.

Loss of well control leading to prolonged oil spills are exceedingly rare, and in approximately 59,000 offshore wells (including nearly 10,000 exploration wells) drilled around the world, there have been only two large oil spill incidents (BSEE 2017).

Oil spilled into the marine environment will spread rapidly and can have adverse effects on marine ecosystems that are exposed to elevated concentrations of hydrocarbons, and/or lower concentrations for extended periods. The location of the Stromlo-1 well at more than 370 km from the coast in the open ocean, greatly reduces its potential for adverse environmental shoreline effects, because any spilled oil would be highly weathered by the time it reached the shore and shallow water environments (at least three weeks old). The well-known and catastrophic oil spills, such as the Exxon Valdez oil tanker spill, were very close to sensitive shorelines where there was almost immediate contact of fresh oil with marine life. In the open ocean, the oil would spread over a large distance because it would not be constrained, and this has the benefit of increasing its exposure to hydrocarbon degrading bacteria and other processes which naturally break down oil.

This section describes the risks associated with a worst credible case oil spill (Level 3) from the well head and discusses the role of measures to stop or reduce the flow of oil to the environment (source control) and to reduce the environmental effects of the spilled oil by applying dispersants (mitigation measures); thereby minimising environmental harm, and reducing risks to As Low As Reasonably Practicable and an acceptable level. Other response measures including oiled wildlife response, containment and recovery and shoreline protection and clean-up are described in the Oil Pollution Emergency Plan and in Section 8.

It is important to note that a conservative approach to assessing oil spill risks is described and that in the event of a spill, the more likely outcomes would be much less because:

- The flow would be stopped by the blowout preventer in less than one day.
- If the blowout preventer failed multiple times (very unlikely), the capping stack would stop the flow soon after.
- The worst credible case discharge scenario selected for assessment of a loss of well control Level 3 spill, assumes total failure of the multiple barriers presented by the blowout preventer and unrestricted annulus flow until a relief well can be drilled after 102 days. This does not allow for probable well bore collapse or other blockages due to debris, which will reduce the flow of oil from the seabed.
- Unrestricted flow for 102 days at an average rate of 6720 m^3/day (total oil released ~685,440 m^3) is conservative because the well is likely to be closed by a relief well sooner than this (P90 = <90 days for a relief well rig from the NWS; <70 days for a rig from Bass Strait).
- Conservative approaches have been used in selecting consequences, based on worst outcomes of a wide range of sensitivities and exposure levels.

- The detailed engineering of a safe drilling program, with all the barriers and safeguards to avoid a loss of well control and subsequent spill, is beyond the scope of this Environment Plan and will be assessed by National Offshore Petroleum Safety and Environmental Management Authority separately in the well operation management plan and Safety Case.
- The drilling is planned to occur in the November–February period, during which time meteorological and oceanographic conditions are more favourable for drilling and during which time conditions also result in lower shoreline loadings of oil (Appendix 7-1).
- Spill response actions including shoreline clean-up, containment and recovery and oiled wildlife response as identified in the Oil Pollution Emergency Plan and assessed in Section 8 will further mitigate the predicted level of risk.

7.7.1.1 External context

Well operations management plan

The Well Operations Management Plan is a regulatory requirement under the *Offshore Petroleum and Greenhouse Gas Storage Act 2006* and the associated Offshore Petroleum and Greenhouse Gas Storage (Resource Management and Administration) Regulations 2011. It is the primary approval document for ensuring a high standard of well integrity. The Well Operations Management Plan details the risk assessment, critical procedures and safety mechanisms to be implemented throughout the duration of the relevant petroleum activity. The Well Operations Management Plan is assessed by National Offshore Petroleum Safety and Environmental Management Authority after the drilling contractor has been selected and commencement of drilling will be contingent on approval of the Well Operations Management Plan. The Well Operations Management Plan is consistent with industry practices and standards, including:

- American Petroleum Institute RP 96 Deepwater well design and construction
- NORSOK D-010 Well integrity in drilling and well operations standard (2013)
- American Petroleum Institute Standard 53 – Safety critical equipment.

Safety case

The Rig Safety Case for the mobile offshore drilling unit and specific to drilling Stromlo-1 identifies the hazards and risks, describes how the risks are controlled and describes the safety management system in place to ensure the controls are effectively and consistently applied. A major focus is on the prevention of loss of well control and subsequent release of hydrocarbons as this is a key safety risk.

The Safety Case is assessed by National Offshore Petroleum Safety and Environmental Management Authority after the drilling contractor has been selected and commencement of drilling is contingent on approval of the Safety Case. National Offshore Petroleum Safety and Environmental Management Authority will only accept the Safety Case when satisfied that the arrangements set out in the document demonstrate that the risks are reduced to As low as is reasonably practicable. National Offshore Petroleum Safety and Environmental Management Authority may conduct audits and inspections on the mobile offshore drilling unit to monitor Equinor Australia B.V.'s application of the Safety Case.

Lessons learned

Equinor Australia B.V. assesses and learns from other operators' experiences to ensure it utilises the latest understanding of potential failings of standard systems and processes and engineering under all conditions and continually improve its own systems, processes and engineering solutions. Lessons learned from major incidents in the last decade, in particular the Macondo in 2010, have resulted in the advancement of regulations, engineering and process solutions to further reduce risks of a Level 3 oil spill, and to facilitate rapid and effective source control and mitigation response if a release were to occur. These include (but are not limited to):

- improving technical and managerial aspects of managing the risks to integrity of the wells
- improved blowout preventer testing program
- availability of capping stack options at multiple locations worldwide
- well design criteria that allow wells to be capped
- designing of capping stacks for rapid air transport

- availability of subsurface dispersant injection systems
- developing titleholder Global Incident Management Assist Teams which provide a global resource of trained incident response personnel that can be mobilised quickly to support escalation to an incident management team
- improving preparedness of operational and scientific monitoring programs (Operational and Scientific Monitoring Plan s) to facilitate more rapid, efficient and effective mobilisation and monitoring (following the Montara Commission of Inquiry in 2010).

In addition, lessons learned from previous loss of well control and exercises are used to frame training and spill response exercises. This supports continuous improvement in response actions.

7.7.1.2 Internal context

For Stromlo-1, Equinor Australia B.V. has committed to lowering potential risks by including the following safeguards in the well planning:

- study, review and application of the learnings from offset wells
- well design to have only one potential hydrocarbon reservoir exposed in the same well section
- the last liner will be set close to the potential hydrocarbon reservoir
- not undertaking a well test in the event of a discovery
- not conducting conventional well coring.

7.7.1.3 Probability of a Level 3 spill

Equinor Australia B.V. has assessed the probability of the three Level 3 oil spill scenarios which have been risk assessed hereafter. Calculation of Stromlo-1 probabilities is based Equinor Australia B.V.'s standard methodology which draws on the most updated statistics from the best international blowout database (i.e. based on the Mira method, Equinor Australia B.V. GL0498, GL0282 and SINTEF Offshore Blowout Database). The probabilities have been compared with those derived following the Australian Maritime Safety Authority method and are slightly higher (Table 7.4). These probabilities, as shown in bold text in the table below, have been used in the risk assessment. The scenarios relate to the modelled spill scenarios as described in the Oil Spill Modelling Study (Appendix 7-1).

Table 7.4 Probability of a large oil spill being stopped with blowout preventer, capping stack or relief well

Reference	Probability of oil spill occurring that is stopped with a blowout preventer (scenario 2)	Probability of oil spill occurring that is stopped with a capping stack (scenario 3)	Probability of oil spill occurring that is stopped with a relief well (scenario 4)
Stromlo-1	8.5E-05	4.0E-05	1.9E-05
Australian Maritime Safety Authority 2011	2.11E-05	9.43E-06	5.50E-06

The probabilities used in the risk assessment relate to the chance of the spill scenario occurring and do not consider further differential probabilities of encountering the spill and experiencing adverse effects in different areas within the spill zone or at different times during the spill. In reality, the environmental consequences from such a spill would also depend on the probability of sensitive organisms being exposed to high enough concentrations and for sufficient duration to have adverse effects.

The associated probabilities (based on frequencies) reflect the historical data on stopping mechanisms and duration of the spill event. The statistics on well blowouts around the world show that most blowouts are successfully stopped in a day by the blowout preventer, some are stopped by natural bridging, and much smaller percentage of blowouts last until the relief well is drilled. Therefore, the probability of the loss of well control being stopped by a relief well scenario is a lower probability than a loss of well control closed by the blowout preventer.

Equinor uses a standard industry methodology which draws on the most current statistics from the best international blowout data base. This is consistent with Equinor's in-house guidance GL0498 and GL0282, the Mira 3 method and SINTEF Offshore Blowout data base.

- GL0498 Guideline for Blowout Scenario Analysis as Input to Environmental Risk Analysis and GL0282 Guideline for Risk and Emergency Preparedness Analysis requires the blowout probability calculation to be influenced by geology, well design, robustness of well barriers and technological factors. Operational blowout probability is based on a combination of type of operation, historical statistics and expert judgement (based on consideration of operation specific conditions).
- Calculating probabilities for Mira input are guided as per Section 5.5.2 of the attached: "Guidance on calculating blowout rates and duration for use in environmental risk analyses" https://www.norskoljeoggass.no/contentassets/d6c1d516cc4945358fea471a8610becf/guidance-blowoutrates-with-supp-report.pdf
- The SINTEF global database (https://www.sintef.no/en/projects/sintef-offshore-blowout-database/) includes data from 642 offshore blowouts worldwide since 1955 (up to Dec 2016). Relevant data is drawn from 51 fields to ensure that data is relevant to the deep-water exploration wells such as Stromlo-1. The time/volume probability distribution from the SINTEF database is used in the Mira assessment.

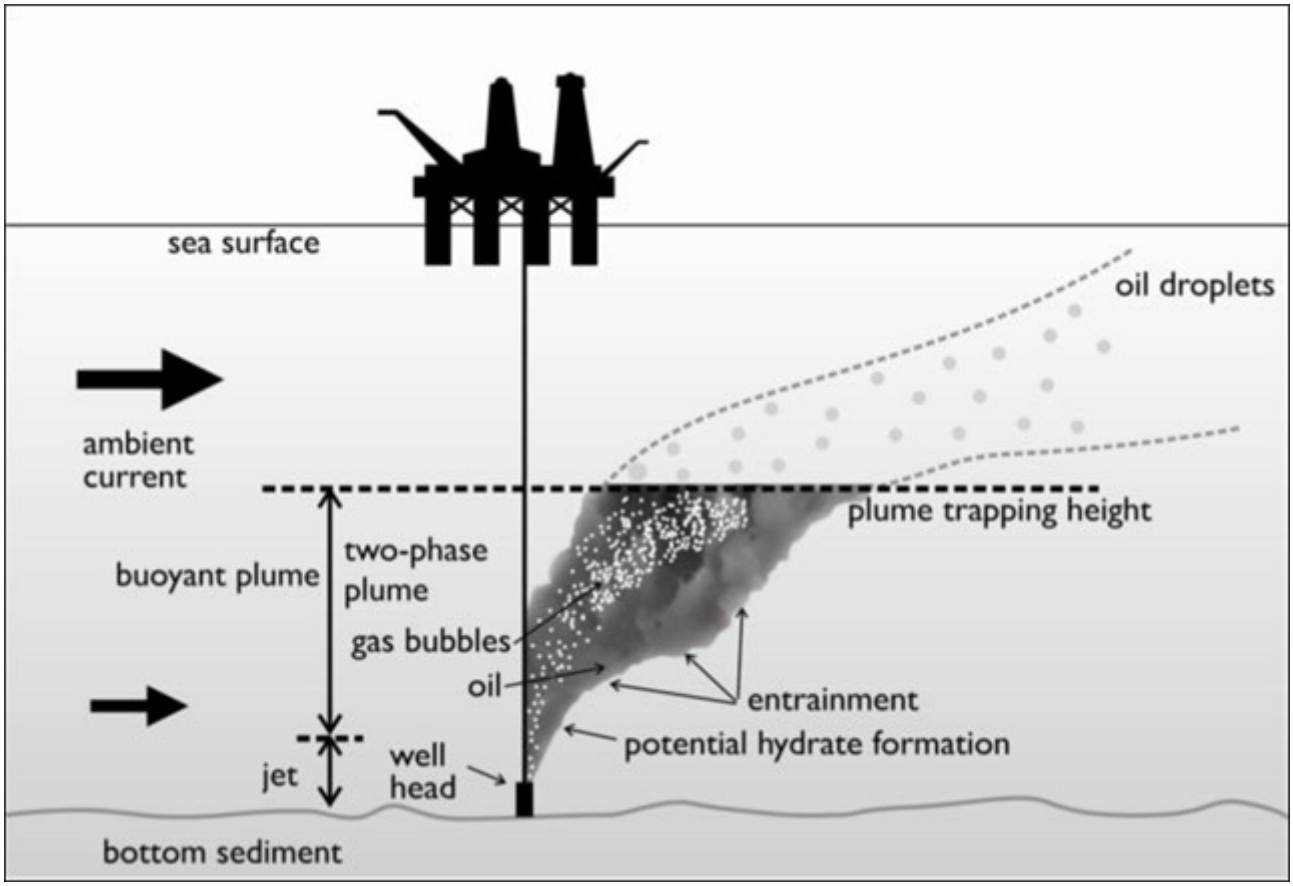
7.7.1.4 Hydrocarbon characteristics

The exact properties of the Ceduna Sub-basin reservoir oil are unknown because no oil has been recovered from the area. Thirteen exploration wells have been drilled in shallower parts of the Great Australian Bight (closer to shore) and these provide useful geological data for interpreting seismic data. Equinor Australia B.V. has assessed the geology of the Stromlo-1 area and predicts that the oil type that may be encountered in this area would most likely be of marine origin (marine source rock). Statfjord C crude oil was selected as being an appropriate analogue for the source rocks in the area based the geological setting. Statfjord C is a medium crude oil found in the North Sea and, as an analogue, provides a useful basis for predicting the fate and behaviour of Stromlo-1 oil, if present.

The hydrocarbon properties for Statfjord C blend crude oil that have been used in the oil spill modelling and in the risk assessment are summarised in Section 2.0 and Appendix 7-1.

7.7.1.5 Fate of medium crude oils in the marine environment

During a loss of well control leading to a spill from the well head, the gas and oil released from the seabed is driven into the water column by the momentum of the high-pressure release. The escaping plume of hydrocarbons will be mixed with sea water as it is jetted out under pressure and will then dissipate in the water column over a short distance (<10 m). The density and buoyancy difference of the gas, water and oil mixture relative to the surrounding waters forces the plume upward. As the plume rises, it continues to entrain ambient sea water due to the velocity differences between the rising plume and the receiving waters. This entrainment reduces the plume's velocity. The oil is mixed rapidly by the turbulence in the rising plume, causing it to break up into small droplets. The oil droplet sizes range from a few microns to millimetres in diameter and are transported upwards by the rising plume. If the buoyant plume is dissipated by entrainment before it reaches the surface, the oil droplets in the plume will be carried to the surface solely by their own rise velocities (generated by the difference in density between the crude oil and surrounding sea water). Figure 7.2 illustrates the various components of a generalised example of a sub-sea release of gas and oil.

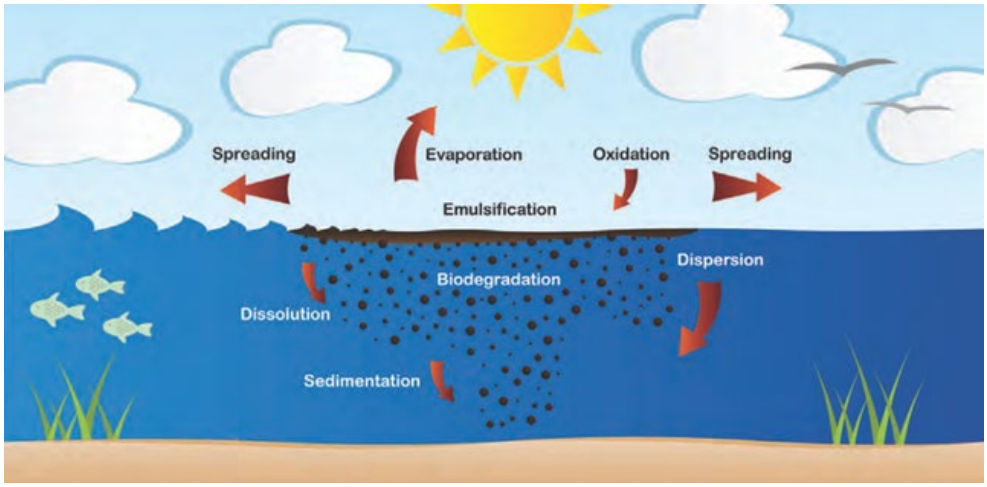


Source: Applied Science Associates (2011)

Figure 7.2 Generalised loss of well control and hydrocarbon plume in the water column

Uncontained oil tends to rise to the surface because it is less dense than sea water, and a slick of fresh oil forms on the sea surface. Some oil will become entrained in the water column as it is jetted out of the well under pressure and forms small droplets (smaller than about 75 µm) which tend to remain suspended in the water column. These droplets are exposed to bacterial degradation and dispersion by ocean currents. Larger droplets of entrained oil, or coalesced droplets, tend to rise to the surface, and can surface some distance from the source. The slick is thickest close to the discharge point and rapidly gets thinner as the oil spreads over the sea surface and weathers. Soluble elements of the oil mixture can dissolve into the sea water from entrained droplets and from under the surface slick.

When the oil reaches the surface, it is subject to natural physico-chemical weathering mechanisms, such as evaporation, emulsification, photo-oxidation and sedimentation (if it attaches to suspended particles). Some of these mechanisms also act on entrained oil; particularly dissolution, microbial biodegradation and sedimentation. Therefore, a large component of the spilled oil is lost to the atmosphere or assimilated in the water column or seabed sediments through natural mechanisms and physical properties begin to change through weathering. These processes are depicted in Figure 7.3. The time-scales of weathering processes for medium crude oil under environmental conditions found in the Great Australian Bight are described in the Oil Spill Modelling Study (Appendix 7-1).



Source: SINTEF (2011)

Figure 7.3 Weathering and fate processes acting on spilled oil in the marine environment

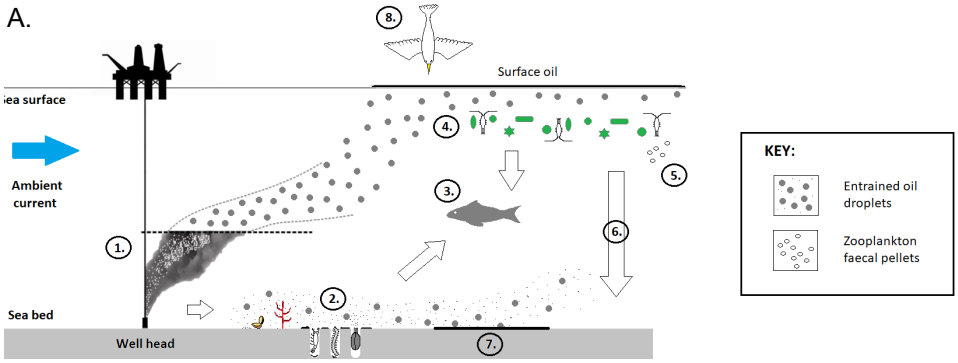
The environmental consequences of a loss of well control and related spill are highly variable and dependent on the characteristics of the hydrocarbons released, the rate and volume of the release, the time of year, the biotic and abiotic dynamics of the receiving environment, water depth at the release point, the proximity of the release point to sensitive environmental receptors and the sensitivity of the receptors to elevated hydrocarbons. Therefore, the following risk assessment is specific to the nature and scale of the credible loss of well control spill in the context of the geographic location that may be affected and environmental values at scales relevant to the area.

7.7.1.6 Potential environmental effects of spilled crude oil

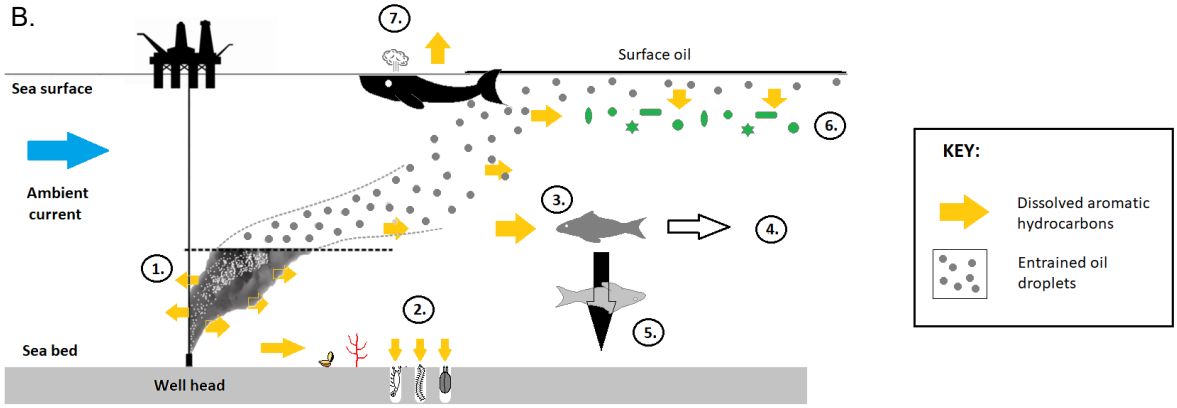
An oil spill has the potential to expose environmental and socio-economic receptors to different hydrocarbon expressions and concentrations, which vary greatly over the geographic extent of the surface slick or in-water plume. The potential for environmental harm reduces with time as the oil weathers and loses the toxic components. Spilled hydrocarbon may contact environmental receptors in the form of the surface slick, in-water (entrained hydrocarbon droplets and dissolved aromatic hydrocarbons) plumes, atmospheric plumes, sedimented oil attached to organic and inorganic particles, and shoreline accumulated hydrocarbons.

The potential environmental effects of the various forms of spilled oil (dissolved, entrained, surface slick, sedimented, evaporated) vary greatly in space and time, as determined by:

- variations in the concentration and thickness of the surface slick, which is affected by spreading, evaporation of lighter components of the oil and biodegradation
- variations in the concentration of entrained and dissolved oil, which is affected by weathering, sedimentation and biodegradation
- the weathering state of the oil; the oil becomes less toxic as the volatile aromatic hydrocarbons are lost; weathering can be rapid initially, but can still occur at much slower rates in weathered hydrocarbons (e.g. tar balls)
- the sensitivity of marine receptors to the oil they contact; their propensity to ecotoxicity, health effects, bioaccumulation, reduced fecundity or survival of juveniles at different concentrations of hydrocarbons
- exposure of the receptors; greatest exposure if they cannot avoid the plume and are close to the source; minimal if they are not present at the time of the spill or transient in the affected area, or if they are seasonal visitors and able to avoid the oil
- exposure is reduced when the oil is heavily weathered because it is less bioavailable and less toxic
- greatest risk if the biota are sensitive, immobile and in the zone of highest hydrocarbon concentration for an extended period.
- potential pathways for biological effects from spilled oil are illustrated in Figure 7.4 A and B. It is important to note that the illustration does not directly represent the predicted behaviour of the Stromlo-1 situation, for example at Stromlo-1 most of the entrained oil would remain at around 1000 m water depth and be below the depth limits of many marine fauna.



1. Oil is split into suspended droplets of oil by the energy of the release from the well head.
2. Exposure of benthic biota to entrained oil droplets and oil absorbed onto organic material causes chemical burns to external and respiratory membranes.
3. Entrained oil also causes chemical burns to sensitive membranes in demersal and pelagic biota, which may cause cysts or tumours.
4. Entrained oil is absorbed onto organic material and grazed on by zooplankton (e.g. copepods).
5. Hydrocarbons are then accumulated into faecal pellets, which may be eaten or form part of "marine snow".
6. "Marine snow", comprising dead organic matter and faecal materials gradually sink to the sea floor. Hydrocarbons are accumulated through additional absorbtion of entrained oil droplets. Sedimentation of "marine snow" one of the processes where spill hydrocarbons can accumulate in sea bed sediments.
7. Hydrocarbons will accumulate in marine sediments where plumes of entrained oil droplets come into contact with the sea floor. This was described as the "bathtub ring effect" following the Deepwater Horizon spill. Accumulated hydrocarbons in marine sediments can have ecotoxic effects to biota at and beneath the sediment surface.
8. Avifauna (birds) and marine mammals (e.g. seals and sealions) can get oiled at or near the water surface. Cleaning of oil from external surface can result in ecotoxic effects from ingestion, or hydrocarbons can be passed on to young during feeding. Seabirds may suffer drowning or hypothermia as oil removes the coating that waterproofs the feathers and keeps the bird dry.



1. Aromatic hydrocarbons dissolve into the water column.
2. Epibiota and infauna are exposed to dissolved aromatics. Direct absorbtion across membranes and respiratory surfaces. Infauna may draw dissolved hydrocarbons into burrows via generation of a respiratory current.
3. Demersal and pelagic biota (e.g. fish, squid) are exposed to dissolved hydrocarbons. Uptake may occur across surface and respiratory membranes.
4. Sublethal effects may include skin systs/tumours, bioaccumulation of hydrocarbon compounds, impacts to fecundity. Fish are capable of processing and excreting some hydrocarbon compounds. Additional predation may increase bioaccumulation up the food web.
5. Ecotoxic effects of dissolved hydrocarbons at sufficient concentrations and durations of exposure may cause mortality. Dead biota may be scavenged or be a vector of hydrocarbons into marine sediments.
6. Dissolved hydrocarbons can also cause ecotoxic effects in plankton, causing mortality or developmental effects in early life stages of macrobiota.
7. Volatile Organic Compounds (VOCs) pass into the atmosphere as part of the wethering process. Air breathing animals, such as cetaceans or marine reptiles, may be exposed and suffer ecotoxic effects.

Adapted from Applied Science Associates (2011)

Figure 7.4 Conceptual model of cause-effect pathways for dissolved aromatic hydrocarbons (A) and for suspended entrained hydrocarbons (B), from a loss of well control spill

7.7.2 Background

Equinor Australia B.V. engaged RPS to undertake three-dimensional fate and trajectory modelling of various oil spill scenarios involving the loss of well control and release of oil from the sub-sea well head. The oil spill modelling involved developing a comprehensive oceanographic model to take into account wind, waves, currents, water temperature and other factors affecting the fate oil in the marine environment. It then introduced a jet of oil and gas from a theoretical loss of well control and spill just above the seabed, using input parameters which characterise the reservoir, flow rates, gas content, oil type, temperatures, exit hole size, timing and duration of the spill.

Detailed information on the modelling inputs and outputs (including justifications) are included in the Oil Spill Modelling Study (Appendix 7-1). Some results of relevance to the risk assessment have been included herein to assist the reader in understanding the risk assessment process.

The outputs of the modelling were then used to support the risk assessment process where thresholds of environmental effects (including socio-economic considerations) were used to derive plots and calculations of the areas and times when thresholds may be exceeded. The maps included herein show contours which represent the outer extremes of where each threshold value may be exceeded at some time during the duration of the spill and for a period afterwards.

Thresholds used to plot potential levels of exposure to dissolved aromatic hydrocarbons, entrained hydrocarbons, oil floating on the sea surface and oil making contact with the shoreline, are listed in Table 7.5 to Table 7.9. The plots of oil at these threshold values in the Oil Spill Modelling Study and in this section are used to represent areas of exposure to inform the risk assessment herein.

It is important to note that some thresholds, for example the 1 g/m^2 threshold (the white contour in the oil spill plots) used to set the extreme limits of the area that many be affected by floating spilled oil do not represent the predicted area of biological effects; rather this low concentration of oil would be a sheen on the water, similar to what may be regularly observed in a coastal marina or waterway. It may affect tourism activities but would have negligible biological effects. Potential biological effects are expected to begin after prolonged exposure to floating oil at >10 g/m^2 (blue contours in the oil spill plots). The pale green contour represents the zone where fresh oil may be encountered. All oil outside this zone will be weathered to various extents; weathering increasing with distance from the well which reflects the amount of time for which the oil has been exposed to the elements.

The areas affected by oil in this assessment are based on predicted hydrocarbon exposure within each of the cells in a modelled three-dimensional grid of cells, and this is tracked in time steps for the duration of the modelled spill (Appendix 7-1).

Section 4 describes the regional upwelling events along the continental slope and shelf that have been identified as important values of the Bonney Upwelling KEF, The Kangaroo Island Pool and Adjacent Shelf Breaks and Eyre Peninsula Upwelling KEF as well as the spatially less defined downwelling along the shelf slope in the middle of the Great Australian Bight, which is not recognised in a KEF. The three-dimensional current data representing horizontal movement at discrete depths in the Oil spill modelling (Appendix 7-1) was extracted for the 2008–2012 period, as described in the modelling report. The net influence of upwelling and downwelling processes on horizontal transport of water at a given depth is incorporated into the regional oceanographic datasets. However, the model does not specifically represent vertical currents between horizontal layers. This was considered reasonable because vertical currents associated with episodic upwelling and downwelling events are weak relative to horizontal currents and buoyancy driven changes. Further detail is provided in Section 3.3 of the Oil spill modelling study Rev 1.

7.7.3 Stochastic modelling

In interpreting the oil spill modelling described in this section and others in the Environment Plan and the Oil Spill Modelling Study, it is important to understand the difference between stochastic and deterministic modelling runs and how they have been used in this risk assessment. Stochastic and deterministic modelling is described in the Oil Spill Modelling Study (Appendix 7-1). A brief summary is provided here to assist in interpreting the modelling outputs referred to herein.

Stochastic analysis was used to provide a summary of the accumulated outcomes of 100 individual spill simulations, all commencing between October and May (the activity period) but starting on different days in that period. The stochastic modelling involved choosing 100 random time points during the period when

drilling could occur (October–May) and then simulating the release of the worst credible volume of oil and gas from near the seabed starting at those times. The 100 individual modelling runs then tracked the fate and trajectory of the released hydrocarbons for the longest duration of the spill (until the well can be killed); the dissolved, entrained and surface floating components were followed for the duration of the release and for a period afterwards (at least one month), and the processes of natural degradation, weathering and dispersion were incorporated. Each spill run behaves in a different way; depending on the daily meteorological and oceanographic conditions throughout the simulation. The amount of oil floating on the surface, entrained or dissolved in the water column or washed up on a coastline was analysed and the maximum concentrations (surface slick, entrained and dissolved oil) and thicknesses or accumulations (beached oil, surface slick) reached in every grid cell across the model domain was documented. This allows calculation of the greatest volumes and concentration reached in each cell for the duration of the spill and allows estimation of the total shoreline loading (amount washed ashore) over the modelled duration. Modelling 100 different spills (runs) allows the calculation of probabilities (as percentages of the total number of runs). For example, if one part of the coast is contacted by oil in 30 of the 100 modelling runs, then there is a 30% probability that part of the coast would be contacted by oil spilled during the October to May period – also assuming the spill lasts for 102 days and flows remain at the conservatively high flow rates used in the model.

Due to the variability in meteorological and oceanographic conditions (wind, waves, currents) between years and between months of the year, it is impossible to predict the exact conditions at the time of a spill, and therefore, the stochastic modelling is valuable in representing the range of possible outcomes. Under each different run, different parts of the coast and offshore waters may receive different amounts of oil and the 100 runs cover the range of likely outcomes (under seasonally characteristic meteorological and oceanographic conditions) and some uncommon events (under unusual conditions) also. By combining the outer boundaries of all 100 runs, a map could be generated representing all areas which may be affected under a broad range of conditions. This set the extent of the areas for which probabilities of exposure were calculated.

The risk assessment in Section 7.7.3 was based on deterministic runs drawn from the stochastic modelling of the worst credible case discharge associated with a Level 3 spill during the period October to May. The single deterministic run resulting in the fastest contact of oil with any shoreline (spill commencing 30 May) was selected to represent the greatest levels of environmental effect that may be predicted for a single spill.

7.7.4 Deterministic modelling

While stochastic modelling provides useful data for calculating probabilities of exposure to pre-defined concentrations / thicknesses and the maximum extent of exposure, based on a large number of theoretical spill events (n = 100); deterministic modelling is more useful for assessing the risks associated with individual spills (and there can only ever be one). The deterministic runs provide a more realistic representation of what would occur during a single (worst credible) spill and, therefore, these runs are more useful for assessing the environmental effects and for dimensioning the spill response plans.

The deterministic model runs based on the “fastest time to shore” and “greatest shoreline accumulation” were selected to represent the “worst-case” environmental outcomes where the freshest oil would contact shoreline areas and in which there would be least time for intervention (fastest time to shore) and the run under which the greatest potential smothering and longer-term toxic effects may be realised (greatest volume of shoreline accumulation). These runs were also used in developing the Oil Pollution Emergency Plan in consultation with state response agencies (Appendix 9-1).

7.7.5 November to February oil spill

The preferred drilling period is November–February when meteorological and oceanographic conditions are more conducive to fast and efficient (cost-effective) drilling operations. An oil spill during this time of year would behave differently to a spill in other times of the activity period (i.e. during October, or during March–May) due to the different prevailing meteorological and oceanographic conditions. Initial modelling indicated volumes of oil ashore would be much lower during November to February. The modelling has confirmed that the environmental consequences associated with a loss of well control are lower during this period.

To assess a situation which is more representative of the centre of the range of possible outcomes, we selected the median of the range of the runs modelled during the November–February period. Applying the planned intervention and mitigation measures provides the closest approximations to the most likely

outcomes of a major spill. This is useful for context in interpreting the range of modelling outcomes and particularly in interpreting the worst-case deterministic results which are less credible, because they represent the extreme upper end of the range of outcomes. Worst-case outcomes would only occur in one out of the 100 modelled spill runs.

As such, commentary in the following risk assessment sections includes mention of this scenario where under certain circumstances risks are significantly lower than for the worst credible case discharge scenario. This case still has the conservatism intrinsic to the modelling to address areas of uncertainty, as described below.

7.7.6 Managing uncertainty

A range of values may be selected for each input parameter used to build the model, reflecting variability in the actual conditions that may be encountered at the time of a loss of well control. Conservative values were used wherever there was uncertainty in actual values for each parameter.

Some examples of conservatism in the modelling and in the resultant risk assessment are:

- High flow rate is assumed, based on complete failure of all barriers and the well-bore remaining open for the entire duration of the spill. Not all barriers would fail completely, for example the blowout preventer rams would more likely partially close the well bore and the bore would be obstructed by debris and infill from the surrounding rock and sediment.
- The worst-case individual runs have been selected to represent the greatest extent of effect, whereas 99% of the outcomes would result in a lesser extent of effects.
- The model registers a threshold exceedance if a concentration is exceeded in a grid cell on one occasion; whereas in reality oil toxicity effects are related to prolonged exposure (often four days or more), especially at the lower concentrations.
- No allowance has been made for containment and recovery and shoreline protection and clean-up, which would further reduce the oil at sea and shoreline loadings

7.7.7 Terms used in spill modelling outputs

Important terms used in the oil spill modelling and risk assessment are defined as follows for the context of the EP:

- dissolved hydrocarbons – the soluble components of oil which are dissolved in (sea) water
- entrained hydrocarbons – oil droplets that are suspended in the water column, though not dissolved
- fresh hydrocarbons (oil) – oil that contains volatile or soluble components, and is potentially amenable to dispersant application (to be confirmed through on-site testing); defined in oil spill modelling as >1% aromatics
- intervention – mechanical measures taken to stop the flow of hydrocarbons following a loss of well control and potential Level 3 spill; including use of the blowout preventer to close the well bore, fitting the capping stack to stop the flow of oil to the surface and drilling a relief well to kill the leaking well and permanently stop the flow of oil
- mitigation – measures taken to minimise environmental harm from spilled oil, including use of dispersants either applied at the surface from vessels and aircraft, or at the well head using a subsurface dispersant injection system
- polycyclic aromatic hydrocarbons (PAH) – uncharged, non-polar organic compounds containing multiple aromatic ring structures, the simplest being naphthalene with two rings
- sea surface hydrocarbons – accumulation of oil at the sea water–air interface; the oil slick
- shoreline contact – theoretical accumulation of oil in intertidal and supratidal (splash zone) areas over the course of the modelled spill duration; to provide a conservative (high) estimate of shoreline loadings. Natural breakdown and removal of beached oil e.g. by waves, is not accounted for and therefore this is a conservative value for oil accumulation

- volatile organic compounds – light hydrocarbons with a low boiling point (hence high vapour pressure at room temperature), hence evaporate easily. Toxic volatile organic analytes in crude and condensate include benzene, toluene and xylene
- weathered hydrocarbons (oil) – oil with <1% volatile or soluble components, and unlikely to be amenable to dispersant application (to be confirmed through on-site testing as described in the Oil Pollution Emergency Plan). Weathered oil may occur in a range of states from an emulsion (mousse) to solid tar balls, depending on oil properties and exposure to air, water, sun and sediments or organic particles
- unmitigated spill – a theoretical scenario where nothing is done to slow or stop the flow of oil from the well until the relief well is able to kill it and nothing is done to treat the spilled oil to minimise environmental harm. Note this is not a realistic scenario but is useful for comparative purposes.

7.7.8 Intervention and mitigation modelling

The worst-case discharge modelling basis and output has been included in the Oil Spill Modelling Study (Appendix 7-1, Rev 1). The modelling assumed an unrestricted, open hole, average continuous discharge of 8943 m3/day for 129 days with no mitigation, intervention or natural infill. The 129 day (tracked for 189 days) duration was based on initial estimates of the time required to drill a relief well. Subsequently, the logistics were re-assessed during As Low As Reasonably Practicable workshops and control measures were put in place to decrease the time to 102 days. However, the 129 days has been kept as a conservative worst case. The output from the stochastic runs was used to assess the risk to the environment (Section 7.7.12 and Appendix 7-5). The output from the deterministic worst-case discharge modelling was to develop the initial response needs analysis and plans and to for Financial Assurance estimates.

Equinor Australia B.V. will immediately employ a range of intervention measures to stop the flow of oil (potentially effective within one day), with multiple levels of contingency in case of failures of individual measures (e.g. multiple ways of closing the blowout preventer and capping stack to be used if the blowout preventer fails). Further, Equinor Australia B.V. would immediately take action to mitigate the effects of spilled oil. This would include mobilising vessels and aircraft capable of applying dispersants to the floating slick of fresh oil near the well and initiate application of subsurface dispersant injection equipment which would rapidly reduce the volume of oil reaching the sea surface. The subsurface dispersant injection works by breaking the oil into small droplets which become entrained in the deep-water column where they slowly rise and are degraded by natural processes including microbial breakdown.

Modelling the worst credible case discharge stochastic and deterministic runs with intervention and mitigation applied provides a realistic representation of the likely fate and trajectories of the spilled oil. This allows assessment of the predicted risk (with sequential intervention and mitigation measures in place) which is representative of the actual level of environmental effects that may occur. In addition, mitigation measures will be applied to protect sensitive areas closer to the coast. These would include containment and recovery actions using booms and skimmers to remove oil from the water surface, clean beaches to reduce accumulation of weathered oil, and oiled wildlife response. These have not been included in the assessment of predicted risk to provide a more conservative assessment and because their effectiveness cannot be accurately predicted hypothetically until the actual spill situation and trajectory is known, the state response agencies have initiated their spill response plans and specific weather and site conditions are known. Under the worst credible case discharge, there would be at least three weeks (P50 = 52 days; maximum = 96 days) in which this planning would be refined, and the response implemented; before first shoreline contact by highly weathered oil.

In the following sections, “mitigated” refers to the application of dispersants from aircraft (ramping up from Day 2) and by subsurface dispersant injection (from Day 9).

7.7.9 Biological effects thresholds used in spill modelling outputs

The maps showing the predicted extent of the oil spill, at the various relevant threshold levels (concentration and thickness) show coloured lines representing the outer extent of the area where nominated thresholds are exceeded. The area within the coloured contour lines are predicted to receive oil exposure above the relevant threshold values (as shown in figure legends) on at least one occasion during the spill; whereas the areas outside the lines do not ever reach those threshold values. This means that many areas within the mapped contour lines for oil on the sea surface or shoreline accumulations of oil may only be exposed to oil above the threshold value for one hour during the 162-day course of the modelling. This provides a

conservative approach to predicting the extent of possible exposure. When considering exposure of receptors to dissolved and entrained oil, the thresholds have been considered over a 96-hour period to match the conditions under which the thresholds were originally established in laboratory studies. This means that any area within the contour lines may be exposed to oil at or above the threshold concentration (as an average concentration) over 96 hours.

Tables of exposure loadings and probabilities in subsequent sections and in the Oil Spill Modelling Study (Appendix 7-1) are based on the same modelled dataset output as the figures (plots of spatial extent of oil) but are represented numerically instead of visually. These tables show exposure probabilities by sections of the coastline, to allow finer assessment of potential exposure in different areas (e.g. IMCRA and IBRA bioregions) and by important areas recognised under legislation (e.g. Australian Marine Parks, Key Ecological Features and Biologically Important Areas).

Exposure to dissolved and entrained components of the spill are better understood through ecotoxicity testing of different doses (concentrations) and different exposure times and widely accepted threshold levels have been set for biological effects of these hydrocarbon components. This is represented by exposure zones where certain threshold values (concentrations in ppb) are experienced for longer than the minimum exposure duration (96 hours). This relates the predicted dose-exposure in the model to accepted ecotoxicity levels eliciting biological responses.

The thresholds used to derive the spill contour plots and probability tables are described below. These are generic thresholds used to represent the extent of potential biological effects; a more site-specific assessment is provided for the main environmental values in the Risk Assessment section below. It is important to note that the threshold values relate primarily to fresh oil which has higher concentrations of volatile, short-chain hydrocarbons which are more toxic to biota (volatile organic analytes and polycyclic aromatic hydrocarbons). These compounds degrade rapidly while the remaining oil mixture continues to weather through natural biological and physical processes. In the modelling outputs, the fresh oil is defined as oil with >1% polycyclic aromatic hydrocarbons and is shown as a pale green contour line. The remaining oil shown in the plots is weathered oil with increasingly lower toxicity as it gets older and more degraded; this corresponds closely with distance from the well as the oil spreads out over time. The thresholds below, being based on fresh oil toxicity levels, are conservative when applied to highly weathered oil; however, there is considerable uncertainty in the actual level of toxicity of weathered oil because it has rarely been tested. It is therefore conservative to assume the same level of effects from weathered oil as from fresh oil and then assess the likely outcomes on a case by case basis for different receptors and situations.

Table 7.5 lists the low, moderate and high thresholds for sea surface loadings, Table 7.6 for dissolved aromatics, Table 7.7 for the entrained hydrocarbons and Table 7.8 for the shoreline loadings.

Table 7.5 Sea surface hydrocarbon threshold values

Thresholds (g/m^2)	Reference	Potential level of exposure	Appearance
1–10[1]	French-McCay (2009); French et al. (1996)	Low	Rainbow to metallic sheen
10*–25	(Koops et al. (2004); Scholten et al. (1996)	Moderate	Metallic sheen
>25	(Koops et al. (2004); Scholten et al. (1996)	High	Metallic sheen to continuous true oil colour

*10 g/m^2 also used to define the threshold for actionable sea surface oil; i.e. where effects may be reduced by intervention measures

Table 7.6 Dissolved aromatic hydrocarbon threshold values

Threshold in parts per billion (ppb)	Reference	Duration of exposure (hours)	Exposure (ppb.hrs)	Range of species potentially affected from acute exposure	Level of exposure
61–502	ANZECC (2000), French-McCay (2002) French-McCay (2002)	96	576–4800	Very sensitive species	Low
50–400	French-McCay (2002)	96	4800–38,400	Average sensitive species	Moderate
>400	French-McCay (2002)	96	>38,400	Tolerant sensitive species	High

Table 7.7 Entrained hydrocarbon threshold values

Threshold parts per billion (ppb)	Reference	Duration of exposure (hours)	Exposure (ppb.hrs)	Range of species potentially affected from acute exposure	Level of exposure
10	ANZECC (2000)	96	960	Highly sensitive species	Very low
70	ANZECC (2000)	96	6720	Very sensitive species	Low
100	ANZECC (2000)	96	9600	Average species	Moderate
500	ANZECC (2000)	96	48,000	Tolerant species	High

Table 7.8 Shoreline contact hydrocarbon threshold values

Oil thresholds on the shoreline (g/m^2)	Reference	Potential level of exposure	Appearance
10^1–100^2	French-McCay et al. (2005a, 2005b) Australian Maritime Safety Authority (2015)	Low	Stain/Film
100*–1000	(Grant et al. 1993; Lin & Mendelssohn 1996; Suprayogi & Murray 1999)	Moderate	Coat
>1000	(Grant et al. 1993; Lin & Mendelssohn 1996; Suprayogi & Murray 1999)	High	Cover

*100 g/m^2 also used to define the threshold for actionable shoreline oil; above this value additional intervention measures may be implemented

The thresholds all have low, moderate and high potential levels of exposure, which are designed to indicate potential for different levels of risk to biota at both individual and population levels. Table 7.9 describes a generic approach to the application of these thresholds.

Table 7.9 High-level guidance to exposure level effects on biota

Level of exposure or contact	Potential effects to individuals
Very low–Low	Unlikely to be any acute (short-term) or chronic (long-term effects, though some behavioural effects (e.g. avoidance) may be observed.
Moderate	Potential for chronic and recoverable effects; some potential for mortality
High	Potential for acute and greater degree of lethal toxic effects

7.7.10 Summary of scenarios

While unlikely, planned mitigation can fail on the day, and theoretically all subsequent mitigation could sequentially fail, but the chances of each successive failure are progressively unlikely. Equinor Australia B.V. would not undertake the drilling program without all the planned mitigation in place as described in Section 7.7. As such the scenario modelled to assess unmitigated risk has only been provided to show how the mitigation reduces the potential extent and duration of effects. Table 7.10 summarises the spill scenarios modelled in with a discussion of each in the sections following, explaining their relevance and what information was determined to aid the environmental assessment.

Note that the volumes of oil discharged daily under each scenario differ according to the duration of the event being considered. As the pressure of the well falls during a sustained loss of well control discharge, the daily discharge will decrease.

Comparisons between the mitigated cases using dispersants and unmitigated cases not using dispersants are discussed in Section 8. The worst-case discharge has been included as it represents a worst-case risk review of consequences to the environment as well as informing response planning as detailed in the Oil Pollution Emergency Plan (Appendix 9-1). The outputs of the modelling (Appendix 7-1, Rev 1) include maps of surface floating oil, in-water oil (dissolved and entrained) and oil ashore at various thresholds (Section 7.7.9).

Table 7.10 Summary of modelled oil spill scenarios used in risk assessment (revised)

	Flow of oil stopped by*	Description of scenario*	Average flow rate (m^3/day)	Duration (days)	Total release volume (m^3)	Appendix 7-1 scenario reference
Mitigated scenarios based on the worst-credible case discharge (WCCD)	Blowout preventer (BOP)	Surface dispersant applied from Day 2	7749	1	7749	Scenario 4
	Capping stack	Complete blowout preventer failure Surface dispersant applied from Day 2 SSDI from Day 9	7596	15	113,940	Scenario 3
	Relief well (RW)	Complete blowout preventer failure and capping stack fails in multiple attempts Surface dispersant applied from Day 2 SSDI from Day 9	6720	102	685,440	Scenario 2
Unmitigated scenario based on worst case discharge (WCD)	Relief well (RW)	Complete blowout preventer failure and capping stack fails in multiple attempts No dispersants used	8943	129	1,153,634	Scenario 1

7.7.10.1 Mitigated worst credible case discharge oil spill stochastic modelling outcomes

This section describes the potential extent of oil exposure of different receptors and values during the worst credible case discharge; occurring any time between October and May. It provides information to support assessment of the predicted level of risk from a worst credible case discharge oil spill for each scenario:

- blowout preventer successful in stopping spill on Day 1 (Appendix 7-1 modelling scenario 4)
- capping stack successful in stopping spill on Day 15 (Appendix 7-1 modelling scenario 3); if the blowout preventer closure was unsuccessful
- relief well (RW) successful in stopping spill on Day 102 (Appendix 7-1 modelling scenario 2); if the blowout preventer and capping stack closures were both unsuccessful.

Aerial dispersant is applied to fresh oil in offshore waters near the release site from Day 2 and is continued until there is no fresh oil present that is amenable to chemical dispersion. subsurface dispersant injection is applied from Day 9 and is continued until either the capping stack is successful on Day 15 or the relief well is successful on Day 102.

Other mitigation measures that have not been applied in the modelling, which would further reduce exposure of receptors, includes application of dispersants from offshore vessels, containment and recovery, shoreline protection and clean-up. This leads to a conservative prediction of exposure to spilled oil under each scenario.

The modelling of the three scenarios above is represented below by the deterministic run which results in the fastest contact with shorelines. This was selected as a conservative prediction of risks because this results in the freshest oil (and most toxic) reaching sensitive nearshore and coastal areas that could be expected during a single oil spill. Other deterministic runs would result in slower contact and hence the oil would be more weathered before it reached the shore. Under different runs the oil spill trajectory would differ; however, it is not predicted that there would be a greater degree of risk under any other runs. A comparison with the “P50” run (median value from a run in February, rather than P100 which is the worst run in late May) demonstrates the much lower exposure risk associated with a spill at that time.

The oil spill modelling outcomes show a substantial reduction in the volume of spilled oil with each successive mitigation step and the associated reduction in the spatial extent of oil exposure to sensitive areas and species. These modelled outcomes also show the effectiveness of dispersant application in reducing the extent of oil on the sea surface; thereby reducing the volume which eventually reaches sensitive shorelines.

Blowout preventer implemented successfully on Day 1

Under this scenario, there is a loss of well control and the blind shear ram of the blowout preventer is closed by remotely operated vehicle intervention, resulting in a complete shut-off of the well. We have reviewed various options and have concluded that we can reduce the risks to As Low As Reasonably Practicable by having a vessel with remotely operated vehicle capabilities in-field during the critical time; when penetrating the potential hydrocarbon reservoir (Appendix 7-4). This is in addition to any remotely operated vehicle capability on the mobile offshore drilling unit, in case the mobile offshore drilling unit is disabled by the incident. This provides contingency response support and greatly increases the likelihood of successful blowout preventer intervention.

The modelled surface exposure and shoreline accumulation are presented in Figure 7.5 and Figure 7.6 respectively. The zones shown in the figures represent the extent of the areas where the lowest biological or socio-economic effects thresholds are exceeded for floating oil on the sea surface and weathered oil washed ashore. The white contour in Figure 7.6 represents the low threshold where a visible sheen may be present at some time during the 162 days of the modelling duration. It would not have biological effects but may affect the socio-economic values of sensitive areas such as aquaculture sites and marine parks.

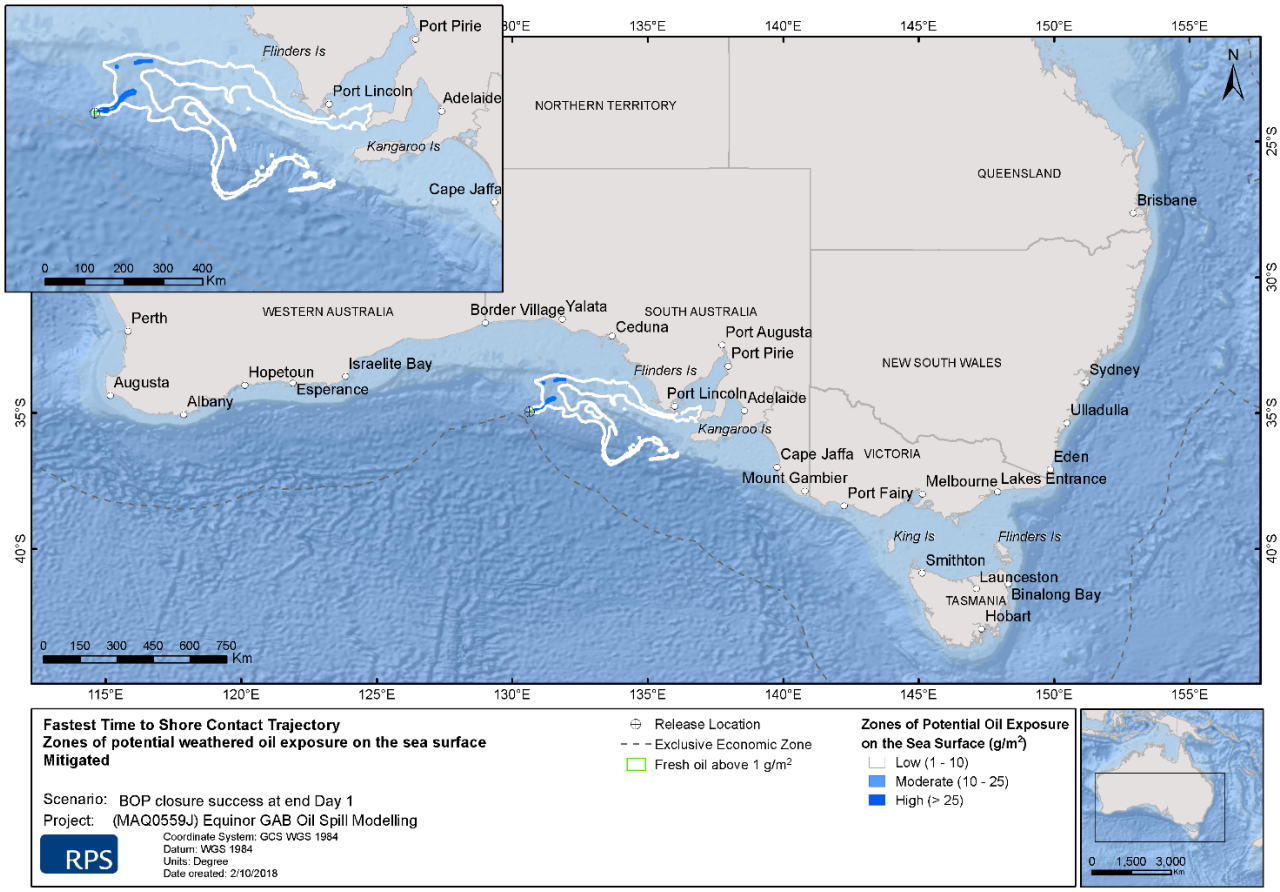


Figure 7.5 Mitigated worst credible case discharge sea surface oil exposure. Blowout preventer successful on Day 1, 7749 m³/day over 1 day, tracked for 45 days, based on fastest time to shore (May)

Figure 7.6 shows the distribution of weathered oil predicted to reach shorelines under the deterministic spill run which would reach the shore fastest. The maximum amount of weathered oil predicted to reach shorelines in this run, exceeds biological effects loadings (>100 g/m²) in a few areas on the Eyre and Yorke peninsulas and coastal islands.

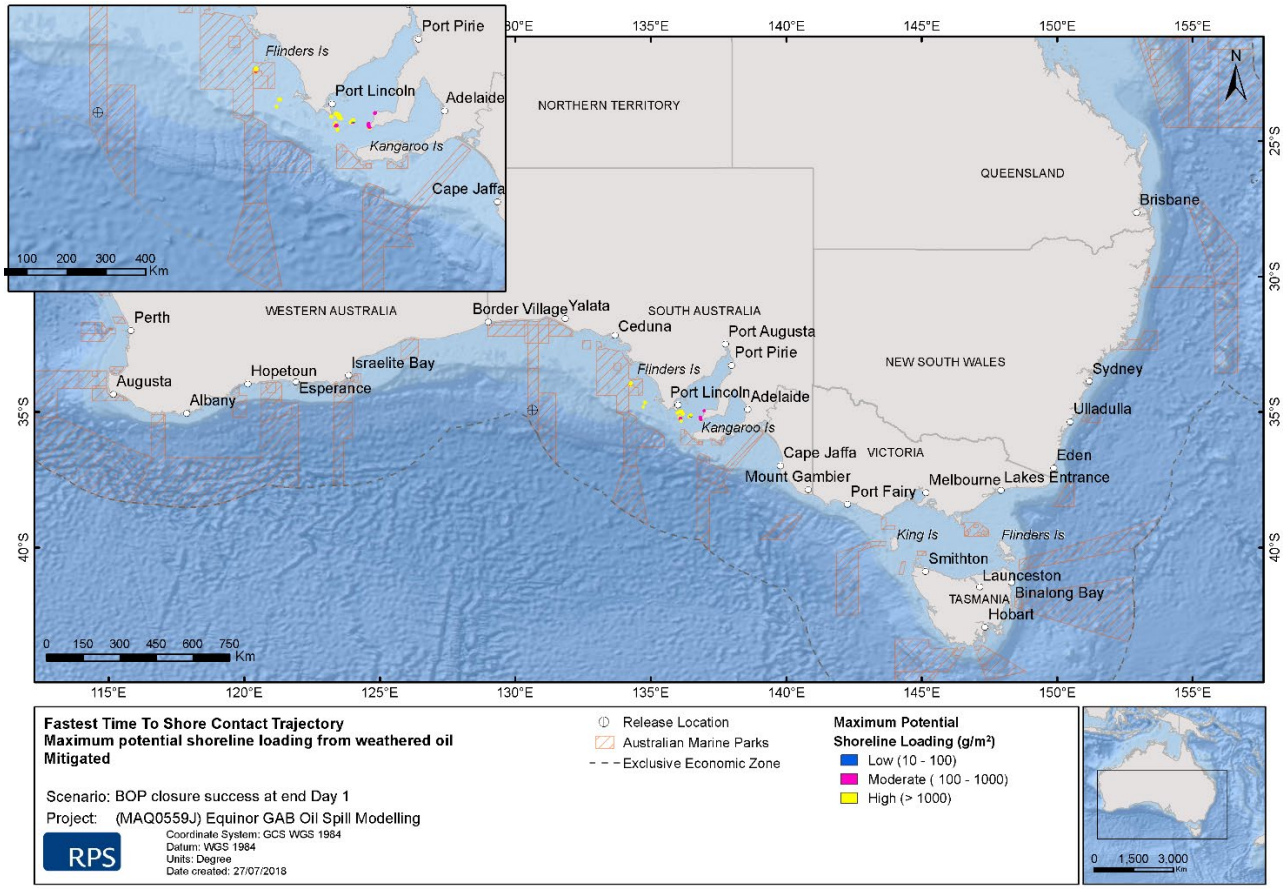


Figure 7.6 Mitigated worst credible case discharge shoreline loading. Blowout preventer successful on Day 1, 7749 m³/day over 1 day, tracked for 45 days, based on fastest time to shore (May)

Capping stack success on Day 15

If the blowout preventer cannot be closed by any of the alternative methods, Equinor Australia B.V. will start installing a capping stack. If successful, this would stop oil flowing within 15 days. The risks of an oil spill have been reduced to As Low As Reasonably Practicable by reducing the time required to install a capping stack (Appendix 7-4). Aerial dispersants would be applied from Day 2 and subsurface dispersant injection would commence from Day 9. Should the first attempt at installing the capping stack fail, we will repeatedly re-attempt the installation until successful or the well has been killed by a relief well.

The modelled sea surface exposure resulting from the 15-day spill run that results in the fastest shoreline contact for the period October–May and is stopped by a successful capping stack installation is shown in Figure 7.7. The fresh oil on the sea surface (green contours) remained within 100–200 km of the well. Low to moderate concentrations of weathered oil in nearshore surface waters were limited to oceanic waters off the South Australian coast and nearshore waters off the Eyre Peninsula.

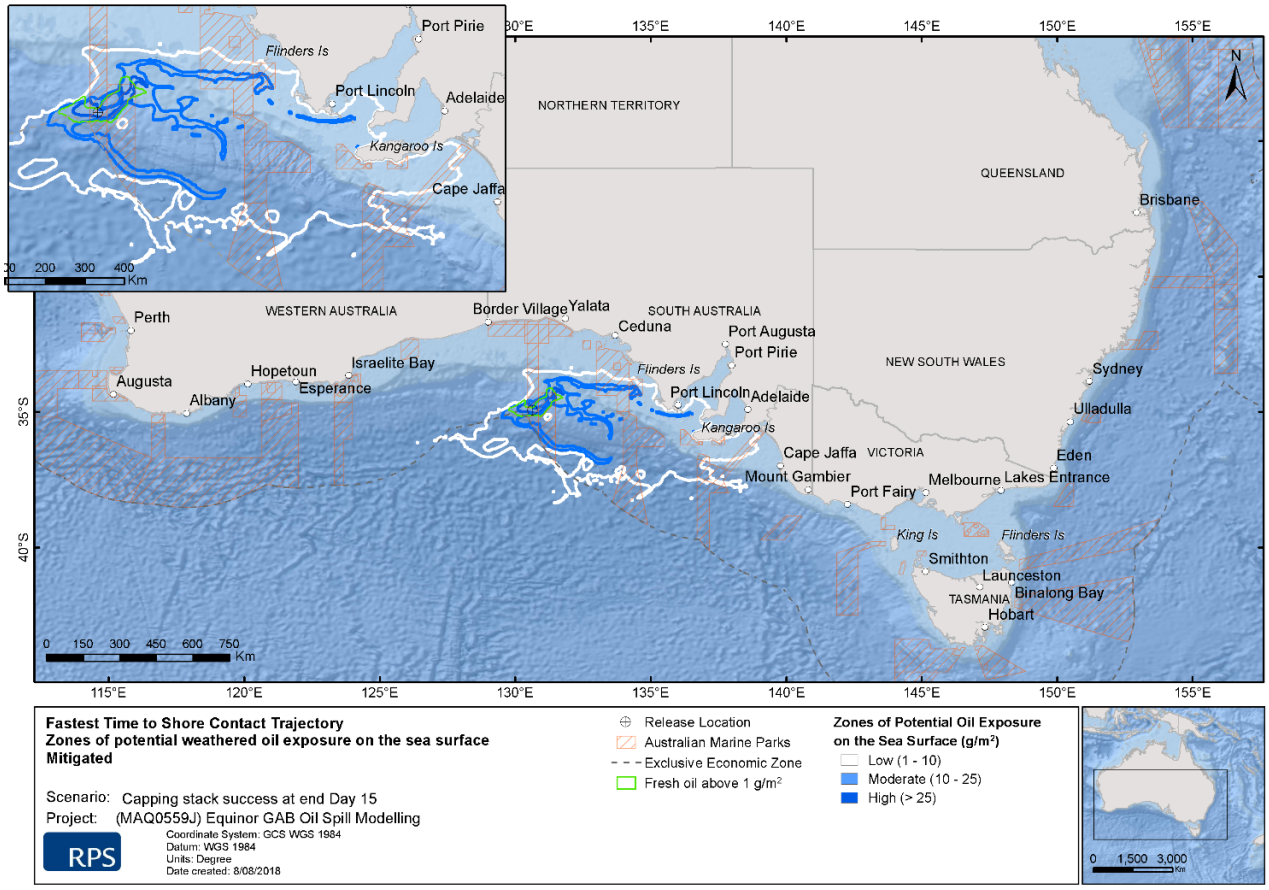


Figure 7.7 Mitigated worst credible case discharge sea surface exposure. Blowout preventer unsuccessful, capping stack successful on Day 15, 7596 m³/day over 15 days, tracked for 55 days, based on fastest time to shore (May)

With aerial and subsurface dispersant injection dispersant mitigation and the capping stack in place, the predicted extent of weathered oil contacting the shoreline was restricted to the South Australian coast; no contact was predicted for Victoria and Tasmania for this run. High shoreline loadings (>100 g/m²) were limited to the coast between Flinders Island and Kangaroo Island (Figure 7.8).

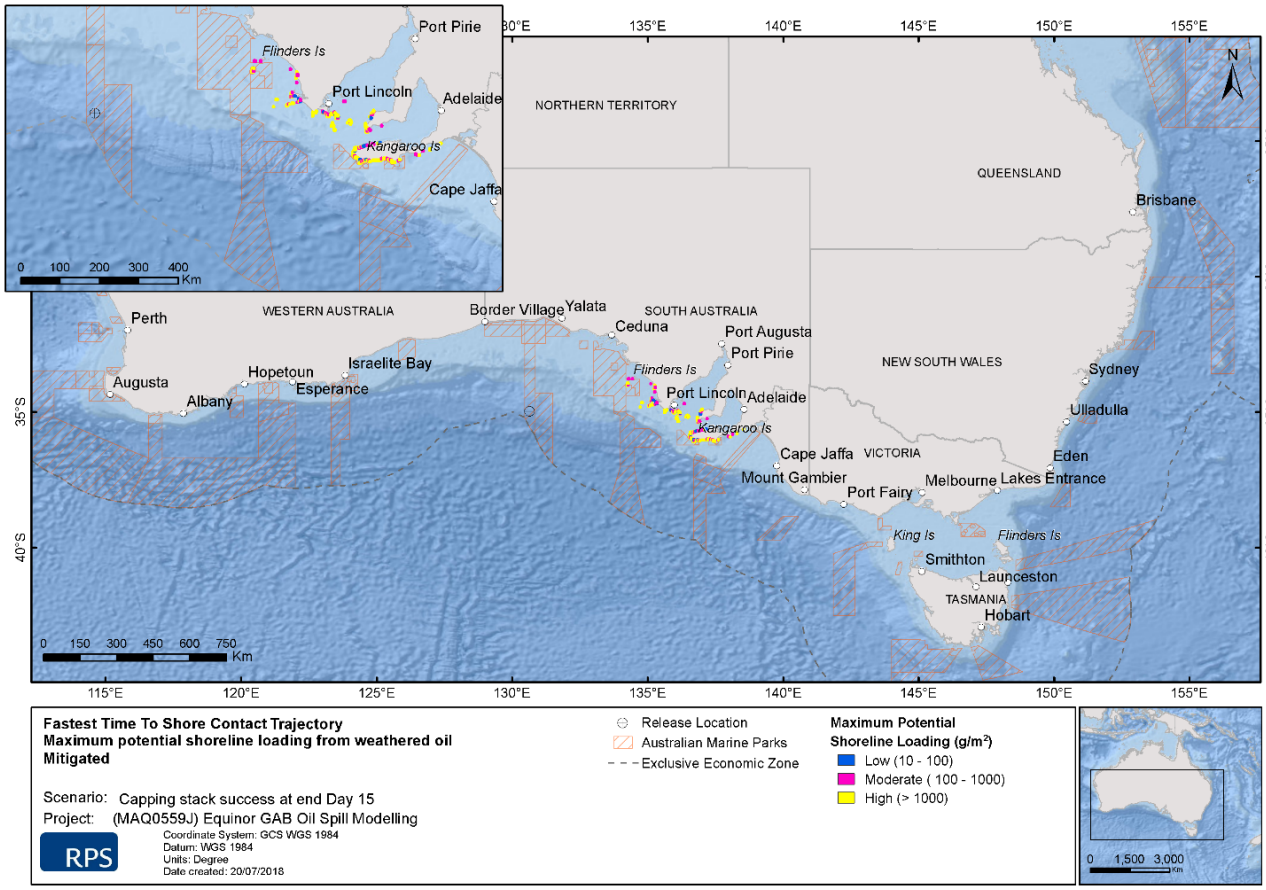
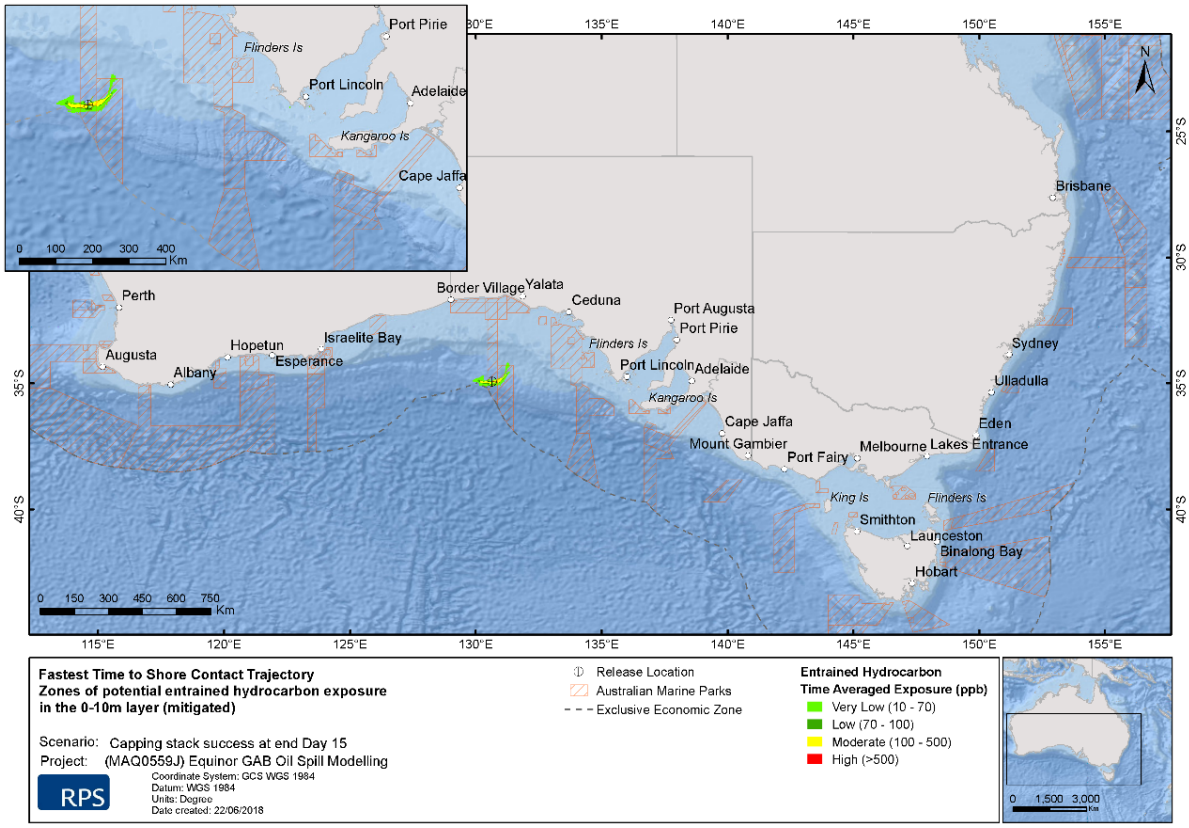


Figure 7.8 Mitigated worst credible case discharge shoreline contact. Blowout preventer unsuccessful, capping stack successful on Day 15, 7596 m³/day over 15 days, tracked for 55 days, based on fastest time to shore (May)

The plumes of the "water accommodated fraction" (dissolved and entrained hydrocarbons) over the course of the 55-day modelling run are shown in Figure 7.9 (lower images from Figure 99 and Figure 100 in Appendix 7-1). The plot shows the hydrocarbon plume in the surface waters (0–10 m below the sea surface) where it has risen from the depths and been dispersed from the surface. The predicted biological effects thresholds (moderate and high) are only exceeded within approximately 100 km of the well location.



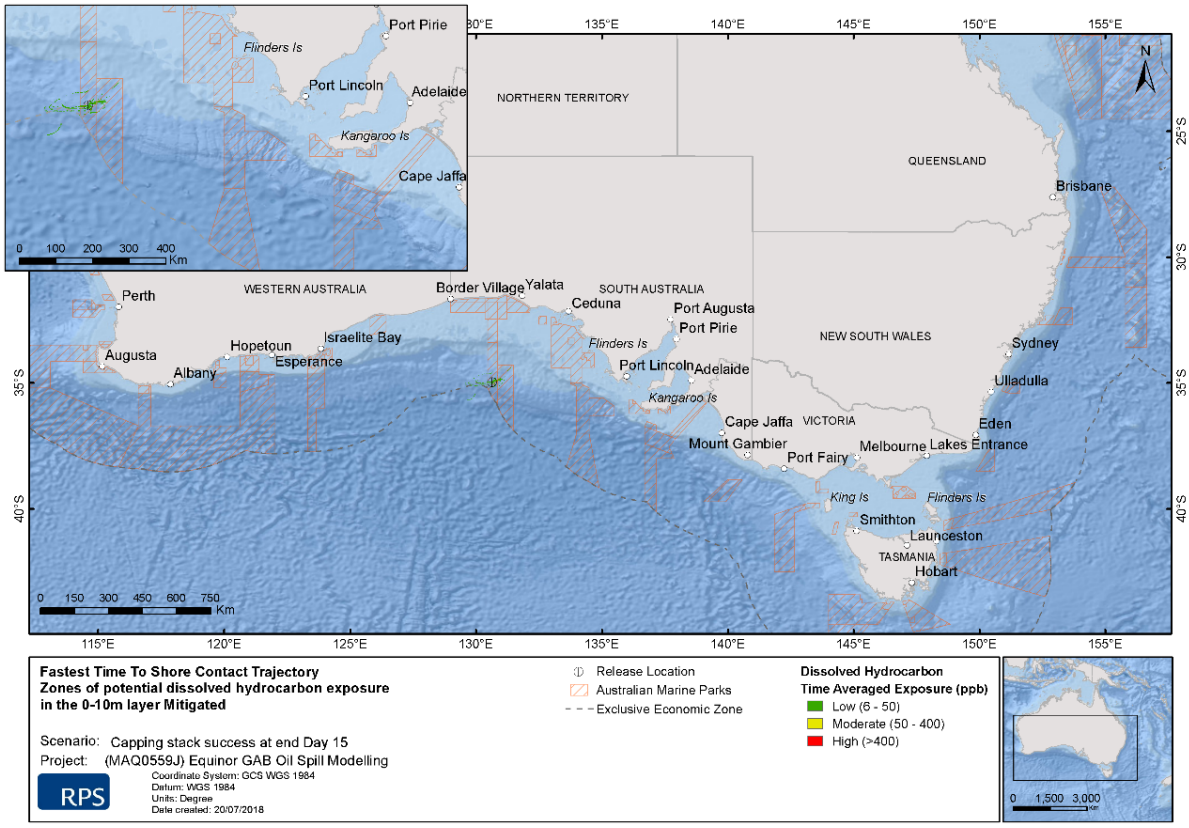


Figure 7.9 Mitigated worst credible case discharge entrained (top) and dissolved (bottom) hydrocarbon concentrations in surface waters (0–10 m). Capping stack successful on Day 15, 7596 m^3/day over 15 days, tracked for 55 days, based on fastest time to shore (May)

Relief well successful on day 102

In the highly unlikely event that the blowout preventer cannot be closed, and a capping stack cannot be installed, then the drilling of a relief well is the ultimate solution to a loss of well control situation. Preparations for drilling a relief well would be initiated immediately after a loss of well control leading to a major spill, in case the other intervention measures (blowout preventer and capping stack) both fail; this would reduce the lead time for drilling the relief well. The faster the relief well can be drilled, the smaller the volume of oil released and the lower the environmental effects; therefore, we have reduced the risks of an oil spill to As Low As Reasonably Practicable by reducing the time required to drill the relief well (Appendix 7-4).

Surface oil

The modelled extent of the slick of oil on the sea surface, resulting from the 102-day spill run resulting in the fastest contact with the shoreline is shown in Figure 7.10. This shows that a single spill would result in low concentrations of oil (<10 g/m^2) contacting the coast and nearshore and offshore waters from the Eyre Peninsula to southern Victoria. No fresh oil would reach coastal waters and floating oil at biological effects concentrations (>10 g/m^2) would be limited to waters of the Eyre Peninsula.

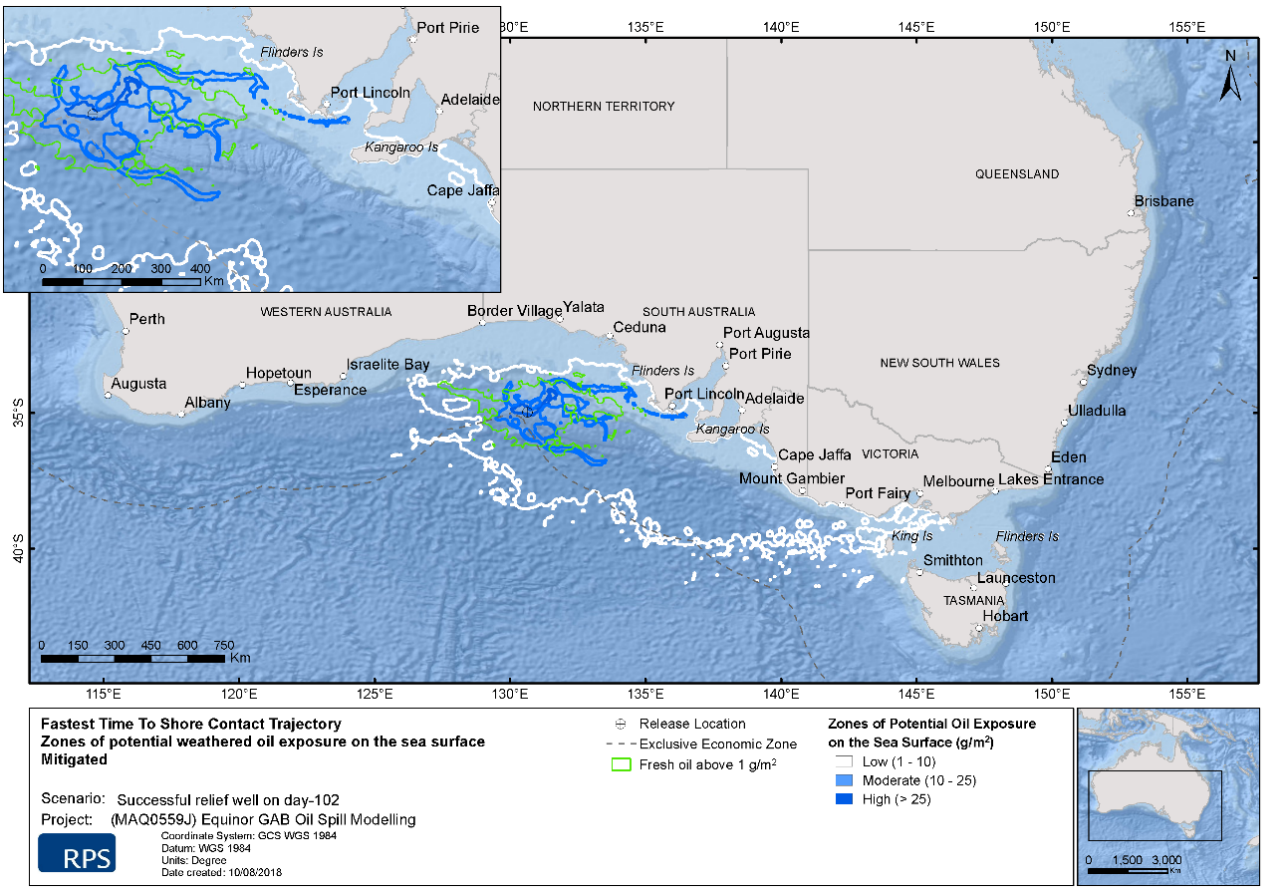


Figure 7.10 Mitigated worst credible case discharge sea surface exposure. Relief well successful on Day 102, 6720 m^3/day over 102 days, tracked for 162 days, based on fastest time to shore (May)

For comparison, a deterministic run from the preferred drilling period (November–February), is presented in Figure 7.11. The modelling shows that a 102-day spill in this period would result in lower exposure to surface oil for coastal receptors, with no surface oil above biological effects concentrations reaching coastal waters.

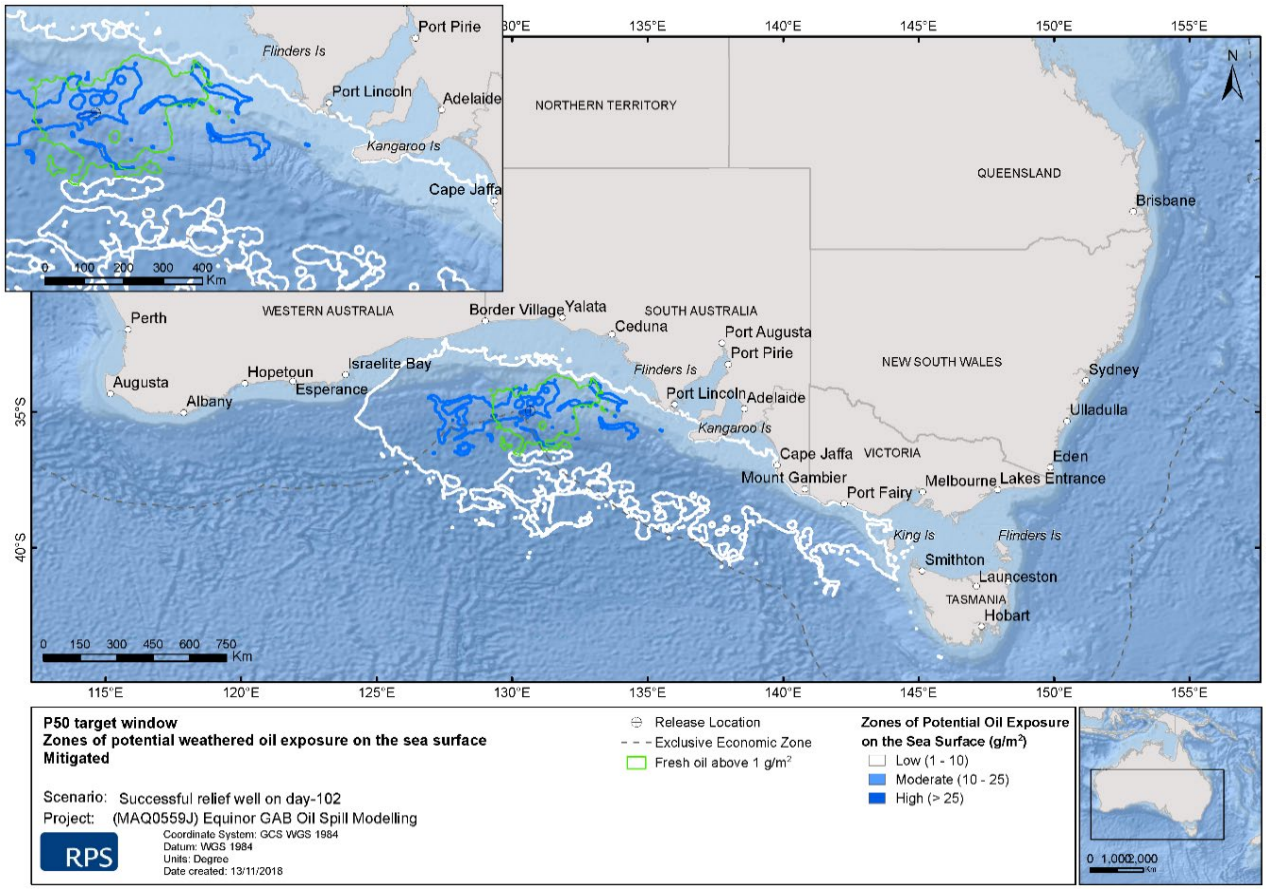


Figure 7.11 Mitigated worst credible case discharge sea surface exposure, based on 7 February 2009 deterministic run resulting in the median volume of weathered oil ashore during the preferred drilling window of Nov–Feb, average 6720 m³/day over 102 days, tracked for 162 days

Shoreline loading

Figure 7.12 shows the predicted shoreline loading of weathered oil for the worst credible case discharge mitigated case, based on the deterministic run with the fastest shoreline contact. Weathered oil at concentrations above the biological effect threshold (>10 g/m²) are predicted to contact shorelines at some time during the 162-day modelling run, from Eyre Peninsula to southern Victoria and north-west Tasmania.

The mitigated modelling run results predict a similar extent of exposure to the unmitigated case (Figure 56, Appendix 7-1), however, with a reduction in the level of shoreline loading or removal in certain areas, particularly from Border Village to Albany (west of the well); and Wilsons Promontory to Sydney (east of the well). There were also fewer eastern Tasmanian shorelines contacted by weathered oil.

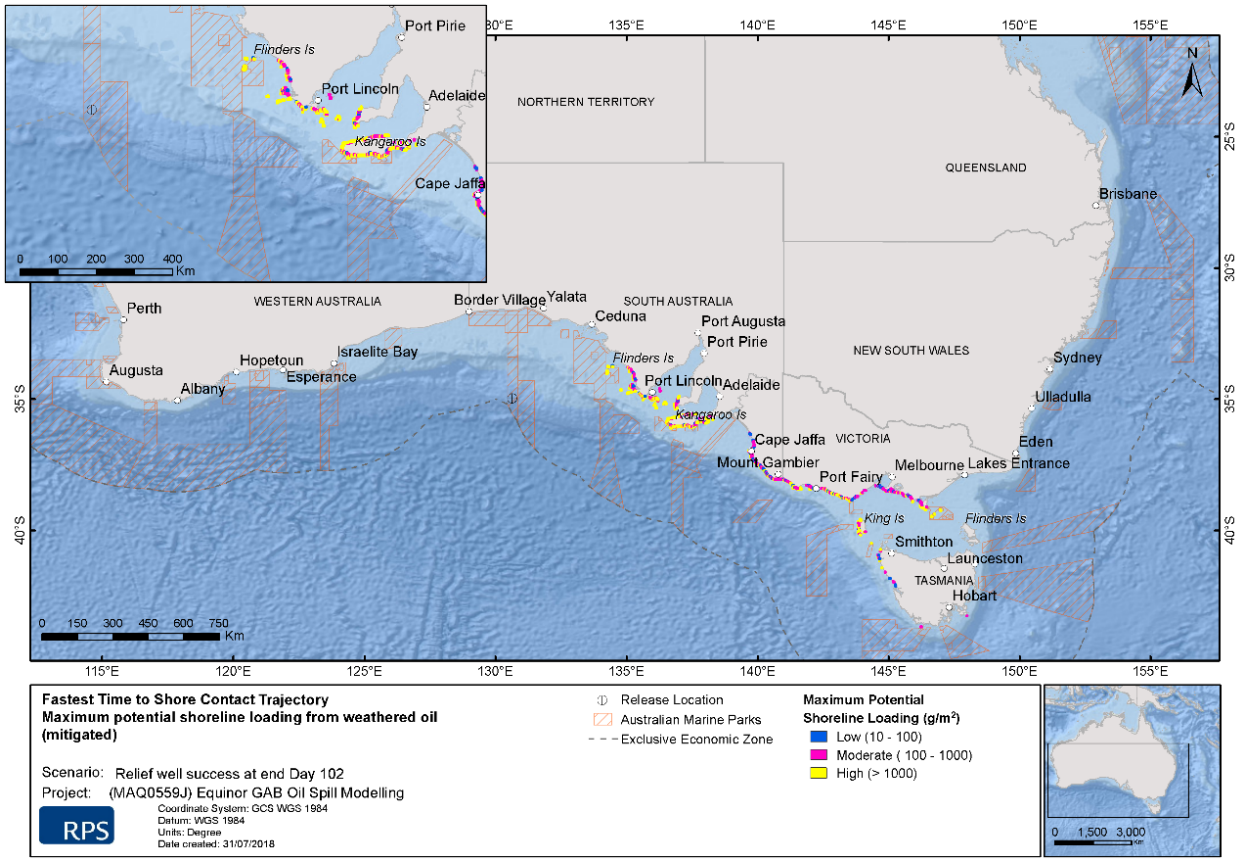


Figure 7.12 Mitigated worst credible case discharge maximum shoreline loading, average 6720 m³/day over 102 days, tracked for 162 days, based on fastest time to shore (May)

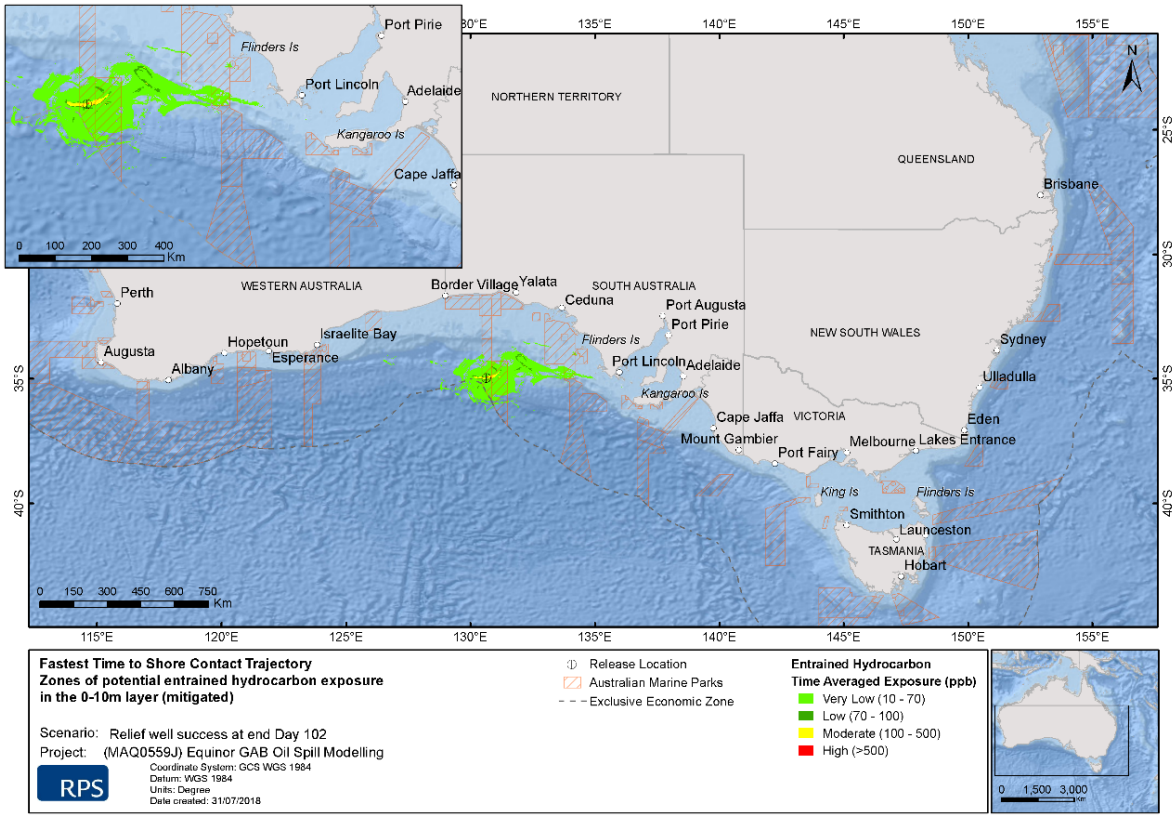
In-water oil exposure

Figure 7.13 (top) shows the predicted zones of entrained hydrocarbon exposure at the sea surface (0–10 m below the sea surface) for the mitigated worst credible case discharge scenario. The plot shows the results from the deterministic run with the fastest shoreline contact, which commenced in late May. Entrained oil at concentrations predicted to have an adverse biological effect (>100 ppb) is limited to an area of <100 km around the well and does not reach coastal waters or shorelines.

Plots of entrained oil concentrations integrated over greater depth ranges are included in the spill modelling report (Figure 49 and Figure 50; Appendix 7-1). Plots from the stochastic modelling of the entrained hydrocarbon plume at 80–100 m below the sea surface and over the 0–200 m depth range, show the entrained oil plumes with mitigation (dispersants applied) and without mitigation. The mitigated plumes of entrained oil are larger at all depths as a result of the aerial dispersants and subsurface dispersant injection causing a greater volume of oil to become entrained and to remain trapped deeper than 250 m below the sea surface (Figure 59 in Appendix 7-1).

Figure 7.13 (bottom) shows the potential exposure to dissolved hydrocarbons for the worst credible case discharge with mitigation until the relief well successfully kills the well at Day 102. The plot shows the results from the deterministic run with the fastest shoreline contact, which commenced in late May. Dissolved oil at concentrations predicted to have a moderate adverse biological effect (>50 ppb) is limited to an area of ~100 km around the well and does not reach coastal waters or shorelines. No dissolved hydrocarbon exposure at the moderate threshold is predicted to arrive in any of the state coastal waters, AMPs, Key Ecological Features or IMCRA meso-scale bioregions.

Plots of dissolved oil concentrations integrated over greater depth ranges are included in the spill modelling report (Figure 52 and Figure 53; Appendix 7-1). Plots from the stochastic modelling of the dissolved hydrocarbon plume at 80–100 m below the sea surface and over the 0–200 m depth range, show the dissolved oil plumes with mitigation (dispersants applied) and without mitigation. The mitigated plumes of dissolved oil are larger at 80–100 m below the surface but tend to be smaller in the surface 0–10 m, because of the dispersant application.



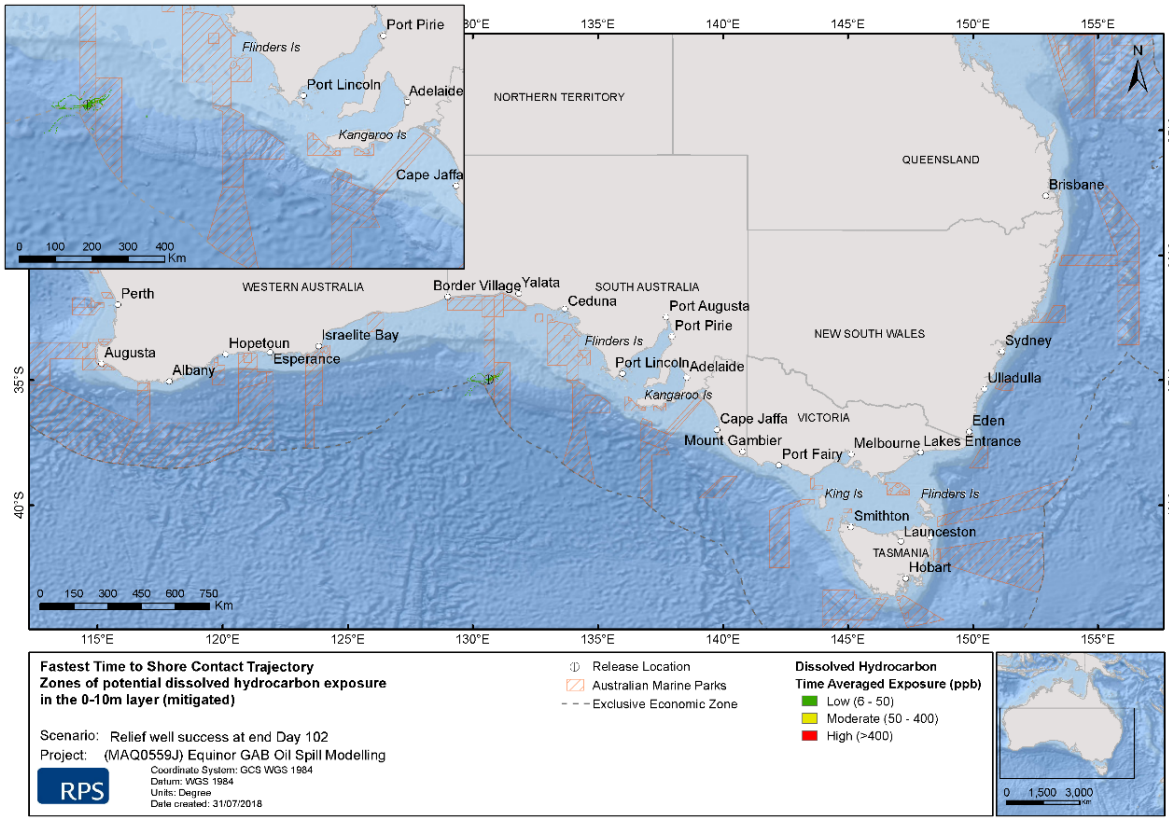


Figure 7.13 Mitigated worst credible case discharge entrained (top) and dissolved (bottom) hydrocarbons in surface waters (0–10 m). Relief well success on Day 102, Oct–May, 6720 m^3/day release over 102 days, tracked for 162 days, based on fastest time to shore (May)

7.7.11 Level of acceptable risk

The risk of a loss of well control will be acceptable if:

Factors in determining acceptability	Acceptability criteria
Internal context	Operations are compliant with relevant internal standards listed under Section 7.7.4 Risk treatment
	The planned well (design and associated operations) is demonstrably within technical capabilities of Equinor Australia B.V.
External context	The petroleum activity is consistent with government policies for resource exploitation
	There are no unaddressed objections or claims from relevant persons or raised during public comment period
Legislation and conventions	Compliance with legislation related to environmental risk in relation to loss of well control
Industry standards and practices	Consistent with good industry practices and standards for exploration drilling

7.7.12 Risk assessment

Appropriate assessment (see Section 5.0) requires determining the As Low As Reasonably Practicable decision context for a loss of well control and the assessment technique applied:

As Low As Reasonably Practicable decision context	Although exploration drilling is a well understood and implemented activity nationally and internationally and within Equinor Australia B.V.'s experience, there are risks given the nature of the activity and the associated uncertainties. Stromlo-1 will test a new geological play concept and although 13 wells have been drilled previously in this region, none were deemed prospective. Consequently, understanding the reservoir and hydrocarbon properties relies on detailed engineering practices and interpretation of geological and geophysical data. There has been significant relevant persons' interest in the risks associated with a major oil spill.
Assessment technique	Precautionary Approach – Decision Context C The precautionary approach has been applied in this risk assessment in the following ways: • Scientific uncertainty has been reduced by undertaking scientific baseline studies in the GAB. • Comprehensive oil spill modelling study has been undertaken. • Risk assessments are based on multiple oil spill scenarios and conservative assumptions where uncertainty remains. • Views of relevant persons have been considered.

The following risk assessment particularly focuses on EPBC-listed species and protected areas and predicts oiling effects in terms of population-level changes and restitution (recovery) times. Potential oiling effects to important ecological habitats and to socio-economic receptors are also discussed. The assessment should be read in conjunction with the appendices to this section:

- Appendix 7-1: Oil spill modelling study
- Appendix 7-2: Protected matters search tool report – Risk Environment that May Be Affected
- Appendix 7-3: Existing environment of Risk Environment that May Be Affected
- Appendix 7-4: Loss of well control As Low As Reasonably Practicable assessment
- Appendix 7-5: Risk assessment for unmitigated worst-case scenario.

All species are sensitive and vulnerable to some level of oiling, but some are at greater risk of population decline than others. This could be because their populations are already low; or are numbers are in decline due to human activities or environmental change; or have limited distributions and thus a large percentage of their population could be exposed to oil following a loss of well control. For these reasons, the effects of a loss of well control are described for the most vulnerable species rather than examining the potential effects on all individual species that might encounter oil. This is not a detailed evaluation for each species but an overview of the range of potential effects. In some cases, a range of assessments are presented where species status and seasonal presence differ considerably, or the logic behind coming up with the same overall category risk differs significantly.

Protected Matters are defined in Part 3 of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and described in Appendix 7-3 'Existing environment of the risk EMBA'. The Act lists Matters of National Environmental Significance (MNES) which have been determined for the Risk EMBA using the Protected Matters Search Tool (PMST). These matters comprise World Heritage Properties, National Heritage Places, Wetlands of International Importance, Listed Threatened Species and Communities, Listed Migratory Species, Commonwealth Marine Areas and additional matters protected under the EPBC Act (Commonwealth Land, Commonwealth Heritage Places, Listed Marine Species, Whales and other Cetaceans, Critical Habitats, Commonwealth Terrestrial Reserves and Commonwealth Marine Reserves of National Environmental Significance.

In addition to matters listed above, the following features were considered: legislated protected areas such as State Reserves, Nationally Important Wetlands, KEFs and TECs and Biologically Important Areas for protected species. The National Conservation Value Atlas (http://www.environment.gov.au/webgis-framework/apps/ncva/ncva.jsf) was also used as a search tool. The conservation status and IUCN protection category of an area were considered along with an assessment of any high conservation habitats and species.

Relevant guidelines (such as the Matters of National Environmental Significance Significant Impact Guidelines 1.1 *Environment Protection and Biodiversity Conservation Act 1999*, DoTE, 2013), threatened species recovery plans (e.g. the DoEE's Species Profile and Threats Database), plans of management (such as Commonwealth reserve management plans), management principles and other documents e.g. threat abatement plans and advice, published on the DoEE website in relation to matters protected under Part 3 of the EPBC Act.

The Protected Matters (PM) above and the following are considered throughout the risk review and into response planning (Section 9):

- commercial fisheries stocks and fishing areas using state and Commonwealth reports and consultation with fishery experts
- sensitivities identified within recent research such as the GAB Deep Marine Program and GAB Research Program
- consultation throughout the development of this EP
- receptors named within the states' oil spill plans.

The likelihood of each of the consequences described in the table below is related to the probability of the loss of well control leading to a Level 3 oil spill. The range of probabilities associated with the three source control outcomes are listed in Table 7.4 and fall within the same band of probabilities identified in the risk matrix in Section 5.0.

Sensitive receptors/ values
The following receptors may be exposed to varying amounts of fresh or weathered oil in the event of a loss of well control incident leading to a Level 3 oil spill: • marine and intertidal (shoreline) flora and fauna, including protected species • water quality • marine sediment quality • offshore air quality • coastal socio-economic receptors, such as recreational areas, fisheries, tourism operations, heritage and protected areas.

Risks

The range of potential effects depends on the distance of the receptor/value from the source and therefore how dispersed and weathered the oil is when it makes contact. Shorelines will not receive any oiling for at least three weeks, during which time oil will weather considerably and present a much lower threat of toxicity or smothering than fresh oil. Risk exposure to receptors/values includes through:

- potential toxicity effects to flora and fauna (and potentially spill responders) resulting from exposure to surface, sedimented, entrained and dissolved hydrocarbons
- potential coating and smothering of marine and shoreline flora and fauna from exposure to surface, entrained hydrocarbons and accumulation of hydrocarbons on shorelines
- potential human health, economic, social, amenity, aesthetic, heritage (including native title), research and environmental protection effects resulting from direct exposure to surface, dissolved and entrained hydrocarbons and accumulated hydrocarbons on shorelines; or resulting from effects to biota of socio-economic importance (e.g. fisheries).

Offshore air quality

Sensitivity

The likelihood of a 102-day spill resulting in a gaseous release is 1.9E-5 (Section 3.0). As no well has yet been drilled at the Stromlo-1 site, no accurate gas to oil ratio (GOR) is available. As the GOR will deplete over time, the Oil spill modelling study (Appendix 7-1) estimated the GOR to be roughly 122–129 m^3/m^3 i.e. 819,840–866,880 m^3 gas per day released from the seabed. Evaporation (especially of the lighter volatiles) will account for some of the gas loss to the atmosphere. Entrainment is increased through the use of sub-sea dispersants and will reduce the volume to atmosphere (see weathering and fate graphs, Figure 62, Appendix 7-1). Depending on the duration, such a release will result in local airshed degradation and contribute to the global GHG inventory.

Predicted effects in context of this event

Management of health and safety risks to offshore staff (vessels, MODU and response personnel) are detailed in the well operation management plan and safety case. Given the distance offshore (more than 370 km) and exposure to the open ocean winds (average 13–16 knots or variable direction), the gas release is not predicted to affect any coastal community or population centre. Transient seabirds including threatened and migratory species protected under the EPBC Act, may be exposed to elevated atmospheric hydrocarbons while directly in the gas plume, however, being highly mobile, they are largely able to avoid the area. Air breathing marine mammals and reptiles are discussed further below.

As such effects predicted are largely behavioural on an individual as opposed to population level. The overall consequence Category 1–3 (i.e. short-term effects on local populations with restitution times <1 month after cessation of the spill).

Seabirds

Sensitivity

Seabirds are those species of bird whose normal habitat and food source is derived from the sea, whether that be coastal, offshore or pelagic. Birds foraging at sea have the potential to directly interact with oil on the sea surface some considerable distance from breeding sites during normal foraging activities (e.g. albatrosses, petrels). Species most at risk include those that readily rest on the sea surface (such as shearwaters) and surface plunging species such as terns. As seabirds are top order predators, any effect on other marine life (e.g. fish kills) may disrupt and limit food supply both for adults and young.

In the case of seabirds, direct contact with hydrocarbons is likely to foul feathers, which may result in hypothermia due to a reduction in the ability of the bird to thermo-regulate and impair water-proofing. Direct contact with surface hydrocarbons may also result in dehydration, drowning and starvation (Australian Maritime Safety Authority 2013; DSEWPaC 2011b). The greatest vulnerability in this case occurs when birds are feeding or resting at the sea surface (Peakall et al. 1987).

Toxic effects of hydrocarbons on birds may result where the product is ingested as the bird attempts to preen its feathers. Whether this toxicity ultimately results in mortality will depend on the volume of hydrocarbons consumed and other factors relating to the health and sensitivity of the bird. Birds that are coated in oil also suffer from damage to external tissues including skin and eyes, as well as internal tissue irritation in their lungs and stomachs. Engelhardt (1982), Clark (1984), Geraci & St. Aubin (1988) and Jenssen (1994) indicated that the threshold thickness of oil that could impart a lethal dose to some intersecting wildlife individual is 10 µm (~10 g/m^2). Scholten et al. (1996) indicates that a layer 25 µm thick would be harmful for most birds that contact the slick.

There are many listed threatened bird species likely to occur over a wide geographic area in the GAB region and beyond. In the event of a loss of well control, these birds are potentially at risk of surface exposure. Birds are not likely to be significantly affected by in-water concentrations of hydrocarbons due to their limited exposure time in the water column.

Seabirds rafting, resting, diving, or feeding at sea have the potential to come into contact with surface oil at various exposure levels. If seabirds have a long duration of exposure to areas of heavy surface oiling, it is likely that some individuals may die as a result of this exposure. As many species forage at sea for prolonged periods (e.g. albatrosses),

or undergo seasonal migration, mortalities are not easily identified. It may therefore take several years to identify potential effects at the populations level, and scientific monitoring programs will take this into consideration (e.g. with direct input to design and termination of relevant monitoring plans from relevant state relevant persons in the OSMP Scientific Advisory Group (SAG)).

Predicted effects in context of this event

Many seabird species listed as threatened and/or migratory in the EPBC Act and those with BIAs within the area that may be affected by sea surface oil above 10 g/m^2 and shore loadings above 100 g/m^2. These are fully described in Appendix 7-3. Most species are abundant and have wide distributions throughout Australia. Three species have been assessed as representative of the seabirds to demonstrate the possible range of scale of effects: the little penguin (*Eudyptula minor),* the endemic shy albatross (*Thalassarche cauta*) and the short-tailed shearwater, or "muttonbird" (*Puffinus tenuirostris*).

In Australia, the distribution of the little penguin ranges from Perth, Western Australia to Tasmania and New South Wales. In South Australia, the status, abundance and distribution of this species is not fully known. The little penguin is not considered at risk globally, but some colonies are at risk on a regional scale (Cannell et al. 2016). However, (Evans et al. 2017) reported declines in the populations of two little penguin colonies found on the west side of the Eyre Peninsula. Declines in the status of this species has also been reported from Tasmania (Stevenson & Woehler 2007). This species has several traits that make it particularly vulnerable to a 102-day oil spill: the species does not fly and thus is consistently in contact with water when away from resting and breeding locations and; this species has strong attachment to its natal area (Colombelli-Négrel 2016). Consequently, birds are likely to retain a strong attachment to a site even if the site and adjacent waters are severely contaminated by oil. The Oil Spill Modelling Study indicated that weathered oil in concentrations >10 g/m^2, which are known to kill birds (French-McCay 2009; French et al. 1996), could potentially reach the South Australian mainland, Kangaroo Island and the western side of Bass Strait (Appendix 7-1). However, with the blowout preventer and capping stack applied and offshore dispersant applied, volumes of oil ashore are halved and number of sites affected reduced. As such, the effect of a 102-day mitigated release of oil could have a long-term consequence (restitution time 3–10) on the local populations of little penguins in Australia and consequence Category 6.

The shy albatross population in Australia (~ <17,000) is spread across three breeding colonies on islands off Tasmania (Appendix 7-3) – Albatross Island in the Bass Strait approximately 28 km off the north-west coast of Tasmania and Mewstone and Pedra Branca, both approximately 25 km off the south coast of Tasmania. A study by Brothers et al. (1997) indicated that the main foraging area for this species was over the south-eastern continental shelf of Australia, but within 200 km of the colony. (Hedd et al. 2001) found that during the incubation and chick-brooding periods, many birds from Albatross Island foraged extensively over the western side of Bass Strait.

The Oil Spill Modelling Study (Appendix 7-1) indicated that under a 102-day oil spill, low oil concentrations (1–10 g/m^2) could potentially reach waters surrounding Tasmania. However, concentrations >10 g/m^2, which could potentially have lethal effects on seabirds (French-McCay 2009; French et al. 1996) extend only as far east as the western side of Bass Strait and are not predicted to overlap with the 200 km foraging range of the albatross. Surface oil is therefore unlikely to affect albatrosses at a population level. Indirect effects through the ingestion of prey contaminated by entrained and dissolved oil may affect individual birds.

As with other species of albatross, the shy albatross is currently threatened by fishing activity (Thomson et al. 2015). Phillips et al. (2010) recorded over 40 albatross deaths in 2006 due to entanglement in long lines and nets.

Albatross Island is home to ~5000 pairs and lies about 1137 km away. Albatross forage ~<200 km from the nests in the waters west of north-west Tasmania during nesting. Whilst no surface oil >1 g/m^2/m^2 is forecast within 200 km of the colony, a small number of non-nesting individuals may be exposed to fresh oil while foraging further across the central GAB. The population on Albatross Island is considered stable whilst other populations are declining, or their status is unknown.

As such, consequences from a 102-day spill are likely to affect only a small number of individual foraging birds. Juveniles take ~10 years to reach maturity and usually only lay one egg every two years; therefore, population recovery would be slow; however, national (and regional) populations are expected to recover from loss of individuals over successive breeding seasons (three to 10-year period) and ranked as Category 6.

There are no actions described in this EP that hinder or contravene the objectives and actions contained in the National Recovery Plan for Threatened Albatrosses and Giant Petrels 2011–2016 (DSEWPaC 2011a).

Over 23 million short tailed shearwaters breed on ~ 285 coastal islands in south-east Australia and Tasmania, foraging in groups of up to ~20,000 birds. Hence large numbers could be exposed to fresh oil at one time, within their probably foraging range; however, the BIA for this species does not overlap areas where predicted surface loadings are predicted to exceed >10 mg/m^2. Approximately 200,000 short tailed shearwaters are harvested in Tasmania each year, and this harvest rate is considered sustainable for the population; therefore, loss of one or more large flocks of foraging birds could potentially be offset by a temporary closure of the shearwater harvest. Loss of 1–2 flocks of foraging birds resulting from a WCCD oil spill could result in large number of birds being affected but population level effects are unlikely and, given their rapid breeding rates and large population size, restitution is likely within 1–3 years and ranked as Category 5.

If the capping stack is successfully fitted on Day 15, the modelling shows the length and severity of shoreline loadings (hence number and extent of roosting sites potentially affected) and the extent and likelihood of exposure to sea surface oil, reduces substantially for all three species. Hence the risk consequences for all three are lowered by a category.

Should the blowout preventer be closed successfully on Day 1, effects are highly localised, temporary and likely to be limited to individuals rather than populations.

Species	Qualitative risk assessment for the planned mitigation scenarios		
	Relief well Day 102	CS fitted Day 15	BOP closed Day- 1
Little penguin	6*	5	1-3
Shy albatross	6*	5	1-3
Short tailed shearwater	5*	4	1-3

* When sea exposure contours of an oil spill during November–February were assessed, no known penguin roosting sites, shearwater BIA roosting sites (Tasmanian coastline or Bass Strait islands) or shy albatross BIA foraging areas (within 200 km of Albatross Island) are predicted to be exposed to sea surface oil above the low threshold. With capping stack success or blowout preventer success, no sites are exposed even to the low threshold. As such, consequence rankings can be reduced by one category.

Shorebirds

Sensitivity

Shorebirds are likely to be exposed to oil when it directly effects the intertidal zone and onshore due to their feeding habitats. Shorebird species foraging for invertebrates on exposed sand and mud flats at lower tides will be at potential risk of both direct effects through contamination of individual birds (ingestion or soiling of feathers) and indirect effects through ingestion of contaminated prey items and/or the contamination of foraging areas that may result in a reduction in available prey items (Clarke 2010).

Toxic effects of hydrocarbons on birds may also result where the oil is ingested during preening. Whether this toxicity ultimately results in mortality will depend on the volume of hydrocarbons consumed and other factors relating to the health and sensitivity of the bird. Birds that are coated in oil may also suffer from damage to external tissues including skin and eyes, as well as internal tissue irritation in their lungs and stomachs. Engelhardt (1982), Clark (1984), Geraci & St Aubin (1988) and Jenssen (1994) indicated that the threshold thickness of oil that could impart a lethal dose to some intersecting wildlife individual is 10 µm (~10 g/m^2). Scholten et al. (1996) indicates that a layer 25 µm thick would be harmful for most birds that contact an oil slick.

There are many listed threatened bird species likely to occur over a wide geographic area in the GAB region and beyond. In the event of a loss of well control, these birds are potentially at risk of surface and shoreline exposure. Birds are not likely to be significantly affected by in-water concentrations of hydrocarbons due to their limited exposure time in the water column. Shorebirds foraging for food in intertidal areas or along the high tide mark and splash zone, or who nest in coastal areas are most at risk of effects from exposure.

Predicted effects in context of this event

Shorebirds, also known as waders, inhabit intertidal areas of coastal and freshwater wetlands. As described fully in Appendix 7-3, shorebirds are principally found along the shores of beaches, estuaries, rock platforms and wetlands, where they feed mainly on invertebrates taken from mud and other soft substrates. Shorebirds typically have long legs in relation to their body size and do not swim. Thus, shorebirds are threatened by oil in different ways to seabirds. Whereas seabirds are at risk from surface oil when they dive beneath the surface to feed, shorebirds are at greatest risk from oil in shallow intertidal areas where they forage for food (Henkel et al. 2012). Henkel et al. (2012) noted that declines in shorebird populations were possible from oil, due to acute mortality as well as habitat modification and effect such as loss of intertidal invertebrate prey.

The shorebird, the eastern curlew (*Numenius madagascariensis*) is listed as critically endangered under the EPBC Act due to an ongoing decline of its population and loss of habitat. Like many shorebirds, this species does not swim and migrates between Australia and its breeding grounds in the northern hemisphere. Australia probably supports the greatest numbers of this species during the non-breeding period. In Australia, numbers of this species are reported to be declining at most sites where it is being monitored (Lilleyman et al. 2016). In the area potentially affected by the spill, this species has been reported from the western coast of Victoria, Bass Strait and Streaky Bay. The Oil Spill Modelling Study (Appendix 7-1) suggested that there is a risk of oil coming ashore at some of these locations during a mitigated oil spill, but the extent and severity is sequentially reduced through the implementation of the capping stack or the blowout preventer. Table 27 (Appendix 7-1) shows the probabilities of shoreline contact with weathered oil for state coastal waters and describes how probabilities for exposure to moderate thresholds of oil typically reduced with use of offshore dispersants (except for South Australia which remained at 100% probability with and without dispersants). Noticeably, the coastal waters of New South Wales probability of exposure to moderate thresholds dropped from 30% to 11%. While the modelling results indicated that some shoreline and tidal flats oiling could occur at concentrations >100 g/m^2 along some sections, the extent and likelihood of exposure in those areas are significantly reduced by the implementation of the capping stack on Day 15 and blowout preventer on Day 1.

The eastern curlew could be present in large numbers during drilling as they start to arrive on the east coast from September to November and most leave the east coast again from late February to March. As such, concentrations are predicted to potentially have severe effects in some areas to some populations (the east coast populations are unlikely to be affected to the same degree as the South Australian population).

For reasons described above, the effect of a 102-day release of oil could have a long-term consequence (restitution time

3–10 years and ranked Category 6) on the regional population of the eastern curlew and other similar threatened migratory shorebirds. If the capping stack is successfully fitted on Day 15, the modelling shows the length and severity of shoreline loadings (hence number and extent of roosting sites potentially affected) reduces substantially and only weathered oil may affect isolated sections of coast where shorebirds may forage or breed. Hence the risk consequences are lowered by two risk categories. Should the blowout preventer be closed successfully on Day 1, effects are predicted to highly localised and limited to individuals rather than populations.

Species	Qualitative risk assessment for the planned mitigation scenarios		
	Relief well Day 102	CS fitted Day 15	BOP closed Day- 1
Eastern curlew	6*	4	1-3

* When the mass balance for an oil spill during November–February were assessed for a mitigated 102-day spill, 18,729 m^3 of weathered oil is predicted to come ashore compared to 48,256 m^3 for the greatest volume ashore during a spill in May. As such the probability to exposure to moderate and high weathered oil loading thresholds for coastlines where curlews may be foraging and nesting is reduced, and the consequence is reduced by one category to 5.

In addition, further mitigation will be assessed and where appropriate (e.g. sheltered bays close to known breeding sites and roosts) instigated such as the provision and use of containment and recovery measures (e.g. booms and vacuums) and oil wildlife response as detailed in Section 8.

Marine reptiles

Sensitivity

Marine reptiles (including turtles) are potentially directly affected by the toxicity of in-water and surface hydrocarbons through ingestion, volatile organic compounds through inhalation, as well as potentially suffering from effects of physical contact with surface hydrocarbons.

During the Macondo spill in the Gulf of Mexico, many marine turtles were collected. Many of the live turtles collected were visibly oiled, however the majority of these recovered and were released back into the environment. However, conservative thresholds of 10 g/m^2 sea surface oil are suggested based on the lowest concentrations that may cause effects on other wildlife.

While there are five turtle species listed under the EPBC Act as potentially occurring in area that may be affected, they are not noted to reside in the area in significant numbers. There are no known aggregations or nesting beaches along coasts that could be affected by shoreline loadings.

Predicted effects in context of this event

Five species of marine turtles were identified in the PMST report as potentially occurring in the region (Appendix 7-2). The yellow-bellied sea snake (*Pelamis platurus*) may also be present in the area that may be exposed to oil above 10 g/m^2 sea surface oil, but most species are likely to be vagrants from tropical regions. None are known to reproduce and or aggregate in the area and there are no turtle nesting beaches in southern Australia or reptile BIA in the region. Although a mitigated loss of well control may affect individuals of these species, it is unlikely to result in population-level responses or reduce the area of occupancy of the species in the region and ranked Category 1–3. The extent of potential effects is reduced further to highly localised and temporary – should the capping stack be fitted successfully by Day 15 or the blowout preventer closed successfully on Day 1.

Species/Receptors	Qualitative risk assessment for the planned mitigation scenarios		
	Relief well Day 102	CS fitted Day 15	BOP closed Day 1
Turtles and sea snakes	1-3	1-3	1-3

Plankton

Sensitivity

Plankton has the potential to be directly affected by in-water hydrocarbons as a result of toxicity effects. Oil can affect the rate of photosynthesis and inhibit growth in phytoplankton, depending on the concentration range. For example, photosynthesis is stimulated by low concentrations of oil in the water column (10–30 ppb) but becomes progressively inhibited above 50 ppb. Conversely, photosynthesis can be stimulated below 100 ppb for exposure to weathered oil (González et al. 2009). The threshold of 70 ppb for in-water hydrocarbons is considered appropriate given the variability in the levels at which phytoplankton is affected. In addition, the potential for effects to photosynthesis from shading caused by continuous surface slicks may also be a consideration, though a prolonged surface coverage over an extensive area would be required. A process identified at many sites during the Macondo spill should also be considered. Plankton and other surface material were found to be sinking at rates of more than 10 times the normal level. It was hypothesised that the weathered spilled oil catalysed clumping of organic particles (Schrope 2013). It is currently unclear as to whether this effect was caused by the chemical characteristics of the weathered oil, or a bacterial effect.

The ecological implications of a potential reduction in productivity and/or loss of phytoplankton include localised reduction in feeding opportunities for planktivores, loss of a proportion of the annual recruitment potential (through loss of planktivorous larval stages) and survival rates of organisms with planktonic larval stages due to developmental abnormalities to e.g. spine deformities and brain development/impairment of higher-order cognitive function in

ichthyoplankton (Johansen et al. 2017).

Reproduction by survivors or dispersion from unaffected areas (via sea surface currents) would be likely to rapidly replenish any losses from permanent zooplankton (Abbriano et al. 2011). Plankton have life cycles based on rapid reproduction with levels of high productivity. It is also in the nature of plankton to be dispersive – it is why many benthic taxa have adopted a pelagic early life history stage to increase dispersion via a vector with a consistent food supply. Field observations from oil spills have shown minimal or transient effects on marine plankton (Abbriano et al. 2011). Once background water quality conditions have re-established, the plankton community will take weeks to months to recover (ITOPF 2011), allowing for seasonal influences on the assemblage characteristics. Plankton found in open waters of the exposure zone is expected to be widely represented within waters of the wider GAB region and generally across all waters in the southern offshore region, which aids in the re-establishment of communities.

Predicted effects in context of this event

Central GAB slope and offshore waters were sampled for plankton during the GAB Research Program. Highest concentrations of chlorophyll-a (used as an indicator of phytoplankton abundance) occurred at depths of 60 m (0.43 ug/L) at the 200 m and 400 m isobaths. Chlorophyll-a declined with distance from the shelf edge to low concentrations (0.19 ug/L) at stations at the 1000 m and 2000 m isobaths. A study of the western GAB during summer found that zooplankton biomass was only 2% of that in the Gulf of Carpentaria, with other research indicating that the zooplankton assemblage is dominated by small copepods, meroplanktonic larvae and cladocerans (McLeay et al. 2003). Copepods and Appendicularia were dominant in shelf and offshore waters in the central GAB (Kloser et al.2017).

The Stromlo-1 well location is in 2200 m water depth. An oil spill would therefore result in potential exposure of plankton to high thresholds of dissolved and entrained hydrocarbons in the shelf and offshore waters of the central/eastern GAB (Appendix 7-1). However, the area of direct exposure between plankton and dissolved/entrained hydrocarbons is likely to be off the shelf edge. Plankton are at their highest concentrations below surface waters (e.g. 60 m water depth for phytoplankton during the day) and undertake a vertical migration patterns which would likely reduce their potential for (and duration of) exposure to dissolved and entrained hydrocarbons in comparison to surface waters (0–10 m) hydrocarbon exposure. Offshore dispersant use will increase exposure to entrained and dissolved hydrocarbons.

However, should a proportion of the plankton population be affected by a 102-day oil spill, then the rapid rate of reproduction and tidal mixing are likely to result in a short restitution period. The risk to plankton at the regional scale is therefore predicted to be Category 5 (short term effects on regional populations of regional importance, <1-year restitution time) with potential effects on the food web recognised.

The risk exposure is reduced substantially in areal extent and duration for the scenarios where a capping stack is implemented successfully on Day 15 and the blowout preventer fitted on Day 1.

Species	Qualitative risk assessment for the planned mitigation scenarios		
	Relief Well Day 102	CS fitted Day 15	BOP closed Day 1
Plankton	5	4	1–3

Bony fishes and sharks

Sensitivity

Most adult fishes in the GAB region, including sharks, tend to remain in the mid-pelagic or demersal zones and are likely to encounter in-water hydrocarbons rather than surface hydrocarbons. External exposure, ingestion or absorption of hydrocarbons in the water column from ventilation is possible for many species of adults and juveniles; however generally these species are highly mobile and as such are not likely to suffer extended exposure.

Shallow inshore species are less likely to be able to move away from in-water hydrocarbons and hence may be exposed for longer periods (e.g. up to a few days near Kangaroo Island and Port Lincoln). As fish are most vulnerable to hydrocarbons during their embryonic, larval and juvenile life stages, nursery areas are more likely to suffer developmental effects, morbidity and/or mortality at the lower concentrations.

Shallow inshore fish species include various syngnathids (seahorses, pipefish, pipehorses and seadragons) that are categorised as “listed marine species” under the EPBC Act. Some syngnathid species may occur in water depths from just beneath the surface to up to 50–100 m or with rafts of floating seaweed. However, surface species are potentially more at risk of exposure to weathered surface oils and may suffer effects. Syngnathids are highly unlikely to be found within the around the well location given the deep waters and lack of suitable protective habitat.

Species of commercial value, including the southern bluefin tuna (*Thunnus maccoyii*), are known to be present in the area (see “Socio-economic” below).

The great white shark (*Carcharodon carcharias*), which is listed as Vulnerable under the EPBC Act, is more likely to be found foraging in near shore waters or waters to the south-east around Tasmania and in Bass Straits.

Small pelagic species including sardines are a value of the GAB Commonwealth Marine Reserve. This species is widespread throughout GAB and aggregations are not spatially defined.

Listed migratory fish species in the GAB are the porbeagle shark (*Lamna nasus*), the giant manta ray (*Manta birostris*) and the whale shark (*Rhincodon typus*). These species are widely distributed and similarly no critical habitat for these species is identified within the exposure area. While individuals may be affected by hydrocarbons, significant effects to

these species are not considered likely.

Predicted effects in context of this event

Most bony fish and shark species found in the areas of elevated hydrocarbons above low thresholds have extensive distributions across temperate Australia or even further. However, the contours delineating the moderate and high thresholds of surface, entrained and dissolved oil overly the distributions of several fish species listed as threatened and/or migratory under the EPBC Act. These are fully described in Appendix 7-2. Large-scale population level effects following a loss of well control on fish species, abundances or assemblage composition would be unlikely due to the wide geographical distribution of many fishes of the GAB and the potential for rapid re-colonisation. Further, the modelling report (Appendix 7-1) predicts that zones of entrained and dissolved oils following a loss of well control would not extend far from Stromlo-1. No AMPs or KEFs (including those noted as important fish habitats), were predicted to experience exposure to entrained oil at or above the moderate threshold. For instance, entrained oil at moderate concentrations (100–500 ppb) would largely remain within roughly 200 km of the well (Figure 50, Appendix 7-1). Similarly, moderate levels (50–400 ppb) of dissolved oil would remain within approximately 100 km of Stromol-1 for the 0–200 m water depth (Figure 53, Appendix 7-1, (RPS:2018)). The potentially affected areas rapidly reduce in extent and duration with the implementation of the capping stack and blowout preventer.

Despite their highly restricted distributions, the critically endangered or vulnerable handfishes (*Brachionichthys hirsutus*, *Brachiopsilus ziebelli* and *Thymichthys politus*) (Appendix 7-3) are not considered to be at risk from a loss of well control associated with Stomolo-1. This is because the habitats of all three species are not predicted to be contacted by elevated concentrations of entrained or dissolved oil (Appendix 7-1).

Pelagic species, such as the shortfin mako and porbeagle, and possibly the great white shark, are at greatest risk of being exposed to oil following a loss of well control given their wide foraging areas and risks of consuming contaminated prey. Great whites are known to aggregate near Corner Inlet-90 Mile beach off eastern Victoria as well as around seal colonies. Philopatric characteristics means they may return to the place of birth to breed even if habitats are contaminated. These species are distributed worldwide and thus are unlikely to suffer ecologically important declines in their abundances following a loss of well control. However, taking a conservative approach, they are apex predators so short term (<1 year) effects on regional populations may occur.

There are no actions described in this EP that hinder or contravene the objectives and actions contained in the Recovery Plan for the White Shark (*Carcharodon carcharias*) (DSEWPaC 2013a).

For reasons discussed above the consequences of a 102-day loss of well control on sharks including great whites, could have medium term effects on local populations (related economic effects to fisheries are discussed elsewhere) and ranked Category 5.

If the capping stack is successfully fitted on Day 15, the model output predicts that the extent and concentrations of in-water hydrocarbons and surface oil will be substantially reduced, thus lowering the exposure risk for sharks and most other fish, hence consequence ranking from Category 5 to 4.

Should the blowout preventer be closed successfully on Day 1, risks to sharks are at worst highly localised and temporary and likely to be limited to individuals rather than populations. Potential effects to schools of both pelagic and demersal fish are confined to the immediate vicinity of the MODU and ranked Category 1–3.

No presence of elevated hydrocarbons at deleterious levels is predicted in areas where handfish are likely to be found.

Species/Receptor	Qualitative risk assessment for the planned mitigation scenarios		
	Relief well Day 102	CS fitted Day 15	BOP closed Day 1
Great white shark	5*	4	1–3
Handfish	1–3	1–3	1–3

* When sea exposure contours for an oil spill during November and February was assessed, no known nursery or foraging sites for the white shark such as Corner Inlet off Gippsland were identified as being exposed to sea surface oil even at a low (possible exception of the south coast of Kangaroo island under certain conditions) or any elevated entrained or dissolved oil. Known distribution sites may still be exposed to low levels of surface oil and as such the consequence can be reduced one category to category 4.

In addition, further mitigation will be assessed and where appropriate (e.g. sheltered bays close to known nurseries) instigated such as the provision and use of containment and recovery measures (e.g. booms and vacuums) and oil wildlife response as detailed in Section 8.

Marine mammals – pinnipeds

Sensitivity

Pinnipeds (seals and sea lions) are directly at risk from effects associated with the exposure to surface and shoreline hydrocarbons, particularly given they spend much of their time on or near the sea surface to breathe, and regularly haul out on to beaches. Pinnipeds are also sensitive as they will stay near established colonies and haul-out areas, meaning they are less likely to practice avoidance behaviours. A likely ingestion pathway for pinnipeds is through grooming of oil from fur, which can result from interaction with a range of different weathered stages, possibly ranging from fresh oil (if foraging >200 km offshore) to tar balls encountered at haul-out areas.

As a result of exposure to surface oils, pinnipeds, with their relatively large, protruding, eyes are particularly vulnerable to

effects such as irritation to mucous membranes that surround the eyes and line the oral cavity, respiratory surfaces, anal and urogenital orifices.

For some pinnipeds, fur is an effective thermal barrier because it traps air and repels water and as such oiling can have significant effects to this function if foraging in areas with fresh oil. The oiling effect from weathered oil is unknown.

The Long-Term Environmental Impact and Recovery report for the Iron Barren oil spill (Tasmanian SMPC 1999) concluded that "the numbers of pups born at Tenth Island in 1995 was reduced when compared to previous years. There was a strong relationship between the productivity of the seal colonies and the proximity of the islands to the oil spill wherein the islands close to the spill received fresher oil and showed reduced pup production and those islands more distant to the oil spill did not".

Australian sea lions (*Neophoca cinerea*) have "naturally poor recovery abilities" (TSSC 2005). Due to the extreme philopatry of females and limited dispersal of males between breeding colonies, the removal of only a few individuals annually may increase the likelihood of decline and potentially lead to the extinction of some of the smaller colonies.

There are three pinniped species recorded under the EPBC Act as potentially occurring within the contours of low, moderate and high thresholds for surface oil and shore loading of weathered oil. The Australian sea lion is listed as vulnerable and known to breed within the areas. A Recovery Plan is in place for the Australian sea lion which requires the evaluation of the risk of an oil spill on this species and appropriate mitigations in place.

Australian sea lions are endemic to Australia, found only in South Australia and Western Australia (Gillanders et al. 2013). The distribution of the species extends from the Houtman Abrolhos Islands on the West Australian west coast through the Pages Islands to the east of Kangaroo Island in South Australia (DSEWPaC 2013b), with aggregations more likely to be found on the rocks and sandy beaches on sheltered sides of islands.

There are many sites considered to be critical habitats and only eight sites produce more than 100 pups per season, these being North and South Page islands, Seal Bay on Kangaroo Island, Dangerous Reef (supports the third-largest breeding population in the world), Lewis Island, West Waldegrave Island, Olive Island and Purdie Island, all of which are in South Australia (Edyvane 1999; P.J. Rogers et al. 2013).

Both the long-nosed or New Zealand fur-seal (*Arctocephalus forsteri*) and the Australian fur-seal (*Arctocephalus pusillus doriferus*) are listed marine species with habitat and breeding sites known to occur in the area. No specific foraging areas were identified for the Australian fur seal. However, for the New Zealand fur seal, Baylis (2008) reported that this species utilised the seasonally predictable Bonney Upwelling, but foraged in more oceanic waters when the Bonney Upwelling declined in autumn.

There is limited peer-reviewed information on the response of individual sea lions to contact with fresh and weathered oil. Potential pathways that could compromise the health of marine mammals include skin contact and absorption, inhalation and ingestion (Helm et al. 2015). The same authors suggested that inhalation of the toxic components associate with fresh oil was the most likely mechanism of mortality for marine mammals exposed to oil. French-McCay (2016) proposed that exposure to oil concentrations of 10 g/m^2 could have lethal effects on marine mammals and sub-lethal effects with exposure to concentrations as little as 1 g/m^2.

Predicted effects in context of this event

Of the three pinnipeds known to breed in the Risk Environment that May Be Affected (Appendix 7-3), the Australian sea lion is most vulnerable to human disturbance due to its small population size (DSEWPaC 2013b) and lack of population recovery following historical harvesting, hence the focus in this section.

Of the 58 regular breeding colonies for the Australian sea lion, 48 are in South Australia. All 58 colonies are considered critical habitat for the survival of this species (Appendix 7-3; DSEWPaC 2013b). In terms of pup numbers, the most important regions in South Australia are Nuyts Archipelago, Eyre Peninsula and Kangaroo Island (DEWHA 2010). In South Australia there are <3000 pups per breeding cycle (Shaughnessy et al. 2011). There are few long-term studies examining trends in pup numbers and estimates from year to year are variable making interpretation challenging. However, limited evidence suggest pup production at some sites is stable while at other sites, numbers may be in decline (Goldsworthy et al. 2011). For instance, long term monitoring of pup numbers at Seal Bay indicate a general decline from 1985 to 2007 (DSEWPaC 2013b).

Australian sea lions are known to forage considerable distances from breeding and haul out sites in South Australian waters (Appendix 7-3). Foraging habitat requirements are broad ranging from coastal areas to the shelf break. The mean foraging grounds for sea lions at Dangerous Reef is 28 ± 18 km and 189 ± 25 km at Bunda Cliffs (Hamer et al. (2013) cited in DSEWPC (2013b)). Even pups of about 15 months old can forage a mean distance of 20.8 km from their natal colony (Fowler, Costa & Arnould 2007). Tagged lactating female Australian sea lions demonstrated that individuals can range considerable distances south of Kangaroo Island and Eyre Peninsula (DSEWPaC 2013b; Hamer et al. 2013).

Based on the oil spill modelling results described in Appendix 7-1, there is a risk that breeding colonies ranging from Esperance to Kangaroo Island could be exposed to shoreline oil of ≥100 g/m^2 following a loss of well control (Appendix 7-1) and nursery sites affected by shoreline accumulations (2–27 kg/m^2) near Port Lincoln and in the western GAB. The direct effect to pups from exposure to shoreline oil at these concentrations could result in mortality (Appendix 7-2), while indirect effects could be negative behavioural changes associated with the smell of shoreline oil or contamination of prey items.

Given the population of this species may already be in decline due to fishing and other human pressures (DSEWPaC 2013b), it is plausible that mortality of even a small number of pups or adults as a direct or indirect result of shoreline oiling could increase the rate of decline (DEWHA 2010). Further, shoreline oiling of breeding colonies could potentially

reduce the area of occupancy for this species. This issue is particularly pertinent for female Australian sea lion that exhibit extreme natal site fidelity (Campbell et al. 2008).

Oil spill modelling results presented in Appendix 7-1 suggested that foraging and breeding Australian sea lion populations could be at risk from being exposed to surface oil at concentrations of >10 g/m^2 (Appendix 7-1). Such concentrations could result in reduced reproduction and reduced viability of smaller colonies, possibly leading to colony collapse). Seals may not avoid oiled nurseries due to site fidelity and high natal philopatry. Hence there is potential for long term (>10 years) effects on a nationally important population that have not recovered yet to pre-sealing levels. Conservatively, the effect of a 102-day release of oil on Australian sea lions could have a very long or permanent impact on a population that is already in decline resulting from the loss of individual breeders resulting in consequence ranking of Category 8.

A smaller number of colonies would be affected and to a lesser degree if the capping stack implementation was successful on Day 15 with weathered oil patches at moderate and high thresholds along the eastern coastline of the GAB (Port Lincoln, Eyre Peninsula and Kangaroo island). Colonies in the western GAB and Bass Straits are unimpacted and ranked Category 6 to 7. No colonies are affected should the blowout preventer closure be successful on Day 1 and ranked Category 1–3.

The Recovery Plan for the Australian sea lion (DSEWPaC 2013b) lists oil spills as a threat to sea lions and contains the requirement to "implement jurisdictional oil spill response strategies as required" with management actions developed to mitigate effects of oil spill on populations. This EP is aligned with the objectives of this Recovery Plan, notably focussing on spill prevention in the first instance. Equinor Australia B.V. will support the state agencies in implementing their oiled wildlife response plans (further described in the OPEP).

In contrast to the Australia sea lion, the long-nosed or New Zealand fur seal (*Arctocephalus forsteri*) is increasing in abundance and expanding its range in Australia (Campbell et al. 2014). However, this species is vulnerable to a population decline following a loss of well control because its major breeding locations are found between Kangaroo Island and the Eyre Peninsula (Shaughnessy, Goldsworthy & Mackay 2015). Also, this species may be more vulnerable to oil because oil is believed to adhere more readily to its coat compared with that of the Australian sea lion. Therefore, a 102-day loss of well control on the New Zealand fur seal could also have a long or permanent effect (restitution time >10 years) on its regionally important populations and ranked Category 7.

Species/Receptors	Qualitative risk assessment for the planned mitigation scenarios		
	Relief well Day 102	CS fitted Day 15	BOP closed Day 1
Australian sea lion	8*	6–7	1–3
New Zealand fur seal	7*	5–6	1–3

* When sea exposure contours of the mitigated November–February case were assessed, exposure to low concentrations of sea surface oil was predicted for areas around Port Lincoln and Kangaroo island but no haul out sites are predicted to be exposed to sea surface oil above a moderate threshold. Shoreline loadings are reduced in probability and extent but may still be moderate to high in patches. No haul out sites or breeding sites on the western side of the GAB are exposed to even a low sea surface threshold. As such, the consequences to the Australian sea lion for a 102-day spill can be reduced from Category 8 to 7 and New Zealand fur seal from Category 7 to 6.

For the period November–February, with capping stack successfully implemented, no haul and breeding sites are exposed to surface oil or shoreline loadings (Appendix 7-1). The consequence relates to foraging and for the Australian sea lion can be reduced from 6–7 to 5–6 and New Zealand fur seal from 5–6 to 4–5.

In addition, further mitigation will be assessed and where appropriate instigated such as the provision and use of containment and recovery measures (e.g. booms and vacuums) and oil wildlife response as described in the OPEP and state oiled wildlife response plans.

Marine mammals – cetaceans

Sensitivity

Whales and dolphins can be exposed to the chemicals in oil through:

- internal exposure by consuming oil or contaminated prey
- inhaling volatile oil compounds when surfacing to breathe
- absorption from external exposure, by swimming in oil and having oil directly on the skin and body
- maternal transfer of contaminants to embryos (NRDA 2012).

Direct surface oil contact with hydrocarbons is considered to have little deleterious effect on whales, possibly due to the skin's effectiveness as a barrier to toxicity, and effect of oil on cetacean skin is probably minor and temporary (Geraci & St. Aubin 1988). However, Helm et al. (2015) suggested that inhalation of toxic compounds associated with fresh oil was of greater concern than absorption through the skin and ingestion. French-McCay (2016) proposed exposure to oil concentrations of 10 g/m^2 could result in mortality to marine mammals (Appendix 7-1).

The physical effects from ingested hydrocarbon with subsequent lethal or sub-lethal effects are both applicable to entrained oil. However, the susceptibility of cetaceans varies with feeding habits. Baleen whales are likely to ingest oil as they feed at the surface and in the water column. Toothed whales and dolphins may be susceptible to ingestion of dissolved and entrained oil as they gulp feed at depth. As highly mobile species, in general it is very unlikely that these animals will be constantly exposed to concentrations of hydrocarbons in the water column for continuous durations (e.g.

>96 hours) that would lead to chronic effects. Note also, many marine mammals appear to have the necessary liver enzymes to metabolise hydrocarbons and excrete them as polar derivatives (Ball & Truskewycz 2013).

Entrained and dissolved oil in offshore waters could lead to temporary changes in the behaviour of whales, including avoidance of the plume if their eyes are irritated by oil. Whales possess relatively impermeable skins, so entrained and dissolved oil is not predicted to result in mortality of individuals and thus is unlikely to lead to population level responses.

The restitution time for cetaceans affected at a population level is assumed to be long term, i.e. 40 years, based on consensus on recovery times for marine mammals following the Macondo spill (French-McKay et al. (2018) and Bock et al. (2018).

Predicted effects in context of this event

Thirty-five species of cetaceans have been recorded in the GAB; comprising 11 species of baleen whales and 24 species of toothed whales (PMST report, Appendix 7-2). Of the 35 species, only three have biologically important areas in the Risk Environment that May Be Affected; namely the pygmy blue whale (*Balaenoptera musculus*), the southern right whale (*Eubalaena australis*) and the sperm whale (*Physeter macrocephalus*). Consequently, this evaluation of the potential effects of a Level 3 oil spill focuses on these species. Appendix 7-3 describes aggregation, feeding, migration and calving BIAs for pygmy blue whales, southern right whales and sperm whales in relation to the Stromlo-1 well location. Only the migration BIA of the pygmy blue whale overlaps the well location; the others overlap various parts of the Risk Environment that May Be Affected. Risks to populations of other cetacean species are predicted to be lower because the area is considered less critical to their ongoing survival.

It is plausible that individual whales could encounter fresh surface oil at high concentrations within ~100 km of the well location; however, it is difficult to predict with certainty if a spill would lead to levels of mortality or reproductive depression that would manifest in terms of a population-level response. Nevertheless, given that the populations of these species remain small relative to pre-whaling days (Appendix 7-3) and are thought to have a multi-decadal recovery time, it is conceivable that mortality of even a small number of adults and or calves as result of oiling could inhibit or retard species recovery.

The effects of the mitigated 102-day loss of well control on three representative species are summarised below:

Southern right whale

Southern right whales calve close to the shore and their calving areas fringe the mainland and Kangaroo Island; the Head of Bight is a nationally important area. Mother and calf pairs generally stay within the calving grounds for 2–3 months (DSEWPaC 2012b), their presence in the Head of Bight peaks from mid–late July to mid–late August.

The southern right whale is absent from this region from about December to April and will mainly be at risk if a major spill was to occur in February or later and run for 102 days, because the end of the spill period would overlap the start of the whale re-migration period and weathered oil may be present in coastal aggregation areas.

Based on the modelling results (Appendix 7-1) it is possible that weathered surface oil at high concentrations could contact areas of aggregation, feeding, migration and or calving and affect the southern right whales if they are present.

Breeding and calving grounds at the southern end of the Eyre Peninsula, Kangaroo Island and the South Australian–Victorian border as well as near the Bonney Upwelling are predicted to be at risk of exposure to weathered oil at concentrations of >10 g/m^2 following a mitigated Level 3 oil spill.

The eastern population, which may be affected by a major spill, shows no recovery and is limited to about <300 individuals. Restitution times are considered >10 years, and potential population effects are ranked Category 7 for a relief well success at 102 days, which may have population-level effects on regionally important populations, and ranked Category 6 for capping stack fitting at 15 days due to the lower level of exposure. Risks to the southern right whales are mitigated by the unlikely overlap between the preferred drilling window and the timing of their presence in the areas that may be exposed to oil at concentrations high enough to have biological effects, that only a small proportion of the population re-migrates each year and therefore only a small proportion may be exposed, the highly weathered state of the oil reaching nearshore waters and greater part of the population residing in the west – away from the main areas of oil exposure. If the blowout preventer closes the well in one day no population-level effects are predicted as the exposure to toxic oil components would be low in nearshore waters and the consequence would be Category 4.

Pygmy blue whale

A 102-day oil spill could result in weathered oil contacting feeding aggregation areas of pygmy blue whales near the Bonney Upwelling during November–March, or in direct contact with individual pygmy blue whales transiting across the GAB. Given the predicted long restitution time (>10 years) and possible population-level effects if the spill was to occur at peak aggregation time and a few individual whales were to die due to oil toxicity, the predicted risk is conservatively considered to be Category 8 because the Bonney Upwelling aggregation is considered of national importance. Should a successfully implemented capping stack stop the discharge at 15 days, the affected areas have a significantly reduced overlap with aggregation areas and population effects are less likely given the smaller number of pygmy blue whales possibly affected (ranked Category 6). A spill stopped by a blowout preventer successfully fitted on Day 1 would only affect transiting individuals for a small period, hence consequences are ranked at worst as Category 4.

Sperm whale

Male sperm whales may be present in the GAB throughout the year, though it is likely that sperm whale densities in the region vary in response to seasonal changes in localised productivity associated with upwelling events which may occur 4–5 times a year (Ward et al. 2017; Mackay et al. 2018). Foraging areas for the species are closely associated with the

sub-marine canyons of the continental slope, particularly the Albany Canyon group (>1000 km west of Stromlo-1) and the Kangaroo Island Pool KEF (Bailleul et al. 2017). Of most relevance to the current assessment is the foraging BIA ~100 km north of the well site and the area to the south-west of Kangaroo Island – noted as a key location for sperm whales (Bannister et al. 1996). These are the important sperm whale areas most likely to be affected by a major spill. Groups of sperm whales may be susceptible to ingestion of dissolved and entrained oil, as they gulp feed at depth, if high concentrations of oil reach their foraging areas. They are less susceptible to weathered surface oil.

A 102-day mitigated Level 3 oil spill (Appendix 7-1) could result in weathered surface oil reaching parts of the sperm whale foraging BIA particularly around the Bonney Upwelling; however, sperm whales are unlikely to ingest weathered surface oil due to their deep-water feeding habits. They are more vulnerable to inhalation of toxic compounds when surfacing from deep dives in offshore areas with fresh oil; however, there is minimal overlap of their foraging area BIA and the area that may be exposed to fresh oil. Sperm whales are unlikely to ingest large quantities of the in-water oil components while gulp feeding at depth because there is no exposure to in-water oil predicted for the Albany Canyons and no exposure in the Kangaroo Island Pool canyon area to moderate or high concentrations of dissolved and entrained oil. The modelling report predicts a <5% probability of exposure to low concentrations of entrained oil around Kangaroo Island at 90–100 m water depth. This exposure may have sub-lethal physiological and behavioural effects on sperm whales foraging in the area; but is unlikely to result in mortality of individuals. Given the uncertainty in the actual distribution of sperm whales and the potential for haphazard exposure to fresh surface oil offshore, we conservatively assume the effects may range from behavioural and physiological effects on foraging groups, to mortality of a small number of individuals.

There is no evidence of recovery of sperm whale populations since commercial whaling ceased in 1978 and as such even a small number of individual mortalities may affect the recovery of the regional population. The potential for population-level effects is mitigated by the sex-bias in southern Australian waters, where males dominate the herds of sperm whales recorded in the GAB (Gill et al. 2015; Johnson et al. 2016). While males have historically been targeted by whalers off south-west Australia and their numbers remain depressed, loss of a small number of males is not expected to affect the reproductive output of the national population; however, it may have a long-term (>10 years) effect on the recovery of the regional population and ranked Category 7. Loss of individuals, should it occur, is not predicted to affect the viability of the regional population because it is a small perturbation in relation to natural mortality levels and episodic events such as the mass strandings (115 individuals) in 1998 (Evans et al. 2002), which the current population status has absorbed. The shorter spills of 15 days or one day would engender lower levels of exposure and considered Category 6 and 4 respectively as areas of the BIAs that could be affected are reduced in size, in hydrocarbon exposure and in duration of exposure.

Species/Receptors	Qualitative risk assessment for the planned mitigation scenarios		
	Relief well Day 102	CS fitted Day 15	BOP closed Day 1
PBW – foraging, distribution and migration BIAs	8*	6*	4
Sperm whale – foraging BIA	7*	6*	4
SRW – breeding, foraging, distribution and migration BIAs	7*	6*	4

* When sea exposure contours of a November–February oil spill were assessed, neither the Head of the Bight or Israelite Bay / Bremer Bay calving grounds for the SRW are predicted to be exposed to sea surface oil above a low threshold concentration. This justifies decreasing the consequence ranking by one to Category 6 for the 102-day spill and further to Category 5 for the capping stack scenario.

The Bonney Upwelling feeding aggregation area BIA for PBW may still be exposed to low–moderate sea surface oil concentrations, but over a reduced area, thus reducing exposure of feeding blue whales to oil. This justifies decreasing the consequence ranking by one to Category 7 for the 102-day spill and further to Category 5 for the capping stack scenario.

The foraging BIA for sperm whales may still be exposed to low-moderate sea surface oil concentrations, but over a reduced area, thus reducing exposure of feeding sperm whales to oil. This justifies decreasing the consequence ranking by one to Category 6 for the 102-day spill and further to Category 5 for the capping stack scenario.

Benthic invertebrates other than corals

Sensitivity

Benthic invertebrates include sponges, sea pens, crustaceans, echinoderms, cnidaria, molluscs, annelid worms and many other taxa. Benthic invertebrates inhabit the seabed and are potentially at risk of toxic effects of exposure to in-water hydrocarbons, as well as toxicity and physical oiling resulting in smothering from surface hydrocarbons in intertidal areas. Benthic fauna inhabit three main aspects of the vertical seabed profile, namely:

i. The sediment–water interface (includes epibiota). Organisms are sessile (live fixed to or in the seabed and grow upwards into the water column) or motile. A wide range of feeding types are represented, though filter feeders comprise a greater proportion of communities/assemblages than in subsurface habitats. Organisms inhabiting the sediment-water interface are likely to have the greatest risk of exposure to in-water hydrocarbons, either directly (exposure to dissolved or entrained hydrocarbons) or indirectly though feeding (e.g. filter feeders, surface detritus feeders, surface deposit feeders, herbivores, scavengers and carnivores) due to oil on external surface or within the feed item (absorbed, bioaccumulated or in the gut). Ventilation of respiratory surfaces will also be a method of uptake

of hydrocarbons.

ii. The bioturbation zone (i.e. upper 10 cm of "soft" sediment habitats), is a refuge for infaunal biota (i.e. organisms that actively burrow into sediments). The transition from a well-oxygenated environment to an anoxic environment generally occurs in this zone. Many infaunal species have adapted to this environment by having specialist methods to either irrigate their burrow, or to siphon oxygenated water from the sediment surface. Organisms in this environment are generally surface deposit feeders, subsurface deposit feeders, scavengers or carnivores, though several species can adopt multiple methods for obtaining food. Such as *Nereid polychaete* worms which are active hunters but can also filter feed by producing a mucous net that they hold in their burrow, which catches particles drawn down by the irrigation current. The worm then eats the mucous net with the items caught on it. Organisms drawing water from the sediment surface or feeding on organic material in the upper sediments would be at risk of exposure from spill hydrocarbons.

iii. Deep sediments (>10 cm below the sediment surface). This zone is generally anoxic, and organisms have adapted to living here by either building deep burrows (e.g. scampi can build burrows >1 m deep), have modified appendages to draw down oxygen from oxygenated sediments (e.g. some infaunal sea urchins have modified tube feet that extend into the oxygenated layer), move between the oxygenated and anoxic layers, or have adapted to low-oxygen conditions. Taxa that draw down oxygenated water from the surface are at potential risk of hydrocarbon exposure from a spill in this zone.

Acute or chronic exposure through surface contact, respiration and/or ingestion can result in toxicological risks. The presence of an exoskeleton (e.g. crustaceans) will reduce the effect of hydrocarbon absorption through the surface membrane, except for e.g. respiratory membranes. Other invertebrates with no exoskeleton and larval forms may be more prone to effects from in-water hydrocarbons.

There are multiple mechanisms through which benthic invertebrates may be exposed to spill hydrocarbons. Firstly, hydrocarbons are likely to make contact with the seabed within the close vicinity of the release, hence effects by direct contact localised. Secondly, dissolved and entrained hydrocarbons are likely to adsorb to organic material in the water column or be incorporated into it e.g. copepod faecal pellets. These hydrocarbons may be deposited on the seabed in "marine snow" (clumping, sinking and deposition of organic material from the water column. This process explained oil contamination at depths of 1600 m, below the depth where diffuse oil was found (Schrope 2013), after the Macondo spill. In this way, hydrocarbons may be distributed over a wider area but at lower concentrations. Thirdly, where a plume of dissolved/entrained hydrocarbons travels at depth in close proximity to the seabed, benthic biota may be directly exposed to hydrocarbons and may also take up hydrocarbons through respiration and burrow irrigation). A fourth mechanism was identified during the Macondo spill, where the vertical movement of the plume of dispersed hydrocarbons from the well head was inhibited by stratification of the water column (i.e. halocline/ thermocline). The plume was carried tens of kilometres at depth from the release site, moving into areas with shallower water depth by prevailing currents (at depths of 900–1300 m), where it came into contact with the seabed, and hydrocarbons adhered to sediments (Schrope 2014).

Effects from entrained (including chemically-entrained) oil may potentially include the effects of oxygen depletion in bottom waters resulting from the metabolic processes of bacteria degrading the oil.

Studies undertaken since the Macondo spill have shown that fewer than 2% of the more than 8000 sediment samples collected exceeded the United States Environmental Protection Authority sediment toxicity benchmark for aquatic life, and these were largely limited to the area close to the well head (BP p.l.c. 2015). However, the US EPA states that Oil-Related Organic Compounds are assessed jointly (via a mixture approach) as they have the same type of effect on aquatic organisms. Therefore, potency divisors are not determined from chemical-specific benchmarks, but are intermediates used in calculating aggregate toxicity (i.e. toxicity of the whole mixture). The potential risk to aquatic organisms is assessed by comparing the sum of the calculated values to an event index of 1. Values of greater than 1 indicate a potential to cause acute or chronic effects on sediment-dwelling organisms (such as annelid worms, crustaceans and molluscs). Subsequent studies of the effects of the spill on benthic infauna (e.g. Reuscher et al. 2017)) have identified significant differences in benthic infaunal communities between the identified effect zone and un-affected zone. The sediment effect zone extended up to 16 km from the release location (in the direction of prevailing current flow), with surficial sediments found to have an average polycyclic aromatic hydrocarbon (PAH) concentration of 218 ppb and total petroleum hydrocarbon (TPH) concentration of 1166 ppb. The un-affected zone was determined to be outside of the effect zone based on multivariate analysis, where average PAHs were 14 ppb and TPHs were 102 ppb. Significant differences between these zones were identified from surveys in 2010, 2011 and 2014.

The ecological implications of potential reduction in diversity and abundance of benthic invertebrates will be dependent on the habitat affected. Areas of highly mobile sediment, where diversity and abundance are relatively low, will likely recover quickly. Complex assemblages (e.g. sponge habitat) or deep-water slow-growing sessile invertebrates (e.g. deep-water coral) are likely to recover much more slowly, and loss of these epibiota could change seabed habitat complexity. A reduction in habitat complexity has a knock-on effect on benthic, demersal and pelagic biota though loss of e.g. nursery habitat and food sources (through loss of refugia and ecological niches).

Localised effects to benthic larval stages may occur where hydrocarbons accumulate in seabed sediments, which could affect population recruitment that year. If invertebrates of commercial interest are contaminated by hydrocarbons, tissue taint can remain for several months, although taint may eventually be lost. For example, it has been demonstrated that it took 2–5 months for lobsters to lose their taint when exposed to a light hydrocarbon (NOAA 2002). However, several habitat-modifying/stabilising species are long-lived and require decades to become sexually mature (especially in deep sea habitats), and in such recovery could take longer. A degree of uncertainty is involved in estimates of recovery of

benthic habitats due to the great range in data from an understanding of the benthic habitats found in the Risk Environment that May Be Affected. For example, benthic particulate habitats in Australia (and their value) are poorly understood, despite the global weight of information derived from studies of the environmental effects of benthic trawling, which targets such habitats. Studies have shown that benthic trawling reduces habitat heterogeneity and benthic biological diversity, with resulting effects to e.g. commercial fisheries and higher trophic levels (e.g. Hiddink et al. 2006; Jørgensen et al. 2016; Sköld et al. 2018). Uncertainty will be managed through consideration of the data derived from the Commonwealth Scientific and Industrial Research Organisation/SARDI baseline surveys to assist development and implementation of the Operational and Scientific Monitoring Program (OSMP).

Predicted effects in context of this event

Studies of marine invertebrates within the GAB region have largely concentrated on shallow nearshore environments with the GABMP extending the knowledge about the marine invertebrate communities on the shelf-break, continental slope, continental rise and abyssal plane, i.e. at depths of 200–5000 m.

Highly diverse soft-sediment benthic invertebrate communities occur intermittently along most of the GAB shelf, amongst vast expanses of bare sandy sediments (Currie et al. 2008; DSEWPaC 2012b). These communities are recognised as a KEF of the South-west Marine Region (DSEWPaC 2012a). The high levels of biodiversity are attributed to the unusual width of the continental shelf, the high degree of geographic isolation from similar habitats, and the opportunities for incursions by tropical species in the Leeuwin Current (DSEWPaC 2012a). Community structure changes progressively across the shelf with depth. The species that make up these communities decrease in abundance moving away from the coast. The largest shift in community composition is a significant decline in species richness and biomass that occurs between the inner (0–65 m depth) and mid-shelf (65–200 m) (Currie et al. 2008). A survey undertaken in 2010 of benthic macrofauna in deep offshore waters of the GAB Marine Park reported considerably lower densities with 50–450 individuals/m^2 at 500–2000 m (Currie & Sorokin 2011).

In 2002 and 2006 SARDI surveyed the shelf within and around the GAB Commonwealth Marine Reserve to a depth of 200 m (see Appendix 7-3) and sampled a total of 661 kg of living benthos, including a total of 735 benthic invertebrate species (Currie et al. 2008). Sessile suspension feeding organisms dominated the samples, comprising over 98% of the biomass and 85% of the species collected (Currie et al. 2008). The shelf communities sampled included 360 species of sponge, 138 ascidians and 93 bryozoans, many of which were new to science (Currie et al. 2008). The most common free-living organisms were echinoderms and molluscs, which comprised only 2% of the biomass and 12% of the species collected (Currie et al. 2008).

Highly diverse soft-sediment benthic invertebrate communities occur intermittently along the majority of the GAB shelf, amongst vast expanses of bare sandy sediments (Currie et al. 2008; DSEWPaC 2012b). These communities are recognised as a KEF of the South-west Marine Region (see Section 1.3.4) (DSEWPaC 2012a). The high levels of biodiversity are attributed to the unusual width of the continental shelf, the high degree of geographic isolation from similar habitats, and the opportunities for incursions by tropical species in the Leeuwin Current (DSEWPaC 2012b). Community structure changes progressively across the shelf with depth. The species that make up these communities decrease in abundance moving away from the coast. The largest shift in community composition is a significant decline in species richness and biomass that occurs between the inner (0–65 m depth) and mid-shelf (65–200 m) (Currie et al. 2008). There was a clear peak in abundance of infauna at intermediate depth (400 m) and very low abundance in deep waters; the GAB appears to have relatively low infaunal abundance compared to other areas in this depth range (Tanner et al. 2017). Most species were represented in only a few samples. Infaunal densities peaked at 400 m depth (1320 ± 175 (se) m^2) and declined consistently to 2800 m (268 ± 55 (se) m^2) and were low (268–1320 individuals/m^2) compared to densities documented elsewhere (Tanner et al. 2017).

The Tasmanian live-bearing seastar (*Parvulastra vivipara*), listed as “Vulnerable” under the EPBC Act, was the only threatened marine invertebrate species identified in the PMST report for the Risk EMBA (Appendix 7-2). This species is endemic to south-east Tasmania. Stochastic modelling of an unmitigated 102-day loss of well control has identified that the habitat of *P. vivipara* is outside of the area potentially exposed to spill hydrocarbons, and therefore this species is unlikely to be affected.

Scientific monitoring following the Macondo spill identified several pathways through which hydrocarbons from a loss of well control could cause effects to benthic invertebrate communities. These include direct exposure to dissolved and entrained hydrocarbons in the vicinity of the well (increased if dispersants are used), and sedimentation of entrained hydrocarbons absorbed to organic matter (marine snow) are likely to affect populations at the local scale. Further afield, potential effects to planktonic early life stages (eggs and larval stages) in surface waters and smothering by hydrocarbons in nearshore areas (e.g. tar mats) or intertidal areas (shoreline accumulation) are also likely to affect benthic invertebrates at regional-scale population levels.

As such a 102-day loss of well control may have long term effects on national populations with restitution times from 3–10 years and consequences are ranked Category 7.

Given the area of effect and duration of elevated surface, entrained and dissolved oil are reduced considerably with the successful implementation of the capping stacks at Day 15 and blowout preventer at Day 1 resulting exposure risks are reduced to medium-term effects regional ecosystems for the capping stacks scenario and to localised short-term effects (<1 year) for the blowout preventer scenario, Categories 6 and 4 respectively.

Species/receptors	Qualitative risk assessment for the planned mitigation scenarios		
	Relief well Day 102	CS fitted Day 15	BOP closed Day 1
Benthic invertebrates	7*	6	4

* When sea exposure and in-water hydrocarbon contours for a spill occurring between November–February were assessed, a similar range of potential risks are presented to the same range of receptors. As such, the risk for this period is predicted to remain the same overall.

Deepwater and other coral species

Sensitivity

Deepwater corals (azooxanthellate scleractinian corals) are located in offshore benthic habitats and are most likely to be susceptible to exposure to in-water hydrocarbons and dispersed hydrocarbons. Coral gametes or larvae in the surface layer where they are exposed to the slick may also be fouled (Epstein et al. 2000). Physical oiling of coral tissue can cause a decline in metabolic rate and may cause varying degrees of tissue decomposition and death (Negri & Heyward 2000). Effects to deep-water corals from the hydrocarbons and dispersed hydrocarbon plume were identified up to ~25 km from the Macondo release location (Fisher et al. 2014). Corals were covered with clumps of flocculated brown material containing oil droplets ("floc") (NOAA 2018). Stress indicators observed included tissue loss, sclerite enlargement and excess mucous production (White et al. 2012).

While cnidarian corals are generally associated with tropical waters, they can also be found in deep, dark, cold waters worldwide, including species such as *Solenosmilia variabilis*, which has a worldwide distribution and may form dense aggregations in depths of 1000 to 1400 m in waters off southern Australia (Althaus et al. 2009; Freiwald et al. 2004; Koslow et al. 2001).

Corals that are known to occur in the GAB include three reef-building species in shallow waters (e.g. found in the deep reefs (>10 m deep) around the Kent Group of islands in Bass Strait, off north-east Tasmania) and more than 50 non-reef-building species in waters up to 900 m deep (DEH 2005). The Anna's Pimple and Murray's Mount pinnacles are within the Risk EMBA and are expected to support diverse and unique benthic faunas, such as stony corals, black corals and octocorals (Currie & Sorokin 2011). However, towed camera surveys by Commonwealth Scientific and Industrial Research Organisation during the GAB Deepwater Marine Program (which was completed in 2018) did not find evidence of large aggregations of these species, although some individual colonies were recorded.

Predicted effects in context of this event

The nearest known deep-water coral colonies are located approximately 100 km to the north-east of EPP39. The closest habitats which may support deep water coral colonies are Anna's Pimple and Murray's Mount pinnacles which are approximately 20 km to the north-east of the Stromlo-1 well.

Surveys following the Macondo oil spill identified effects to the health and survival of deep-water corals from entrained oil in flocculant organic matter up to a distance of around 25 km from the well location (Fisher et al. 2014). Modelling of a mitigated 102-day loss of well control indicated that the vertical plume of entrained hydrocarbons would be spatially-constrained, with low levels of exposure approximately 1700 m water depth other than in the immediate vicinity of the well (Appendix 7-1). This indicates that direct exposure of deep-water corals from a mitigated loss of well control is possible, however there is no known abundance in the area at depth, so effects may be limited. Should exposure at moderate to high levels of entrained and dissolved oils occur (possibly through the use of dispersants offshore), the effects to individual deep-water coral outcrops may be Category 7 given the restitution period for some species may exceed >10 years as they are slow growing.

With a successful fitting of the capping stack on Day 15, modelling shows the extent and duration of the exposure to entrained and dissolved oils will be considerably reduced compared to the 102-day spill. While restitution of individual outcrops may still be long term, the number of outcrops that could be affected would decrease to those in close vicinity to the spill source and ranked Category 5.

With a successful fitting of the blowout preventer on Day 1, only corals in close proximity of the well head are predicted be exposed to deleterious effects, however, given the water depth >2000 m substantial outcrops are not likely and ranked Category 4.

Species/receptors	Qualitative risk assessment for the planned mitigation scenarios		
	Relief well Day 102	CS fitted Day 15	BOP closed Day 1
Deep water coral	7*	5	4
Other coral	5	4	4

* When sea exposure contours of a November–February oil spill were assessed, no known substantial outcrops of deep-water coral sites are predicted to be exposed to threshold entrained and dissolved above a moderate and none above the low threshold for dissolved oil.

However, as all locations of deep-water coral are unknown (nearest known are ~100 km distant) and restation times remain lengthy, the ranking has conservatively been kept the same.

Benthic habitats
Sensitivity
Benthic habitats are generally exposed in-water (dissolved and entrained) and depositional hydrocarbons (e.g. absorbed by organic marine snow, in faecal pellets or in the tissues of sunken dead organisms). Nearshore and intertidal benthic species may be exposed to surface and shoreline accumulation of oil. Exposure can lead to effects including mortality, and recovery of benthic habitats exposed to entrained hydrocarbons may be expected to return to background conditions within months to years of contact. However, several studies have indicated that rapid recovery rates may occur even in cases of heavy oiling (Burns et al. 1993; Dean et al. 1998 in Committee on Oil in the Sea 2003), though this will be dependent on e.g. water depth and the community or assemblage of organisms and their life histories. The Risk EMBA supports a diverse range of particulate ("soft") sediment habitats, comprised of many species of sponges, echinoderms, annelid worms, crustaceans, molluscs, ascidians, cnidarians and bryozoans. Infaunal abundance has been found to peak at a water depth of 400 m, declining consistently with increasing depth (Tanner et al. 2017). Shallow-water hard substrate (emergent bedrock and consolidated mixed substrate) habitats in ≤30 m water depth, are likely to be dominated by epibiota such as macroalgae, seagrass, sponges, hydroids, bryozoans or ascidians. These habitats are highly productive and provide a wide range of food sources and ecological niches for biota, increasing local biodiversity. They are home to a wide range of invertebrate flora and fauna and demersal fish species, including species of commercial importance (e.g. scallops, crabs, lobsters and various demersal and pelagic fish species). Unconsolidated mixed and particulate sediments are likely to be dominated by burrowing fauna (e.g. annelid worms, molluscs, echinoderms, crustaceans, cnidarians) and may have sporadic high densities of motile filter feeders (such as scallops, sea pens or brittlestars) in areas of high current flow. Many of the organisms that live in these habitats are habitat modifiers (e.g. through burrows or shell production), stabilising and/or oxygenating the sediments around them, and providing additional ecological niches for colonisation by other fauna – increasing local biodiversity. Deep-water habitats (off the continental shelf) are generally characterised by low densities of biota. However, habitat-forming and habitat-modifying organisms may be larger, long lived and have slower growth rates – with some taxa becoming sexually mature after decades (e.g. infaunal bivalve molluscs). Inshore and intertidal benthic habitat may be exposed to surface and shoreline oil. Resident fauna such as annelid worms, molluscs and crustaceans may suffer lethal effects if oil penetrates the sediments, especially in highly productive sheltered shorelines where oil is more likely to be retained.
Predicted effects in context of this event
Several unique factors combine to contribute to the high level of biodiversity and endemism in the GAB. These include a long period of geological isolation, a persistent high wind and wave energy environment, warm water intrusion via the Leeuwin Current from Western Australia, and cold water, nutrient-rich upwellings in the east (DSEWPaC 2012b). Taxonomic groups with exceptional diversity in this area include red algae, ascidians (sea squirts), bryozoans (including lace corals), molluscs (shellfish) and echinoderms (such as sea urchins and sea stars). Rogers et al. (2013) stated that about 70% of the seabed in the GAB is composed of soft unconsolidated particulate sediments. Due to large variations in bathymetry, however, there are marked differences in sedimentary composition and benthic assemblage structure across the region (Rogers et al. 2013). The inner coastal regions of the GAB support a diverse range of seagrasses, macroalgal habitats and sponge-dominated communities but the autotrophic habitats (such as seagrass and macroalgae) are restricted by light penetration and therefore are generally limited to water depths less than 100 m (DEWHA 2007; McLeay et al. 2003). Due to the waters of the well location being considerably deeper than this (>2000 m), it is expected that deep-water sponge communities (e.g. associated with the ancient coastline KEF) and communities associated with sea mounts are likely to be present and of potential nature conservation interest. Direct effects from dissolved and entrained hydrocarbons to deep water benthic habitats in the GAB may occur within 25 km of the well location (based on Macondo oil spill scientific monitoring surveys), but to apply a precautionary approach because of likely differences between Stromlo-1 location and oil type and the Macondo oil spill situation, this may be considered as the 40 km extent of the Impact EMBA (planned activities). Habitat persistence, cyclicity and successional processes may also be affected by effects to planktonic early life history stages, and subsequent poor recruitment. This may result in the shift in the trajectory of the habitat, resulting in the change in nature of and ecosystem services provided by the habitat affected. Shallow-water threatened ecological communities (TECs; such as the giant kelp (*Macrocystis* spp.) or *Posidonia* TECs) may also be affected by spill hydrocarbons (e.g. ecotoxic effects, smothering, light reduction if persistent surface slicks are present). Marine plants and macroalgae are sensitive to surface, dissolved and entrained hydrocarbons. As habitat-forming species, loss of habitat will have significant effects to a wide range of dependent biota (see further under "macroalgae" and "seagrasses" below). The consequences of a 102-day mitigated loss of well control on benthic habitats is potentially Category 6 due to the regional-to-national scale of the potential effects and the worst case long-term (restitution time) effects on local ecosystems. Given the extent and duration of effects are reduced significantly with the successful implementation of the capping stacks and blowout preventer, so the consequences to benthic habitats lessen to medium term effects on local populations and short-term effects on sensitive areas of local importance (respectively) and ranked Category 5 and 4.

Species/receptors	Qualitative risk assessment for the planned mitigation scenarios		
	Relief well Day 102	CS fitted Day 15	BOP closed Day 1
Benthic habitat	6*	5	4

* When sea exposure and in-water hydrocarbon contours for a spill occurring between November–February were assessed, a similar range of potential risks are presented to the same range of benthic habitat types. As such, the risk for this period is predicted to remain the same overall as for the period October to May.

Mangroves and salt marshes

Sensitivity

The effects of surface hydrocarbons on mangroves include damage by smothering of lenticels (mangrove breathing pores) on pneumatophores or aerial prop roots, or the lower trunk; or by the loss of leaves (defoliation) due to chemical burning. It is also known that mangroves take up hydrocarbons from contact with leaves, roots or sediments, and it is suspected that this uptake causes defoliation through leaf damage and tree death (Wardrop et al. 1987).

Entrained and dissolved hydrocarbons may affect mangrove communities through the sediment/mangrove root or sea water/root interface. Entrained and dissolved hydrocarbons contain contaminants that may become persistent in the sediments (e.g. trace metals, PAHs), leading to direct effects on mangroves due to direct uptake, or indirect effects due to effects on benthic infauna and thus leading to reduced rates of bioturbation and subsequent oxygen stress on the plants root systems.

Observed thresholds for effects are likely to vary depending on the health of the system, the hydrocarbon spilled and the environmental conditions; however, observations by Lin and Mendelssohn (1996) demonstrated that more than 1 kg/m^2 of oil during the growing season would be required to affect salt marsh or mangrove plants significantly.

Mangroves grow in intertidal mud and sand, with specially adapted aerial roots (pneumatophores) that provide for gas exchange during low tide (DEWR 2006). In South Australia, mangroves can reach a height of 5 m and are found mainly in low energy, muddy, sheltered coastal areas such as gulfs and bays, (McLeay et al. 2003, DEWR 2006). Key mangrove locations include:

- along the west coast of Eyre Peninsula – at Tourville Bay, Murat Bay, St Peters Island, Laura Bay, Smoky Bay, Streaky Bay, and Venus Bay
- Spencer Gulf – at Tumby Bay, Arno Bay, Franklin Harbour, Whyalla, northern Spencer Gulf (Two Hummock Point to Yatala Harbour), Port Germain, Port Pirie, Port Broughton, and near Wallaroo (with Spencer Gulf having the most extensive areas in South Australia) in northern and eastern Gulf St Vincent (DEWR 2006; Edyvane 1999; Gillanders et al. 2013).

Mangroves are also present at coastal locations within the wider Risk EMBA, typically within sheltered bays and inlets. In Victoria, mangroves are known to occur at Western Port and Corner Inlet, and at larger estuaries like the Yarran and Barwon rivers. The number of species and distribution increases further north where mangroves are found. In New South Wales, many species occur along the coast within tidal estuaries, coastal lakes and bays.

“Subtropical and temperate coastal salt marsh” (otherwise referred to as coastal salt marsh) is listed as a vulnerable Threatened Ecological Community (TEC) under the EPBC Act. This TEC is usually associated with soft substrate shores of estuaries and embayments (sandy and/or muddy) along low wave energy coastlines (DoE 2013). The physical environment for the TEC is coastal areas under regular or intermittent tidal influence, with salt marsh being the key vegetation type – that being salt-tolerant grasses, herbs, sedges, rushes and shrubs generally less than 50 cm high (DoE 2013).

Salt marshes occur in sheltered conditions, commonly in the strandline zone, and the vegetation offers a large surface area for oil absorption and trapping. Additionally, many salt marsh grasses, which can be dominant over large areas, have corrugated leaf surfaces which increase their holding capacity.

Evidence from case histories and experiments shows that the damage resulting from oiling is very variable – as are recovery times. Lighter, more penetrating oils are more likely to cause acute toxic damage than heavy or weathered oils. In areas of light to moderate oiling where oil is mainly on perennial vegetation with little penetration of sediment, the shoots of the plants may be killed, but recovery can take place from the underground systems. Good recovery commonly occurs within one to two years. Where thick deposits of viscous oil or mousse accumulate on the marsh surface, vegetation is likely to be killed by smothering and recovery delayed because persistent deposits inhibit recolonisation.

There are small isolated salt marshes present along the coast of the Risk EMBA (e.g. Oyster Harbour at Albany, Davenport Creek near Ceduna, Baird Bay, Streaky Bay, Kangaroo island and Coffin Bay and parts of the middle and upper reaches of the Spencer and St Vincent gulfs).

Predicted effects in context of this event

The Oil Spill Modelling Study (Appendix 7-1) predicts that under a mitigated Level 3 oil spill, concentrations of oil (>100 g/m^2) could contact areas of the Risk EMBA that support mangrove and salt marsh habitats. These concentrations pose a moderate to high level of threat to mangrove and salt marsh species (Appendix 7-2). Based on the modelling results, mangrove and salt marsh habitats at most risk, are those approximately between Ceduna / Streaky Bay and around Coffin Bay, South Australia. The modelling results also indicates that most mangrove and salt marsh habitats high up the Spencer Gulf and the Gulf St Vincent, South Australia and Melbourne (Port Philip Bay to Corner Inlet, and

Gippsland, are beyond the contours of low sea surface thresholds (Appendix 7-1).

The ecological significance of a spill on these habitats will be dependent on the degree of oiling and weathered state of the oil, and the total amount of habitat affected. Based on the modelling results, a single spill could expose a large area of coastline to moderate to high volumes of oil, but probabilities are low. At worst, oil affected mangrove and salt marsh habitats could take decades to full recovery (Burns et al. 1993).

Oil ashore is likely to be weathered (minimum of 21 days for stranding in South Australia coastlines that support listed salt marsh and mangrove locations (such as around Ceduna, Streaky Bay, Coffin Bay and Kangaroo Island) where the probability of shoreline contact varies from low to high. The northern reaches of the Spencer Gulf will not be exposed to elevated sea surface oil or shoreline loadings, but the south of the gulf may experience exposure to low thresholds of sea surface oils. Western Australian coastlines may experience moderate and high shoreline loadings but the probability of exposure to sea surface low level thresholds is low.

For reasons discussed above, the consequences of a 102-day oil spill on local mangrove and salt marsh habitats could have long effects (restitution time 3–10 years) and potentially damage a large area of these habitats in the Risk EMBA. Because mangroves and salt marsh are important benthic primary producers and provide nursery habitat for other species, the loss mangroves and salt marsh could have long-lasting indirect effects on other organisms (EPA 2016) hence conservative ranking of Category 6 has been applied.

Fitting the capping stack at Day 15 has low potential for medium term effects on sensitive areas of local importance and ranked Category 4. Success with the blowout preventer on Day 1 will result in a very low likelihood of any effects and ranked Category 1–3.

Species/receptors	Qualitative risk assessment for the planned mitigation scenarios		
	Relief well Day 102	CS fitted Day 15	BOP closed Day 1
Mangroves, salt marshes	6*	4	1-3

* When sea exposure contours of a November to February oil spill were assessed, no mangroves or salt marshes are predicted to be exposed to threshold sea surface at even low thresholds (shoreline loadings are reduced in probability and extent but may still be low to moderate in patches). As such, in this scenario, consequences reduced by one to 5 for a 102-day spill.

In addition, further mitigation will be assessed and where appropriate instigated such as the provision and use of containment and recovery measures (e.g. booms and vacuums) where practical (e.g. in sheltered bays) as detailed in Section 8.

Seagrass

Sensitivity

Seagrasses generally grow in sediments in intertidal and shallow subtidal waters where there is enough light and are common in sheltered coastal areas such as bays or lees of islands. As such, they may be exposed to both surface and subsurface hydrocarbons. Submerged vegetation in nearshore areas can be exposed to oil by direct contact (i.e. smothering) and by uptake by rhizomes through contaminated sediments. Exposure also can take place via uptake of dissolved/entrained hydrocarbons through plant membranes and seeds may be affected by contact with oil contained within sediments (NRDA 2012).

When seagrass leaves are exposed to petroleum hydrocarbons, sub-lethal quantities of the soluble fraction can be incorporated into the tissue, causing a reduction in tolerance to other stress factors (Zieman et al. 1984). The toxic components are thought to be the polycyclic aromatic hydrocarbons (PAHs), which are lipophilic and therefore able to pass through lipid membranes, accumulating in the thylakoid membranes of chloroplasts (Ren et al. 1994).

The susceptibility of seagrasses to hydrocarbon spills will therefore depend largely on distribution. Deeper communities will be protected from oiling under all but extreme weather conditions. Shallow seagrasses are more likely to be affected by dispersed oil droplets or, in the case of emergent seagrasses, direct oiling. Theoretically, intertidal seagrass communities would be the most susceptible because the leaves and rhizomes may both be affected.

Seagrass distribution in the GAB is patchy, typically in sheltered areas around Ceduna/Streaky Bay, within Spencer Gulf and Gulf St Vincent, west of Eucla, Israelite Bay/Recherche Archipelago and Nuyts Archipelago). Beyond this area, significant areas for seagrass can be found on the New South Wales coast. The *Posidonia australis* seagrass meadows of the Manning–Hawkesbury ecoregion is listed as an “endangered” TEC within the Risk EMBA.

Intertidal seagrass communities may come into direct contact with oil on shorelines. While the toxicity of the hydrocarbons is likely to have been reduced due to weathering, there remains the effect from smothering. Any reduced growth rates or temporary loss of seagrass cover (noting that rhizomes would remain intact) may result in dieback of seagrasses and some degradation of the habitat value.

Seagrasses, both ephemeral genera (*Halophila* spp.) and perennial genera (*Posidonia* spp.) are found across southern Australia (Waycott et al. 2014). In the GAB, seagrasses are typically more abundant in shallow (<20 m water depth) and sheltered environments. Although most seagrass species have extensive distributions (Waycott et al. 2014), others may be threatened. Short et al. (2011) listed *Posidonia sinuosa* as one of 10 threatened species of seagrass. Found from Kalbarri, Western Australia, to about Cape Jaffa, South Australia (Short et al. 2010), this species is declining in abundance at about 1% per annum (Short et al. 2011). *Posidonia* species typically take longer to recover following disturbance than most other species of seagrass (Collier et al. 2009; Kirkman & Kuo 1990).

Predicted effects in context of this event
The Oil Spill Modelling Study (Appendix 7-1) predicts that a mitigated loss of well control, surface oil concentrations of between 1 to 10 g/m^2 could reach areas supporting *P. sinuosa* in South Australia around Streaky Bay to Coffin Bay and the southern stretches of the Spencer Gulf but would not reach the Manning–Hawkesbury region. However, as *Posidonia* spp. are subtidal, they are unlikely to be adversely affected by floating oil. Subtidal seagrasses are more likely to be exposed to entrained and dissolved hydrocarbons; however, the modelling indicates little exposure of nearshore waters to in-water oil above effects thresholds. For reasons discussed above, a 102-day loss of well control is likely to have medium-term effects (restitution time 1–3 years) on *P. sinuosa* and other seagrass meadows and associated local ecosystems. Because seagrasses are important benthic primary producers and provide nursery habitat for other species, the loss of seagrass meadows could have indirect effects on other organisms (EPA 2016). Extensive seagrass meadows are also known from Spencer Gulf in South Australia (Appendix 7-2) and off Adelaide (Rouse et al. 2016). However, the Oil Spill Modelling Study (Appendix 7-1) predicts that under a mitigated loss of well control, surface oil and shoreline oil are unlikely to reach the upper Spencer Gulf or extend to Adelaide. Given the distance from the potential source of the spill and the natural subtidal distribution of *Posidonia* seagrass communities, the modelling showed that submerged seagrasses in these locations are unlikely to be exposed to significant levels of in-water hydrocarbons and dissolved fractions that tend to result in the greatest effects. The modelling shows that entrained and dissolved oil only has a 2–3% probability of contacting coastal areas at Eyre and Eucla at moderate concentrations. No areas are predicted to be exposed to high concentrations which could lead to seagrass death. While affected *Posidonia* meadows would be slow to recover, the extent of predicted effects will be minimal given they are largely protected by the overlying water and the concentrations of entrained and dissolved oil would be low. The intertidal seagrasses would be more likely to be affected by shoreline accumulations of oil; however, these affects would be reduced by dispersant application and these communities recover more rapidly. Overall, consequences are ranked Category 4 for a 102-day spill. Even if the capping stack was successfully fitted on Day 15, it is possible for some locations (e.g. Coffin Bay) to be affected albeit to a lesser degree but with restitution times predicted to be <1 year for local populations and ranked Category 4. If the blowout preventer is successfully fitted on Day 1, potential effects are ranked Category 1–3 as no known substantial seagrass beds are predicted to be exposed to elevated hydrocarbons.

Species/receptors	Qualitative risk assessment for the planned mitigation scenarios		
	Relief well Day 102	CS fitted Day 15	BOP closed Day 1
Seagrasses	4	4	1–3

Macroalgae
Sensitivity
Macroalgae generally grow on intertidal and subtidal rocky or consolidated substrata in shallow waters to >70 m depth in the Great Australian Bight (Commonwealth of Australia 2005), although some species can grow at depths of up to >100 m (where conditions allow) (Gurgel & McDermid). As such, they may be exposed to in-water hydrocarbons; however, are more likely to be susceptible to surface hydrocarbon exposure in intertidal habitats as opposed to subtidal habitats. Reported toxicity responses to oils have included a variety of physiological changes to enzyme systems, photosynthesis, respiration, and nucleic acid synthesis (Lewis & Pryor 2013). Smothering, fouling and asphyxiation are some of the physical effects that have been documented from oil contamination in marine plants (Blumer et al. 1971; Cintron et al. 1981). The effect of hydrocarbons however is largely dependent on the degree of direct exposure and how much of the hydrocarbon adheres to algae, which will vary depending on the oils' physical state and relative "stickiness". The morphological features of macroalgae, such as the presence of a mucilage layer or the presence of fine "hairs" will influence the amount of hydrocarbon that will adhere to the algae. A review of field studies conducted after spill by Connell et al. (1981) indicated a high degree of variability in the level of effect, but in all instances, the algae appeared to be able to recover rapidly from even very heavy oiling. The rapid recovery of algae was attributed to the fact that for most algae, new growth is produced from near the base of the plant while the distal parts (which would be exposed to the oil contamination) are continually lost. Other studies have indicated that oiled kelp beds had a 90% recovery within 3–4 years, however full recovery to pre-spill diversity may not occur for long periods after the spill (French-McCay 2004). Exposure to in-water hydrocarbons poses the greatest threat to sensitive macroalgal assemblages, specifically the Giant Kelp Forests TEC, that grow on rocky reefs from the sea floor ≥8 m below sea level. The largest extent of this TEC is in Tasmanian coastal waters. Some patches are also found in Victoria and south-east South Australia (DSEWPaC 2012b).
Predicted effects in context of this event
Southern Australia supports high macroalgae diversity (Huisman et al. 1998) and some of these species are defined as rare because they have only been recorded in a small number of locations (Scott 2013). Some species, such as the giant kelp (*Macrocystis pyrifera*) are also in decline due to climate change. Indeed, the Giant Kelp Marine Forest of south-

eastern Australia has been listed as an endangered threatened ecological community (TEC) (Appendix 7-2, Appendix 7-3). The "Giant Kelp Marine Forests of South East Australia" are found in shallow waters from about Cape Jaffa to Port MacDonnell, close to the South Australian–Victorian border and along the Tasmanian coast. The nearest location where the TEC is known to occur is approximately 750 km from the well location).

The Oil Spill Modelling Study (Appendix 7-1) predicts that under a 102-day mitigated loss of well control, surface oil concentrations of between 1 to 10 g/m^2 could contact areas supporting *M. pyrifera* from Cape Jaffa to Port MacDonnell and along the west coast of Tasmania with exposure to moderate shoreline loadings in smaller isolated areas. Little is known about the effects of oil on *M. pyrifera*, but some studies (e.g. Edgar & Barrett 2000; Reed & Lewis 1994) suggest that this species, like other macroalgae, may be some of the least sensitive marine species to oil exposure. Further subtidal distribution of these macroalgae would reduce exposure to surface oil and in the absence of moderate to high concentration of oil in the water, effects are expected to be minimal.

The consequences of a 102-day loss of well control on *M. pyrifera* are ranked Category 1–3 because the modelling indicates these areas are unlikely to be exposed to in-water hydrocarbons concentrations high enough to have an adverse effect on the macroalgae.

With a successful fitting of the capping stacks on Day-15 and a blowout preventer on Day-1, no effects are predicted from sea surface oil or water column exposure and ranked Category 1–3.

Species	Qualitative risk assessment for the planned mitigation scenarios		
	Relief well Day 102	CS fitted Day 15	BOP closed Day 1
Macroalgae	1–3	1–3	1–3

Shorelines

Sensitivity

The fate of spilled oil reaching shorelines depends on the characteristics of the oil, the type and width of the shoreline, the area of shoreline affected and the energy environment (Gundlach 1987; Reed et al. 1986; Reed & Gundlach 1989; Reed et al. 1989; Reed et al.1988). Even when beached, oil will continue to weather. However, several additional processes become important – refloatation, penetration into the substrate, and retention/transport in the shore-groundwater system. A considerable study of shoreline oiling, fates and removal processes was performed as part of the development of the COZOIL model for the U.S. Minerals Management Service (Reed et al. 1986, Gundlach 1987, Reed et al. 1988, Reed et al. 1989, Reed & Gundlach 1989). The shoreline interaction algorithms used in the oil spill modelling are based on this work.

The movement of oil on and off, into and out of the shoreline is a very dynamic process, changing as wind, wave and tide conditions change. In the oil spill modelling, each shoreline cell has an oil holding capacity based on oil viscosity, shoreline type, beach slope, beach width and shoreline grid cell length. Volatiles are assumed to evaporate off the shoreline immediately. Oil is removed from the shoreline or buried over time at a rate specific to the shore type. Deposition ceases when the holding capacity for the shore surface is reached (or when oil is no longer entering the shoreline system). When carrying capacity has been reached, oil subsequently reaching the area is resuspended and the slick continues to move along shore. After stranding, oil on the shoreline is removed over time through natural processes of degradation and resuspension.

There are a wide variety of different types of shorelines found along Australia's southern coast and offshore islands. The type of shoreline will influence the volume of hydrocarbon that could be stranded ashore and its thickness before the shoreline saturation point occurs. For instance, a sandy beach may allow hydrocarbon to percolate through the sand, and weathered oil may be buried, thus increasing its ability to hold more hydrocarbon ashore over tidal cycles and various wave actions in comparison to a rocky shore; hence hydrocarbon can increase in thickness onshore over time.

Shoreline data was obtained from the OzCoasts Smartline data set sourced via Geoscience Australia. The data was based on Environmental Sensitivity Index (ESI) codings (NOAA 2002) in line with IPIECA Guidelines. Shoreline types ranged from Rank 1: exposed, impermeable vertical substrates to Rank 10: vegetated emergent wetlands.

Predicted effects in context of this event

The following discussion considers the potential effects of shoreline accumulation with surface and SSDI mitigations (and natural attenuation). For 100 simulations, the case with the greatest volume ashore was considered in detail for each state (Appendix 7-1)

South Australian shorelines (which include island shorelines) would be at greatest risk from a loss of well control in May. They are the closest to the well location, with the shortest time to shoreline contact (~21 days) and will be subject to the highest levels of shoreline accumulation. The maximum fresh volume ashore was 6.5 m^3. By Day 162, the volume of weathered crude remaining ashore was predicted to be 42,941 m^3 for the mitigated case compared to 144,158 m^3 (~21%) if no dispersant was used. Although the effect of a loss of well control on individual shorelines will depend on the type of shoreline, aspect and whether they are high or low energy shores (e.g. NOAA 2002), overall, the consequence to shorelines in South Australia are likely to be Category 7 and long-term, with a restitution period of >10 years.

Shorelines in Victoria are also likely to be at risk from a loss of well control. They are most likely to be contacted by hydrocarbons from a loss of well control after South Australia, with a minimum time to shoreline contact of 43 days. Although the effect on individual shorelines will depend on the type of shoreline, aspect and whether they are high- or

low-energy shores (e.g. NOAA 2002), the effect to shorelines in Victoria may be long lasting, with a restitution period >10 years. This will greatly depend on the characteristics of hydrocarbons accumulating on shorelines. The maximum volume of fresh oil ashore was ~7.1 m^3. By Day 162, the volume of weathered crude remaining ashore was predicted to be 159,439 m^3 (~23%) and 52,950 m^3 (~8%) for the unmitigated (i.e. no dispersant) and mitigated (with dispersant) modelling, respectively.

March produced the run with the highest volume of oil ashore on Tasmania's western shorelines and the Bass Strait islands e.g. Flinders Island, are likely of contact from hydrocarbons at low to high levels. However, the modelled minimum time-to-contact was 54 days (e.g. King Island), with contact on mainland Tasmanian shores predicted to be around 60 days (Appendix 7-1). This means that the oil is likely to be weathered (possibly mousse, but likely to be more the consistency of tar balls), and therefore although accumulation may still be high, the potential for effects will be lower than from fresh oil. By Day 162, the volume of weathered crude remaining ashore was predicted to be about three times higher at 152,496 m^3 (~22%) and 48,845 m^3 (~7%) for the unmitigated (no dispersant) and mitigated (dispersant) modelling, respectively.

Modelling (May) indicated that New South Wales has very long minimum-time to contact (around double that of Tasmania and Western Australia at ~109 days). By Day 162, the volume of weathered crude remaining ashore was predicted to be 3.5 times higher at 151,748 m^3 (~22%) and 39,534 m^3 (~6%) for the unmitigated and mitigated modelling, respectively.

Should the spill travel west, modelling indicated that the most likely spots for shoreline loading in Western Australia were near the South Australia and Western Australia border (Israelite Bay to Esperance) with minimum time to contact around 56 days. By Day 162, the volume of weathered crude remaining ashore was predicted to be 8058 m^3 (~1%) and 1531 m^3 (~0.2%) for the unmitigated (no dispersant) and mitigated (dispersant) modelling, respectively.

For each state, the consequence is reduced when capping stack and the blowout preventer are implemented successfully on Day 15 and Day 1 respectively and ranked Category 4–5 and 1–4 respectively.

Value	Qualitative risk assessment for the planned mitigation scenarios		
	Relief well Day 102	CS fitted Day 15	BOP closed Day 1
South Australian shorelines	7	4–5	1–4

A spill during the preferred drilling period (November–February) would result in lower shoreline loadings for all states due to the prevailing winds and currents. Coasts potentially exposed to sea surface loadings at a low threshold are limited to the coastline on the southern tip of the Eyre peninsula, Kangaroo Island and from Cape Jaffa to east of Port Fairy. The probability of shoreline loadings at moderate and high thresholds are reduced but possible mostly along the southern tip of the Eyre peninsula, Kangaroo Island, Cape Jaffa to Port Fairy and around King Island.

In addition, further mitigation will be assessed and where appropriate, instigated such as the provision and use of containment and recovery measures (e.g. removal from beaches, booms and vacuums) where practical (e.g. in sheltered bays) as detailed in Section 8..

Coastal settlements and infra-structure

Sensitivity

Coastal settlements are potentially at risk of effects of reduced intrinsic or visual amenity values from both shoreline and surface hydrocarbon exposure. Aspects of coastal settlements that are at risk include recreational activities, protected areas, aesthetics, and cultural/heritage and spiritual values. Effects potentially include loss of access, restriction of activities, and loss of the resources themselves with broader consequences for communities.

The thresholds at which effects to coastal settlements may occur will vary depending on the aspects at risk. As an example, effects to aesthetics may be triggered by hydrocarbon visibility at the sea surface, or visible effects to fish, mangroves, heritage sites, protected areas, etc.

Predicted effects in context of this event

There are 104 areas defined as "Urban Centres and Localities" by the Australian Bureau of Statistics (2018) with coastal infrastructure or developments within or immediately adjacent to the Risk EMBA (Appendix 7-3). The distribution of these coastal settlements and the characteristics of the resident populations varies markedly throughout the area that may be affected. Ignoring the potential effects to economic values (covered in a following section), effects to coastal settlements and infrastructure could include:

- compromise to human physical and mental health
- decline in amenity or recreational values
- decline in aesthetic values
- decline in water quality
- damage to public infrastructure such as desalination plants
- reputational damage to regions contacted by oil.

The well location is located approximately 372 km south of the Australian mainland. This part of the mainland is dominated by the Nullarbor Plain, with very few populated settlements. Most settlements in this stretch of coast are

based around roadhouses that are used as stop off points for drivers along the Eyre Highway.

Ceduna and Port Lincoln are the largest towns in the region. Ceduna's economy is centred on crop and sheep farming, tourism, fishing and port activities that ship salt, gypsum and heavy mineral concentrate from mines located to its north (Thevenard Port is located 3 km east of the town).

Many other coastal settlements are scattered along the coasts that (depending on the actual spill characteristics, and fate and trajectory of the discharge), shoreline exposure to hydrocarbons has the potential to affect various coastal settlements extending from Esperance to Cape Patterson. Many of these coastal settlements are important regionally, nationally and internationally.

However, with dispersant applied far offshore, effects from surface and weathered oil accumulated along shorelines (Section 5.0, Appendix 7-1 and Section 8.0) are reduced for all states and in South Australia (nearest shoreline) effects may include temporary health warnings, temporary closures of tourist sites/activities, reduced aesthetic values, damage to reputation and damage to public infrastructure.

Although the effect on individual settlements will depend on the type of shoreline, aspect and whether they are high- or low energy shores, with a restitution period of 1–10 years they are ranked Category 5 to 6. The successful implementation of a capping stack and of blowout preventer closure would reduce the exposure risk to coastal settlements in duration and severity of sea surface exposure and shore loading and additional containment and recovery would be considered on a case by case basis where a high efficacy can be expected. Consequence will be reduced to 4 and 1–3 for the capping stack and blow out preventer scenarios, respectively.

Receptor	Qualitative risk assessment for the planned mitigation scenarios		
	Relief well Day 102	CS fitted Day 15	BOP closed Day 1
Coastal settlements, infrastructure	5–6	4	1–3

Protected areas (including AMPs, KEFs and Ramsar sites)

Sensitivity

Australian Marine Parks (AMPs)

Australian Marine Parks (AMPs) in the Risk EMBA are described in Appendix 7-2. AMPs vary in their conservation objectives, but all are designed to conserve fauna, habitats and water quality over the long term. Most AMPs are zoned into different sections of varying levels of protection. Zones with lower protection levels permit a range of different human activities. For instance, a Multiple-Use Zone allows extractive type activities such as fishing and oil exploration. The proposed Stromlo-1 well is inside a Multiple-Use Zone of the Great Australian Bight Marine Park (GAB AMP).

A temporary deterioration of water quality could still have negative effects on organisms, such as plankton, seabirds, marine mammals and fisheries resources. These effects are discussed individually in other sections.

Entrained hydrocarbons may also cause negative effects to benthic sediments and habitats through deposition/ sedimentation in marine snow and faecal pellets (e.g. from copepods). Accumulation of hydrocarbons in sediments can have deleterious effects on marine benthic infauna and can be bioaccumulated through food webs.

Sensitive receptors within AMPs that may comprise part of the justification for the designation may also use the air–water interface, at which point they may be exposed to surface hydrocarbons and volatile organic compounds in the air.

Key Ecological Features

Key Ecological Features are the parts of the marine ecosystem that are important for the biodiversity or ecosystem functioning and integrity of the Commonwealth Marine Area. KEFs present within or overlapping the Risk EMBA are listed in Appendix 7-3 (Table 1.2).

Ramsar sites

Ramsar sites are wetlands of international importance (Section 4.0), some are situated along the shoreline of the Risk EMBA and some located immediately adjacent to the Risk EMBA (Appendix 7-3). Most Ramsar sites have minimal risk of receiving oil following a loss of well control because they have no or very narrow connections to the sea. If surface oil was to enter a Ramsar site or Nationally Important Wetland, the level of effect would be dependent on the type of receptors exposed to oil and the proportion of the site exposed to oil as well as the nature of the oil (fresh versus weathered).

Predicted effects in context of this event

Australian Marine Parks (AMPs)

Surface and in-water oil entering these AMPs will compromise water quality until the oil is broken down and or currents shift the weathering oil outside the boundaries of the AMPs. Thus, water quality effects are predicted to persist only over the short to medium term in the AMPs.

The Oil Spill Modelling Study (Table 23, Appendix 7-1) predicts that under a 102-day mitigated LOWC, the degree of effect to AMPs and restitution time ranges widely depending on the nature and scale of the LOWC, the prevailing wind and current direction, and the proximity of the AMP from the release point. Modelling (Table 24, Appendix 7-1) indicated that three AMPs (GAB MP, Western Eyre and Murray (at 1% probability)), could be exposed to high thresholds of sea surface oil and six AMPs exposed to the moderate threshold for sea surface oil, with minimum time to contact ranging

from 14 days to 60 days. No AMPs (other than the GAB MP) were predicted to experience exposure to entrained oil or dissolved oil at or above the very low thresholds.

The GAB AMP will be most affected by a 102-day LOWC release, with consequence being Category 6 (long-term effects on environmentally sensitive areas of national importance, restitution period 3–10 years).

For AMPs, a successful capping stack implementation will reduce effects to medium term for the GAB Marine Park and the successful blowout preventer fitting on Day 1 will reduce the restitution time to short term for the GAB Marine Park.

Key Ecological Features

The only KEFs where surface oil exposure was predicted to exceed the low threshold were the Bonney Coast Upwelling (35% at the moderate threshold, 0% at high) and the Kangaroo Island Pool (79% at moderate, 13% at high) (Table 25, Appendix 7-1). Minimum times before exposure for the Bonney Coast Upwelling KEF for the mitigated cases were 35 days and 44.5 days for low and moderate exposure respectively, and a 27% probability of exposure to very low levels of entrained hydrocarbons at the 0–10 m depth range. Minimum times before exposure for the Kangaroo Island Pool KEF for the mitigated cases were 14.8, 20.6 and 24.1 days for low, moderate and high thresholds respectively. Exposure of the Kangaroo Island Pool KEF was predicted to exceed low levels of entrained hydrocarbon exposure at the 0–10 m depth range (2% probability) and very low levels at the 90–100 m depth range (5% probability). No other KEFs would be exposed to dissolved or entrained hydrocarbons at or above the low threshold for the 0–10 m and 90–100 m depth range (Tables 36, 37, 41 & 42, Appendix 7-1).

The Kangaroo Island Pool KEF will be most affected by a 102-day LOWC release, with consequence being Category 5 (short-term effects on nationally important KEF, restitution period <1 years).

With a successful capping stack fitting on Day 15, the Bonney Coast Upwelling and the Kangaroo Island Pool KEFs are the only KEFs that could be exposed to a low surface oil threshold albeit at a low probability. No effects at the KEFs water depths are predicted for a successful closure of the blowout preventer on Day 1.

Ramsar sites and Nationally Important Wetlands

Sensitive receptors found in Ramsar sites connected to the sea could include mangroves, salt marshes, fishes, shorebirds and seabirds. The consequences of oil to these specific receptors have been described under those receptors. If a Ramsar site was exposed to oil following a LOWC, it is likely to have a long term or permanent effect. However, most of the wetlands are above sea level and/or closed to the ocean with seasonal or permanent sandbars and unlikely to be open in summer when there are typically lower river flows.

A number of Ramsar sites (e.g. the Coorong, Lake Alexandrina and Albert Wetland, Picaninnie Ponds Karst Wetland, Port Philip Bay, east coast of Tasmania and Flinders Island sites, Corner Inlet and Gippsland Lakes) could be exposed to low thresholds of surface oiling under specific metocean conditions. However, many of these (e.g. Picaninnie Ponds Karst Wetland) have sand dunes between the ocean and the wetlands hence the wetland itself is highly unlikely to be affected in any manner.

Likewise, several nationally important wetlands lie interspersed along the coast west of Esperance in Western Australia and from Ceduna in South Australia, though Victoria to north of Sydney (New South Wales). These could be exposed to low sea surface exposures during November to May under certain metocean conditions. Should sea water with low levels of weathered oil enter the wetlands, the absence of toxicity effects to flora and fauna should ensure that the values of those wetlands are not compromised

For Ramsar sites, a successful implementation of the capping stacks is predicted to reduce exposure risks such that no Ramsar sites are affected from surface or in-water hydrocarbons, but weathered oil loadings ashore are possible. With a successful fitting of the blowout preventer on Day 1, no effects are predicted.

Nationally important wetlands such as those around Ceduna, Streaky Bay, Coffin Bay and west Kangaroo Island could be exposed to low to moderate sea surface thresholds under a 102-day spill scenario. With a successful capping stack implementation, some of these South Australian wetlands could be exposed to low threshold sea surface effects and moderate to high loadings of weathered oil ashore. No effects are predicted when the blowout preventer is successfully closed on Day 1.

Species/receptors	Qualitative risk assessment for the planned mitigation scenarios		
	Relief well Day 102	CS fitted Day 15	BOP closed Day 1
AMPs (GAB MP)	6	5	4
KEFs	5	1–3	1–3
Ramsar wetlands	6*	5	1–3

* When sea exposure contours of the mitigated case were assessed for the November–February period, the probability of sea surface exposure and the extent of shoreline loadings reduces.

No Ramsar wetlands are predicted to be exposed to threshold sea surface even at a low threshold. but low-moderate shoreline loadings of weathered oil may come ashore e.g. near the South Australian–Victoria border and King Island. As such, consequences for Ramsar wetlands reduce from Category 6 to 5.

Nationally important wetlands on the west of Kangaroo Island and the Eyre Peninsula south-west of Port Lincoln are unlikely to be exposed to surface oil.

In addition, further mitigation will be assessed and where appropriate instigated such as the provision and use of

containment and recovery measures (e.g. booms and vacuums) where practical (e.g. across narrow access low flow estuaries) as described in Section 8.0.

Other socio-economic values

Sensitivity

A wide range of socio-economic activities occur in the Risk EMBA; key sensitivities include (but are not limited to):

- commercial fisheries
- aquaculture
- shipping and ports
- defence
- tourism and recreation (including recreational fishing and surfing)
- heritage (including Native Title).

The thresholds at which effects may occur to socio-economic values vary depending on the aspects at risk. For example, shipping and defence are likely to be affected at the level of temporary exclusions from sea areas during response; whereas commercial fisheries and aquaculture may be affected by temporary fishery closures, restrictions on sales (e.g. catches are unsafe for human consumption) or effects to market value (e.g. perceived and real tainting).The socio-economic effects of an oil spill would vary, depending on the characteristics of the specific activity affected, and the nature and scale of the spill, but have potential for long-term effects to the region and state economies. Market condition, management and behavioural responses are likely to have an effect on the economic outcomes (e.g. GAB fisheries; Pascoe 2018).

The socio-economic effects of a major oil spill to commercial fisheries, aquaculture and ports, defence, tourism and heritage are well documented (Cohen 1993; Smith et al. 2014; Sumaila et al. 2012). However, effects to fisheries are probably best known. Surís-regueiro et al. (2007) reported the economic cost to Spanish fishers resulting from the Prestige oil spill. A primary reason for the monetary cost was the temporary cessation to fishing activities following the spill. Similarly, major economic effects to fishers followed the Macondo spill (McCrea-Strub et al. 2011). This was also mainly due to fishery closures. Sumaila et al. (2012) estimated significant economic loss to both commercial and recreational fishing, and to aquaculture industries following the Macondo spill. The authors predicted long-term losses in total revenue and total profits. Major spill can also have negative effects to regional and national tourism economies (Ritchie et al. 2013).

There are Native Title claims over shorelines of South Australia, Western Australia, New South Wales and Victoria, within the Risk Environment that May Be Affected and within these claims there are sites of cultural significance which may be affected if exposed to floating oil and shoreline accumulations of oil.

Sites of cultural importance to Aboriginal peoples include coastal middens, campsites with freshwater springs and areas linked to song lines. The documented traditional Aboriginal community connections with the offshore area are those of the Mirning, Wirangu, Narangga, Kaurna and Ngarrindjeri (Appendix 7-3) who identify as having Dreamtime connections to whales and sea lions (totems), and responsibility over the “Sea Country” of the Great Australian Bight. The Dreaming is the worldview that structures Aboriginal Australian cultures and provides Aboriginal peoples with a framework for understanding and interpreting each person's place in the world. The Dreaming describes the strong physical, cultural and spiritual connection that Aboriginal Australians have to the land and all living beings.

A major oil spill could have consequences for marine life and coastal amenity and may affect the connection some communities have with their totems and ‘Sea Country’. In addition, response activities may impede these connections. Aside from disturbance to habitats and marine fauna that are of cultural significance to Aboriginal communities along potentially affected coastlines, spill response activities may create disturbance to cultural values. Section 8.7 evaluates the risks associated with shoreline protection and clean-up activities such as the movement of responders, vehicles and equipment through dune areas disturbing cultural heritage artefacts/sites. Issues raised by the Miwi-Inyeri Pelepi-Ambi Aboriginal Corporation (MIPAAC), the Mirning People and an Elder of Ngarrindjeri Nation were loss of access to culturally significant areas and temporary exclusion during a response, adequacy of the oil spill response capacity, the loss of amenity of coastal sites, degrading the health of the ocean, and affecting their spiritual connection to the sea, ocean, marine life and people.

Predicted effects in context of this event

Aquaculture (oyster farming) in Denial Bay and Smoky Bay are important industries for the area (District Council of Ceduna 2017). Port Lincoln is well regarded for its tuna fishing and on-grow (ranching) activities. Like Ceduna, its economy is based on crop, sheep and beef farming, as well as tuna, prawn, abalone and scale fishing and shark cage diving.

Fish in general are discussed above (see “Bony fish and sharks”).

Southern bluefin tuna

SBT occur throughout the Atlantic, Pacific and Indian oceans feeding on fish, cephalopods, crustaceans and salps. The SBT fishery covers the entire sea area around Australia out to 200 NM from the coast (Australian Fisheries Management Authority 2018). The Blue Fin Tuna (BFT) Commonwealth Fishery has been selected as representative of the largest fishing interest in the GAB. Fishing is mostly concentrated inshore of the 200 m isobath. SBT are wild caught in the GAB

largely from January (but can be from December) and towed in nets to near Port Lincoln where they are fed local sardines supplemented by imported feedstock till harvesting is completed around the end of August.

Whilst the sustainability status is "uncertain" (Australian Fisheries Management Authority 2018), stocks are "low" (DEE n.d.) and the SBT is now considered "conservation dependent". All assessments of the SBT stock indicate that catches of SBT are the primary factor that has caused the decline of the stock to its current low level and which has prevented the recovery of the stock (DEE 2018). Current low stock levels are due to a combination of factors including reduced levels of spawning stock and fishing effects on spawning populations (DEE, Southern bluefin tuna, available at http://www.environment.gov.au/biodiversity/threatened/nominations/ineligible-species/thunnus-maccoyii). For this assessment, effects to population levels were assumed in the order of magnitude as the annual allowable catch (which for 2017–2018 was 6165 tonnes).

The Fishery Status Report (2019) for 2017–18 estimates the gross value of production (combined value of catch at the point of transfer to farming pens and catch sold direct into global markets) as $39.7 million (https://www.agriculture.gov.au/abares/research-topics/fisheries/fishery-status/southern-bluefin-tuna-fishery#233-economic-status). The 8102 tonnes exported in 2016-2017 were valued at $123 million based on post-ranching exports (http://www.agriculture.gov.au/SiteCollectionDocuments/abares/publications/fsr2018.pdf). ABSTIA estimate the value at $120-280 million (ABSTIA communications, 20 March 2019).

Assessment of the potential financial and socio economic impacts of a spill on the Southern Bluefin Tuna Fishery considered the relationship between the catch value and the value of Individual Transferable Quotas, the value of the caught stock and the farmed/exported stock, and the importance of Individual Transferable Quotas as collateral for financing (due to the high value added and investment in processing facilities).

Juvenile SBT are known to occur in the GAB from about November to March, leaving between March and July (Appendix 7-3), hence they could be in the GAB if the spill occurred early during the activity period. By maturity, most fish have migrated into the deeper waters of the South Atlantic, Indian and south-west Pacific oceans (DEE 2018) – but not the whole population migrates.

Juveniles are generally more sensitive to oil and other contaminants than adults. In the GAB, SBT form schools near the sea surface (<200 m deep) during the day, feeding on sardines or krill. Given these behavioural traits, juvenile SBT could be exposed to surface oil, entrained and/or dissolved oil following a loss of well control. Compared with early life stages, there is little knowledge on what concentrations juvenile or adult SBT and other pelagic bony fish predators can tolerate before resulting in mortality or sub-lethal responses (Esbaugh et al. 2016; Incardona et al. 2014). Oil related effects to prey, such as sardines (Evans et al. 2017), could also directly or indirectly affect SBT and their recovery in the GAB. Floating weathered oil could reach sea cages under specific oceanic conditions.

A major part of the SBT annual growth is gained in their ~5-month residency in the GAB with known spawning grounds in the north-east Indian Ocean. Population effects are unlikely in the offshore waters, but large numbers may be affected at lethal and sub-lethal thresholds near shore with fishery effects (and public perception effects) likely to have very long-term effects. A temporary (short- or long-term) fisheries closure put in place by the fisheries themselves or by the regulators in combination with oil tainting (actual or perceived), would lead to financial losses to fisheries and economic losses for individual licence holders. Fisheries closures and the flow on losses from the lack of income derived from these fisheries may have widespread socio-economic consequences, such as job loss (for example in fisheries service industries in tackle and bait supplies, fuel, marine mechanical services, etc). It is noteworthy that after the Macondo oil spill, the multi-species tuna fishery landings had recovered within one year (Carroll et al. 2016)

Recovery will be in part dependent on the recovery of sardine stocks. Sardines are a fast-growing fish. Two mass mortality events (1995, 1998) are thought to have killed more fish over a larger area than any other recorded fish kills, each event estimated to have killed over 70% of spawning biomass in South Australian waters (PIRSA 2017; Ward et al. 2001). Victorian fisheries reported catches of 2344 t for 2016–2017.PIRSA regards stocks as currently "sustainable" with the total allowable catch for 2017 as 42,750 t (Ward et al. 2017).

For reasons discussed above the consequences of a 102-day loss of well control could have very long-term effects (restitution time >10 years) on populations of national or international importance and ranked as Category 7. Given the successful capping stack implementation significantly reduces the effects of the event by reducing the affected area and its duration, the likely consequences are lessened to medium term effects recovery in 1–3 years for activities or populations of national or regional importance) and ranked Category 6. Given the successful blowout preventer implementation on Day 1, consequences are reduced to short term effects (restitution time <1 year) for activities of national or regional importance with effects being localised to the central GAB around the MODU and ranked Category 5.

Historic and natural heritage sites, and Indigenous heritage values

Impacts from unplanned events on biological and ecological values of the Risk EMBA are assessed in Section 7.0 under the appropriate headings of the risk assessment tables.

Impacts on and recovery of Aboriginal heritage values are linked to beaches, coastal vegetation and marine life as assessed individually above. Sites of significance are likely to be above the high tide mark; however, impacts from degraded aesthetics of sites along the coast may take time to recover and loss of access to sites during a response will be temporary (<1 year).

Potential for impacts during oil spill response are minimised through the application of Scientific Monitoring Plan 9 (SMP9) "Assessment of Impacts and Recovery of Areas of Particular Recreation, Tourism, Conservation, Heritage and Native Title Importance". This Plan is summarised in Table 5.2 of Section 5.0 in the OPEP (Appendix 9-1), including activation and termination criteria. It provides a framework to evaluate the impacts of an oil spill on, and recovery of,

areas of particular cultural heritage or Native Title importance. Effective consultation post-release, pre-exposure and post-exposure, will ensure the appropriate communities and agencies are involved, monitoring methods and timelines agreed, and potential disturbance minimised.

Other commercial activities

The Oil Spill Modelling Study (Appendix 7-1) predicts that under a mitigated loss of well control, surface oil concentrations of between 1 to 25 g/m^2 could contact parts of areas supporting commercial fishing grounds and aquaculture regions, resulting in temporary closures. Surface oil is also predicted to reach major ports and thus could pose a risk to commercial infrastructure. Entrained oil may affect offshore fisheries if operating largely beyond the 200 m isobath. Carroll et al. (2016) provided a detailed assessment of the economic impacts to the seafood industry in the US states of Alabama, west Florida, Louisiana, Mississippi, and Texas following the Macondo (Macondo) spill in the Gulf of Mexico. The Macondo spill was similar in duration to the worst-case credible spill scenario described in this EP. Carroll et al. (2016) examined impacts to 10 categories of fishery: shrimp (prawns), oysters, menhaden (fish of the genera *Brevoortia* and *Ethmidium*), blue crab, reef fish, pelagic finfish, other crustaceans, bait, other shellfish and miscellaneous finfish. Overall, the oil spill led to between US$51.7 and US$952.9 million loss in total sales. This loss cost the region US$21.4–US$392.7 million in value-added services, US$21.6–US$309.8 million in income, and affected 740–9315 jobs. The harvesting sector bore the brunt of the impact. Positive impacts were reported for less affected states because of the increased price for seafoods in short supply. In some instances, impacts to fishery stocks appeared to have been very short lived. For example, the authors concluded that the shrimp (prawn) harvests had rebounded within two years following the spill. Carroll et al. (2016) also summarised seafood industry trends to better understand the effects of the spill on the seafood industry. The trend analysis highlighted the challenges in predicting the economic consequences of oil spills to seafood industries.

Based on the modelling results, areas of southern Australia could be at risk of accumulating large volumes of shoreline oil. Some of these areas support locally, regionally and nationally important tourism activities and commercial infrastructure at risk of oiling. Section 8.0 discusses the role of dispersants applied far offshore to minimise effects of oiling on nearshore and shoreline environments and infrastructure.

For reasons discussed above the consequences of a 102-day loss of well control could have very long-term effects (restitution time >10 years) on populations of national or international importance ranked Category 6 to 7. Given the successful capping stack implementation significantly reduces the effects of the event by reducing the affected area and its duration, the likely consequences are lessened to medium term effects recovery in 1–3 years for activities or populations of national or regional importance) and ranked 6. Given the successful blowout preventer implementation on Day 1, consequences are reduced to short term effects (restitution time <1 year) for activities of national or regional importance with effects being localised to the central GAB around the MODU and ranked Category 5.

Species / other	Qualitative risk assessment for the planned mitigation scenarios		
	Relief well Day 102	CS fitted Day 15	BOP closed Day 1
SBT	7*	6	5
Other commercial activities	6–7	6	5

* When sea surface oil exposure contours of a November–February oil spill were assessed (Appendix 7-1), the area around Port Lincoln (important for SBT ranch sites) and a large portion of the eastern and far western GAB (especially inland of 200 m isobath) are not predicted to be exposed to sea surface oil above the low threshold. As such, consequences could be reduced by one category.

7.7.12.1 Representative species

Table 7.11 lists the factors considered when certain receptors, locations and socio-economic values were selected as representative of a grouping of similar receptors, to ensure the worst-case consequences were covered.

Table 7.11 Representative environmental groups for assessment of oil spill risks

Receptor group/s	Sub-group/s	Species/Value within the Risk EMBA	Factors considered in selecting representative taxa/areas
Avifauna	Seabirds	Shy albatross	Solitary foragers protected under National Recovery Plan, endangered, breeding colonies within Risk EMBA, slow recovery, endemic. Represents other albatross, petrels
		Short tailed shearwater	Large flocks, commercially harvested, open ocean migration. Represents other migratory seabirds that forage in large flocks e.g. terns

Receptor group/s	Sub-group/s	Species/Value within the Risk EMBA	Factors considered in selecting representative taxa/areas
		Little penguin	At risk on a regional scale, spend large percentage of time in the water, value to tourism, nesting on shoreline in Risk EMBA
	Shorebirds	Eastern curlew	Important intertidal foraging areas in Risk EMBA, migratory, critically endangered, large flocks
Marine reptiles	Turtles and sea snakes	Generic	No specific taxon selected due to low probability of occurrence of all taxa, similar life histories and sensitivities. Endangered or vulnerable
Plankton	Phytoplankton, zooplankton	Generic	Important basal role in food web, particularly in areas of upwelling near Kangaroo Island / Bonney Coast Upwelling
Bony fishes and sharks	Syngnathids	Generic	Conservation significant benthic fish, in shallow waters of the Risk EMBA
	Small pelagic fishes and other bony fishes	Small pelagic fishes of the SW Marine Region	Small pelagic fishes KEF based on baitfish in the eastern GAB. Listed as a value of Australian Marine Parks within Risk EMBA, intermediate role in food web, habitat within the water column (e.g. demersal/pelagic)
	Southern bluefin tuna	Migrating juveniles	High order predator role in food web. Commercially important species which migrates into GAB. Conservation Dependent species.
	Sharks and rays	Great white shark	Apex predator role in food web. BIA in region, listed as value of marine parks. Representative of 5 threatened and 7 migratory shark species.
	Handfish	Spotted, Ziebell's and Red Handfish	Critically endangered, endemic benthic fish, sparse distribution in shallow waters of the Risk EMBA
Marine mammals	Pinnipeds	Australian sea lion	Vulnerable species protected under the Recovery Plan, not increasing or declining populations, breeding and resting sites in centre of Risk EMBA, documented BIAs in the region, noted as a value of specific protected areas (e.g. KEFs and marine parks), tourism value, links to indigenous culture, stakeholder interest
		New Zealand fur seal	Listed species (not threatened), increasing population, breeding and resting sites in centre of Risk EMBA, documented BIAs in the region, value of specific protected areas (KEFs and marine parks), tourism value, links to indigenous culture, stakeholder interest
		Australian fur seal	Listed marine species (not threatened), breeding and resting sites to east of Risk EMBA, documented BIAs in the region, noted as a value of specific protected areas (KEFs and marine parks), tourism value, links to indigenous culture, stakeholder interest
	Cetaceans	Pygmy blue whale	Endangered and migratory species, stakeholder interest, foraging BIA in upwelling zones in east of Risk EMBA, slow recovery, representative of migratory, transient baleen whales
		Southern right whale	Endangered, migratory, iconic species linked to tourism and indigenous culture, stakeholder interest, calving BIA and migratory route in Risk EMBA, recovering, representative of nearshore whales and other cetaceans
		Sperm whale	Migratory, deep foraging areas along shelf edge in Risk EMBA, slow recovery, representative of other sperm whale species and other toothed whales

Receptor group/s	Sub-group/s	Species/Value within the Risk EMBA	Factors considered in selecting representative taxa/areas
Benthic communities and habitats	Benthic invertebrates	Generic	Important role in benthic food webs, general assemblages of sponges, seapens, crustaceans, echinoderms, cnidaria, annelid worms, molluscs, representative of benthic habitats across the region
	Benthic habitats	Generic	Support benthic communities ecologically, range of responses to exposure to oil, range of locations and water depths, range of dependent biota, representative of soft sediments, shallow water hard substrate, unconsolidated mixed and particulate sediments
	Corals	Deep-water and shallow water corals	Solitary deep-water corals represent slow growing and slow recovering benthic communities in deep areas of central bight; shallow water corals represent sensitive coastal habitat forming taxa
Coastal habitats	Mangroves and saltmarshes	Generic	Important habitats and support food webs, role in coastal stability, national or regional importance, relatively slow recovery, listed as values of coastal parks and reserves. Tropical and Temperate Coastal Saltmarshes are protected as a TEC. Representative of vegetated habitats on coast
	Shorelines	Generic	Important habitats for a wide range of biota, representing sandy beaches, muddy flats, rocky bays and cliffs, includes areas with coastal reserves
Intertidal and shallow water habitats	Seagrasses	*Posidonia* spp.	Perennial seagrass, important as benthic habitat in sheltered bays, in places is listed as a threatened ecological community, slow growing and slow to recover from disturbance, representative of other seagrasses and associated biota, potentially exposed to resuspension of shoreline loadings
	Macroalgae	Generic and Giant Kelp Marine Forests of South East Australia	Threatened ecological community, larger species, slower recovery than smaller taxa, representative of macroalgal communities including associated biota
Protected areas	Australian Marine Parks	Great Australian Bight Marine Park	Legislated protected areas, range of associated values, highest exposure to fresh and weathered oil (surface and in water), quickest time to exposure, only marine park exposed to fresh oil, stakeholder interest, representative of the other marine parks within the Risk EMBA which will be less exposed
	Key Ecological Features	Benthic Communities of the Eastern GAB Bonney Upwelling and the Kangaroo Canyons	Legislated protected areas, support values of national or international importance, underwater features potentially exposed to in-water oil and floating surface oil (Bonney Upwelling area), biological values associated with KEFs may be at risk from oil, regional ecological importance in primary productivity, food webs and species diversity (including whale aggregations), representative of KEFs further from the site which would at lower risk
	Ramsar wetlands, wetlands of national importance	Wetlands around Ceduna, Streaky Bay, Coffin Bay, west Kangaroo Island and southern St Vincent Gulf	Closest wetlands on coast within Risk EMBA, connected to the sea and potentially exposed, legislated protected areas, slow recovery habitats, representative of coastal wetlands from WA to NSW

Receptor group/s	Sub-group/s	Species/Value within the Risk EMBA	Factors considered in selecting representative taxa/areas
Coastal settlements and infrastructure	Coastal amenity	Port Lincoln (SA) Victor Harbour (SA) Portland (VIC) Warrnambool (VIC) Torquay-Jan Juc (VIC) Ocean Grove-Barwon Heads (VIC).	Largest coastal settlements (>10,000 people) in states contacted by oil in first 50 days of a spill (Appendix 7-1), consideration of the coastal towns that would experience highest loadings, and, representative of risks to other coastal towns
Socio-economic values	Shipping and Ports	Port Lincoln Adelaide	Closest ports, stakeholder interest, tourism, centres for shipping and supporting Stromlo-1 program, representative of other ports in Risk EMBA.
	Defence	Restricted areas off Kangaroo island, southern Tasmania and the NSW coast	Access to the sites may be affected during response, national security, representative of Defence activities at lower risk further from well location
	Commercial fishing	Southern bluefin tuna fishery Sardine fisheries	Linked fisheries, extend to continental shelf break, closest to well location and within Risk EMBA, stakeholder interest, important socio-economic implications for the region, representative of Commonwealth and state fisheries which overlap Risk EMBA
	Aquaculture	SBT ranches Molluscs and finfish	Range of feeder types, range of pen /rack set ups with differing potential exposure to plumes, important socio-economic implications for the region, representative of in-water coastal operations
	Coastal tourism	Swimming, surfing, recreational fishing, whale watching	Range of commercial values, seasonal differences, important socio-economic implications for the region, widespread along the coast and coastal waters, perception risks, representative of tourism and recreational activity areas along the coast in the Risk EMBA
	Heritage and cultural	Native Title areas	Important cultural and socio-economic values for the region, broadly subject to same stressors and exposure pathways; therefore representative of European and Aboriginal heritage (including Native Title).

7.7.13 Risk treatment

7.7.13.1 ALARP workshops

Equinor Australia B.V.'s senior management reviewed the suite of control measures described within the Environment Plan to mitigate the risk of a loss of well control, and considered alternative, additional and improved control measures that may be able to further reduce the consequence. ALARP workshops also considered whether the predicted risks following the demonstration of As Low As Reasonably Practicable for each risk assessed within the Environment Plan were low.

Four ALARP workshops were held between September 2017 and May 2018:

1. ALARP Workshop 1 on 27 September 2017 covered "Good Practice" – review issues raised in Environmental Hazard Identification and application of industry standards and practice, assessed additional controls if relevant.
2. ALARP Workshop 2 on 10 October 2017 covered "Engineering Risk Assessment" and "Precautionary Approach" – review issues raised in Environmental Hazard Identification and application of sound engineering and scientific principles and methods, assessed additional controls if relevant.
3. ALARP Workshop 3.1 on 7 March 2018 covered "Source Control" – source control strategies and alternatives considered.

4. ALARP Workshop 3.2 on 16 April and 15 May 2018 covered "Spill Response" – spill response strategies and alternatives considered.

Appendix 7-4 records the considerations of Equinor Australia B.V. in determining whether risks from a loss of well control were demonstrably As Low As Reasonably Practicable. The ALARP workshops considered a number of alternatives for implementing various additional source control measures in the event of a loss of well control, with the aim of reducing the amount, or effect, of oil released.

The measures adopted are summarised below:

- sub-sea intervention by a remotely operated vehicle to close the blowout preventer
  - potential to completely shut-off the flow soon after the incident. If the blowout preventer intervention does not succeed in shutting-off the flow, it is likely that it will partially restrict the well bore and reduce the volume of oil lost.
  - standard industry practice would result in well shut-in within 10–21 days (using a remotely operated vehicle vessel from the North West Shelf or Singapore)
  - Equinor Australia B.V. has committed to having a remotely operated vehicle on a standby vessel which could result in well shut-in within one day
  - this would result in a potential reduction in duration of the spill by 101 days and with a volume reduction of 677,691 m^3 hydrocarbons released (or an equivalent of a 98.9% reduction in potential volume spilled in comparison to the 102-day release total release volume of 685,440 m^3)
  - if successful, other measures would not be required
- subsurface dispersant injection
  - would be used if sub-sea intervention by a remotely operated vehicle was unsuccessful, and would continue to be used while a capping stack was being installed and relief well drilled
  - prevents or minimises the amount of oil exposure to shallow coastal waters and shorelines, where it could cause considerable damage to sensitive environmental resources, such as shorebirds and mammals, and disrupt socio-economic activities
  - standard industry practice would result in subsurface dispersant injection being deployed within 23 days (using a vessel from Singapore)
  - Equinor Australia B.V. has committed to having the capability to deploy subsurface dispersant injection within nine days (using a contracted vessel in the Great Australian Bight and subsurface dispersant injection by air from Singapore)
- sub-sea capping stack
  - would be used if sub-sea intervention (closing the blowout preventer) by a remotely operated vehicle was unsuccessful and would be used in conjunction with subsurface dispersant injection until the capping stack is fitted
  - a sub-sea capping stack provides a means of choking back and stopping the flow from a well, establishing a barrier
  - standard industry practice would result in capping the well within 24–35 days (using a capping stack transported on a vessel from Singapore)
  - Equinor Australia B.V. has committed to having the capability to cap the well within 15 days by having a capping stack flown from Singapore to Adelaide and using a sub-sea construction vessel to site
  - this has the potential to reduce the duration of hydrocarbon release by up to 87 days and with a spill volume reduction of 571,500 m^3 (equivalent to a reduction of up to 83.4% of potential volume spilled in comparison to the 102-day release total release volume of 685,440 m^3)
- drilling a relief well (RW)
  - would be initiated (in conjunction with subsurface dispersant injection) if sub-sea intervention by a remotely operated vehicle and installation of a capping stack was unsuccessful

- drilling a relief well is the ultimate solution to a worst-case situation. If the mobile offshore drilling unit is unavailable, a relief well rig would be required to drill the relief well. Pre-spud, drilling and other activities (e.g. ranging, interception, killing well) would take approximately 68 days minimum if there was a rig and full crew on standby east of Port Lincoln
- standard industry practice would result in "killing" the well within 88–102 days (assuming a relief well rig is mobilised from NWS or Singapore)
- the ultimate control of a loss of well control is to kill the well by drilling a relief well. Equinor Australia B.V.'s logistics study determined that 88–102 days would be required to control the well (i.e. stop the flow of oil). These time frames are based on an Equinor Australia B.V. assessment of estimates of equipment, personnel and rig/vessel availability, contracting, mobilisation times, transit times, site preparation (e.g. spudding of the relief well) and drilling the relief well. The longer duration of 102 days considered incorporated a degree of conservatism to complete this risk assessment as described in Appendix 7-4.
- additional well head and surface casing will be available in Adelaide
- extensive logistics planning for deployment of all required equipment and vessels.

7.7.13.2 Comparisons of using dispersants (mitigated) versus no dispersants (unmitigated)

A discussion of the environmental risks of using dispersants is provided in Section 8.0. A brief summary of the modelling and associated mass balance results that compares scenarios using dispersants with those scenarios not using dispersants, notes the following issues which were considered as part of determining risk treatment requirements:

- The effect of dispersant on droplet size results in predicted increase in the rate of biodegradation, changes to buoyancy characteristics, a reduction of evaporation rates and a reduction of volumes of oil ashore. This is shown by comparing the predicted weathering and fates of dispersed versus undispersed oil over 162 days. While the dispersant reduces the volumes of weathered oil ashore, the volume of entrained oil increases considerably. By Day 162, the volume of weathered crude oil remaining ashore was 89,038 m^3 and 28,712 m^3 for the unmitigated and mitigated modelling, respectively. Furthermore, 104,118 m^3 and 40,838 m^3 of weathered crude remained on the sea surface for the unmitigated and mitigated simulations, respectively.
- Maximum volumes of oil ashore and lengths of shorelines affected are reduced using dispersant offshore. The maximum lengths of shoreline oiled above the moderate threshold decrease from 2838 km in an unmitigated case to 2148 km in a mitigated case (Figure 46; Appendix 7-1).
- The three-dimensional profile of entrained hydrocarbon exposure from a seabed release shows how in an unmitigated case, oil collects on the surface, whereas with subsurface dispersant injection, the oil moves into the water column (around the 250–1000 m water depth), diluting oil concentrations rapidly. Such effects were taken into consideration when evaluating potential risks to biota in the water column (e.g. pelagic versus demersal fish, air breathing pinnipeds).

Each simulation was based on a 6720 m^3/day sub-sea release of crude oil over 102 days, tracked for 162 days.

Modelling predicts that upwelling and downwelling would have little influence on the three-dimensional distribution of dispersed oil. The SSDI is expected to be effective in entraining a large proportion of the oil released subsea. Three-dimensional modelling showed this would remain largely at depth with a proportion of larger droplets rising very slowly to the surface during which time, much of it would degrade naturally. Oil entrained and dissolved at depth in the central GAB is not predicted to migrate into the downwelling and upwelling areas represented in the Key Ecological Feature maps and in oceanographic studies cited herein. The modelling showed that the in-water plumes of dispersed oil would not reach the shelf-edge areas where upwellings occurs in summer and weak downwelling may occur year-round, at concentrations which would have biological effects (moderate and high thresholds). Therefore these events will not affect the fate and trajectory of in-water oil components in a biologically meaningful way.

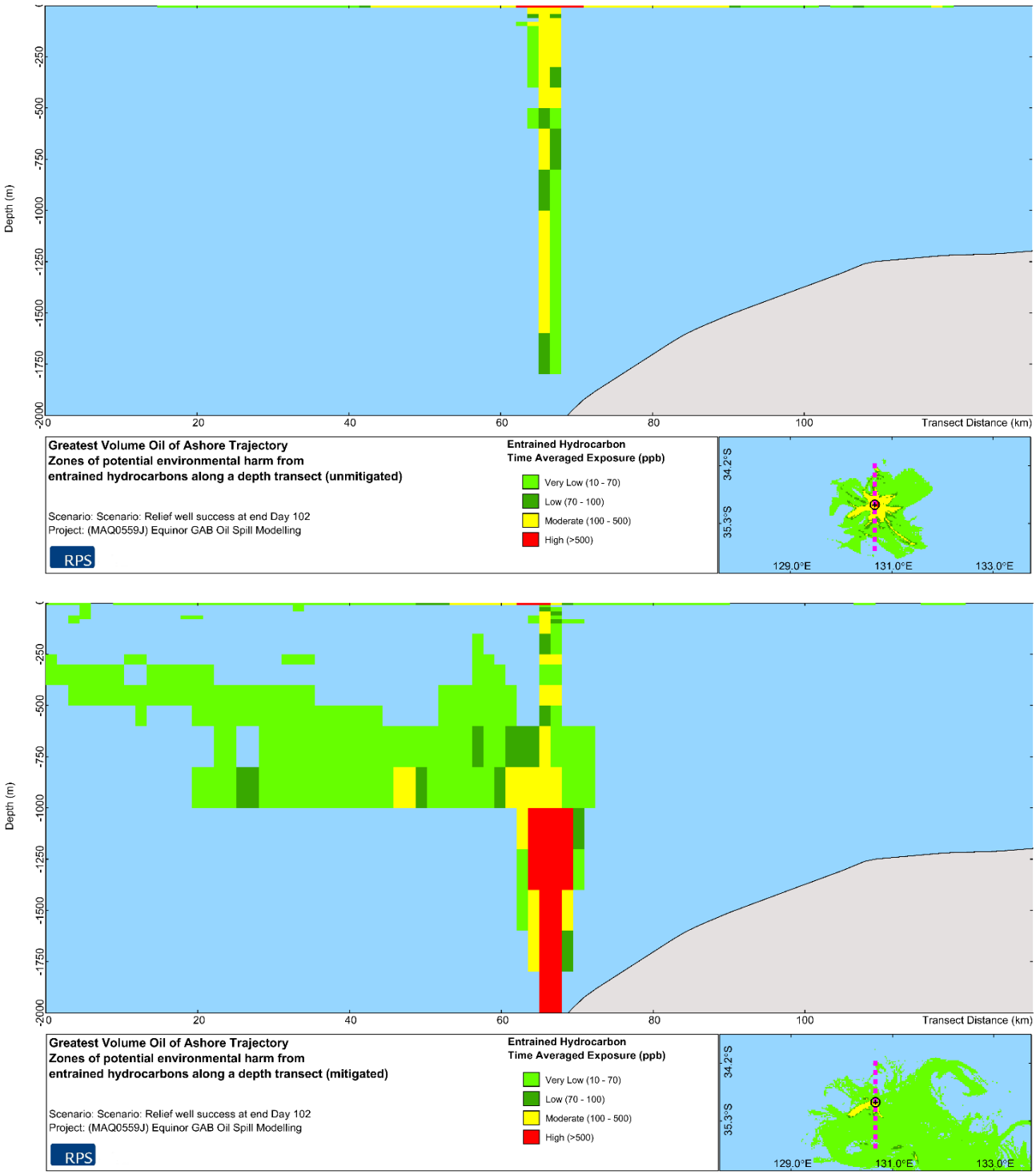


Figure 7.14 3-D profiles of the maximum potential entrained oil for the unmitigated (top image) and mitigated (bottom image) cases. Based on the greatest volume of weathered oil ashore (May)

7.7.13.3 Loading on shoreline by IBRA bioregion

IBRA is a classification which divides the Australian territory into 89 bioregions, according to their climate, geology, landform, native vegetation and species information (Thackway and Cresswell 1995), with the most recent version accessible from the Department of Environment and Energy (DoEE). These regions are shown in Figure 7.15 with respect to the location of Stromlo-1.

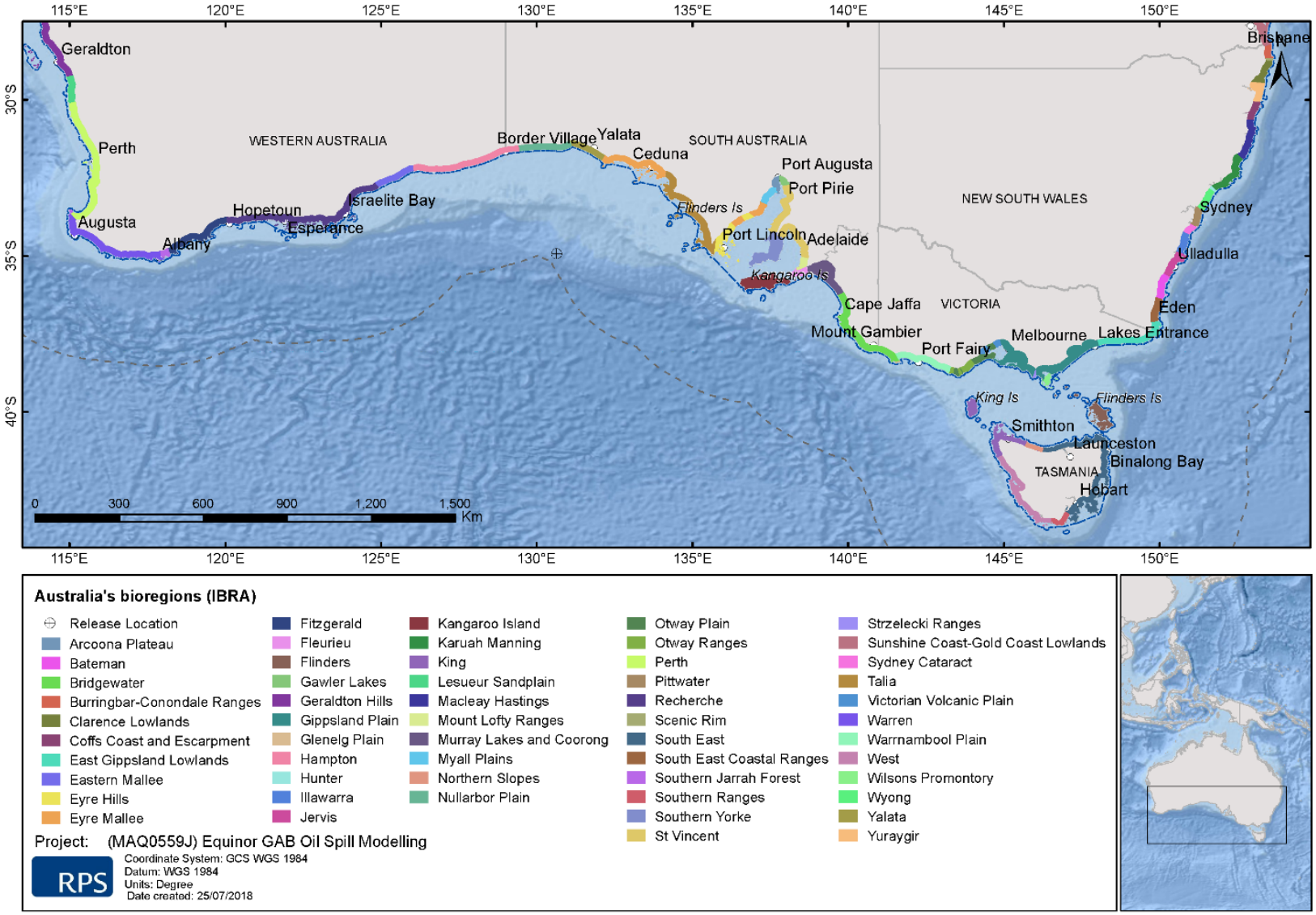


Figure 7.15 Interim biogeographic regionalisation for Australia (IBRA) subregions

A summary of probability of shoreline contact, minimum time of contact and load for each sub-region (as per the Interim Biogeographic Regionalisation for Australia (IBRA) is provided in Table 7.11. This table was used in conjunction with the modelling figures and Figure 7.15 to determine levels of risk for receptors at various locations.

Table 7.12 Probability, minimum time and loading of weathered oil contact to shorelines for each IBRA subregion. Based on 100 oil spill simulations (October to May) with mitigation

Interim biogeographic regionalisation for Australia (IBRA) subregion	Mitigated						
	Probability of shoreline contact (%)			Minimum time before shoreline contact (days)			Load on shoreline (g/m^2)
	Low	Mod.	High	Low	Mod.	High	Mean
West	46	45	33	63	63	68	1103
Southern Jarrah Forest	0	0	0	-	-	-	0
King	65	65	61	55	55	55	3817
Flinders	47	47	43	67	67	67	4197
Kangaroo Island	93	93	92	31	32	32	7084
Hunter	0	0	0	-	-	-	0
Fitzgerald	0	0	0	-	-	-	0
Recherche	21	21	20	58	58	59	2758
Eastern Mallee	0	0	0	-	-	-	0
Warren	0	0	0	-	-	-	0
Hampton	4	4	4	56	59	62	4941
Nullarbor Plain	4	4	2	61	62	66	1792
Eyre Mallee	29	29	16	38	38	38	1539
Talia	100	100	100	21	21	22	12622
Eyre Hills	92	92	92	26	26	26	10,280
St Vincent	0	0	0	-	-	-	0
Southern Yorke	88	88	85	37	37	37	3356
Mount Lofty Ranges	2	2	0	135	135	-	624
Fleurieu	64	60	46	65	65	71	936
Murray Lakes and Coorong	41	40	15	54	66	89	357
Glenelg Plain	74	74	73	44	44	44	6653
Bridgewater	86	86	79	42	42	42	3750
Warrnambool Plain	80	80	76	45	45	46	2094
Otway Ranges	68	64	43	62	62	85	578
Otway Plain	73	72	53	62	62	63	1221
Gippsland Plain	48	45	39	88	88	89	771
Strzelecki Ranges	15	13	5	92	92	108	502
Wilsons Promontory	57	57	54	66	66	67	5777
East Gippsland Lowlands	13	12	6	126	129	129	685
South East Coastal Ranges	1	1	0	132	132	-	279
Bateman	1	1	1	109	109	110	953

Interim biogeographic regionalisation for Australia (IBRA) subregion	Mitigated						
	Probability of shoreline contact (%)			Minimum time before shoreline contact (days)			Load on shoreline (g/m^2)
	Low	Mod.	High	Low	Mod.	High	Mean
Jervis	0	0	0	-	-	-	0
Illawarra	2	1	0	148	148	-	127
Sydney Cataract	0	0	0	-	-	-	0
Pittwater	0	0	0	-	-	-	0
Wyong	1	1	0	151	151	-	190
Karuah Manning	0	0	0	-	-	-	0
South East	5	3	0	93	93	-	200
Southern Ranges	7	7	3	104	104	104	476

Each simulation was based on a 6720 m^3/day sub-sea release of crude oil over 102 days, tracked for 162 days. Mod. represents Moderate.

7.7.13.4 Environmental performance outcomes (EPO 7.7)

Equinor Australia B.V. will maintain control of the well for the duration of the activity with no loss of well integrity resulting in loss hydrocarbons to the marine environment

7.7.13.5 Context for assessment

Legislative and other requirements	In accordance with Regulation 13(5) of the OPGGS(E) Regulations, response techniques are outlined in the OPEP for the activity The well operation management plan must be accepted under the Offshore Petroleum and Greenhouse Gas Storage (Resource Management and Administration) Regulations 2011 this will detail well design and detail safety measures to prevent a spill
Industry standards	Blowout preventer Original Equipment Management (OEM) standards American Petroleum Institute Standard 53 American Petroleum Institute RP 96 Deepwater well design and construction provides engineers a reference for deep-water well design as well as drilling and completion operations. This recommended practice can also be useful to support internal reviews, internal approvals, contractor engagements, and regulatory approvals. NORSOK D-010 Well integrity in drilling and well operations standard (2013): defines the minimum functional and performance requirements and guidelines for well design, planning and execution.
Equinor Australia B.V. standards	Risk levels determined and As Low As Reasonably Practicable assessment as per RM100 Manage Risk and if necessary elevated to management for sign-off on acceptability of predicted risk level. Relevant persons' views considered as per FR11 Sustainability standard MODU and vessel management in accordance with WR2613 Contractor Management and TR2217 Ship and Maritime Requirements Construction of Exploration wells process (DW100) will be followed during designing, planning and executing the well, which include loss of well control preparedness Self-verification (SV) and Oversight (OS) Program used to continually verify status of barriers

7.7.13.6 Control measures and performance standards

Control measures	Environmental performance standards	Measurement criteria	Responsibility
Well Operations Management Plan	EPS 7.7.1: The well operation management plan and application to drill accepted by Regulator under Part 5 of the OPGGS (Resource Management and Administration) Regs 2011	Records demonstrate the well operation management plan and application to drill are accepted by NOPSEMA prior to commencement of activities	Equinor Australia B.V. Drilling Manager
	EPS 7.7.2: • Well barriers identified in the Well Operations Management Plan will be utilised to ensure: • all permeable zones penetrated by the well bore, containing hydrocarbons or over-pressured water, shall be isolated from the surface environment by a minimum of two barriers. • discrete hydrocarbon zones shall be isolated from each other (to prevent cross-flow) by a minimum of one barrier • all normally pressured permeable water-bearing formations shall be isolated from the surface by a minimum of one barrier • barriers shall be effective over the lifetime of well construction, plugging and abandonment • effectiveness of primary and secondary barriers shall be verified (physical evidence of the correct placement and performance)	Records confirm the well barriers identified are in place and utilised with a minimum of two barriers in place for all permeable zones penetrated by the wellbore	
	EPS 7.7.3: In compliance with specifications in the well operation management plan: • The fluid barrier comprises a drilling fluid of a suitable weight, composition and volume to counter pore pressure and over pressure zones • The minimum specifications for cementing conductor, casings and liners are implemented to maintain well integrity	Records demonstrate the weight, composition and volume of drilling fluids are applicable to down hole conditions being experienced Daily drilling logs and cementing daily reports (“WELLCOM”) demonstrate acceptance criteria for cement criteria for the conductor, casings and liners are met	Equinor Australia B.V. Drilling Supervisor
Blowout preventer (BOP) and BOP control systems – apply API Standard 53 requirements for BOP system	EPS 7.7.4: BOP system to include: • Autoshear (Emergency system) • Deadman system (Emergency system) • Emergency Disconnect Sequence (EDS) • Redundant control stations • BOP real-time pressure monitoring system (P/T gauge on BOP)	Records demonstrate: • BOP and BOP control systems are in compliance with API standard 53 criteria for selected options • BOP specifications and function/pressure testing were undertaken in accordance with OEM standards • Equinor’s Technical Requirements (GL3594 – Well Control Manual)	Equinor Australia B.V. Drilling Manager

Control measures	Environmental performance standards	Measurement criteria	Responsibility
	• ROV-based secondary control system, or alternative such as an acoustic subsea secondary control system.	• independent verification against American Petroleum Institute standard 53 criteria function and pressure testing were conducted as per requirements of American Petroleum Institute standard 53	
	EPS 7.7.5: Compliance with the preventative maintenance schedule ensures safety critical equipment, specifically the BOP has been maintained in accordance with the manufacturer's specifications	PMS records show the maintenance of the BOP and associated safety equipment is current	MODU Maintenance Supervisor
	EPS 7.7.6: Prior to use, the BOP will be subjected to verification as part of the Rig Verification before start of contract	Records demonstrate the Rig Verification has been performed	Equinor Australia B.V. Drilling Manager
Blowout preventer (BOP) and BOP control systems – nature and duration of BOP intervention	EPS 7.7.7: In the unlikely event of automated system failure, • BOP intervention would be attempted within 24 hours of commencement of emergency response • Intervention to continue for up to 48 hours • the BOP rams would be closed manually by either - the ROV stabbing into the BOP ROV control panel (conforming to API 17H hot stab), or if available, the acoustic system will operate critical functions from a remote panel onboard a lifeboat, or standby vessel, or from DP operator station at bridge of the MODU if not disabled.	Response logs confirm that: • BOP intervention first attempted in < 24 hours and if not successful, attempts continue until 48 hours	Equinor Australia B.V. Drilling Manager
Blowout preventer (BOP) and BOP control systems – pipe-centring capability	EPS 7.7.8: Assessment of MODU BOP system specifications during technical evaluation to consider cost and benefit in improving BOP reliability by including V-shaped blind shear ram	Revised ALARP report documents consideration of V-shear rams in technical evaluation process. Selected MODU capability matches outcome of ALARP assessment	Equinor Australia B.V. Drilling Manager
Blowout preventer (BOP) and BOP control systems – additional SAR capabilities and vessel management	EPS 7.7.9: SAR capabilities: • additional SAR capability within 12 hours during hydrocarbon zone penetration, to free up the SCV and enable it to attempt BOP closure within 24 hours • all support vessels to have SAR capabilities • all vessel crews to be adequately trained in SAR activities	Vessel logs demonstrate: • support vessel within 12 hours steam of well location – under current weather conditions • pre-mobilisation inspection records confirm all support vessels have SAR capabilities • training records or induction packages show SAR activities are understood by crews	Equinor Australia B.V. Drilling Manager

Control measures	Environmental performance standards	Measurement criteria	Responsibility
Blowout preventer (BOP) and BOP control systems – personnel and procedures	EPS 7.7.10: Interface compatibility between ROV, BOP intervention skid and the rig's BOP to be verified prior to the petroleum activity on Stromlo. • ROV supervisor on SCV with subsea BOP intervention competence/experience and clear instructions for the intervention is onboard the vessel before the LOWC risk is possible (reservoir section exposed). • Video link for remote specialist support tested and functioning effectively prior to arriving on location at Stromlo-1	Records of pre-mobilisation checks confirm that: • operational review of ROV, BOP intervention skid and MODU ROV compatibility carried out prior to arriving on location at Stromlo-1 • crew log for MODU and training records confirm ROV supervisor has appropriate skills and experience • video link has been tested and is functional prior to arriving on location at Stromlo-1	Equinor Australia B.V. Drilling Manager
Blowout preventer (BOP) and BOP control systems – safety case	EPS 7.7.11: The vessel will have a valid safety case which includes well intervention activities (including BOP closure) prior to start of operations	Safety Case revision date and drilling logs confirm safety case revision accepted prior to start of operations	Equinor Australia B.V. Drilling Manager
BOP intervention (BOP) – light debris clearance equipment and tooling for ROV	EPS 7.7.12: • After contracting the MODU, assess potential debris that can reasonably be in the water and obstruct the BOP ROV intervention panel or SSDI access • Assess practicability and cost of debris clearance tooling for the ROV contracted with the MODU / support vessels	Records confirm: • assessment of potential BOP and SSDI obstructions associated with selected rig drilling system • assessment of potential ROV tooling available with selected ROV system • ALARP assessment conducted on additional tooling for ROV	Equinor Australia B.V. Drilling Manager
Remotely Operated Vehicle	EPS 7.7.13: Remotely operated vehicle available such that the blowout preventer can attempt closure within 24 hours.	Records demonstrate BOP installation attempts initiated within 24 hrs	Incident Commander
	EPS 7.7.14: Should remote closure of the BOP on the MODU fail: • ROV vessel will be in field during drilling operations • ROV survey of seabed at well location to determine situation before closure of BOP • ROV BOP closure attempted within 24 hours of the loss of well control	BOP closure: successful/ unsuccessful Records and ROV video files identify that attempt(s) at BOP closure using an ROV were attempted within 24 hours of first notification of a loss of well control Records show that should BOP closure be unsuccessful, sequential source control methods were initiated immediately	Incident Commander
Relief well (RW) rig, equipment and supplies	EPS 7.7.15: The relief well plan is accepted by NOPSEMA as part of the Well Operation Management Plan and undertaken according to the timeline defined in the well operation management plan Plans include identifying suitable relief well rig, feasibility and any specific considerations for relief well kill and well capping, specifying the location, well path design and dynamic kill modelling	Prior to start of drilling in compliance with the Well Operations Management Plan: • rig suitable to drill the relief well has been identified • multiple potential relief well surface location identified • documented relief well path design in the WOMP • dynamic kill modelling verified	Equinor Australia B.V. Drilling Manager

Control measures	Environmental performance standards	Measurement criteria	Responsibility
	EPS 7.7.16: Mutual aid is available through Australian Petroleum Production and Exploration Association	Australian Petroleum Production and Exploration Association mutual aid memorandum of understanding for relief well drilling is in place	Equinor Australia B.V. Drilling Manager
	EPS 7.7.17: Equinor Australia B.V. will contract suitable drilling rig to undertake drilling of a relief well with shortest mobilisation time to Stromlo-1 location	• Drilling log shows the relief well drilled as soon as reasonably practicable but in 102 days maximum • Records confirm that rigs on North West Shelf prioritised and mutual aid agreements enacted • Records confirm rigs in Bass Strait prioritised if suitable and show reduction in mobilisation and drilling time • Records indicate the Incident Action Plan (IAP) was activated in accordance with the OPEP • Records indicate NOPSEMA acceptance of the revised Safety Case for the rig that will drill the relief well • Documentation shows the application and provision of an exemption under the EPBC Act if required for the relief well	Equinor Australia B.V. Incident Commander
	EPS 7.7.18: Primary relief well rig in Australian waters with an Australian Safety Case identified before drilling into the reservoir, such that a relief well could be drilled and the well killed in 88 days	Records confirm: • relief well rig from within Australian waters identified • NOPSEMA-accepted Safety Case for the rig	Equinor Australia B.V. Drilling Manager
	EPS 7.7.19: Relief well rig mobilised from North West Shelf (WA), Bass Strait or Singapore, whichever is the shortest mobilisation timeframe at the time relief rig is required	IMT log and other records demonstrate rig available in shortest mobilisation timeframe selected.	Equinor Australia B.V. Incident Commander
	EPS 7.7.20: Relief well rig mobilised with BOP and access to enough riser length for water depth of 2239 m	IMT log, equipment records demonstrate relief well rig mobilises with BOP and can access riser length for water depth of 2239 m.	Equinor Australia B.V. Incident Commander
	EPS 7.7.21: Backup drilling equipment pre-mobilised and available in Adelaide to start relief well (drill top holes) prior to drilling	Purchase records, supply base equipment inventory demonstrate relief well drilling equipment available in Adelaide.	Equinor Australia B.V. Drilling Manager
	EPS 7.7.22: Suitable relief well rig with Australian Safety Case identified prior to spud at Stromlo-1	Records confirm: • relief well rig selected prior to spud • backup rig identified at same time • records indicate NOPSEMA acceptance of the revised Safety Case for the rig that will drill the relief well	Equinor Australia B.V. Drilling Manager
	EPS 7.7.23: Relief well rig has adequate equipment, specifications and supplies to commence relief well on arrival at Stromlo-1 location	Records confirm: • assessment of gaps in relief well equipment, specifications and supplies prior to spud • logistics plan to fill any gaps/shortfalls in place prior to spud	Equinor Australia B.V. Drilling Manager

Control measures	Environmental performance standards	Measurement criteria	Responsibility
	EPS 7.7.24: Relief well safety case revision for drilling at Stromlo-1 initiated as soon as practicable after notice of major spill	• Safety case documentation confirms timely initiation	Equinor Australia B.V. Drilling Manager
Relief well rig to have accepted Australian safety case	EPS 7.7.25: Relief well rig identified and confirmed to have valid Australian safety case, prior to reservoir exposure	Pre reservoir inspection report confirms safety case in place for identified RW rig	Equinor Australia B.V. Drilling Manager
Relief well drilling supplies	EPS 7.7.26: Gaps in riser and well control equipment needs assessed and filled as necessary • Long Lead Items (LLI) for a timely spud, including all hardware for spudding and completing the top-hole of the RW in Adelaide • Rig equipment compatible with RW plan (casing running, wellhead, etc • All LLI for RW top-hole to be located in Adelaide	Records show that RW rig has all equipment needed to drill RW top-hole prior to primary well spud	Equinor Australia B.V. Drilling Manager
Multiple capping stacks available for use	EPS 7.7.27: The capping stacks are: • at least one available in Singapore, or closer, prior to and during the drilling program • capable of being fitted, with one fitted in 15 days • pressure rated to Stromlo-1 requirements • compatible with the Stromlo-1 blowout preventer design • effective at least until the relief well is successful • to be fitted repeatedly until success or relief well drilled	Records demonstrate that a contract is in place with the providers of capping stacks	Equinor Australia B.V. Drilling Manager
Detailed logistics plan for LOWC source control	EPS 7.7.28: Logistics plan to: • be ready before operations start • include procedures and arrangements for – pre-filled customs paper for all items – bio-clearance procedures for Singapore – Singapore Airline Cargo (SIA Cargo) – arrangement and call-off plan – B747F loading procedures for Changi – and call-off plan – transport plans from Sydney, Melbourne and Adelaide airports – ready for call-off	Records demonstrate Logistics Plan is in place prior to spud	Equinor Australia B.V. Drilling Manager

Control measures	Environmental performance standards	Measurement criteria	Responsibility
Capping stack (CS) and active heave compensation crane – operability specifications	EPS 7.7.29: • The SCV contract requirements will include SCV to have AHC rated to 4 m Hs and the associated wave periods (minimum) • SCV AHC capable of 110 ton lift and deployment in 2300 m water depth	Pre-mobilisation compliance check records confirm ratings of AHC on SCV are adequate	Equinor Australia B.V. Drilling Manager
Capping stack (CS) – heavy duty debris clearance equipment	EPS 7.7.30: • Work-class ROV on site throughout drilling and able to support site assessment and identify debris clearance requirements within 24 hours (during BOP intervention as required) • Heavy duty debris clearance package from WWC in Singapore available on site on day seven after the LOWC incident • Debris clearance mission plan developed in first 72 hours	Contract in place with WWC prior to mobilisation • WWC contract includes access to light and heavy debris clearance equipment • Contract in place with OSRL prior to mobilisation • OSRL contract includes access to light debris clearance equipment	Equinor Australia B.V. Drilling Manager
Track SCV in Australia and SE Asia	EPS 7.7.31: • Submit safety case for capping for additional vessel within 10 days • Within 5 days of LOWC, decide whether to mobilize second capping stack. Decision to be made on criteria which will include the following: – The flow path is through the wellhead and its integrity is intact – It is reasonable to solve the situation by a capping stack (given debris and potential inclined BOP situation) – The flow intensity and the fluid flowing (oil, gas, or water) is detrimental to the environment • Second capping stack will be installed within 40 days of LOWC.	• Tracking listing of SCV in the region • Safety case template for capping stack prepared before operations starts	Equinor Australia B.V. Drilling Manager
SCV Safety Case inclusion of capping stack deployment	EPS 7.7.32: Accepted Safety Case for the SCV will include provision for capping stack deployment	NOPSEMA-approved Safety Case with capping stack deployment	Equinor Australia B.V. Drilling Manager
Subsurface dispersant injection (SSDI) equipment	EPS 7.7.33: SSDI equipment: • is available for the duration of the drilling program • can be activated within nine days in the event of LOWC • can be deployed from a crane on the MODU or the sub-sea	Contracts in place that provide access to SSDI equipment Records demonstrate that SSDI was activated by Day 9 following first report of the spill Records and MODU/sub-sea construction vessel crane specifications demonstrate that SSDI equipment could be deployed	Equinor Australia B.V. Drilling Manager

Control measures	Environmental performance standards	Measurement criteria	Responsibility
	construction vessel • is functional at the injection location from Day 9 for the duration of the release • is capable of treating the predicted Stromlo-1 volumes until well kill.	from the MODU or sub-sea construction vessel crane Activity records, dispersant use records and daily logs demonstrate SSDI activity throughout the response Servicing contracts in place over the duration of SSDI response	
	EPS 7.7.34: Multiple SSDI options under existing OSRL/ WWC contracts	• Records of communications with OSRL and WWC confirm options available at time of activity	
	EPS 7.7.35: SSDI delivery system plan (either CT unit or Kevlar hoses) to be made explicit before spud, including PSV fitting / deployment plan	• Records show SSDI delivery system and PSV plan in place prior to spud	
Access to Subsea dispersant toolkit from AMOSC in Perth and Coiled Tubing unit in Perth, deployment SCV on contract	EPS 7.7.36: Contract with AMOSC to provide a toolkit in Perth, Coiled Tubing Unit available in Perth and a contract in place for deployment SCV	Pre-mobilisation check shows there is a toolkit available from AMOSC in Perth, tubing unit in Perth and a contract in place for an SCV	Equinor Australia B.V. Drilling Manager

7.7.14 Outcome

Factors affecting acceptability	Acceptability criteria	Demonstration of acceptability
Internal context	Operations are compliant with relevant internal standards listed under Section 7.7.13.4 Risk treatment	In accordance with RM100, residual risk is medium and therefore, all practicable control measures have been and will be considered in reducing the risk to As Low As Reasonably Practicable. Subject matter experts and senior management have reviewed and approved this environment plan. Equinor Australia B.V. will contract equipment and services that will comply with this EP MODU and vessel management in accordance with WR2613 Contractor Management and TR2217 Ship and Maritime Requirements Self-verification (SV) and Oversight (OS) Program used to continually verify status of barriers
	The planned well (design and associated operations) is demonstrably within technical capabilities of Equinor Australia B.V.	Equinor Australia B.V. has demonstrated a long track records of safe offshore operation in harsh and remote environments Construction of Exploration wells process (DW100) will be followed during designing, planning and executing the well, which include loss of well control preparedness
External context	The petroleum activity is consistent with government policies for resource exploitation	Petroleum drilling is a permissible activity within the GAB Marine Park Multi Use Zone (IUCN Category VI) After consultation, release of exploration permits by the National Offshore Petroleum Titles Authority demonstrate support for petroleum exploration in the Great Australian Bight

Factors affecting acceptability	Acceptability criteria	Demonstration of acceptability
	There are no unaddressed objections or claims from relevant persons or raised during public comment period	New relevant issues identified as a result of the public comment process will be addressed New relevant person objections or claims will be considered in line with the ongoing consultation (Section 9.0)
Legislative and other requirements	Compliance with legislation related to environmental risk in relation to loss of well control	In accordance with Regulation 13(5) of the OPGGS(E) Regulations, response techniques are outlined in the Oil Pollution Emergency Plan (OPEP) for the activity The well operation management plan must be accepted under the Offshore Petroleum and Greenhouse Gas Storage (Resource Management and Administration) Regulations 2011. This will detail well design and detail safety measures to prevent a spill
Industry standards and practices	Consistent with good industry practices and standards for exploration drilling	Well control equipment systems managed in accordance with American Petroleum Institute (American Petroleum Institute) Standard 53 Deepwater well design and construction engineering and drilling and completion operations in accordance with American Petroleum Institute Recommended Practices 96 The minimum functional and performance requirements and guidelines for well design, planning and execution are compliant with NORSOK D-010 Well integrity in drilling and well operations standard (2013)

7.7.14.1 Residual risk summary

The summary of predicted risks below draws on the highest level of predicted risk (across the various receptors and sensitivities) and shows the highest risk ranking for each spill scenario (risk treatment 1, 2 or 3 or no treatment 4).

Residual risk	Risk ranking
Risk treatment 1: blowout preventer success Day 1	Low
Risk treatment 2: capping stack success Day 15	Medium
Risk treatment 3: relief well success Day 88 - 102	Medium
No risk treatment 4: WCD, relief well success Day 129, unmitigated	Medium

7.7.14.2 As Low As Reasonably Practicable assessment outcomes

The likelihood of a loss of well control during the activity is extremely low when considering industry statistics and the preventative controls in place. Wells are designed with essential engineering and safety controls to prevent a loss of well control incident occurring. Additional industry standard and activity-specific controls to reduce loss of well control have also been implemented including (but not limited to) procedures such as the well operation management plan, Safety Case and well management practices, crew training and awareness and an Oil Pollution Emergency Plan accepted by the state agencies. These standards and controls are considered to reduce the environmental risks to As Low As Reasonably Practicable, and the risk control strategy is deemed to be acceptable.

A detailed As Low As Reasonably Practicable assessment has been conducted to examine ways of augmenting blowout prevention controls, source control options and spill mitigation using dispersants. All the program improvements and new controls have been integrated into the risk assessment and no new controls are deemed necessary to reduce risks further (Appendix 7-4).

No further controls have been identified that do not have a disproportionate high cost in relation to environmental benefit.

Equinor Australia B.V. is continuing to seek logistical efficiencies to further reduce response times through the ongoing contracting process.

For demonstration of As Low As Reasonably Practicable (ALARP) please see Appendix 7.4.

7.7.14.3 Demonstration of acceptability

Factors affecting acceptability	Acceptability criteria	Demonstration of acceptability
Internal context	Operations are compliant with relevant internal standards listed under Section 7.7.13.4 Risk treatment	In accordance with RM100, residual risk is medium and therefore, all practicable control measures have been and will be considered in reducing the risk to As Low As Reasonably Practicable. Subject matter experts and senior management have reviewed and approved this environment plan. Equinor Australia B.V. will contract equipment and services that will comply with this EP MODU and vessel management in accordance with WR2613 Contractor Management and TR2217 Ship and Maritime Requirements Self-verification (SV) and Oversight (OS) Program used to continually verify status of barriers
	The planned well (design and associated operations) is demonstrably within technical capabilities of Equinor Australia B.V.	Equinor Australia B.V. has demonstrated a long track records of safe offshore operation in harsh and remote environments Construction of Exploration wells process (DW100) will be followed during designing, planning and executing the well, which include loss of well control preparedness
External context	The petroleum activity is consistent with government policies for resource exploitation	Petroleum drilling is a permissible activity within the GAB Marine Park Multi Use Zone (IUCN Category VI) After consultation, release of exploration permits by the National Offshore Petroleum Titles Authority demonstrate support for petroleum exploration in the Great Australian Bight
	There are no unaddressed objections or claims from relevant persons or raised during public comment period	Equinor Australia B.V. has consulted with relevant person and there are no outstanding objections or claims from state response agencies New relevant issues identified as a result of the public comment process will be addressed New relevant person objections or claims will be considered in line with the ongoing consultation (Section 9.0)
Legislative and other requirements	Compliance with legislation related to environmental risk in relation to loss of well control	In accordance with Regulation 13(5) of the OPGGS(E) Regulations, response techniques are outlined in the Oil Pollution Emergency Plan (OPEP) for the activity The well operation management plan must be accepted under the Offshore Petroleum and Greenhouse Gas Storage (Resource Management and Administration) Regulations 2011. This will detail well design and detail safety measures to prevent a spill
Industry standards and practices	Consistent with good industry practices and standards for exploration drilling	Well control equipment maintained in accordance with Original Equipment Manufacturer (OEM) standards Well control equipment systems managed in accordance with American Petroleum Institute (American Petroleum Institute) Standard 53 Deepwater well design and construction engineering and drilling and completion operations in accordance with American Petroleum Institute Recommended Practices 96 The minimum functional and performance requirements and guidelines for well design, planning and execution are compliant with NORSOK D-010 Well integrity in drilling and well operations standard (2013)

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8.0 Risks associated with oil spill response

8.1 Background

This section describes Equinor Australia B.V.'s assessment of the environmental risks associated with implementing the proposed response techniques outlined in the Oil Pollution Emergency Plan for the activity, in accordance with Regulation 13(5) of the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009. Also presented are the environmental performance outcomes, performance standards, controls and measurement criteria required to manage and mitigate the identified risks (where not already presented in Sections 6.0 and 7.0; note that those specific to the Oil Pollution Emergency Plan are presented in Section 9.0). The effects of spill response activities are considered risks – i.e. of uncertain probability, because they will only happen in the event of a spill which is an unplanned event and has a variable probability of environmental consequences. Response to a worst credible case discharge is considered here and the full duration of the spill is conservatively assumed; whereas a shorter duration is more likely due to blowout preventer closure stopping the flow of oil after Day 1, or in the unlikely event of that failing after multiple attempts, the successful application of the capping stack stopping the flow after 15 days. Further detail on the oil spill risks is provided in Section 7.0 and the Oil Spill Modelling Study (Appendix 7-1).

A high-level a priori (before the event) net environment benefit analysis (NEBA) was undertaken for the purposes of assessing spill mitigation strategies. The a priori net environment benefit analysis is relevant to the entire activity period and the Risk Environment that May Be Affected and was used to identify spill response actions in developing the Oil Pollution Emergency Plan (Appendix 9.1).

In the event of an oil spill, detailed net environment benefit analysis assessments would be undertaken prior to response operations commencing and to support decisions throughout the response. The net environment benefit analysis process allows re-assessment of the environmental risks associated with various mitigation options; using situational awareness information from the first strike response actions and initial monitoring data. This is aligned with industry best-practice (IPIECA-IOGP 2013 and 2018).

The risk assessment herein examines changes in the consequences associated with implementing each response action. It does not re-examine the risks associated with a mitigated major oil spill – these are covered in Section 7.0. The acceptability of the residual risks takes into account the environmental benefits of implementing the response actions.

The additional vessel and mobile offshore drilling unit activities associated with implementation of the response measures are considered to engender small incremental increases in the duration and area of effects above those already considered in the assessment of planned (Section 6.0) and unplanned events (Section 7.0). The risks associated with these small increases in consequence are still considered to be As Low As Reasonably Practicable and of acceptable levels.

The sources of impact and risk associated with the additional use of vessels and the mobile offshore drilling unit that have already been considered in Sections 6.0 and 7.0 respectively are:

- displacement of other marine users
- seabed disturbance
- underwater sound
- light emissions
- atmospheric emissions
- routine and non-routine discharges
- routine drilling discharges
- physical interaction – collision with marine fauna
- support vessel operations – vessel collision.

8.2 Response methods assessed

The a priori net environment benefit analysis and As Low As Reasonably Practicable logistics assessments have supported the selection of the response strategies described as intervention and mitigation measures in the Section 7.7 major oil spill risk assessment and in the Oil Pollution Emergency Plan. The key response strategies assessed herein are:

i) The immediate surveillance of the spill and ongoing monitoring of its direction and characteristics.

ii) Intervention measures to stop the flow of oil and thereby reduce the amount of oil spilled – the source control (including well intervention) measures comprise a series of well control steps starting with clean-up of seabed debris and well closure using the blowout preventer, stopping the flow of oil using a capping stack and killing the well by drilling a relief well. These intervention measures will be implemented in simultaneous operations to reduce environmental risks to As Low As Reasonably Practicable as described in Appendix 7.4.

iii) Mitigation measures to reduce the environmental effects of the spill. The mitigation measures for reducing environmental harm comprise a suite of techniques, targeting fresh oil being released from the well head by; applying dispersants sub-sea and close to the well head and at the sea surface offshore. Dispersant application is considered a primary spill mitigation response strategy immediately after a spill and on an ongoing basis where supported by net environment benefit analysis and in-situ efficacy testing.

In addition, containment and recovery (offshore and nearshore), shoreline protection and clean-up and oiled wildlife response will be applied where conditions are suitable, and where supported by net environment benefit analysis.

In the event of a loss of well control leading to an oil spill, immediate source control actions will be implemented to stop the flow of oil. Oil spill mitigation responses will be implemented in accordance with the Oil Pollution Emergency Plan (Appendix 9-1) and as required by the government spill response agencies.

The oil spill modelling has shown that intervention using the blowout preventer and capping stack in combination with sub-sea and sub-sea dispersant application is highly effective in reducing the amount of surface oil reaching sensitive coastal areas.

8.3 Summary of risk assessment of response actions

Table 8.1 summarises the risk assessment of spill response actions of a 102-day major oil spill.

Table 8.1 Summary of risk assessment of the oil spill response actions

#	Source of risk	Potential environmental effects from undertaking the action	Residual risk	ALARP	Acceptable
C.1	Source control (relief well, capping stack, BOP)	Reduction in volume of oil spilled Discharge of drilling fluids (synthetic based muds) and cuttings while drilling the relief well within the Impact EMBA Localised burial of benthic habitats, reduction in water quality and localised chemical toxicity to water column and sediment biota around the relief well location	Low	Yes	Yes
C.2	Dispersant application	Decreased surface oil and shoreline loadings Increased entrained and dissolved oil in water column with potential for increased toxicity to demersal and pelagic biota Increase sedimentation of dispersed oil affecting benthic biota and habitats	Medium	Yes	Yes
C.3	Containment and recovery	Increased vessel traffic resulting in increased risk of cetacean/vessel collision Discharge of oily decant water or minor secondary spill resulting in reduction in water quality	Low	Low	Low

#	Source of risk	Potential environmental effects from undertaking the action	Residual risk	ALARP	Acceptable
C.4	Shoreline protection and clean up	Degradation of sensitive/protected shoreline habitats or disturbance of biota due to movement of human responders and removal of oiled material	Low	Yes	Yes
C.5	Oiled wildlife response	Fauna casualties through mishandling, disturbance and stress	Low	Yes	Yes
C.6	Operational and scientific monitoring	Misinformation or insufficient information resulting in inefficient response Sample collection effects on biota in affected and reference sites	Low	Yes	Yes

8.4 Source control

8.4.1 Risk description

If a loss of well control event and a Level 3 oil spill were to occur, source control actions such as deployment of a remotely-operated vehicle to close the blowout preventer, clearing debris, fitting the capping stack and drilling a relief well would be elements of the primary response strategy to stop the flow of hydrocarbons. These are described in the Oil Pollution Emergency Plan (Appendix 9-1).

These are necessary actions to stop the flow of oil and minimise safety and environmental risk, and these actions are therefore considered acceptable in principle. The following increases in environmental consequences would arise while undertaking source control actions:

- Reduced water quality (increased turbidity); the action of the remote operated vehicle thrusters during blowout preventer closure and debris clearance and equipment placing may resuspend sediments and drilling muds deposited on the seabed around the well with consequent localised reduction in water quality (increase in turbidity and suspended solids).
- Benthic habitat and biota disturbance; deploying the capping stack will disturb a small area of benthic habitat, limited to the footprint of any infrastructure placed on the seabed during the operation; the disturbance would be in the order of 50 m^2 around the well and most likely be in the area already affected by cuttings discharges.
- Smothering and toxicity of biota in the water column; relief well drilling will engender an incremental increase in all the discharges associated with drilling – drilling muds, cuttings, cement and test fluids.

8.4.2 Level of acceptable risk

The level of risk will be acceptable if the:

- Source control measures (remote operated vehicles, capping stacks, vessels and relief well drilling) to stop a loss of well control are standard practices and have previously been accepted for use in the Australian and International offshore petroleum industry.
- Environmental benefits of using this equipment to mitigate a loss of well control outweigh the potential negative environmental impacts arising from undertaking the source control actions.

8.4.3 Risk assessment

Implementing the source control (well intervention) measures would have localised negative effects on seabed habitat, marine water quality, air quality, protected species behaviour – limited to the immediate vicinity of the well. This would be offset by the broader positive effects on socio-economic and protected area values in coastal waters and on shorelines and will reduce adverse consequences for Matters of National Environmental Significance and commercial fish species in offshore waters.

Risk description	Reduced water quality from turbidity increases during remote operated vehicle activities and equipment placing Benthic habitat and biota disturbance from equipment placing Smothering and toxicity of biota in the water column, sediment and benthic habitats from muds, cuttings, cement and chemical discharges
Consequence evaluation	The application and consequence of these measures will depend on the emergency situation and should be considered in the context of the potential consequences should no action be taken and the spill left to continue. The extent of the effects is predicted to remain within the Operational Area, except for vessel sound and the discharges associated with relief well drilling, which are likely to be within approximately 1–2 km from the well location (see Appendix 6-2); at a safe distance from the spill site. The additional effects on the receiving environment will not increase the risk ranking for any of the source-control activities because they represent small incremental increases in effect area and duration and are very unlikely to be required. The consequences of these actions remain as previously assessed and the probability that these additional consequences will occur, is the same as for the risk of a loss of well control because they will be implemented in that event. The resuspension of sediments and drilling muds deposited on the seabed around the well with consequent localised reduction in water quality, risk of smothering and toxicity impacts may affect sediment biota and benthic communities already affected by the drilling mud deposition. The consequence of this increase in disturbance is considered Category 1–3 consequence as it will not affect recovery potential for the area. Vessel-based deployment of a remote operated vehicle, a capping stack and subsurface dispersant injection (SSDI) equipment and relief well support will require additional vessel movements and consequently additional noise, light, routine liquid and solid discharges and gaseous emissions. The additional vessel movements will increase slightly the previously assessed risk of vessel collisions, marine fauna collisions, vessel discharges and dropped objects this is considered a Category 1–3 consequence as it will not affect recovery potential for the area. Deploying the capping stack will disturb a small area of benthic habitat around the well, which is expected to recover fully in the short term and will only lead to a minor increase in the consequence of the activity. Relief well drilling will engender an incremental increase in all the discharges associated with drilling – drilling muds and cuttings, test fluids, vessel and MODU wastes, air and noise emissions. The primary well consequences were considered Category 1–3 (Section 6.0) as impacts are localised. Similarly, recovery from effects arising from drilling the relief well (discharges of muds, cement, test fluids and cuttings) is predicted within a month of cessation of the drilling. The impacts from the cuttings pile are localised. Hence as per Section 6.0, consequences from drilling the relief well are ranked Category 1–3.
As Low As Reasonably Practicable decision context	The largest risk from source control activities is from activities associated with drilling the relief well. The necessary discharge of muds, cuttings and cement and test fluids during drilling is a well understood and practiced activity both nationally and internationally. Modelling (Appendix 6-2) of the primary drilling was used to inform the potential extent of cuttings deposition from a relief well which removes some of the uncertainty and to understand the potential extent and concentrations that may result in environmental impacts. No additional control measures are required to continue to reduce impacts to As Low As Reasonably Practicable. Taking this in consideration, Decision Context B-Engineering Risk Assessment should be applied to demonstrate impacts are As Low As Reasonably Practicable.
Assessment technique	Engineering Risk Assessment

8.4.4 Risk treatment

8.4.4.1 Environmental performance outcomes (EPO 8.4)

No significant increase in environmental risk levels as a result of increase in activities associated with well intervention measures.

8.4.4.2 Context for assessment

Legislative and other requirements	OPGGS Act requires the EP to detail control measures to reduce oil spill impacts and to assess the impacts of the response activities outlined in the OPEP for the activity OPGGS (Resource management and administration) Regulations 2011 requires NOPSEMAs acceptance of the Well Operations Management Plan which contains a description of the source control and blow out contingency measures
Industry standards	NOPSEMA Guidance note: Well operations management plan content and level of detail N-04600-GN1602 Revision 1, June 2016 International Association of Oil & Gas Producers (IOGP) – Capping & Containment, Global Industry Response Group recommendations – Report No. 464, May 2011.
Equinor Australia B.V. standards	MODU and vessel management in accordance with WR2613 Contractor Management and TR2217 Ship and Maritime Requirements.

8.4.4.3 Control measures and performance standards

The same control measures described in Section 7.7 are considered effective in reducing risks associated with response activities to As Low As Reasonably Practicable and no further assessment of controls for the incremental increase in these discharges is presented because they are already As Low As Reasonably Practicable and the environmental benefit of the source control actions significantly outweighs any disbenefit from the actions. Control measures in addition to those outlined in Section 7.7 for reducing the effects of the planned drilling activity to As Low As Reasonably Practicable, which would be implemented to minimise environmental harm in the event of a spill response, are described below.

8.4.5 Outcome

Predicted risk	Consequence	Probability	Risk ranking
	Category 1–3	P= 0.000019	Low
Demonstration of As Low As Reasonably Practicable	The controls used to reduce risks to As Low As Reasonably Practicable will be the same as those adopted for the planned activities and those outlined in the WOMP. The risk to the environment from source control activities is Low and therefore no additional controls are required to reduce the risk to As Low As Reasonably Practicable.		

Criteria	**Demonstration of Acceptability**
a. The source control measures (remote operated vehicles, capping stacks, vessels and relief well drilling) to stop a loss of well control are standard practices and have previously been accepted for use in the Australian and International offshore petroleum industry.	The use of remote operated vehicles, capping stacks, vessels and relief drilling to stop a loss of well control, are standard practices in the Australian and International offshore petroleum industry. They are necessary key components of successful spill response that have been approved for other projects by Regulatory Authority in Australia.
b. The environmental benefits of using this equipment to mitigate a loss of well control outweigh the potential negative environmental impacts arising from undertaking the source control actions	Not undertaking these activities in the event of a loss of well control is unacceptable as the environmental benefits of employing this equipment to stop a loss of well control far outweigh the potential localised environmental effects of using this equipment. The risks are not significantly increased from those considered for planned and unplanned events associated with the main drilling activity.

8.5 Surface and subsurface dispersant application

8.5.1 Risk description

Dispersant application is a globally recognised and practiced response technique, recognised under the National Plan, and is considered the primary and most effective spill mitigation action in the event of a loss of well control leading to a Level 3 oil spill at the Stromlo-1 site. Direct dispersant application at the sub-sea site leaking fresh oil (subsurface dispersant injection) has been shown through the oil spill modelling ("mitigated" cases) to be highly effective in reducing the predicted volume of oil reaching sensitive shorelines and coastal waters. Application of dispersants at the sea surface (from vessels and aircraft) will have additional benefit in redistributing some of the fresh oil that has surfaced, back into the water column for further dilution and biodegradation.

Given the distance from shore and the water depth at Stromlo-1, dispersing oil into the water column at the sub-sea well head will have significant benefit, reducing the environmental consequences of a spill by reducing the volume of oil reaching the sea surface for wind-driven transport towards more sensitive coastal areas and by increasing the biodegradation rate of the fine oil droplets.

Equinor Australia B.V. has contracts in place with Oil Spill Response Limited and Wild Well Control to provide subsurface dispersant injection equipment and personnel. Dispersants would be sourced from the Australian Marine Oil Spill Centre, Australian Maritime Safety Authority National Plan stockpiles and the Oil Spill Response Limited global dispersant stockpile. There is potential to obtain additional stock from mutual aid, and dispersant manufacturers would be requested to increase dispersant production. A sub-sea construction vessel (for remote operated vehicle operations including wave compensated crane for sub-sea site clearance and subsurface dispersant injection deployment) will be either on contract, or available in the region. The activity platform supply vessels will be capable of spraying dispersants. Australian Maritime Safety Authority, Aerotech 1st Response and Oil Spill Response Limited aircraft and personnel will be contracted to undertake aerial dispersant operations from Ceduna and Adelaide airports. Additional Vessels of Opportunity will be contracted to undertake vessel dispersant operations, unless they are required for higher priority response activity, e.g. source control.

Dispersants would primarily be applied by Equinor Australia B.V. in deep water at the well head or at the surface near the well site where there might be fresh oil. The primary mechanism for applying dispersants will be using subsurface dispersant injection equipment deployed to the seabed close to the well head. This will maximise the "encounter rate" between dispersant and oil which is fresh and is amenable to chemical dispersion. Dispersants may also be sprayed on the sea surface near the source where the fresh surface oil slick is thick enough for the dispersant to be effective (>10 g/m^2). Dispersants will only be considered for use at specific locations/times where testing shows the oil to be amenable and supported by the net environment benefit analysis.

The main goals of dispersant use are to:

- reduce environmental impacts caused by surface slicks (e.g. impacts to marine mammals, seabirds, shoreline values)
- rapidly reduce oil toxicity through dilution in a large water mass
- enhance the natural dispersion processes caused by breaking wave turbulence at the sea surface and by turbulence at the well head
- enhance natural microbial biodegradation rates by increasing the interface between oil and water and thereby making the oil more bioavailable
- reduce the extent and volume of stranded oil, thereby minimising impacts to shoreline habitats and biota and lessening the scale of shoreline clean up and associated adverse effects of the shoreline response actions (Section 8.7)
- reduce health and safety risks to human responders and air-breathing marine fauna who would otherwise be exposed to greater concentrations of volatile organic compounds at the sea surface.

Dispersants may be applied via subsurface dispersant injection and by sea surface spraying application from aircraft and vessels. The process of application engenders environmental risk due to:

- the use of additional vessels with associated increase in risk of marine megafauna and vessel collision and routine discharges. Vessel strike during planned and unplanned activities is assessed in Section 7.3. The use of additional vessels will increase this risk due to the increase in number of vessels and area covered. However, spraying vessels will travel at <8 knots and as such the main risk factor in vessel strike will not increase
- the use of aircraft (air emissions and noise)
- the discharge of chemicals to the sea with associated potential toxicity effects of dispersed/dissolved hydrocarbons
- increasing the entrainment of oil in the water column.

Oil dispersants approved under the National Plan for Maritime Environmental Emergencies (National Plan) and listed in the Register of Oil Spill Control Agents (OSCA) will be used (Dasic Slickgone NS listed 1/2/18, Dasic Slickgone EW listed 21/3/18, Finasol 51 OSR listed 12/11/14 and Finasol 52 OSR listed 14/10/2015) in a loss of well control situation and under the process described in the OPEP. Oil Spill Control Agents approval for dispersants covers the chemical regardless of where it is sourced from (e.g. Australian or international stocks) for use in actions under the National Plan.

The accepted Environment Plan provides approval for dispersant use as described in the Environment Plan. Part 3 of the EPBC Act requires the referral of actions that may have an impact on EPBC listed receptors. Oil Spill Control Agents manufactured outside of Australia during the response phase will be checked against the OSCA register to confirm that the specific products (and formulations) are still registered and in-date prior to being brought into the country. This process aligns with the industry-standard IPIECA process (IPIECA-IOGP, 2014), but for OSCA-registered dispersants, confirmation of currency on the register will be required rather than a priori dispersant testing.

8.5.1.1 Risks and benefits associated with dispersant use

The application of dispersants will increase the amount of oil that is entrained and dissolved in the water column, reducing exposure of coastal ecosystems to floating weathered oil, as well as reducing the risk of exposure of seabird and marine mammal populations to floating oil (Bock et al. 2018; French-McCay et al. 2018; NRC 2005, 2013). It changes the distribution of the oil by removing it from the sea surface and dispersing it into the water column. This can increase the risk of toxic effects on planktonic, pelagic, demersal and benthic organisms (Hook & Lee 2015). French-McCay et al. (2018) simulated a deep-water oil well blowout to evaluate the potential benefits of subsurface dispersant injection. The authors concluded that subsurface dispersant injection has the potential to reduce the exposure of humans and wildlife to toxic volatile organic compounds of oil, increase biodegradation rates of oil and, and reduce the amount of oil at the surface and along shorelines.

Bock et al. (2018) used a comparative ecological risk assessment to investigate the benefit of subsurface dispersant injection. Their study also supported the conclusion that subsurface dispersant injection had important ecological and economic benefits because it reduces the risk of oil contacting shorelines and marine surface fauna.

A negative effect of subsurface dispersant injection is that the surfactants increase the bioavailability of oil components in the water column and more oil may remain at depth, potentially increasing the toxicity risk to deep-water fauna (French-McCay et al. 2018).

Modelling of a 102-day oil spill indicates potential for a small proportion of the buoyant oil that is entrained after subsea dispersant application, to rise to the sea surface in coastal / shelf waters. The surfacing oil will have been less exposed to the weathering processes (evaporation, emulsification and oxidation) affecting floating oil and therefore may be fresher than surface oil reaching the same areas. This phenomenon is reflected in the modelling results for a mitigated WCCD scenario (Figures 82 and 91 in Appendix 7-1). The volumes of fresh oil which may reach shorelines are low (average of 2 m^3 and maximum 41 m^3).

8.5.1.2 Dispersant and dispersed oil toxicity

Surfactant formulations used in chemical dispersion agents are commonly also used in many household products (e.g. dishwashing soap and laundry detergents), and comprise a mix of solvents, surfactants and additives. The active ingredients reduce the interfacial tension between water and oil, thus facilitating the formation of small oil droplets which disperse rapidly into the water column from the sea surface or from the

well head plume. The toxicity of dispersants and the toxicity of dispersed oil are dependent on a range of factors including oil type, dispersant composition and concentration, sensitivity of receptor species and their life history, making generalisations difficult.

For the most studied dispersant formulations the increased risk for most taxa appears to come from the increased solubility (hence bioavailability) of the toxic components of the oil, not the dispersant itself (Negri et al. 2018). Adams et al. (1999), Brakstad et al. (2018), Clark et al. (2001), Fingas (2011, 2002), Hansen et al. (2014), and Mitchell & Holdway (2000) found current dispersants to be significantly less toxic than the oil alone or the dispersed oil. Gardiner et al. (2013) suggest that the chemical dispersant does not alter the toxicity of the oil or the underlying mechanism of toxicity in the spiked exposures, but rather enhances the absolute concentration of the dissolved hydrocarbons that contribute to toxicity. This conflicts with some earlier beliefs, for example Gulec et al. (1997) suggested that some dispersants may be more toxic than the oil and the dispersed oil. Adams et al. (2014) found chemically-enhanced water-accommodated fractions (CEWAFs) to be more toxic to Atlantic herring than the water accommodated fractions (WAF); possibly reflecting the more effective dispersion due to chemicals. Contrary to this, Bejarano et al. (2014) reviewed dispersant toxicity studies and found that for Corexit 9500, the CEWAF was less toxic than the WAF. The NRC (2005) drew similar conclusions to Bejarano et al. (2014), reporting that evidence suggests that CEWAF is similar or less toxic than the WAF, depending on the basis of the study (measured TPH or nominal oil concentrations) (King & Dethier 2017).

Following application of chemical dispersants sub-sea or at the sea surface, the chemicals themselves are rapidly dispersed and diluted by oceanic water currents and buoyancy mixing. Benner et al. (2010) estimated Corexit 9500 dispersant concentration in field to be approximately 0.030 mg/L immediately following application. This is an order of magnitude(s) below the concentrations predicted to be acutely toxic (Clark et al. 2001; Fuller & Bonner 2001; Singer et al. 2001), suggesting that the dispersant concentrations in this actual application would not be acutely toxic.

Other studies have shown that the initial mixing in the water column also results in a rapid decrease in hydrocarbon concentrations in the water column, which fall to below detection limits within a matter of hours following dispersant application (in the absence of an ongoing source). For example, Lee et al. (2013) suggests that applying dispersant to a 0.1 mm thick slick of oil on the sea surface in 1 m waves, facilitates mixing in the top 1–1.5 m of the water column; representing a 10,000-fold dilution of the dispersed hydrocarbons. This turbulent mixing could reduce concentrations to below acute toxicity threshold concentrations in hours. This is supported by field trials (Gardiner et al. 2013) conducted with a variety of oil types and the dispersant Corexit 9500, showing that within hours, dispersed oil concentrations diminished with depth and time, to concentrations below effects concentrations. This indicates that in areas only exposed to spilled oil for a short period (towards the extremities of the area affected), the effects would also be temporary as the oil would rapidly be diluted to non-toxic concentrations.

Clark et al. (2001) reported embryonic and larval stages to be more sensitive than adults to dispersants and dispersed oil. The USEPA (2010) compared the acute effects of eight dispersants on two species and found that Corexit 9500 was slightly toxic to the crustacean, but “practically non-toxic” to the fish.

Word et al. (2015) reports that the range of dispersant concentrations causing 50% mortality (LC50 values) is very similar to the acute toxicity of various household consumer products. Singer et al. (1995, 1996) found the toxicity of Corexit 9500 to be similar to that of other dispersants, and equal to or less toxic than several other commonly used household products.

Dispersants pre-approved by Australian Maritime Safety Authority for use will be selected from the Oil Spill Control Agent (OSCA) Register. The Australian Maritime Safety Authority Efficacy Test Protocol for the Register (Australian Maritime Safety Authority 2012) lists the toxicity testing requirements that ensure products meet the requirements of acceptable practice for the National Plan, and products with a high acute toxicity (LC50 <10 ppm, 96 hours) (NRC 1989) or containing prohibited substances are not permitted. As such, impacts to the environment from the use of OSCA-registered dispersants are acceptable and on application at the recommended dosage, dilution and dispersion will significantly reduce the concentrations to levels considered unlikely to have significant effects on protected species or marine biota and habitats. The assessment of the environmental effects of using dispersants hereafter is based on the effects of redistributing the oil plume into the water column, conservatively assuming the oil retains its toxicity and assessing the degree of exposure of various environmental values and sensitivities to entrained and dissolved oil. The “mitigated” cases shown in the Oil Spill Modelling Study (Appendix 7-1) demonstrate the effectiveness of the dispersant application in reducing sea surface exposure, but also in increasing the exposure of water column biota to entrained and dissolved oil.

8.5.1.3 Biodegradation of dispersed oil

Biodegradation is the dominant process that removes entrained petroleum from the environment. Oil degrading bacteria metabolise petroleum, integrating carbon from the petroleum hydrocarbons into their biomass. Microbes using enzymes break the hydrocarbon molecules down at the interface between the small hydrocarbon droplets and the sea water. Thus, reducing the size of the entrained oil droplets not only increases their propensity to remain entrained (droplets <70 µm may never surface – Appendix 7-1), but also increases their bioavailability. The higher surface area to volume ratio of the oil can significantly increase the biodegradation rate (Atlas & Hazen 2011). Chemical dispersion also reduces the proportion of oil that is free to form emulsions at the sea surface which are less readily degraded by microorganisms. While the Stromlo-1 oil type is considered unlikely to form a stable emulsion due its low asphaltene content and any reduction in emulsification is expected to enable greater biodegradation. Hydrocarbon-degrading bacteria are ubiquitous in the marine environment and have been found in the soft sediments and waters of the Great Australian Bight, even in the absence of a known source of hydrocarbons (Hook et al. 2016). Populations of hydrocarbon degrading bacteria are expected to increase rapidly in response to a ready source of hydrocarbons, following a spill.

Several studies have shown that some dispersants enhance the rate of biodegradation of oil while other studies suggest no effect, or possibly retardation due to toxicity of the dispersant to microbes (National Research Council 2005). The rate of biodegradation of the dispersed oil and dispersant in the marine environment depends on several factors including type of dispersant, oil–water ratio, available mixing energy, sea water temperature, droplet size, nutrient presence, microbial community composition and bioavailability of the petroleum compounds to biodegrading microorganisms (Fingas 2011; NRC 2005).

The oil spill response may involve different commercial chemical dispersants, depending on how long the response runs for, and each dispersant may have different biodegradation characteristics; however, three of the most commonly used commercial dispersants have been compared (Dasic Slickgone NS, Corexit 9500, and Finasol ODR52) and found to have similar biodegradation characteristics (Brakstad et al. 2018). Brakstad et al. (2018) reports that Slickgone NS, a common oil spill dispersant does not inhibit biodegradation of oil at dispersant concentrations relevant to response operations. The dispersant did not affect oil degrading microbial activities or suppress oil biodegradation at low oil concentrations and microbial communities were not significantly affected by increasing dispersant concentrations. Zahed et al. (2011) found low concentrations of dispersed crude oil had a half-life of days to a few weeks, and that Corexit can improve the biodegradation rate. This supports the prediction that the indigenous bacterial assemblages of the Great Australian Bight would be able to degrade dispersed oil in the presence of most dispersant types.

8.5.1.4 Net environment benefit analysis

Net environmental benefits analysis is a process for assessing the relative merits, in terms of net environmental benefit, of alternative oil spill response strategies. The net environment benefit analysis assesses the benefit of applying a spill response measure in comparison with other measures or an unmitigated spill effect. Equinor Australia B.V. has a process which will be used for this activity, based on international best-practice, and a net environment benefit analysis tool specially developed for the project.

An “a priori” net environment benefit analysis was undertaken for the initial response measures as part of the spill response selection process undertaken during the planning phase in support of development of the EP. Use of sub-sea dispersant application, originally used successfully during the Macondo spill response, is an accepted strategy that is considered appropriate for this project and an important response tool by response agencies worldwide. Equinor Australia B.V. has therefore included subsurface dispersant injection in the response strategy pending positive outcomes from the operational net environment benefit analysis process. The environmental consequences relate to classifications used in the Equinor Australia B.V. risk matrix have been provided (Section 5.0). The mitigated consequences relate to the effects of the dispersant application in reducing surface oil and shoreline loading but increasing dissolved and entrained concentrations. The semi-quantitative scores take into account the magnitude of the predicted change in effect levels and the conservation significance or other importance of the receptor group, for example matters of national environmental significance are weighted heavily.

The a priori net environment benefit analysis and demonstration of efficacy from Macondo spill, support the use of dispersants as the primary strategy for mitigating the effects of a major spill, in the deep-water, offshore setting of the well-site. Surface and sub-sea application may be used separately or in combination.

Although dispersants offer environmental, social and economic benefits to many receptors, the dispersants and their application are not without their own inherent risks, not all of which are environmental or measurable, but will still be considered prior to application. Such examples are listed below in Table 8.2 based on IPIECA (2018 accessed at http://www.oilspillresponseproject.org/strategy/net-environmental-benefit-analysis).

Table 8.2 Summary of generalised benefits and drawbacks of dispersant use

Benefits	Drawbacks
• Reduces oil accumulation on shorelines, reducing risk for sensitive shoreline environmental and socio-economic receptors • High treatment efficiency and encounter rate possible with sub-sea dispersant application • Large volumes of fresh oil can be treated by subsurface dispersant injection relative to other identified response strategies and tactics which may be impractical >300 km at sea • Reduced concentrations of volatile hydrocarbons at the water surface; likely to reduce effect on marine mammals, seabirds and human health • No recovered oil storage requirements • Enhances natural biodegradation with potentially high oil elimination rate • Prevents oil in a sub-sea spill from surfacing, mitigating harm to sea birds, mammals, and other wildlife that occur at the sea surface • Lower man-power requirements (e.g. than beach clean-up without dispersant mitigation) • Sub-sea dispersant application treats oil at source before it spreads over a larger area at the sea surface, reducing the need for surface recovery or surface spraying • Dispersants reverse, stop, or eliminate water-in-oil emulsion formation particularly for low-viscosity oils. Emulsions can become very stable and a challenge to treat with any response option • Sub-sea dispersant application is not sensitive to weather or sea-state and can be safely applied 24/7.	• Potential effects of increased dispersed and entrained oil on water column-dwelling biota • Less known about long term effects of sub-sea use • Surface dispersants applied by vessel and aircraft has a limited “window of opportunity” for use due to weathering of the oil • Temporary reduction in water quality • Specialised equipment and expertise required • Potential effect on fishing industries due to public perception of dispersants’ effects on seafood • Reduced efficiency on high viscosity, high asphaltene/resin oils in calm, cold seas, and sub-sea dispersant application has a lower efficiency on very light oils (e.g. condensates) • Transfers oil from the surface to the water column and seabed where it remains until biodegraded (rather than collected and removed) • Aerial dispersant response limited to daylight hours and weather-dependent; reduced encounter rates results in increased proportion of dispersant applied being ineffective/failing to encounter spill hydrocarbons • Dispersed oil has a slower weathering rate than oil at the surface.

8.5.1.5 Dispersant effectiveness

Dispersant applications were simulated in SIMAP (Appendix 7-1) by specifying the assumed effectiveness (per cent of the oil treated) for subsea dispersant at 90% when injected directly into the turbulent plume of fresh oil at a ratio of 1 part dispersant: 100 parts oil; and surface dispersant effectiveness of 52% (at a ratio of 1 part dispersant: 25 parts oil) in single spill scenarios 2 and 3 when used on the Statfjord C crude (a paraffinic crude). It is important to note that the model accounts for changing the interfacial tension between the oil and the water within the blowout model, which is run to calculate droplet size distributions for a given situation. Very small droplets will become entrained and the model tracks their fate in the water column.

The percent of oil treated (effectiveness) is examined in two ways: for surface application it is seen as the removal of oil from the surface, in subsea (SSDI) application it is the reduction of oil droplet sizes for a certain percent of the oil. Numerous laboratory tests demonstrate a high effectiveness for the proposed dispersants (Dasic Slickgone NS and EW, Finasol 51 OSR and 52 OSR) across a wide range of oil types for surface and SSDI application, including varying release diameters, oil release rates, dispersant injection techniques and injection rates.

In the event of a loss of well control, oil and associated gas released from the seabed will rapidly drive upward into the water column due to high-pressure momentum. As the oil/gas droplets move higher into the water column they will encounter lowering atmospheric pressures, resulting in increasingly larger oil droplets

(100's µm – mm's) that will rise to the surface rapidly. For sub-sea dispersant injection treatment to be effective it must reduce the surface tension in the oil droplets and therefore reduce the droplet size, effectively slowing the speed of the oil droplets' rise to the point where the oil can be dispersed in the water column and is made bioavailable to hydrocarbon degrading bacteria and sedimentation processes (see Section 7.7.1.5 of the Environment Plan). Considering the applied effectiveness definition for sub-sea dispersant injection as reduction of oil droplet size for a certain percent of the oil treated and considering direct application of the dispersant to the source, the level of effectiveness can be up to 100%. This considers that the dispersant is applied directly at the source under turbulent, high pressure conditions. Note that when turbulence is very high, and atmospheric pressure high due to the depth (as is the case at Stromlo-1 in excess of 2000 m) the oil droplets are already reduced in size and so leaves little room for dispersant ineffectiveness (Brandvick et. al 2016). Equinor Australia B.V. believes that 100% of the spilled oil can be effectively treated; based on tests performed at SINTEF SeaLab (Trondheim, Norway), high pressure tests at SWRI, and large scale tests at Ohmsett (all experiments performed in the API Subsea Dispersant Injection Joint Industry Task Force, 2012-2017). The modelling assumed sub-sea dispersant injection efficiency at 90% to cover the relative uncertainty of the oil type that will be encountered in the Stromlo-1 well.

The fact that the Stromlo-1 well will have a concentrated source of oil flow, combined with the generally low oil viscosity (treating a constant flow of fresh oil) and a high turbulence at the release point makes mixing of dispersant into the oil very efficient. Dispersant injection (injection point, frequency and ratio required) has been examined extensively (refer to Brandvik et al 2016a and 2019 studies) at SINTEF.

Analysis of surface dispersant application efficiency is taken as percent removal of oil from the surface. This takes into account the influence of metocean conditions and weathering as described below. Equinor Australia B.V. has modelled oil spill scenarios with the assumed surface dispersant effectiveness at 52% (1 dispersant: 25 oil). Brandvick et. al (2019) tested the efficiency of Finasol OSR-52 and Dasic Slickgone NS at SINTEF using traditional IFP testing (surface application testing) on four different oil types: naphthenic, asphaltenic, paraffinic and waxy. On paraffinic oil, surface application testing showed Dasic NS at 78% effectiveness (removal of oil from the surface) and Finasol OSR 52 at 68% effectiveness. When applied to asphaltenic oil Dasic NS performed at 80% efficiency and Finasol OSR-52 at 68% efficiency, demonstrating negligible difference in efficiency when applied to differing oil types, and efficiency markedly higher that what has been assumed for the Stromlo-1 modelling. A 2017 SINTEF report displays results from a different mode of asphaltenic oil (Grane) that shows 76% efficiency for Dasic NS and 62% for Finasol OSR 52, again higher than the conservative 52% assumed efficiency for dispersants applied to Stromlo-1 oil.

Surface dispersants are not appropriate for use in all situations as certain metocean conditions and the stages of oil weathering reduces their effectiveness. Metocean conditions affect surface dispersant effectiveness in several ways: the amount of dispersant dispensed vs what contacts the oil is wind-dependent; oil exposure to sunlight results in photochemical oxidisation; and oil dispersion from the surface and throughout the water column is dependent on wave energy.

High energy conditions mix dispersants and oil, increasing the effectiveness (due to a higher encounter rate) of surface dispersants (API et al. 2001, USCG 2009, NOAA 2010). Temperature can affect dispersion of oil but is only significant if it results in icing (Fingas 2011); laboratory testing by Daling and Brandvik et. al. (1995) saw a reduction in dispersant effectiveness up to 20% with lowering temperatures. Temperature has been shown to effect dispersant success in subsea injection testing (Brandvik et al 2019). Recent research by Ward et. al. (2018) attributes a decrease in dispersant effectiveness (COREXIT EC9500A) after the Deepwater Horizon spill largely to photochemical oxidisation and emulsification, instead of to the previously accepted major pathways of evaporation and emulsification. The oxygen content, viscosity, density and adhesion of the studied oil (DWH oil) increased with sunlight exposure and correlated to a decrease in dispersant effectiveness in lab testing.

Winds speeds must be below 35 knots to provide safe operating conditions for planes and to increase the accuracy of the dispersant application. In dispersant modelling there is often a lower threshold (5 m/s, Fingas 2011) applied for wind speed to acknowledge the requirement of natural wind energy to mix dispersants and oil. If there is insufficient mixing due to low wind levels (resulting in a loss of wave generation, in particular high-energy breaking waves) the encounter rate of oil and dispersant is reduced and negatively impacts the effectiveness of surface dispersants. However, research by Lewis et al. (2010) demonstrates that even when applied in calm conditions, up to 6 days prior to weather conditions conducive to mixing, dispersants will aid dispersion of oil. Over time, a reduction in effectiveness was due to dispersant loss via leaching rather than oil weathering. Therefore, timely dispersant application in favourable metocean conditions will positively influence the effectiveness of surface dispersant application.

Spreading is considered to be one of the most important weathering processes of oil as it provides a larger surface area for evaporation and dissolution, however over time this will decrease as oil weathers. The evaporation or dissolution of low molecular weight compounds leave resins and asphaltenes that can form a 'mousse' compound that is too thick for dispersants to be effective (AMSA 2019). SINTEF (2019) observed a decrease in effectiveness of Corexit 9500 on Macondo oil after weathering (e.g. increased viscosity) in both high and low energy laboratory testing, demonstrating that regardless of the metocean inputs, once oil has begun the weathering process dispersant effectiveness will decrease over time. Field testing can determine the visual appearance of oil that has weathered beyond the point where dispersants will have the desired effect and subsequent aerial application can be guided to remaining surface oil that will have benefit from dispersant application (NRT 2013). It has been observed that natural dispersion increases with increased oil weathering, reducing the requirement and applicability of dispersant application (Fuentes et al 1995).

Equinor Australia B.V. has considered metocean conditions and oil weathering processes in the effectiveness of surface and subsea dispersants in modelled oil spill Scenario 2 (Appendix 7-1). The 3D oil spill fate and trajectory models used are among the best in the world and in addition to using them to simulate the behaviour of oil spills, they have been successfully validated in the field, for example in tracking lost objects, tracking spilled oil and replicating the behaviour of the Macondo spill. Being 3D models, they can simulate the behaviour of surface, entrained, dissolved and shoreline components of a spill, the weathering of the oil and effect of dispersants in local sea conditions. The models are run under a series of 100 different weather patterns drawn from the local area to simulate the variation in how the spilled oil may behave, including considering the metocean conditions and oil weathering processes. This allows assessment of the most likely fate and trajectory at defined times. The models have been improved following the Macondo spill, using data collected from the spill site to validate input assumptions e.g. droplet size and dispersion, and they have been improved by laboratory studies of the fate of oil and dispersants in the sea. All parts of the Australian oil industry (particularly the North West Shelf and Bass Strait) use the same model and it is part of the National Plan for oil spill response.

Prior to dispersant use, efficiency of dispersant on spilled oil will be tested in the field (in situ), as described in the OPEP (Appendix 9-1). The determination of which dispersants will be applied via surface or subsurface methods will be examined by in-field testing. Surface applied dispersant must be able to break down weathered oils, whereas SSDI does not have to break through weathered oils, but must react quickly when injected into the highly turbulent environment of the wellhead (SINTEF 2017). Dispersants would not be applied to a vessel diesel spill, as it is more effective to leave it to evaporate naturally. Testing is part of a decision-making and ongoing assessment process that includes Net Environmental Benefit Analysis (NEBA) and information obtained from Operational and Scientific Monitoring (Appendix 9-2).

8.5.2 Level of acceptable risk

The level of risk from the use of specific dispersants will be acceptable when:

- Equinor Australia B.V. will assess the efficacy of the dispersant application and reassess dispersant use based on these data
- The net environment benefit analysis assessment indicates that the environmental and socio-economic benefits of using dispersants following a loss of well control outweigh potential negative effects
- Dispersants selected according to the Australian Maritime Safety Authority ecotoxicity acceptability criteria for Oil Spill Control Agent (OSCA) product listing under the National Plan.

8.5.3 Risk assessment

The application of dispersant in the event of a loss of well control and major spill of 102-days will result in an increase in the proportion of spilled hydrocarbons becoming entrained, which decreases surface and shoreline loading, but increases exposure to pelagic biota in offshore waters and possibly localised sedimentation of hydrocarbons to the seabed in the deep offshore waters. Modelling of the fate and trajectory of chemically-dispersed oil was conducted to assess the effects of applying dispersants and the exposure of sensitive receptors to the greater volumes of entrained oil. It also examined the effectiveness of the dispersant strategy in reducing effects on coastal and shoreline receptors.

The modelling of chemically dispersed oil is shown as “mitigation” scenarios in Appendix 7-1 where details of the modelling assumptions and input and output parameters are also provided. The application of sub-sea dispersant has a significant effect in reducing the volumes of oil reaching the sea surface and eventually reaching the shorelines and coastal waters.

Environmental impact assessment, controls, environmental performance standards and measurement criteria for the sources of impacts and risks already assessed within the scope of the Environment Plan (e.g. additional vessel and aircraft operations) are detailed in Sections 6.0 and 7.0.

The risks associated with the proportional increase of entrained and dissolved oil using dispersants are described below. More detail on the distribution of environmental values and sensitivities (receptors) in the areas that may be affected by dispersed oil is provided in Appendix 7-3, which covers the entire Risk Environment that May Be Affected; an area based on 100 stochastic model runs.

Section 7.7 describes the predicted environmental risks associated with a loss of well control leading to a Level 3 oil spill with mitigation in place and the chemical dispersant application as per the Oil Pollution Emergency Plan. The risks of exposure to surface oil and shoreline accumulations of oil are covered in Section 7.7Therefore, this section is limited to risk assessing the increase in exposure to dissolved and entrained oil as a result of chemical dispersion.

Consequence evaluation
Receptor – Seagrass
Sections 4.0 and 7.7 describe how seagrasses generally grow on sediments in well-lit, intertidal and shallow subtidal waters in sheltered coastal bays and the lee sides of islands. Seagrasses are patchily distributed across the GAB coastline (Streaky Bay, Coffin Bay, within Spencer Gulf and Gulf St Vincent, Recherche Archipelago and Nuyts Archipelago). Beyond this area, significant areas for seagrass occur on the southern New South Wales, Victorian and Western Australia coasts. *Posidonia* spp. meadows have a very slow recovery rate; whereas some seagrasses e.g. *Zostera*, *Heterozostera* and *Halophila* spp. are more able to recolonise after disturbance (Kirkman et al. 1995). Subtidal seagrasses can be exposed to oil by direct contact with the WAF and by rhizomal uptake from contaminated sediments. The main exposure pathway to entrained and dissolved hydrocarbons for the subtidal *Posidonia* meadows of southern Australia is through uptake of the WAF hydrocarbons through plant cell membranes. In addition, seeds may be affected by contact with oil contained within sediments (NRDA 2012) and the buoyant seedlings of *Posidonia* spp. may also be exposed to floating oil; however, this effect would be reduced by dispersant application. When seagrass leaves are exposed to hydrocarbons, sub-lethal quantities of the soluble fraction can be incorporated into the tissue, causing a reduction in tolerance to other stress factors (Zieman et al. 1984). Given the distance from the potential source of the spill (>450 km), and the natural distribution of seagrass communities, based on the outcomes of the model, submerged seagrasses in these locations are unlikely to be exposed to levels of in-water hydrocarbons and dissolved fractions that tend to result in the greatest impacts. The modelling shows that entrained and dissolved oil only has a 2–3% probability of contacting coastal areas at Eyre and Eucla at moderate concentrations. Seagrass meadows in the upper reaches of the Spencer and St Vincent gulfs, Recherche Archipelago, New South Wales, South Australia or Western Australia are not predicted to be exposed to lethal concentrations. While affected *Posidonia* meadows would be slow to recover, the extent of predicted effects is minimal given they are largely protected by the overlying water and the concentrations of entrained and dissolved oil would be low. The intertidal seagrasses would be more likely to be affected by shoreline accumulations of oil; however, these affects would be reduced by dispersant application offshore. Overall, consequences for increased exposure to dissolved and entrained hydrocarbons are ranked Category 1–3.
Receptor – Seabirds and shorebirds
Seabirds and shorebirds are widely distributed across the GAB, from Esperance, Western Australia to the Bass Strait islands; in offshore foraging grounds and in adjacent coastal breeding, foraging and roosting habitats. The change in the risk profile for these birds as a result of dispersant application offshore relates primarily to the benefit gained from the reduced sea surface oiling. The greater proportion of oil becoming entrained and dissolved would increase exposure for diving birds in offshore areas where the concentrations are high enough to have an adverse effect, and indirectly thorough hydrocarbon biomagnification through the food web. Prey fish species, such as sardines and other baitfish, exposed to entrained or dissolved oil may retain some hydrocarbons in their tissues which would then be taken up by the birds. The short-tailed shearwater has a foraging biologically important area in the central and western GAB. Shorebirds are unlikely to be exposed to dissolved and entrained oils as the plume of higher concentrations does not reach any shoreline and only reaches the coastal waters of a few IMCRA regions (probability of 3 and 2% of exposure to moderate concentrations in parts of the Eucla and Eyre IMCRA regions respectively) (Section 11.1.3 in Appendix 7-1). Sea surface slicks and shoreline accumulation effects on wading shorebirds, roosting seabirds and foraging birds in general will be reduced by dispersant application offshore.

Consequence evaluation
Diving seabirds may be exposed to increased concentrations for both dissolved and entrained but reduced exposure to surface oils. Most of the entrained and dissolved oil will remain below 250 m deep where it will engender a negligible risk to diving birds (Figure 86, Appendix 7-1). Given the depth at which most of the entrained oil will suspend until it is biodegraded and the reduction in the exposure of birds in offshore, coastal and nearshore areas to floating oil and shoreline accumulations, the overall consequences are considered limited to local effects on individuals with short-term effects on local populations if the abundance of prey decreases. Overall, consequences for increased exposure to dissolved and entrained hydrocarbons are ranked Category 1 to 4.
Receptor – Macroalgae
Macroalgae are generally restricted to intertidal and subtidal rocky substrata in shallow waters to ~30 m depth (though they can grow to >100 m in very clear water). The key macroalgal value for the region is the Giant Kelp Forests off the Victorian, south-eastern South Australian and Tasmanian coasts. This is largely restricted to shallow waters (<10 m) about 750 km from the well site at the closest. Physiological responses to oils include a variety of changes to enzyme systems, photosynthesis, respiration, and nucleic acid synthesis (Lewis & Pryor 2013). Increased exposure to entrained and dissolved hydrocarbons could affect subtidal macroalgae beds, but modelling shows no affect is predicted. The modelling indicates these areas are unlikely to be exposed to in-water hydrocarbon concentrations high enough to have an adverse effect on the macroalgae. The time to contact is likely to be >44 days for kelp forests off the Victorian coast, and >55 days for Tasmania, during which time dissolution and biodegradation will reduce the toxicity and durations of exposure to below defined thresholds of ecological risk (see Appendix 7-2). Overall, consequences are ranked Category 1–3 because only limited impacts are predicted.
Receptor – Benthic invertebrates, habitats and communities
The presence and types of benthic invertebrates, habitats and communities are described in Section 7.7. The key sensitivities in the area that could be exposed to higher concentrations of in-water hydrocarbons at the seabed are a diverse soft sediment ecosystem, comprising many species of sponges, echinoderms, ascidians, bryozoans, bivalves, cnidarians and crustaceans. The species that make up these communities are less diverse moving away from the coast and the seabed in the vicinity of the well site where the greatest accumulation may occur, is thought to be less species rich and less abundant than shallower areas and areas to the east of the GAB (Section 4.0). Impacts from entrained (including chemically-entrained) oil may include the effects of oxygen depletion in bottom waters resulting from the metabolic processes of bacteria degrading the oil (biological oxygen demand). Chemical oil dispersants, such as those used during the Macondo spill (e.g. Corexit 9500) may affect transport of oil from the water column by forming marine oil “snow” with detritus, plankton/phytoplankton and microbes/bacteria that sinks to the seabed (Passow et al. 2016). While some of the “snow” biodegrades before reaching the seabed, some accumulates on the seabed resulting in increased oil in sediments where it is biodegraded by sediment microbes. Surface deposit or detritus feeders such as annelid worms, gastropods, or echinoderms are most likely to be affected by sedimented hydrocarbons rather than from entrained/dissolved oil. While exposure can lead to impacts including mortality, recovery of benthic habitats exposed to entrained hydrocarbons would be expected to be rapid, following return to background water quality conditions within weeks to months of contact. (Burns et al. 1993; Dean et al. 1998 in Committee on Oil in the Sea 2003). Benthic species and habitats within Key Ecological features around the 90–100 m water depth (such as the Kangaroo Island Pools and canyons and the ancient coastline) are not likely to be exposed to levels of in-water hydrocarbons above thresholds of ecological significance (Table 50, Appendix 7-1). Resident fauna such as worms, molluscs and crustaceans may suffer impacts from oil in marine snow that penetrates the sediments. Deepwater hard corals (*Phylum Cnidaria*) generally occur at up to 900 m in the GAB and would be adversely affected by increased sedimentation of oiled detritus and entrained hydrocarbons. Anna’s Pimple and Murray’s Mount (23.4 km and 19.5 km from Stromlo-1 respectively) are expected to support diverse benthic faunas, such as stony corals, black corals and octocorals (Currie & Sorokin 2011). If dispersant is applied, it is possible that corals associated with these seamounts would be exposed to hydrocarbons in the water column at moderate to high levels given their proximity to the source. Following the Macondo spill (White et al. 2014), deep water corals were found to have been impacted by flocculant material (containing oil) up to approximately 20 km from the release location in the direction of prevailing current. The modelling indicates that deposition around the well head during drilling (muds and cuttings deposition) is omni-directional, so it is possible the seamounts’ benthic communities would be affected. Species residing in offshore locations are more likely to be exposed to significant levels of in-water hydrocarbons with the application of subsurface dispersant injection depending on their water depth and location with respect to the spill, and potential increase of oil deposition into deep-water benthic sediments. The ecological implications of potential reduction in diversity and abundance of benthic invertebrates will be dependent on the habitat affected. Areas of highly mobile sediment, where diversity and abundance are relatively low, will likely recover quickly. Complex assemblages (e.g. sponge habitat) or deep-water slow-growing sessile invertebrates are likely to recover much more slowly.

Consequence evaluation
Persistent toxic components in some dispersants have been found in deep sea corals (White et al. 2014) following Given, the very slow recovery of some deep-sea biota, the recovery may be slow in the event of benthic effects. Overall, predicted impacts to benthic habitats vary widely according to species and location (nearshore versus offshore), worst case consequences for slow growing corals are ranked Category 7 due to potential recovery times >10 years.
Receptor – Marine reptiles
Marine reptiles, specifically turtles and sea snakes, are potentially directly impacted by the toxicity of in-water hydrocarbons through ingestion of floating oil and breathing of volatile hydrocarbons at the sea surface. While there are five species of turtle and one sea snake listed under the EPBC Act as potentially occurring in the exposure zone, they are present at very low abundances, and there are no known breeding or aggregation areas. Individual marine reptiles may come into contact with moderate-high concentrations of oil in the offshore areas of the GAB close to the source of the spill. However, with the very sparse population of marine reptiles in the GAB and no marine reptile BIAs within the region, potential impacts to marine reptile populations are considered to be minimal. Overall, consequences are ranked Category 1–3.
Receptor – Plankton
Plankton may be directly impacted by in-water and surface hydrocarbons. Plankton are an important food source for commercially targeted fish species (such as sardines) and planktonic larval stages of pelagic and benthic biota are broadly distributed in low densities across the region. Larval densities are expected to be lower further from shore and from source populations in the shallower waters of the shelf. Field observations from oil spills show minimal or transient effects on marine plankton (Volkman et al. 2004). Oil can affect the rate of photosynthesis and inhibit growth in phytoplankton, depending on the concentration. For example, photosynthesis is stimulated by low concentrations of oil in the water column (10–30 ppb) but becomes progressively inhibited above 50 ppb. Conversely, photosynthesis can be stimulated below 100 ppb for exposure to weathered oil (Volkman et al. 2004). The threshold of 70 ppb for in-water hydrocarbons is considered appropriate given the rapid weathering process, and the variability in the concentrations at which phytoplankton are impacted. Reproduction by survivors or migration from unaffected areas would be likely to rapidly replenish any losses from permanent zooplankton (Volkman et al. 2004). Once background water quality conditions have re-established, the plankton community will take weeks to months to recover (ITOPF 2011), allowing for seasonal influences on the assemblage characteristics. Plankton found in open waters of the GAB are expected to be widely represented across the southern offshore region. This broader metapopulation would aid in the re-establishment of communities if there was a population decline. The modelling shows that in-water exposure at threshold may result in a large area around the source of the spill. At these levels, some sensitive mature individuals and early life stages (larvae, gametes and juveniles) may experience mortality upon exposure. Modelling indicates that exposure to in-water concentrations is unlikely to have an adverse effect on plankton in important upwellings areas and other areas of biological significance, such as near Kangaroo Island, canyons, adjacent shelf break, Eyre Peninsula Upwellings Key Ecological Feature (Appendix 7-1), and thus effects on higher trophic levels are not expected. Once background water quality conditions are re-established, plankton populations are expected to rapidly recover due to the redistribution of plankton from surrounding waters mixing under ambient metocean conditions. Dispersant application is predicted to increase the probability of exposure of planktonic communities to moderate concentrations of in-water oil by 2% and 3% in the Eyre and Eucla IMCRA bioregions respectively. Exposure to greater concentrations of dissolved and entrained hydrocarbons due to the use of dispersants is predicted to result in short-term impacts to local plankton populations, which, taking into consideration the role of plankton in the food web, is considered a Category 4 consequence.
Receptor – Commercially fished species: rock lobster, crabs and fish
Deepwater crabs, scallops and lobsters are commercially important invertebrates in southern Australian coastal and shelf waters. Giant crabs are largely found on the outer continental shelf and upper slopes at depths of 140–270 m (see Appendix 7-3). Spanner crabs found largely along the New South Wales coast and blue swimmer crabs in the upper reaches of the Spencer and St Vincent gulfs are not predicted to be affected because they occur largely beyond the areas exposed to moderate concentrations of entrained and dissolved oil. Scallops are trawled in the Bass Straits up the Victorian–South Australian border out to the Exclusive Economic Zone (concentrated around 10–20 m). Rock lobsters are similarly found <200 m water depth but wide-ranging planktonic larvae may be transported out into the deep offshore waters of the GAB in low densities. Effect pathways to invertebrates are predicted as described above. No areas of commercial crabbing, scallop and rock lobster harvesting, or commercial invertebrate stocks are predicted to be affected by moderate–high concentrations of entrained or dissolved hydrocarbons or to increased oiled particle sedimentation. Modelling predicts no exposure to entrained or dissolved oil at concentrations that may cause harm to rock lobsters (Figure 74 and Figure 79, Appendix 7-1).

Consequence evaluation
The overall consequences to commercially and ecologically important benthic invertebrate taxa are predicted to be short-term effects on local populations and are considered Category 4. Some fish species of commercial value, specifically the southern bluefin tuna (*Thunnus maccoyii*) are seasonally present in the area largely in the first quarter of the year, hence could be potentially exposed to elevated hydrocarbon concentrations in the water column. While most of the entrained oil is predicted to remain >250 m below the sea surface (Figure 86, Appendix 7-1), there will be elevated hydrocarbon concentrations under the surface slick which may affect pelagic fishes such as SBT and their prey (e.g. sardines, krill). However, this species does not tend to aggregate for long periods as far offshore as the well location where the oil will be fresher and subsurface dispersant injection applied. The application of dispersants offshore is predicted to reduce the exposure of fish in inshore areas, including juvenile SBT and fish in aquaculture pens, to floating oil. If there was an actual effect on SBT, the affected fish may take <1 year to be rid of any hydrocarbons while recovery of affected stock would depend in part on the recovery of affected prey (fish and plankton). Hence restitution may take 1–3 years for regional populations to recover. As such, consequences are ranked Category 6.
Receptor – Fish, including cephalopods
Pelagic fish including sharks and squid, in the deep water of the GAB region, may be exposed to greater concentrations of dissolved and entrained hydrocarbons as a result of subsurface dispersant injection application if they are deeper than ~250 m and therefore within the modelled plume of entrained oil. However, generally these species are highly mobile and only a small proportion would be expected to remain at the depth of the entrained plume for long enough to suffer extended exposure to moderate–high concentrations of oil. The richer assemblages of fish and cephalopods in the shallower waters of the shelf are unlikely to be exposed to moderate–high concentrations of entrained oil as a result of dispersant use in offshore waters. None of the coastal IMCRA bioregions are predicted to be exposed to high concentrations of entrained or dissolved oil and only two (Eyre and Eucla IMCRA regions) are expected to receive moderate concentrations (2% and 3% probability respectively). No AMPs (other than the GAB MP) and no KEFs (including western demersal slopes and associated fish communities) were predicted to experience exposure at or above the moderate entrained or dissolved oil thresholds. Shallow inshore species include various syngnathids (seahorses, pipefish, pipe horses and seadragons) that are categorised as “listed marine species” under the EPBC Act. Some syngnathid species may occur in water depths up to 50–100 m and the probability of high levels of in-water exposure at depths 50–100 m was assessed and determined to be low. Syngnathids are not expected to be found close to the source of the release due to the lack of suitable habitat. Some pelagic fish may benefit from reduced surface oil being diluted throughout the water column with much of the entrained oil suspended below 250 m while biodegrading which may negatively affect demersal populations. As such consequences are ranked Category 5 with restitution times for local populations and ecosystems predicted to be 1–3 years.
Receptor – Marine mammals
Marine mammals can be exposed to chemically dispersed hydrocarbons through: • internal exposure by consuming oil or contaminated prey • external exposure, by swimming in oil and having oil directly on the skin and body • maternal transfer of contaminants to embryos (NRDA 2012). Pinnipeds The Australian sea lion has foraging BIAs along the WA coast from approximately Albany to Israelite Bay in the western GAB and from west of Eucla to just east of Kangaroo Island and Gulf St Vincent in the eastern GAB. These areas include breeding colonies and haul out sites and are close in many cases to similarly important areas for the New Zealand fur seal. There are also a few haul-out sites and smaller breeding colonies for the Australian fur seal around Portland, Cape Otway, Wilsons Promontory and on the smaller islands in the Bass Strait. Using dispersant offshore, reduces the exposure of important coastal and shoreline habitats. Modelling predicts sites in the western GAB, Portland east and Bass islands may be exposed to reduced levels of surface oil while sites in the eastern GAB may experience oil at high thresholds (see Section 7.7.3). Only the South Australian sites around the Eyre Peninsula and Kangaroo Island are predicted to be exposed to entrained oil (Figures 72-74, Appendix 7-1) at the low and very low thresholds with a 2% and 3% probability of exposure to moderate concentrations for haul outs and colonies within the Eyre and Eucla IMCRA regions. Foraging individuals may encounter patches of fresh oil depending on the extent of their range. Using dispersant 200–400 km offshore reduces exposure to shoreline oiling but increases the area offshore that is exposed to elevated entrained oil and increases the risk of small amounts of fresh oil reaching coastal areas. This may affect a limited number of New Zealand fur seals foraging in the central Great Australian Bight. Other pinnipeds have more restricted foraging ranges but could still be exposed to patches of fresh oil closer to the coast. This is a minor increase of the consequence to the pinnipeds.

Consequence evaluation
Cetaceans Physical impacts from ingested hydrocarbon with subsequent lethal or sub-lethal impacts are applicable to entrained and surface oil. However, the susceptibility of cetaceans varies with feeding habits. Baleen whales are likely to ingest surface oil as they feed at the surface and in the water column. Toothed whales and dolphins may be susceptible to ingestion of dissolved and entrained oil as they gulp feed at depth. As highly mobile species, in general it is very unlikely that these animals will be constantly exposed to elevated concentrations of hydrocarbons in the water column for continuous durations (e.g. >96 hours) that could lead to chronic effects. Note also, many marine mammals appear to have the necessary liver enzymes to metabolise hydrocarbons and excrete them as polar derivatives (Ball & Truskewycz, 2013). The potential impacts on three species with BIA in the region and known to be in the GAB for some of the drilling period, are presented below. Impacts on other cetacean species are likely to be similar to those described here but may vary in intensity according to the level and duration of exposure to hydrocarbons in the water column. While some individuals may be affected, population level effects on these other transient species, are considered unlikely. Southern right whale Modelling shows dispersants application reduces the amount of oil reaching important aggregational areas (Appendix 7-1). Mitigated scenario predicts a 2%–3% probability of exposure to moderate thresholds and 2%–5% probability of exposure to low thresholds of in-water hydrocarbons along the southern right whale Head of Bight / Israelite Bay calving grounds and migration and distribution areas. Thus, there is little potential for impacts from entrained oils on population levels. Given the reduction in surface oil and volatiles in calving areas dispersant application will not increase the consequences. Pygmy blue whale The mitigated 102-day modelling indicates a minor increase of exposure to entrained oil: very low–moderate dissolved and entrained oil concentrations (Appendix 7-1) and high concentrations in the immediate vicinity of the well site. The increased exposure to entrained oil and dissolved oil will result in minor increase of the consequence. This is offset by decrease in surface oil and reduction in the consequences for whales feeding at the surface. Sperm whale The mitigated 102-day modelling indicates that dispersant application would increase exposure of parts of the sperm whale foraging BIA to low to moderate dissolved and entrained hydrocarbon concentrations, (Appendix 7-1). This will be offset by decrease in exposure to surface oil for sperm whales at the sea surface. In summary, overall consequences to cetaceans from the dispersant application are ranked Category 1–3.
As Low As Reasonably Practicable decision context
The use of dispersants is widespread nationally and internationally and is an agreed component of the oil spill response strategy as outlined in the OPEP. In general, the use of dispersants will engender a significant environmental benefit; however, there is potential for increase in risk for some receptors. Decision context C should be applied to demonstrate impacts and risks are As Low As Reasonably Practicable given the relevant persons' interest in the use of dispersants in the Great Australian Bight. As Low As Reasonably Practicable also considers the potential disbenefit of not implementing dispersant response strategies, the complexity of positive vs. negative impacts of dispersant use and the uncertainty regarding the characteristics and subsequent behaviour of the oil.
Assessment technique
Precautionary approach applied – Decision context C. The precautionary approach has been applied in this risk assessment in the following ways: • Scientific uncertainty has been reduced by undertaking scientific baseline studies on the distribution of southern bluefin tuna in the Great Australian Bight. • Modelling and risk assessment are based on conservative assumptions where uncertainty remains. • Views of relevant persons have been considered in the a priori NEBA process.

8.5.4 Risk treatment

The a priori net environment benefit analysis supported use of dispersants in the deep offshore waters where it is likely to be highly effective at the well head. Following a spill, operational net environment benefit analysis will consider the impacts, risks and benefits of applying dispersants to the oil spill to inform the Incident Management Team's decisions on where and when to use them. This will be supported by results of in-field dispersant efficacy testing.

8.5.4.1 Environmental performance outcomes (EPO 8.5)

Dispersant applied offshore when supported by a neutral or positive NEBA.

8.5.4.2 Context for assessment

Legislative and other requirements	OPGGS(E) Regs 2009 requires the Oil Pollution Emergency Plan to address preparedness and response techniques such as surface and subsurface dispersant application
Industry standards	NOPSEMA Guidance Note: Oil Pollution Risk Management GN 1488 Rev 2 Feb 2018 IPIECA Dispersants: sub-sea application Revision 2016
Equinor Australia B.V. standards	Supported by a neutral or positive NEBA

8.5.4.3 Control measures and performance standards

Control measure	Performance standards	Measurement criteria	Responsible
Dispersant Exclusion Zones	EPS 8.5.1: Dispersant application only within application zones defined by IMT, following consultation with stakeholders Dispersant application and exclusion zones informed by surveillance (including modelling) and monitoring outcomes No spraying of dispersants within Threatened Environmental Communities (TEC) or SRW calving BIA (refer to Appendix 7-3)	IAP provides defined dispersant application and exclusion zones Records of communications with government agency stakeholders Daily logs Surveillance and monitoring (OSMP) outcomes Records indicate no spraying within SRW BIA or TECs	Incident Commander
Chemical dispersant efficacy testing	EPS 8.5.2: In-field quick dispersant efficacy test undertaken for new chemical dispersants, and dispersant application only continued if semi-quantitative test (per the National Plan Oil Spill Dispersant Effectiveness Field Test Kit Operational Guide, AMSA 2012) shows efficacy of 50% or greater. Dispersant efficacy tested each time a new dispersant is introduced to the response	Efficacy testing records show: • all chemical dispersants used in response have passed efficacy tested before use. • IMT logs demonstrates dispersant application halted if dispersant shown to be ineffective.	Incident Commander
Selected dispersant testing for SSDI efficacy– pre-mobilisation	EPS 8.5.3: Equinor will test samples of the OSCA-registered dispersants identified as pre-approved for use by AMSA in the SINTEF laboratory using DIET (specialised SSDI test): • dispersants must be shown to be effective in dispersing oil in SSDI application to be included in the response plan. • dispersants with low efficacy rejected or subject to further consideration if necessary, for example, NEBA analysis in the event that lower efficiencies can still provide net environmental benefit.	SINTEF report confirms selected dispersants tested and are effective in dispersing oil analogue	Safety and Sustainability Manager
Dispersant efficacy testing – in field	EPS 8.5.4: Dispersant efficacy under surface and SSDI application will be tested as follows: • In-field dispersant efficacy testing (simple bottle test) shows dispersant application likely to be effective • If dispersant passes efficacy test and NEBA supports response, relevant dispersant application strategy/ies will be implemented.	Records and daily logs demonstrate that all dispersants tested and approved prior to use Records of in-situ efficacy testing used in NEBA assessment prior to dispersant use Records of in-situ monitoring assessments indicate that dispersant is effective after implementation of surface and subsurface dispersant injection and test outcomes used in ongoing NEBA	Incident Commander

Control measure	Performance standards	Measurement criteria	Responsible
SSDI dispersant efficacy testing – in field	EPS 8.5.5: Additional dispersant efficacy testing under SSDI application will be considered for application during the response and in OMP4 as follows: • ROV inspection will be conducted to confirm that the subsea injection of the dispersants is effectively being applied to the plume of leaking oil. • Visually, by examining the output from video cameras on ROVs to assess whether the shape or colour of the oil discharge changes with dispersant addition • SINTEF Silhouette Camera system to monitor effect on droplet sizes of implementing SSDI • Acoustically, by analysing backscatter data generated from a ROV-mounted sonar • towed fluorimeter survey under the surface slick to measure the concentrations of oil in water • particle size analysis using a LISST (laser in-situ scattering and transmissometry) analyser to measure oil droplet size distributions • water sampling for PAH (polycyclic aromatic hydrocarbon) analysis • Visually, by analysing the area of oil on the sea surface in aerial images • Air monitoring for VOCs and percentage lower explosive limit (LEL) on vessels in close proximity to the well site before and after dispersant addition.	Records of in-situ monitoring assessments indicate that dispersant is effective after implementation of subsurface dispersant injection and test outcomes used in ongoing NEBA Records show that in finalising OMP4 these alternative and additional techniques have each been assessed for suitability to response, taking into account site conditions at the time	Incident Commander
NEBA	EPS 8.5.6: NEBA completed prior to operational spraying of dispersant onto the oil	Records show how NEBA has guided spraying activities	Incident Commander
	EPS 8.5.7: Surveillance (including modelling) and OSMP data inform ongoing NEBA assessments	Surveillance and OSMP records Records show how surveillance and OSMP data informed NEBA	Incident Commander
	EPS 8.5.8: NEBA reviewed and validated during each operational period shift of the IMT	IAP and daily IMT logs show that NEBA reviewed every operational shift of the IMT	Incident Commander
OSCA-registered and approved dispersant as primary dispersants for response	EPS 8.5.9: OSCA listed dispersants will be used both surface and subsurface application. Other dispersants may only be considered where there is an operational/safety need to apply dispersants, where OSCA-registered dispersants are not available, and where they have been approved following Equinor dispersant assessment process	Records show OSCA listed and approved dispersant as primary dispersant for response with documentation and communications with government agency stakeholders supporting use any use of other dispersants.	Environment Unit Lead
Dispersants selection process	EPS 8.5.10: OSCA register approved or listed dispersants will be used.	Dispersant selection and use is documented. Dispersant application log records of types of dispersants, volume applied and method and location of application.	Incident Commander

Control measure	Performance standards	Measurement criteria	Responsible
OSMP	EPS 8.5.11: OSMP Scientific Advisory Group maintains objectivity of response through contribution to planning and independent review of outcomes OSMP monitoring provides information on hydrocarbons, dispersants and dispersed hydrocarbons in marine waters Other OSMP monitoring provides information on the potential/occurrence of species at potential risk, and provides information on any observed impacts in or adjacent to dispersant application zones OSMP outcomes inform ongoing NEBAs, response operations and provide key information on impacts and recovery to inform post-spill investigations and future global oil and gas activities	Records of OSMP SAG communications and document reviews OSMP monitoring and impact assessment reports Records demonstrate how OSMP outcomes informed ongoing NEBAs Records of summaries of OSMP findings in post-spill investigation records Records of "lessons learned" from dispersant application activities	Environment Unit Lead
Vessel-based dispersant application	EPS 8.5.12: Vessel-based surface dispersant application will be undertaken only where environmental conditions are suitable for application and it is safe to do so Dispersants will be targeted at areas of thickest oil Considerations of patchiness and windrows will be taken into account in planning and operations Surveillance and monitoring outcomes will not inform ongoing NEBAs	Records (including dispersant application logs, daily logs and IAP) demonstrate that vessel dispersant application was undertaken following NEBAs in accordance with tactical response plan (TRP) – Dispersants and C&R	Incident Commander
	EPS 8.5.13: Two PSVs will be capable of undertaking vessel-based dispersant application	Records demonstrate that PSVs were fitted with dispersant application equipment (as defined in Tactical Response Plan – Dispersants and C&R)	Incident Commander
SSDI operations – vessel support	EPS 8.5.14: • PSV with approved safety case for SSDI available on contract before operations start • PSV can receive fuel and dispersant supply transferred at sea • At-sea fuel and dispersant transfer plan ready before start of operations • Manufacture or purchase of suitable clips to hold injection nozzle to BOP prior to mobilisation to location from within Australia • SSDI Plan including details on choice of CT unit or Kevlar hoses, finalised after MODU contracted and prior to mobilisation	• Functional requirements for work in GAB as a general PSV • Installation plan for SSDI conduit system (i.e. Coiled Tubing setup/frame) • Tank capacity >1000 m^3 • Inspection shows clips are onboard during mobilisation • SSDI Plan and bulk liquids transfer plan review shows documents completed before mobilisation	Equinor Australia B.V. Drilling Manager
Fixed wing aerial dispersant capability (FWADC)/ Aerotech 1st Response aerial dispersant operations	EPS 8.5.15: Alignment of aerial dispersant operations undertaken in accordance with FWADC Concept of Operation	Records of FWADC/Aerotech 1st Response aerial dispersant operations maintained, which define that aerial dispersant operations align with the FWADC Concept of Operation	Incident Commander

Control measure	Performance standards	Measurement criteria	Responsible
Pre-stored dispersant across multiple sites	EPS 8.5.16: Pre-store dispersant • ~50 m^3 across multiple sites including Port Adelaide and MODU/vessels • ~6 m^3 dispersant stored at Ceduna Airport • enable aerial application within two days	Pre-mobilisation check confirms dispersant pre-stored across multiple sites	Equinor Australia B.V. Drilling manager
Visual observation of dispersant effectiveness via ROV	EPS 8.5.17: Assessment of dispersant efficacy from remote operated vehicle visual observations while implementing subsurface dispersant injection	Records of in-situ visual assessment indicate that dispersant is effective after implementation of subsurface dispersant injection	Incident Commander

8.5.5 Outcome

Predicted risk	Consequence	Probability	Risk ranking
	Category 7	P= 0.000019	Medium
Demonstration of As Low As Reasonably Practicable	No further control measures have been identified which may reduce the environmental consequence of using dispersant.		

Acceptability criteria	Demonstration of acceptability
Dispersants meet the Australian Maritime Safety Authority ecotoxicity acceptability criteria for Oil Spill Control Agent (OSCA) product listing under the Australian National Plan	Dasic Slickgone NS (Slickgone) and Finasol 52 OSR are the prime dispersant types that would be used in the event of a loss of well control. Both dispersants meet the Australian Maritime Safety Authority ecotoxicity acceptability criteria (including testing on species relevant in Australia) for Oil Spill Control Agent (OSCA) product listing under the Australian National Plan. The use of dispersants as a potential control measure following a loss of well control is a practice that has been previously accepted in Australian and international waters under specific conditions.
The NEBA assessment indicates that the environmental benefits of using dispersants following a loss of well control outweigh potential negative effects	The general NEBA indicates that using a dispersant offshore significantly reduces the risk to surface and intertidal receptors and values by reducing the volume of oil ashore and on the surface. A specific NEBA would be developed to ensure net benefits over the course of the response. Dispersant application will only be undertaken if NEBA shows a neutral or positive benefit. To maximise benefits, dispersant efficacy testing will be undertaken, and efficacy will be continually monitored (e.g. using remote operated vehicle video/monitoring instrumentation, visual surface observations, operational monitoring). Dispersant response will be continually evaluated to optimise response activities (e.g. every operational period), or immediately following identification of any significant change in risk Subsurface dispersant injection may reduce risk to human health and safety from volatile organic compounds for offshore surface response teams (as observed during the Macondo spill). The a priori NEBA has supported the selection of dispersants as a primary response strategy.
Equinor Australia B.V. will assess the efficacy of the dispersant application and reassess dispersant use based on these data	Equinor Australia B.V. to conduct in-situ efficacy testing. In addition to the testing, the efficacy of the dispersant application is also considered when the NEBA is undertaken.

8.6 Containment and recovery

8.6.1 Risk description

Containment and recovery typically involve the deployment of booms and oil skimmers from suitable vessels, as well as the collection, transfer and disposal of oil and oily water recovered during the response. The oil and water mix would be stored temporarily in support vessel tanks on the decks of vessels or in vessel internal tanks. Recovered sea water may need to be decanted and returned to the sea to free up storage capacity and enable greater volumes of oil to be recovered without making the potentially long voyage back to port, increasing the effectiveness of the containment and recovery. The decant water will contain hydrocarbons and their discharge may affect local biota.

The containment and recovery techniques need to be adapted to local conditions and consider meteorological and oceanographic conditions at the time and site constraints. Additional risks associated with the containment and recovery response are:

- accidental loss of waste during waste generation, transport and disposal with risk of secondary contamination of a non-contaminated area
- additional vessels will be needed to deploy and recover booms and the increased number of vessels and the containment booms will increase the risk of interaction/collision with marine fauna
- contamination of surface waters due to decanting of treated sea water.

Due to their slow speeds, the vessels used to store and transport the oily waste have a very low probability of collision (resulting in a loss of containment which would lead to spilling oily waste back into the sea) or of collision with marine fauna. The standard industry vessel risk management controls are described in Sections 6.0 and 7.0.

8.6.2 Level of acceptable risk

The level of risk from the use of containment and recovery techniques will be acceptable when:

- The net environment benefit analysis supports the implementation of the containment and recovery response actions and the actions are in accordance with state response agency directions in state waters
- Decanting of oil with sea water is allowable by Australian Maritime Safety Authority in an oil spill emergency response.

8.6.3 Risk assessment

Waste generation, transport and disposal with risk of secondary contamination
Implementing the selected containment and recovery response strategies will result in the generation of the following waste streams that will require management and disposal: • recovered contaminated liquids (oil/water mixture) • semi-solids/solids (e.g. oily solids and contaminated boom) collected during containment and recovery operations • debris (e.g. seagrass wrack, sand, woods, plastics) collected during containment and recovery operations. If not managed and disposed of correctly, wastes generated during the response have the potential for secondary contamination and effects on wildlife through contact with or ingestion of waste materials, and contamination risks. Equinor Australia B.V.'s waste management plan will detail how the waste generated during response will be managed in cooperation with state agencies who will be coordinating the nearshore response efforts. The waste plan will be finalised after contractor selection, finalisation of the logistics plan and discussion with the state agencies. The largest volume of oily water that could be spilled is conservatively considered to be 1060 m^3 (i.e. 106 m^3 oil based on the ratio 1:10 of oil to water) assuming a single vessel is used for temporary storage from one strike team with a minimum recovery rate of 75.5 m^3 per day with an operational period of 14 days. The biological consequences of spilling a small volume of weathered oil, on open water sensitive receptors for an area unimpacted by the Level 3 release are likely to be similar to those associated with the unplanned release of hydrocarbons as a result of a bunkering scenario (Section 7.6). In such a scenario, there is potential for localised consequences to megafauna, plankton, fish populations (surface and water column biota) within the spill affected area, but no impacts to

commercial fish stocks would be expected. Accidental loss of up to 106 m^3 of highly weathered oil (mixed into a larger volume of water by the skimmer action) would affect local populations of marine biota with short-term (<1 month) effects on local populations. In offshore waters this would not be expected to affect important areas or populations; whereas in coastal areas, the consequences may be impacts on biota likely to recover quickly (plankton, fish) and reduced public amenity. This equates to a Category 1–3 consequence.
Additional vessels and the containment booms will increase the risk of interaction/collision with marine fauna
The scale of the containment and recovery actions will depend on the fate and trajectory of the spill, if it is feasible to apply offshore (low probability of success) and the state agencies' decisions around shoreline protection. Typical booms used in containment and recovery operations are designed to sit on the water surface, meaning that fauna capable of diving, such as cetaceans and pinnipeds can readily avoid contact. Impacts to species that inhabit the water column such as sharks and fish are not expected. Additionally, many fauna such as cetaceans, are likely to detect and avoid the activity area, and are not expected to be present in large numbers near the containment and recovery operations. The vessels involved in the containment and recovery actions will be moving slowly and will present little risk to marine megafauna in the area. The noise of the vessel motors may have a positive effect on scaring marine fauna from the immediate area, with consequent reduced exposure to the thickest patches of oil (which would be targeted by the containment and recovery team). The presence of extra vessel and the booms may lead to an individual level effect, most likely limited to behavioural effects with very limited and short-term (<1 month) effects on marine megafauna in any particular area. This equates to a Category 1–3 consequence.
Contamination of surface waters due to decanting of treated sea water
The discharge of the oily water in an area affected by a major spill will have a net benefit in reducing the load of hydrocarbons in the marine environment because it will contain a lot less oil than the intake oil and water mix. The localised additional consequence to the marine environment is considered Category 1–3 and the effects will be short-term as the discharged water mixes in with a large volume of sea water.
As Low As Reasonably Practicable decision context
The practice of containment and recovery is well understood with a clear understanding of the release pathways, and the control measures required to manage these. Taking this in consideration Decision Context A should be applied to demonstrate that risks are As Low As Reasonably Practicable.
Assessment technique
Good Practice – Identified industry good practices adopted to reach As Low As Reasonably Practicable

8.6.4 Risk treatment

Nearshore containment and recovery response will be directed by the state response agencies with support from Equinor Australia B.V. State agencies will update and finalise response planning after a Level 3 spill has occurred.

The following recommendations will be part of actions undertaken to minimise environmental effects from containment and recovery and will be refined in line with agency directives:

- Decanting will occur during daylight hours only and after a minimum residence time of 30 minutes for optimal separation of oil from water.
- The boom will also be monitored to ensure any trapped fauna are released as early as possible.
- The temporary storage device will be checked prior to use to ensure that it is not contaminated with hazardous residues that may previously have been stored in that device.
- Where possible internal baffles will be used in the temporary storage device to speed up separation and prevent remixing of the oil and water.
- If feasible, free water should be discharged into a secondary storage container or within the containment booms in the path of the recovery device (to retain any accidentally discharged oil).
- Visual monitoring will be carried out at the discharge site whilst decanting to ensure that only water is released.
- Decanting area will be selected to minimise environmental effects.

8.6.4.1 Environmental performance outcomes (EPO 8.6)

No increase in the level of environmental harm from an oil spill as a result of containment and recovery actions.

Maximise oil recovery effectiveness and prevent effects on priority protection areas safely and within deployment constraints.

8.6.4.2 Context for assessment

Legislative and other requirements	OPGGS(E) Regs 2009 requires the Oil Pollution Emergency Plan to address preparedness and response techniques such as containment and recovery MARPOL 73/78 Annex 1, Regulation 4.3 (Exceptions) provides for discharge of substances containing oil when used for the purpose of combating specific pollution incidents in order to minimise the damage from pollution. Transport and handling of waste in a response would be in accordance with the relevant licences and regulations
Legislation	Environmental Protection (Controlled waste) Regulations 2004 – identifies the requirements for the transport, uploading and disposal of controlled waste
Industry standards	IPIECA-IOGP (2013) "The use of decanting during offshore oil spill recovery operations" IPIECA – A guide to shoreline clean up techniques, Revision 2016 NOPSEMA Guidance Note: Oil Pollution Risk Management GN 1488 Rev 2 Feb 2018 Australian Marine Oil Spill Centre TRP
Equinor Australia B.V. standards	Supported by a neutral or positive NEBA

8.6.4.3 Control measures and performance standards

Additional EPSs related to containment and recovery operations are provided in Section 13.2 of the OPEP (Appendix 9-1).

Control measures	Environmental performance standards	Measurement criteria	Responsibility
NEBA and human health and safety assessments to be conducted to assess decant in area of CAR	EPS 8.6.1: Equinor Australia B.V. will maintain a continuous NEBA and human health and safety assessment process throughout the response Decant water only to be discharged if supported by NEBA	Records that NEBA assessments have been reviewed every operational period and following identification of a significant change in risk Records show Equinor Australia B.V. conducted NEBA as part of input to response plan	Safety and Sustainability (SSU) Manager
Containment and recovery equipment (booms, skimmers, storage)	EPS 8.6.2: Deployment of equipment will be undertaken only when: • it is safe to do so • when expected to be effective • within the range of environmental conditions identified as suitable for the specific equipment (based on manufacturer's instructions/ guidance and the response strategy as described in the TRPs	Daily logs and records of containment and recovery operations demonstrate that CAR equipment was deployed safely, effectively and following consideration of environmental conditions	Incident Commander
Decanting process (from vessel tanks and temporary storage containers)	EPS 8.6.3: Approval received from Australian Maritime Safety Authority for the discharge of decant water in line with the following regulatory requirements: • decant during daylight hours only • decant to the apex of the containment boom only • following a minimum residence time of 30 minutes	Records of Australian Maritime Safety Authority approval for discharge of decant water, IMT log records volume decanted and discharged, with locations and date/time	Vessel Master

Where an authorised government officer, such as the designated State Controller, directs Equinor to act in such a manner that adherence to the commitments described in the EP including the OPEP can no longer reasonably be achieved, and as a result an environment performance standard can no longer be met, the failure to meet that standard will not constitute a non-conformance under this EP. However, any such instances will be listed in the post-activity environmental performance report described in Section 9.0 of the EP.

8.6.5 Outcome

Predicted risk	Consequence	Probability	Risk ranking
	Category 1–3	P= 0.000019	Low
Demonstration of As Low As Reasonably Practicable	The incremental risk to the environment from the activities is low and therefore no additional controls are required to reduce the risk to As Low As Reasonably Practicable. The predicted risk associated with Containment and Recovery activities are low and therefore no additional controls are required to reduce risks to As Low As Reasonably Practicable.		

Acceptability criteria	**Demonstration of acceptability**
The NEBA supports the implementation of the CAR response actions and the actions are in accordance with state response agency directions in state waters	CAR activities will only be implemented following NEBA, and therefore only if it engenders a neutral or net benefit to the environment. The unplanned release of non-hazardous and hazardous wastes through inadequate containment practices is unlikely to have any significant environmental effects as impacts would be temporary and localised in an area widely affected by spilled oil, with the net result of an unplanned release being similar to having taken no action. Given the likely low abundance of MNES in the area and the negligible incremental risk in spilling recovered water, or decanting oil in water, only individual-level effects are predicted.
Discharge of oily waste sea water is an allowable activity and consistent with industry practice	Decanting of water from the temporary storage vessel is consistent with IPIECA's recommendations (IPIECA-IOGP 2013).

8.7 Shoreline protection and clean-up

8.7.1 Risk description

8.7.1.1 Risks of implementing response actions

Shoreline protection and clean-up consists of different manual and mechanical techniques employed to prevent or reduce exposure of shoreline biota to weathered hydrocarbons, to minimise ongoing contamination and reduce environmental impacts by promoting recovery. The techniques need to be adapted to local conditions and take into account meteorological and oceanographic conditions at the time and site constraints. In response to an actual spill and after revision of the tactical response plans, the details of the shoreline protection and clean-up response strategies will be finalised and executed as directed by the respective state response agency. The key elements of the shoreline protection and clean-up plan with potential for environmental effects may be:

- decontamination of oiled personnel and equipment on site, at accommodation and facilities, an area for washing contaminated materials and for storing wastes
- shoreline clean-up involves personnel to manually remove oil and oiled debris, vehicle access to shorelines, accommodation, other facilities, and storage
- protection of important shoreline resources by installing nearshore booms to contain or deflect floating weathered oil.

- waste management will be required at all sites to prevent further contamination; this would require vehicle access, temporary storage on site, and transport to final depot
- shoreline cleaning using water flushing kits may be used.

A net environment benefit analysis assessment will be conducted prior to initiating any of these elements and they will only be implemented if they engender a neutral or positive environmental effect. The Operational (Type I) Monitoring Plans (OMPs) and Scientific (Type II) Monitoring Plans (SMPs) will be revised as required to be site and event specific.

Additional risks associated with the shoreline clean-up response, not yet included within the scope of the EP, include:

- human presence (including light, noise, etc.) in sensitive areas may adversely affect important natural behaviours of biota, e.g. nesting of shorebirds and seabirds, or pinnipeds and lead to secondary contamination of foreshore and backshore areas such as dunes
- ground disturbance due to manual raking and turnover of sandy beaches or intertidal flats to remove accumulations of weathered oil, which could affect sediment infauna, cultural heritage sites, temporary exclusion of residents and tourists from amenity beaches,
- vegetation cutting and compression in preparing storage areas, vehicle access tracks and accommodation areas
- waste management of contaminated water, personal protection equipment, vegetation, sand, etc. Waste generation and disposal practices will be outlined in the Waste management plan (Oil pollution emergency plan)) for the activity. A draft plan has been prepared, which will be finalised after contractor selection and logistics reviews.

8.7.2 Level of acceptable risk

The level of risk from shoreline protection and clean-up will be acceptable when:

- A neutral or positive net environment benefit analysis supports implementation of the response actions and they are in accordance with state response agency directions.

8.7.3 Risk assessment

While shoreline protection and clean-up plans have not been finalised and can only be completed once the fate and trajectory of the spilled oil and the actual oil type and volume are known, it is assumed that effects on marine sediment quality, water quality, air quality, protected species, benthic and shoreline habitats, haul-out/roosting and breeding areas, socio-economic factors and protected areas are possible.

Damage or loss of habitat from oil spill response techniques is expected in most cases to be localised to the area in which the technique is being employed but may have secondary impacts to features further along shorelines.

The oil spill modelling indicates that in the case of a loss of well control, under the worst case running for 102 days until the relief well can be drilled, the maximum length of shoreline that may be exposed to accumulations of oil at concentrations above the minimum loading for effective shoreline clean-up operations (>100 g/m^2) is approximately 1500 km (Figure 61 in Appendix 7-1). This is considered the maximum length of shoreline that might be subject to shoreline clean-up and consequently the effects of the response activities. It is important to note that this is the maximum length of shoreline that may be amenable to clean-up and on average it would be much less than this and some areas will not be accessible or suitable for clean-up activities. The modelled shoreline accumulation also assumes that once oil reaches a shoreline, it remains there (for the full 162 days modelled) and that oil continues to accumulate at the same location, adding to the loading, whereas in many locations it would be a temporary deposit that is removed by natural processes with consequently diminishing concentrations.

The risks described below conservatively assume independence of response measures; they are based on a mitigated spill outcome of the worst-case discharge scenario, without any nearshore containment or deflection booming which would reduce impacts under real situations. Details on the nearshore and onshore response actions are not available at this time because they fall under the auspice of the state control agencies and will be directed by them, with support from Equinor Australia B.V. as requested.

The environmental receptors and sensitivities in the areas that may be affected by weathered oil are described in Appendix 7-3 Existing Environment of the Risk Environment that May Be Affected (Risk EMBA).

Damage to or loss of intertidal or shoreline habitat
Damage to shoreline habitats is likely to be caused by: • high-pressure washing (detaching intertidal rock biota such as limpets, mussels and algae) • compression/compaction of shoreline sediments from vehicles and mechanical recovery techniques • disturbance of shoreline biota by human responders and vehicles • removal of oiled biota • collection of oiled sediments and wrack from beaches leading to loss of sandy habitats and sediment infauna. Damage to intertidal shoreline habitats and communities may have indirect effects on the food chains; affecting the macrofauna communities which they support. In addition, the removal of habitat (such as sand from beaches) may also make them more vulnerable to ongoing erosion. Affected sites are predicted to recover through beach replenishment due to natural sediment transport processes and recolonisation by beach biota. Shoreline clean-up or shoreline protection actions could affect significant stretches of the coast with medium-term (1–3 years) effects on local populations in areas with greater response focus (tourism sites, aquaculture sites). This equates to a Category 5 consequence.
Disturbance to cultural heritage sites
The movement of responders, vehicles and equipment through backshore and dune areas may disturb or damage cultural heritage artefacts or sites. Adverse effects are expected to be localised to the area of disturbance and for important sites, the areas can be pre-cleaned – artefacts can be relocated or protected by exclusion zones. The most likely cultural heritage artefacts to be present are Aboriginal shell middens, especially where freshwater and brackish water sources occur nearby, such as along the Coorong coast (see Appendix 7-3). Disturbance to culturally significant artefacts may also affect spiritual associations and management and mitigation would be coordinated with local indigenous custodians, as appropriate. Shoreline clean-up actions could affect isolated parts of the coast with medium-term (1–3 years) effects on heritage values. This equates to a Category 5 consequence.
Temporary exclusion of residents and tourism from amenity beaches
The presence of stranded oil and clean-up operations will necessitate temporary beach closures, with ground disturbance also requiring beach closures. During shoreline clean-up operations, it would also be expected that entire beaches would be closed. As described in Appendix 7-3, there are many recreational activities, including fishing and tourism, that are linked to coastal areas. The exclusion of residents and tourists from beaches has the potential to result in impacts to local tourism businesses, as well as negatively impacting local residents. Given that coastal exclusions may be in place for the entire release duration and for an extended clean-up period once the well is killed, there is the potential for a prolonged consequence to tourism and local residents. Consequently, it is expected that shoreline clean-up operations have the potential to negatively affect communities over the medium term (1–3 years). This equates to a Category 5 consequence.
As Low As Reasonably Practicable decision context
Risks arising from shoreline protection and clean up are well known and understood and guidelines by IPIECA and NOPSEMA have been considered in developing the OMPs, TRPs and SMPs. Regulatory relevant persons will be involved during the implementation of such activities. Taking this in consideration Decision Context A should be applied to demonstrate the risks are As Low As Reasonably Practicable.
Assessment technique
Good Practice – Identified industry good practices adopted to reach As Low As Reasonably Practicable

8.7.4 Risk treatment

The Oil Pollution Emergency Plan and Operational and Scientific Monitoring Plan have been provided to the state response agencies to inform the state tactical response plans. The Oil Pollution Emergency Plan and Operational and Scientific Monitoring Plan describe how the response will be implemented and include consideration of minimising environmental (including cultural) impacts. In developing the area tactical response plans, the following will be considered:

- lessons learned from previous shoreline clean-up operations (such as the South Australian annual spill response exercise) to inform response strategies to reduce environmental impacts of the response
- response activities in particularly sensitive protected areas are likely to be limited and undertaken under close management control of relevant authority or relevant persons group.

Shoreline response will be directed by the state response agencies with support from Equinor Australia B.V. State agencies will update and finalise response planning after a Level 3 spill has occurred. The following shall be considered during the plan refinement process:

- Zones and wash down areas shall be set up in the event of a shoreline response to minimise the risk of secondary contamination.
- Clean up strategies shall be defined and implemented by state control agencies.
- Operational monitoring will provide real-time indicators of impacts from the response and negative impacts shall trigger a re-evaluation (including of the net environment benefit analysis) and where/when appropriate, termination of response at relevant locations.

8.7.4.1 Environmental performance outcomes (EPO 8.7)

No increase in the level of environmental harm from an oil spill as a result of shoreline and protection clean up actions.

8.7.4.2 Context for assessment

Legislative and other requirements	OPGGS(E) Regs 2009 requires the Oil Pollution Emergency Plan to address preparedness and response techniques such as shoreline protection and clean up
Industry standards	NOPSEMA Guidance Note: Oil Pollution Risk Management GN 1488 Rev 2 Feb 2018 IPIECA – A guide to oiled shoreline assessment (SCAT) surveys Revision 2016 IPIECA – A guide to oiled shoreline clean-up techniques Revision 2016
Equinor Australia B.V. standards	Supported by a neutral or positive NEBA

8.7.4.3 Control measures and performance standards

Control measures	Environmental performance standards	Measurement criteria	Responsibility
NEBA	EPS 8.7.1: Site-specific NEBA completed to validate a priori NEBA and reviewed and validated during each operational shift of the IMT	Site-specific NEBA, Incident Action Plan, IMT log shows NEBA reviewed each operational shift of the IMT	Equinor Australia B.V. Incident Commander (if directed by the state control agency)
	EPS 8.7.2: NEBA considers key protection priorities	NEBA records show key protection priorities considered	Equinor Australia B.V. Incident Commander (if directed by the state control agency)
Human Health and Safety assessments	EPS 8.7.3: Minimise health and safety risk through thorough assessment prior to undertaking specific activities	Records of human health and safety assessments demonstrate that risk assessments had been undertaken and any mitigations actioned prior to undertaking response activities (where safe to do so) Records demonstrate that response activities were terminated or suspended pending review where a significant credible risk was identified.	SSU Manager

Control measures	Environmental performance standards	Measurement criteria	Responsibility
Shoreline Clean-up Assessment Technique (SCAT)	EPS 8.7.4: Outcomes of SCAT provide intelligence on shoreline sensitivities (including heritage sites) and oiling on shorelines SCAT outcomes identify accessibility of locations Outcomes of SCAT inform update/development of site-specific TRPs SCAT outcomes inform whether shoreline response can be undertaken safely and effectively with a neutral or positive NEBA determined	SCAT reports Incident Action Plan Completed TRPs Daily logs Health and Safety Assessment reports Weather/sea forecasts and reports Records of communication with external Subject Matter Experts (SMEs) where required	Incident Commander
Tactical Response Plan (TRP) - Shoreline	EPS 8.7.5: Existing overarching shoreline response TRP reviewed and updated. Initial review and update completed five days before first shoreline contact. A continuous review process will then be implemented to capture development of new site-specific TRPs, and identify revised lists of primary, secondary and tertiary response sites	Records demonstrate TRP reviewed at least 5 days before modelling indicates likely first shoreline contact Ongoing revisions of document demonstrate that new site-specific TRPs have been captured and identified as either primary, secondary or tertiary sites.	State control agency (supported by Equinor Incident Commander)
Site-specific shoreline tactical response plans (TRPs)	EPS 8.7.6: Existing site-specific shoreline TRPs reviewed and updated, and new primary and secondary shoreline TRPs developed from template TRP, based on Shoreline Clean-up Assessment Technique (SCAT) surveys New tertiary sites identified and site-specific guides prepared based on template TRP.	SCAT survey reports Completed site-specific shoreline TRPs New sites categorised (primary, secondary or tertiary) and listed in Tactical Response Plan (TRP) - Shoreline	State control agency (supported by Equinor Incident Commander)
	EPS 8.7.7: TRPs for shoreline locations finalised for implementation within two days of commencement of the predicted time to first shoreline contact.	Completed site-specific shoreline TRPs and records of date of approval that demonstrate two-day timeframe for completion was met.	State control agency (supported by Equinor Incident Commander)

Where an authorised government officer, such as the designated State Controller, directs Equinor Australia B.V. to act in such a manner that adherence to the commitments described in the EP including the OPEP can no longer reasonably be achieved, and as a result an environment performance standard can no longer be met, the failure to meet that standard will not constitute a non-conformance under this EP. However, any such instances will be listed in the post-activity environmental performance report described in Section 9.0 of the EP.

8.7.5 Outcome

Predicted risk	Consequence	Probability scale	Risk level
	Category 5	P= 0.000019	Low
Demonstration of As Low As Reasonably Practicable	The incremental risk to the environment from the response activities is low and therefore no additional controls are required to reduce the risk to As Low As Reasonably Practicable. They will only be undertaken if NEBA shows net benefit. Predicted risk is Low and therefore no additional controls are required to reduce risks to As Low As Reasonably Practicable.		

Acceptability criteria	Demonstration of acceptability
A neutral or positive NEBA supports implementation of the response actions and they are in accordance with state response agency directives	Shoreline protection and clean-up will only be used as directed by state agencies and after a NEBA and therefore only if it engenders a neutral or positive benefit to the environment. A continual assessment process will monitor the effects and potential impacts from the response (e.g. operational monitoring). Where negative impacts are identified, rerunning the NEBA process would be triggered and maintain risks at As Low As Reasonably Practicable Historically public and regulatory relevant persons have identified shoreline protection and clean up as part of the response strategy. Ongoing consultation will inform Equinor Australia B.V. of internal and external public and regulatory expectations.

8.8 Oiled wildlife response

8.8.1 Risk description

An oiled wildlife response (OWR) would involve reconnaissance from vessels, aircraft and shoreline surveys, as well as the capture, transport, rehabilitation and release of oiled wildlife. Additional risks associated with wildlife response include:

- hazing
- pre-emptive capture and capturing of oiled wildlife
- relocation of unoiled wildlife
- transporting wildlife
- stabilisation of wildlife
- cleaning and rinsing of oiled wildlife
- rehabilitation (e.g. diet, cage size, housing density)
- release of treated wildlife.

Site-specific ("on-the-ground") wildlife reconnaissance would be undertaken with oil spill response Shoreline Clean-up Assessment Technique teams where appropriate, to optimise response resources. Therefore, potential risks associated with wildlife reconnaissance have already been included in this Environment Plan as part of vessel/aerial reconnaissance and Shoreline Clean-up Assessment Technique.

In the event of a spill, modelling indicates that an extensive length of the coastline may be exposed to shoreline accumulation of hydrocarbons. Based upon priority protection locations, maximum shoreline loadings and understanding of the receptor sensitivities, there are a number of locations where animals – specifically birds and pinnipeds – have the potential to be oiled. Large numbers of these animals may be oiled due to aggregating on the coast, given that coastal areas provide habitat for breeding and foraging (e.g. for a large range of shorebirds). The level of risk to wildlife (and hence the potential for exposure to oiled wildlife response intervention) will be directly related to accessibility of the shoreline/wildlife, the nature of shorelines (e.g. exposed/sheltered, rocky/sandy shores, shoreline slope), the level of shoreline accumulation, the potential for contact, and in particular the physico-chemical characteristics of the hydrocarbon (e.g. level of weathering) on that shore.

8.8.2 Level of acceptable risk

The risk of oiled wildlife response activities will be acceptable when:

a. Activities are undertaken after a neutral or positive net environment benefit analysis and as determined by the relevant state Incident Management Teams.

b. Activities are managed in line with the most current relevant oiled wildlife response plan by state Incident Management Teams/ oiled wildlife response agencies and supported by Equinor Australia B.V.

c. Equinor Australia B.V. provide training of two Category 6 oiled wildlife response teams and resources required by state Incident Management Teams to support oiled wildlife response.

d. Preparation and agreement of an Incident Management Team communications plan (between Equinor Australia B.V. and state Incident Management Teams) and mobilisation of Liaison Officers (LOs) into Incident Management Teams facilitate effective communication pathways between Equinor Australia B.V. and state Incident Management Teams.

e. Equinor Australia B.V. provides intelligence to state Incident Management Teams to support effective coordination of a "whole of response" approach.

f. Consultation with relevant state relevant persons identify oiled wildlife response as part of the response strategy.

8.8.3 Risk assessment

Oiled wildlife response potentially causes impacts to marine sediments, water quality, air quality, shoreline biota, biota utilising the sea surface, protected species, socio-economic factors and protected areas.

Oiled wildlife response will be undertaken in state jurisdictions, under the control of state Incident Management Teams, supported by Equinor Australia B.V. and oiled wildlife response agencies (e.g. Australian Marine Oil Spill Centre). Equinor Australia B.V. will provide local training centres to enable training of local communities to provide two Category 6 oiled wildlife response teams across the response area. Equinor Australia B.V. will provide personnel (e.g. Australian Marine Oil Spill Centre) and equipment to support this response as required by the relevant state Incident Management Teams. An oiled wildlife response specialist in the Equinor Australia B.V. Incident Management Team will work with the Equinor Australia B.V. Incident Management Team logistics section to facilitate and coordinate provisioning of resources requested by state Incident Management Teams. Equinor Australia B.V. will also support development of response plans, provision of logistical support, and consultation with relevant wildlife management agencies. Equinor Australia B.V. will mobilise a trained and experienced wildlife branch director from their Global Incident Management Assist Team into their Incident Management Team to provide a direct Incident Management Team contact for state Incident Management Teams and response agencies. The wildlife branch director can engage with state Incident Management Teams to coordinate responses and ensure that Equinor Australia B.V. response activities and capabilities meet the states' response needs. The Wildlife branch director will also explore options to improve effectiveness of the arrangements and reduce risk (e.g. through provision of additional resources), in response to the evolving nature and scale of the response.

An evaluation of the impacts to wildlife from oiled wildlife actions are as follows:

- hazing
  - disturbance of target biota with potential for behavioural impacts and stress-related responses
- capturing wildlife
  - inefficient capture techniques (e.g. due to inadequate training) have potential to cause stress, exhaustion or injury to wildlife
  - pre-emptive capture/translocation could cause undue impacts when oiling is not certain
- transportation
  - inefficient transport techniques have the potential to cause injury, stress and thermoregulation pressures to wildlife
- stabilisation of wildlife
  - inefficient stabilisation of wildlife techniques has the potential to cause injury to wildlife and thermoregulation stress, in addition to potential for mortality during the triage process
- cleaning and rinsing of oiled wildlife
  - inefficient cleaning and rinsing techniques have the potential to cause injury and exhaustion of wildlife (e.g. removing the natural water-proofing on feathers)
- rehabilitation (e.g. diet, cage size, housing density)
  - inefficient rehabilitation techniques have the potential to cause injury and thermoregulation stress
- release of treated wildlife

  - potential for stress to wildlife if released in an unfamiliar site
  - potential for rehabilitated wildlife to return to the oiled area of capture
  - potential for stress when adjusting to the release site
- shoreline surveys
  - potential for disturbance of roosting/resting birds and/or pinnipeds
  - potential damage/destruction of shorebird eggs/nesting sites
  - potential abandonment of young due to disturbance of breeding sites
  - potential for destruction/damage to sensitive habitat due to trampling/4wd access
  - potential for increased stress in already stressed/impacted biota
- waste generation and disposal.

Consequence evaluation: fauna casualties
Hazing and exclusion of wildlife from known congregation, resting, feeding, breeding or nesting areas may result in the prevention of species accessing their preferred resources. This approach may also result in additional disturbance/handling stress without any benefit as many species tend to return to sites from which they have been moved. This may result in reduced healing capacity, reduced reproduction and species recruitment, as well as reduced energy stored for migratory animals. The incorrect handling of fauna may also result in increased stress levels and therefore increased fauna casualties. Although fauna interactions from oiled wildlife response and shoreline clean-up techniques are expected to be limited to the duration of the response, there is the potential that these effects may result in longer term impacts to local populations where a large proportion of the local population may be exposed to oil and subsequently oiled wildlife response (especially where OWR success rates are low). For example, beach nesting shorebirds such as the hooded plover only nest on sandy beaches, and their eggs are small and well camouflaged. This means that they are easily trodden on by personnel actively involved in response techniques. In addition to this, if the incubating adult is scared off the nest by hazing activities, the eggs may become compromised, which will prevent the chick developing in the egg, and the egg will not hatch. This may also result in adults abandoning young. The result could be a significant reduction in local species reproductive success (recruitment) if this was to occur for an entire local population. Fauna casualties from shoreline clean-up response and oiled wildlife response techniques have the potential to result in an incremental effect on fauna populations (though oiling is expected to pose a greater risk). However, there is still the potential for the techniques to result in localised degradation of the environment or effects on individuals as opposed to population level.
As Low As Reasonably Practicable decision context
Risks arising from oiled wildlife response are well known and understood and guidelines by the state response agencies have been considered in developing the OMPs and SMPs. Regulatory relevant persons will be involved during the implementation of such activities. Taking this in consideration Decision Context A should be applied to demonstrate the risks are As Low As Reasonably Practicable.
Assessment technique
Good Practice – Identified industry good practices adopted to reach As Low As Reasonably Practicable

8.8.4 Risk treatment

8.8.4.1 Environmental performance outcomes (EPO 8.8)

No significant increase in the level of environmental risk from an oil spill as a result of oiled wildlife response actions.

8.8.4.2 Context for assessment

Legislative and other requirements	An OWR plan (OWRP) in draft or final form exists for each state within the EMBA. In several cases plans are being reviewed, with the Western Australia Plan being adapted for several states (to align with state objectives, policies/legislation, feasibility, protection

	priorities, etc.). Each OWR describes how the response will be implemented and includes consideration of environmental (including socio-economic) impacts and their controls.
Industry standards	NOPSEMA Guidance Note: Oil Pollution Risk management GN1488 Rev 2 Feb 2018 Draft WA-SA Australian Species Response Plan – Australian Sea lion WA Oiled Wildlife Response Plan – Australian Marine Oil Spill Centre and Department of Parks and Wildlife, 2014 International Petroleum Industry Conservation Association (IPIECA) 2004, A guide to Oiled Wildlife Response Planning, International Petroleum Industry Conservation Association, no. 13
Equinor Australia B.V. standards	Supported by a neutral or positive NEBA

8.8.4.3 Control measures and performance standards

Control measures	Environmental performance standards	Measurement criteria	Responsibility
NEBA	EPS 8.8.1: NEBA reviewed and validated during each operational shift of the IMT	Incident Action Plan, IMT log shows NEBA reviewed each operational shift of the IMT	Equinor Incident Commander (if directed by the state control agency)
	EPS 8.8.2: NEBA considers key protection priorities	NEBA records show key protection priorities considered	Equinor Incident Commander (if directed by the state control agency)
Human Health and Safety assessments	EPS 8.8.3: Minimise health and safety risk through thorough assessment prior to undertaking specific activities	Records of human health and safety assessments demonstrate that risk assessments had been undertaken and any mitigations actioned prior to undertaking response activities (where safe to do so) Records demonstrate that response activities were terminated or suspended pending review where a significant credible risk was identified.	SSU Manager
Oiled Wildlife Response Plan	EPS 8.8.4: Equinor Australia B.V. will support state IMTs/OWR agencies in mobilising and maintaining an oiled wildlife response undertaken by the relevant state IMT/OWR agency	Evidence of financial support, logistical support, provision of resources (including SMEs) will be maintained	IMT Oiled Wildlife Advisor for the relevant state IMT
	EPS 8.8.5: The IMT Environmental Unit leader shall monitor and record the actions under the response to ensure that the requirements of the state control agencies are met.	Communications with state control agencies indicate their requirements are being met All decisions to escalate/de-escalate an OWR response will be made by the state IMT/OWR agency.	
Equinor Australia B.V. to provide suitably trained personnel responsible for effective OWR implementation	EPS 8.8.6: Maintenance of access to oiled wildlife personnel through the National and Global OWR network	Contracts or memberships with providers of oiled wildlife response personnel (e.g. through OSRL) show access to trained personnel will be maintained	
		Evidence of training records for response personnel will be maintained	
	EPS 8.8.7: A full-time OWR liaison	Communications with oiled wildlife	

Control measures	Environmental performance standards	Measurement criteria	Responsibility
	officer will co-ordinate communications between Equinor Australia B.V. and state IMTs to ensure efficient use of available response resources	response training providers will be documented Records show: • Equinor Australia B.V. has provided a full time Liaison officer to mobilised state IMTs, with a state Liaison Officer mobilised into the Equinor Australia B.V. IMT • Communication records show that Equinor Australia B.V. provided resources requested by state IMTs where practicable and in a timely manner • provision of in-time training of two category six OWR teams from local communities by establishing training centres	
Current in-place OWR	EPS 8.8.8: Implementation of OWR plan support state oiled wildlife response objectives Where absent from the relevant in-place oiled wildlife response plan, additional information derived from e.g. up-to-date TRPs, SCAT surveys, spill reconnaissance and OSMP monitoring will be used to identify potential risks to sensitive species. Examples are likely to include (but not limited to): • Vehicular access would be restricted on dunes, salt marshes, mangroves and other sensitive habitats. • Restrictions would also be imposed during nesting season where relevant.	Daily records indicate that: • The relevant (most up-to-date, active) oiled wildlife plan has been used. • Sensitive areas/seasons have been avoided where alternatives exist. • The methodology used is aligned with that recommended in the relevant oiled wildlife response plan. Requested and supported state OWR objectives Data and information obtained during the response phase (e.g. up-to-date TRPs, SCAT survey outcomes, spill response surveillance data and OSMP data) have been used as part of planning and ongoing re-evaluation of OWR activities.	

Where an authorised government officer, such as the designated State Controller, directs Equinor to act in such a manner that adherence to the commitments described in the EP including the OPEP can no longer reasonably be achieved, and as a result an environment performance standard can no longer be met, the failure to meet that standard will not constitute a non-conformance under this EP. However, any such instances will be listed in the post-activity environmental performance report described in Section 9.0 of the EP.

8.8.5 Outcome

Predicted risk	Consequence	Probability scale	Risk level
	Category 1–3	P=0.000019	Low
Demonstration of As Low As Reasonably Practicable	The incremental risk to the environment from the activities is low. Additional resources were considered as part of As Low As Reasonably Practicable considerations as shown below. No additional controls are required to reduce the risk to As Low As Reasonably Practicable. OWR will only be undertaken if supported by a neutral or positive NEBA. Predicted risk is considered low and therefore no additional controls are required to reduce risks to As Low As Reasonably Practicable.		

Acceptability criteria	Demonstration of acceptability
Activities are undertaken after a neutral or positive NEBA shows a net benefit to the environment, as determined by the relevant state IMTs	OWR will only be implemented in a jurisdiction after a NEBA and therefore only if it identifies net benefit to the environment, as determined by the relevant state IMT (with input from state agency scientific advice)
Activities are managed in line with the most current relevant oiled wildlife response plan by state IMTs/OWR agencies and supported by Equinor Australia B.V.	It will be implemented and managed by state IMTs/OWR agencies in line with the current accepted oiled wildlife response plan, with key input from relevant state specialists/subject matter experts and supported by Equinor Australia B.V.
Equinor Australia B.V. provide training of two Category 6 OWR teams and resources required by state IMTs to support oiled wildlife response	Equinor Australia B.V. will implement training of two Category 6 OWR teams across the response area. Trainees will be sourced by Equinor Australia B.V. Equinor Australia B.V. will provide OWR response resources requested by state IMTs where practicable to do so.
Preparation and agreement of an IMT communications plan (between Equinor Australia B.V. and state IMTs) and mobilisation of LOs into IMTs facilitate effective communication pathways between Equinor Australia B.V. and state IMTs	Equinor Australia B.V. will develop communications plans with state IMTs Equinor Australia B.V. will inform state IMTs within 24 hours of a level 2 or 3 spill. State IMTs will mobilise LOs into the Equinor Australia B.V. IMT. Equinor Australia B.V. will mobilise LOs into state IMTs when requested.
Equinor Australia B.V. provides intelligence to state IMTs to support coordination	Equinor Australia B.V. will provide relevant information to support state IMTs in line with the approved Communications Plan. Information will include situational awareness of OWR response that may be in progress in other states

8.9 Operational and scientific monitoring

8.9.1 Risk description

Field-based monitoring, surveillance and reconnaissance activities undertaken during implementation of the Operational and Scientific Monitoring Program may be undertaken in the intertidal, nearshore (coastal) and offshore environments. These activities may result in potential impacts to the receiving environment including:

- seabed, sediment and benthic habitat disturbance during sample collection
- potential collisions with fauna
- seabed disturbance from vessel transits/anchoring
- human (noise, light, presence, etc.) leading to behavioural disturbance of biota. Likewise, vehicle and foot traffic access to shoreline areas and islands may result in disturbance/damage of biota and habitat
- collection of biota.

8.9.2 Level of acceptable risk

Risks associated with undertaking scientific monitoring are acceptable when:

a. Operational and scientific monitoring is a regulatory requirement.

b. The data collected is critical in identifying impacts from the oil spill and from the spill response, and subsequent recovery.

c. Operational monitoring data is critical in identifying efficacy and potential impacts (negative and positive) of the implementation of spill response strategies and tactics to mitigate environmental risk as part of a continual assessment process.

d. The Operational and Scientific Monitoring Plan activities are timely and undertaken without delays that could hinder assessment of impacts and recovery.

8.9.3 Risk assessment

An environmental risk assessment, controls, environmental performance standards and measurement criteria for the sources of risk as part of the planned and unplanned drilling activities are detailed in Sections 6.0 and 7.0. Additional impacts from Operational and Scientific Monitoring Plan activities are assessed below.

Subtidal benthic habitats
Benthic habitats may be disturbed during sample collection by survey gear (e.g. trawls, grabs/cores, sleds, video systems, shovels). Vessel anchoring could affect seabeds (e.g. seagrass habitats). Although sampling will occur over a wide area, the individual areas are predicted to be small (even cumulatively). Recovery of benthic communities from subsequent damage depends on the type of sampling gear used, size of the area affected, habitat characteristics and the frequency of this activity. Impacts are predicted to be highly localised (restricted to the footprint of the vessel anchor, chain or sampling equipment) and temporary in many cases, with full recovery expected. However, impacts to sensitive benthic habitats (e.g. seagrass) or from benthic trawl gear may be longer term even though the area of effect may be relatively small. Overall, consequences are ranked Category 1–3.
Intertidal habitats
OSMP activities in intertidal areas may cause disturbance of seabird/shorebird/pinniped haul-out, roosting or breeding areas. Access to sites (by foot or vehicle) may cause damage to sensitive or protected shoreline habitat. Sample collection is unlikely to result in long-term effects. Sample collection as part of the OSMP may be prohibited in managed protected areas.
Threatened and Protected species: fish, seabirds, shorebirds, pinnipeds
Several individual fish, invertebrates and fish eggs may be collected. Vehicle and foot traffic access to shoreline areas and islands can result in damage to habitats, nests and sensitive vegetation. Such impacts are likely to be localised to areas where no alternative access is possible and sporadic. Human impacts (noise, waste, presence, light, etc.) may lead to behavioural changes of biota, but human and vehicle/vessel presence will only be for short, intermittent periods, and hence behavioural changes are unlikely in the long term. Sample collection as part of the OSMP may be prohibited in managed protected areas. The use of aircraft for surveys may increase the risk of bird strikes and/or noise resulting in behavioural changes, and air emissions degrading air quality. These are ranked Category 1–3 as they are short term, localised and intermittent, with restitution predicted to occur in the short term. No population level impacts to threatened or endangered EPBC listed species are predicted from undertaking the OSMP given the nature of the likely disturbance and the small area of affected habitats predicted. Overall consequences are ranked Category 1–3.
As Low As Reasonably Practicable decision context
Data collection methods used to support operational and scientific monitoring are well understood and the risks are therefore considered to be Low. Legislation requires it and the management controls are part of the daily plans. No relevant persons have raised objections or claims regarding monitoring, but stakeholder participation is expected. Taking this in consideration, Decision Context A should be applied to demonstrate risks are As Low As Reasonably Practicable.
Assessment technique
Good Practice – Identified industry good practices adopted to reach As Low As Reasonably Practicable.

8.9.4 Risk treatment

8.9.4.1 Environmental performance outcomes (EPO 8.9)

Implementing Operational and Scientific Monitoring Program does not significantly increase the risks associated with the oil spill response.

8.9.4.2 Context for assessment

Legislative and other requirements	The OSMP has been developed under OPGGS(E) Regulation 14(8). One of the objectives of the Operational Monitoring component of the OSMP is to monitor the operational effectiveness and impacts of spill response strategies and tactics.
Industry standards	N- 04750-IP1349 – Information Paper – Operational and Scientific Monitoring Programs (NOPSEMA, March 2016) N-04750-IP1342 – Information Paper – Oil Spill Contingency Planning (NOPSEMA March 2016)

8.9.4.3 Control measures and performance standards

Control measures	Environmental performance standards	Measurement criteria	Responsibility
OSMP	EPO 8.9.1: Activation of the OSMP Implementation Plan	Records of activation of the OSMP Implementation Plan are maintained	Planning Section Chief
	EPO 8.9.2: Mobilisation of OSMPs when triggered	Records of activation triggers and OSMP mobilisation documents are maintained IAP Daily logs	
	EPO 8.9.3: OSMP technical leads and field teams contracted to implement the OSMP comprise personnel qualified as per resource register requirements	Copies of training records and certifications maintained	
		Records demonstrate that OSMP personnel included resources identified in the OSMP resource register	
	EPO 8.9.4: Once the OSMP has been activated, Scientific Advisory Group (SAG) (consisting of key stakeholders identified in the Resources Register/OSMP Implementation Plan) mobilised within 24 hours of request by IMT	Equinor IMT log confirms SAG mobilised following activation of the OSMP and within 24 hours of IMT request	
OSMP scopes	EPO 8.9.5: Monitoring data collected on a daily basis to inform response strategies and development of the IAP	Field logs, data/information transfer records, daily logs sample chain of custody forms, laboratory data for samples, OSMP reports and communications detailing recommendations of specific OMPs and SMPs and IAP records are maintained, aligned with OSMP requirements and communicated to the IMT	
	EPO 8.9.6: QA/QC and review of OSMP data and deliverables	OSMP datasets and documents, with QA/QC information indicate QA/QC review	
	EPO 8.9.7: OSMP scopes triggered are undertaken appropriate to the nature and scale of the impacts to the receiving environment and subsequent recovery. Individual monitoring plans will be activated subject to trigger criteria (as defined in the OSMP Implementation Plan (IP) and individual OMPs and SMPs), or if trigger criteria are not met, at the discretion of Equinor Australia B.V. on advice from Regulators and consultation with relevant persons. Individual plans will be terminated when pre-defined termination criteria have been met.	OSMP records that individual plans have been triggered and terminated in accordance with criteria documented in the OSMP IP/individual OMPs and SMPs. Documented communications with the Scientific Advisory Group indicate triggering, technical focus and termination of monitoring plans have been agreed. Data recorded during monitoring is documented and consistent with OSMPs.	

Control measures	Environmental performance standards	Measurement criteria	Responsibility
	EPO 8.9.8: Post-spill reports include details of quantitative impacts of the oil spill	Annual reports summarise results of the (O)SMPs mobilised, data collection activities and available findings. OSMP final reports summarise the qualitative and quantitative assessment of environmental impacts and recovery of receptors once the monitoring program has been terminated.	
Positive and negative impacts of spill response strategies are identified by OSMP	EPO 8.9.9: Potential impacts attributable to spill response strategies will be recorded and communicated to the IMT as soon as reasonably practicable. OSMP data will be used to inform ongoing NEBA assessments.	Field records and daily logs identify that potential impacts of spill response strategies were identified at defined locations, dates and consistent with OSMPs. Communication records identify that this information was communicated to the IMT as soon as reasonably practicable. Records and daily logs demonstrate that OSMP outputs were considered in NEBA outcomes and were applied in the IAP	
OSMP Implementation Plan – permits	EPO 8.9.10: All necessary permits for the collection of samples and access will be in place before activities commence	Applicable permits in place prior to related OSMP activities. Records of communications demonstrate where and when permits were not required.	
Where appropriate, OSMP monitoring plans will include consideration of: • avoidance of sensitive areas/times • lighting, noise, wastes • Sampling techniques • anchoring considerations	EPO 8.9.11: Compliance with OSMP monitoring plans will assist minimisation of potential risks by: • Avoidance of sensitive areas/times where practical (unless a defined part of the specific OSMP scope) • Lighting, noise, waste modifications for sensitive areas • Modified sampling techniques where required Selecting anchoring locations where safety is not compromised to avoid sensitive habitats should vessels require access for sampling or shelter from inclement conditions	OSMP daily logs and reports indicate compliance with OSMP monitoring plans	Environment Unit Lead

8.9.5 Outcome

Predicted risk	Consequence	Probability scale	Risk level
	Category 1–3	P=0.000019	Low
Demonstration of As Low As Reasonably Practicable	The OSMP is considered critical for: • identifying the scale of impacts of the spill • providing situational awareness to the IMT • identifying potential impacts from the response (to inform NEBA) • identifying recovery from the spill. The risks associated with undertaking the operational and scientific monitoring activities are low and therefore no additional controls are required to reduce risks to As Low As Reasonably Practicable.		

Acceptability criteria	Demonstration of Acceptability
a. Operational and scientific monitoring is a regulatory requirement	This OSMP fulfils the requirements of the OPGGS(E) Regs 2009 Reg 14
b. The data collected is critical in identifying impacts from the oil spill and from the spill response, and subsequent recovery	Operational monitoring identifies potential impacts and risks to receptors throughout the operational phase of the response. Operational monitoring provides critical situational awareness, which is used to ground-truth oil spill modelling and to support response strategy decision making Scientific monitoring provides a quantitative assessment of effects and recovery, and can be applied to fill knowledge gaps (e.g. post-release pre-exposure baseline data collection)
c. Operational monitoring data is critical in identifying efficacy and potential impacts (negative and positive) of the implementation of spill response strategies and tactics to mitigate environmental risk as part of a continual assessment process	The objectives of operational monitoring include identifying impacts from the oil spill and from the spill response (to mitigate environmental risk and assess response efficacy) as part of a continual assessment process
d. The OSMP activities are timely and undertaken without delays that could hinder assessment of impacts and recovery	The Borthwick enquiry (2010) stated that the "prolonged delay in undertaking scientific monitoring of the Montara oil spill was unacceptable. The delay has restricted the scope for assessment of the environmental damage from the blowout". The enquiry recommended having an "off the shelf" OSMP ready to revise in the event of a spill. Implementing activities in timely accordance with those stated in the EP, OPEP and OSMP will minimise the risk of delays. Not implementing an OSMP in response to a Level 2 or 3 spill (which have potential for significant environmental damage) is considered unacceptable.

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9.0 Implementation strategy

Equinor Australia B.V.'s Implementation Strategy has been developed to comply with the requirements of the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009. Our strategy describes herein the specific measures and arrangements we will implement for the duration of the Stromlo-1 exploration drilling program and validity period for the environment plan.

9.1 Equinor Australia B.V.'s environmental management system

9.1.1 Overview

Equinor Australia B.V. Management System is structured in three levels (as shown in Figure 9.1); (1) fundamentals, (2) requirements and (3) recommendations. Regardless of where we work, the fundamentals apply without exception. Requirements apply to particular areas of Equinor Australia B.V. and are tailored to relevant business needs. Recommendations are supporting documents that provide additional information to help us understand how to meet requirements in the most efficient way. We regularly test how well our Management System is working through an assurance process, which includes self-assessments, verifications and audits.

Equinor Australia B.V. management system is compatible with the recognised environmental management standard, ISO 14001.

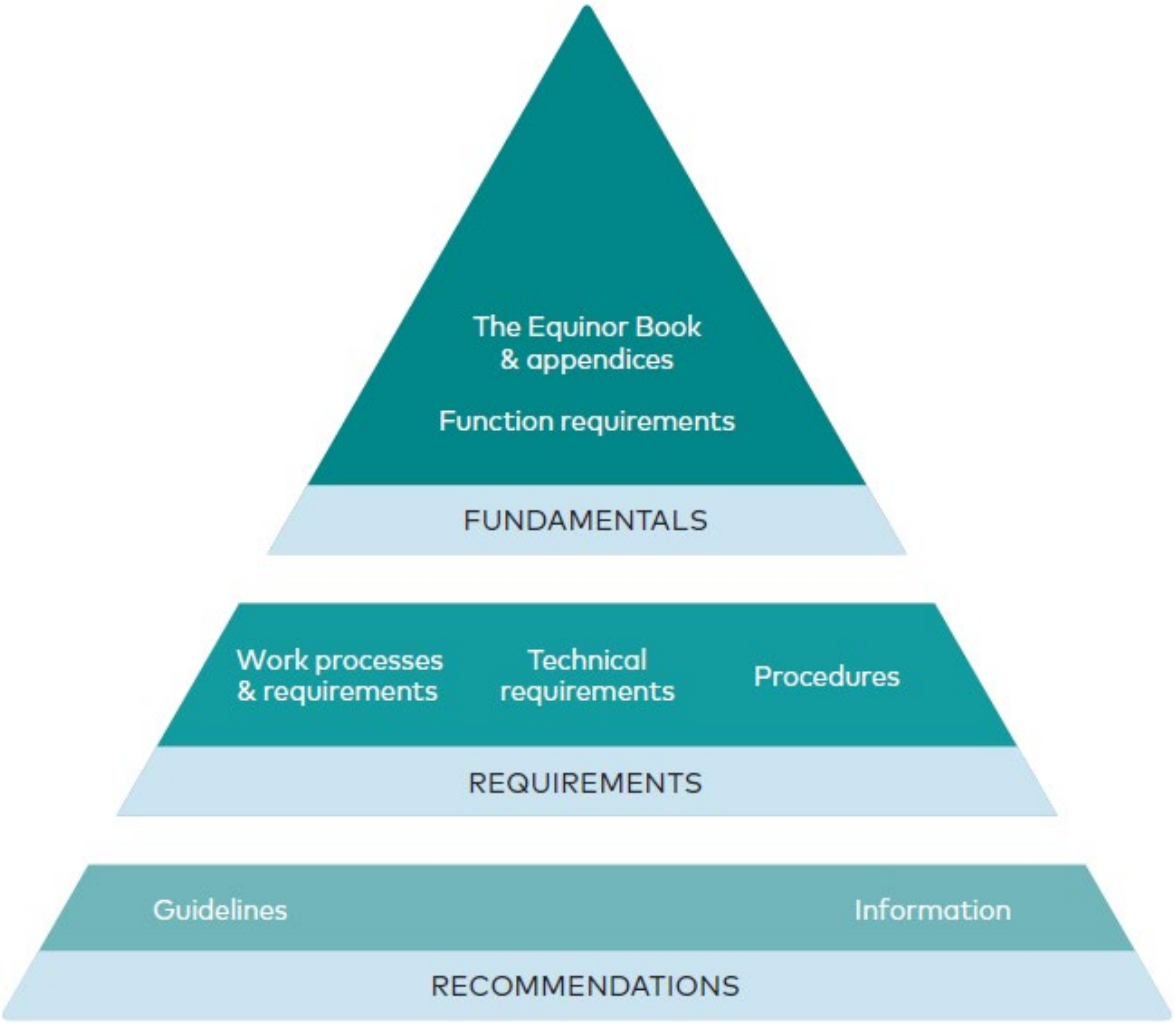

Figure 9.1 Equinor Australia B.V.'s Management System hierarchy

9.1.2 The Equinor Book

Equinor Australia B.V.'s corporate governance is outlined in The Equinor Book (and appendices) and on our corporate website under "How and why". The Equinor Book is the core of our Management System. It describes the most important requirements for the whole company and defines a common framework for the way we work. It sets standards for behaviour, performance and leadership. The Equinor Australia B.V. Book has two main sections:

- "Who we are" describes the foundation for everything Equinor Australia B.V. does and includes Equinor Australia B.V.'s vision, values and commitments.
- "How we work" shows how Equinor Australia B.V. drives performance and enables profitable, safe and sustainable results. It reflects Equinor Australia B.V.'s collaborative culture and ensures Equinor Australia B.V. manages risks and executes tasks safely and precisely, while continuously improving along the way.

9.1.3 Function requirements

Supporting The Equinor Book, Equinor Australia B.V.'s function requirements specify how our business is managed, through setting of standards and by defining mandatory management activities. Equinor Australia B.V.'s function requirements are essential regulations for the company and are valid company-wide without exception.

Equinor Australia B.V.'s Sustainability function requirement (FR-11) is shown in Figure 9.2 and is the equivalent of an Environmental Policy defined under ISO 14001. Our corporate sustainability function sets the strategic direction on human rights, climate, environment and social issues. They report on sustainability performance to the Equinor Australia B.V. corporate executive committee and the Equinor Australia B.V. ASA Board of Directors.

9.1.4 Requirements and recommendations

The Equinor Book and function requirements are supported by requirements and recommendations. Requirements include work processes, technical and operational requirements and procedures that define how corporate requirements are met, whilst being adapted to individual business area needs and to comply with local legislation. Examples relevant to managing the environment include waste requirements, chemical management work processes.

Recommendations (guidelines and information papers) provide additional guidance to help us understand how to meet our requirements in the most efficient way.

9.1.5 Risk management

Risk management is integrated into all Equinor Australia B.V.'s business processes worldwide. Our approach to risk management is documented in our risk management standard (RM100 Manage Risk). Guidelines and technical requirements that support this standard include:

- GL0139 – ALARP principles
- GL0386 – Guideline for impact assessment in projects
- GL0449 – Identification and handling of environmental aspects
- GL0498 – Guideline for blowout scenario analysis as input to environmental risk analysis.

For this activity, our risk management process and these guidelines and technical requirements in addition to ISO 31000 (Risk management) were reviewed and adapted to develop a process that would meet the requirements of the OPGGS(E) Regulations 2009 (refer to Section 5.0). This enabled us to identify, understand, mitigate and reduce environmental and socioeconomic impacts and risks to As Low As Reasonably Practicable and acceptable levels.

We use quantitative and qualitative impact and risk analyses to obtain a balanced picture of probability and consequences of planned and unplanned activities, to assess critical functions and defects, and as a basis for improvements. Our process draws on multidisciplinary expertise and necessary control measures to manage risks and impacts are implemented. In addition, a component of the impact and risk assessment process undertaken for the activity, we have considered stakeholder perspectives.

Our monitoring, assurance and performance review processes (Sections 9.6, 9.7 and 9.8) enable us to ensure the outcomes of the control measures identified and any potential changes that could influence the impacts or risks are monitored and communicated to Equinor management. This enables us to reassess the risk and identify any modifications required to control measures to maintain impacts and risks to As Low As Reasonably Practicable and acceptable levels. This feed-back process is closely linked to our Management of Change process described in Section 9.11.

9.1.6 Emissions and discharges

Our technical requirement standard TR1011 'Environmental requirements for offshore installations' establishes the principles and corporate environmental performance requirements for offshore installations and has been referred to as a standard for many of the planned impacts in this EP. A number of standard requirements support the implementation of TR1011 including:

- energy management
- air emissions
- wastewaters (drainage water, cooling water, bilge water, etc.)
- drilling fluids and cuttings
- use of chemicals and additives
- spill prevention
- waste.

9.1.7 Chemical management

Equinor Australia B.V. applies SF601.01 'Chemical management' to ensure the control of procurement and safe use of purchased chemicals. This document aligns with the CHARMS and OCNS systems. Figure 9.2 summarise the chemical management standard requirements in SF601.01.

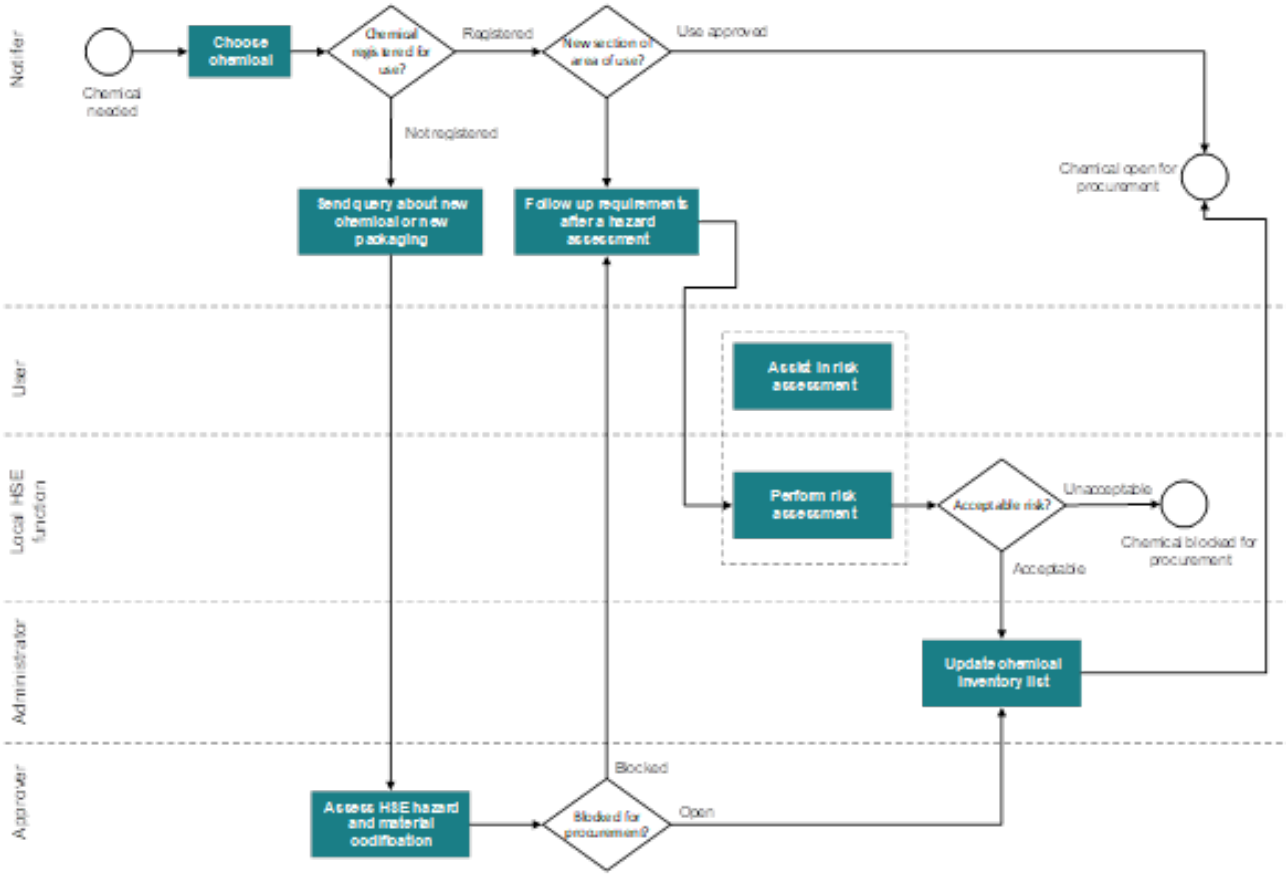

Figure 9.2 Chemical management

equinor

Purpose
The purpose is to provide the basis for enabling cost effective environmental and social performance that protects and creates value for Equinor and communities, enables us to effectively address the climate change challenge and to respect human rights and that secures our license to operate.

Scope
The scope of sustainability is to ensure responsible environmental, social and economic performance enabling business resilience.

Fundamentals
1. Management of environmental and social performance shall be an integrated part of strategies, business planning, risk management and decision-making processes.
2. Continual improvement shall be achieved through systematic analysis of significant environmental and social aspects, setting ambitious targets and implementing measures.
3. Energy demand shall be minimised and energy efficiency optimised through design and operation of our facilities.
4. We shall actively work to limit greenhouse gas emissions from our activities.
5. All Equinor operated assets shall work systematically to reduce all flaring and to eliminate routine flaring, in order to fulfil our commitment to zero routine flaring by 2030. In our partner-operated assets we shall work actively to help achieve the same objective.
6. Efficiency of natural resource use shall be optimised through substitution, reduction, reuse and recycling efforts.
7. Management of our planned activities shall include development and implementation of cost-effective measures to avoid, minimise or mitigate adverse environmental and social impacts, all in accordance with good international practice and applicable laws and regulations.
8. Communities significantly affected by our activities shall be actively consulted, and their views considered in the decision processes.
9. Our activities shall contribute to social and economic development in communities where we operate
10. Adverse impacts on human rights of those affected by our activities shall be avoided. Appropriate remedy shall be provided if adverse impacts have occurred.
11. Our sustainability reporting shall be open, clear and reliable, reflecting material sustainability issues and impacts, and in accordance with relevant requirements and reporting frameworks.

Figure 9.3 Equinor Australia B.V.'s sustainability function requirement (Environmental Policy)

9.2 Environment Plan organisation, roles and responsibilities

The organisational structure for the Stromlo-1 exploration drilling environment plan comprises Equinor Australia B.V. personnel based in Norway, Western Australia and South Australia, supported by contractors. The roles and responsibilities relevant to the implementation of the requirements of this Environment Plan are defined in Table 9.1 (Equinor Australia B.V.), Table 9.2 (drilling contractor) and Table 9.3 (other contractors).

9.2.1 Equinor Australia B.V.

Equinor Australia B.V.'s Country Manager is based in Perth and has overall accountability for implementation of, and compliance with this EP.

In the event of an oil spill, roles and responsibilities would be dependent on the response category level (Level 1, 2 or 3). These are clearly described in the Oil Pollution Emergency Plan (Appendix 9-1) and the Operational and Scientific Monitoring Program Implementation Plan (Appendix 9 2).

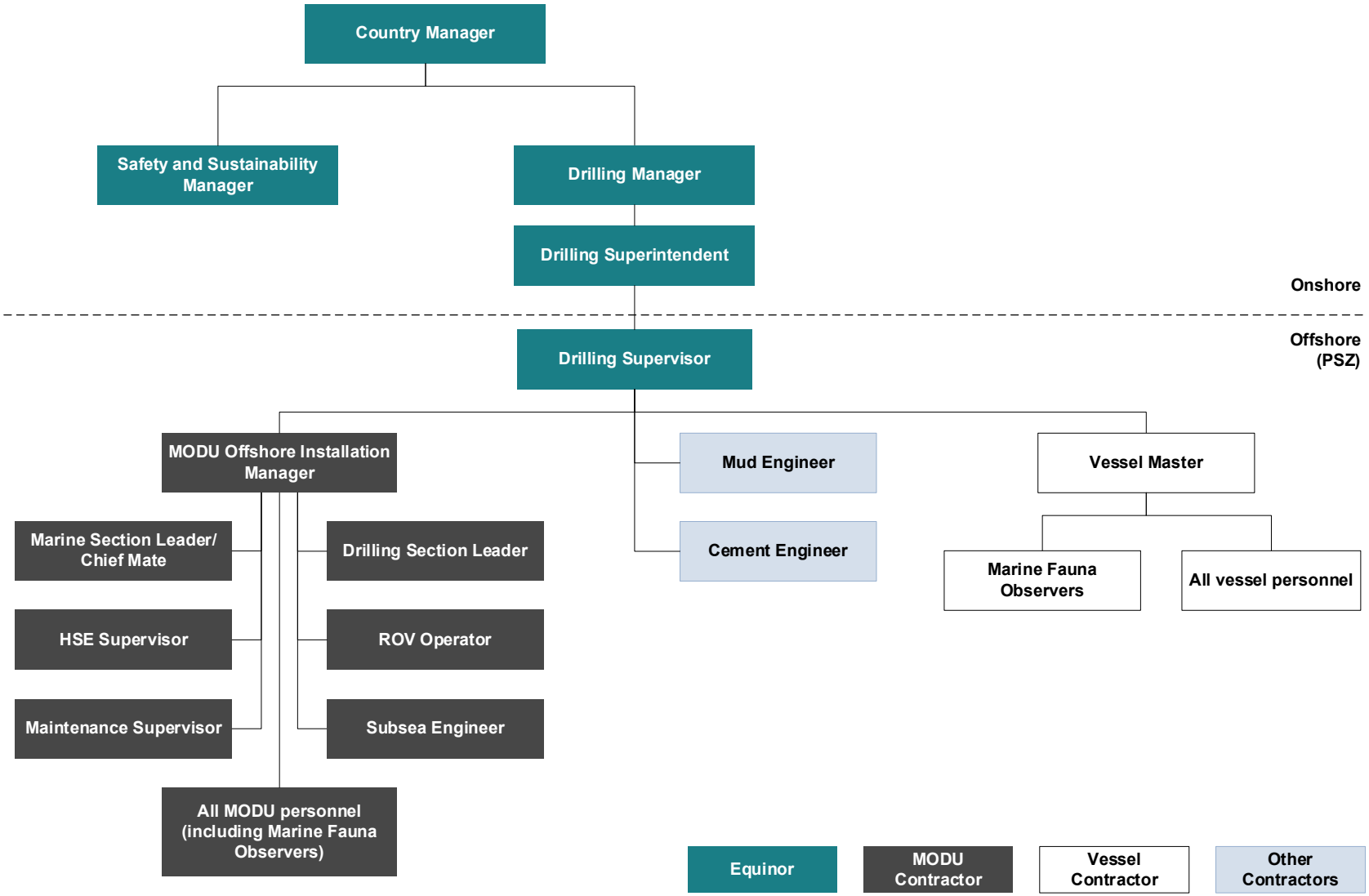

Figure 9.4 Organisational structure for the Stromlo-1 exploration drilling program environment plan

Table 9.1 Equinor Australia B.V. personnel roles and responsibilities

Function: Country Manager
Location: Onshore Australia
Overall accountability and responsibility for ensuring compliance with applicable legislation, implementing the control measures and meeting the environmental performance standards, in accordance with this EP, including: • ensuring all statutory approvals have been obtained • ensuring all relevant reporting and notification activities are undertaken • ensuring sufficient resources are available to meet the environmental performance outcomes for the activity, including emergency situations (e.g. oil spill response) • ensuring consultation with relevant persons is ongoing during the petroleum activity. In addition, the Country Manager ensures that our Management System is implemented locally, and activities comply with our policies relating to safety and sustainability, security risk and emergency preparedness and response.
Function: Safety and Sustainability (SSU) Manager
Reports to: Equinor Australia B.V. Country Manager
Location: Onshore Australia
Supports the Country Manager by leading the implementation of our safety and sustainability requirements in this EP, including environment, regulatory consultation, community engagement, security, risk and emergency response. In the event of an emergency, is responsible for implementing the Oil Pollution Emergency Plan. The SSU Manager is also responsible for: • advising Equinor Australia B.V. management and contractor personnel on regulatory, industry, environmental, health, safety and security requirements • ensuring emergency preparedness planning and emergency response training is completed • implementing the Incident Management System according to the OPEP • ensuring health, safety and environment (HSE) assurance activities are undertaken for the activity • participating in Equinor Australia B.V. and contractor risk assessment processes as required (e.g. via assurance activities, Management of Change process, incident investigations) • ensuring all SSU incidents, non-conformances and system failures are investigated, root causes identified, and recommendations communicated in accordance with Equinor Australia B.V. operational practices to prevent re-occurrence • ensuring that changes in environmental impacts and risks are considered as part of the Management of Change process • ensuring spill response requirements are implemented in accordance with the OPEP.
Function: Drilling Manager
Reports to: Equinor Australia B.V. Country Manager
Location: Onshore Australia/Norway
Responsible for ensuring that drilling operations and activities are planned and implemented safely and efficiently in compliance with applicable legislation, the control measures and environmental performance standards identified in this EP. The Drilling Manager is also responsible for: • ensuring that well design and operational planning are optimised so that robust design and safe operation are achieved to comply with the Equinor Australia B.V. technical specifications and the Well Operations Management Plan • ensuring compliance with SSU management systems, including organising and implementing administrative routines • advising, developing and leading personnel within the organisation in executing the activity • verifying quality standards are met • ensuring use of efficient work methods, tools and technology to achieve environmental performance • ensuring that our Chemicals Management work process (SF601.01) is followed for the assessment, selection and use of chemicals • ensuring that emergency response duty team is operative, in accordance with established Equinor Australia B.V. duty rosters and instructions.

Function: Drilling Superintendent
Reports to: Drilling Manager
Location: Onshore Australia
Supports the Drilling Manager by leading the planning and execution of activities in a safe and efficient manner, and in compliance with applicable legislation, the control measures identified in this EP and in alignment with Equinor Australia B.V.'s corporate requirements. The Drilling Superintendent is also responsible for: • ensuring that personnel from Equinor Australia B.V. and contractors are allocated according to scope requirements and have the appropriate training, qualifications and experience to deliver those services • ensuring integration of drilling contractor and service companies in the performance review of the activities and follow-up • ensuring that the control measures identified in the EP are implemented throughout the execution of the petroleum activity • ensuring that SSU inspections are conducted • following-up on the outcomes of incident and non-conformance investigations and ensuring that corrective actions are completed • ensuring that notifications, internal reporting and external reporting requirements (including reportable and recordable incident reports) are conducted in accordance with this EP • implementing the Management of Change process when triggered (e.g. due to new or modified activities, changes in impacts or risks, changes to legislation, requirement to update processes or procedures in response to drills, exercises or incident investigations) • acting as Operational Section Chief in the case of an emergency (refer to the OPEP).
Function: Drilling Supervisor
Reports to: Drilling Superintendent
Location: Mobile Offshore Drilling Unit
Responsible for ensuring that the operations on the drilling rig and at the rig site are planned and implemented in accordance with applicable legislation, the control measures identified in this EP and in alignment with Equinor Australia B.V.'s corporate requirements. The Drilling Supervisor is responsible for daily planning, coordination, implementation and reporting of drilling rig operations 24-hours a day (for their shift period). The Drilling Supervisor is also responsible for: • continually monitoring and reviewing the planned activities according to approved plans and Equinor Australia B.V. operational practices and processes • maintaining awareness on the progress of the activity and monitoring operational parameters • ensuring that all personnel have completed a project induction and understand their obligations with respect to the management of environmental impacts and risks • implementing the control measures in this EP to maintain environmental risks to As Low As Reasonably Practicable • participating in meetings with the drilling contractor and service companies to review operations plans, risk assessments and ensuring risks and control measures are communicated and incorporated into work conducted where relevant • providing input to the Drilling Superintendent regarding the choice of HSE equipment and services and for ensuring that these are ordered and delivered at the correct time • ensuring that the work being conducted, the personnel participating in the work, and the services and equipment that are delivered are as stipulated in the contract through the use of verification processes • participating in safety meetings and safety delegate meetings • conducting safety inspections with the drilling contractor • ensuring that the personnel participating in the work comply with approved project methodology of identifying and handling risk • ensuring drilling fluids and cementing programs are implemented according to the WOMP • ensuring that vertical seismic profiling operations are conducted in accordance with the requirements in this EP • ensuring that non-conformances (both positive and negative) are reported in Synergi and corrective actions are closed out • ensuring that notifications, internal reporting and external reporting requirements are conducted in accordance with this EP • ensuring emergency preparedness in accordance with the IMT functions (refer to the OPEP).

Function: All Equinor Australia B.V. personnel
Reports to: Line supervisor
All Equinor Australia B.V. personnel are responsible for: • participating in and completing any required project inductions or environmental awareness sessions • participating in emergency drills and exercises as required • participating in the development of safe work procedures.

9.2.2 Drilling contractor

The most senior contractor position on the mobile offshore drilling unit is the Offshore Installation Manager who reports to the Equinor Australia B.V. Drilling Supervisor based on the mobile offshore drilling unit. The Offshore Installation Manager has complete authority and responsibility for taking all necessary actions to ensure the safety of personnel, pollution prevention and the efficient operation of the facility.

The organisational structure for the drilling contractor relevant to this Environment Plan is shown in Figure 9.4, however a more detailed description of the mobile offshore drilling unit organisation and the roles and responsibilities of personnel is in the mobile offshore drilling unit Safety Case.

Table 9.2 Drilling contractor roles and responsibilities

Function: MODU Offshore Installation Manager
Reports to: Equinor Australia B.V. Drilling Supervisor
Location: Mobile Offshore Drilling Unit
The OIM is responsible for the daily control and management of the MODU. The OIM also has over-riding authority and responsibility to make decisions regarding environment protection and pollution prevention with respect to the MODU. The MODU OIM is also responsible for: • co-ordinating vessel entry into the petroleum safety zone and for communication between the MODU and support vessels • overseeing work activities and work programs • ensuring work is undertaken in accordance with procedures, work instructions and in compliance with legislative requirements and EP commitments • ensuring that offshore personnel have completed a project induction and understand their obligations with respect to the management of environmental impacts and risks under this EP • ensuring the facility training program is fully implemented • ensuring waste management complies with the international marine pollution protocol of 1973 and 1978 (MARPOL 73/78) requirements and the performance criteria specified in this EP • ensuring that procedures are in place for bunkering activities and that they are followed • ensuring the atmospheric emissions requirements in this EP are complied with • monitoring and ensuring closeout of non-compliances, corrective actions and audit recommendations • assuming the role of MODU Emergency Response Team Leader if the OPEP is activated • reporting incidents, near misses and dangerous occurrences in accordance with Synergi.
Function: Marine Section Leader/Chief Mate
Reports to: Offshore Installation Manager
Location: Mobile Offshore Drilling Unit
The Marine Section Leader is responsible for acting as the person in charge in the absence of the OIM. The Marine Section Leader is also responsible for: • overseeing the maintenance of deck equipment, firefighting and life-saving equipment • ensuring compliance with MARPOL 73/78 requirements • managing marine biosecurity requirements such as ballast water and hull fouling.

Function: Drilling Section Leader
Reports to: Offshore Installation Manager
Location: Mobile Offshore Drilling Unit
The Drilling Section Leader is the department head of the drilling department and supports the OIM with the implementation of work activities and programs during drilling. They are the technical subject matter expert in well control and provide advice to the OIM during well control-related emergencies. The Drilling Section Leader is also responsible for: • directing and monitoring drilling operations • ensuring accurate and up to date reports/logs are maintained by drilling personnel and environmental data and records are captured and maintained as required by the EP • verifying that drilling personnel have the appropriate training, competency and experience for their roles prior to the petroleum activity commencing • undertaking verifications and inspections against the drilling contractor's HSE Management System • ensuring the blowout preventer stack is installed in accordance with the Well Operations Management Plan and undertaking pressure and function tests and maintaining records of the tests • undertaking daily observations of the BOP stack with remotely operated vehicle technicians to ensure equipment is operated within manufacturer's specifications • performing maintenance on sub-sea equipment in accordance with the Planned Maintenance System (PMS).
Function: Maintenance Supervisor
Reports to: Offshore Installation Manager
Location: Mobile Offshore Drilling Unit
The Maintenance Supervisor maintains the MODU's Planned Maintenance System and allocates maintenance tasks to department heads on a daily basis. The Maintenance Supervisor is also responsible for: • tracking and confirming that maintenance tasks have been closed out • inspecting and maintaining hull and all on-board machinery, including equipment, systems and components for performance and defects • ensuring that all machinery performs within manufacturer's specifications • in conjunction with the vessel contractor, ensuring that all bunkering and fuel transfers are undertaken in accordance with this EP • ensuring that sufficient spare parts are held on board to effectively maintain the MODU • ensures that engine room waste (solid and liquid) is disposed of in accordance with this EP and MODU waste management practices.
Function: HSE Supervisor
Reports to: Offshore Installation Manager
Location: Mobile Offshore Drilling Unit
The HSE Supervisor is responsible for ensuring that the environmental requirements in this EP are implemented on board the MODU. The HSE Supervisor is also responsible for: • ensuring compliance with the MODU Safety Case and associated bridging documents is maintained • training and inducting all MODU personnel in environmental aspects such as environmental policy, pollution prevention measures, spill clean-up and response procedures, and waste management requirements) • maintaining records of training and inductions • ensuring implementation of the Waste management plan (OPEP) • maintaining a waste inventory and inspecting the waste collection area • conducting inspections of hazardous materials storage areas to ensure they are being safely stored and maintained • undertaking regular HSE inspections and verifications against the HSE requirements for the petroleum activity (including EP requirements) • monitoring HSE performance and ensuring corrective actions and recommendations from inspections and audits are closed out • liaising with the Equinor Australia B.V.'s SSU Manager on any non-conformances, near misses and incidents and responsible for the close out of corrective actions.

Function: Sub-sea Engineer
Reports to: Offshore Installation Manager
Location: Mobile Offshore Drilling Unit
The Sub-sea Engineer is responsible for maintaining sub-sea equipment in accordance with the Planned Maintenance System. The Sub-sea Engineer is also responsible for evaluating all BOP fluids in accordance with our Chemicals Management work process (SF601.01) and ensuring they are approved prior to use.
Function: Remotely operated vehicle contractor
Reports to: Offshore Installation Manager
Location: Mobile Offshore Drilling Unit
The ROV contractor is responsible for conducting pre- and post-drill surveys to identify and if possible, quantify the extent of drill cuttings deposition within areas surrounding the well location. They also support oil spill response activities as required (refer to the OPEP).
Function: All MODU personnel
Reports to: Line supervisor
Location: Mobile Offshore Drilling Unit
All MODU personnel are responsible for: • participating in and completing the required project induction • participating in emergency drills and exercises as required • participating in the development of safe work procedures • reporting all environmental hazards, incidents and near-misses to their immediate supervisor as soon as possible.

9.2.3 Other contractors

Table 9.3 summarises the environmental roles and responsibilities for other contractors identified in Figure 9.4.

Table 9.3 Other contactor roles and responsibilities

Function: Mud Engineer
Reports to: Equinor Australia B.V. Drilling Supervisor
Location: Mobile Offshore Drilling Unit
The Mud Engineer is responsible for implementing the drilling fluids program, primarily ensuring that mud is mixed to the required specifications. The Mud Engineer is also responsible for: • ensuring compliance with chemical management processes and the requirements in this EP • ensuring that only chemical additives approved by Equinor Australia B.V. (and specified in this EP and the WOMP) are used • ensuring drill cuttings are treated to ensure residual oil on cutting targets and performance standards in this EP are achieved • testing SBM to ensure that the environmental performance standards in this EP are achieved.
Function: Cement Engineer
Reports to: Equinor Australia B.V. Drilling Supervisor
Location: Mobile Offshore Drilling Unit
The Cement Engineer is responsible for implementing the Cementing Plan, primarily ensuring that cement is mixed to the required specifications and that casing is properly cemented within the well bore. The Cement Engineer is also responsible for ensuring the cementing requirements in this EP are met.

Function: Dedicated Marine Fauna Observers
Reports to: Offshore Installation Manager
Location: Mobile Offshore Drilling Unit
Marine fauna observers are responsible for maintaining a watch for cetaceans and other marine fauna that move within the vicinity of the MODU during vertical seismic profiling operations. They are also responsible for: • conducting observations in accordance with MFO procedures and the requirements in this EP • recording and reporting all sightings.
Function: Vessel Master
Reports to: Equinor Australia B.V. Drilling Supervisor
Location: Offshore Support Vessel
The Vessel Master has complete authority and responsibility for taking all necessary actions for safety, pollution prevention and the efficient operations of the vessel. The Vessel Master is also responsible for: • operating support vessels in line with all Australian and international legislation, regulations and this EP • maintaining clear communication with the MODU for all vessel operations • ensuring vessel crew have completed a project induction and understand their obligations with respect to the management of environmental impacts and risks under this EP • ensuring waste management complies with MARPOL 73/78 requirements • ensuring that hazardous materials are safely stored and maintained, and spill kits are available • ensuring bridge watch (for cetaceans) is maintained during support vessel operations • ensuring that procedures are in place for bunkering activities and transfer hoses are inspected • ensuring that planned maintenance is undertaken according to the Planned Maintenance System schedule • maintaining support vessel in a state of preparedness for emergency response • managing marine biosecurity requirements such as ballast water and hull fouling • ensuring relevant vessel crew are trained (e.g. spill response, lifting, bunkering) and training records are available • reporting any incidents occurring within the Operational Area to the MODU OIM and ensuring that follow-up actions are carried out.
Function: Dedicated Marine Fauna Observers
Reports to: Vessel Master
Location: Offshore Support Vessel
Marine fauna observers are responsible for maintaining a watch for cetaceans and other marine fauna that move within the vicinity of the support vessel during vertical seismic profiling operations. They are also responsible for: • conducting observations in accordance with MFO procedures and the requirements in this EP • recording all sightings and reporting them to the Vessel Master.
Function: All vessel personnel
Reports to: Vessel Master
Location: Offshore Support Vessel
All vessel personnel are responsible for: • participating in and completing any required project inductions and environmental awareness sessions • participating in emergency drills and exercises as required • reporting all environmental hazards, incidents and near-misses to their line supervisor as soon as possible • participating in the development of safe work procedures.

9.3 Contractor management

The requirement to comply with this Environment Plan will be included in contracts for the mobile offshore drilling unit and support vessels. During the process of preselection and selection, contractors will be provided with a copy of this Environment Plan and Equinor Australia B.V.'s sustainability requirements. They are required to demonstrate they have a health, safety and environment management system in place that provides a systematic approach for meeting Equinor Australia B.V.'s requirements and the requirements in the EP. We will evaluate the contractor's health, safety and environment management system, verify their systems are in place and ensure that it meets the requirements of this EP. We will also ensure the contractor has a training and competency program in place that provides ongoing technical and safety training to ensure the skills of their personnel are maintained.

Following contract award contractors must meet the requirements of this EP, including the Oil Pollution Emergency Plan. Equinor Australia B.V.'s Contractor Management working requirements (WR2613) outlines the process, interfaces, collaboration, roles and responsibilities necessary to achieve a high level of performance from our selected drilling and well contractors. We review and accept our contractors' operational documents for the activity prior to mobilisation to the well location.

During the petroleum activity, all contractor personnel will be required to attend a project induction that will cover the environmental requirements in these Environment Plan and ensure they are aware of their environmental responsibilities. We will assess contractors' health, safety and environment performance via inspections, verifications and monitoring KPIs and provide contractors with regular feedback on their performance and areas for improvement. We will also review contractor compliance with the environmental performance standards relevant to their scope of work.

9.4 Training and competency

In accordance with Equinor Australia B.V.'s Competence Management in Drilling and Wells working requirements (WR2516) we will verify that the training and competency expectations for our personnel and our contractors are met prior to mobilisation. We track training and certification of personnel in dedicated software.

Contractors will be required to have their own competency programs and systems for establishing, verifying and tracking the knowledge, skills and abilities of their personnel. The requirements for contractor personnel in terms of training, competency and experience will be communicated to the contractor through contract terms and conditions. This includes the training competency requirements described in this EP. Their health, safety and environment management system must ensure that health, safety and environment responsibilities are outlined in position descriptions and that training and competency matrices detail the positional health, safety and environment and technical competency requirements. Dedicated marine fauna observers will have experience in observing for cetaceans and other marine fauna including distance estimation and reporting.

The training and competency requirements for personnel with responsibilities in oil spill response are outlined in the Oil Pollution Emergency Plan (Appendix 9-1) and the Operational and Scientific Monitoring Program (Appendix 9-2).

All Equinor Australia B.V. and contractor personnel will be required to attend a project induction to ensure personnel are aware of environmental aspects such as:

- overview of the content in this Environment Plan and that requirements are legally binding
- environmental sensitivities and key risks associated with the petroleum activity and location
- environmental requirements for waste management, chemical management, fuel transfers and bunkering
- marine fauna procedures including observations, avoidance actions (caution zone and no approach zone) and reporting
- spill prevention, clean-up and response (including awareness of the Oil Pollution Emergency Plan and Operational and Scientific Monitoring Plan)
- incident reporting and recording
- management of change.

Records of attendance will be maintained, and personnel will complete an assessment following the induction which will evaluate the attendee's understanding of the topics presented in the induction. The Equinor Australia B.V. Drilling Supervisor and Offshore Installation Manager are responsible for verifying these inductions take place and for retaining the attendance records.

9.5 Ongoing consultation

Subregulation 14(9) of the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009 specifies that the Implementation Strategy must provide for appropriate consultation with relevant authorities of the Commonwealth, state or territory, and other relevant interested persons or organisations (see Section 3.0, Categories 1,2 or 3 – Relevant Person).

Therefore, in addition to the consultation process undertaken during the preparation of this EP, Equinor Australia B.V. will provide for ongoing consultation for the duration of the EP. Ongoing consultation will involve the following:

1. Maintain list of relevant persons:
   - A list of relevant persons will be maintained and updated to add new persons or remove those who are no longer considered relevant (e.g. if their functions, interests or activities change). The process of determining if persons are relevant or not will follow the methods outlined in Section 3.2.2.
   - A review of relevant persons will be undertaken prior to mobilisation.
2. Ongoing communications:
   - We will maintain a dedicated email address for stakeholders to communicate with us throughout the petroleum activity (gabproject@equinor.com).
   - Relevant persons will be consulted before, during and after the activity as follows:
     - They will be provided project updates and advised of any material changes to the petroleum activity.
     - Notifications will be made in accordance with Section 9.10.1.
     - State emergency response agencies will continue to be consulted on emergency response arrangements and response capability.
   - If at any time prior to the cessation of activities under this EP we become aware of the potential to affect a relevant person's functions, interests or activities that was not previously identified, we will immediately contact and consult with the relevant person.
3. Provide sufficient information and reasonable period:
   - We will continue to meet the requirements of OPGGS(E) Regulations 11A(2) and (3), by providing sufficient information to relevant persons and a reasonable period for them to respond.
4. Manage feedback:
   - For unresolved or new objections or claims raised by relevant persons related to their functions, interests or activities either prior to or during the activity, we will assess the merit of the objection or claim and respond, following the approach outlined in Appendix 3-1.
   - If their objections or claims indicate a significant new or significantly increased environmental impact or risk, an assessment of the significance of the new or increased impact or risk will be undertaken in accordance with the Management of Change process outlined in Section 9.11. Where deemed necessary, we will adopt additional control measures to ensure impacts and risks remain ALARP and acceptable. Relevant persons whose functions, interests or activities could be affected by the new or increased impact or risk will be consulted throughout this process.
   - Records of all consultation with relevant persons will be maintained and readily available.

9.6 Environmental monitoring and data collection

During the petroleum activity Equinor Australia B.V. will undertake periodic monitoring and environmental data collection (e.g. associated with emissions and discharges, fauna sightings, etc.). The monitoring and data collection requirements, frequency and recording mechanisms have been determined through the environmental impact and risk assessment process and are based on the environmental objectives, control measures, environmental performance standards and measurement criteria in Sections 6.0, 7.0 and 8.0 of this EP. The objective of monitoring is to verify that environmental objectives, control measures and environmental performance standards are met and to collect and maintain records in accordance with the measurement criteria defined in those sections to demonstrate compliance.

Table 9.4 describes the environmental monitoring that will be undertaken during the petroleum activity. In addition to the monitoring and data collection in Table 9.4, assurance activities (Section 9.7), performance reviews (Section 9.8) and the execution of oil spill exercises, tests and drills (Section 12 of the OPEP) will enable Equinor to monitor environmental performance, ensure non-conformances are addressed, and that continual improvement is supported. Operational data such as fuel consumption, drilling discharges, waste discharges, fauna sightings, and any incidents or unplanned events are reviewed during daily progress meetings and during HSE inspections on the MODU and vessels.

In the unlikely event of a loss of well control, the operational monitoring requirements are extensive and are documented in the Oil Pollution Emergency Plan and the Operational and Scientific Monitoring Plan, rather than in Table 9.4.

Table 9.4 Environmental monitoring and data collection

Impact or risk	Monitoring requirement associated with control measures and EPSs	Responsibility		Frequency	Measurement criteria
		MODU	Vessels		
Planned events					
Seabed disturbance	ROV survey of footprint area	✓	✗	Prior to spud and following drilling	ROV operator logs and daily drilling reports
Underwater sound	Marine fauna observations	✓	✓	Prestart and during vertical seismic profiling operations	Marine fauna data sheets
Atmospheric emissions	Fuel consumption (e.g. engines, generators and incinerators)	✓	✓	Daily	Fuel procurement records, daily drilling reports, metering records (of volume consumed)
	Use of low sulphur fuel only	✓	✓	Each bunkering operation	Bunker delivery notes and daily drilling reports
	Maintenance of combustion, heating, ventilation and air conditioning equipment	✓	✓	According to PMS or manufacturers specifications	Maintenance records
Discharge of drill cuttings and fluids	Drilling fluid ROC targets	✓	✗	Minimum of once per day or every 500 ft drilled formation (to a max of three measurements per day)	ROC records
	Discharge volumes	✓	✗	Daily	Daily well reports
	Calibration of ROC equipment	✓	✗	Daily	Calibration records
	Maintenance of solids control equipment (shale shakers and	✓	✗	According to PMS or manufacturers specifications	Maintenance records

Impact or risk	Monitoring requirement associated with control measures and EPSs	Responsibility		Frequency	Measurement criteria
		MODU	Vessels		
	centrifuges)				
	ROV survey of primary cuttings deposition	✓	✗	Prior to spud and following drilling	ROV operator logs and daily drilling report
Excess cement discharges	Cement discharge volumes	✓	✗	Daily	Daily well report
Cooling and brine water discharges	Maintenance of RO plant and equipment	✓	✓	According to PMS or manufacturers specifications	Maintenance records
Sewage, grey water and putrescible waste discharges	Treatment of sewage discharges	✓	✓	Prior to discharge	Sewage disposal records
	Discharge of sewage (discharged at moderate rate)	✗	✓	During discharge	Sewage disposal records
	Maintenance of sewage treatment system	✓	✓	According to PMS or manufacturers specifications	Maintenance records
	Observation of food waste maceration	✓	✓	Prior to overboard discharge	Garbage record logs
	Maintenance of food macerator	✓	✓	According to PMS or manufacturers specifications	Maintenance records
	Disposal of residual bilge water from OWS	✓	✓	As required	Oil transfer book
	Maintenance of OWS, oil content monitor and bilge alarm	✓	✓	According to PMS or manufacturers specifications	Maintenance records
BOP fluid discharges	Volumes of BOP fluids discharged	✓	✗	During BOP pressure testing and pressure function testing	Daily drilling report
Unplanned events					
Introduction of a marine pest	Ballast water discharge occurrences and locations	✓	✓	As discharge is required	Ballast water record book
Vessel collision with marine fauna	Marine fauna observations	✗	✓	During vessel movements within the Operational Area	Official logbook
Loss of solid materials overboard	Solid waste disposal transfers	✓	✓	On transfer to support vessels for onshore disposal	Waste manifest
Loss of containment of hazardous substances	Observations of bunkering operations	✓	✓	During bunkering transfer	Permit to work and safe job analysis records
	Volume of bulk stored hydrocarbons (including aviation fuel)	✓	✓	According to inspection program	Daily drilling report
	Maintenance of transfer hoses, storage systems and other equipment, lifting gear	✓	✓	According to PMS or manufacturers specifications	Maintenance records, hose register

Impact or risk	Monitoring requirement associated with control measures and EPSs	Responsibility		Frequency	Measurement criteria
		MODU	Vessels		
	Toxicity of chemicals used	✓	✓	Prior to approval of use	Chemical inventory
Vessel collision	24-hour bridge watch on vessels	✗	✓	Daily	Official logbook
	Monitoring PSZ for vessels	✓	✓	Daily	Radio communication logs
Loss of well control	Monitoring in accordance with the OPEP and OSMP	✓	✓	As defined in the OPEP and OSMP	As defined in the OPEP and OSMP

9.7 Environmental assurance

Equinor Australia B.V. implements a risk-based assurance framework to confirm our Management System is effective, to ensure personnel are accountable for managing risks, assurance activities and findings and to capture learnings and implement improvements. We employ three levels of assurance depending on the requirements for independence, the complexity of operations, the level of risk and performance history. The three levels are:

- Self-assessments: conducted by line management to demonstrate controls are in place and to identify ways to reduce risk and improve performance. Line managers determine the scope of self-assessments and at an operational level they focus on critical operational and technical barriers and key controls. These are workshops performed according to an internal assurance plan.
- Verifications: business area management tool for assessment of high impact risks and used where an independent view is required to provide the necessary level of confirmation of control. This is the equivalent of what is usually referred to as an 'audit' in Australia and will be used to verify environmental compliance during the petroleum activity.
- Audits: independent assessment to evaluate and improve the efficiency and effectiveness of corporate performance, Management System and governance. These are undertaken at a corporate level.

An environmental compliance register will be developed for the activity. As a minimum this will include:

- environmental protection outcomes, environmental protection standards and measurement criteria in the EP and appendices
- other key commitments made within this EP, in particular requirements within the Implementation strategy
- timeframes relevant to the items listed above (e.g. pre-activity, during activity, post-activity)
- roles responsible for the requirements.

The environmental compliance register will be managed by the SSU leader and used to assure compliance with this EP.

The following assurance activities will evaluate environmental performance against the EPOs and EPSs in the EP:

- Rig and vessel surveys: Inspection undertaken by Equinor personnel when the rig has been contracted. Inspection covers (among other operational, technical and HSE items) environmental aspects such as mud and solids control systems, environmental emissions and discharge control (including drainage) and the management of loss of containment. Similar survey will be performed on relevant equipment on PSVs and SCV when the vessels have been contracted. Conducted by Equinor personnel.
- Pre-mobilisation environmental desktop compliance review: Undertaken by Equinor environmental advisor or environmental delegate. This will be undertaken at least six weeks prior to mobilisation of the rig to location, following the OPEP Level 3 desktop exercise. The review will verify that pre-mobilisation

EPOs and EPSs have been met and assure environmental preparedness for the activity following mobilisation. It will also include reviewing evidence of contractor readiness for the activity (e.g. environmental equipment, systems, procedures are in place and training and competency requirements met).

- Environmental compliance verification: Undertaken by Equinor environmental advisor or environmental delegate during drilling. Verification will include a full review of compliance with EPOs and EPSs and will involve an office component and onsite component. The onsite component may be conducted by an Equinor HSE representative instead of the environmental advisor depending on bed availability. If this is the case, the HSE representative will work closely with the environmental advisor to ensure all verification items are evaluated for compliance and the necessary records readily available.
- MODU inspections of environmental monitoring equipment and records: Undertaken by Equinor HSE personnel or delegate on a weekly basis during the activity (including during drilling operations). These inspections may be performed as part of a general HSE inspection and will verify that environmental monitoring equipment is compliant with the EP and records are available to demonstrate compliance. Examples of environmental inspection items that would be inspected include equipment associated with bunkering and transfers between the MODU and support vessels, containment equipment including chemical storage, spill prevention and response equipment, waste storage, transfer and disposal equipment, drilling fluids, oil/water separation equipment.
- Vessel HSE inspections: Undertaken by vessel personnel in accordance with their inspection schedule. Inspections will include verifying environmental monitoring equipment (e.g. bunkering and transfer equipment, chemical storage, waste management, spill prevention and response) and checking that records are available to demonstrate compliance.

We implement our internal process MS403 'Execute Audit/Verification' for executing verification activities, which is summarised in Figure 9.5. As the risk owner, the Drilling Manager prepares the mandate for the verification, which includes the purpose, scope, criteria and planned timeframe for execution. They will identify the verification team who will have the necessary qualifications for conducting the task.

Preparation for the verification involves:

- clarifying the execution and scope
  - identify governing documentation and key personnel
  - agree verification methods, techniques and tools (e.g. office-based components and site components, data review, interviews, etc.)
  - schedule for the verification.
- notifying personnel being verified
- preparing a work plan that covers date, time and location for opening and closing meetings and interviews
- preparing work documents and tools including a compliance register that includes the EPOs, EPSs and measurement criteria as a minimum.

Execution of the verification involves:

- conducting an opening meeting
- collecting and reviewing information through interviews, meetings, review of documents and data, etc. to verify compliance with items in the compliance register
- evaluating the evidence collected and reviewing against the commitments in the compliance register, including EPOs, EPSs and measurement criteria
- drawing conclusions, identify non-conformances and develop findings
- proposing corrective actions to address findings
- conducting a closing meeting.

Any observations that indicate a critical condition will be communicated to the Drilling Manager as soon as practicable so they can address the situation immediately.

A verification report is developed by the Team Leader and reflects any changes or updates since the closing meeting. The Drilling Manager reviews and approves the report, and it is then distributed to relevant personnel. Following the verification activity, the Drilling Manager ensures that:

- findings have been evaluated, and lessons learned identified
- corrective actions have been assigned to action owners and due dates for closure have been set
- corrective actions are entered and tracked to closure in Synergi
- all non-conformances identified are managed according to the process in Section 9.9
- learnings based on the results of the verification are communicate to relevant Equinor personnel or contractors.

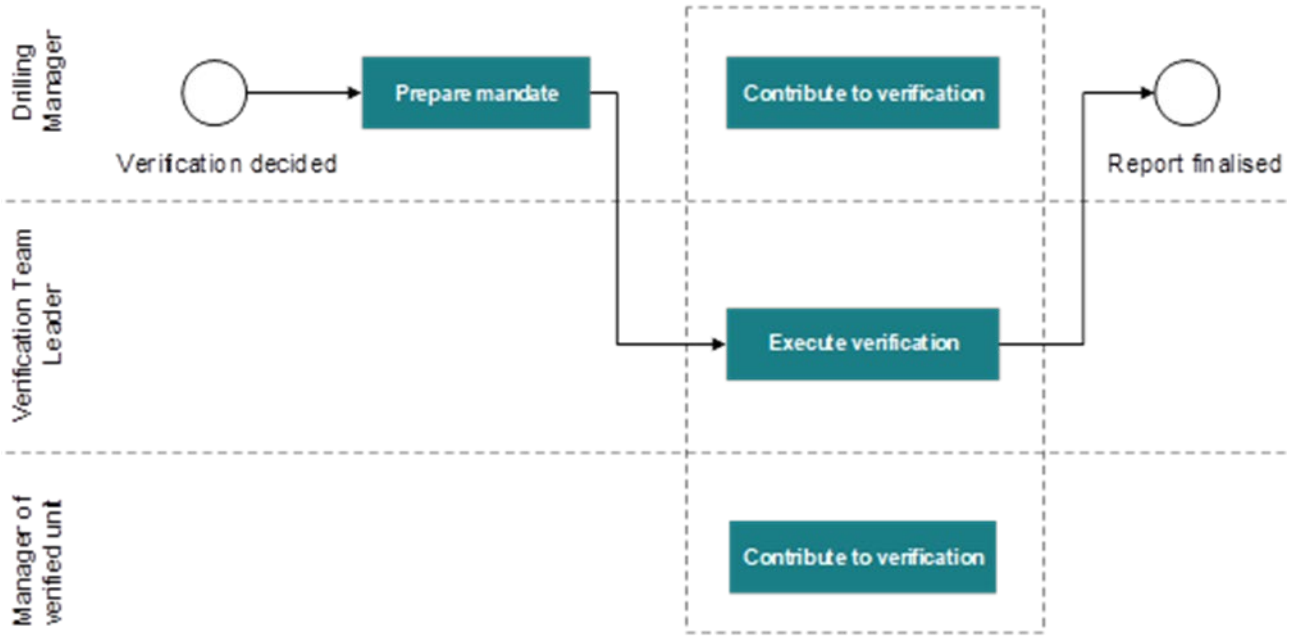

Figure 9.5 Process for execution of verification

9.8 Reviews of environmental performance

Equinor Australia B.V. will monitor environmental performance to ensure that for the duration of the petroleum activity:

- The environmental impacts and risks of the activity continue to be identified and reduced to a level that is as low as reasonably practicable.
- Control measures detailed in the environment plan are effective in reducing the environmental impacts and risks of the activity to as low as reasonably practicable and an acceptable level.
- Environmental performance outcomes and standards set out in this Environment Plan are being met.
- Opportunities for improvement, non-conformances or incidents are identified, responded to, reported and investigated (as required).

Environmental performance is reviewed at daily meetings between the MODU and onshore office. HSE items are discussed including incidents and near misses, verification, inspection and review outcomes, performance against HSE key performance indicators. Technical data associated with drilling progress is also reviewed during these meetings.

The EPO, control measures and EPSs in Section 9.13 will ensure the Implementation Strategy is effective in ensuring impacts and risks are ALARP and managed to acceptable levels.

A complete review of environmental performance will be conducted at the end of the activity within one month of the MODU demobilising from the well location, and report submitted to NOPSEMA within three months of activity completion under this EP. Additional ad hoc performance reviews may be undertaken during the activity if requested by Equinor management. The following information will be considered and assessed during reviews of environmental performance under this EP:

- records of environmental verifications, compliance reviews and inspections
- verification findings, non-conformances and the close-out of corrective actions
- records of environmental incidents and near misses, and their reporting and investigation outcomes
- monitoring records and data collected in accordance with Table 9.4
- consultation records including a relevant person's list, any stakeholder feedback received during the activity assessment of merit and Equinor Australia B.V.'s response or proposed response
- Management of Change records documenting any changes identified and approved via the Management of Change process during the activity, including changes to, or new impacts or risks identified during the activity
- notification and reporting records for all notifications, internal and external reporting requirements required under this EP

An environmental performance report will be submitted to National Offshore Petroleum Safety and Environmental Management Authority within three months of completion of the activity to assess and confirm compliance with the accepted environmental performance objectives, standards and measurement criteria outlined in this Environment Plan (refer to Section 9.10.4).

The information listed above will be summarised and included in the Environmental Performance Report submitted to NOPSEMA (refer to Section 9.10.4). Importantly, a full assessment of performance against all environmental performance outcomes, control measures and environmental performance standards in the EP will be conducted and included in the Report. Any non-conformances identified during performance reviews will be managed according to the process in Section 9.9.

9.9 Management of non-conformance

Equinor Australia B.V. considers environmental non-conformances as incidents. All personnel are required to report any near misses and incidents as soon as possible. If a non-conformance with the control measures or environmental performance standards in this Environment Plan is identified it will be internally reported, investigated and corrective actions tracked to close-out using Synergi. Any non-conformances that trigger external reporting will be reported in accordance with Section 9.10. Our Preparedness and Response work process (SF700) outlines our response to environmental incidents. For oil spills that occur during the activity, the response process is defined in the Oil Pollution Emergency Plan (Appendix 9-1).

Findings that arise from investigations into non-conformances are internally classified according to their criticality. Criticality relates to the potential environmental effect of the item. The classification is evaluated into one of three categories outlined in WR27314 'Execute verification by team leader' follows:

- Acceptable (risk rating 1-3): severe non-conformance with regulatory requirements
- Improvement needed (risk rating 4 5): non-conformance with regulatory requirements
- Critical (risk rating 6 9): in accordance with regulatory requirements or minor/negligible non-conformance.

This process requires consideration of the risk associated with the non-conformance using the Equinor risk matrices (Section 5.5.1).

9.9.1 Environmental incidents

Our Preparedness and Response work process (SF700) outlines our response to environmental incidents. For oil spills that occur during the activity, the response process is defined in the Oil Pollution Emergency Plan (Appendix 9-1).

The mobile offshore drilling unit and support vessels will be required to have an Emergency Response Manual and approved Shipboard Oil Pollution Emergency Plan or Shipboard Marine Pollution Emergency Plan as appropriate. The vessel specific responsibilities, procedures and resources available in the event of a hydrocarbon or chemical spill from vessel activities are detailed in the Shipboard Oil Pollution Emergency Plan/SMEMP in accordance with the requirements of the International Convention for the Prevention of Pollution from Ships 73/78 Annex I.

The bridging documentation between Equinor Australia B.V.'s incident management systems and the safety cases for the mobile offshore drilling unit and vessels will be required to be developed by the contractor(s) and approved by Equinor Australia B.V., prior to the commencement of the activity. The bridging documents will define which entity assumes control for different emergency response scenarios, including environmental incidents.

Environmental incidents under this Environment Plan are:

- introduction of a marine pest
- collision with marine fauna
- loss of solid waste materials overboard
- loss of containment of hazardous materials
- diesel spill due to vessel collision
- loss of well control.

In addition, Equinor considers environmental non-conformances with EPOs and EPSs as incidents.

All personnel must report near misses and incidents to their line supervisor as soon as practicable, regardless of their significance.

Equinor Australia B.V.'s incident investigation process identifies the root causes of the incident from which corrective actions can be determined. We will discuss near misses and incidents with our contractors and work with them to review the relevant control measures and to identify opportunities to improve environmental performance. If a near miss or incident significantly increases the risk of negative consequences to the environment, a stop work order may be issued by the relevant person in charge, and operations suspended.

Part of the incident response and investigation process will involve determining whether the incident is a "recordable" or "reportable" incident under the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009. These reporting requirements are covered in Section 9.10.

9.10 Environmental notifications and reporting

9.10.1 Notifications

The notifications in Table 9.5 include those that are required from National Offshore Petroleum Safety and Environmental Management Authority, those requested by relevant persons during the formal consultation period and those Equinor Australia B.V. have committed to. It should be noted that all oil spill related notifications are in the Oil Pollution Emergency Plan (Appendix 9-1) and therefore are not included in this table.

Table 9.5 External notifications

Relevant person	Responsible party	Notifications	Method	Timing
Before activity commences				
All relevant persons	Country Manager	Provide notice prior to the arrival of rig at well location Contact details as per consultation database	Written	Email four weeks prior to arrival unless otherwise requested
Australian Maritime Safety Authority, Commonwealth	Equinor Australia B.V. Drilling Superintendent	Provide notice to the Joint Rescue Coordination Centre of estimated MODU mobilisation date and details to enable AusCoast warning broadcasts to be issued Email: rccaus@amsa.gov.au Phone: 1800 641 792 or +61 2 6230 6811	Written/ Verbal	24-48 hours prior to mobilisation

Relevant person	Responsible party	Notifications	Method	Timing
		Information required includes MODU details (name, callsign and Maritime Mobile Service Identity (MMSI)), satellite communications details (INMARSAT-C and satellite telephone), area of operation, requested clearance from other vessels and when operations start and end.		
Department of Defence/ Australian Hydrographic Office (AHO), Commonwealth	Equinor Australia B.V. Drilling Superintendent	Provide notice of the estimated MODU mobilisation date to enable the promulgation of Notice to Mariners Email: datacentre@hydro.gov.au	Written	At least four working weeks prior to mobilisation
		Provide notice of commencement of activity Email: datacentre@hydro.gov.au	Written	Three weeks prior to the commencement of the activity
Department of Environment and Energy, Director of National Parks, Commonwealth	Country Manager	Provide notice when the EP is approved by NOPSEMA	Written	When the EP is approved by NOPSEMA
	Country Manager	Provide start dates for the activity and drilling. Email: marineparks@environment.gov.au	Written	Four weeks prior to spud, and upon date of spud
Department of Mines, Industry Regulation and Safety, Western Australia	Country Manager	Provide notice of commencement of activity Email: petroleum.environment@dmirs.wa.gov.au	Written	Four weeks prior to spud
Department of Primary Industries and Regional Development, Western Australia	Country Manager	Provide notice of commencement of activity Email: environment@dpird.wa.gov.au	Written	At least six weeks prior to commencement of the activity
Department for Energy and Mining, South Australia	Country Manager	Provide notice of the confirmed spud date Email: dem.engineering@sa.gov.au	Written	Four weeks prior to spud
NOPSEMA	Country Manager	Provide notice of commencement of activity Email: submissions@nopsema.gov.au	Written	At least 10 days prior to spud
During activity				
NOPSEMA	Country Manager	Provide notice of a change of contact person, titleholder or joint venture arrangement Email: submissions@nopsema.gov.au	Written	As required
After activity				
All relevant persons	Country Manager	Provide notice of the cessation of operations Contact details as per Consultation Manager database	Written	When activity has ceased
Department of Defence/ AHO	Equinor Australia B.V. Drilling Superintendent	Provide notice for each MODU move, advise location of abandoned well head and once MODU has been demobilised from the drilling area Email: datacentre@hydro.gov.au	Written	Prior to leaving site and then once the MODU has moved location/been demobilised

Relevant person	Responsible party	Notifications	Method	Timing
DMIRS, Western Australia	Country Manager	Provide notice of the activity end date Email: petroleum.environment@dmirs.wa.gov.au	Written	Upon cessation of the activity
NOPSEMA	Country manager	Provide notice of the completion of the activity Email: submissions@nopsema.gov.au	Written	Within 10 days of the MODU demobilising
	Country Manager	Provide notice of the end date of operation of the EP Email: submissions@nopsema.gov.au	Written	When all activities are concluded and obligations under the EP have been completed

9.10.2 Routine reporting

The Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009 require Equinor Australia B.V. to report recordable incidents to National Offshore Petroleum Safety and Environmental Management Authority on a monthly basis. Recordable incidents are defined as "a breach of an environmental performance outcome or environmental performance standard and is not a reportable incident".

As soon as practicable after the end of the calendar month or by the 15th day of every month, we will provide a monthly recordable incident report that includes:

- all recordable incidents that occurred during the calendar month
- all material facts and circumstances concerning the recordable incidents
- any action taken to avoid or mitigate any adverse environment consequences of the recordable incidents
- the corrective action that has been taken, or is proposed to be taken, to stop, control or remedy the recordable incident
- the action that has been taken, or is proposed to be taken, to prevent a similar incident occurring in the future.

The report will be completed using the online proforma at http://www.nopsema.gov.au/environmental-management/
environmental-resources/ or emailed to submissions@nopsema.gov.au. If no recordable incidents have occurred during the calendar month, we will lodge a report listing nil incidents.

9.10.3 Incident reporting

The incident reporting requirements that apply during the petroleum activity are defined in Table 9.6. External reporting in the event of an oil spill is also covered in the Oil Pollution Emergency Plan.

The Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009 require Equinor Australia B.V. to report reportable incidents to National Offshore Petroleum Safety and Environmental Management Authority. Reportable incidents are defined as "incidents relating to the activity that have caused, or have the potential to cause, moderate to significant environmental damage".

Using Equinor Australia B.V.'s risk matrix, "moderate to significant environmental damage" equates to an environmental consequence of Category 4 or greater. Based on the environmental risk assessment, the risks that have a consequence of Category 4 or greater are:

- vessel collision resulting in a diesel spill
- loss of well control.

In accordance with the Oil Pollution Emergency Plan, the threshold for verbal reporting of hydrocarbon spills to National Offshore Petroleum Safety and Environmental Management Authority is more than 80 litres. Therefore, Equinor Australia B.V. will use this threshold for the purposes of the reportable incident reporting outlined in Table 9.6.

Table 9.6 External incident reporting requirements

Agency	Responsible party	Report and content	Method	Timing
Reportable incidents (hydrocarbon spills)				
Commonwealth NOPSEMA	Equinor Australia B.V. Drilling Superintendent	Report must include: • all material facts and circumstances concerning the incident that are known at the time • any actions taken to avoid or mitigate any adverse environmental effects • any corrective actions that have been taken, or are proposed to be taken, to prevent a repeat of similar incidents occurring. Phone: 08-6461 7090.	Verbal	ASAP or not later than two hours after incident is identified
		As a minimum the report must include: • all material facts and circumstances concerning the incident that are known at the time • any actions taken to avoid or mitigate any adverse environmental effects • any corrective actions that have been taken, or may be taken, to stop, control or remedy the reportable incident • actions taken, or proposed to be taken, to prevent a repeat of similar incidents occurring. Complete proforma at: http://www.nopsema.gov.au/environmental-management/environmental-resources/, and submit online, or via email at submissions@nopsema.gov.au.	Written	ASAP and not later than three days after the first occurrence of the incident
Commonwealth NOPTA	Equinor Australia B.V. Drilling Superintendent	A copy of the written reportable incident report (refer to above). Email: info@nopta.gov.au	Written	Within seven days of providing a written report to NOPSEMA
South Australian Department for Energy and Mining	Equinor Australia B.V. Drilling Superintendent	A copy of the written reportable incident report (refer to above). Email: dem.engineering@sa.gov.au	Written	Within seven days of providing a written report to NOPSEMA
Introduction of a marine pest within the Operational Area				
Department of Agriculture and Water Resources	Equinor Australia B.V. Drilling Superintendent	Email: mpsc@agriculture.gov.au	Written	As soon as practicable following presence of marine pest has been confirmed
Primary Industries and Regions South Australia	Equinor Australia B.V. Drilling Superintendent	FishWatch Phone: 1800 065 522 (24/7)	Verbal	As above
Injury to EPBC Act listed migratory or threatened species within the Operational Area				
Commonwealth Department of Environment and Energy	Equinor Australia B.V. Drilling Superintendent	Phone: (02) 6274 1372 or 1800 110 395 Or Email: compliance@environment.gov.au	Verbal or written	ASAP but no later than three days of becoming aware of the incident

Agency	Responsible party	Report and content	Method	Timing
NOPSEMA	Equinor Australia B.V. Drilling Superintendent	Email: submissions@nopsema.gov.au or Online secure file transfer: https://securefile.nopsema.gov.au/filedrop/submissions	Written	As above
Injury to whales from ship strike within the Operational Area				
Australian Antarctic Division – Australian Marine Mammal Centre	Vessel Master or MODU OIM	Injury to whales from ship strike Online via the National Ship Strike Database: https://data.marinemammals.gov.au/report/shipstrike/new	Online form	ASAP but within seven days of becoming aware of the incident

9.10.4 Performance reporting

An environmental performance report will be submitted to National Offshore Petroleum Safety and Environmental Management Authority within three months of completion of the activity to assess and confirm compliance with the accepted environmental performance outcomes and environmental performance standards.

Developing the report will involve reviewing the performance monitoring data and records described in Section 9.6 against the environmental performance outcomes and environmental performance standards in this EP. The report will include sufficient information to demonstrate compliance with all environmental performance outcomes and environmental performance standards.

9.11 Management of Change

Equinor Australia B.V. follows the DW912 Management of Change process to manage permanent or temporary changes that may arise during all phases of a drilling program (Figure 9.4). Personnel are required to report changes within their work area that may adversely affect the environment to their line supervisor. The change will be escalated to the Equinor Australia B.V. Drilling Superintendent who is responsible for ensuring that the Management of Change process is implemented. The Equinor Australia B.V. Safety and Sustainability Manager is involved in evaluating the implications of proposed changes with regard to this EP.

Under Regulation 17 of the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009, the following changes *will* require this Environment Plan to be revised and submitted to National Offshore Petroleum Safety and Environmental Management Authority:

- a new activity (proposed revision to be submitted before the commencement of a new activity)
- any significant modification or new stage of the activity that is not provided for in this Environment Plan (proposed revision to be submitted before or as soon as practicable after
- the occurrence of any significant new environmental impact or risk, or significant increase in an existing environmental impact or risk, not provided for in this EP; or
- the occurrence of a series of new environmental impacts or risks, or a series of increases in existing environmental impacts or risks, which, taken together, amount to the occurrence of
  - i. a significant new environmental impact or risk; or
  - ii. a significant increase in an existing environmental impact or risk that is not provided for in this EP
- if a change in the titleholder will result in a change in the manner in which the environmental impacts and risks of an activity are managed (proposed revision to be submitted as soon as practicable).

The following events may trigger the Management of Change process for this activity and could result in a revision to this EP:

- changes to the existing activity that have the potential to adversely affect the environment and have not been assessed under this EP. For example, change in location, vessel type, equipment, changes to procedures and processes
- if the outcomes of environmental monitoring, assurance activities, non-conformance or incident investigations and performance reviews indicate that control measures no longer demonstrate an impact or risk is As Low As Reasonably Practicable or managed to an acceptable level
- incidents that identify new or increased impacts or risks that are not identified in this EP
- changes in our ability to meet the environmental performance outcomes in this EP
- changes to legislation, new or now relevant technical or scientific information and publications
- changes to protection areas, plans or requirements for protected species
- if consultation identifies new or increased impacts or risks that are not identified in this Environment Plan
- changes to state or Commonwealth emergency management or oil spill frameworks or resources.

As shown in Figure 9.4 our Management of Change process involves the following:

- register and describe the change in change log
- subject matter experts evaluate the implications of the change. An environmental evaluation is undertaken by the Equinor Australia B.V. Safety and Sustainability Manager (or delegate) and will involve assessing the implications of the change with regard to this EP. Depending on the nature of the change, this assessment would include reviewing the change against the lists above, as well as ensuring the impacts and risks
- determine if a Project Change Proposal is required
- document the decisions made in the change log
- approve or reject the change.

If the change is approved, we will then plan and execute the change, including revising this Environment Plan and submitting the proposed revision to National Offshore Petroleum Safety and Environmental Management Authority if required. Review of this Environment Plan is described further in Section 9.13.

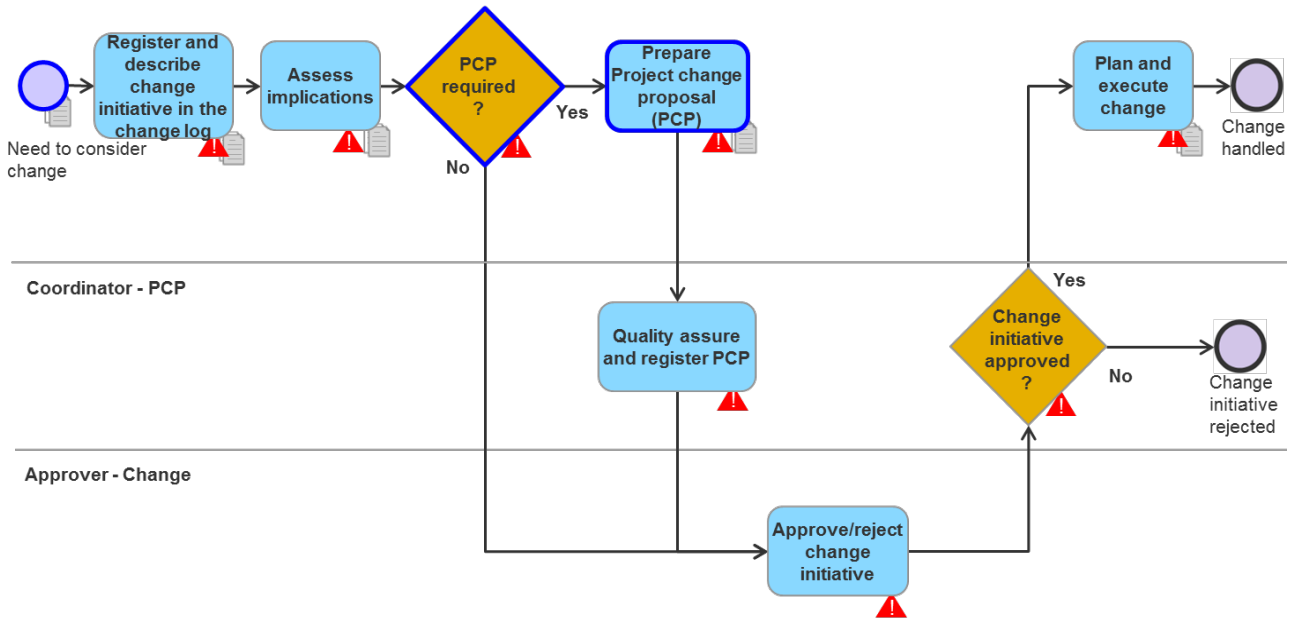

Figure 9.6 Equinor Australia B.V.'s Management of Change process

9.12 Records management

Equinor Australia B.V. will store operational documents and records that are relevant to the Environment Plan in Australia. Records generated for the petroleum activity will be retrievable and retained for five years after the day when the Environment Plan ceased to be in force. Operational documents and records associated with this Environment Plan will include:

- the Environment Plan that is in force and versions of the Environment Plan previously in force
- project induction presentation and induction attendance records
- training certification records, training and competency matrices
- daily drilling reports and daily well reports
- sewage logs and waste manifests
- marine fauna observation sheets
- calibration and maintenance records
- inspection and self-assessment records
- environmental performance reports
- Management of Change records
- consultation records
- written incident notifications
- recordable and reportable incident reports submitted to National Offshore Petroleum Safety and Environmental Management Authority
- incident investigation records
- evidence of close-out of corrective actions from incident investigations and inspections.

Records will be made available in accordance with Regulation 28 of the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009 to the persons listed under OPGGS(E) Subregulation 28(2) (on request in writing).

9.13 Environment Plan reviews

Equinor Australia B.V.'s Management of Change process will be followed to assess changes or modifications to the petroleum activity (as described in Section 2.0 of this EP) to determine if the change triggers a revision of the Environment Plan under Regulation 17 of the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009.

If the change does not trigger revision under the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009, we will amend the Environment Plan and record the changes within the EP. If the Management of Change assessment determines that a change does trigger a revision of the Environment Plan under Regulation 17 of the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009, we will update the Environment Plan and re-submit it to National Offshore Petroleum Safety and Environmental Management Authority for acceptance.

If National Offshore Petroleum Safety and Environmental Management Authority require revision and resubmission of the Environment Plan under Regulation 18 of the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009, we will update the Environment Plan and re-submit it to National Offshore Petroleum Safety and Environmental Management Authority for acceptance.

Updates made to the Environment Plan will be communicated to Equinor Australia B.V. personnel and contractors and a copy of the updated Environment Plan provided to them.

9.14 Performance of the implementation strategy

EPO 9.14: The Implementation Strategy ensures that impacts and risks continue to be reduced to ALARP and to acceptable levels.

Control measure	Environmental performance standard	Measurement criteria	Responsibility
Environmental monitoring and data collection	EPS 9.14.1: Impacts and risks are monitored according to the requirements and frequency in Table 9.4.	Emissions, discharges, waste data, maintenance records, marine fauna observations, etc.	MODU OIM / Vessel Master
	EPS 9.14.2: Monitoring data and records maintained as evidence that measurement criteria reached.	Monitoring data and records stored and readily available.	MODU OIM / Vessel Master
Environmental assurance program	EPS 9.14.3: Rig and vessel inspections conducted when MODU contracted. Inspections include environmental related systems for mud and solids control, emissions and discharges (including drainage) and spill containment.	Inspection records/reports cover verification of environmental related systems.	MODU OIM / Vessel Master
	EPS 9.14.4: Pre-mobilisation environmental desktop compliance review undertaken at least six weeks prior to mobilisation of the MODU (within Australia) to well location. Review to verify pre-mobilisation EPOs, control measures and EPSs have been met and assure preparedness for the activity.	Compliance report on outcomes of review Report demonstrates date of review at least six weeks prior to mobilisation.	SSU Manager
	EPS 9.14.5: Environmental verification of compliance with EPOs and EPSs undertaken during drilling. Verification includes office and site-based components.	Verification report demonstrates undertaken during drilling with office and site-based components.	SSU Manager
	EPS 9.14.6: HSE inspections of the MODU conducted on weekly basis and onboard vessels according to vessels inspection schedule.	MODU weekly HSE inspection records, vessel HSE inspection records.	MODU OIM / Vessel Master
Environmental performance reviews	EPS 9.14.7: Relevant environmental data (included in daily report) reviewed at daily progress meetings.	Daily progress reports	Equinor Drilling Supervisor
	EPS 9.14.8: Performance review conducted within one month of the MODU demobilising and report submitted to NOPSEMA within 3 months of activity completion under this EP.	Final performance report that demonstrates timeframes met.	SSU Manager
Process for handling non-conformances	EPS 9.14.9: Non-conformances treated as incidents and internally reported, investigated and corrective actions tracked to close-out using Synergi.	Synergi records, incident reports, verification reports, compliance review reports, HSE inspection reports, daily progress reports.	MODU OIM / Vessel Master
Notifications and reporting	EPS 9.14.10: Notifications and routine reporting conducted in accordance with Section 9.10.1 and 9.10.2.	Communications records (phone log, emails, etc.), daily progress reports, monthly recordable incident reports.	Country Manager/ Drilling Superintendent
	EPS 9.14.11: Any non-conformances or incidents that trigger external reporting will be reported in accordance with Section 9.10.3.	Synergi records, incident reports, communications records (phone log, emails, etc.), daily progress reports	Drilling Superintendent MODU OIM/ Vessel Master for injury to whales from ship strike

Control measure	Environmental performance standard	Measurement criteria	Responsibility
Management of change (MoC) process	EPS 9.14.12: MoC process triggered in response to items listed in Section 9.11 and recorded in the change log.	Change log, MoC records	Drilling Superintendent
	EPS 9.14.13: Environmental evaluation of the implications of changes undertaken as part of MoC process.	Change log, MoC records of environmental evaluation	Drilling Superintendent
Records management	EPS 9.14.14: Records associated with implementation of this EP, including the OPEP, OSMP and OPEP WMP maintained and readily available.	Document management systems, records storage systems demonstrate records stored and retrievable.	MODU OIM / Vessel Master

10.0 Abbreviations, acronyms and definitions

Acronym/abbreviation	Description
AFMA	Australian Fisheries Management Authority (Commonwealth)
ALARP	As Low As Reasonably Practicable
AMOSC	Australian Marine Oil Spill Centre
AMSA	Australian Maritime Safety Authority (Commonwealth)
ANZECC	Australia New Zealand Environment and Conservation Council
API	American Petroleum Institute
APPEA	Australian Petroleum Production and Exploration Association
ARMCANZ	Australian National Health and Medical Research Council
AUV	Autonomous Underwater Vehicle
BACI	Before-After Control-Impact
BIA	Biologically Important Area
BOP	Blowout preventer
BP	BP p.l.c. (formerly British Petroleum)
BP	BP Exploration (Alpha) Australia Pty Ltd
CAMBA	China–Australia Migratory Birds Agreement
CAN	Conductor Anchor Node
CAR	Containment and recovery
CAS	Chemical Abstracts Service
CD	Chart Datum (= LAT)
CHARM	Chemical Hazard Assessment and Risk Management
CMR	Commonwealth Marine Reserve
CS	Capping stack
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DAWR	Department of Agriculture and Water Resources (Commonwealth)
DBCA	Department of Biodiversity, Conservation and Attractions (Western Australia)
DEE	Department of the Environment and Energy
DEWHA	Department of the Environment, Water, Heritage and the Arts (now DEE)
DEWNR	Department of the Environment, Water and Natural Resource (South Australia)
DIIS	Department of Industry, Innovation and Science (Commonwealth)
DMIRS	Department of Mines, Industry Regulation and Safety (Western Australia)
DP	Dynamic positioned
DoT	Department of Transport (Western Australia)
DPIPWE	Department of Primary Industries, Parks, Water and Environment (Tasmania)
DPIRD	Department of Primary Industries and Regional Development (Western Australia)
EDS (in drilling)	Emergency disconnect sequence
EEZ	Exclusive Economic Zone
EMBA	Environment that May Be Affected
EP	Environment Plan
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
EPBC Regulations	Environment Protection and Biodiversity Conservation Regulations 2000
EPP39	Exploration permit 39
Equinor Australia B.V.	Equinor Australia B.V. (previously Statoil Australia Theta B.V.)
ERP	Emergency Response Plan
ESD	Ecologically Sustainable Development
FWADC	Fixed Wing Aerial Dispersant Capability
GAB	Great Australian Bight
GAB CMP	Great Australian Bight Commonwealth Marine Park
GHG	Greenhouse Gas
GMP	Garbage Management Plan
GMDSS	Global Maritime Distress and safety System

Acronym/abbreviation	Description
GOR	Gas to oil ratio
HAT	Highest Astronomical Tide
HSE	Health, Safety Environment and Quality
IAP	Incident Action Plan
IAPP	International Air Pollution Prevention
IMP	Introduced Marine Pest
IMT	Incident Management Team
IP	Implementation Plan
ISO	International Standards Organization
ISPP	International Sewage Pollution Prevention
IUCN	International Union for Conservation of Nature
KEF	Key Ecological Feature
LAT	Lowest Astronomical Tide (= Chart Datum)
LO	Liaison Officer
LOWC	Loss of well control
MARPOL	International Convention for the Prevention of Pollution from Ships
MDO	Marine diesel oil
Metocean	Meteorological and oceanographic
MFO	Marine Fauna Observer
MGO	Marine gas oil
MNES	Matters of National Environmental Significance
MODU	Mobile Offshore Drilling Unit
MP	Marine Park
SDS	Safety Data Sheets
NEBA	Net Environmental Benefit Analysis
NOAA	National Oceanic and Atmospheric Administration
NOPSEMA	National Offshore Petroleum Safety and Environmental Management Authority
NOPTA	National Offshore Petroleum Titles Administrator
NSW	New South Wales
OCNS	Offshore Chemical Notification System
OIM	Offshore Installation manager
OIW	Oil in water
OMP	Operational (Type I) Monitoring Plan
OPEP	Oil Pollution Emergency Plan
OPGGS Act	*Offshore Petroleum and Greenhouse Gas Storage Act 2006*
OPGGS(E) Regulations	Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009
OSMP	Operational and Scientific Monitoring Program
OSPAR	Oslo and Paris Conventions (1998)
OSRL	Oil Spill Response Limited
OWR	Oiled Wildlife Response
OWS	Oily water separator
PAH	Polycyclic Aromatic Hydrocarbons
PIRSA	Department of Primary Industries and Regions
PLONOR	Pose Little or No Risk to the Environment
PMS	Planned Maintenance System
PMST	Protected Matters Search Tool
POMS	Pacific Oyster Mortality Syndrome
PSV	Platform supply vessel
PSZ	Petroleum Safety Zone
PTS	Permanent Threshold Shift
PTW	Permit to work
QA/QC	Quality Control/Quality Assurance

Acronym/abbreviation	Description
rms	Root Mean Squared
RO	Reverse osmosis
ROC	Retained Oil on Cuttings
ROV	Remotely Operated Vehicle
RPS	RPS Australia West Pty Ltd
RSI	Response severity index
SA	South Australia
SAG	Scientific Advisory Group
SARDI	South Australia Research and Development Institute
SBT	Southern bluefin tuna
SCAT	Shoreline Clean-up Assessment Technique
SDS	Safety Data Sheet
SEL	Sound Exposure Level
SME	Subject Matter Expert
SMP	Scientific (Type II) Monitoring Plan
SMPEP	Shipboard Marine Pollution Emergency Plan
SOPEP	Shipboard Oil Pollution Emergency Plan
SPL	Sound Pressure Level
SSDI	Sub-Surface Dispersant Injection
SSU	Safety and sustainability (ref. definitions)
Statoil	Statoil Australia Theta B.V. (now Equinor Australia B.V.)
STP	Sewage treatment system
TEC	Threatened Ecological Community
TPH	Total Petroleum Hydrocarbons (now TRH)
TRH	Total Recoverable Hydrocarbons
TRP	Tactical response plan
TSS	Total suspended solids
TTS	Temporary Threshold Shift
UK	United Kingdom
US EPA	United States Environmental Protection Agency
VOC	Volatile Organic Compounds
VSP	Vertical seismic profiling
WA	Western Australia
WBM	Water based mud
WCD	Worst Case Discharge
WCCD	Worst Credible Case Discharge
WOMP	Well operations management plan
Units of measurement	
°	Degrees
°C	Degrees Celsius
cm	Centimetre
g	Grams
g/m^2	Grams per square metre
Hr	Hour
Hz	Hertz
km	Kilometre
L	Litre
m	Metres
m^2	Square metre
µg	Microgram
ml	Millilitres
µm	Micrometre

Acronym/abbreviation	Description
mm	Millimetres
m/s	Metres per second
mS/cm	Micro Siemens per centimetre
NM	Nautical Mile
NTU	Nephelometric turbidity unit
Pa, µPa	Pascal, micropascal
ppb	Parts per billion
psu	Practical salinity unit
RFU	Raw fluorimeter unit
T	Tonnes
TB	Terabyte
Definition of terms	
Intertidal descriptors	
Shoreline	Coastal fringe, comprising the intertidal and supralittoral zones. This definition also includes steep-sloping or vertical landforms (e.g. cliffs, stacks, natural arches) and potentially artificial structures emerging from the subtidal zone.
Intertidal	The area of the shoreline regularly exposed to tidal immersion and emersion; The area between LAT and HAT.
Infralittoral	The “Splash zone”. The area on the landward side of the intertidal that is regularly exposed to drops of sea water caused by waves splashing on shorelines.
Subtidal descriptors	
Coastal	Within the context of this OSMP, “Coastal” waters describe the zone between LAT and ≤100 m water depth (below chart datum (= LAT)). This definition is not based on maritime boundaries but is defined based on approximate practical depth ranges for use of specific sediment sampling equipment (e.g. 0.025 m^2 van Veen grab). This zone lies between the Intertidal and Offshore zones.
Offshore	Within the context of this OSMP, “Offshore” waters describe the zone between 100 <500 m water depth (below). This definition is not based on maritime boundaries but is defined by approximate practical depth ranges for use of specific sediment sampling equipment (e.g. 0.2 m^2 van Veen grab, 0.1 m^2 box core). This zone lies between Coastal and Deep Oceanic Waters.
Deep Oceanic Waters	Within the context of this OSMP, “Deep Oceanic Waters” describe the zone in Commonwealth waters and the Australian EEZ >500 m water depth (below chart datum (= LAT)). This definition is loosely based on maritime boundaries (e.g. the outer extent of the EEZ) but is mainly defined by approximate practical depth ranges for use of specific sediment sampling equipment (e.g. too deep for equipment not specifically designed for sampling in very deep waters). This zone is found on the outer boundary of the Offshore zone.
General terms	
Contractor	The term "contractor" is used to refer to an individual worker which will need access to company controlled areas and/or data networks, and who is not a permanent employee. This group includes temporary staff, service personnel, consultants and trainees.
Impact EMBA	The geographical area encompassing the environment that may be affected by the planned activities in the Operational Area. The maximum extent of underwater noise effects (with a conservative buffer allowance) is the dimensioning factor for this area
Risk EMBA	The geographical area encompassing the environment that may be affected by the unplanned events associated with the planned activities within the Operational Area. The maximum extent of an oil spill due to a loss of well control resulting in a major blowout is the dimensioning factor for this area.
Supplier	Contractor, vendor, supplier, manufacturer or manufacturer’s agent that supplies the equipment and is normally responsible for service support
SSU, safety and sustainability (functions)	A term replacing HSE for most purposes