# Prelude Floating LNG Project
## Draft Environmental Impact Statement

**Shell Development (Australia) Proprietary Limited**
**EPBC 2008/4146**

**October 2009**

## Disclaimer

This draft Environmental Impact Statement (EIS) has been prepared by Shell Development (Australia) Proprietary Limited (Shell) for submission to the Commonwealth Minister for Environment, Heritage and the Arts (the Minister) under the *Environment Protection and Biodiversity Conservation Act 1999*. The draft EIS has been prepared for this purpose only and no one, other than the Minister, should rely on the information contained in the draft EIS to make any decision. In preparing the draft EIS, Shell has relied on information provided by specialist consultants and other third parties who are identified in the draft EIS. Shell has not verified the accuracy or completeness of the information obtained from these sources, except where expressly acknowledged in the draft EIS.

## Copyright

## Acknowledgements

This draft EIS has been prepared in conjunction with an independent consultant, Environmental Resources Management (ERM), and specialist sub-consultants including the Centre for Marine Science and Technology, Curtin University; Centre for Whale Research; Deltares and specialists from ERM. Shell acknowledges the valuable contributions of these consultants.

## Invitation to Comment

Shell Development (Australia) Proprietary Limited (Shell) proposes to develop the Prelude petroleum reserves within Exploration Permit WA-371-P. The Prelude FLNG Project is located in Commonwealth waters approximately 200 kilometres offshore northwest Western Australia, in the northern Browse Basin.

The Project will be carried out using a Floating Liquefied Natural Gas (FLNG) facility designed to extract and process natural gas and associated condensate, thereby avoiding the need for a "traditional" development comprising offshore platforms, export pipelines, an onshore liquefaction plant and export jetty. The Prelude FLNG Project is scheduled to commence production in 2016 with an estimated operational life of 25 years. Annual production is estimated to peak at 3.6 million tonnes of LNG, 1.3 million tonnes of condensate and 0.4 million tonnes of Liquefied Petroleum Gas.

The Commonwealth Minister for the Environment, Heritage and the Arts has determined that the Prelude FLNG Project is a controlled action under the *Environment Protection and Biodiversity Conservation Act 1999* (*EPBC Act*). It was determined that an Environmental Impact Statement (EIS) would be required for the proposal. The controlling provisions under the *EPBC Act* are:

- sections 18 and 18A (listed threatened species and communities);
- sections 20 and 20A (listed migratory species); and
- sections 23 and 24A (marine environment).

Shell has prepared a draft EIS for the Prelude FLNG Project in accordance with Part 8 of the *EPBC Act*. The draft EIS covers the drilling, installation, commissioning, operation, maintenance and decommissioning phases of the project.

## Viewing the Draft EIS

Copies of the draft EIS will be held for viewing at the following locations:

- Broome Public Library, Cnr Haas and Hamersley St, Broome
- Derby Public Library, Clarendon St, Derby
- The Department of Industry and Resources, 1st Floor, 100 Plain St, East Perth
- Battye Library, Alexander Library Building, 25 Francis St, Perth
- Northern Territory Library, Bennett St, Darwin
- DEWHA Library, John Gorton Building, King Edward Terrace, Parkes, Canberra

Copies of the draft EIS are also available from Shell. Electronic copies of the draft EIS are available free of charge and may be downloaded from www.shell.com.au/prelude. Hard copies of the Executive Summary are available free of charge and hard copies of the full draft EIS are available for a charge of $20. Copies can be obtained by:

- Telephoning: 1800 037 298
- Emailing: SDA-Preludedrafteis@shell.com
- Writing to: Prelude Draft EIS, Shell Development (Australia) Pty Ltd, 250 St Georges Terrace, Perth WA 6000

## Submissions

Interested persons or organisations may make a written submission in relation to the draft EIS. Submissions may be in relation to general issues covered by the draft EIS or on specific elements of the Prelude FLNG Project. All submissions received by Shell will be acknowledged, and copies forwarded to DEWHA.

Submissions should:

- specify which chapter or section each point relates to;
- include factual and supporting information, including the source;
- specify whether you wish for your submission to remain confidential;
- provide personal details, including name and address, and identify any special interest that you have in the Prelude FLNG Project.

Unless the submission specifies that it is to be confidential, all submissions will be treated as public documents. Submissions may be referred to or quoted in the final EIS.

Submissions should be sent by e-mail or post to the above address.The draft EIS is available for public comment for a period of 30 business days and submissions close on **FRIDAY 20th NOVEMBER 2009.**

# FOREWORD

Thank you for taking the time to review the Draft Environmental Impact Statement for the Prelude Floating Liquefied Natural Gas (FLNG) Project.

This Project involves the extraction, liquefaction and sale of natural gas and condensate from the Prelude field located off the north west coast of Australia, some 475 km north-north east of Broome. As Operator and 100% equity holder of the WA-371-P exploration permit, Shell intends to develop the field in a timely, economic and environmentally sustainable manner.

The Prelude FLNG Project will be the first application of Shell's innovative FLNG technology as a means to develop a relatively small and remote gas field which would otherwise be uneconomic to develop. By locating the processing and liquefaction facilities directly over the gas field, there is no need for an offshore platform, a pipeline to shore, jetty and dredging for shipping or onshore construction. This not only reduces cost, but also reduces the environmental footprint of the project.

This Project is an example of how Shell is responding globally to what we call the "3 Hard Truths".

1. **Increasing energy demand** – the world continues to need more energy due to population growth and increasing standard of living in developing countries. LNG from Prelude will be exported to Asia providing cleaner energy to some of the highest growth rate countries in energy demand.
2. **No easy oil** – oil and gas is a finite resource and becoming increasingly difficult to find and develop, with new discoveries in deeper waters further offshore and often as smaller, separate finds. For Prelude, the FLNG solution enables access to an otherwise stranded gas resource.
3. **Carbon constrained world** – finding, developing and supplying energy needs to be done at a low carbon intensity to avoid worsening the impacts of climate change on our planet. LNG is an energy source that emits far less $CO_2$ for power generation than coal or fuel oil over the extraction to combustion lifespan.

The Prelude FLNG Project is a very exciting project for Shell in Australia:

- It is fast! The Prelude gas discovery was made in January 2007 and the project is expected to begin production in 2016, making it a fasttrack LNG development;
- It will be Shell's first application of FLNG technology, a solution which has the potential to unlock much of Australia's, and the world's, stranded gas assets;
- It has a low environmental footprint which is restricted to its location 200 km offshore, away from sensitive environmental receptors such as turtles, whales and the Kimberley coastline; and
- It will deliver economic benefits to the region and Australia through 25 years of operation, producing a valuable export commodity and employing Australians to operate and maintain the FLNG facility.

I encourage you to review this draft EIS and provide feedback on Shell's proposed Prelude FLNG Project. We look forward to hearing from you.

Jon Chadwick

**Jon Chadwick**
Shell's Executive Vice President, Upstream International - Australia

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# EXECUTIVE SUMMARY

## INTRODUCTION

The Australian Commonwealth Government awarded Shell Development (Australia) Proprietary Limited (Shell) Exploration Permit WA-371-P in January 2006, as a 100% equity holder. The title area is located in the Northern Browse Basin, a hydrocarbon province with major undeveloped gas fields. In November 2006, Shell commenced drilling activities and in January 2007 discovered the Prelude field.

*Figure ES.1 Location of Prelude FLNG Project (Exploration Permit Area WA-371-P)*

Shell proposes to develop the Prelude field using a Floating Liquefied Natural Gas (FLNG) Facility which will produce, liquefy and export the gas resource in line with the Australian Offshore Petroleum Development policy. This project is named the 'Prelude FLNG Project'. The proposed Prelude FLNG Project is located approximately 200 km offshore northwest Australia and 475 km north-northeast of Broome (see *Figure ES.1*).

The purpose of the draft Environmental Impact Statement (EIS) is to provide the regulator the information required to assess the proposal against the requirements of the *Environment Protection and Biodiversity Conservation Act 1999* (*EPBC Act*), to inform the general public about the proposal, and to demonstrate that the potential negative impacts of the proposed project are addressed and potential positive benefits maximised. The draft EIS:

- presents details of the Prelude FLNG Project concept;
- describes the physical, biological and human components of the environment where the Project will be located. This includes technical studies (including modelling where appropriate), literary reviews, collection of primary data and stakeholder consultation;
- identifies and assesses potential environmental or socio-economic impacts associated with the proposed Project using accepted Impact Assessment methodologies;
- defines mitigation and management measures to minimise any potential adverse impacts; and
- demonstrates compliance with the *EPBC Act*.

## SHELL DEVELOPMENT (AUSTRALIA)

The project proponent and title holder of Exploration Permit WA-371-P is Shell Development (Australia) Proprietary Limited (Shell), a subsidiary of Royal Dutch Shell plc[1] which is a major global energy organisation employing around 3,000 people in Australia. The Australian organisation is divided broadly into 'upstream' and 'downstream' businesses. The upstream business is based in Perth, Western Australia and finds, develops and supplies Liquefied Natural Gas (LNG), condensates and Liquefied Petroleum Gas (LPG) to overseas markets, and natural gas to domestic customers.

Shell is committed to sustainable development and to produce energy responsibly. This means helping meet the world's growing need for energy in economically, socially and environmentally responsible ways.

Shell has a comprehensive set of policies, standards and procedures for managing its projects and operations with consideration of environmental matters. Shell's policy and commitment to Health, Safety and Environment (HSE) includes a commitment to 'pursue the goal of no harm to people' and to 'protect the environment'. Shell's activities in Australia are managed in line with the Shell Group global HSE policies, standards and procedures.

Shell's approach to Responsible Energy can be found at: http://www.shell.com

Shell's commitments and standards are available at: http://www.shell.com/home/content/responsible_energy/integrated_approach/our_commitments_and_standards/dir_commitments_standards.html

The most recent Shell Group Sustainability Report is available at: http://www.shell.com/home/content/responsible_energy/sustainability_reports/dir_shell_sustainability_reports.html

Shell's HSE philosophy in Australia can be found at: http://www.shell.com/home/content/au-en/about_shell/2008/environment_and_society/people_and_enviro.html?LN=/leftnavs/zzz_lhn2_4_2.html

## LEGAL REQUIREMENTS & STANDARDS

The Prelude FLNG Project will be located in Australian Commonwealth waters. The primary environmental legislation relating to its approval is the Commonwealth *EPBC Act* and the accompanying EPBC Regulations, 2000. The *EPBC Act* is administered by the Commonwealth Minister for the Environment, Heritage and the Arts. This draft EIS has been prepared in accordance with Guidelines issued for the Project by DEWHA and in accordance with the provisions of the *EPBC Act*. These requirements, together with other relevant Australian and international guidance and regulations, and Shell's own Policies, Standards and Guidelines, have been taken into consideration in the Prelude FLNG Project design and draft EIS.

Compliance with relevant environmental and social performance standards and draft EIS commitments will be implemented through the Prelude Health Safety and Environment Management System (HSE-MS). Safety requirements are addressed separately in accordance with National Offshore Petroleum Safety Authority (NOPSA) requirements[2].

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[1] *Royal Dutch Shell plc and the companies in which it directly or indirectly owns investments are separate and distinct entities. In this publication, the collective expressions 'Shell' and 'Shell Group' may be used for convenience where reference is made in general to those companies. Likewise, the words 'we', 'us', 'our', and 'ourselves' are used in some places to refer to the companies of the Shell Group in general. These expressions are also used where no useful purpose is served by identifying any particular company or companies.*

[2] *NOPSA is a Statutory Agency regulating Commonwealth, State and Territory coastal waters with accountability to the relevant Ministers. The role of NOPSA is to administer offshore petroleum safety legislation.*

# PRELUDE FLNG PROJECT

## *Overview*

The objective of the Prelude FLNG Project is to produce, liquefy and export the gas resources of the Prelude field to help meet growing global energy demands.

## *Project Concept and Design*

The FLNG concept provides a technically innovative solution for the development of the small and remote Prelude field in a cost-effective and environmentally and socially sound manner. By floating the LNG facility, the Prelude FLNG Project avoids the need for a "traditional" onshore development scenario that would ordinarily comprise offshore platform(s), export pipeline(s), an onshore liquefaction plant, export jetty and the associated facility preparation works including coastal dredging. The Prelude FLNG Project will comprise:

- A steel, double-hulled floating facility, approximately 480 m in length by 70-80 m wide. On this substructure the gas receiving, processing (treating, separation and liquefaction), storage and offloading equipment will be mounted. The facility also contains other associated components such as the control room, maintenance areas and accommodation. It will be designed to produce 3.6 million tonnes per annum (mtpa) of LNG, plus LPG and condensate for export.
- Upstream facilities including subsea production wells and manifolds; subsea flowlines; riser base manifolds; flexible risers that transport the gas, condensate and any produced formation water to the FLNG facility; and, umbilicals used to control the wells and associated facilities.

The proposed Prelude FLNG facility will be the first of its kind to be deployed in Australia. In concept, the FLNG facility will be similar to existing Floating Production, Storage and Offloading (FPSO) facilities used for production of hydrocarbons. The main design elements of the FLNG facility are:

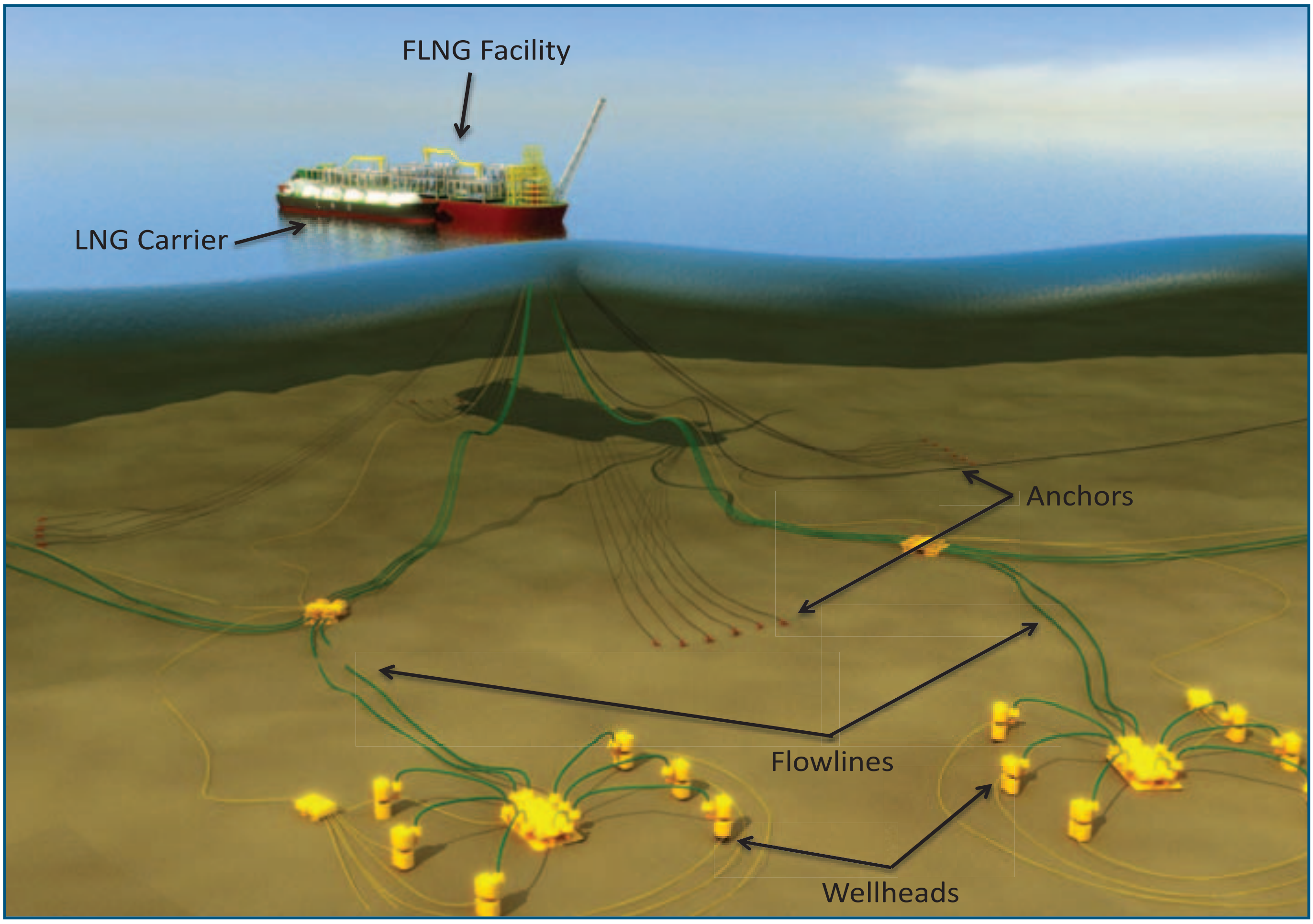
- Gas will reach the facility from seafloor wellheads via flowlines for processing on the facility topsides where the gas is treated to remove acid gases such as carbon dioxide and hydrogen sulphide, impurities, and water.
- A refrigeration plant will then cool the gas to separate out heavier hydrocarbons, which form condensate and LPG. Cooling continues until the natural gas reaches a temperature of minus 162°C, at which point it becomes a liquid and is transferred to insulated tanks within the FLNG facility to be stored at near atmospheric pressure.
- Cooling requirements for processing of the gas will require approximately 50,000 $m^3$/hr of seawater which will be taken from a depth of around 150 m below sea level.
- Power requirements will be met by steam boilers. The steam will drive compressors and electrical generators and also provide process heat requirements.
- LNG and LPG tankers will moor alongside the FLNG facility. Hard loading arms with swivel joints and quick connect/disconnect flanges will be used for transferring the LNG and LPG products to the tankers. Condensate tankers will be moored astern of the FLNG facility and condensate transferred by a floating hose as per standard industry practice for FPSOs.
- The FLNG facility will not disconnect during bad weather and is designed to withstand severe weather including a 1 in 10,000 year weather event. The facility will be held in position by four groups of six anchor chains, arranged around the FLNG turret. The chains are secured by suction piles which penetrate deep into the seabed.

*Figure ES.2* provides an indicative illustration of the proposed FLNG facility and associated infield infrastructure.

## *Prelude FLNG Project Schedule*

Front-End Engineering and Design (FEED) for the project is expected to begin in the second half of 2009 with the Financial Investment Decision (FID) scheduled for early in 2011. From the FID it will take approximately five years for the FLNG facility to be constructed and then towed to location. Whilst the facility is being built, the subsea production wells will be drilled and the infrastructure installed in time to supply gas to the FLNG facility on its arrival at the field.

*Figure ES.2 Illustration of the Proposed FLNG Facility and Associated Infield Infrastructure*



The development drilling program is expected to take approximately two years, commencing in 2013. An indicative timeline for the project is provided in *Table ES.1*.

*Table ES.1 Indicative Project Timeline*

| Project Phase | Target Date |
|---|---|
| Development drilling | 2013 |
| Subsea construction | 2014 |
| FLNG facility construction and delivery to field | 2015 |
| Commissioning | 2015 |
| First gas | 2016 |
| Decommissioning | 2040 |

### *Prelude FLNG Project Stages*

The key elements of the Prelude FLNG Project included in the draft EIS are:

- development well drilling;
- subsea structure installation;
- tow-out and hook up of the FLNG facility;
- commissioning;
- operations; and
- decommissioning.

Onshore support facilities required during construction, commissioning and operation will be located in the existing ports of either Broome or Darwin and established in existing industrial areas. The operation of these onshore facilities will be subject to consideration under the Western Australian State or Northern Territory government planning and approvals processes (as applicable) and are outside the scope of the draft EIS.

The FLNG facility will be constructed and commissioned at a Korean Shipyard. The overseas construction of the FLNG facility is outside the scope of the draft EIS.

### *Prelude Activities and Environmental Aspects*

A summary of key infield installation, commissioning, operation, maintenance and decommissioning activities are described in *Table ES.2*. For each of these activities the key environmental aspects are described. These have been addressed in detail in the draft EIS.

*Table ES.2 Summary of Key Activities and Associated Environmental Aspects for the Prelude FLNG Project*

| Prelude FLNG Project - Key Activities | | |
|---|---|---|
| **Infield Installation Activities** | | |
| **Activity** | **Key Details** | **Environmental Aspects** |
| Development Drilling | • Mobile Offshore Drilling Unit drills 8 production wells over 2 year period<br>• Water and synthetic based muds<br>• Flaring for 1 to 2 days per well during completion | • Drill cuttings (approximately 1,000 $m^3$ per well) disposed overboard<br>• Water based drill mud disposal to sea upon completion of well drilling program. Synthetic based mud as coating on drill cuttings (approximately 36 $m^3$ per well)<br>• Atmospheric emissions from flare<br>• Noise emissions<br>• Light emissions<br>• Disturbance of seabed |
| Installation of Subsea Facilities<br>FLNG Hook Up | • 8 wells tied back to the manifolds and connected to FLNG facility via 4 x 4 km flowlines<br>• Footprint size of 4 anchor grouping is approx. 150 $m^2$<br>• Risers and umbilicals connect subsea facilities to FLNG facility. Duration of FLNG installation and hook up approximately 6 months<br>• 500 m exclusion safety zone extending from the outer edge of the FLNG facility and subsea infrastructure | • Physical disturbance of seabed (approximately 8,000 $m^2$) |
| Vessel Activities (including towing FLNG facility to site) | • Tugs, pipe lay /crane vessel<br>• Remotely Operated Vechicles with support vessel<br>• Riser and umbilical installation vessels | • Energy usage – fuel<br>• Atmospheric emissions<br>• Noise and light emissions<br>• Discharge of ballast and bilge water |
| **Commissioning Activities** | | |
| **Activity** | **Key Details** | **Environmental Aspects** |
| Logistical support | • Supply vessels (weekly)<br>• Helicopter flights (average 2 return per day) | • Atmospheric emissions<br>• Physical presence of vessels and helicopters<br>• Ballast water<br>• Bilge water and drainage water<br>• Noise and light emissions |
| Hydrotesting and dewatering of flowlines and FLNG facility pipe work | • Seawater, corrosion inhibitor, biocide and MEG | • Hydrotest water discharge |
| **Operation and Maintenance Activities** | | |
| **Activity** | **Key Details** | **Environmental Aspects** |
| Logistical support | • 1 supply vessel call per 1 to 2 weeks<br>• 1 vessel on standby at FLNG facility and 1 in port<br>• 6 return helicopter flights per week<br>• 500 m exclusion zone | • Noise and light emissions<br>• Ballast water<br>• Atmospheric emissions |

*Table ES.2 Summary of Key Activities and Associated Environmental Aspects for the Prelude FLNG Project (Continued)*

| Prelude FLNG Project - Key Activities | | |
|---|---|---|
| **Operation and Maintenance Activities** | | |
| **Activity** | **Key Details** | **Environmental Aspects** |
| Well, infield flowline and flexible riser operations<br>FLNG facility operations | • Subsea control fluid – water based<br>• Life of field – 25 years<br>• Design capacity of 3.6 mtpa LNG, 0.4 mtpa LPG and 1.3 mtpa condensate | • Estimated discharge volume of Subsea control fluid is 23 $m^3$ per year<br>• Noise emissions<br>• Light emissions<br>• Produced formation water and drainage water discharge<br>• Cooling water discharge (7.5˚C to 16˚C above ambient seawater temperature with residual chlorine concentration – 0.2 ppm)<br>• Estimated atmospheric emissions – $CO_2$ – 2,300,000 tpa, $H_2S$ – 171 tpa, NOx – 2,278 tpa, VOC – 1,799 tpa<br>• Waste – hazardous and non hazardous solid wastes returned to shore<br>• Sewage/grey water |
| Export shipping | • LNG carriers weekly<br>• LPG tankers monthly<br>• Condensate tankers once per fortnight<br>• 2 Standby tugs | • Ballast water discharge<br>• Accidental spillages<br>• Noise and light emissions |
| Maintenance activities | • Maintenance of wells and the FLNG facility on an estimated 4 year cycle | • Noise emissions<br>• Light emissions<br>• Atmospheric emissions |
| **Decommissioning Activities** | | |
| **Activity** | **Key Details** | **Environmental Aspects** |
| Flushing of subsea flowlines<br>Capping of wells<br>Removal and towing of FLNG facility | • Flush flowlines until oil-in-water below 30 mg/l<br>• Wells will be plugged with cement<br>• Flowlines and manifolds removed if required<br>• Tugs and Supply vessels | • Treated on FLNG Facility prior to discharge<br>• Physical presence<br>• Air emissions<br>• Noise and light emissions |

## *Alternatives Considered*

Shell examined a range of alternatives to develop the Prelude field including 'do nothing', a traditional onshore LNG plant at a number of proposed locations and the technically innovative offshore FLNG solution. The preferred outcome of the assessment was FLNG as it offered:

- the lowest environmental footprint;
- a lower development cost; and
- flexibility to subsequently relocate the FLNG facility to other fields.

The application of FLNG technology for the Prelude FLNG Project could provide the catalyst for the development of other small, remote gas fields (often referred to as stranded gas assets) that are otherwise difficult to develop commercially with conventional solutions.

## *Possible Future Expansion or Modification*

The FLNG facility is designed to operate in the field for 25 years with the Prelude production period dependent upon the actual volume of reservoir gas. When the pressure reduces in the Prelude field as gas is produced, the decline in production rate may be backfilled by tiebacks from other gas sources in the region in order that the FLNG facility continuously operates efficiently at full throughput. Exploration is still underway but likely backfill gas sources are the nearby Concerto field, the Crux field and the Libra field. Such tiebacks would be the subject of a separate environmental approvals process to cover their field development.

## CONSULTATION

Consultation for the Prelude FLNG Project has been conducted to meet the Commonwealth's expectations for an EIS level assessment and is in accordance with Shell's requirements. Key stakeholders included in the consultation process to date are government, Non-Government Organisations, businesses, residents, industry and indigenous groups. Key stakeholder interests include but are not limited to:

1) Project economics.
2) Health, safety and the environment.
3) Greenhouse gas emissions.
4) Employment and business opportunities.

Stakeholder engagement and consultation is an integral part of Shell's project development process, helping to inform business decisions and identify issues that require action. Shell has internal policies and processes that outline the requirements of stakeholder engagement. These are underpinned by the Shell Group's General Business Principles that govern how Shell conduct its affairs.

Stakeholder engagement is a key element of a project Impact Assessment process. The Prelude FLNG Project has adopted a systematic process starting with issues analysis, leading to stakeholder identification, development of a Stakeholder Engagement Plan and development of stakeholder relationships and partnerships through a variety of engagement methods.

Stakeholders identified for the Prelude FLNG Project comprise individuals and organisations including federal government, state and territory governments, non-government organisations (NGOs), local businesses and residents, industry representative organisations, indigenous representative groups and academia.

Since 2007, Shell has conducted three main 'waves' of engagement, broadly held in line with the EIS process (after the discovery of the field, after submission of the Environmental Referral and prior to the draft EIS submission). In addition to these engagements there have been separate briefings with specific stakeholders, either as a one-off on a particular issue or as regular updates for those stakeholders with a high level of interest in the Project. For example, the NOPSA and the Australian Maritime Safety Authority (AMSA) have been regularly briefed on the design and operation of the FLNG facility.

An overview of the issues raised by government and industry representatives includes:

- tax revenues (onshore versus offshore);
- project milestones and economics;
- integration with other Browse Developments;
- safety of the FLNG facility;
- security of the FLNG facility;
- domestic gas possibilities;
- carbon dioxide management; and
- Shell's evaluation of onshore facility locations.

Representatives of community organisations and NGOs including the Kimberley Land Council, Kimberley Development Commission, Environs Kimberley, Save The Kimberley, Shire of Broome and World Wildlife Fund had questions similar to those raised by government but also have interests relating to:

- onshore facilities, workforce opportunities (including fly-in fly-out) and accommodation requirements in Broome;
- potential environmental impacts eg cooling water management, carbon dioxide emissions, waste management;
- indigenous opportunities eg employment;
- safety, with regard to increased vehicle and air movements, and emergency response procedures;
- opportunities for local businesses; and
- issues associated with exploration activities eg number of drilling wells and location of activities offshore.

### *Future Engagement*

Stakeholder engagement will continue to help inform and guide development planning for the Prelude FLNG Project. This will include systematic engagement on the relevant aspects of:

- the environmental impact of the proposed Prelude FLNG Project;
- the decision on the location of the onshore Maintenance Workshop;
- the hydrocarbon recovery and Field Development Plan;

- the decision for the project to enter the FEED phase;
- identifying possible partnerships and opportunities for Shell's Social Performance Plan for the Prelude FLNG Project;
- safety and security of the FLNG facility; and
- maximising the amount of employment opportunities the Project will generate for Australia eg through the development of an Australian Industry Participation Plan.

## ENVIRONMENTAL & SOCIAL CONTEXT

The draft EIS describes the environmental and social context (or baseline) of the Prelude FLNG Project including physical environment, local and regional ecosystems, communities and habitats, key flora and fauna species and the social and cultural environment.

### *Physical Marine Environment*

The physical marine environment of the project area is typical of the North West Shelf. Literature review and baseline assessment confirmed the following characteristics:

1) A subtropical climate with a distinct monsoon season where cyclones generally occur between December and April. Sea wave heights during extreme cyclones are recorded up to 7 m.
2) Sea surface temperatures range between 27°C and 30°C and in deeper waters (~150 m) are approximately 19°C.
3) The sea floor comprises of fine clays, muds and sands. No reefs or areas of rocky substrate are known within the Project area.
4) Offshore North West Shelf waters are typically low in nutrients. Low nitrate concentrations and low phytoplankton abundance were measured in the project area (July 2008).

The Prelude FLNG Project is located in waters approximately 250 m deep. There are no significant topographical features or changes to seabed bathymetry in the project area. Browse Island is the nearest feature of significance, located approximately 40 km south southeast of the project area. Other islands/reefs in the region include Scott Reef and Sandy Islet (approximately 140 km southwest), Seringapatam Reef (approximately 80 km west) and Ashmore Reefs and Cartier Island (approximately 140 km north).

National and multinational oil companies have undertaken petroleum activities, including seismic surveys and exploratory drilling, in the Browse Basin for four decades.

### *Ecosystems, Communities and Habitats*

Key ecosystem characteristics of the project area are:

1) No reefs, seagrass or algal beds or islands occur within the project area.
2) There are Humpback Whale migration routes and calving areas within the region, however these are a considerable distance away from the project area, nearer the coast.
3) Pygmy Blue Whales are known to transit through the region but there are no known aggregation areas in or near the project area.
4) The closest turtle breeding area to the project area is Browse Island, 40 km south southeast.
5) There are bird migration routes within close proximity to the project area but no nesting sites.

General regional and local characteristics related to ecosystem, communities and habitat are described in *Table ES.3*.

### *Key Flora and Fauna Species*

Regionally, offshore north west Australia supports a variety of species including whales, dolphins, sharks and turtles. Vulnerable, endangered and migratory species listed under the *EPBC Act* that occur in the region include the Humpback Whale, Blue Whale, Green and Flatback turtles and several species of migratory birds. While some of these species are present in the region in significant numbers, none have any specific dependence on the project area. Low densities of migratory shorebirds and seabirds protected under the Japanese-Australia Migratory Bird Agreement (JAMBA), China-Australia Migratory Bird Agreement (CAMBA) and Republic of Korea-Australia Migratory Bird Agreement (ROKAMBA) bilateral agreements may also pass through the project area. A summary of key species is provided in *Table ES.4*.

*Table ES.3 Characteristics Related to Ecosystems, Communities and Habitats*

| Characteristics | Description |
|---|---|
| Sound | Natural underwater sounds are produced by wind, waves, currents, rain, echo-location and communication noises generated by cetaceans. Fish choruses, vessel and seismic survey noises were also recorded during investigations. |
| Plankton | Phytoplankton were found to be highly diverse but low in abundance. Overall densities of crustacean assemblages were relatively low. |
| Macrobenthos | Macrobenthos (organisms which live within the seabed sediments) was found to be high in diversity of species but low in abundance. |
| Corals | Offshore atolls and fringing reefs around Browse Island support major assemblages of reef building corals but there are no known shallow coral reefs present within the WA-371-P title area. |
| Seagrasses and Macroalgae | The average depth of the project area precludes the occurrence of seagrasses and macroalgae. |
| Existing and proposed Marine Protected Areas | There are no known areas of environmental significance in the immediate vicinity of the project area. No endangered or vulnerable species reside permanently in the project area, although some pass through on migratory routes. Browse Island, located 40 km away, is a Western Australian Class C Reserve (No. 22697) vested with the Conservation Commission under DEC control. The Island is a regionally important turtle and bird nesting site and is surrounded by coral reefs. |
| Key flora and fauna species | See *Table ES.4* |

### *Socio-Economic and Cultural Environment*

The project area is located in open ocean and there are no known cultural or heritage issues associated with the Prelude FLNG Project.

The project area may be traversed by mariners and fishermen but the area does not appear to overlap with any known sea lanes or active fishing grounds.

The project area lies within the area that allows access rights for traditional Indonesian fishers to continue customary practices to harvest species such as trepang, trochus, abalone and sponges in Australian waters. These traditional fishers fish in shallow waters so they are only found in deepwater areas during transit to and from reef locations, so are unlikely to be affected by the Prelude FLNG Project.

Tourism is significant along the coast of the Kimberley from Exmouth to Broome. Whilst charter fishing companies frequent the broader region there are no known tourist attractions or destinations within the project area.

## POTENTIAL IMPACTS

### *Overview*

Identifying impacts starts in the earliest phases of the project design and continues through the lifecycle of the project. The Impact Assessment methodology undertaken during the draft EIS provides a robust process for:

- identification of potential impacts;
- prediction of the significance of an impact;
- development of mitigation and/or management measures; and
- monitoring and reporting the effectiveness of the proposed mitigation measures.

### *Key Impacts*

The *EPBC Act* defines a ‘significant impact’ as an impact which is important, notable or of consequence, having regard to its context or intensity. Whether or not an action is likely to have a significant impact depends upon the sensitivity, value and quality of the environment which is impacted, and upon the intensity, duration, magnitude and geographic extent of the impacts.

*Table ES.4* *Key Species of Fauna*

| Species | Importance[3] | Species Information |
|---|---|---|
| Humpback Whale (*Megaptera novaengliae*) | *EPBC Act* – Vulnerable<br>IUCN – Least concern | Whales migrate seasonally through the waters of northwest Australia from Antarctic summer feeding grounds to winter calving grounds off the Kimberley coast. Calving grounds are south of the project area near the coast. Humpback whales have been sighted inside the Browse Basin study area where water depths are approximately 250 m. Core migration routes tend to be closer to the shoreline as shown in *Figure ES.3*. |
| Blue Whale (*Balaenoptera musculus*) (Two sub-species occur in Australian waters, the southern hemisphere `true' blue whale (*Balaenoptera musculus intermedia*) and the `pygmy' blue whale (*Balaenoptera musculus brevicauda*). | *EPBC Act* – Endangered<br>IUCN – Critically Endangered ('true' blue whale) | Information on migratory patterns and feeding/calving areas is limited. Indications suggest that the western WA continental slope, from the Perth Canyon towards the Indonesian Archipelago, is a likely migratory path between feeding areas in the south and an undetermined northern calving area. Perth Canyon off Rottnest Island is the only recognised feeding area for blue whales in Western Australia (December to April). No sightings of 'true' blue whales in the project area have been made during surveys, although pygmy blue whales have been spotted and recorded on noise loggers. |
| Australian Snubfin Dolphin (*Orcaella heinsohni*) | *EPBC Act* – Migratory<br>IUCN – Near Threatened | Snubfin dolphins occur in shallow, tropical and subtropical areas up to 20 km from shore. The species has been reported to occur in WA from Broome (18°S) northward. Abundance and distribution are little known, particularly along the West Kimberley Coast region. No key localities, including calving areas, are known in Australian waters. |
| Indo-Pacific Humpback Dolphin (*Sousa chinensis*) | *EPBC Act* – Migratory<br>IUCN – Near Threatened | Distribution in Australia extends south to Ningaloo Reef on the west coast. These dolphins inhabit coastal, estuarine and occasionally riverine environments. The species occurs close to the coast, generally in less than 20 m depth. Information on the biology and ecology of the species in Australian waters is limited. No calving areas are known in Australian waters. |
| Green Turtle (*Chelonia mydas*) | *EPBC Act* – Vulnerable<br>IUCN – Endangered | The North West Shelf is one of the four major breeding units recognised in Australia. Nesting in the region occurs between approximately October and February each year, with adult females laying an average of five clutches per breeding season, each approximately 14 days apart. The nearest known turtle breeding, nesting, or feeding grounds are located 40 km to southeast of the project area on Browse Island. The island represents a regionally important turtle nesting site for green turtles. |
| Flatback Turtle (*Natator depressus*) | *EPBC Act* – Vulnerable<br>IUCN – Data Deficient | Flatback turtles are found only in the tropical waters of northern Australia, Papua New Guinea and Indonesia. Nesting is only known to occur in Australia, with six major aggregations recognized, including the Kimberley region. Nesting sites are widely distributed along the mainland coast of the Pilbara and Kimberley, and among offshore islands. Flatback turtles make long reproductive migrations similar to other species of sea turtles, although these movements are restricted to the continental shelf. Nesting in the region occurs mainly in December and January. The project area does not contain any habitats that would be frequented by Flatback turtles. |
| Whale Shark (*Rhincodon typus*) | *EPBC Act* – Vulnerable<br>IUCN – Vulnerable | Relatively limited information is available on population trends. Whale sharks have a broad distribution in tropical and warm temperate seas, both oceanic and coastal. In Australia, whale sharks are known to aggregate seasonally in coastal waters off Ningaloo Reef (March-July)and to a lesser extent at Christmas Island (December-January) and in the Coral Sea (November-December) for feeding. There are no known mating areas in Australian waters. Limited satellite tracking data collected by CSIRO suggests that whale sharks may migrate through the project area, however, there are no oceanographic features in the vicinity of the project area which could encourage feeding aggregations. |
| Streaked Shearwater (*Calonectris leucomelas*, also known as *Puffinus leucomelas*) | *EPBC Act* – Listed<br>IUCN – Least Concern | The Streaked Shearwater is a broadly distributed pelagic species which breeds and nests only in Japan and its offshore islands. After breeding, the Streaked Shearwater will migrate toward southern Australia and may pass through the project area. |
| JAMBA, CAMBA and ROKAMBA species | JAMBA, CAMBA and ROKAMBA | Fifty-four species of migratory shorebirds are known to utilise the East Asian-Australasian Flyway (EAAF), en route to 119 internationally important sites in Australia. *Figure ES.4* illustrates the locations of the internationally important shorebird sites in north western Australia in the context of these major flight paths. Low densities of migratory shorebirds and seabirds protected under the JAMBA, CAMBA and ROKAMBA bilateral agreements may pass through the project area. |

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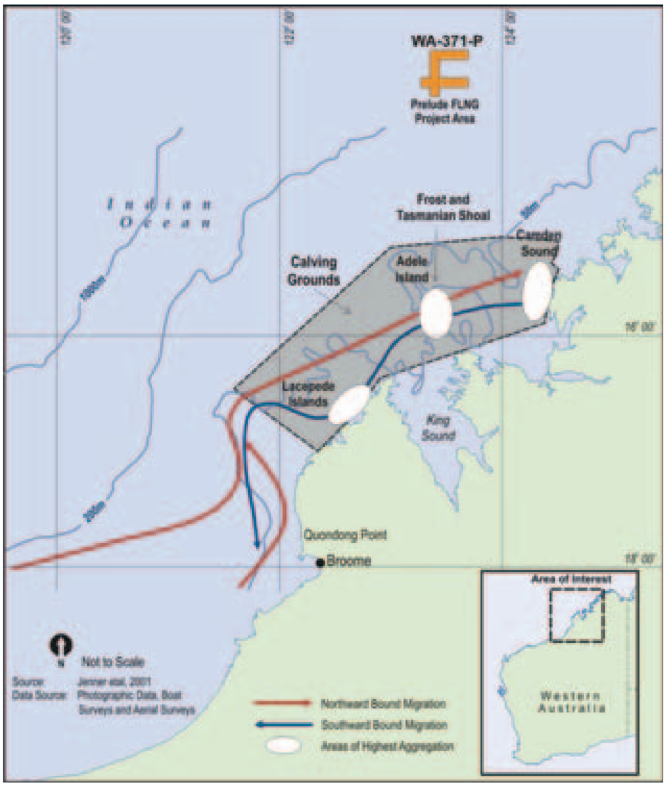
[3] *Details and definitions of IUCN Classifications can be found at:* http://www.iucnredlist.org/static/categories_criteria

*Figure ES.3 Humpback Whale Calving Ground and Migratory Routes*



*Source: Jenner et al. 2001*

The DEWHA (2006) Significant Impact Guidelines set out criteria to assist in the determination of significance, with specific reference to matters of National Environmental Significance (NES). These guidelines have been used in assessing magnitude and each relevant impact has been specifically assessed against them.

For potential impacts associated with the Prelude FLNG Project, the significance of each impact is determined by assessing the impact magnitude against the likelihood of the impact occurring, as summarised in the impact significance assessment matrix (*Figure ES.5*).

Impacts evaluated as Moderate, Major and Critical require the adoption of management or mitigation measures to avoid or reduce them to 'as low as reasonably practical' (ALARP).

Potential impacts resulting from all phases of the Prelude FLNG Project lifecycle were assessed. These are summarised in *Table ES.5*. The summary table provides a brief description of the:

- *Activity* – what is it that has the potential to result in an impact? Such as physical presence, air emissions or liquid waste.
- *Receptor* – what is the environmental and socio-economic component that is susceptible to impacts? Such as the seafloor (physical), migratory species (biological) or revenue from commercial fishing (socio-economic).
- *Description of a Potential Impact* – what may occur as a result of an interaction between a specific activity and receptor, such as the presence of subsea infrastructure disturbing the physical seabed?
- *Impact Significance* – categorised as Minor, Moderate, Major and Critical for each stage of the project life cycle defined as offshore **construction, commissioning, operation and maintenance** (including support and logistics) and **decommissioning**.
- *NES Significance* – a statement regarding whether each evaluated impact is considered to trigger the *EPBC Act* definition of significance in regards to matters of NES (*Section 18* and *18A*: Listed threatened species and communities; *Section 20* and *20A*: Listed migratory species; and, *Section 23* and *24A*: Commonwealth marine environment).

**No negative impacts associated with the Prelude FLNG Project have been categorised as Major or Critical**, meaning that all impacts were assessed as either:

- **Minor** - impacts can be managed through effective standard operating procedures; or
- **Moderate** - impacts can be mitigated to ALARP through the implementation of conventional mitigation measures.

Impacts that were assessed as **Moderate** are summarised as follows:

- Disturbance to the seabed through development drilling, the establishment of subsea infrastructure and during the construction phase is assessed as a **Moderate negative** impact. The potential impacts associated with these activities have been reduced by:
  - the selection of FLNG over the alternative development option; and
  - drilling impacts will be managed to ALARP by the application of standard industry drilling practices.
- Greenhouse gas emissions have been assessed in an Australian context as a Moderate negative impact during the operations phase. The FLNG facility is

*Figure ES.4 Internationally Important Shorebird Sites and Potential Shorebird Flight Pathways.*

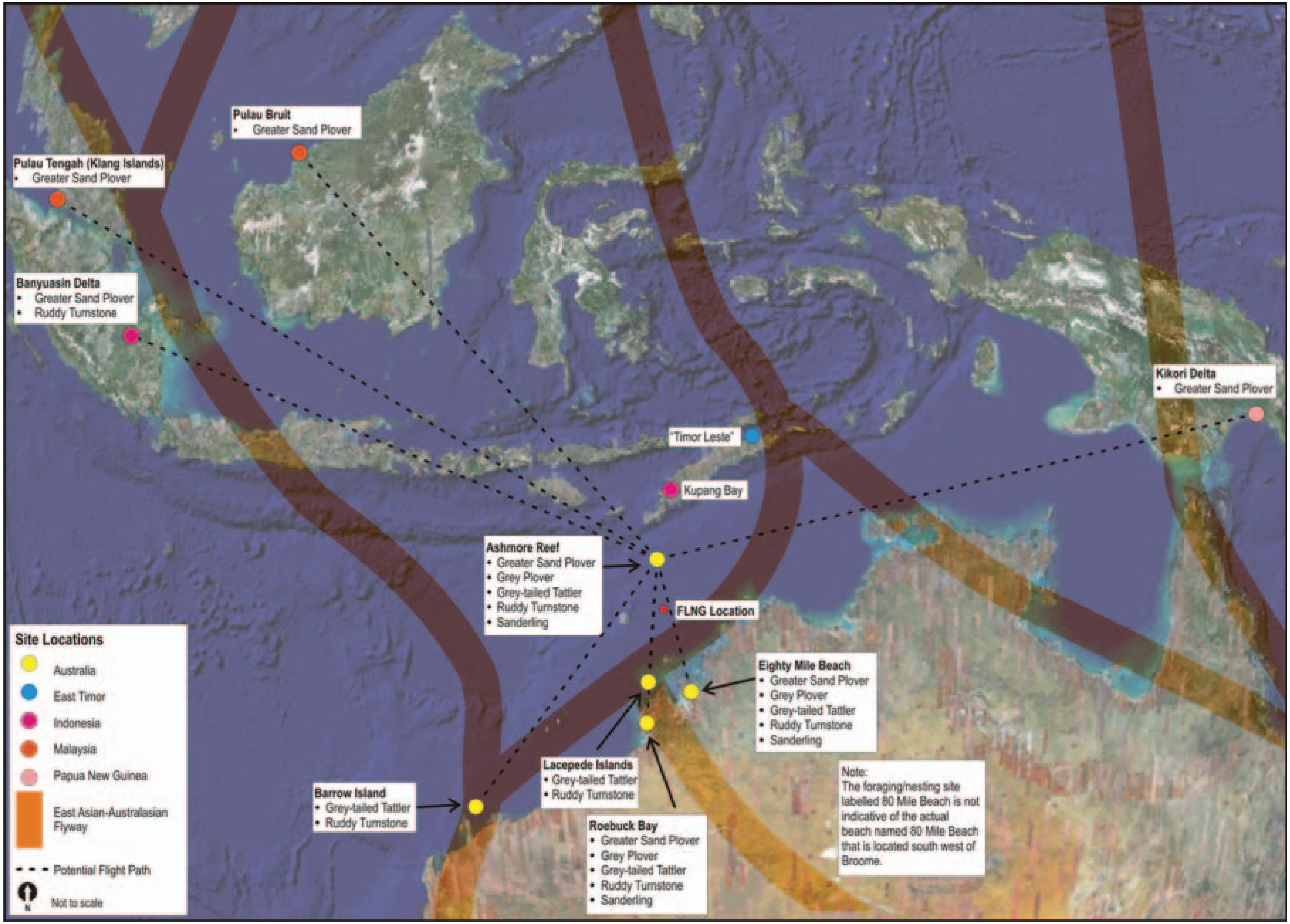


*Figure ES.5 Environmental, Social & Health Impact Significance Assessment Matrix*

| | | Likelihood | | | |
|---|---|---|---|---|---|
| | | Unlikely | Possible | Probable | Certain |
| Magnitude | Low | Minor | Minor | Moderate | Moderate |
| | Medium | Minor | Moderate | Moderate | Major |
| | High | Moderate | Moderate | Major | Critical |

15 - 25% less $CO_2$ intensive than a conventional onshore LNG plant but still has a carbon footprint of 2.3 mtpa of GHG gases emitted at full throughput.

- Economic impacts were assessed as a Moderate positive impact as the Prelude FLNG Project could directly create more than 500 jobs in Australia during the drilling and construction phases and 320 direct jobs for 25 years during the operational phase. Most of the operational jobs will be held by Fly-In, Fly-Out workers on the FLNG facility. The project is also expected to employ maintenance staff and logistics personnel in Broome and/or Darwin. Indirectly, the project can be expected to support employment in local small business and revenue for local merchants and service suppliers.

### *Cumulative Impacts*

Given the lack of existing development in the area, the Prelude FLNG Project is not anticipated to give rise to cumulative effects at a local scale. Regionally, cumulative socio-economic impacts may arise as higher levels of boat and small aircraft movements between Broome or Darwin and offshore destinations, and higher passenger levels at Broome airport. However, in view of the number of vessel and passenger movements involved, the overall cumulative impact of the project is anticipated to be minor. The Prelude FLNG Project will not give rise to significant cumulative impacts to EPBC listed species, migratory species or the marine environment.

$CO_2$ emissions from the Prelude FLNG Project contribute to total Australian emissions. The effects of global warming and associated climate change are the cumulative effect of many such sources across the globe and it is the cumulative effects that ultimately bring about climate change. Whilst $CO_2$ emissions from the Prelude FLNG project have been assessed as a moderate impact, the FLNG facility incorporates a number of technological and process efficiencies which results in an energy efficient LNG plant design and the Prelude FLNG Project has been designed and developed in anticipation of a GHG emissions cap and trade scheme. The costs associated with GHG emissions generated by the Prelude FLNG project have formed part of the criteria for assessing process and equipment selection.

## IMPACT MITIGATION, MANAGEMENT & MONITORING

### *Overview*

Shell's approach to the ongoing management of potential impacts to ALARP levels through the life cycle of the Prelude FLNG Project can be summarised as follows:

- Design Mitigation Measures: Avoiding or reducing potential impacts at source through engineering/ design so that a feature that may potentially cause an impact is designed out or modified.
- Management Measures: Establishing and implementing operational procedures to reduce the risk of an impact occurring in the first place or its severity if it was to occur.
- Monitoring of Facility Performance and Management Measures: Set in place monitoring procedures to provide verification of the overall design and effectiveness of the mitigations measures and thereby allow for adjustment accordingly.

*Table ES.5 Summary of Impacts*

| Aspect | Receptors | Impact Description | Mitigated Impact Significance | | | | NES Significance |
|---|---|---|---|---|---|---|---|
| | | | Construction | Commissioning | Operation & Maintenance | Decommissioning | |
| **Physical Impacts** | Fish<br>Benthic fauna | The physical presence of subsea infrastructure and production wells will cover an area of approximately 8,000 m$^2$. Installation of subsea facilities will cause localised impacts to benthic habitats. | Moderate | Moderate | Moderate | Moderate | Not significant |
| **Presence of Vessels and Aircraft** | Cetaceans<br>Turtles<br>Fish<br>Birds | Collisions between vessels and marine fauna (eg cetaceans and turtles) is considered unlikely in view of the remote location of the facility from cetacean migration paths and congregation areas, and avoidance capabilities. Impacts from helicopter movements are anticipated to be low given the low frequency of flights, choice of flight path and avoidance behaviour by birds. | Minor | Minor | Minor | Minor | Not significant |
| **Artificial Lighting** | Turtles<br>Fish<br>Birds | Artificial lighting is required for all stages of the project. Artificial lighting has the potential to impact marine fauna. The predominant effect of exposure to artificial light on turtles is moderation of natural behaviour eg light pollution on nesting beaches can alter critical nocturnal behaviours in adult and hatchling turtles. However, the nearest nesting beach to the project is Browse Island (~40 km from the FLNG facility) and FLNG facility lighting is not expected to disrupt breeding/nesting behaviour.<br>The project is located adjacent to potential minor flight paths for migratory shorebirds and lighting may attract birds within a 5 km radius. As the FLNG facility will be located 20 km from the nearest potential flight path at its closest point, it is expected to result only in a low level of light attraction. | Minor | Minor | Minor | Minor | Not significant |
| Underwater Noise | Cetaceans<br>Turtles<br>Fish | Underwater noise will be produced during all stages of the project from construction activities, vessel movements and operation of the FLNG facility. Potential impacts include disturbance and behavioural changes, masking of other biologically important sounds (such as vocal communication or echolocation) or physical injury to hearing or other organs. Noise frequencies produced from the project will overlap with hearing and vocalisation frequencies of baleen whales and to a lesser extent with those of toothed whales. Underwater noise from the FLNG operations reach levels at which cetaceans can show minor response at 2 km radius from the facility during offtake activities and 700 m during normal operations. Project noise may cause very localised disturbance to fish or turtles within 200 m of the facility during offtake activities and 30 m during normal operations. However fish, turtle and cetacean numbers in the project area are very low and few individuals, if any, will be affected. | Minor | Minor | Minor | Minor | Not significant |

*Table ES.5* *Summary of Impacts (continued)*

| Aspect | Receptors | Impact Description | Mitigated Impact Significance | | | | NES Significance |
|---|---|---|---|---|---|---|---|
| | | | Construction | Commissioning | Operation & Maintenance | Decommis-sioning | |
| Solid Waste | Cetaceans<br>Turtles<br>Fish Birds<br>Benthic fauna | Solid wastes will be generated throughout all phases of the Prelude FLNG Project. Drill cuttings discharged to the marine environment have the potential to have localised effects on water quality and sediments. | Minor (Moderate for drill cuttings) | Minor | Minor | Minor | Not significant |
| Liquid Waste | Cetaceans<br>Turtles<br>Fish Birds<br>Benthic fauna<br>Plankton<br>Water Quality | Liquid effluents have the potential to damage the marine environment through acute or chronic toxicity, oxygen depletion, thermal or salinity stress. Throughout the life of the FLNG facility, liquid wastes will be treated prior to discharge to sea. Modelling has demonstrated that the zone of effect for these discharges is small (10s of meters) and any impacts will be local to the discharge point. Given the low abundance and high mobility of receptors such as fish and whales, the level of impact from these discharges is considered low. Localised impacts to benthic fauna may result, for example, from subsea control fluid release over the long-term. However, due to the relatively low biological abundance and the wide distribution of similar community types throughout the region, the impact is considered minor. | Minor | Minor | Minor | Minor | Not significant |
| GHG emissions | Global climate and environment | GHG emissions will be generated during the installation and commissioning, production and decommissioning phases of the Prelude FLNG Project.<br>During production of 5.3 mtpa of hydrocarbons (including LNG, LPG and condensate), the facility is forecast to emit 2.3 mtpa of carbon dioxide ($CO_2$).<br>Approximately half the estimated annual emissions arise from combustion of fuel gas to power the liquefaction process. The remaining emissions arise from venting of reservoir $CO_2$. | Minor | Minor | Moderate | Minor | Not significant |
| Other Air Emissions | Browse Island | Air emissions will meet Occupational Health and Safety requirements and given the distance to the nearest non-human sensitive receptor (Browse Island), no significant impacts are likely.<br>Designing the facility with the objective of reducing total emissions is the primary method through which emissions have been controlled. The facility has been designed to run as efficiently as possible. | Minor | Minor | Minor | Minor | Not significant |

*Table ES.5* *Summary of Impacts (continued)*

| Aspect | Receptors | Impact Description | Mitigated Impact Significance | | | | NES Significance |
|---|---|---|---|---|---|---|---|
| | | | Construction | Commissioning | Operation & Maintenance | Decommissioning | |
| Unplanned Events: Hydrocarbon Spill and Leaks | Invertebrates, Turtles, Cetaceans, Fish, Birds | Apart from mobile receptors transiting the open ocean in the area, the closest sensitive location is Browse Island, located 40 km to the SSE. Hydrodynamic spill modelling has established that in the worst modelled scenario, a 1000 tonne spill of condensate in December with no spill response, there is a less than 1% probability of oil, at a concentration sufficient to produce a rainbow sheen, reaching Browse | Minor | Minor | Minor | Minor | Not significant |
| Unplanned Events: Introduced Marine Species | Marine biota | Throughout the life of the project, LNG, LPG and condensate tankers, support and supply vessels have the potential to introduce species through ballast water and hull fouling. Due to the remoteness of the project area and lack of suitable habitat there is a low likelihood that such species would survive to become established. | Minor | Minor | Minor | Minor | Not significant |
| Socio-Economic Effects | Industry<br>Commerce<br>Government<br>Heritage<br>Tourism | i) Expenditures and tax revenues associated with the project have the potential to impact positively on local, state and national industry and commerce. Impacts will be in the form of employment, opportunities for local businesses and contractors, and increased government tax revenues generated by the project. | Moderate (+ve) | Minor (+ve) | Moderate (+ve) | Minor (+ve) | Not applicable |
| | | ii) Interruption of commercial and recreational fishing and shipping through presence of safety exclusion zone and vessel activities. | Minor | Minor | Minor | Minor | |
| | | iii) Visual and aesthetic values and impacts on tourism. | Minor | Minor | Minor | Minor | |
| | | iv) Damage to sites of cultural and historical significance. | Minor | Minor | Minor | Minor | |

As such the operational philosophy of the Prelude FLNG Project is captured through the management objectives set out in *Table ES.6*.

### *Design Mitigation Measures*

The Prelude FLNG Project has been designed with the intent to avoid, wherever practicable, potential negative impacts that could be associated with the project and to reduce those that remain to ALARP levels. This priority of reducing and managing impacts continues throughout the project phases.

Design mitigation measures for the FLNG facility are numerous and described where relevant in the draft EIS. In general, these reflect three key design elements aimed at managing potential environmental impacts:

- Ensuring facility integrity to reduce the risk of spills and leaks;
- Application of the FLNG concept to reduce the environmental footprint for the development of the Prelude field; and
- Achievement of technical efficiencies to reduce emissions of greenhouse gases.

A number of extensive studies have been conducted throughout the design process to ensure that the FLNG facility will withstand extreme weather events with negligible risk to personnel or environment. The facility has been designed to withstand a 1 in 10,000 year storm event. This corresponds to a maximum individual wave height of 27.5 m. Over the predicted 25 year operating period for this project, the probability of such an event happening is considered to be less than 0.25%.

Key to the Prelude FLNG Project GHG footprint management is that it combines the traditional offshore and onshore LNG components into one integrated FLNG facility, and as such:

- Avoids a long pipeline to shore. This reduces the materials, energy and other potential environmental impacts that would otherwise be present during construction and operation.
- The design reduces the compression requirements

*Table ES.6 Management Objectives*

| Aspect | Objectives |
|---|---|
| Marine Environment | • Maintain biodiversity, species distribution and function of marine ecosystem.<br>• Ensure that potential risks to significant marine communities and species are avoided or mitigated and controlled.<br>• Avoid significant impacts to *EPBC Act* listed species (as defined in *EPBC Act* Policy Statement 1.1). |
| Air Quality/ GHG Emissions | • Reduce emissions through the use of technological efficiencies.<br>• Minimise flaring and venting to only that required for safety reasons.<br>• Reduce GHG emissions to ALARP levels within the context of the development restrictions of this project, through the: 1) Decision to implement FLNG as the means of hydrocarbon extraction and production; and, 2) Technological efficiencies. |
| Noise | • Reduce noise impacts to ALARP levels.<br>• Manage noise through the use of technological efficiencies and design mitigation measures. |
| Light | • Reduce light spill to ALARP levels through design measures and selection of technologies. |
| Waste and effluent | • Treat effluent prior to discharge to accepted industry and regulatory standards.<br>• Reduce the pollutant load of controlled water discharges from operations.<br>• Handle and dispose of waste in a manner as to control loss to environment.<br>• Implement a "minimise, segregate, recycle and reuse" approach to the project as appropriate. |
| Hydrocarbon/ chemical release | • Reduce risks of accidental discharge through design measures and handling practices. |
| Workforce and public health | • Ensure risks to health and safety are reduced to ALARP levels through good design of facilities, development of appropriate procedures, strict vetting of logistics providers and sufficient competency of workforce and contractors by recruitment and training programs. |
| Engagement | • Open communication and implement transparent feedback mechanisms with relevant stakeholders. |
| Economic Development | • Optimise the opportunities for economic benefits to the local and regional community provided by the project. |

during the later life of the field as the reservoir pressure declines, as gas does not have to be transported a long distance to the LNG plant.

- Avoids the need for any additional processing requirements to remove water from the gas and condensate to make it suitable for transport in a carbon steel pipeline to shore.

Additionally, the FLNG facility itself has a number of efficiency improvements over an onshore LNG Plant such as:

- Use of cold seawater from 150 m depth as coolant rather than coastal seawater or air cooling.
- The production processes use a dual mixed refrigerant liquefaction cycle to enable optimum efficiency for differing gas compositions and ambient temperatures.
- The process minimises LNG boil-off by avoiding long recirculating loading lines. By minimising such boil-off, the downgrade from LNG to fuel gas is reduced and the overall thermal efficiency of the liquefaction process is increased.
- Use of steam boilers avoids the need for high pressure fuel compression, reducing fuel consumption.

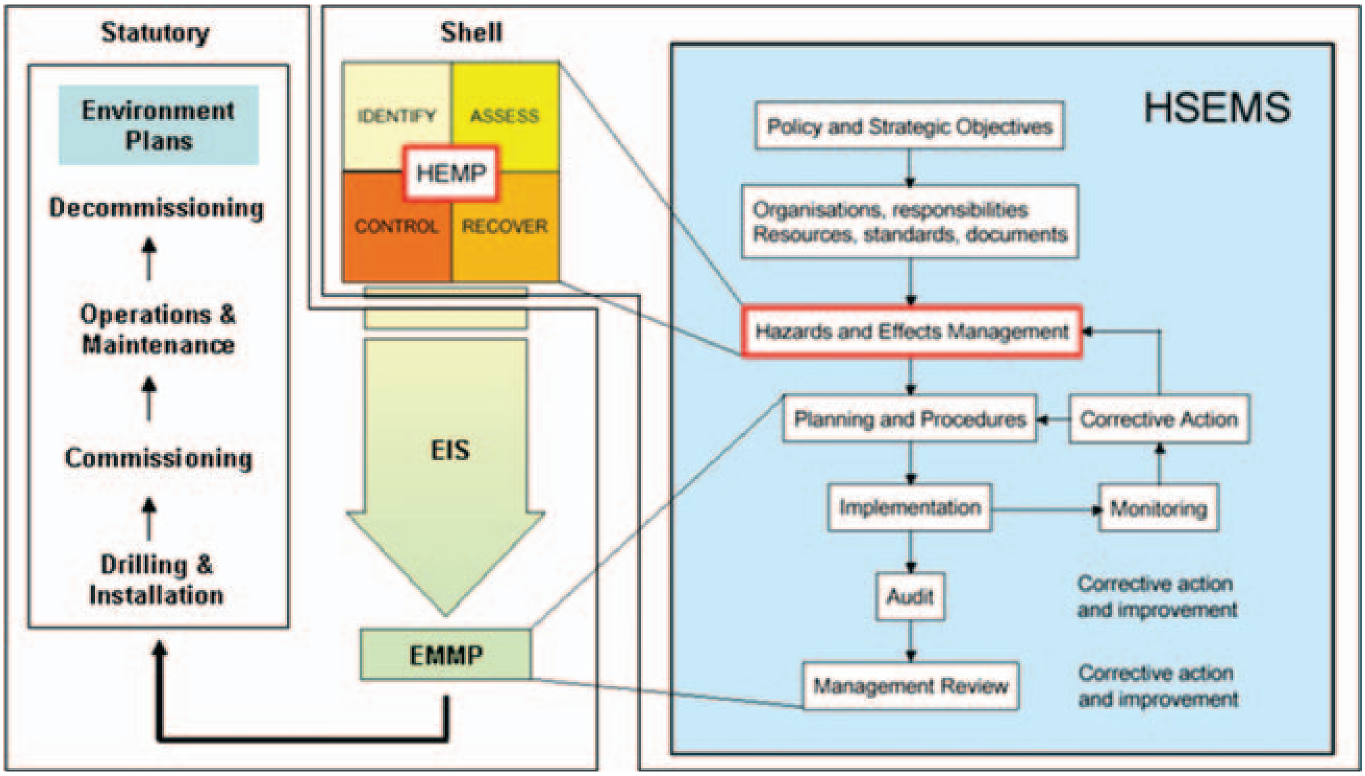
### *Management Measures*

Realisation of the objectives outlined in *Table ES.6* will be managed through the implementation of a Prelude FLNG Project specific Health Safety and Environment Management System (HSE-MS) and will incorporate the management commitments in the draft EIS and the statutory-required Environment Plans for key stages of Project development. As per Shell's company policy, the HSE-MS will be accredited to, and audited against, the internationally recognised ISO14001 requirements. The Project specific HSE-MS relationship to the statutory requirements of this draft EIS, including the Environmental Management and Monitoring Plan, which is outlined in *Chapter 7*, and the Environment Plans for the different phases of the project lifecycle, is outlined in *Figure ES.6*.

### *Monitoring*

Monitoring will be required in order to demonstrate compliance with legal limits, expected Government mandated Conditions of Approval and Shell's project

*Figure ES.6 Relationship between the EIS, EPs and HSE-MS*



requirements (compliance monitoring) established in the draft EIS.

Monitoring will also provide verification of the overall design and effectiveness of the implemented control measures. The key objectives of Shell's proposed monitoring activities are to:

- monitor discharges and emissions to ensure compliance with relevant standards and Shell's environmental objectives;
- provide an early indication if any of the environmental control measures or practices are failing to achieve acceptable standards;
- determine whether environmental changes are attributable to the project activities, other activities or as a result of natural variation;
- provide a basis for continuous review and improvement to the operational monitoring program; and
- provide data to be used in subsequent FLNG environmental impact assessments.

### *Decommissioning Procedures*

At the end of the Prelude field life, the FLNG facility infrastructure will be decommissioned, in accordance with the prevailing legislation and industry best practical technology at that time. The FLNG facility will be towed to a dry-dock facility for refitting and re-use on another project. Subsea production wells will be plugged and abandoned and the subsea infrastructure will be removed if required.

## CONCLUSION

Shell has undertaken a draft EIS for the Prelude FLNG Project in accordance with Australian Commonwealth legislative requirements, Shell Group Policies and international standards.

The Prelude FLNG Project presents the opportunity for the first use of FLNG technology in Australia. FLNG has been selected by Shell as the preferred development option due to its low environmental and socio-economic footprint, lower development cost and flexibility to relocate to other fields. The Prelude FLNG Project may become a catalyst for the development of other stranded gas fields in Australia and the region.

### *In conclusion:*

- the drilling of development wells, installation of seabed infrastructure and routine operations of the FLNG facility do not represent a significant risk to any listed or migratory species, threatened ecological communities, or the marine, socio-economic or cultural environment; and
- in the unlikely event that a non-routine incident occurs, oil spill modelling has illustrated that under worse case conditions the potential environmental impacts will be minor.

Overall, it is concluded that by implementing the design features and mitigation measures described within the draft EIS, the Prelude FLNG Project will have no significant impacts upon the environment and, in particular, upon matters of NES, nor any significant negative socio-economic or health impacts.

# 1 INTRODUCTION

This document is a draft Environmental Impact Statement (EIS), which has been prepared by Shell Development (Australia) Proprietary Limited (Shell) with respect to the proposed Prelude Floating Liquefied Natural Gas (FLNG) Project.

The Australian Commonwealth Government awarded Shell Exploration Permit WA-371-P in January 2006. The title area is in the Northern Browse Basin, a hydrocarbon province with major undeveloped gas fields in the outer and central basin, and minor oil discoveries on its eastern margin[4]. In November 2006, Shell commenced drilling activities and in January 2007 discovered the Prelude field.

Shell propose to develop the Prelude field, using a FLNG Facility which will produce, liquefy and export gas resources in line with the Australian Offshore Petroleum Development policy. This is termed the 'Prelude FLNG Project'.

The FLNG facility is to be located in Commonwealth waters approximately 200 km offshore northwest Western Australia, within the WA-371-P title area (see *Figure 1.1*).

This draft EIS has been prepared in consultation with the Commonwealth Department of Environment, Water, Heritage and the Arts (DEWHA), in conformity with the *Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)* and the guidelines provided by the DEWHA to Shell in July 2008 (see *Appendix A).*

## 1.1 PROJECT TITLE

The formal title of the action is the 'Prelude Floating Liquefied Natural Gas (FLNG) Facility, WA'. It is referred to herein as the 'Prelude FLNG Project'.

*Figure 1.1 Location of Exploration Title Area WA-371-P*

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[4] *Government of Western Australia, Department of Mines and Petroleum (http://www.dmp.wa.gov.au/1878.aspx)*

## 1.2 LOCATION OF THE PROPOSED PROJECT

The project area is located in offshore waters approximately 475 km north-northeast of Broome and 825 km west of Darwin. The project area, which comprises the subsea infrastructure and FLNG facility, is located in open ocean, in about 250 m of water depth. It contains no reefs or land above sea level; the nearest land is Browse Island, which is about 40 km from the proposed location of the FLNG facility (*Figure 1.2*).

*Figure 1.2 Location of the Proposed Prelude FLNG Project*

The navigational coordinates for the proposed position of the FLNG facility are:

| Latitude | | | Longitude | | |
|---|---|---|---|---|---|
| Degrees | Minutes | Seconds | Degrees | Minutes | Seconds |
| 13 | 47 | 25.53 S | 123 | 19 | 55.09 E |

## 1.3 DEVELOPMENT OBJECTIVES

The objectives of the proposed Prelude FLNG Project are to:

- commercialise the hydrocarbon resources of the Prelude field and optimise recovery of these resources;
- manage all environmental, health, security and safety issues in accordance with recognised industry standards and Shell's requirements;
- provide an acceptable return on investment; and
- demonstrate Shell's FLNG technology as a means to unlock further stranded gas reserves in Australia and elsewhere.

## 1.4 EIS PURPOSE AND SCOPE

The primary purpose of the draft EIS is to:

- describe the project, its major elements and schedule;
- describe the existing environment for the project area;
- identify and assess any potential impacts during the project lifecycle;
- define mitigation and management measures that minimise any adverse impacts on the environment; and
- demonstrate compliance with the *EPBC Act*.

The Health, Safety, Security, Environmental and Social Performance (HSE)[5] requirements of the project start with compliance with the law of the Commonwealth of Australia and applicable state legislation of Western Australia and/or the Northern Territory, as well as applicable internationally accepted norms and standards as specified in *Chapter 2* of this draft EIS. In addition, international agreements to which Australia is a party have been applied as well as Shell Group[6] Policies, Procedures and Guidelines. The most stringent of these considerations are being adopted on this project. These codes and standards, which are discussed in *Chapter 2*, will be supplemented and in some areas superseded by various specific HSE philosophies developed for the project.

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[5] *For brevity the acronym HSE is used to describe Health, Safety, Security, Environment and Social Performance throughout this draft EIS.*

[6] *Royal Dutch Shell plc and the companies in which it directly or indirectly owns investments are separate and distinct entities. In this publication, the collective expressions 'Shell' and 'Shell Group' may be used for convenience where reference is made in general to those companies. Likewise, the words 'we', 'us', 'our', and 'ourselves' are used in some places to refer to the companies of the Shell Group in general. These expressions are also used where no useful purpose is served by identifying any particular company or companies.*

Compliance with these standards will be confirmed through the implementation of a Project specific Environmental Management and Monitoring Plan (EMMP) as described in *Chapter 7* of this draft EIS.

The assessment process used in the preparation of this draft EIS has identified potential impacts at each stage of the Prelude FLNG Project. These stages are summarised as follows:

- offshore construction activities including development well drilling, preparation of the sea bed, installation of subsea infrastructure, mooring chain and anchor installation and tow out and hook up of the FLNG;
- commissioning including hydrotesting of the subsea infrastructure;
- operations (including support and logistics) and maintenance; and
- decommissioning.

The draft EIS does not include consideration of aspects of the project conducted outside Australia, including the construction and commissioning of the FLNG facility or the shipping and use of Liquefied Natural Gas (LNG), Liquefied Petroleum Gas (LPG) or condensate outside Australia. The potential environmental impacts associated with these activities will be managed via the approvals processes of the country in which the work is undertaken.

## 1.5 INTRODUCTION TO THE PRELUDE FLNG FACILITY

The FLNG concept provides a technically innovative solution to developing small and remote gas field in a cost-effective and environmentally low impact manner. It does this by avoiding the need for a 'traditional' development comprising offshore platform(s), export pipeline(s), onshore liquefaction plant, export jetty(s) and dredged shipping channel(s) for export tankers.

The FLNG facility will be similar in concept to existing Floating Production, Storage and Offloading (FPSO) facilities for production of hydrocarbons. It has the following attributes:

- the fabrication and pre-commissioning of the FLNG facility will occur in an overseas shipyard. The facility will then be towed to the title area;
- the FLNG facility will be moored to the seabed via a turret around which the facility can weathervane;
- gas from the target reservoir will be extracted via subsea wells and will flow via flowlines and flexible risers to the internal turret of the FLNG facility;
- all reservoir, subsea control, processing, storage and loading will be operated from the FLNG facility;
- logistical support for the movement of personnel, equipment and materials will be provided from a Maintenance Workshop in an established Australian port; and
- the design concept allows for redeployment of the FLNG facility to another location at a later stage or tie-in from another field.

The FLNG facility will be entirely self-sufficient, using natural gas extracted from the Prelude field to generate all its energy needs. It combines the functions of an offshore gas receiving facility, with a gas treatment and liquefaction plant, and storage and offloading of products. All of these functions will be performed on the FLNG facility, with hydrocarbon products (LNG, LPG and condensate) loaded for export directly onto product carrier ships.

Key design elements of the FLNG facility are summarised as follows:

- the steel, double hulled substructure will have an approximate length of 480 m and width of 70-80 m;
- the FLNG facility will be designed to produce for export 3.6 million tonnes per annum (mtpa) of LNG, plus LPG and condensate; and
- the FLNG facility will not disconnect during bad weather and is designed to withstand a 1 in 10,000 year weather event.

A drawing of the FLNG facility is provided in *Figure 1.3*.

## 1.6 PROPONENT

The project proponent and title holder for Exploration Permit Area WA-371-P is Shell Development (Australia) Proprietary Limited (Shell). Shell is the largest equity LNG producer among international energy companies and has the most diverse LNG supply portfolio in the world. Directly or indirectly, Shell owned approximately 9% of the world's LNG capacity as of March 2009.

In Australia, Shell finds, develops and supplies gas and condensate to overseas markets and to domestic customers in Western Australia. Shell has been active in Australia since 1901.

Contact details for Shell are:

Shell Development (Australia) Proprietary Limited
250 St Georges Terrace
Perth 6000
Western Australia

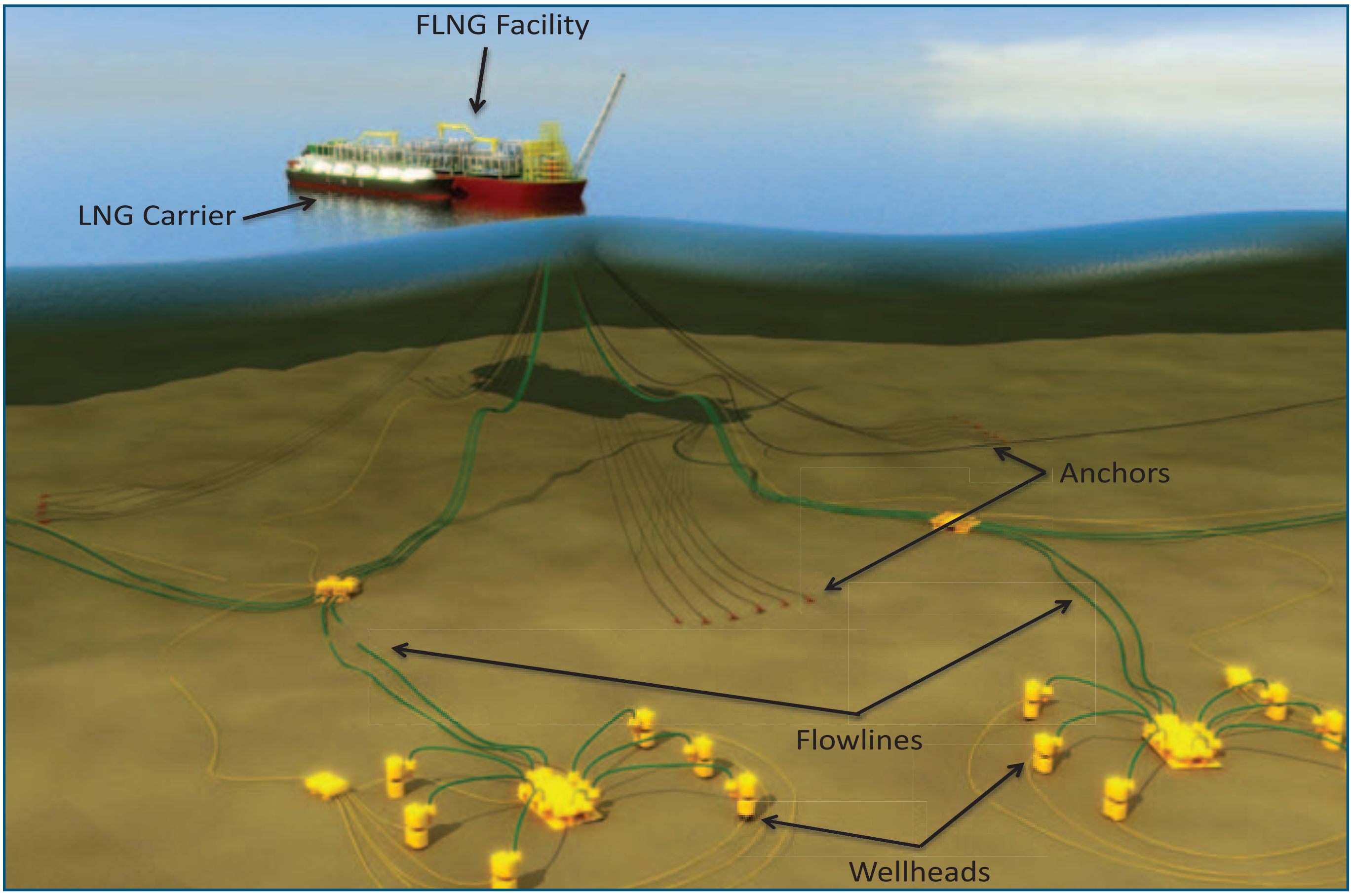
## 1.7 PROPONENT'S ENVIRONMENTAL COMMITMENT

Shell has a comprehensive set of policies, standards and procedures for environmental matters. Shell's current environmental policy and commitment to HSE was adopted in the Shell General Business Principles in 1997[7]. It includes a commitment to 'pursue the goal of no harm to people' and to 'protect the environment' and requires the use of risk-based management systems, which are audited regularly. All Shell companies, contractors and Shell operated joint ventures are required to manage HSE in line with Shell's Policy and Commitment as discussed in *Chapter* 2.

Shell's approach to develop Responsible Energy can be found at: http://www.shell.com

Shell's commitments and standards are available at: http://www.shell.com/home/content/responsible_energy/integrated_approach/our_commitments_and_standards/dir_commitments_standards.html

*Figure 1.3 FLNG Facility and Associated Infield Infrastructure*



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[7] *http://www.shell.com/home/content/aboutshell/who_we_are/our_values/sgbp/sgbp_30032008.html*

The most recent Shell Sustainability Report is available at: http://www.shell.com/home/content/responsible_energy/sustainability_reports/dir_shell_sustainability_reports.html

Shell's HSE philosophy in Australia can be found at: http://www.shell.com/home/content/au-en/about_shell/2008/environment_and_society/people_and_enviro.html?LN=/leftnavs/zzz_lhn2_4_2.html

## 1.8 PROJECT HISTORY

Exploration Permit WA-371-P was awarded to Shell in January 2006. In November 2006, as 100% equity holder and operator, Shell started an exploration drilling program and in January 2007 discovered the Prelude field. All 12 commitment wells for the title area have been drilled.

Following selection of the FLNG concept as the proposed development mechanism, Shell submitted to DEWHA a referral (Prelude Floating Liquefied Natural Gas Facility, EPBC: 2008/4146) pursuant to the *EPBC Act* on 8 April 2008. On 7 May 2008 DEWHA determined that the proposed Prelude FLNG Project was a 'controlled action' under the provisions of the *EPBC Act* and the assessment level was set as EIS. Guidelines on the content of the draft EIS, pursuant to section 102 of the *EPBC Act*, were developed by DEWHA in July 2008 and are provided in *Appendix A*. The other major approvals required for the proposed project fall under the *Offshore Petroleum and Greenhouse Gas Storage Act 2006 (OPGGS Act)* and associated regulations which, in relation to petroleum activities carried out in Commonwealth waters off the Western Australian coast, are administered by the Western Australian (WA) Department of Mines and Petroleum (DMP). These are discussed further in *Chapter 2*.

## 1.9 ORGANISATION OF THIS DRAFT EIS

This draft EIS is prefaced by an Executive Summary and the remainder of the report structure is summarised as follows:

*Chapter 2* establishes the Policy, Legal and Administrative Framework for the project. It provides an overview of the legislation, standards and guidelines that are considered applicable to the project.

*Chapter 3* describes the public consultation activities and outcomes from engagement that have been undertaken during the preparation of the draft EIS.

*Chapter 4* describes the project and provides those details of the development and operation of the Prelude FLNG Project considered relevant to the draft EIS.

*Chapter 5* provides a detailed description of the marine offshore environment in which the Prelude FLNG Project will be located.

*Chapter 6* is the assessment of the environmental, social and health impacts of the project, including potential impacts arising from noise and light emissions associated with the FLNG facility.

*Chapter 7* summarises the proposed impact mitigation measures for the Prelude FLNG Project along with proposed environmental and social management plans. It describes arrangements for mitigation implementation and monitoring within a management framework.

The Appendices include the DEWHA draft EIS Guidelines, a glossary of terms and a cross-reference table indicating where the specific requirements of the DEWHA Guidelines are addressed in the draft EIS.

# 2 POLICY, LEGAL AND ADMINISTRATIVE FRAMEWORK

## 2.1 OVERVIEW

This section provides an overview of the legislation, standards and guidelines which are applicable to the project, including the following:

- Australian policy, legislation and regulations;
- relevant international and/or industry policies, guidelines, standards and technical guidance;
- relevant provisions contained within international conventions and protocols to which Australia is a signatory; and
- applicable Shell Standards and Guidelines.

## 2.2 COMMONWEALTH POLICY FRAMEWORK

The location of the proposed Prelude FLNG Project is in Commonwealth waters and is therefore subject to Commonwealth legislation (*see Figure 4.4*). The following are Commonwealth government policies regarding petroleum development and marine protection that are relevant to the Prelude FLNG Project.

### 2.2.1 Australian Offshore Petroleum Development Policy

Titles are issued to the private sector by Commonwealth and State government agencies to facilitate exploration and development of petroleum reserves within Australia. As the title holder for Exploration Permit WA-371-P, Shell has an obligation to undertake exploration of its titles and to certify the nature and extent of the reserves within this area. As resources have been found in the WA-371-P title area, Shell is required to investigate the manner in which it can make these reserves available to resource buyers.

### 2.2.2 Commonwealth National Oceans Policy

Australia's Oceans Policy was introduced in 1998. The Policy has a number of aims, including:

- exercising and protecting Australia's rights over its marine jurisdictions;
- meeting its obligations under the United Nations *Convention on the Law of the Sea 1982* which was ratified in 1994;
- understanding and protecting the marine environment; and
- promoting ecologically sustainable economic development and establishing integrated planning and management.

Under the Oceans Policy, a Nationally Representative System of Marine Protected Areas is currently being established. These are based on the principles of multiple-use and Ecologically Sustainable Development. This policy has been implemented through the *EPBC Act*, as outlined in the Strategic Plan of Action for the National Representative System of Marine Protected Areas (ANZECC, 1998).

There are six categories of marine protected area, none of which cover the location of the proposed Prelude FLNG facility. The Ashmore Reef and Cartier Island are the closest

Marine Protected Areas, located approximately 200 and 175 km north of the WA-371-P title area, respectively.

## 2.3 LEGISLATIVE FRAMEWORK

### 2.3.1 Introduction

This section describes legislation of relevance to the project. Key legislation is described in *Section 2.3.2*. A detailed listing of legislation is included in *Table 2.1*.

### 2.3.2 Key Legislation

### *Environment Protection and Biodiversity Conservation Act 1999*

The *EPBC Act* and EPBC Regulations 2000 form the legislative basis for this draft EIS. The *EPBC Act* provides for the protection of the environment and conservation of biodiversity in Australia (including Australian waters) by the Commonwealth Government. The *EPBC Act* is administered by the Commonwealth Minister for the Environment, Water, Heritage and the Arts.

Under the *EPBC Act*, any action that is likely to have a significant impact on matters of National Environmental Significance (NES) must be:

- undertaken in accordance with an approval from the Minister who administers the Act;
- approved through a bilateral agreement with a state or territory; or
- approved through a process accredited by the Minister.

There are seven matters of NES under the Act:

- World Heritage sites;
- National Heritage places;
- wetlands of international importance (Ramsar);
- nationally threatened species and ecological communities;
- migratory species;
- Commonwealth marine areas; and
- nuclear actions.

*Table 2.1 Commonwealth Legislation and Regulations relevant to the Prelude FLNG facility*

| Key Commonwealth Legislation and Regulations pertaining to the Oil and Gas Industry |
|---|
| *Environment Protection and Biodiversity Conservation Act 1999* |
| *Offshore Petroleum and Greenhouse Gas Storage Act 2006* |
| *Petroleum (Submerged Lands) (Management of Environment) Regulations 1999* |
| *Petroleum (Submerged Lands) (Management of Safety of Offshore Facilities) Regulations 1996* |
| *Petroleum (Submerged Lands) Act - Schedule of Specific Requirements as to Offshore Petroleum Exploration and Production 2005* |
| **Other Commonwealth Legislation and Regulations** |
| *Energy Efficiencies and Opportunities Act 2006* |
| *Environmental Protection (Sea Dumping) Act 1981* |
| *National Greenhouse and Energy Reporting Act 2007* |
| *Australian Heritage Council Act 2003* |
| *Australian Maritime Safety Authority Act 1990* |
| *Historic Shipwrecks Act 1976* |
| *National Environmental Protection Council Act 1998* |
| *Native Title Act 1993* |
| *Navigation Act 1912* |
| *Protection of the Sea (Oil Pollution Compensation Fund) Act 1983* |
| *Ozone Protection and Synthetic Greenhouse Gas Management Act 1989* |
| *Quarantine Act 1908* and *Australian Ballast Water Management Requirements 2001* |
| *Protection of the Sea (Powers of Intervention Act) 1981* |

Actions with the potential to impact on a matter of NES trigger the Commonwealth environmental assessment and approval process. The process to which this draft EIS is subject is shown in *Figure 2.1*.

Shell submitted an *EPBC Act* referral to DEWHA on 8 April 2008 for the subsea construction and operation of the Prelude FLNG facility within title area WA-371-P (Ref: 2008/4146). The referral was exhibited on the DEWHA website for 10 working days for public comment and no comments were received. DEWHA deemed the proposal to be a 'Controlled Action' on 7 May 2008. The controlling provisions for the proposal as outlined in Part 3, Division 1, of the Act, are:

- *sections 18* and *18A* (listed threatened species and communities);
- *sections 20* and *20A* (listed migratory species); and
- *sections 23* and *24A* (Commonwealth marine environment).

DEWHA determined that the proposed Prelude FLNG Project would be assessed by an EIS. Scoping of potential impacts from the proposed action was carried out by DEWHA and these were detailed in its preliminary guidelines for the EIS. The preliminary guidelines were issued to set out the scope of environmental, social and economic studies required in the draft EIS and to:

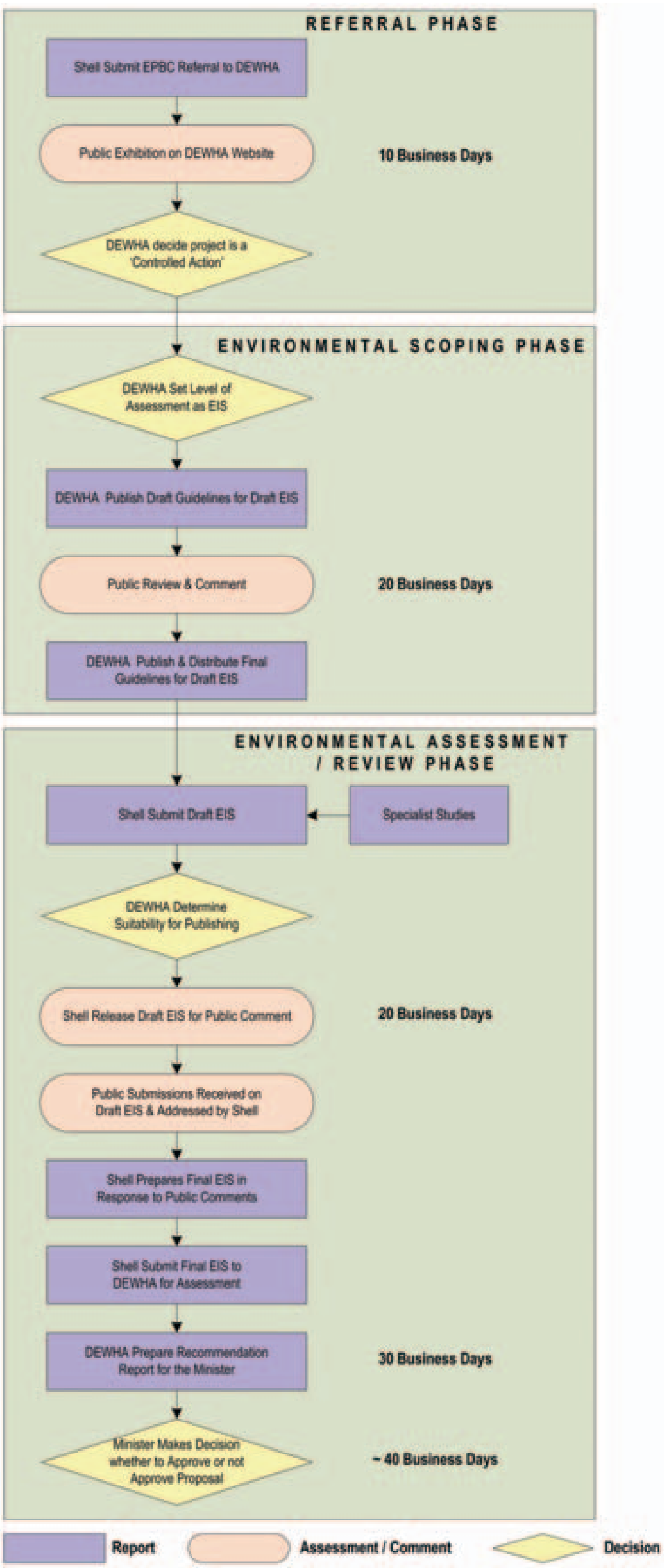
- provide guidance on the scope of the EIS;
- communicate this to relevant stakeholders;
- obtain input on issues relating to the Prelude FLNG Project; and
- enable the Commonwealth to consider that input when developing the Final Guidelines for the project EIS.

The Draft Guidelines were finalised by DEWHA in July 2008 (see *Appendix A*). The key potential impacts identified in the Final Guidelines are:

- physical environment impacts;
- biodiversity impacts;
- air and water pollution impacts; and
- socio-economic impacts.

This draft EIS has been prepared in line with the Final Guidelines.

*Figure 2.1 EPBC Approvals Process for the Prelude FLNG Project*



### *Offshore Petroleum and Greenhouse Gas Storage Act 2006*

Approval is required under the *Offshore Petroleum and Greenhouse Gas Storage Act 2006* (*OPGGS Act*) from the Designated Authority (in this case, the Western Australia Department of Mines and Petroleum (DMP)) to construct, operate and decommission a petroleum facility. The *OPGGS Act* came into effect on 1 July 2008, updating and replacing the *Petroleum (Submerged Lands) Act (PSLA) 1967* in its entirety. To date there have been no changes to the regulations under the *PSLA 1967*, which continue to apply under the *OPGGS Act*.

Approvals required under the *OPGSS Act* and regulations include the following:

- production licence for the offshore facilities in Commonwealth waters (*see Section 2.4.1*);
- infrastructure licence (see *Section 2.4.2*);
- Safety Case assessment and acceptance (see *Section 2.4.3*); and
- Environment Plan assessment and acceptance (see *Section 2.4.5*).

## 2.3.3 Other Legislation

### *Protection of the Sea (Prevention of Pollution from Ships) Act 1983*

*The Protection of the Sea (Prevention of Pollution from Ships) Act 1983* regulates discharges from ships to protect the sea from pollution, and gives effect to the International Maritime Organization's *International Convention for the Prevention of Pollution from Ships, 1973* (MARPOL). This includes a prohibition against discharges of oil or oily mixtures, noxious liquid substances, packaged harmful substances, sewage and garbage to the sea. The Act also imposes a duty to report certain incidents involving prohibited discharges and maintain record books, a shipboard oil pollution emergency and shipboard waste management plan.

The FLNG facility, once in place, is a petroleum facility under the *OPGGS Act* and is not subject to the *Protection of the Sea (Prevention of Pollution from Ships) Act 1983* or MARPOL requirements. However, vessels travelling to or from the FLNG facility are subject to this act.

### *Energy Efficiencies Opportunities Act 2006*

The Commonwealth government's Energy Efficiency Opportunities (EEO) program encourages large energy-using businesses to improve their energy efficiency by identification, evaluation and implementation of cost-effective energy savings opportunities. Participants in the program are required to assess their energy use and report publicly on the results of the assessment and their business response. Participation in the program is mandatory under the Act for corporations that use more than 0.5 petajoules (PJ) of energy per year.

Shell is committed to using energy efficiently to provide products and services. Shell registered for the program in March 2007 and has also submitted an assessment and reporting schedule to the Department of Resources Energy and Tourism (DRET) covering Shell's downstream activities. *Table 2.2* outlines the timeframes for companies reporting under this legislation.

The Prelude FLNG Project will become part of Shell's EEO annual reporting when it is operational.

*Table 2.2 EEO Timeline Schedule*

| Activity | Timing |
|---|---|
| First five year assessment cycle: | 1 July 2006–30 June 2011 |
| Submit application for registration: | 1 July 2006–31 March 2007 |
| Submit assessment and reporting schedule: | 1 July 2006–31 December 2007 |
| Conduct first assessments: | by 30 June 2008 |
| Publish first public report and submit a report to the Secretary of DRET: | Within 15 months of the end of the first assessment or by 31 December 2008, whichever is earlier |
| Publish subsequent public reports: | Annually following the first public report |
| Complete all EEO assessments: | by 30 June 2011 |
| Submit final report to the Secretary of DRET: | by 31 December 2011 |
| Submit assessment and reporting schedule for second five year assessment cycle: | by 31 December 2012 |

### *National Greenhouse and Energy Reporting Act 2007*

The National Greenhouse and Energy Reporting System (NGERS) is designed to provide a single, national framework for reporting GHG emissions and abatement actions by corporations, as well as energy production and consumption. This framework commenced on 1 July 2008.

Reporting obligations are imposed upon corporations that satisfy particular emissions/energy thresholds (refer to *Table 2.3*). Corporations are defined by the Act as the corporate group, including the controlling corporation and particular subsidiaries, joint ventures and partnerships.

*Table 2.3 Thresholds for Reporting for NGERS.*

| Commencing Year | Corporations threshold | Facilities threshold |
|---|---|---|
| 2008/9 | 125,000 MT or using/ producing more than 500 TJ of energy | 25,000 MT or using/ producing more than 100 TJ energy |
| 2009/10 | 87,500 MT or more than 350 TJ of energy | TBA |
| 2010/2011 | 50,000 MT or more than 200 TJ of energy | TBA |

Data reported through the system will underpin the proposed Carbon Pollution Reduction Scheme. The ability to monitor, report and verify businesses' emissions data will be essential for maintaining the environmental and financial integrity of the trading system.

Shell will be required to report as a corporate group under the *NGER Act* and emissions from the FLNG facility will be incorporated into the total emission reporting by Shell Australia, once the FLNG facility becomes operational.

### *Australian Ballast Water Management Requirements 2001*

Australian ballast water management requirements are consistent with International Maritime Organisation (IMO) guidelines for minimising the risk of introducing pest species in ships' ballast water. Australia introduced mandatory ballast water management requirements to reduce the risk of introducing aquatic organisms into Australia's marine environment through ship's ballast water. The Australian Ballast Water Management Requirements are applicable to aspects of the Prelude FLNG Project that occur within Australia's Territorial Sea.

## 2.4 ADMINISTRATIVE FRAMEWORK

The following sections outline additional approvals required under Commonwealth legislation.

### 2.4.1 Production Licence

A petroleum production licence is required for offshore petroleum production facilities under the *OPGGS Act*. A production licence provides the legal right to recover petroleum from an area, subject to meeting conditions specified by the licence. The production licence is granted for an indefinite term and is called a *life of field production licence*. Shell has not yet applied for a production licence, which will only be issued after the necessary environmental approvals for the development have been secured.

### 2.4.2 Infrastructure Licence

An infrastructure licence is required prior to construction or operation of an infrastructure facility in an offshore area under the *OPGGS Act*. An infrastructure facility includes a facility engaged in petroleum activities that either rests on the seabed or is fixed or connected to the seabed (whether or not the facility is floating). An infrastructure licence remains in force indefinitely. Shell has not yet applied for an infrastructure licence, which will only be issued after the necessary environmental approvals for the development have been secured.

### 2.4.3 Safety Case

*The Petroleum (Submerged Lands) (Management of Safety on Offshore Facilities) Regulations 1996* require that an operator must not construct or install a facility until the operator has obtained a `Consent to Construct and Install' from the Designated Authority (in this case the WA DMP). Before this may be granted, the National Offshore Petroleum Safety Authority (NOPSA) must have accepted a Facility Description, a Formal Safety Assessment and those parts of the Safety Management System that relate to construction and installation.

An operator must not operate a facility until the operator has obtained a `Consent to Use'. This may only be granted if there is a Safety Case in force for the facility. For the Safety Case to be in force it must have been submitted by the operator and it must have been accepted, or provisionally accepted, by NOPSA.

Shell will prepare and submit the required Safety Cases to NOPSA as the project is developed to ensure timely approvals prior to construction, installation and start-up.

### 2.4.4 Oil Spill Contingency Plans

An Oil Spill Contingency Plan will be developed for the FLNG facility's operation as part of its Emergency Response Plan, as specified in *Section 202* of the *PSLA Schedule of Specific Requirements as to Offshore Petroleum Exploration and Production 2005*. Oil spill modelling has been carried for a number of spill scenarios which are discussed in *Section 6.9.2*.

### 2.4.5 Environment Plans

Environment Plans (EP) are required under Part 2 of the *Petroleum (Submerged Lands) (Management of Environment) Regulations 1999* for offshore petroleum activities in Commonwealth waters. The Regulations specify that an operator must not carry out a petroleum activity unless there is an accepted EP in force for the activity. EPs must describe the activity, the receiving environment, environmental aspects and an assessment of potential impacts. In addition, an EP must contain appropriate risk-based environmental performance objectives and standards, an implementation strategy and provide criteria for determining whether the objectives and standards are met.

A series of EPs will be developed in reference to the relevant stages of the project life cycle as follows:
- drilling and well construction;
- installation, hook-up and commissioning;
- operations and maintenance; and
- decommissioning.

### 2.4.6 Environmental Management System

A Health, Safety, Security, Environment and Social Performance Management System (HSE-MS) will be developed to cover the project, and is the means by which Shell will implement its policy, practices and procedures for achieving specified environmental standards and delivering improvement in environmental performance.

The HSE-MS will be developed to comply with Shell Group requirements and with the international standard on environmental management systems ISO 14001. The Prelude HSE-MS will be audited against the ISO 14001 standard, by an accredited independent third party, in order to achieve certification to this standard.

To ensure that the project achieves the standards required, a systematic approach to monitoring and measuring performance and taking corrective action will be developed through the development of an Environmental Management and Monitoring Plan (EMMP) which will detail:
- statutory reporting requirements;
- commitments made in the draft EIS and EPs;
- success criteria in fulfilling the policy commitment to continuous improvement;
- monitoring to measure progress against objectives, targets and plans;
- data requirements to the Shell Group in order to fulfil corporate reporting requirements; and
- matrices outlining the responsibilities for monitoring and reporting.

The EMMP will be incorporated into the Prelude HSE-MS. The framework EMMP is discussed further in *Chapter 7*.

## 2.5 INDUSTRY GOOD PRACTICE STANDARDS

In addition to the offshore environmental management procedures and reporting required under legislation, there are voluntary industry codes that are relevant to the project, as discussed in this section.

In Australia, the petroleum exploration and production industry operates within an industry code of environmental practice developed by the Australian Petroleum Production and Exploration Association (APPEA, 2008). This code provides guidelines for activities and has evolved from the collective knowledge and experience of the oil and gas industry both nationally and internationally. The code also provides the Australian petroleum industry with clear guidance on management practices and measures to protect the environment during exploration, production and decommissioning phases. Shell is a signatory to the APPEA guidelines and will adhere to them in the implementation of the project.

The following international guidelines are also applicable to the Prelude FLNG Project:

- the Oil and Gas Industry: Operating in Sensitive Environments 2003 – International Petroleum Industry Environmental Conservation Association (IPIECA); and
- Environmental Management in Oil and Gas Exploration and Production 1997 – United Nations Environment Program Industry and Environment (UNEP IE) and the Oil Industry International Explorations and Production Forum (E&P Forum).

## 2.6 INTERNATIONAL AGREEMENTS AND CONVENTIONS

Australia is signatory to numerous international conventions and agreements that obligate the Commonwealth Government to prevent pollution and protect specified habitats, flora and fauna. Those of relevance to the Prelude FLNG Project are listed in *Table 2.4*.

## 2.7 INTERNATIONAL STANDARDS AND GUIDELINES

Shell refers to World Bank (WB)/International Finance Corporation (IFC) guidelines as the basis for many of its operation guidelines. The WB/IFC guidelines are the minimum environmental, social and health standards for

*Table 2.4 Overview of International Conventions and Australia's Obligations applicable to the Prelude FLNG Project*

| Convention | Summary | Obligations |
|---|---|---|
| International Convention for the Prevention of Pollution from Ships/ Vessels ( MARPOL), 1973 as amended by the protocol, 1978 | • The legislation giving effect to MARPOL 73/78 in Australia is the *Protection of the Sea (Prevention of Pollution from Ships) Act 1983*<br>• Preventing and minimising pollution of the marine environment from ships - both accidental pollution and that from routine operations | • Requirements in preventing and minimising pollution caused by ships/vessels<br>• Actions in response to a spate of tanker accident to prevent environmental pollution at sea. |
| Japan Australia Migratory Bird Agreement or JAMBA | • This agreement recognises the special international concern for the protection of migratory birds and birds in danger of extinction that migrate between Australia and Japan. | • The Australian Government shall take special protective measures, as appropriate, for the preservation of species or subspecies of birds which are in danger of extinction |
| China Australia Migratory Bird Agreement or CAMBA | • This agreement recognises the special international concern for the protection of migratory birds and birds in danger of extinction that migrate between Australia and China. | • The Australian Government shall take special protective measures, as appropriate, for the preservation of species or subspecies of birds which are in danger of extinction |
| United Nations Convention on Biological Diversity, 1992 | • Seeks to ensure conservation of biological diversity and sustainable use of its components<br>• Promotes fair and equitable sharing of the benefits that can be drawn from genetic resources | • Requirement to identify and monitor components of biological diversity and threats to these components and adopt necessary conservation measures |
| Convention on the Conservation of Migratory Species of Wild Animals (commonly referred to as the Bonn Convention) | • The Bonn Convention aims to improve the status of all threatened migratory species through national action and international agreements between range states of particular groups of species. | • The Australian Government shall take special protective measures, as appropriate, for the preservation of species which are in danger of extinction |
| Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal, 1989 | • Seeks to control and reduce transboundary movements of hazardous wastes, minimise the hazardous wastes generated, ensure environmentally sound waste management and recovery practices and assist developing countries in improving waste management systems | • Includes a complete ban on exports of hazardous wastes from industrialised to developing countries<br>• Phase out of transboundary movement of hazardous waste for recycling or recovery |
| Vienna Convention on the Protection of the Ozone Layer, 1985 | • Seeks to control human activities found to have adverse impacts on the ozone layer<br>• Supported by the Montreal Protocol and amendments (see below) | • Protection of human health and the environment against adverse effects resulting from human activities which modify the ozone layer |

*Table 2.4 Overview of International Conventions and Australia's Obligations applicable to the Prelude FLNG Project (continued)*

| Convention | Summary | Obligations |
|---|---|---|
| Montreal Protocol on Substances that Deplete the Ozone Layer, 1987 | • Specific requirements for reductions in emissions of gases that deplete the ozone layer<br>• Amended four times: London 1990, Copenhagen 1992, Montreal 1997 and Beijing 1999 | • Use of carbon tetrachloride, 1,1,1-trichloroethane and hydrobromofluorocarbons and halons must be phased out<br>• Use of chlorofluorocarbons and halons must be phased out in 'eligible developing countries' by 2010<br>• Use of methyl bromide must be phased out by 2015<br>• Use of hydrochlorofluorocarbons must be phased out by 2040 |
| United Nations Framework Convention on Climate Change, 1992 | • Seeks to stabilise greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system, within a sufficient time frame to allow ecosystem to adapt naturally, protect food production and enable sustainable economic development | • Reduction in emissions of greenhouse gases, particularly carbon dioxide and implementation of measures to facilitate adequate adaptation to climate change<br>• Formation of nationally comparable inventories of emissions and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol<br>• Promotion of technologies to assist all parties in meeting their commitments<br>• Sustainable management and conservation of sinks<br>• Requirement for *Annex I* 'developed countries' to return emissions of carbon dioxide and other greenhouse gases (not controlled by the Montreal Protocol) to 1990 levels. Australia is an Annex I country but has additional concessions. |
| Kyoto Protocol, 1997 | • Ratified by Australian Government in 2008<br>• Follow on from the Framework Convention on *Climate Change* | • Contains legally binding reductions in the emissions of greenhouse gases for specific countries (in Annex I of the Protocol) additional to those identified in the Framework Convention (above)<br>• Requirements for establishment of system of monitoring and review of greenhouse gas emissions (not already controlled through the Montreal Protocol (above) |
| Convention on the International Maritime Organization 1948 | • Establish International Maritime Organisation (IMO) which is responsible in setting standards and adopting regulations that apply to all vessels that operate internationally.<br>• Provide machinery for co-operation among Governments in regulations and practices relating to technical matters of all kinds affecting shipping engaged in international trade.<br>• Adopt the highest practicable standards in matters concerning maritime safety, efficiency of navigation and prevention and control of marine pollution from ships. | • Comply with international shipping regulations set by IMO, when ratified, for international shipping businesses |
| International Convention on Load Lines (LL) 1966 | • Set limitation on the draught to which a ship may be loaded, an important consideration in its safety | • Before proceeding to sea on an international voyage, ships have to be surveyed, marked and provided with an International Load Line Certificate (1966) or, where appropriate, an International Load Line Exemption Certificate |
| United Nation Convention on Law of the Sea, 1982 | • This convention recognises the desirability of establishing a legal order for the seas and oceans which will facilitate international communication, and will promote the peaceful uses of the seas and oceans, the equitable and efficient utilisation of their resources, the conservation of their living resources, and the study, protection and preservation of the marine environment. | • Right of navigation, overflight, scientific research and fishing on the high seas<br>• Obligation to cooperate with other States in adopting, measures to manage and conserve living resources;<br>• Prevent and control marine pollution and are liable for damage caused by violation of their international obligations to combat such pollution;<br>• Settle by peaceful means on disputes concerning the interpretation |

*Table 2.4 Overview of International Conventions and Australia's Obligations applicable to the Prelude FLNG Project (continued)*

| Convention | Summary | Obligations |
|---|---|---|
| Convention on Safety of Life at Sea (SOLAS), 1974 | • Improve the safety of shipping, including subdivision and stability; machinery and electrical installations; fire protection, detection, and extinction; lifesaving appliances; radiotelegraphy and radiotelephony; safety of navigation; carriage of grain; carriage of dangerous goods; and nuclear ships. | • Apply measures to enhance vessel safety including: standards for ship design and construction; stability; fire protection, lifesaving, communications, navigation, safety management and certification<br>• Require vessels to upgrade fire protection and lifesaving equipment, and install low-level lighting, smoke detectors and automatic sprinklers. |
| The Convention on International Regulations for Preventing Collisions at Sea 1972 (COLREGS) | • Set out the 'rules of the road' to be followed by ships and other vessels at sea | • All vessels must comply with the provisions of these Rules with respect to the number, position, range or arc of visibility of lights or shapes, as well as to the disposition and characteristics of sound-signalling appliances. |
| Convention for the Suppression of Unlawful Acts Against the Safety of Maritime Navigation, 1988 | • Provide requirement to ensure that appropriate action is taken against persons committing unlawful acts against ships and fixed platforms engaged in the exploitation of offshore oil and gas.<br>• These actions include the seizure of ships by force; acts of violence against persons on board ships; and the placing of devices on board a ship which are likely to destroy or damage it | • Take appropriate measures to prevent unlawful acts which may threaten passengers and crews |
| The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW), 1978, amended 1995 | • Establish requirements for basic safety training and certification for all crew members engaged in international voyages, and advanced training requirements for crew members with assigned safety or pollution prevention duties.<br>• Specify minimum standards for crew competence and set criteria for evaluation of crew training by the flag administration.<br>• Measures for watch keeping personnel to prevent fatigue. | • Provide detailed information to IMO concerning administrative measures taken to ensure compliance with the Convention education and training courses, certification procedures and other factors relevant to implementation.<br>• Requirements to ensure that training, certification and other procedures are continuously monitored by means of a quality standards system<br>• Requirements for watch keeping personnel to prevent fatigue. |
| The Convention on Civil Liability for Oil Pollution Damage (CLC) 1992 | • Specify requirements to ensure that adequate compensation is available to victims and which places the liability for the damage on the ship owner. | • The Convention requires ships covered by it to maintain insurance or other financial security in sums equivalent to the owner's total liability for one incident. |
| Convention on International Maritime Satellite Organisation (INMARSAT), 1976 | • Concern the use of space satellites for improved communication, enabling distress message to be conveyed much more effective than by conventional radio. | • Requirements for a satellite communications system devoted to maritime purposes. |
| Convention on Facilitation of International Maritime Traffic (FAL), 1965 | • Set up Standards and recommended Practices on formalities, documentary requirements and procedures which should be applied on arrival, stay and departure to the ship itself, and to its crew, passengers, baggage and cargo to prevent unnecessary delays in maritime traffic, to aid co-operation between Governments, and to secure the highest practicable degree of uniformity in formalities and other procedures. | • Apply IMO "Standards" and "Recommended Practices" on formalities, documentary requirements and procedures for ship on arrival, stay and departure. |
| The International COSPAS-SARSAT Program Agreement | • Space System for the Search of Vessels in Distress | • Manage the space segment obligations under the International Cospas-Sarsat Program Agreement |

WB funded projects, unless the standards of the host country are more stringent. Shell will always adhere to Australian legislation and guidelines in the first instance unless international standards are more stringent. Those standards and guidelines considered are set out in *Table 2.5*

The relevant requirements of the legislation, conventions, standards and guidelines outlined in this chapter have been captured and incorporated into the Prelude HSE premise document. The HSE premise is the 'rule set' for the design of the FLNG facility.

*Table 2.5 International Guidance Relevant to the Prelude FLNG Project*

| | Organisation | Title |
|---|---|---|
| Apr-07 | IFC | General Environmental, Health and Safety (EHS) Guidelines |
| Apr-07 | IFC | EHS Guidelines: Offshore Oil and Gas Development |
| Apr-07 | IFC | EHS Guidelines: Liquefied Natural Gas Facilities |
| Apr-07 | IFC | EHS Guidelines for Natural Gas Processing |
| Mar-99 | WB | World Bank Pollution Prevention and Abatement Handbook |
| Jul-07 | IFC | IFC Guidance Note 1: Social and Environmental Assessment and Management Systems |
| Jul-07 | IFC | IFC Guidance Note 3: Pollution Prevention and Abatement |
| Jul-07 | IFC | IFC Guidance Note 4: Community Health, Safety and Security |
| Jul-07 | IFC | IFC Guidance Note 6: Biodiversity Conservation and Sustainable Natural Resource Management |
| Jul-07 | IFC | IFC Guidance Note 8: Cultural Heritage |
| Apr-06 | IFC | IFC Performance Standard 1: Social and Environmental Assessment and Management Systems |
| Apr-06 | IFC | IFC Performance Standard 3: Pollution Prevention and Abatement |
| Apr-06 | IFC | IFC Performance Standard 4: Community Health, Safety and Security |
| Apr-06 | IFC | IFC Performance Standard 6: Biodiversity Conservation and Sustainable Natural Resource Management |
| Apr-06 | IFC | IFC Performance Standard 8: Cultural Heritage |
| Dec-03 | IFC | Good Practice Note: Addressing the Social Dimensions of Private Sector Projects |
| Mar-06 | IFC | A Guide to Biodiversity for the Private Sector |

## 2.8 SHELL HSE POLICY AND COMMITMENT

### 2.8.1 Introduction

The Shell General Business Principles (Shell, 2005) govern how all of the Shell companies which make up the Shell Group conduct their affairs. As part of these principles, Shell commits to contribute to sustainable development, that is balancing short and long-term interests and integrating economic, environmental and social considerations into decision-making.

Further details on the Shell General Business Principles can be found at the following link: http://www.shell.com/home/content/aboutshell/who_we_are/our_values/sgbp/sgbp_30032008.html

One of Shell's General Business Principles is to have a systematic approach to Health, Safety, Security, Environment and Social Performance (HSE). It is a requirement for all Shell companies, joint ventures under Shell control and contractors to manage HSE in line with Shell's HSE Policy and Commitment.

The Shell HSE commitment is to:

- pursue the goal of no harm to people;
- protect the environment;
- use material and energy efficiently to provide our products and services;
- develop energy resources, products and services consistent with these aims;
- publicly report on our performance;
- play a leading role in promoting best practice in our industries;
- manage HSE matters as any other critical business activity; and
- promote a culture in which all Shell employees share this commitment.

The HSE Policy requires every Shell company to:

- have a systematic approach to HSE management designed to ensure compliance with the law and to achieve continuous performance improvement;
- set targets for improvement and measure, appraise and report performance;
- require contractors to manage HSE in line with this policy;
- require joint ventures under operational control to

apply this policy and use its influence to promote it in other ventures; and

- include HSE performance in the appraisal of all staff and reward accordingly.

### 2.8.2 HSE Control Framework

Shell HSE Control Framework provides guidance on good practice in managing specific HSE risks that are relevant to all Shell Group businesses. The Prelude FLNG Project sits within the Upstream business. Upstream has adopted the Group guidelines through the EP Business HSE Control Framework, which contains three elements:

- Volume 1: HSE Management System Elements controlling documents.
- Volume 2: HSE Management in the Business controlling documents.
- Volume 3: Hazard and Effect Management Process (HEMP) Requirements, Tools and Techniques controlling documents.

Specific HSE risks covered by the HSE Control Framework include:

- ozone depleting substances;
- waste;
- SOx and NOx;
- soil and groundwater monitoring/remediation;
- greenhouse gases and energy use and efficiency;
- biodiversity;
- continuous flaring and venting;
- volatile organic compounds; and
- water in the environment.

Shell established a set of Global Environmental Standards in July 2007 for all its operations as a baseline for continuous improvement as required by the Group HSE Commitment and Policy and addressing, amongst others, the HSE risks outlined in the HSE Control Framework. Shell has also set a number of environmental objectives including the control and minimisation of waste disposal and zero reportable oil and chemical spills. All operating companies are required to set targets for improvement and measure, appraise and report performance.

The Shell's Sustainability Report (Shell, 2008) and related information outlining Shell's environmental performance can be located at the following website links:

- http://www.shell.com/home/content/responsible_energy/environment/
- http://www.shell.com/home/content/responsible_energy/approach_to_reporting/our_approach/our_approach_to_reporting_26042007.html

### 2.8.3 Shell Group Biodiversity Standard

The Shell Group Biodiversity Standard recognises that Shell's activities have the potential to cause impacts to biodiversity. The standard reflects that '*a failure to protect biodiversity could jeopardise [Shell's] licence to operate while a strong reputation built on the effective management of biodiversity will be a competitive advantage*'. The standard requires Shell companies to demonstrate commitment to operating responsibly in respect to biodiversity and to seek ways of making a positive contribution towards its conservation.

The standard requires that Shell companies:

- work with others to maintain ecosystems;
- respect the concept of protected areas;
- seek partnerships to enable the Group to make a positive contribution towards the conservation of global biodiversity;
- conduct environmental assessments, including the potential impacts on biodiversity, prior to all new activities and significant modifications to existing activities; and
- bring focused attention to the management of activities in internationally recognised biodiversity hotspots, including the identification of, and early consultation with, key stakeholders.

### 2.8.4 Minimum Health Management Standards

The Minimum Health Management Standards set down the minimum requirements for the management of health in companies where Shell has operational control.

The seven standards include:

- Health Risk Assessment;
- Monitoring of Health Performance and Incident Reporting and Investigation;
- Health Impact Assessment;
- Human Factor Engineering in New Projects;
- Product Stewardship;
- Fitness to Work; and
- Local Health Facilities and Medical Emergency Response.

# 3 CONSULTATION

## 3.1 INTRODUCTION

Stakeholder engagement and consultation is an integral part of Shell's project development process, helping to both inform business decisions and identify issues that require action. Shell has internal policies and processes which outline the requirements of stakeholder engagement. These are underpinned by Shell's General Business Principles, which govern how the Shell companies that make up the Shell Group conduct their affairs (*Section 2.8.1*).

Stakeholder engagement is a key part of any Shell project or activity. Stakeholder engagement is a systematic process, starting with developing an understanding of the issues, identifying stakeholders, developing a Stakeholder Engagement Plan (SEP) and then creating and maintaining stakeholder relationships and partnerships using a variety of engagement methods. Stakeholder engagement is seen as a two-way process, designed to ensure stakeholders are able to understand, absorb, respond and interact within appropriate timeframes.

In line with Shell's General Business Principles, as well as the "Interim Industry Guide to Community Involvement" of the Western Australian State Government, Shell is committed to:

- informing stakeholders of the proposed Prelude FLNG Project;
- maximising the level of accurate and accessible information about the project;
- providing adequate time for stakeholders to consider and engage in meaningful dialogue;
- identifying and attempting to resolve potential issues;
- using stakeholder feedback to inform and improve business decisions; and
- delivering a net benefit.

A wide range of stakeholders have been identified for the Prelude FLNG Project, comprising individuals and organisations from stakeholder groups including federal government, state government, non-governmental organisations, industry and the local community.

Regular consultation with the Prelude FLNG Project's identified stakeholders will continue throughout the project's lifespan, ensuring that queries and concerns raised are addressed and, where feasible, appropriate responses are built into the design and/or management plans.

## 3.2 METHODS OF ENGAGEMENTS

### 3.2.1 Stakeholder Engagement Plan

A critical tool in stakeholder engagement has been the development of a detailed SEP for the project, which has helped guide and focus the timing and content of engagements as well as provide a means of capturing feedback. The Prelude FLNG Project SEP is based on:

- identification of stakeholders; and
- identification of stakeholder issues.

Where appropriate, stakeholders' concerns and the actions or plans developed to address these concerns are reported in the SEP. The SEP also contains:

- a stakeholder engagement database which provides details on where/when/why/how the engagement took place and what feedback was received; and
- future engagement planning for upcoming project milestones.

Importantly this plan does not only identify the main stakeholders for the project and where and when consultations should take place, but also provides the ability to capture feedback from stakeholders to inform business decisions. The SEP is a live document which is updated regularly to reflect changes in views and opinions and business decisions, as appropriate.

### 3.2.2 Engagements

Since the Prelude field discovery in 2007, there have been three main 'waves' of engagement with stakeholders concerning the Prelude FLNG Project. These have been in relation to key project development milestones, as follows:

1) after the discovery of the Prelude field in 2007;
2) during the announcement of FLNG as the preferred development option and submission of the Environmental Referral in April 2008; and
3) prior to submission of this draft EIS.

Stakeholders engaged initially were Federal and State Government Ministers and departments. These face-to-face meetings included an introduction to the project, FLNG facility technology and safety parameters, and advice that this will be the first Shell-operated gas project in Australia.

In the second phase of engagements, the concept of FLNG was introduced to a broader range of stakeholders including Non-Government Organisations (NGO), industry and Kimberley community representatives as well as government. As FLNG is a new application of existing technology, these engagements involved face-to-face meetings with individuals or groups, explaining the concept, how it is different to conventional onshore LNG developments and the relative benefits. These engagements provided an opportunity for Shell to receive feedback on the concept and its general application to developing gas resources. Stakeholders were also briefed on the Environmental Referral which was submitted in April 2008.

The latest set of engagements spoke to a similar group of stakeholders around details to be included in this draft EIS, indicating that once the draft EIS was finalised by the regulator and Shell, that there would be an opportunity for public comment.

For key stakeholders with a high interest in the Prelude FLNG Project there have also been individual consultations, in addition to the three main phases of engagement described above. These engagements undertaken with key stakeholders are shown in *Table 3.1*.

Future rounds of engagement will be undertaken when there is new information (such as the decision on the location of the Maintenance Workshop) or when the project is nearing a key milestone (such as the decision for the project to enter the Front-End Engineering and Design (FEED) phase).

The engagement methods used for each consultation to date have included:

- specific briefings with key stakeholders;
- discussion of the Prelude FLNG Project as part of industry and community conferences and workshops; and
- engagement with the media.

These are detailed below.

#### *Specific briefings*

Specific briefings with key stakeholders have occurred in all three phases of engagement, some of which are outlined below.

For the announcement of FLNG as the preferred development option and the submission of the Environmental Referral in April 2008, meetings were held during March-April 2008 with key stakeholders including state and federal government and Kimberley stakeholders (see *Table 3.1*). The purpose of these sessions was to provide a high level briefing on the project, in particular the specifics of the FLNG process as well as the logistical aspects of the project.

Prior to the submission of this draft EIS, briefings were held with the same stakeholders, focusing more on the baseline studies that had been undertaken.

In addition to the main phases of consultation, there have been separate briefings with stakeholders, either as a one-off on a particular issue, or as ongoing regular updates for those stakeholders with a high level of interest in the project. For example, the National Offshore Petroleum Safety Authority (NOPSA) and the Australian Maritime Safety Authority (AMSA) have been regularly briefed on design and operation of the FLNG facility.

### *Conferences and Workshops*

At the annual conference of the Australian Petroleum Production and Exploration Association (APPEA) in April 2008, Shell's Executive Director of Gas and Power made a presentation where she announced that FLNG technology was the preferred development option for the Prelude field.

A Prelude FLNG Project representative was also invited to present at a workshop organised by the Northern Development Taskforce (NDT) in Broome in July 2008 which was attended by numerous Kimberley stakeholders (see *Table 3.1*). The NDT was established in June 2007 to coordinate the issues relating to the development of Browse Basin gas in the Kimberley as well as the National Heritage Listing of the Burrup Peninsula. Shell was invited to present on Prelude along with other companies that had gas development proposals in the Browse Basin area.

### *Media*

Effective communication with the media is a vital part of presenting Shell's capabilities and the Prelude FLNG Project. To aid this, Shell has in place a Disclosure Standard which outlines how information is provided to the media which ensures compliance with legal and regulatory requirements. For the Prelude FLNG Project, media coverage has been an important way to increase awareness among stakeholders.

At the APPEA conference in April 2008, Shell's Executive Director of Gas & Power gave a press conference in addition to her presentation to the conference. In this she provided further details to the media about the proposed Prelude FLNG Project, with the information reported in local, national and international news outlets and publications.

Since the announcement of FLNG as the preferred development option for Prelude, Shell has received further media inquiries on the status of the project. All media inquiries are responded to in a timely manner and information is provided in accordance with the Disclosure Standard.

## 3.3 STAKEHOLDERS

Stakeholders identified consist of pre-existing stakeholders, as a result of Shell's ongoing activities in Western Australia, as well as others identified through initial engagements with regulators and government agencies, desk-top research and regional contacts (see *Table 3.1*). The stakeholders can be broadly grouped as follows:

- local[8] residents;
- local businesses;
- local indigenous representative groups and Traditional Owners;
- Federal Government;
- WA State and NT Government;
- local government organisations;
- NGOs;
- industry representative organisations;
- tourist operators and tourists;
- academia; and
- fishing and pearling operators.

*Table 3.1* presents a summary of all the stakeholders that have been consulted to date by Shell, at what stage in the project's development they were engaged, as well as which of these stakeholders we expect to have more engagement with in future. The table indicates timings of the engagement, defined as follows:

- Stage 1: after the discovery of the Prelude field in 2007, in the very early stages of the project's development;
- Stage 2: around announcement of FLNG as the preferred development option for the Prelude field and submission of the Environmental Referral in April 2008;

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[8] *'local' refers to the town or region around where Shell will have some onshore activities related to the Prelude LNG Project*

*Table 3.1* *Prelude FLNG Project Stakeholders*

| **Stake-holder Group** | **Stakeholder** | **Timing of engagement** | | | | | |
|---|---|---|---|---|---|---|---|
| | | Stage 1 | Stage 2 | Stage 3 | NDT workshop | Targeted engagements | Planned engagements |
| Federal Government | Resources & Energy Minister and/or Advisor | ✓ | ✓ | ✓ | | ✓ | ✓ |
| | Environment Minister and/or Advisor | | ✓ | ✓ | | ✓ | ✓ |
| | Climate Change Minister and/or Advisor | | | ✓ | | ✓ | ✓ |
| | Prime Minister's Office | | ✓ | ✓ | | | ✓ |
| | Deputy Leader Opposition and/or Advisor | | ✓ | ✓ | | | ✓ |
| | Shadow Resources & Energy Minister and/or Advisor | | | ✓ | | | ✓ |
| Federal Government Agencies | Department of Resources, Energy and Tourism (DRET) | ✓ | ✓ | ✓ | | ✓ | ✓ |
| | Department of Environment, Water, Heritage and the Arts (DEWHA) | | ✓ | ✓ | | ✓ | ✓ |
| | Department of Climate Change | | | ✓ | | | ✓ |
| | National Offshore Petroleum Safety Authority (NOPSA) | | ✓ | ✓ | | ✓ | ✓ |
| | Australian Maritime Safety Authority (AMSA) | | ✓ | ✓ | | ✓ | ✓ |
| | Department of Families, Housing, Community Services and Indigenous Affairs | | | | ✓ | | ✓ |
| WA State Government | Premier's Office | | ✓ | ✓ | | ✓ | ✓ |
| | Resource Minister and/or Advisor | ✓ | ✓ | ✓ | | ✓ | ✓ |
| | Member for Broome | | ✓ | ✓ | | | ✓ |
| | Minister for Regional Development and /or Advisor | | | ✓ | | ✓ | ✓ |
| NT Government | Chief Minister and/or Advisor | | | ✓ | | | ✓ |
| | Department of Regional Development, Primary Industry, Fisheries and Mines | | | | | | ✓ |
| | Planning and Lands Minister and/or Advisor | | | | | | ✓ |
| | Environment Minister and/or advisor | | | | | | ✓ |
| | Resources and Fisheries Minister and/or Advisor | | | | | | ✓ |
| | Darwin Port Authority | | | | | | ✓ |

*Table 3.1 Prelude FLNG Project Stakeholders (continued)*

| **Stake-holder Group** | **Stakeholder** | **Timing of engagement** | | | | | |
|---|---|---|---|---|---|---|---|
| | | Stage 1 | Stage 2 | Stage 3 | NDT workshop | Targeted engagements | Planned engagements |
| WA State Government Agencies | Department of Industry and Resources (DoIR)* | | ✓ | ✓ | | | ✓ |
| | Department of Environment and Conservation (DEC) | | ✓ | ✓ | | | ✓ |
| | Environmental Protection Authority (EPA) | | ✓ | ✓ | | | ✓ |
| | Department of State Development^ | | | ✓ | | ✓ | ✓ |
| WA State Government Agencies | Tourism WA | | | ✓ | ✓ | | ✓ |
| | Department for Planning and Infrastructure | | | | ✓ | | ✓ |
| | Department of Fisheries | | | | ✓ | | ✓ |
| | LandCorp | | | | ✓ | | ✓ |
| | Office of Native Title | | | | ✓ | | ✓ |
| | Department of Housing and Works | | | | ✓ | | ✓ |
| | Department of Education and Training | | | | ✓ | | ✓ |
| | Department of Health | | | | ✓ | | ✓ |
| | Department of Indigenous Affairs | | | | ✓ | | ✓ |
| Local Government Organisations | Shire of Broome | | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Shire of Derby/West Kimberley | | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Kimberley Development Commission | | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Port of Broome | | ✓ | ✓ | ✓ | ✓ | ✓ |
| Non Governmental Organisations | World Wildlife Fund (WWF) | | ✓ | ✓ | | ✓ | ✓ |
| | Save the Kimberley | | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Environs Kimberley | | ✓ | ✓ | ✓ | ✓ | ✓ |
| | The Wilderness Society | | | ✓ | ✓ | ✓ | ✓ |
| | Australian Cons. Foundation | | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Broome Chamber of Commerce | | | ✓ | ✓ | | ✓ |
| | Cons. Council WA | | | | ✓ | | ✓ |

** Restructured into the Department of Mines and Petroleum, the Department of State Development and the Department of Commerce*

*^ Was previously the Northern Development Taskforce*

*Table 3.1* *Prelude FLNG Project Stakeholders (continued)*

| **Stakeholder Group** | **Stakeholder** | **Timing of engagement** | | | | | |
|---|---|---|---|---|---|---|---|
| | | Stage 1 | Stage 2 | Stage 3 | NDT workshop | Targeted engagements | Planned engagements |
| Industry Representative Organisation | WA Chamber of Minerals and Energy (future updates) | | ✓ | ✓ | | | ✓ |
| | APPEA | | | ✓ | | | ✓ |
| Aboriginal Representative Bodies | Kimberley Land Council (KLC) | | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Traditional Owners Taskforce | | | | ✓ | | ✓ |
| | West Australian Indigenous Tourism Operators Committee | | | | ✓ | | |
| | Kimberley Aboriginal Law and Culture Centre | | | | ✓ | | |
| Tourist Operators | Kimberley Marine Tourism Association | | ✓ | ✓ | ✓ | | ✓ |
| | Australia's Northwest | | | | ✓ | | ✓ |
| | Broome Visitor Centre | | | | ✓ | | ✓ |
| | Derby Visitor Centre | | | | ✓ | | ✓ |
| Academia | Curtin University | | | | ✓ | | ✓ |
| | Australian Institute of Marine Science | | | | ✓ | | |
| | University of Western Australia | | | | ✓ | | ✓ |
| | Centre for Whale Research | | | ✓ | ✓ | ✓ | ✓ |
| Fishing and Pearling | Western Australian Fishing Industry Council | | ✓ | ✓ | ✓ | | ✓ |
| | Recfish west | | | | ✓ | | |
| | Kimberley Professional Fishermen's Association | | ✓ | ✓ | ✓ | | |
| | Pearl Producers Australia | | | | ✓ | | |

- Stage 3: prior to submission of the Environment Impact Statement in July – September 2009;
- NDT workshop: engaged through their presence at the NDT workshop in July 2008;
- Targeted engagements: for those stakeholders who have a higher interest in the project or a specific element of the project, face to face briefings have been held outside of the main project milestones; and
- Planned engagements: those stakeholders Shell expects to consult with in the future.

## 3.4 CONSULTATION RESULTS

The Prelude FLNG Project consultation efforts have generally been well received, with many stakeholders displaying a keen interest in learning about FLNG technology. During the consultation sessions undertaken to date, numerous questions have been raised around economic, social and environmental impacts. A summary of the key questions raised, Shell's response and the references to further information in this draft EIS are presented in *Table 3.2*.

### 3.4.1 Consultation with Regulators

The Prelude FLNG Project has been regularly consulting with various regulators in the Federal and State Governments. Questions raised during these briefing sessions related to:

- potential environmental impacts eg noise and cooling water;
- tax revenues (onshore versus offshore);
- project milestones and project economics;
- integration with other Browse Developments;
- safety of the FLNG facility;
- security of the FLNG facility;
- domestic gas possibilities;
- carbon dioxide management; and
- Shell's evaluation of onshore facility locations.

### 3.4.2 Consultation with Local Communities

Consultation with the public has to date been with representatives of community organisations such as the Kimberley Land Council and the Shire of Broome.

Key subjects discussed included:

- workforce numbers and accommodation requirements in Broome;
- potential environmental impacts eg cooling water management, carbon dioxide emissions;
- indigenous opportunities eg employment;
- safety with regard to increased vehicle and air movements;
- opportunities for local businesses;
- land requirements for the maintenance workshop; and
- waste management requirements for the project.

Further engagement is planned and will be undertaken at the appropriate stages of the project design and decision making process.

### 3.4.3 Consultation with NGOs

Numerous NGOs have been consulted by Shell including Kimberley Land Council, World Wildlife Fund, Australian Conservation Foundation, Save the Kimberley and Environs Kimberley. Key questions raised by the NGOs relate to:

- project scheduling and milestones, eg Final Investment Decision (FID);
- emergency response procedures, eg during a cyclone;
- exploratory issues, eg number of drilling wells and location of activities offshore;
- potential environmental impacts, eg cooling water management, carbon dioxide emissions;
- indigenous opportunities, eg employment;
- onshore facilities and workforce details such as numbers of employment opportunities; and
- project benefits to the State.

### 3.4.4 Consultation with Industry and Commerce

High-level briefings have been provided to various industry bodies, for example, the WA Chamber of Minerals and Energy, as well as Broome specific industry representatives such as the Port of Broome and the Kimberley Development Commission.

Key questions raised by the industry and commerce bodies relate to:

- Front-End Engineering and Design (FEED) and project economics;
- integration with other Browse Developments;
- safety of the FLNG facility;
- workforce numbers and accommodation requirements in Broome;

*Table 3.2 Summary of Stakeholder Questions Raised During Consultations*

| Stakeholder Issue | Shell Response |
|---|---|
| What happens in a cyclone or extreme weather? | The FLNG facility has been designed to withstand a one in 10,000 year weather event. Modelling has used cyclonic conditions and shown that the FLNG design will withstand even the most severe cyclones. In a cyclone, the FLNG facility will stay on station and essential staff will remain onboard. |
| What will Prelude deliver WA in terms of local content, jobs, flow on benefits and the supply base? | Shell will provide a full and fair opportunity for Australian industry to supply goods and services. Shell is developing an Australian Industry Participation Plan that will ensure that Australian businesses are aware of tenders for project activities. There will be around 320 jobs directly associated with the development: 100 onshore and 220 offshore (two shifts of 110 each), plus indirect jobs associated with support services such as supply boat and helicopter transfers, maintenance support and material supply. A number of locations for a Maintenance Workshop are being considered and no final decision has been made. |
| What will be the impact on Broome in terms of the Port, land, accommodation, aviation, waste management and workforce? | Shell is currently using Broome as a supply base for drilling activities. The majority of activities onshore will revolve around the transport of people, equipment and materials. A number of Maintenance Workshop locations are being considered and no final decision has been made. A baseline social study has been carried out in order to better evaluate the possible impacts the project may have on Broome. Once this is fully evaluated, Shell will be able to look at mitigations to these impacts. These details will be included in Shell's Social Performance Plan (SPP) for Prelude which is in the early stages of development. Under the SPP, and where appropriate and in line with project execution, Shell will build on existing relationships it has with organisations in the Kimberley (eg Indigenous Community Volunteers organisation) to form partnerships that are aligned to Shell's social investment focus of health, education and environment. |
| What would be the benefits to indigenous groups ie education, training and jobs? | Shell around the world participates in the local communities in which we operate, including indigenous communities. Shell already has a presence in the Kimberley region through social investment partnerships with Indigenous Community Volunteers and Conservation Volunteers Australia, among others, and expects we will increase our range of partnerships as the Prelude FLNG Project progresses. We will engage with community representatives during this process. |
| Will the FLNG facility have any impacts on whales, turtles, coral reefs or the Kimberley coastline? | The FLNG is of sufficient distance from the Kimberley coast, turtle breeding areas, whale calving areas and coral reefs to operate without impact on these receptors. Support vessels out of Broome and Darwin will not create a material increase in vessel numbers in the area and strict cetacean management protocols will be put in place. There will be no infrastructure connected to, or visible from, the Australian mainland coast. |
| How will Shell manage $CO_2$ emissions – will it use carbon capture and storage technology to geosequester? | Prelude is a small and isolated gas resource that doesn't have the economies of scale to make CCS economically viable. However, the FLNG facility has around 15-25% less $CO_2$ emissions than a conventional onshore LNG facility. It has a reduced environmental footprint because there is no onshore processing plant, no long pipelines, no jetty and no dredging required. Of the $CO_2$ produced from combustion and the reservoir, only $CO_2$ from the reservoir is technically possible to sequester via CCS. Shell supports the Government's introduction of the Carbon Pollution Reduction Scheme (CPRS). It is also supportive of the Government's Global CCS Institute and was the first company to sign a Memorandum of Understanding with the Government to become a founding member of the Institute. Shell believes CCS will be a key technology to combat climate change. However, the decision to deploy CCS will be made on a project by project basis and it is currently too expensive for deployment at Prelude. |
| Will a FLNG facility replace the Kimberley LNG Precinct? | Shell believes FLNG may be an option for stranded gas reserves where conventional schemes are not economic. FLNG is particularly well suited to tapping into small, remote deposits. As such, it is complementary to conventional onshore LNG developments. |
| How is Shell going to develop the field – is there any chance of Prelude and the neighbouring Ichthys being joined? | Prelude and Ichthys are separate hydrocarbon reserves being developed by Shell and Inpex/Total, respectively. |
| Will the Prelude FLNG Project supply domestic gas for WA? | The Prelude field is small and remote, located 475 km from Broome, and the Prelude FLNG Project does not include a gas pipeline to shore. Shell appreciates WA's aspirations for long-term security of domestic gas supply. Through Shell's participation in the North West Shelf Venture and the Gorgon Joint Venture, Shell is and will continue to supply gas to WA's domestic gas market. |
| What are the associated safety and security issues? | After comprehensive studies, model testing and in-depth reviews, Shell's FLNG design safety is considered equal to the latest FPSO or integrated offshore facility.<br>In the unlikely event of a safety incident, emergency plans would be activated. The FLNG design incorporates security features to prevent unauthorised access and Prelude will work with Australian authorities to ensure a safe and secure operation. |

- potential environmental impacts, eg cooling water management, carbon dioxide emissions;
- indigenous opportunities eg employment;
- opportunities for local businesses;
- land requirements for the maintenance workshop; and
- waste management requirements for the project.

## 3.5 FUTURE ENGAGEMENTS

Stakeholder engagement will continue to help inform and guide development planning for the Prelude FLNG Project. There will be focused briefing programs in the lead-up to all project milestones, so that stakeholders are aware of and have an opportunity to comment on proposed activities in a timely manner. This will involve regular updating of the SEP as well as development of targeted engagement plans around specific project milestones or issues. In 2009, this will include face to face or group meetings on the relevant aspects of:

1) the potential environmental impact of the proposed Prelude FLNG Project;
2) the decision on the location of the Maintenance Workshop;
3) the hydrocarbon recovery and Field Development Plan of Prelude gas;
4) the decision for the project to enter the Front-End Engineering and Design (FEED) phase;
5) identifying possible partnerships and opportunities for Shell's SPP for the Prelude FLNG Project;
6) safety and security of the FLNG facility; and
7) maximising the amount of work the project will generate for Australia eg through the development of an Australian Industry Participation Plan.

Future engagements, such as on the topics above, will involve engagement methods used to date (face-to-face meetings, presentations at industry and community conferences, and engagement with media) and new tools, such as the establishment of a Prelude FLNG Project website, and conducting supplier workshops to outline potential opportunities to local businesses and individuals. The website will not only provide the latest information on the project for the public but will also alert business to opportunities as they arise.

The Federal Government review of this draft EIS document and the public comment period will provide stakeholders with further opportunity to provide formal input into the process. Shell welcomes this input, both during the public comment period and beyond, and will respond and continue to work with all stakeholders.

# 4 PROJECT DESCRIPTION

## 4.1 OVERVIEW

This chapter of the draft EIS provides details of the development and operation of the Prelude FLNG Project, and provides the basis upon which the prediction and evaluation of the environmental, social and health impacts has been conducted. The key elements of the Prelude FLNG Project included in this study are:

- general construction activities at the offshore location, such as preparation of the seabed;
- development well drilling;
- subsea structure installation;
- tow out and hook up of the FLNG facility;
- commissioning;
- operations; and
- decommissioning.

Onshore support facilities required during construction, commissioning and operation will be located in existing ports and associated industrial areas. The operation of these will be subject to consideration under the Western Australian State or Northern Territory government planning and approvals processes (as required) and are outside the scope of this draft EIS. Similarly, the fabrication and pre-commissioning of the FLNG facility will occur in an overseas shipyard and is outside the scope of this draft EIS.

### 4.1.1 What is LNG?

The main output from the Prelude FLNG Project will be Liquefied Natural Gas (LNG), which is natural gas in liquid form. When natural gas is cooled to minus 162°C, it contracts to one six-hundredth of its original volume and becomes a colourless, odourless, non-toxic and non-corrosive liquid with a high energy to volume ratio. LNG typically consists of between 85% to 99% methane; the remaining percentages generally comprise small amounts of ethane, propane, butane and pentane.

LNG is stored at near atmospheric pressure, reducing the storage hazard compared with pressurised fuels. Should a release to the atmosphere occur, it will evaporate and disperse quickly as it is lighter than air. As such, LNG can be safely and economically transported over long distances to locations beyond the reach of pipelines.

The LNG supply chain typically involves:

1) extracting the natural gas from the geological strata in which it is contained;
2) transporting the gas via a pipeline(s) to a treatment and liquefaction plant;
3) conditioning and dehydrating the raw gas to remove impurities such as carbon dioxide and water and the heavier hydrocarbons, which form natural gas liquids such as Liquid Petroleum Gas (LPG)[9];

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[9] *LPG is usually a mixture of propane and butane*

4) liquefying the conditioned gas, through cooling, and storing it in cryogenic tanks;
5) loading the LNG into purpose built carrier vessels and transporting it to international markets;
6) unloading and storage at LNG receiving terminals;
7) converting the LNG back to gaseous form by heat exchange; and
8) distributing the natural gas to the consumer via gas transmission lines.

The Prelude FLNG Project will involve the first five of the above stages in the LNG supply chain, from the extraction of the raw natural gas, through treatment and liquefaction, to loading of the LNG into purpose built carriers for distribution and transit through Australian waters.

The core concept of the FLNG facility is to mount the treatment and liquefaction facilities on to a barge-like floating structure, so that processing and distribution can be undertaken at the offshore gas field rather than installing pipelines back to a shore based treatment, liquefaction and export facility.

As such, the concept avoids the environmental and social impacts associated with a pipeline to deliver the raw gas onshore from the offshore field, and the coastal modifications and land take that is required for a shore based facility.

## 4.2 PROJECT OVERVIEW

### 4.2.1 The Project

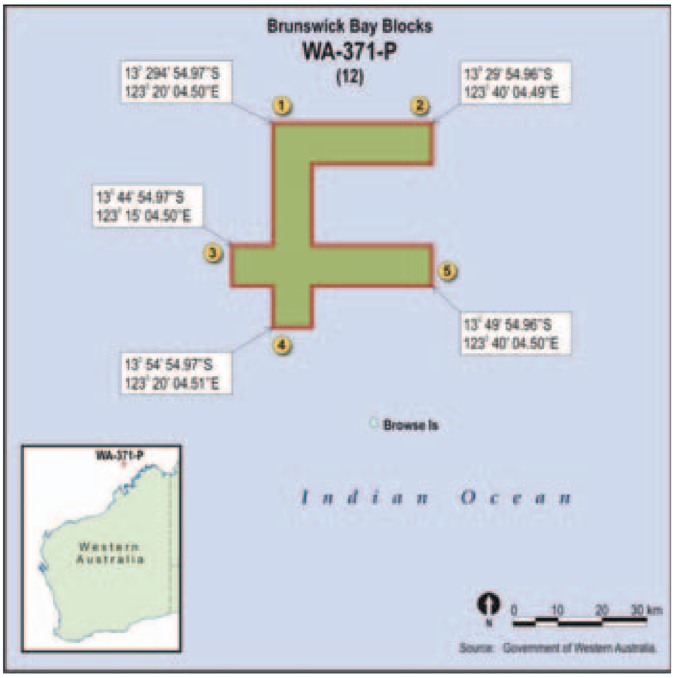
The Prelude field is located in the Caswell Sub-basin of the northern Browse Basin, approximately 475 km NNE of Broome, in Exploration Permit WA-371-P (see *Figure 4.1*).

Shell proposes to locate a FLNG facility over this field. Exploration Permit Area WA 371-P is located entirely within Australian Commonwealth waters with an average water depth of about 250 m.

The Prelude FLNG Project will comprise:

- upstream facilities including wells, flowlines, umbilicals and flexible risers (see *Figure 4.2* and *Figure 4.3*); and
- the FLNG facility, which includes liquefaction units, product storage and loading facilities, associated utility systems and a control room, maintenance facilities and accommodation.

*Figure 4.1 Exploration Permit Area WA-371-P*



Source: Government of Western Australia

Support will be provided during the project's development and operation from onshore facilities which are planned to be located within established industrial areas of Broome and/or Darwin:

- *Drilling Activities*: Broome will act as the support base for the drilling activities and vessels will operate out of the Broome Port.
- *Installation & Operation of the FLNG facility*: A Maintenance Workshop will be located in either Broome or Darwin, utilising existing port facilities for marine operations.
- *Aviation*: Broome Airport will be the aviation base for helicopter support to the FLNG facility. A forward refuelling point will be located on the Dampier Peninsula north of Broome, at or close to Lombadina.

These onshore facilities will be subject to consideration under the Western Australian State or Northern Territory government planning and approvals processes and are outside the scope of this draft EIS.

*Figure 4.2 FLNG facility and Associated Infield Infrastructure*

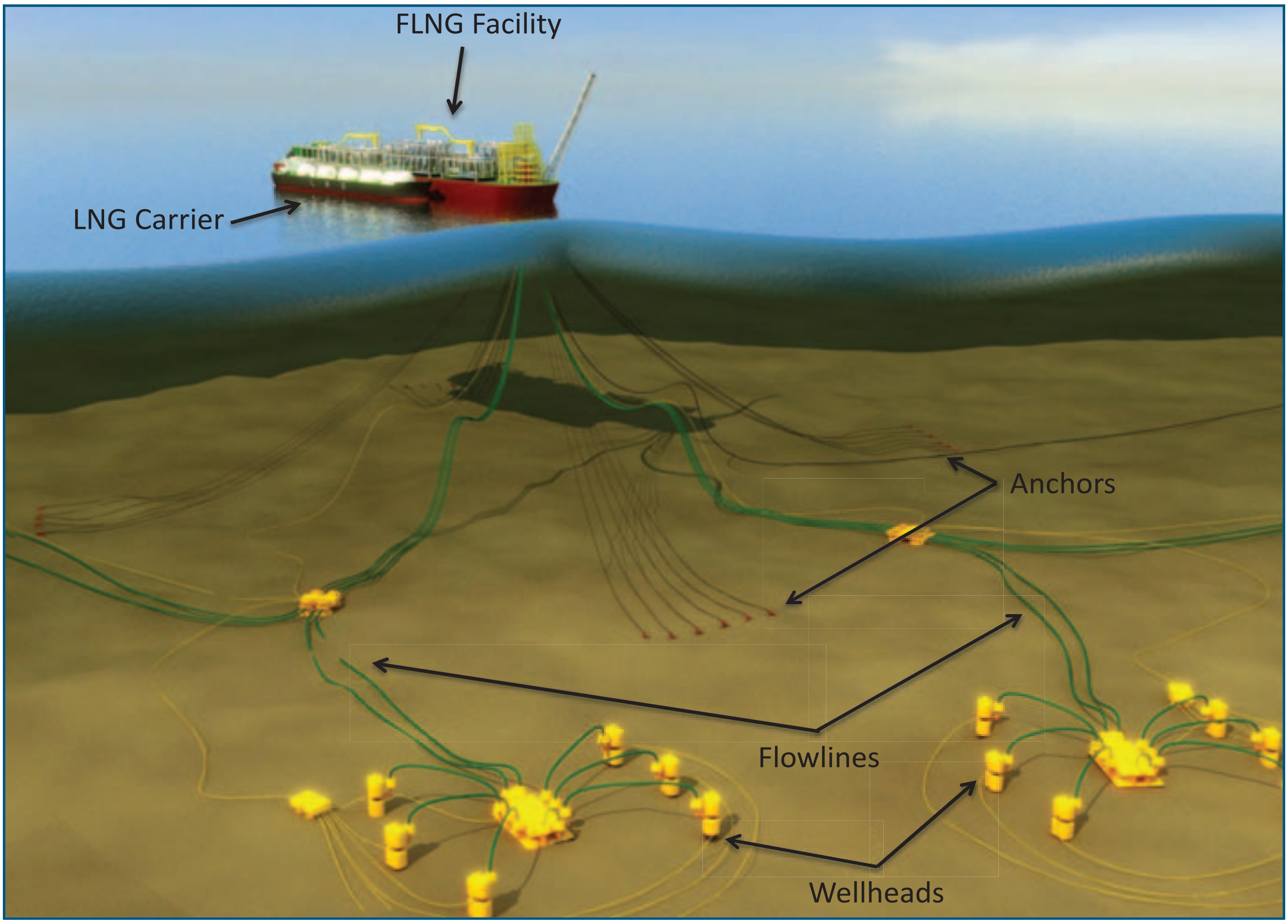
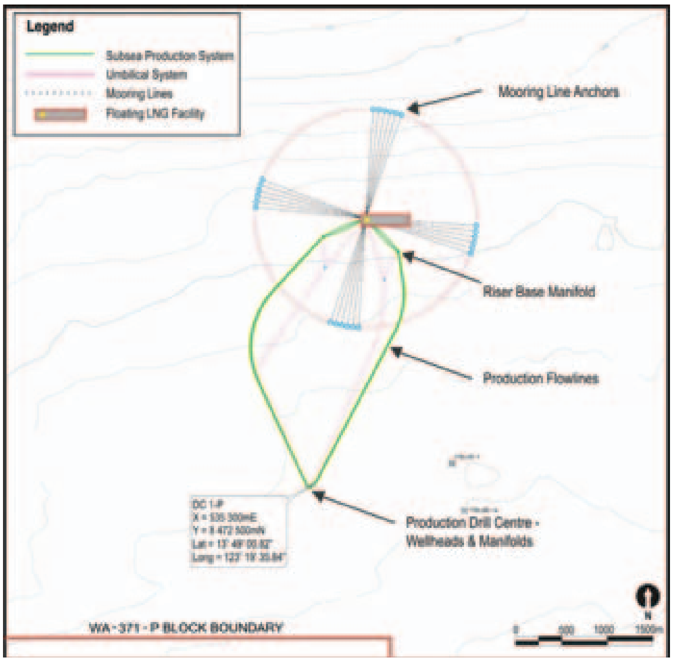


*Figure 4.3 FLNG facility & Subsea Infrastructure*



### 4.2.2 Project Justification

#### *Shell's Obligation as Petroleum Title Holder*

Petroleum Titles are issued to the private sector by Commonwealth and State government agencies to facilitate exploration and development of petroleum reserves within Australia. As the title holder for Exploration Permit WA-371-P, Shell has an obligation to undertake exploration of its title area, certify the nature and extent of the petroleum reserves and, if economically viable, develop them. Having established that the Prelude field holds hydrocarbon reserves, Shell has identified FLNG as the viable means to commercialise the reserves.

#### *Project Objectives*

The project objectives are to extract, treat and sell the discovered gas resources in the Prelude field to meet growing energy demand. The FLNG concept provides a technically innovative solution to developing this small and remote gas field in a cost-effective and environmentally low impact manner. It does this by avoiding the need for a 'traditional' development scenario comprising offshore platforms, export pipelines, onshore liquefaction plant and export jetty.

Shell is committed to contributing toward sustainable development and to producing energy responsibly. This means helping meet the world's growing need for energy in economically, socially and environmentally responsible ways.

The Prelude FLNG Project presents the opportunity for the first use of FLNG technology in Australia.

### *Production Capacity*

The FLNG facility will have a design capacity of 3.6 million tonnes per annum (mtpa) of LNG, 0.4 mtpa of LPG and 1.3 mtpa of condensate.

### *Project Lifespan*

The project is aiming to commence Front-End Engineering and Design (FEED) in the second half of 2009 and to take a Final Investment Decision (FID) to commit to the project in early 2011. From FID it will take about five years before the FLNG facility has been built and towed to site ready for start-up. During this period the subsea wells will be drilled and the subsea infrastructure installed ready to supply gas to the FLNG facility on its arrival. Current planning indicates that the development drilling program is expected to take approximately two years.

The FLNG facility will be designed to operate for up to 25 years between dry docks and the hull will be designed for a 50 year life. It is intended that the facility will remain on station over the Prelude field for 25 years.

An indicative timeline for the project development is provided in *Table 4.1*.

## 4.3 ANALYSIS OF ALTERNATIVES

### 4.3.1 Onshore LNG and FLNG

Shell examined a range of options to develop the Prelude field including a traditional onshore LNG plant at a number of proposed locations and a technically innovative offshore FLNG solution. The criteria used to assess these options were as follows:

*Table 4.1 Indicative Project Timeline*

| Project Phase | Target Date |
|---|---|
| Development drilling | 2013 |
| Subsea construction | 2014 |
| FLNG facility construction and delivery to field | 2015 |
| Commissioning | 2015 |
| First gas | 2016 |
| Decommissioning | 2040 |

- technical – feasibility and safety;
- environmental – impact during construction, operation and decommissioning, and assessment against compliance with the objectives of the *EPBC Act*;
- commercial – cost, schedule and business case;
- organisational – do-ability and logistics; and
- political – access to site and approvals process.

Prior to the Northern Development Taskforce (NDT) site selection process in 2008, Shell undertook a comprehensive LNG site selection study in 2006 across the Kimberley region to explore feasible options for a land based LNG facility. A preliminary list of twenty six onshore sites was short listed to six sites and these were assessed against the criteria shown above, ranking both the likelihood of their occurrence and the respective potential impacts.

With a reserve capacity of only 2-3 trillion cubic feet of natural gas, the size of the Prelude field and its distance from shore meant that the economic viability of a conventional onshore processing plant and associated pipeline infrastructure was considered sub-optimal compared to a FLNG facility.

Further, the onshore options were all found to require a significantly larger environmental footprint than the FLNG facility. All onshore options would require a significant land-take and the associated land clearing for the onshore processing infrastructure, an export pipeline (with rock stabilisation in shallow water), a causeway and a jetty with dredging for shipping access.

In terms of the controlling provisions under the *EPBC Act* for the Prelude FLNG project, the onshore options would:

- Increase the size of the environmental footprint within Commonwealth Marine waters due to the requirement for an export pipeline to shore; and
- Increase the potential for impacts on humpback whales and other listed and migratory species using waters inshore of the Prelude FLNG facility location because processing and transport operations for a conventional onshore LNG project take place onshore and nearshore.

A FLNG facility was chosen as the proposed development solution for the following reasons:

- lower development and decommissioning cost;
- smallest environmental footprint in the least sensitive location and with simplest decommissioning and rehabilitation requirements; and
- flexibility to subsequently relocate and reuse the FLNG facility to other fields.

However, it should be stressed that the application of FLNG is not the optimal development solution for all offshore gas fields because:

- The production capacity of an FLNG facility is limited, due to the deck space required for process equipment, constraining throughput and economics, especially for projects with substantial gas assets. The FLNG capacity of 3.6 mtpa has less “economy of scale” than the latest onshore designs eg. Gorgon trains totalling 15 mtpa and the latest Qatar LNG trains, each of 7.8 mtpa;
- FLNG projects are more difficult to expand as expansion is only achievable by the installation of additional ‘stand alone’ facilities. Expansion of onshore plants can achieve considerable capital cost and materials savings and only incremental additional environmental impacts because they may not need to build additional common-use infrastructure such as power generation or export jetties; and
- FLNG also has higher operating and maintenance costs compared to onshore plants, with very limited operational synergies available for multiple FLNG facilities compared to an onshore plant operating multiple gas trains.

FLNG is seen as a solution for developing small, remote gas fields that are difficult to develop commercially with conventional solutions (often referred to as stranded gas assets). The application of FLNG for the Prelude project could provide the catalyst for the development of other stranded gas assets in Australia and the region.

### 4.3.2 Do Nothing Alternative

The ‘do nothing’ alternative was not considered as this option is neither in keeping with Shell’s obligations as the title holder for Exploration Permit Area WA 371-P, nor its commercial objectives as an oil and gas producer. However, the development of the Prelude field would have been delayed if FLNG was not an option. FLNG has made the development of this remote gas resource commercially viable.

## 4.4 DESIGN CONSIDERATIONS

### 4.4.1 HSE Design Standards

The HSE requirements of the project start with compliance with the Australian Commonwealth and applicable state and territory legislation, and applicable internationally HSE codes, standards and guidelines, as specified in *Chapter 2* of this draft EIS. In addition, international agreements to which Australia is a party have been applied as well as Shell Group Policies, Standards, Procedures and Guidelines including:

- Shell EP HSE Manuals EP2005/95000;
- Shell Design and Engineering Practices; and
- Shell HSE Control Framework.

The most stringent HSE standards are being adopted on this project. These are detailed in the HSE Premises for the Prelude FLNG Project, which details the minimum set of standards for the project to ensure that identified risks to people, assets, reputation and the environment have been addressed in the project design. The design mitigations together with the management measures that will be developed will ensure risks are acceptable and ‘As Low As Reasonably Practicable’ (ALARP).

### 4.4.2 Emissions Reduction – Carbon Footprint

The Carbon Pollution Reduction Scheme (CPRS) represents the Australian Government’s policy approach to reducing emissions of GHG from Australian industry. The Prelude FLNG project is being designed and developed in the context of the impending CPRS. Consideration of costs associated with GHG emissions has formed part of the criteria for assessing project process and equipment selection.

The design of the FLNG facility incorporates a number of measures to reduce its carbon footprint:

- The Prelude FLNG Project combines the offshore and onshore components into one integrated FLNG facility which reduces the use of materials (steel, concrete etc) and land take:
    - By being located over the gas field, it avoids a long pipeline to shore. This reduces the materials and energy use as well as other potential environmental impacts that would otherwise be present during the pipeline construction and operation.
    - During the later life of the field, as the reservoir pressure declines, compression of feedgas will be required. The energy requirements to compress the feedgas for FLNG are reduced compared to a conventional design with an onshore LNG plant as there is a shorter distance to the FLNG plant and less pressure drop between it and the field.
    - The design avoids the need for any additional processing requirements to remove water from the gas and condensate to make it suitable for transport in a carbon steel pipeline to shore.
- The FLNG facility itself has a number of efficiency improvements over an onshore LNG Plant such as:
    - The development uses cold seawater from 150 m depth as coolant rather than coastal seawater or air cooling. Water from this depth is colder than coastal seawater and therefore reduces energy requirements for liquefaction.
    - The production processes use a dual mixed refrigerant liquefaction cycle to enable optimum efficiency for differing gas compositions and ambient temperatures.
    - The process minimises LNG boil-off by avoiding long recirculating loading lines. By minimising boil-off, the downgrade from LNG to fuelgas is reduced and the overall thermal efficiency of the liquefaction process is increased.
    - Use of steam boilers avoids the need for high pressure fuel compression, reducing fuel consumption.

These efficiencies result in the FLNG facility being 15 - 25% less $CO_2$ intensive than a similar onshore LNG plant.

### *Opportunity For Sequestration*

In evaluating $CO_2$ sequestration potential for any project, the first consideration is to determine which $CO_2$ stream can be sequestered. The options are:

- sequester only the reservoir $CO_2$ that has been separated from the feedgas and is available as a nearly pure $CO_2$ stream; and
- seek to also capture and sequester the $CO_2$ contained in the fluegas emitted from the combustion of fuelgas in the steam boilers.

Capture and sequestration of the fluegas $CO_2$, from the boiler exhaust stacks, is not feasible as it is not proven technically, requires too much equipment space and would be too expensive. Sequestration therefore has only been considered in respect of the reservoir $CO_2$.

### *Sequestration Targets*

Two possible subsurface structures have been evaluated as potential sinks to enable long-term, secure geo-sequestration of the reservoir $CO_2$.

#### a. Sequestration into the Swan Formation

This would inject reservoir $CO_2$ back into the Swan formation, which contains the Prelude field, at 4000 m depth, some distance away from the crest of the Prelude field where the gas producer wells will be located. The $CO_2$ would be compressed to 250 bar, dehydrated (inter-stage) and then pass through the swivel in the turret on the FLNG facility, back down a flexible riser to the sea floor and then to a single injection well.

Technical areas requiring further work are:

- this would be the first project to reinject $CO_2$ back into a producing gas reservoir at the start of field life. The extent and rate of $CO_2$ recirculation within the gas reservoir is uncertain and may impact on $CO_2$ content in the feedgas in the later life of the Prelude field;
- in the early years, re-start of the $CO_2$ compressors after a trip could prove difficult due to high reservoir backpressure; and
- the $CO_2$ reinjection could have a pressure maintenance and a positive sweep effect in the reservoir, providing an enhanced oil recovery benefit.

**b. Sequestration into the Puffin Aquifer**

The Puffin aquifer is a sandstone formation at 1800 m depth which contains saline water below an overlying shale layer.

Injection of $CO_2$ into an aquifer has the following precedents:

- Offshore Norway, Statoil-Hydro has been reinjecting 1 mtpa of $CO_2$ into the aquifer overlaying their Sleipner field since 1998.
- Also in Norway, the Statoil-Hydro Snohvit LNG Project (5 mol% $CO_2$ and 4.5 mtpa LNG capacity) began reinjecting its reservoir $CO_2$ in 2008 by a 160 km return pipeline into a sandstone formation beneath the gas reservoir at 2600 m depth and at a rate of 0.7 mtpa of $CO_2$.
- In Australia, the Gorgon Project proposes to sequester 3.5 mtpa of $CO_2$ into the Dupuy saline aquifer below Barrow Island.

Technical areas requiring further work are:

- more data required about the Puffin shale sealing layers and their effectiveness in containing the $CO_2$; and
- further engineering studies to confirm that only 4 stages of compression for a 130 bar injection pressure system are required.

### *FLNG facility Capability to inject $CO_2$*

The next issue to consider is whether the FLNG facility can safely and reliably compress the $CO_2$ stream to the high pressure required and inject it, via the turret, in to the subsea $CO_2$ injection well. Some of the issues for sequestration of the reservoir $CO_2$ from the FLNG facility that require further work are:

- A $CO_2$ compression system capable of reinjecting the $CO_2$ to the required pressure for reinjection back into a gas reservoir would be the largest such system ever built to operate at such high pressures. It would need about 20 MW power to drive 5 stages of compression to achieve 250 bar, with intercooling and dehydration of intermediate streams.
- The reliability and availability of the $CO_2$ reinjection system is not proven and could affect the net $CO_2$ reinjected. For example, known industry data suggests an 80% availability of the system which means that the net $CO_2$ reinjected would be 770 ktpa rather than the full 966 ktpa produced. Whenever the reinjection facilities are shutdown (whether planned or unplanned), then the $CO_2$would be vented safely to atmosphere.
- Super critical $CO_2$ has a strong solvent effect on rubbers and elastomers and material testing is required for the swivel and flexible riser components of the $CO_2$ return pipeline through the FLNG turret.

Overall, the sequestration of reservoir $CO_2$ has significant cost and technical uncertainties still to be resolved and adds a degree of complexity to the FLNG design. For this first application of the FLNG technology it is therefore proposed to safely vent the reservoir $CO_2$ up the flare stack once it has been separated from the feedgas.

Economic factors will also be significant in a decision whether to sequester the reservoir $CO_2$ and this will largely be dependent on the design of the Australian CPRS, the emerging price of carbon and the overall volume of reservoir $CO_2$ compared to the capital and operational cost of geosequestration. The Prelude field is small and compared to larger gas fields, lacks the volume of reservoir $CO_2$ and economy of scale to make geosequestration economically attractive given the high, upfront capital costs involved.

The approach for Prelude greenhouse offset is as follows:

- Support the proposed CPRS and meet all obligations under the Scheme; and
- Maximising energy efficiency and reducing emissions wherever practicable, as outlined in this section.

Sequestration of the reservoir $CO_2$ may be reconsidered for the project at a later stage if sufficient progress has been made in overcoming the technical issues, which continue to be studied. To facilitate this, deck space has been allowed in the FLNG facility design for a future $CO_2$ compression module to be installed. Sequestration of the reservoir $CO_2$ would also require the drilling of an addition well (injection well) and the installation of a flowline from the FLNG facility to the injection well, marginally increasing the project's footprint on the sea floor.

Beyond the Prelude project, Shell is working on a number of initiatives in Australia and globally that aim to fast track the commercialisation of Carbon Capture and Storage (CCS) technology. One example of this is Shell's partnership with the Weyburn-Midale $CO_2$ project in

Canada, where geological storage of $CO_2$ has been studied since 2000. In Australia, Shell has voluntarily been involved in a number of CCS initiatives. It was the first company to sign a Memorandum of Understanding with the Australian Government to become a founding member of the Global CCS Institute. Under this MoU, Shell has provided expertise in establishing the framework of the Institute, and will actively participate in its programs and services. Shell also participates in the CO2CRC Otway Project, Australia's first demonstration of the deep geological storage or geosequestration of $CO_2$. Shell is also a joint venture participant of the Gorgon Joint Venture, which once operating, will be the world's largest CCS project. Shell has also been voluntary reporting greenhouse gas emissions since 1995, when Shell joined the Federal Government's Greenhouse Challenge Plus program.

### 4.4.3 Safety and Security

As well as environmental aspects, safety and security considerations have significantly influenced the design of the FLNG facility.

The FLNG concept combines activities across several disciplines including offshore production, gas processing, liquefaction and shipping. FLNG is complex and to reduce overall major hazard risks it is essential to reduce the potential consequences of hydrocarbon leaks through process and layout design.

A large portion of the engineering assessment work undertaken to date has been to identify potential safety issues and develop the design and layout of the FLNG facility to address them. Over the past 10 years, Shell has conducted an extensive series of safety studies and experimental work to guide the FLNG design. This has enabled development of a series of safety philosophies covering process containment, layout, gas detection, emergency blowdown, passive and active fire protection and escape, evacuation and rescue.

The current design is integral to managing personal safety on both the FLNG facility and visiting LNG, LPG and condensate carriers. It incorporates several specific safety features including 20 m gaps between process modules and the location of the most hazardous plant areas at the bow, away from the accommodation and temporary refuge located at the stern.

In addition to the challenges presented by the LNG process, there are also safety risks associated with mooring and loading operations and with operating at a remote offshore location. The present design has been assessed using a quantitative risk assessment and risk levels are comparable to other Floating, Production, Storage and Offloading (FPSO) type facilities. The design will be developed further during the detailed design phase, through application of the ALARP philosophy[10] that applies across the project.

In addition to the above there are a large number of features designed to prevent escalation of process releases on the vessel, such as process isolation, blowdown, active and passive fire protection, and provision of diverse escape and evacuation routes. These all help mitigate the effect of any potential incident, whatever the cause.

There have been two security assessments conducted for the Prelude FLNG Project, one in The Hague, The Netherlands in July 2008 and the other in Perth, Australia in August 2008.

The philosophy that has been adopted in response to security incidents relys on passive measures to:

- safeguard the safety of the crews of the FLNG facility and associated support vessels;
- contain any persons boarding the FLNG facility and prevent access to the living quarters or process areas;
- mitigate the consequences (people, assets, environment, reputation) arising from any event; and
- facilitate host country security services in the protection of the FLNG facility.

A response plan covering a number of scenarios will be prepared, with input from national Australian security services and the Shell Corporate Affairs Security group.

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[10] *The ALARP philosophy aims to reduce negative impacts or risks to be 'as low as reasonably practicable'.*

### 4.4.4 Unplanned Events

An Emergency Response Plan covering all credible HSE emergency scenarios during all phases of the project will be developed for the project, as discussed further in *Chapter 7*.

### 4.4.5 Extreme Weather Events - Cyclone Design and Precautions

A key part of the safety studies described in *Section 4.3.3* has been the assessment of the affects of extreme weather events on the FLNG facility. The facility has been designed to withstand a 1 in 10,000 year storm event. This corresponds to a maximum individual wave height of 27.5 m. Over a 25 year operating period, the probability of such an event happening is less than 0.25%. Further information on historical cyclonic activity in the region is provided in *Section 5.2.3*.

Several model tank tests were performed to examine the response of the FLNG facility to different wave and wind loadings. In response to these studies key cyclone design and operational controls considered for the FLNG facility include:

- The FLNG facility is not self-propelled and has been designed so that it does not need to be decoupled from the turret mooring system during a cyclonic event. The turret structure and its associated 24 mooring chains, with suction anchors, will be designed to resist loads due to hull deflections, mooring loads and direct slamming loads that may be encountered in extreme 1 in 10,000 year weather event.
- Major overhauls and maintenance will be conducted outside the cyclone season wherever possible so as to minimise movements of equipment, materials and people during this time. Those personnel on the FLNG facility as a cyclone approaches will stay onboard but will not be allowed on deck during passage of the cyclone.
- The FLNG facility is expected to continue production until wind speeds exceed 70 knots. Precautionary measures such as the timely securing of all loose materials and the movement of tugboats to safe location/ harbour will be clearly defined in the weather policy.
- Offloading of hydrocarbons to tankers will only occur in accordance with the Tanker Loading Operation Guidance Policy, which will detail the maximum allowable wind and wave conditions for tanker mooring and offloading. No mooring or offloading will occur during weather conditions that exceed the mooring and offloading design criteria.

## 4.5 COMPARISON TO OTHER PROJECTS

No FLNG facilities have been built before so there are no comparable projects in the region. However there are a number of FPSO facilities currently operating in the area which provide the closest parallel to the proposed FLNG facility, including the following operators:

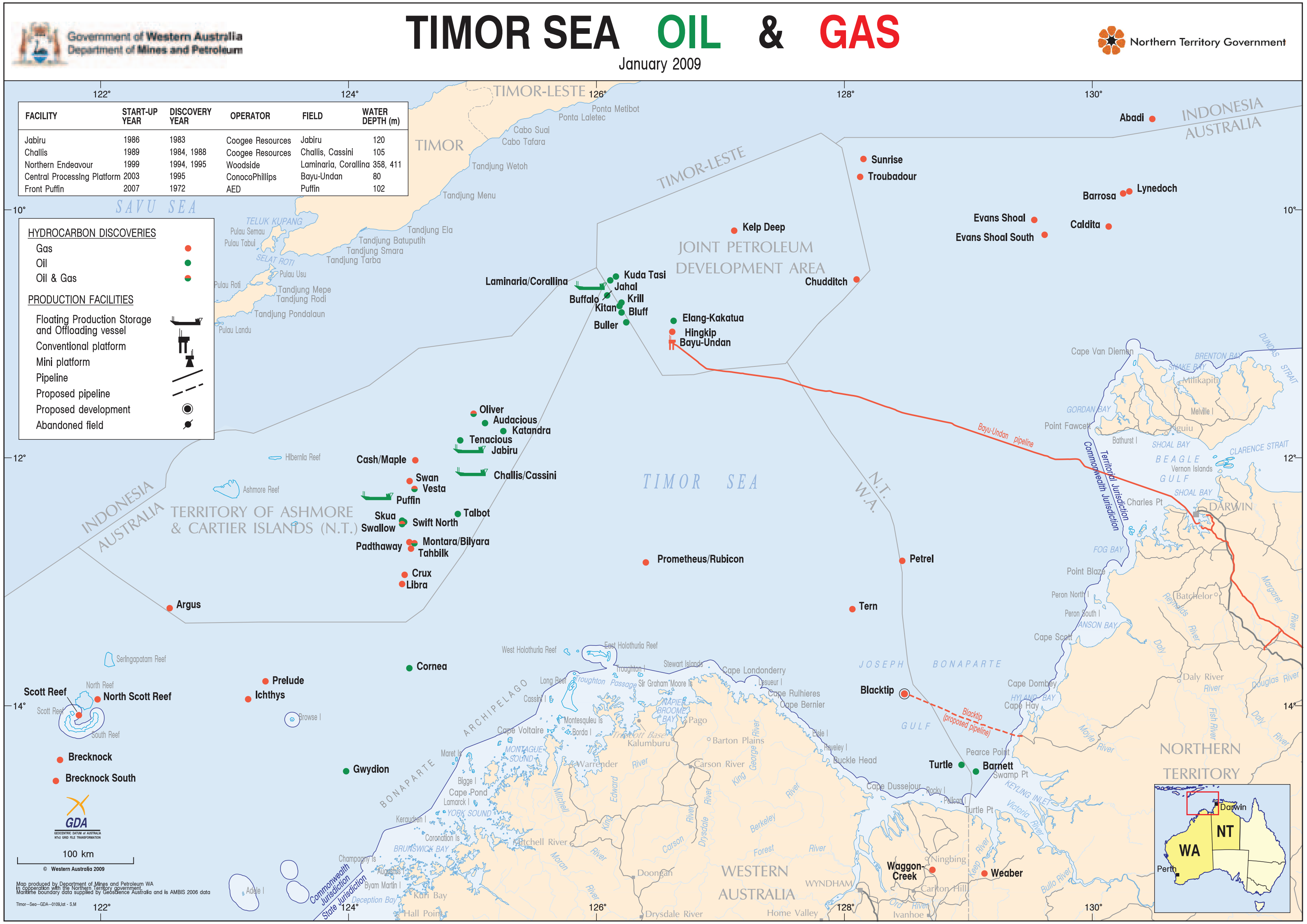
- AED:
  - Puffin oil development
- PTTEP Australia
  - Jabiru and Challis oil field development
- Santos
  - Exeter/Mutineer oil field development
- Eni
  - Woolybutt oil field development
- BHP Billiton:
  - Griffin oil and gas project
  - Stybarrow oil field development
  - Pyrenees oil field development
- Woodside Energy:
  - Laminaria-Corallina oil field development
  - Cossack Pioneer development
  - Vincent oil field development
  - Enfield oil development
- Apache Energy
  - Van Gogh oil field development

There are further proposed developments in the area as summarised below and in *Figure 4.4.*

### *Ichthys Development – INPEX*

The Ichthys gas field in Exploration Permit WA-285-P, held by INPEX (76%) and Total (24%), is adjacent to the Prelude field. According to their EPBC referral, INPEX (as Operator) propose to develop the Ichthys field via 50 subsea wells producing to a platform or semi-submersible offshore processing facility for separation of condensate (with export via an FPSO moored nearby) and the dehydration and compression of the gas, which will then be transported by subsea pipeline to an onshore gas liquefaction plant at Blaydin Point, Darwin.

*Figure 4.4 Oil & Gas Developments Adjacent to Prelude*



| FACILITY | START-UP YEAR | DISCOVERY YEAR | OPERATOR | FIELD | WATER DEPTH (m) |
|---|---|---|---|---|---|
| Jabiru | 1986 | 1983 | Coogee Resources | Jabiru | 120 |
| Challis | 1989 | 1984, 1988 | Coogee Resources | Challis, Cassini | 105 |
| Northern Endeavour | 1999 | 1994, 1995 | Woodside | Laminaria, Corallina | 358, 411 |
| Central Processing Platform | 2003 | 1995 | ConocoPhillips | Bayu-Undan | 80 |
| Front Puffin | 2007 | 1972 | AED | Puffin | 102 |

### *Browse Development – Woodside Energy*

The Browse gas fields include the Torosa, Brecknock and Calliance discoveries which are located 425 km northwest of Broome in title areas held by Woodside (as Operator), BHP Billiton, BP, Chevron and Shell (as Joint Venture Participants). Two options for the location of the development's LNG processing facilities are under consideration; the State Government's proposed LNG precinct in the James Price Point coastal area in the Kimberley and the existing Woodside-operated facilities located near Karratha. Appraisal, engineering, environmental and social impact studies are ongoing.

### *Crux Development – Nexus*

The Crux field is located in Production Permit AC/L9 in the Browse Basin and is held by Nexus (85%) and Osaka Gas (15%). Nexus (as Operator) has received environmental approval and a production licence for a liquids stripping project but has yet to announce when their proposed condensate recovery project will proceed.

Nexus sold the rights to the Crux gas, excluding condensate, to Shell. The gas sales agreement enables Nexus to undertake its liquids stripping project until 31 December 2020, at which time Shell will assume ownership of the title and will have the right to extract the gas and any remaining condensate.

### *Existing LNG Developments*

Existing LNG developments offshore northern Australia are:
- the North West Shelf Venture (NWSV) project, located in the Carnarvon basin approximately 1,000 km southwest from the Prelude FLNG Project and feeding the NWSV LNG Plant on the Burrup Peninsula;
- Pluto LNG project (under construction), located approximately 1,100 km SW of the Prelude FLNG Project; and
- Bayu Undan offshore development, located approximately 600 km northeast of the Prelude FLNG Project and feeding the Darwin LNG Plant.

## 4.6 PRELUDE DEVELOPMENT DESCRIPTION

### 4.6.1 Introduction

The Prelude FLNG Project will comprise:
- upstream infrastructure; and
- the FLNG facility.

### 4.6.2 Upstream (Subsea) Infrastructure

The upstream infrastructure of the FLNG facility comprise:
- the production wells; production manifolds; subsea flowlines; riser base manifolds; and, flexible risers that transport the gas, condensate and any produced formation water (PFW)[11] to the FLNG facility; and
- the FLNG facility interface, including the umbilicals used to control the wells and associated facilities.

The upstream infrastructure is illustrated in *Figure 4.5*.

Subsea wells will be drilled and completed from the seafloor and connected to subsea production manifolds, which link to flowlines (~4 km) that connect to the FLNG facility. The production manifolds will be controlled from the FLNG facility via umbilicals. Taken together, the subsea infrastructure will cover an area of about 8,000 m$^2$ of the seabed.

### *Production Wells*

The wells will be completely subsea and no wellhead platform is required for this development. The wells are conventional subsea wells, with the drilled hole diameter reducing sequentially from 914mm (36 inch) diameter at the sea bed to 216mm (8.5 inch) diameter at reservoir depth. The reservoir is at 4,100 m total vertical depth below sea level but to optimise the length of the well within the gas reservoir (and hence the gas flow into the well), the reservoir sections will be drilled horizontally. Therefore, the total drilled length for each well will be about 5,400 m, producing 900 to 1,000 m$^3$ of excavated rock fragments (drill cuttings) per well. These drill cuttings will be deposited overboard in accordance with industry standards.

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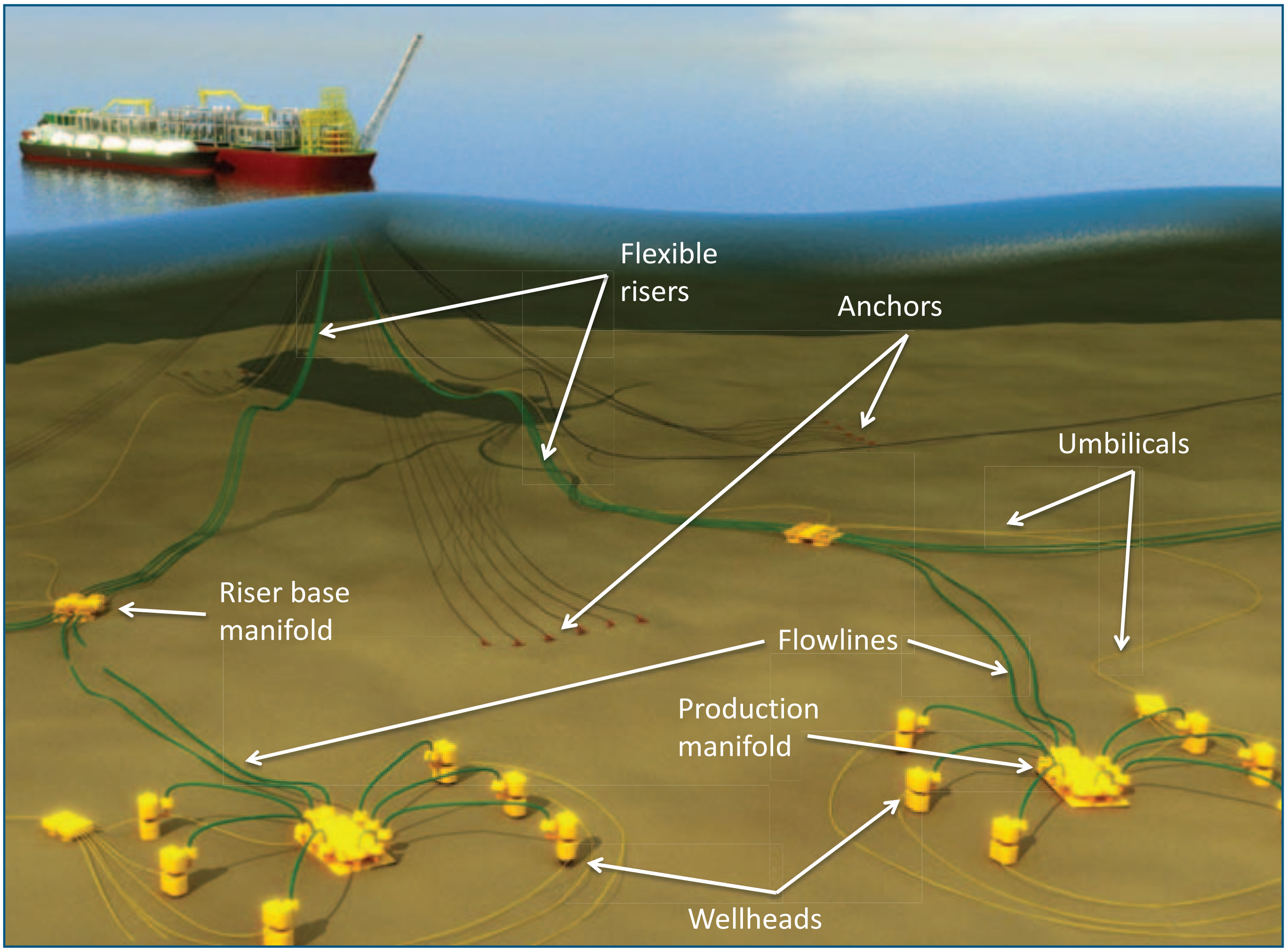
[11] *PFW is water that has accumulated naturally within the same rock strata as the hydrocarbons and that flows to the surface with the gas and hydrocarbon liquids from the production wells. It comprises a mixture of condensed water and saline formation water.*

*Figure 4.5* *Subsea Infrastructure*



See *Chapter 6* for further details on drill cuttings disposal.

The current design is for a total of eight production wells, each tied back to the subsea manifolds via individual well jumper lines. These deviated wells will be distributed in a radial pattern from a single drill centre, extending to intersect the reservoir over a 4.5 km diameter.

Drilling and completion of the eight wells is expected to take two years and will be undertaken by a third party mobile offshore drilling unit (MODU) hired by Shell. After all eight wells are completed, the MODU drilling rig will be off-hire and will depart the title area.

### *Subsea Flowlines*

The subsea flowlines are about 4 km in length and constructed from steel, with an internal cladding of corrosion resistant alloy and external insulation for heat retention to enable flow assurance with minimum chemicals injection. Each flowline pair will be looped to allow round trip pigging[12] from the FLNG facility.

### *Riser Base Manifolds*

Two riser base manifolds will be installed on the seabed adjacent to the FLNG facility. Each will connect the flowlines from four of the wells to the flexible risers that convey the

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[12] *Pigging refers to the practice of using pipeline inspection gauges or 'pigs' to perform various operations on a pipeline, such as cleaning and inspection, without stopping the flow of the product in the pipeline.*

gas and associated liquids to the FLNG facility. The riser base manifolds will also be individually connected to the FLNG facility via the umbilicals, which carry electrical power, hydraulics to operate the manifold valves, chemicals to maintain hydraulic flows and cabling to transmit signals that allow the manifolds to be controlled from the FLNG facility.

#### *Flexible Risers*

Eight 12 inch flexible risers will convey the gas from the riser base manifolds on the seabed to the underside of the FLNG turret. The flexible risers will be designed to accommodate the motions of the FLNG facility on the ocean surface.

### 4.6.3 FLNG facility

The FLNG facility will process the gas from the production wells into LNG, LPG and condensate. These products will be stored and subsequently offloaded to purpose built marine tankers for delivery to market. The processing, storage and offloading equipment (termed the topsides facilities) will be mounted on a hull, about 480 m long and 75 m wide. The FLNG facility will weigh 600,000 tonnes deadweight when fully ballasted.

The FLNG facility will be a double hull design (both sides and bottom), so that the contents, including the LNG, LPG and condensate storage, are contained within an internal hull completely encased by an outer hull, providing additional containment and protection.

*Figure 4.6* provides an indicative illustration of the proposed FLNG facility. The FLNG facility will be permanently moored to the seabed and will be able to weathervane (rotate around the mooring turret according to wind and current directions) to minimise the influence of weather and sea conditions. The FLNG facility will have 3x5 MW azimuth thrusters, used to maintain a fixed heading during tanker berthing.

The FLNG facility will provide:

- a stable platform for the topsides gas treating and liquefaction plant;
- storage and facilities to export LNG, LPG and condensate;
- accommodation for operations, maintenance and support personnel;
- ancillary facilities including all workshops, offices and central control room for the FLNG facility; and
- utilities and services which are required to support operations and offshore maintenance.

*Figure 4.6 FLNG facility*

The FLNG facility will be designed to meet or exceed the most stringent of Australian requirements or the Shell Engineering Reference Documents, a series of Shell Group Standards that reflect best practice in design, procurement, construction, commissioning and operation of offshore facilities, liquefaction plants and LNG carriers.

#### *Turret Mooring System*

The FLNG facility will be permanently moored with a forward mounted, freely weathervaning, turret mooring system. The turret will support the mooring system, flexible risers and umbilicals and will be designed to resist loads due to hull deflections, mooring loads and direct slamming in extreme 1 in 10,000 year weather conditions.

#### *Anchor System*

The FLNG facility will be held in position by four groups of six anchor chains, arranged at the four quadrants around the FLNG turret. The chains are secured by suction piles which will penetrate deep into the seabed. The piles will typically be 10 m in diameter and 20 m to 30 m in length, with each weighing between 140 and 180 tonnes.

Suction piles are installed by gently lowering the pile into the seabed. The bottom of the pile is open but the top is closed. Once the pile has reached self weight penetration, installation resumes by pumping out the entrapped water inside the pile, with the resulting vacuum drawing or sucking the pile deeper into the seabed.

### *FLNG Production Facilities*

Key process units are summarised in *Table 4.2*

## 4.7 FLNG PROCESSES

### 4.7.1 Introduction

Once the feed gas has reached the FLNG facility, processing will commence on the FLNG topsides. When processing at 100% design capacity, the volume of feed gas equates to 680 million standard cubic feet per day (scfd) which produces 3.6 mtpa of LNG, 0.4 mtpa of LPG and 1.3 mtpa of condensate.

The feed gas is delivered from the turret and the condensate fraction is stabilised and drawn off to storage. Any Production Formation Water (PFW) that may be associated with the hydrocarbons is separated off for treatment prior to discharge to sea. The gas is then metered and treated to remove acid gases such as carbon dioxide and hydrogen sulphide (termed 'sweetening' the gas), impurities and water. The dry, sweet gas is then cooled by refrigerant streams to separate out the heavier hydrocarbons, which are fractionated and recovered as condensate and LPG. The refrigerant process continues, reducing the temperature of the dry sweet gas until it liquefies. The resulting LNG is then routed for storage in insulated tanks at atmospheric pressure, prior to being offloaded to a tanker.

An overview of the process is provided in *Figure 4.7* and in greater detail in the following sections.

*Table 4.2 Overview of Key Production Facilities on FLNG Facility*

| Key Process | Unit |
|---|---|
| Production facilities | Gas reception |
| | Gas/liquid separation |
| | Liquid stabilisation and storage |
| | Acid gas removal and disposal |
| | Gas dehydration (molsieve unit) |
| | Trace mercury removal |
| | LNG/LPG liquefaction via refrigerant process |
| Power/Steam Generation | 4 steam turbine generators located in the hull (2x30 MW and 2x20 MW), with 1 boiler located within the hull and five on the topsides |
| Waste Water Treatment | Treatment unit for process water |
| | Macro Porous Polymer Extraction treatment of produced formation water (PFW) |
| Pressure Relief | Seven main flare stacks in a common structure |
| Chemical Injection | Mono-Ethylene Glycol (MEG) injection dosing as required |
| Drainage | Open deck drainage and internal deck drainage |
| Storage | Condensate, LNG and LPG from process trains transferred directly to dedicated atmospheric pressure storage tanks in hull of FLNG facility. |
| | LNG: 6 storage tanks with a total capacity of 220,000 $m^3$ |
| | LPG: 4 storage tanks with a total capacity of 90,000 $m^3$ |
| | Condensate: 6 storage tanks with a total capacity of 126,000 $m^3$ |
| Offloading | LNG and LPG - side by side loading via hard loading arms |
| | Condensate – tandem loading astern via flexible hoses |

### 4.7.2 Metering, Separation, and Stabilisation of the Feed Gas

The FLNG facility will receive hydrocarbons through the risers via the turret. The multiphase fluid will be fed into three-phase inlet separator(s), where water and hydrocarbon liquids are separated out from the gas. The gas and condensate streams will be separately measured by fiscal quality metering systems.

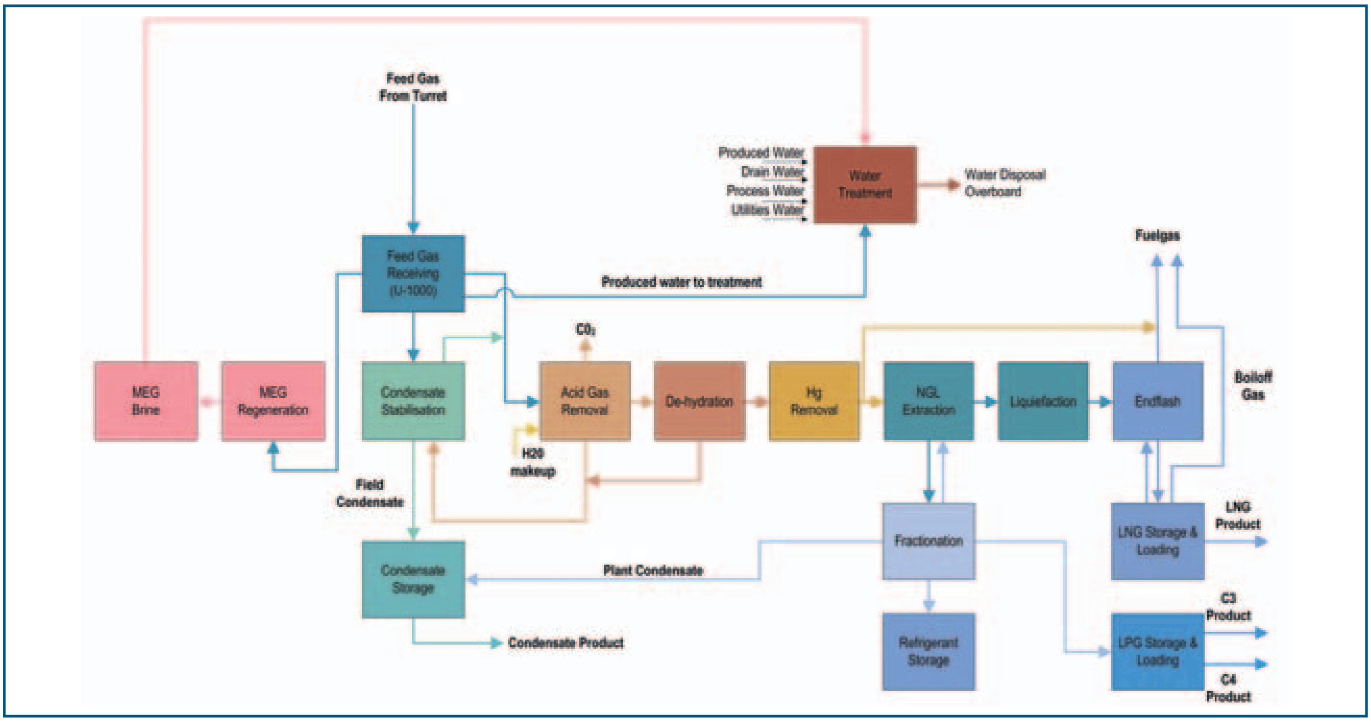
Any associated PFW will be routed to a treatment system to remove hydrocarbons prior to discharge. The hydrocarbon liquid stream will be routed to the condensate stabilisation unit to yield condensate, which will then be transferred to the main condensate storage tanks on the FLNG facility.

The gas will be then be routed to the Acid Gas Removal Unit (AGRU) together with compressed gas from the condensate stabilisation unit.

### 4.7.3 Acid Gas Removal

The acid gases, carbon dioxide ($CO_2$) and traces of hydrogen sulphide ($H_2S$) will be removed from the gas stream via the

*Figure 4.7 FLNG Process Overview*



AGRU to prevent freezing and subsequent blockages in the liquefaction unit.

The gas stream flows up the absorber columns against a counter current flow of an aqueous amine solution (activated Monodiethylamine (aMDEA)), removing the $CO_2$ by chemical reaction to less than 50 ppm in the treated gas stream. The amine solution is drawn from the bottom of the absorber, rich in acid gas components, and the pressure reduced and flashed at an intermediate pressure to release the entrained and dissolved hydrocarbons. The flash gas is routed to the fuel gas system. The flashed solvent is then heated to allow the chemical reaction to reverse and release the acid gas in the regeneration column. The amine solution is then cooled and recycled to the absorber as "lean" solution ready to absorb more acid gas, while the acid gas is vented to atmosphere via the flare stack to ensure its safe disposal.

### 4.7.4 Gas Dehydration

The gas leaving the AGRU will be saturated with water. To prevent the freezing of water in the liquefaction unit, the water must be removed. The first step is to cool the gas against the cooling water system and Precooled Mixed Refrigerant to condense the water. Thereafter, the gas will be transferred through the molsieve unit, fixed bed vessels that remove the remaining water content to less than 1 ppm by adsorption onto an alumina silicate crystal. The molsieve beds are regenerated by a reverse flow of heated dry gas on a rotation cycle (two beds in service, one bed on regeneration). The condensed water is reused as make-up water for the aqueous amine system.

### 4.7.5 Mercury Removal

Based on the Prelude well results, mercury is not expected to be present in the feedgas. However, the generic design of the FLNG facility makes provision for a mercury treatment unit downstream of the dehydration unit to prevent possible corrosion of the aluminium material in the Main Cryogenic Heat Exchanger. The unit will comprise a single guard bed containing sulphur impregnated activated carbon on which the mercury will be absorbed to reduce the mercury level in the gas stream to below 10 ng/$Sm^3$. After several years, the bed contents will be changed over for fresh adsorbent. The waste mercury contaminated bed material will be sent to shore for appropriate hazardous waste disposal at a licensed facility.

### 4.7.6 NGL Extraction and Fractionation

Once the gas has passed through the gas treating units, the treated and dried gas still has heavy components to be removed in the Natural Gas Liquids (NGL) extraction unit prior to liquefaction.

In the NGL extraction unit, feed gas cooling and turbo expansion enable separation of a proportion of the NGLs from the feed gas. The gas is then compressed, while the liquids are fractionated into ethane, propane, butane and a light condensate product. Ethane is either returned to the natural gas stream, used for make-up refrigerant or used as fuel gas. Propane and butane are stored as separate refrigerated products at atmospheric pressure, and the light condensate is mixed with stabilised condensate produced.

### 4.7.7 Liquefaction

Liquefaction of the overhead gas after NGL extraction takes place at high pressure against the Precooled Mixed Refrigerant in coil wound heat exchangers and then the Mixed Refrigerant cycle in the Main Cryogenic Heat Exchanger.

The gas is compressed, liquefied and then subcooled in the cryogenic heat exchangers and then flashed (allowed to expand into a separator or drum) to atmospheric pressure, thereby removing excess nitrogen. The resulting LNG, at a temperature of -162°C, is transferred to insulated storage tanks at atmospheric pressure.

### 4.7.8 Cooling Water System

The cooling process will employ a closed loop freshwater cooling system. Seawater will be utilised as the main cooling medium, serving as a heat sink for a number of process heat exchangers.

The FLNG facility will require approximately 50,000m$^3$/hr of cooling water, taken from a depth of around 150 m below sea level. Eight risers, with an outer diameter of 42 inches, capable of a maximum flow velocity of 2.7 m/s, will be used to provide the required volume. The cooling water will be returned to the sea at approximately 39°C to 42°C, which is 7.5°C to 16°C above ambient seawater temperature, and will contain a residual hypochlorite concentration of 0.2 ppm.

The water intake risers will hang freely below the hull, located towards the aft of the vessel, about 370 m from the turret, so as to avoid collision with the flexible production risers and the mooring lines.

An electro–chlorination system will produce sodium hypochlorite from seawater which will be continuously injected into the inlet of each cooling water riser to prevent marine growth in the system. The system will be monitored to control the dosing to produce a level of 0.2 ppm free residual chlorine at the cooling water discharge outlets. Oxygen scavengers will also be injected into the system to prevent corrosion. The cooling water will be discharged to sea through a series of outlet pipes at an optimal shallower depth, which is expected to be between 10 to 17 m below sea level.

### 4.7.9 MEG System

Mono-Ethylene Glycol (MEG) will be used to inhibit the formation of hydrates from the well head to the FLNG facility. Hydrates are crystalline structures that form when water and hydrocarbon molecules interact under high pressures and low temperatures, typically in subsea flowlines. The FLNG facility system will be equipped with an 800 m$^3$/day MEG regeneration system to provide buffer storage, collection and regeneration of the MEG used to treat the incoming gas from the reservoirs.

### 4.7.10 Product Storage and Export

Condensate, LNG and LPG from the process trains will be transferred directly to dedicated atmospheric pressure storage tanks in the hull of the FLNG facility. There are six LNG membrane design tanks totalling 220,000 m$^3$ capacity, each with thick insulation to reduce heat leak. Nevertheless, a small proportion of the gas regasifies (termed ‘boil off gas’) and this gas is compressed to the low pressure fuel gas and is used for heat and power generation on the FLNG facility.

The propane and butane (providing LPG) are stored at atmospheric pressure in four insulated tanks totalling 90,000 m$^3$ storage capacity. The condensate is stored in six tanks totalling 126,000 m$^3$ storage capacity.

LNG and LPG tankers will moor alongside the starboard side of the FLNG facility with fenders protecting the steel hulls from contact with the FLNG facility. Hard loading arms with swivel joints and quick connect/disconnect flanges will be used for transferring the LNG and LPG products to the tankers (see *Figure 4.8*).

The condensate tankers will be moored astern of the FLNG facility and condensate transferred by a floating hose as per conventional FPSO practice.

*Figure 4.8 Full scale LNG loading arm testing rig*

### 4.7.11 Ancillary Systems

#### *Power Generation and Emergency Power*

Power and heat to the plant will be provided by steam boilers and steam turbine power generators. Steam is generated by six boilers running on low pressure fuel gas, one located within the hull and five on the topsides. The electric demand on the FLNG facility is 60 MW, which is meet by four generators (two back-pressure and two extraction) located in the hull that have an installed capacity of 2 x 30 MW and 2 x 20 MW. Approximately 8% by weight of the gas intake is used for fuel gas requirements.

During the commissioning process, until the gas stream is available, diesel will be used to fuel the diesel engine driven generating equipment to provide about 10 MW of power for the facility control room and to provide general utilities such as lighting and air conditioning. This diesel equipment will also provide a backup/emergency power during operation.

#### *Drainage*

There will be two drainage systems on the FLNG facility, an open deck system and an internal deck system.

**a) Open Decks**

Drainage from these open areas will predominantly comprise washdown water, sea spray run-off and rainwater.

For safety reasons, the open deck areas where the LNG or LPG process equipment is located will be grated so that spilled material quickly falls through the deck and away from the process equipment. To avoid embrittlement of the structure by cryogenic liquids, other open deck areas will have a 500 mm camber to freely drain LNG or LPG spills overboard as quickly as possible.

Deck areas, which house equipment for handling condensate, will be bunded and fitted with scuppers (deck drains) that direct spills to the slops tank. This water is referred to accidentally oil contaminated water (AOC water). The drain gullies will be fitted with splitter boxes so that spills or leaks are diverted to the slops tank but high volumes of run-off rain water can be channelled directly overboard.

Bunding will be provided around both the Amine and MEG units to contain any spills, which will be routed to a waste tank for collection and subsequent transfer to the supply vessel for onshore disposal.

**b) Internal Decks**

For the interior FLNG facility decks, equipment will be bunded and will drain to an oily water retention tank and on to the Waste Water Treatment Plant (WWTP). This water is referred to continuously oil contaminated water (COC water). Oily residues from the sludge tank will be discharged to the supply vessels for onshore disposal at a suitably licensed facility.

#### *Waste Water Treatment*

The FLNG facility will be provided with a WWTP for process water and collected drainage to remove suspended solids and dispersed and dissolved hydrocarbons from the water prior to discharge to sea. The following aqueous waste streams will be discharged to the WWTP:

- Produced Formation Water (PFW);
- pigging water from flowline cleaning activities;
- utilities water from the mixed bed ion exchangers used for steam condensate regeneration and boiler feed water preparation; and
- utilities water from the boilers (boiler blow down).

The drainage design provides for the flows to be routed through the slops tanks to the WWTP. The WWTP will be capable of handling up to 20,000 bbl/day (3,200 $m^3$/day) of aqueous waste streams, via a Macro Porous Polymer Extraction (MPPE) package, which will treat the produced water to achieve the *Petroleum (Submerged Lands) (Management of Environment) Regulations 1999* requirement for a daily average of 30 mg/L of oil in water. The discharge water quality will be continuously monitored by an Oil Discharge Monitor (ODM). Once treated, the water will be discharged overboard from the WWTP. A 5,000 $m^3$ water buffer tank upstream of the WWTP can be used for temporary storage in the unlikely event of the interruption to the WWTP operation.

### *Produced Formation Water*

PFW is water that has accumulated naturally within the same rock strata as the hydrocarbons and that flows to the surface with the gas and hydrocarbon liquids from the production wells. It comprises a mixture of condensed water and saline formation water.

Data from the investigations of the Prelude field formations have so far suggested that relatively low rates of PFW will be produced from the gas reservoir. However, provision has been made to treat and dispose of up to a maximum of 2,200 $m^3$/day of PFW. The modelling and assessment of the potential environmental impact associated with PFW in this draft EIS is based on this worst case scenario of a discharge of 2,200 $m^3$ per day, as described in *Chapter 6*.

### *Pressure Relief System*

The FLNG facility will be equipped with a number of flare stacks which will provide a pressure relief system to safely dispose of pressurised hydrocarbon gas and liquids during emergency situations, upsets and shutdowns of the facility. Separate flare stacks for water wet streams and cryogenic streams are required to avoid mixing and potential for freezing and blockages.

There will be seven main flare stacks, installed within a common structure:

- High pressure warm wet flare;
- Low pressure warm wet flare;
- High pressure cold dry flare;
- Low pressure cold dry flare;
- acid gas vent;
- marine stack; and
- a spare flare.

The common flare structure will be approximately 154 m in length and will be inclined at an angle of 30 degrees from the vertical, supported on a boom structure so that it projects at least 60 m from the side of the FLNG facility. It will be located near the turret on the port (left hand) side of the FLNG facility.

In normal operation, each flare stack has a minimum pilot flame only that is barely visible. Its purpose is to ensure that in the event of a non-routine event, such as a plant trip, the much larger quantities of hydrocarbon released to the flare are safely combusted. Such non-routine flaring events can be at very high flowrates (as much as 50% of the design plant throughput) but only occur for a limited period.

### *Diesel Fuel and Other Utility Systems*

The FLNG facility will have a 3,600 $m^3$ storage capacity for diesel fuel, loaded from supply boats. Low sulphur grade diesel will be used primarily for non-routine equipment start ups and the emergency generators, and if necessary, to provide fuel to support vessels. Hence, consumption will be low or zero during normal operations.

Aviation fuel (JetA1) storage will be provided on the FLNG facility adjacent to the helideck for helicopter refuelling. The volume is estimated at about 6,500 litres, in line with the volume held on existing operating drilling rigs currently in the area.

### *Additional Utilities*

Additional utilities (instrument air, nitrogen, seawater desalination, domestic waste water treatment) will be supplied by facilities located mainly within the machinery room at the stern of the FLNG facility.

A sewage treatment plant will be provided and will comprise two 50% units sized in total for 400 persons. The expected flow rate of sewage and greywater (laundry, galley, shower and basin water) is 30 $m^3$/day during commissioning and 10 $m^3$/day during operations.

Desalination will be via three, Multi-effect Distillation-Thermal Vapour Compressor units, each of which has a maximum capacity of 35 t/hr (~35 $m^3$/hr), with standard requirements expected to be about 70 t/hr (~70 $m^3$/hr). The 'brine' (concentrate from the desalination unit), will be discharged via the cooling water outlet at a rate of approximately 5,000 t/day (~5,000 $m^3$/day). All discharge points will be arranged within the aft 40 m of the FLNG facility.

### 4.7.12 Accommodation, Maintenance, Control Room and Laboratory.

In total, about 320 personnel will be employed in the operation of the FLNG facility. During normal operations, approximately 220 personnel will work onboard the FLNG facility, working as two 110 man crews on a rotational roster (eg three weeks on, three weeks off) and will be employed to carry out operations, maintenance and to provide support functions. The remaining 100 personnel will comprise day staff located ashore at the Maintenance Workshop and/or in Perth and will be employed to provide other technical and administrative support.

Accommodation for the crew, recreational facilities, medical facilities, control room, canteen, technical service and administration facilities, workshops and stores are located in the stern accommodation block which also serves as a temporary refuge in case of emergencies. A helipad and associated fuelling facilities will be located adjacent to the accommodation block and a deck area for loading/offloading supply vessels will be located at the stern of the FLNG facility.

## 4.8 DEVELOPMENT LIFE CYCLE

### 4.8.1 Development Drilling

*Overview*

Drilling will be conducted by a Mobile Offshore Drilling Unit (MODU) using standard offshore drilling methods. Eight production wells will be drilled over a two years period.

A drilling rig has a continuous high consumption rate of materials and turnover of tools; therefore, the drilling rig will require an offshore supply vessel call every two or three days and refuelling (diesel) once every two to three weeks.

Well drilling for the Prelude FLNG Project will use two types of muds, both water based mud (WBM) and synthetic based mud (SBM). The SBM will be used on the deeper and more challenging well sections. WBMs are usually discharged to sea at the end of their useful life or at the end of the drilling program, whereas SBMs are recovered and returned onshore for recycling or disposal.

*Table 4.3* provides the proposed mud properties to be used at Prelude.

Cuttings from sections drilled with SBM are passed through a dryer before discharge to reduce the volume of synthetic mud coating the rock. Some small quantities of mud will nevertheless be lost overboard with the drill cuttings, estimated at approximately 36 $m^3$ of SBM for each well.

Following completion of the well, the well will be flowed to the drilling rig to remove liquids from the well (well cleanup), before closing in the well to await hookup to the subsea facilities.

*Table 4.3 Properties of Proposed Drilling Muds*

| Hole Size | Mud Type | Main Components |
|---|---|---|
| Shallower, less technically challenging hole sections ( 36", 26" and 17.5" sections) | Water Based Mud | Water, bentonite, barite, soda, ash, caustic soda, lime |
| Deeper and more technically challenging hole sections ( 12.25" and 8.5" sections) | Synthetic Based Mud | Detailed SBM formulation is still to be determined but potential base oils include Alpha Olephin blends (eg. MI Novatec) or refined alkanes with carbon chains of $C_{10}$-$C_{20}$ (eg Shell Saraline 185V) |

Cleanup involves flowing well fluids and brine to the rig storage tanks and diverting reservoir gas to burners. Well cleanup will typically involve flowing the well at up to 150 million scfd and burning the produced fluid for one to two days to ensure all drilling liquids are removed from the well. During clean-up, the well's flowing performance will be assessed. It is likely that all eight well clean-ups will be undertaken one after the other at the end of the drilling program.

### *Emissions to Air*

Gaseous emissions arising during proposed development drilling will largely be combustion related, from operation of equipment and machinery and well clean-up. These include atmospheric emissions of sulphur dioxide (SOx), nitrogen oxides (NOx), $CO_2$ and particulates in smoke. The quantities of gaseous emissions are relatively small and will, under normal circumstances, be quickly dissipated into the surrounding atmosphere.

### *Liquid Waste*

Liquid wastes from the drilling program are expected to include:

- Grey water and sewage in the order of 10 $m^3$ per day, which will be treated by the on-board treatment system.
- Minor kitchen waste, shower and laundry wastes that will be capable of passing through a 25 mm diameter screen prior to discharge.
- WBM, which is discharged to sea in bulk at the end of the drilling program as per standard oil industry practice.
- Minor volumes of SBM (approximately 36 $m^3$ per well) – all discharges of cuttings contaminated with SBM mud will be measured using standard Australian oilfield procedures and should contain less than 6.9% residual SBM by weight. There will be no dumping of bulk SBM.
- Minor volumes of hazardous waste such as used oil, chemicals, solvents, acids/ caustics, paint and drilling fluid additives. These will be stored on board the rig, pending transport onshore for disposal at suitably licensed facilities.

### *Solid Waste*

Solid wastes from the drilling program are expected to include:

- Minor volumes of non-hazardous wastes including paper, rope, various packaging timber, metal and plastic which will be stored for onshore disposal at the end of the drilling program.
- Drill cuttings, estimated at 1,000 $m^3$ per well.
- Minor volumes of hazardous waste including aerosol cans, batteries and oil filters which will be stored for onshore disposal.

## 4.8.2 Subsea Installation and FLNG Hook-up

### *Installation of Upstream Facilities*

The majority of the subsea facilities will be installed prior to the arrival of the FLNG facility. Specialised installation vessels will be used to install the subsea flowlines, umbilicals and flexible risers. Crane vessels will be used to install the subsea manifolds. A subsea construction vessel will be used to hook-up and connect the wells, subsea systems, flowlines and umbilicals, and the installation of the suction piles and mooring chains that will hold the FLNG facility in place. Details of the foundations for the subsea manifolds and suction piles will be finalised on completion of geotechnical and geophysical studies. No trenching or rock stabilisation of the flowlines or umbilicals is envisaged.

### *Installation of FLNG facility*

Tugs will be used to transport the FLNG facility from the overseas integration yard to its location within WA-371-P. The FLNG facility will then be moored to the seabed by four suction pile anchor groupings equally spaced, which will contain multiple anchor lines per grouping. Further geotechnical investigation is required prior to the final selection and design of the anchoring system but it is anticipated that 6 anchors per grouping will be required.

### *Emissions to Air*

The only air emissions generated during the subsea installation will be from vessel engines and diesel generators operating on an incidental basis eg power generation, cranes, fire water pump etc.

### *Liquid Waste*

Liquid wastes from the subsea installation and hook up activities are expected to include:

- grey water and sewage in the order of 10 m$^3$/ day, which will be treated by on-board treatment systems;
- minor kitchen waste, shower and laundry wastes that will be capable of passing through a 25 mm diameter screen prior to discharge; and
- minor volumes of hazardous waste such as used oil, chemicals, solvents, acids/ caustics and paint, which will be transferred onshore for disposal at an appropriately licensed facility.

*Solid Waste*

Solid wastes from the subsea installation and hook up activities are expected to include:

- minor volumes of non-hazardous wastes including paper, rope, various packaging timber, metal and plastic, which will be periodically transferred onshore for recycling or disposal; and
- minor volumes of hazardous waste including aerosol cans, batteries and oil filters.

*Summary*

A summary of key activities and their potential environmental implications is provided in *Table 4.4*.

### 4.8.3 Commissioning

The majority of the commissioning of the FLNG facility will take place at the overseas construction yard and nearby waters over a period of about eight months, with only limited commissioning activities of the FLNG facility occurring on location in title area WA-371-P, over a period of about four months.

After the FLNG facility has been moored on location, the flexible risers and subsea umbilicals will be installed into the FLNG facility turret. Pressure testing, pre-commissioning and commissioning of the overall production system from the wells through to and including the FLNG facility will then be conducted.

*Table 4.4 Summary of Infield Installation Activities*

| Infield Installation Activities | | | |
|---|---|---|---|
| **Activity** | **Key Details** | **Environmental Aspects** | **Potential impacts on *EPBC Act* Matters** |
| Development Drilling | Mobile Offshore Drilling Unit drills 8 production wells over 2 year period<br>Water and synthetic based muds<br>Flaring for 1 to 2 days per well during completion | Drill cuttings (approximately 1,000 m$^3$ per well) disposed overboard<br>Water based drill mud disposal to sea upon completion of well drilling program<br>Synthetic based mud as coating on drill cuttings (approximately 36 m$^3$ per well)<br>Atmospheric emissions from flare<br>Noise emissions<br>Light emissions<br>Disturbance of seabed | Physical disturbance impacts on Commonwealth Marine Environment<br>Noise and light impacts on listed species |
| Installation of Subsea Facilities | 8 wells tied back to the manifold and connected to FLNG facility via 4 x 4 km flowlines | Physical disturbance of seabed (approximately 8,000 m$^2$) | Physical disturbance impacts on Commonwealth Marine Environment |
| FLNG Hook Up | Footprint size of 4 anchor grouping is: approx. 150 m$^2$<br>Risers and umbilicals connect subsea facilities to FLNG facility. Duration of FLNG installation and hook up approximately 6 months<br>500 m exclusion safety zone extending from the outer edge of the FLNG facility and subsea infrastructure | Physical disturbance of seabed (approximately 150 m$^2$) | Physical disturbance impacts on Commonwealth Marine Environment |
| Vessel Activities (including towing FLNG facility to site) | Tugs, pipe lay /crane vessel<br>Divers and ROVs with support vessel<br>Riser and umbilical installation vessels | Energy usage – fuel<br>Atmospheric emissions<br>Noise and light emissions<br>Discharge of ballast and bilge water | Noise and light impacts on listed species<br>Vessel interactions with listed species |

The production system piping will be filled with about 1,500 m$^3$ of treated seawater. The system is then pressure tested and following a successful test, the system is dewatered by using compressed air to push tools called 'pigs' through the pipework. The hydrotest seawater will be discharged to the marine environment through the FLNG facility.

Commissioning the umbilicals that supply hydraulic/chemical and power/communications services to the subsea wells and manifolds will involve displacing fluids into the flowlines. Hydraulic lines contain water based, subsea control fluid which remains in the umbilical until ultimately discharged to sea during valve operations throughout the operational life of the Prelude FLNG project. Chemical injection lines contain storage fluid which will be displaced into the flowlines with MEG for the MEG lines or compatible buffer fluids for the remaining chemical injection lines. These fluids will be displaced into the flowlines and routed back to the FLNG facility for handling and recycling or onshore disposal. A summary of key commissioning activities is provided in *Table 4.5*.

The workforce on the FLNG facility during this phase will be around 400 at peak and averaging 14 helicopter flights each week. Weekly supply vessel journeys between the onshore Maintenance Workshop and the site will be required to ship materials and equipment.

### Emissions to Air

Emissions during the commissioning phase will occur through the incidental use of diesel driven power generators and air and sea transportation. The sources are principally diesel engines and work vessels, which will be diffused sources producing relatively minor emissions. Emissions generated after the introduction of hydrocarbons to the facility are addressed in *Section 4.8.4*.

### Liquid Waste

Liquid wastes from the commissioning activities are expected to include:

- grey water and sewage in the order of 30 m$^3$ per day, which will be treated by the on-board treatment system;
- kitchen waste, shower and laundry wastes that will pass through a 25 mm diameter screen prior to discharge;
- minor volumes of hazardous waste such as used oil, chemicals, solvents, acids/caustics and paint, which will be transferred onshore for disposal at an appropriately licensed facility;
- hydrotest seawater and inhibitor (about 1,500 m$^3$); and
- buffer (diesel) and MEG from umbilical line flushing, which will be recycled on board.

### Solid Waste

Solid wastes arising during commissioning are expected to include:

- minor volumes of non-hazardous wastes including paper, rope, various packaging timber, metal and plastic which will be periodically transferred onshore for recycling or disposal; and
- minor volumes of hazardous waste including aerosol cans, batteries, used oils and oil filters, which will be periodically transferred onshore for recycling or disposal.

### Summary

A summary of key activities and their potential environmental implications is provided in *Table 4.5.*

*Table 4.5 Summary of Commissioning Activities*

| Commissioning Activities | | | |
|---|---|---|---|
| **Activity** | **Key Details** | **Environmental Aspects** | **Potential impacts on *EPBC Act* Matters** |
| Logistical support (including environmental incidents during testing and commissioning) | Supply vessels (weekly)<br>Helicopter flights (average 2 return per day) | Atmospheric emissions<br>Physical presence of vessels and helicopters<br>Ballast water, bilge water and drainage water<br>Noise and light emissions | Noise and light impacts on listed species<br>Vessel interactions with listed species |
| Hydrotesting and dewatering of flowlines and FLNG facility pipework | Seawater, corrosion inhibitor, biocide and MEG | Hydrotest water discharge | Discharge impacts on Commonwealth Marine Environment |

### 4.8.4 Operation and Maintenance

#### *Production (Operations) Phase*

The processing and utility facilities will be operated from the central control room on the FLNG facility. During the initial start up phase of any LNG facility, which is expected to take up to 3 months for Prelude FLNG, a higher than normal frequency of plant upsets with resultant flaring can be expected. It is possible that flaring could occur several times a week during this period.

After the initial start up period, flaring will be less frequent, occurring less than 1% of the time. Over the life of the project, flaring would be associated with process start up, shut down and unplanned events as a safety requirement. Associated impacts from all flaring activity are discussed in *Chapter 6*.

The following operations are anticipated:

- start-up, ramp-up and shut-down of individual wells;
- injection of chemicals into the well-streams for management of hydrates and wax;
- monitoring of pressures, temperatures and flow rates from individual wells;
- well-testing of individual wells; and
- pigging operation in the flowlines if required.

Inspection and intervention on the subsea facilities will be undertaken when required using specialised intervention vessels.

#### *Export of Hydrocarbons*

During loading, a LNG or LPG carrier would moor alongside the FLNG facility or a condensate tankers would moor in tandem astern of the FLNG facility, with the FLNG facility using its thrusters as necessary to maintain position. Two 80 tonne bollard pull tugs will assist with the docking process for LNG and LPG carriers while only one tug is required when docking condensate tankers. Note that only one tanker of any description will be loaded at a time.

Each storage tank on the FLNG facility will have its own dedicated loading pumps. Boil off gas generated during LNG or LPG loading operations will not be flared but will be routed back to the low pressure fuel gas system via the vapour return lines.

Product will be transported to market by vessels as follows:

- Weekly LNG carriers;
- Monthly LPG tankers; and
- Condensate tankers every 2-3 weeks.

#### *Overview of Emissions to Air*

Atmospheric emissions include $CO_2$, $NO_x$, sulphur and volatile organic compounds (VOC) including benzene, toluene, ethylbenzene and xylene (BTEX). It is a Shell standard that new installations shall be designed not to flare or vent hydrocarbons continuously for disposal. Generally discharge streams will be compressed and used as fuel gas. Other streams may be directed to the flare on the grounds of hazard (such as gas containing BTEX, $H_2S$ etc) or very low flow rates. A continuous small pilot flame will be necessary on the flare for safety reasons, comprising a continuous flow of small quantities of purge gas. The impacts associated with these emissions are discussed in *Chapter 6*.

**a) Venting**

A general 'no venting' principle with respect to the disposal of hydrocarbon streams from process units and other equipment will be applied during the operation of the FLNG facility. Some venting, however, may be necessary in special cases where routing to the flare is prohibited for safety or other technical reasons.

**b) Flaring**

A "no flaring" principle for disposal of hydrocarbon streams, which applies to normal plant operations, will be applied to the project. Any flaring that is required will follow the recommendations of API 521, Pressure Relieving and Depressurising Standard, which outlines that the flare shall be luminous and bright and show smokeless combustion at all operating gas flow rates. During start-up and shut-down, controlled flaring will be necessary to ensure safe operating procedure.

**c) $CO_2$**

*Table 4.6* provides a summary of estimated $CO_2$ emissions during plateau production levels. The feedgas contains 9%vol $CO_2$ that must be removed to avoid the $CO_2$ freezing as the natural gas is liquefied. This $CO_2$ is referred to as 'reservoir $CO_2$' and is separated from the natural gas and directed to atmosphere by a vent line up the flare stack. The other main source of $CO_2$ is that produced from combustion of fuelgas in the steam boilers for heat and power.

*Table 4.6 Summary of $CO_2$ emissions*

| $CO_2$ | (000's tpa) |
|---|---|
| Reservoir $CO_2$ vented | 966 |
| Combustion – $CO_2$ | 1260 |
| Flare – $CO_2$ | 58 |
| **Total $CO_2$ Emissions** | **2284** |

### d) $NO_x$

$NO_x$ emissions will be produced from boiler and flaring operations. Calculation of the $NO_x$ emissions from the boilers was based on maximum allowable $NO_x$ discharge limit of 240 mg/Nm$^3$ for this equipment (*Table 4.7*). There are also a number of diesel drivers that will run on an incidental basis for emergency power generation, fire water pump etc. The emissions are an order of magnitude smaller than the boilers and flaring contributions and have not been included in this assessment.

*Table 4.7 Summary $NO_x$ emissions*

| $NO_X$ (as $NO_2$) | tpa |
|---|---|
| Boilers | 2144 |
| Flare | 134 |
| **Total** | **2278** |

### e) Sulphur emissions

The hydrogen sulphide ($H_2S$) in the feed gas is almost completely removed in the AGRU and vented (see *Table 4.8*). As a result, very little $H_2S$ will end up in the fuel gas to the boilers to be converted into SOx (estimated less than 1 tonne per annum). The remaining $H_2S$ will be distributed over the products and not emitted.

*Table 4.8 Summary $H_2S$ emissions*

| $H_2S$ | tpa |
|---|---|
| Vented with Reservoir $CO_2$ | 171 |

### f) VOCs

The FLNG facility provides for a vapour return from the LNG and LPG carriers during loading to reduce VOC emissions. Similarly, vapours produced during the transfer of product to the LNG, LPG and condensate storage tanks on the FLNG facility will be returned to the low pressure fuel gas system. Also, the latest proven designs in flanges, pumps, seals and valves will also be used in the FLNG facility to reduce fugitive emissions to ALARP levels. *Table 4.9* summarises estimated VOC emissions.

## *Liquid Waste*

Liquid wastes from the normal operational activities are expected to include:

- PFW and MEG brine. Data to date suggested that relatively low rates of PFW will be produced from the gas reservoir. However, provision has been made to treat and dispose of up to 2,200 m$^3$ per day;
- Accidentally and continuously contaminated water. Drainage will be routed through the WWTP which will be capable of handling up to 20,000 bbl/day (~3,200 m$^3$ per day) of aqueous waste streams;
- desalination brine will be discharged at a rate of approximately 5,000 t/day (~5,000 m$^3$ per day);
- utilities water from the mixed bed ion exchangers used for steam condensate regeneration and boiler feed preparation;
- utilities water from the boilers (boiler blow down);
- oils and lubricants which will be collected and returned onshore for recycling and/or disposal;
- approximately 23 m$^3$ of water-based subsea control fluids are likely to be discharged to sea per year as a result of routine releases from Subsea Control Valves in the subsea infrastructure, which control the flow of hydraulic fluid to various field valves, enabling them to open and close;
- grey water and sewage in the order of 10m$^3$ per day, which will be treated by the on-board treatment system before discharge;
- kitchen waste, shower and laundry wastes that will be capable of passing through a 25mm diameter screen prior to discharge;
- ballast water from product tankers;
- hazardous waste such as used oil, chemicals, solvents, acids/caustics and paint, which will be transferred onshore

*Table 4.9 Summary VOC emissions*

| VOC / BTEX | Acid Gas Vent (tpsd) | Flare unconverted HC (tpsd) | Condensate storage tanks (tpsd) | Fugitive emissions (+10 %) (tpsd) | Total (tpsd) | Total (tpa) |
|---|---|---|---|---|---|---|
| ETHANE | 0.2 | 0.4 | | 0.1 | 0.7 | 221 |
| PROPANE | 0.0 | 0.1 | | 0.0 | 0.1 | 37 |
| IBUTANE | 0.0 | 0.0 | 0 | - | 0 | 30 |
| BUTANE | 0.0 | 0.0 | 0.3 | - | 0.3 | 101 |
| BENZENE | 1.1 | - | 0 | - | 1.1 | 369 |
| TOLUENE | 3.1 | - | 0 | - | 3.1 | 1039 |
| XYLE NE | - | - | 0 | - | 0 | 3 |
| **Total** | **4.4** | **0.5** | **0.4** | **0.1** | **5.4** | **1,799** |

*Note: An allowance has been included for emissions from condensate tanks when vapours are unable to be routed to the fuel gas system due to maintenance or shutdown.*

for disposal at an appropriately licensed facility; and
- cooling water discharge at 50,000 $m^3$/hour containing a maximum of 0.2 ppm free residual chlorine at the cooling water discharge outlets.

The impacts from liquid waste discharges are discussed in *Chapter 6*.

## Solid Waste

Solid wastes arising during normal operations are expected to include:
- non-hazardous general wastes such as paper, rope, various packaging timber and metal;
- non-hazardous materials from the production process such as sands and grit from pigging; and
- hazardous waste including used or spoilt water treatment chemicals, used mercury absorbent, used molsieve, process sludges, batteries, used lube oils and oil filters.

Solid wastes will be returned to shore for processing. The waste management strategy during operations and maintenance is designed to optimise segregation of waste in the offshore location and to minimise contamination of recovered waste destined for recycling or disposal.

## Maintenance

Over the course of their lives the production wells may require maintenance work which will be carried out by a MODU 'working over' the well. This will involve similar processes and facilities as described for the development drilling process above but without the use of drill muds and the generation of drill cuttings. The maintenance work is carried out within the existing steel cased hole and uses seawater brines to balance the pressures exerted by the gas in the reservoir. The brine is discharged to sea after use.

Maintenance of the FLNG facility will consist of routine day to day maintenance and planned shutdowns for major scheduled maintenance. The offshore maintenance team will carry out first line routine maintenance (such as greasing, vibration monitoring, normal repairs, etc.) and assist visiting maintenance crews. Planned maintenance will be executed campaign-style for both normal operations and during maintenance shutdowns with teams coming to the FLNG facility or to the Maintenance Workshop where FLNG equipment has been transported.

Plant layout has been designed to allow safe, easy and fast removal, transport and reinstatement of all components that might require removal for maintenance work.

The planned maintenance strategy shall be developed to ensure:
- the maintenance activities (with resultant higher movements of personnel and equipment) are planned to reduce HSE risks to ALARP; and
- maximum availability and integrity of the FLNG facility whilst optimising costs and manning.

Biological accumulation on the FLNG facility hull is unlikely due to application of anti-fouling. In the event that it does occur, any build-up will be removed by mechanical cleaning by divers or Remotely Operated Vehicles (ROV).

### *Supply, Support and Logistics*

Supplies to and wastes from the facility will be transported via an offshore supply vessel calling at the FLNG facility every one to two weeks initially and then every two to three weeks when steady operation is achieved. The FLNG facility has a fairly steady consumption rate of materials and consumables but has sufficient storage capacity and payload relative to its steady state demand levels to minimise downtime.

Support vessels operating out of the support centre will include one custom-built supply vessel, one standby vessel and two custom built tugs (with emergency response capabilities).

Personnel will be transported to and from the FLNG facility by helicopter. Because of the large distance to the Prelude location, helicopters will need to refuel for their onward or return flights. Aviation fuel storage (estimated at about 6,500 litres) will be provided on the FLNG facility, which is in line with the volume held on existing operating drilling rigs working in the area.

The helicopter operating base will be located in Broome. A forward refuelling point will likely be located at the northern end of Dampier Peninsula in the region of Lombadina and Cape Leveque. On average, six flights per week will be required during FLNG facility operations and three flights per week during drilling.

### *Workforce*

In total, about 320 personnel will be employed in the operation of the FLNG facility. During normal operations, approximately 220 personnel will work onboard the FLNG facility, working as two 110 man crews on a rotational roster (eg three weeks on, three weeks off), employed to carry out operations, maintenance and/or provide support functions. The remaining 100 personnel will comprise day staff located ashore at the Maintenance Workshop and in Perth and will be employed to provide technical and administrative support.

### *Summary*

A summary of the main anticipated operational and maintenance activities and their potential environmental implications is provided in *Table 4.10*.

### 4.8.5 Possible Future Expansion or Modification

The length of time that the Prelude field will be production will depend upon the actual amount of gas in the reservoir but field planning is for 25 years. When the Prelude field pressure eventually does start to reduce, the decline in production rate is likely to be backfilled by tiebacks from other gas sources so that the FLNG facility can continue to operate efficiently at full throughput. Exploration is still underway but potential gas sources include the nearby Concerto field, the Crux field and the Libra field. Sufficient spare tie-in points have been allowed for potential future gas tiebacks. Such tiebacks are not included in the scope of this draft EIS and will be the subject of a separate environmental approvals process to cover their field development and connecting pipelines.

### 4.8.6 Decommissioning, Abandonment and Restoration

At the end of project life the FLNG facility infrastructure will be decommissioned in accordance with the prevailing legislation and industry best practice at that time. Decommissioning is a petroleum activity and requires approval under the *OPGGS Act*, including approval of the Decommissioning Environment Plan and Safety Case prior to decommissioning activities commencing. It is currently envisaged that the production wells will be plugged and abandoned. Subsea infrastructure will be designed to enable removal as required under the *OPGGS Act*. The FLNG facility will be towed to a drydock facility for refitting. Infield activities are expected to take about 4 months to complete. After the successful completion of decommissioning activities, Shell will apply to surrender the Prelude production and infrastructure licenses. Once satisfied that Shell has complied with all requirements for the surrender of these licences, the Designated Authority can give consent to the surrender of the licences. It is likely that decommissioning and surrender of the licences, from approval of the decommissioning plan through to the Designated Authority's consent to the surrender of the licences, will take about 12 months. A summary of the main anticipated decommissioning activities and their potential environmental implications is provided in *Table 4.11*.

*Table 4.10 Summary of Operation and Maintenance Activities*

| Operation and Maintenance Activities | | | |
|---|---|---|---|
| **Activity** | **Key Details** | **Environmental Aspects** | **Potential impacts on *EPBC Act* Matters** |
| Logistical support | 1 supply vessel call per 1 to 2 weeks | Atmospheric emissions<br>Physical presence of vessels and helicopters<br>Ballast water, bilge water and drainage water<br>Noise and light emissions | Noise and light impacts on listed species<br>Vessel interactions with listed species |
| Well, infield flowline and flexible riser operations | Subsea control fluid – water based | Estimated discharge volume of Subsea control fluid is 23 $m^3$ per year | Discharge impacts on Commonwealth Marine Environment |
| FLNG facility operations | Life of field – 25 years<br>Design capacity of 3.6 mtpa LNG, 0.4 tpa LPG and 1.3 mtpa condensate | Noise emissions<br>Light emissions<br>Produced formation water and drainage water discharge<br>Cooling water discharge (7.5°C to 16°C above ambient seawater temperature with residual chlorine concentration – 0.2ppm<br>Atmospheric emissions –<br>$CO_2$ – 2,300,000 tpa<br>H2S – 171 tpa<br>NOx – 2,278 tpa<br>VOC – 1,799 tpa<br>Waste – hazardous and non hazardous solid wastes returned to shore<br>Sewage/grey water volumes | Noise and light impacts on listed species<br>Discharge impacts on Commonwealth Marine Environment |
| Export shipping | LNG Carriers weekly<br>LPG tankers monthly<br>Condensate tankers once per fortnight<br>2 Standby tugs | Ballast water discharge<br>Accidental spillages<br>Noise and light emissions | Discharge impacts on Commonwealth Marine Environment<br>Spill impacts on Commonwealth Marine Environment and listed species<br>Noise and light impacts on listed species<br>Vessel interactions with listed species |
| Maintenance activities | Maintenance of wells and the FLNG facility on an estimated 4 year cycle | Noise emissions<br>Light emissions<br>Atmospheric emissions | Noise and light impacts on listed species |

*Table 4.11 Summary of Decommissioning Activities*

| Decommissioning Activities | | | |
|---|---|---|---|
| **Activity** | **Key Details** | **Environmental Aspects** | **Potential impacts on *EPBC Act* Matters** |
| Flushing of subsea flowlines | Flush flowlines until oil-in-water below 30 mg/l | Treated on FLNG Facility prior to discharge | Discharge impacts on Commonwealth Marine Environment |
| Capping of wells | Wells will be plugged with cement<br>Flowlines and manifolds removed if required | Physical presence | Physical disturbance impacts on Commonwealth Marine Environment |
| Removal and towing of FLNG facility | Tugs and Supply vessels | Air emissions<br>Noise and light emissions | Vessel interactions with listed species<br>Noise and light impacts on listed species |

# 5 EXISTING ENVIRONMENT

## 5.1 OVERVIEW

### 5.1.1 Introduction

This chapter provides a detailed description of the baseline environment relevant to the project. It is divided into six sections, relating to;

1) the physical environment;
2) ecosystems, communities and habitats;
3) key flora and fauna species;
4) introduced marine species;
5) existing disturbance; and
6) socio-economic and cultural environment.

The description of the existing environment in the vicinity of the project area and wider region is based on relevant information from desktop studies and field surveys, as described in the following section and throughout this chapter.

### 5.1.2 Data Sources

#### *Desktop Study*

The desktop study comprised a review of available data and information from a variety of sources including, but not limited to, the following:

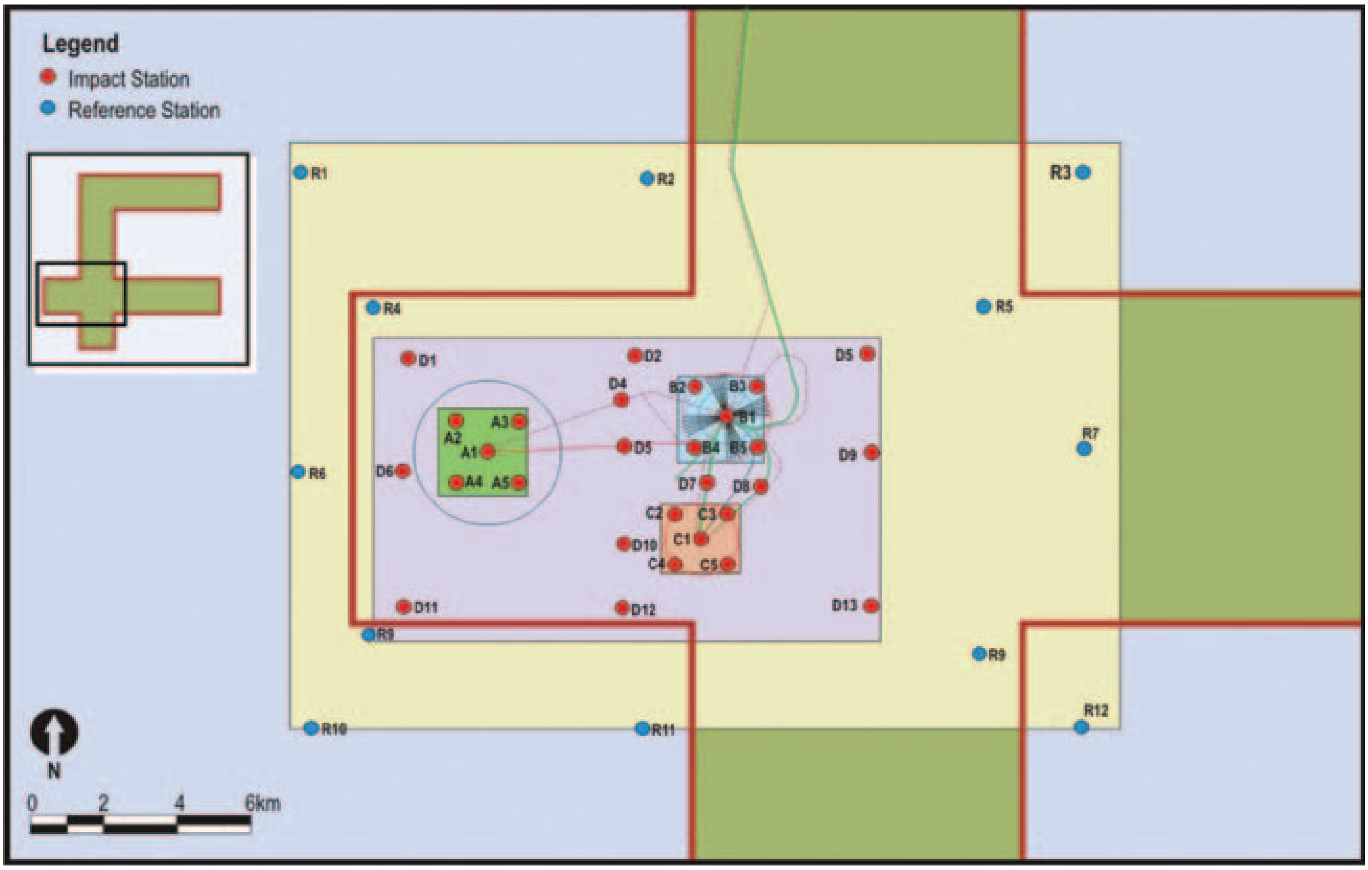
- peer reviewed journals;
- government and client data sources;
- Commonwealth Science and Industrial Research Organisation (CSIRO);
- industry and government technical reports;
- studies within WA-371-P completed by Shell;
- studies from title areas adjacent to WA-371-P which were made available to Shell through information sharing agreements; and
- standards and guidelines, including:
  - Australian and New Zealand Environment Conservation Council (ANZECC) Water and Sediment Quality Guidelines 2000; and
  - WA Department of Environmental Protection Assessment Levels for Soil, Sediment and Water (2003).

#### *Field Surveys*

A number of marine environmental surveys were undertaken to characterise the existing baseline habitat and conditions in the project area. The surveys included the following:

- sampling and data collection for determination of sediment and water quality, macrobenthic and plankton communities (ERM, 2008);
- a survey of cetaceans and other marine megafauna in the region undertaken for INPEX Browse Limited (INPEX) and made available to Shell through an information sharing agreement (RPS, 2007a);
- four 20 day cetacean surveys, conducted by Shell, Woodside and INPEX (Jenner and Jenner, 2009), to coincide with the expected northern and southern migratory periods for pygmy blue whales through the Browse Basin; and
- a baseline survey of underwater noise from September

*Figure 5.1 Survey Design (Sampling Station Layout)*



2006 to August 2008 undertaken for INPEX and made available to Shell through an information sharing agreement.

These surveys are described below in greater detail.

### *Sediment and Water Quality, Macrobenthos and Plankton Communities*

A field survey was carried out in the WA-371-P title area from 11th to 19th July 2008. The survey consisted of 40 sampling stations located within four identified *development* Zones (A-D) and a *reference* Zone (R) located outside the immediate zone of influence of development activities (*Figure 5.1*).

The positioning and extent of development Zones A-C was determined on the basis of the location of the three main operational areas within the proposed facilities layout:

- potential drill centre location (Zone A);
- the Site for the FLNG facility (Zone B); and
- the subsea well structures (Zone C).

The fourth development zone (Zone D) consisted of sampling sites surrounding these three operational areas. A summary of the types of sampling undertaken for each of the sites is provided in *Table 5.1*.

### *Cetaceans and Other Marine Megafauna*

A study was carried out by INPEX, which included the project area and inshore areas off the Kimberley coast, to assess the importance of these areas for cetaceans and other marine megafauna and to establish a baseline dataset on which future monitoring can be planned (RPS, 2007a). The study was conducted between August 2006 and October 2007 and included vessel and aerial surveys, and acoustic logger monitoring. The timing of the surveys was based on the known presence of humpback whale breeding aggregations in the Kimberley from July to November each year (Jenner et al. 2001) and the possible passage of pygmy blue whales through the region.

Vessel-based surveys were conducted in approximately 20 day blocks between August and November 2006 (70 survey

*Table 5.1 Overview of Sampling Undertaken at the Survey Stations*

| Sampling Zones | Sediment Chemistry/ Macrobenthos | Seawater Chemistry | In situ Water Quality | In situ Sediment Redox | Phyto-plankton | Zoo-plankton |
|---|---|---|---|---|---|---|
| FLNG Facility (B) | B1-5 | B1, B2 | B1, B2 | B1-3 | B1 | B1 |
| Subsea Well Structures (C) | C1-5 | C1 | C1 | C1-3 | C1 | C1 |
| Potential Drill Centre (A) | A1-5 | A1 | A1 | A1-3 | A1 | A1 |
| Project Zone of Influence (D) | D1-13 | D1 | D1 | D1, D3, D9, D13 | D1 | - |
| Reference (R) | R1-12 | R3, R10, R11 | R3, R10, R11 | - | R3, R10 | R3, R10 |

days in total) and between July and August 2007 (38 survey days in total). Of the 20 day blocks, five days were spent surveying in the Browse Basin (seven transects). See *Figure 5.2* for vessel transect locations.

Inshore aerial surveys were conducted between Broome and the Maret Islands between early August and late September in 2006 (four survey days) and 2007 (seven survey days).

Another offshore cetacean and marine megafauna study was conducted on behalf of Shell, Woodside and INPEX in the Browse Basin area during 2008 and covered waters in and surrounding WA-371-P (Jenner and Jenner, 2009) (see *Figure 5.3*). The study was carried out between June and November 2008 and comprised of four separate surveys, each of 20 days duration. The timing for the 20 day surveys was selected to coincide with the anticipated northern and southern migratory periods for pygmy blue whales through the study area. Survey period were as follows:

1) June 09 – 29, 2008 (Northern Migration);
2) July 04 -23, 2008 (Northern Migration);
3) October 17 – November 05, 2008 (Southern Migration); and
4) November 11- 30, 2008 (Southern Migration).

A total of 27 cetacean sightings of, at minimum, 8 species were recorded (total 263 animals). Species sighted included a pygmy blue, humpback, pilot, false killer and pygmy killer whales, and a diversity of dolphin species (*Stenella sp., Tursiops sp., Grampus griseus* and *Delphinus sp.*).

Observations from the surveys of cetacean activities in the Browse Basin and the inshore Kimberley region are included in *Section 5.4*.

### *Underwater Noise Survey*

Acoustic loggers were deployed to record vocalising cetaceans and other biological noises including fish and invertebrate activities between September 2006 and February 2007 in the Browse Basin and September 2006 and March 2007 inshore near the Maret Islands (see *Figure 5.2*). Additional noise logging was also completed in 2008.

## 5.2 PHYSICAL ENVIRONMENT

### 5.2.1 Introduction

Information describing climatic conditions in the region was obtained from the Australian Bureau of Meteorology (BOM) (1961-2008) and survey work conducted by Shell. The nearest BOM weather recording station to WA-371-P title area is located at Kuri Bay, approximately 225 km to the southeast. It is noted that data collected at this location may not be truly representative of the offshore marine environment of the project area, and therefore should be used as a guide to climatic conditions only. Climatic information obtained from a Shell metocean buoy, positioned 7.8 km NE from the proposed FLNG facility, included 9-months worth of measured data for wind, air temperature, relative humidity and barometric pressure, collected in two periods between September 4th, 2007 and August 27th, 2008.

Descriptions of oceanographic conditions for the title area presented in this section are based on published information and primary data collected by Shell and INPEX. A complete list of Shell metocean data sets used in this draft EIS is listed in *Table 5.2*.

*Figure 5.2 Locations of Vessel Transects and Noise Loggers in the INPEX Cetacean and Marine Megafauna Survey*

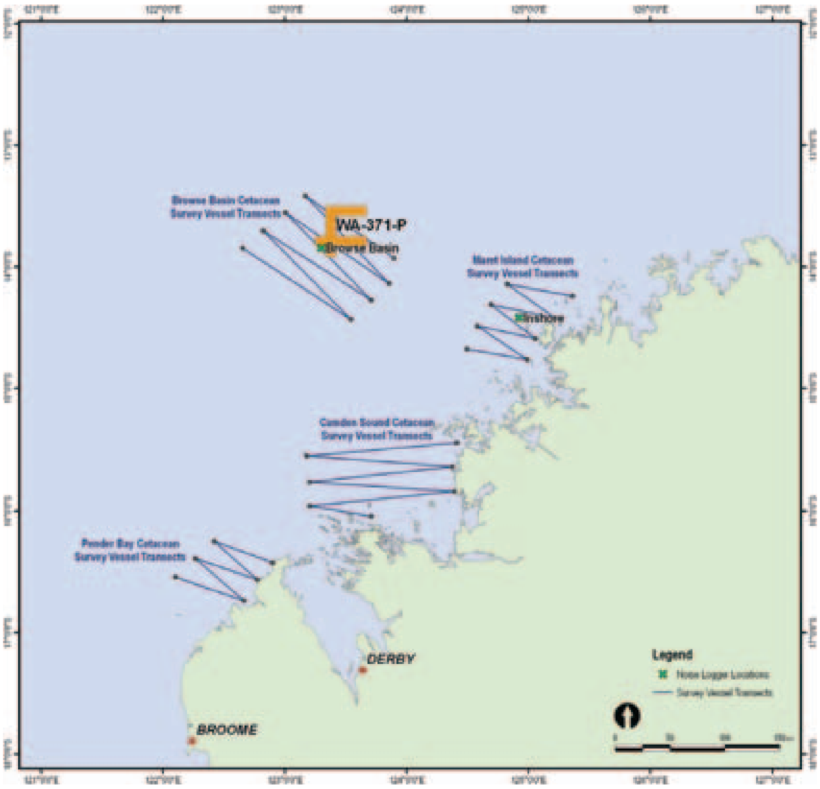


*Figure 5.3 Study Area for the Combined Shell, Woodside and INPEX Cetacean Survey*

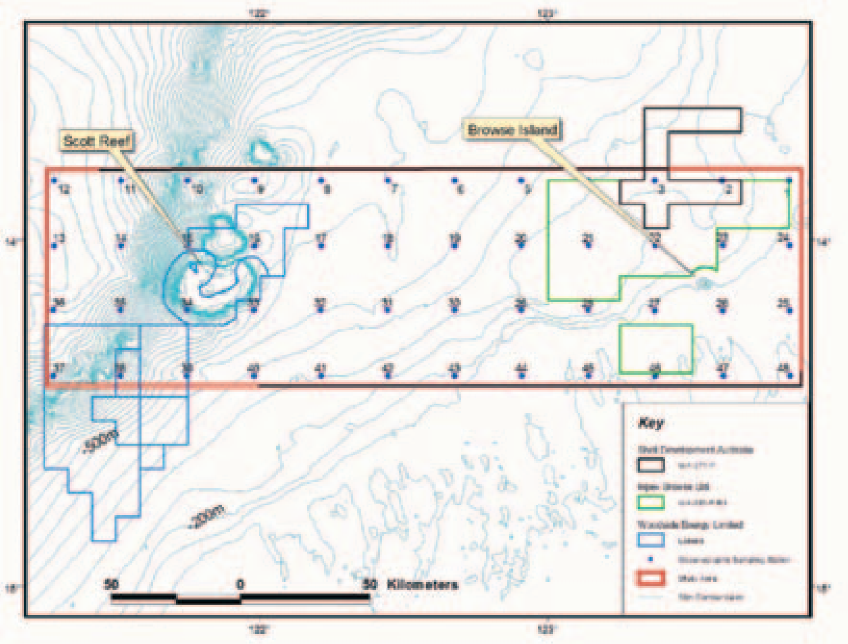


*Table 5.2 Shell Metocean Datasets*

| Dataset | Description |
|---|---|
| 1 | 9-months measured data set of wind, air temperature, relative humidity and barometric pressure |
| 2 | 9-months measured data set of current and temperature (at 40m intervals) for WA-371-P |
| 3 | 9-months measured data set of temperature and salinity (at 5 depths) |
| 4 | Monthly mean data for temperature and salinity for region (from National Oceanographic Data Centre World Database) |
| 5 | 40-years hindcast data set of current and tidal height |
| 6 | Tidal constituents, determined through harmonic analysis |
| 7 | Water depth map |
| 8-1 | Conductivity, Temperature, Depth profiles collected following deployment of the current mooring (17-May-08) |
| 8-2 | Conductivity, Temperature, Depth profiles collected following deployment of the current mooring (31-Jan-08) |

### 5.2.2 Climate and Atmosphere

*Introduction*

The North West Shelf (NWS) region experiences monsoonal weather patterns with a distinct:

- Summer 'wet season' from December to March (northwest monsoon); and
- Winter 'dry season' from April to November (southeast monsoon).

*Wind*

A steady south-easterly airflow originating over the Australian mainland generally dominates during the southeast monsoon and an inflow of moist west to northwest winds prevails during the northwest monsoon, producing convective cloud and heavy rainfall (BOM, 2008b).

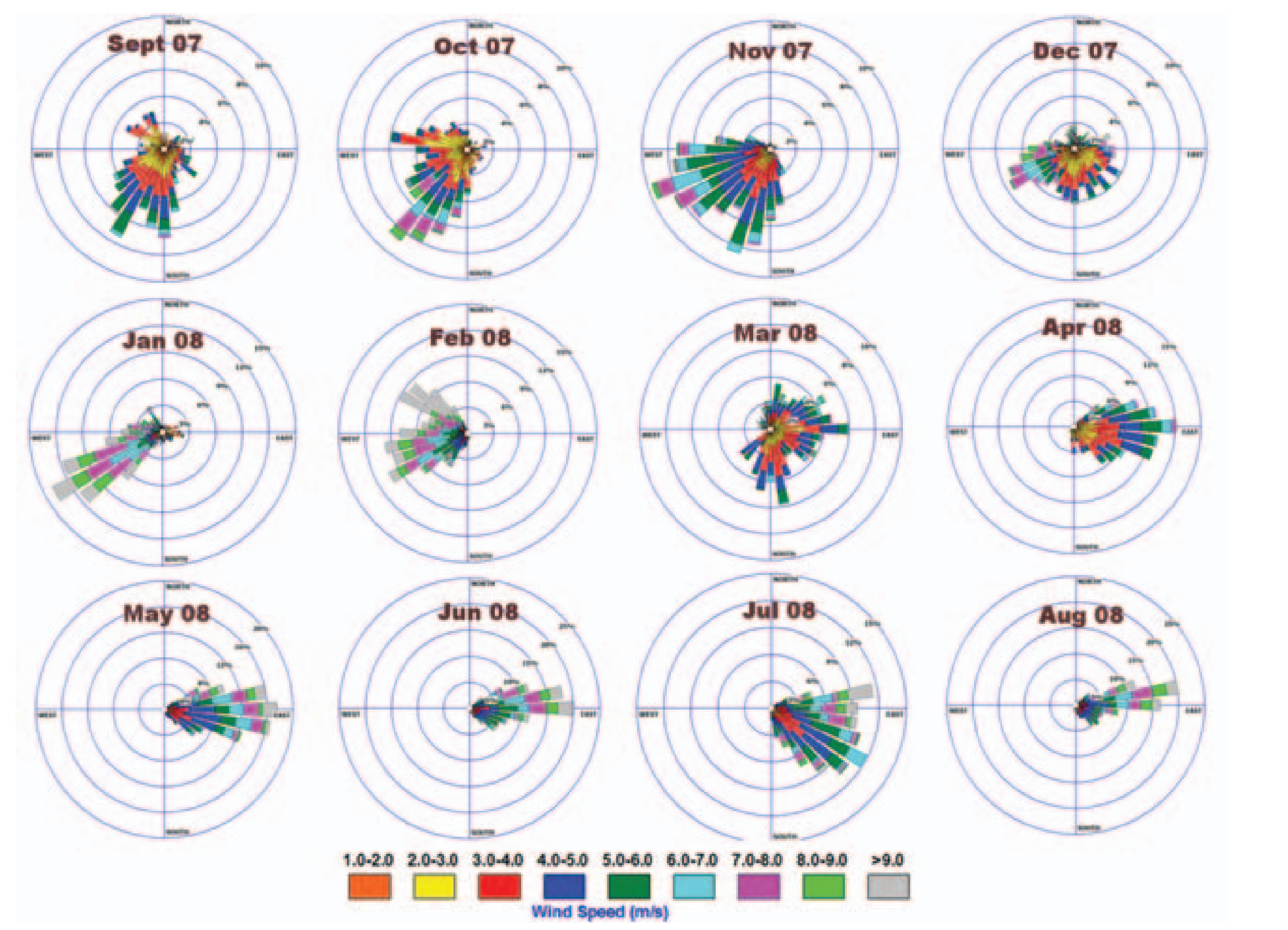
Wind speeds and direction measured at WA-371-P between September 2007 and August 2008 are presented in *Figure 5.4*. The wind directions, although highly variable, can be broken down into two distinct periods:

- The first period extends from September to February where the predominant wind direction is towards the north or northeast and corresponds approximately to the period of the northwest monsoon.
- The second period extends from April to August where the predominant direction is towards the west, which corresponds approximately to the period of the southeast monsoon. March is a transitional month.

*Temperature & Humidity*

Mean air temperatures in the region are around 25°C in July and 30°C in December (BOM, 2008a). Relative humidity is highest between November and April (average

*Figure 5.4 Wind Rose Plots for WA-371-P for September 2007 - August 2008*



minimum 66%, average maximum 69%) and corresponds with the northwest monsoon season. Between May and October, relative humidity is less and ranges from an average minimum of 37% to an average maximum of 49% (see *Table 5.3*).

### *Precipitation*

Rainfall in the region is highly seasonal and is highest during the northwest monsoon season, ranging from an average of 192 mm per month between November and April, and 10 mm per month between May and October at Kuri Bay (BOM, 2008a).

## 5.2.3 Natural Hazards

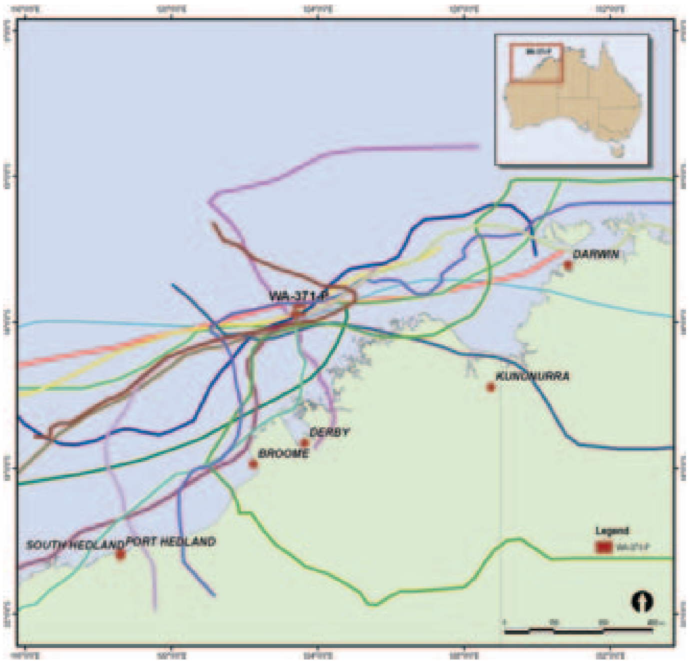
### *Tropical Cyclones*

The project area occurs within an area of cyclonic activity, with cyclones generally occurring between December and April. On average about five tropical cyclones occur during each tropical cyclone season over the warm ocean waters off the northwest coast between 105 and 125°E (BOM, 2008c).

*Figure 5.5* illustrates the paths of tropical cyclones that have passed within 50 km of the project area over the last 50 years (BOM, 2008d).

*Table 5.4* provides details of these cyclones including their maximum average wind speeds and average wind speed when passing within 50 km of the project area. Only two cyclones with average wind speeds above 50 knots have been recorded in the vicinity of the project area since 1986: Chloe in 1995, which had an average measured wind speed of 105 knots; and, Faye in 2004, which had an average measured wind speed 124 knots. *Table 5.5* provides a summary of the metocean extreme conditions for the proposed FLNG facility location.

*Figure 5.5 Tropical Cyclone Paths Passing within 50km of the FLNG Facility Location (1958 to 2007)*



*Source: BOM (2008a)*

### *Tsunamis*

Australia is bounded on the northwest, northeast and east by some 8,000 km of active tectonic plate boundary capable of generating tsunamis. One-third of all earthquakes worldwide occur along these boundaries. The Sunda Arc south of Indonesia, where the Australian Plate is subducting beneath the Sunda Plate, poses the greatest tsunami threat to Australia's northwest coast (Burbidge and Cummins, 2007). Earthquakes off Java have historically caused large tsunamis which have reached heights of four to six meters on Australia's northwest coast.

The tsunami potential for the NWS region is considered to be moderate (Geoscience Australia, 2005). However, tsunamis in the open ocean, such as found at WA-371-P,

*Table 5.3 Mean Annual Climate Data for Kuri Bay*

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean max temp (°C) | 32.8 | 32.5 | 33.1 | 34.3 | 33.0 | 31.3 | 31.1 | 31.9 | 33.1 | 33.8 | 34.3 | 34.0 |
| Mean min temp (°C) | 35.5 | 25.1 | 24.9 | 24.2 | 31.9 | 19.5 | 18.5 | 19.7 | 22.2 | 24.5 | 26.1 | 26.2 |
| Mean rainfall (mm) | 403.3 | 353.3 | 309.9 | 67.7 | 49.3 | 8.9 | 4.9 | 1.1 | 1.8 | 6.9 | 24.8 | 156.9 |
| Mean 9am relative humidity (%) | 75 | 79 | 76 | 66 | 55 | 51 | 51 | 56 | 60 | 62 | 63 | 68 |
| Mean 3pm relative humidity (%) | 69 | 71 | 67 | 53 | 45 | 41 | 39 | 40 | 47 | 55 | 59 | 63 |

*Source: BOM (2008a)*

*Table 5.4 Tropical Cyclones that Passed within 50km of the Proposed FLNG facility Location (1958 and 2007)*

| Tropical Cyclone | Approximate distance to FLNG facility at nearest point (km) | Date | Average Wind Speed when <50km from FLNG (knots) | Central pressure (hPA) | Maximum Average Wind Speed (knots) |
|---|---|---|---|---|---|
| Raymond | 50 | 02/01/2005 | 44.7 | 985 | 44.7 |
| Faye | 35 | 20/03/2004 | 124.4 | 935 | 140 |
| Unnamed # 1 | 30 | 21/01/2003 | 19.4 | 1005 | 35 |
| Sam | 45 | 05/12/2000 | 48.6 | 985 | 97.2 |
| Nicholas | 50 | 13/12/1996 | 33 | 996 | 46.7 |
| Chloe | 37 | 06/04/1995 | 105 | 925 | 106.9 |
| Oscar | 25 | 01/01/1994 | 23.3 | 1002 | 35 |
| Sam | 45 | 13/01/1990 | 38.9 | 995 | 70 |
| Victor | 10 | 03/03/1986 | 40.8 | 994 | 112.7 |
| Chloe | 45 | 25/02/1984 | NA | 1002 | NA |
| Amelia | 20 | 05/12/1981 | NA | 1002 | NA |
| Brian | 45 | 19/01/1980 | NA | 993 | NA |
| Karen | 20 | 02/03/1977 | NA | 998 | NA |
| Irene | 40 | 09/01/1977 | NA | 970 | NA |
| Nellie | 20 | 13/03/1973 | NA | 999 | NA |
| Leah | 25 | 03/03/1973 | NA | 1004 | NA |
| Unnamed # 3 | 45 | 22/01/1960 | NA | 1000 | NA |

Source: BOM (2008a)

*Table 5.5 Metocean extremes for the Proposed FLNG facility location*

| Extreme Independent Criteria | units | Return period (years) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1 | 5 | 10 | 100 | 1,000 | 10,000 |
| Maximum 3 second wind gust speed | ms-1 | 19.7 | 29.6 | 35.3 | 56.2 | 79.0 | 103.1 |
| Maximum 1-min. mean wind speed | ms-1 | 17.9 | 26.4 | 31.3 | 48.7 | 67.1 | 86.0 |
| Maximum 10-min. mean wind speed | ms-1 | 16.4 | 24.0 | 28.2 | 43.0 | 57.9 | 72.9 |
| Maximum 30-min. mean wind speed | ms-1 | 15.7 | 22.9 | 26.7 | 40.2 | 53.6 | 66.6 |
| Maximum 1-hour mean wind speed | ms-1 | 15.3 | 22.1 | 25.8 | 38.5 | 50.8 | 62.7 |
| Significant wave height | m | 5.2 | 6.5 | 7.2 | 11.0 | 14.3 | 18.0 |
| Mean zero-crossing period | s | 7.8 | 8.7 | 9.4 | 10.0 | 11.0 | 11.9 |
| Mean peak wave period | s | 10.0 | 11.2 | 12.1 | 12.9 | 14.1 | 15.3 |
| Period of maximum wave | s | 9.1 | 10.2 | 10.7 | 13.2 | 15.0 | 16.9 |
| Most probable maximum. individual wave height | m | 8.7 | 11.2 | 12.6 | 17.7 | 22.6 | 27.5 |
| Most probable crest of maximum individual wave | m | 5.3 | 6.9 | 7.8 | 11.2 | 14.5 | 17.7 |
| Storm surge | m | 0.1 | 0.2 | 0.3 | 0.6 | 0.8 | 1.0 |

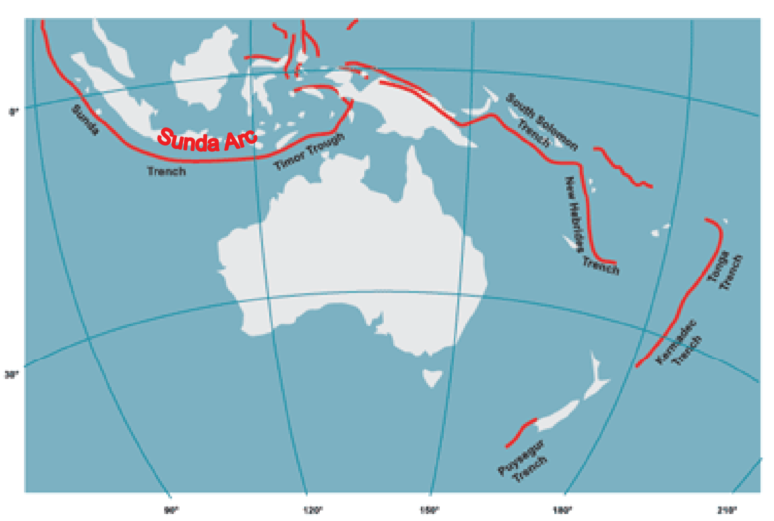
pose few concerns as tsunamis remain relatively small, with wave heights generally less than one metre (Geoscience Australia, 2008a) and well within the metocean design criteria for the FLNG facility.

### 5.2.4 Oceanographic Conditions

#### *Tides and Currents*

The large-scale ocean circulation on the NWS is linked with major Southeast Indian Ocean and Indo-Pacific current regimes, such as the Indo-Pacific Through Flow (ITF), which contributes to the westward flowing South

### *Sunda Arc*



The Sunda Arc is a volcanic arc that has produced the islands of Sumatra and Java and the Sunda Strait and the Lesser Sunda Islands. A chain of volcanoes forms the topographic spine of these islands. The arc marks an active convergent boundary between the East Eurasian plates that underlie Indonesia, especially the Sunda and Burma Plates, with the India and Australian Plates that form the seabed of the Indian Ocean and the Bay of Bengal.

The India and Australian Plates are subducting beneath the Sunda and Burma plates along the Sunda Arc. The tectonic deformation along this subduction zone in the Java Trench (Sunda Trench) caused the 2004 Indian Ocean earthquake of December 26, 2004.

There are two distinct zones for earthquake activity in the Sunda Arc. The 1977 Sumbawa and 1994 Java earthquakes occurred in the eastern part of the arc, where relatively old (approximately 100 million years) oceanic lithosphere subducts offshore Java. Very few of the classical subduction zone earthquakes occur in this part of the arc—1994 being the only confirmed event of this type. The largest earthquake generated tsunamis in the eastern Sunda Arc are actually normal faulting events in the Australian plate, in the `outer rise' where the subducting plate bends prior to diving beneath Indonesia.

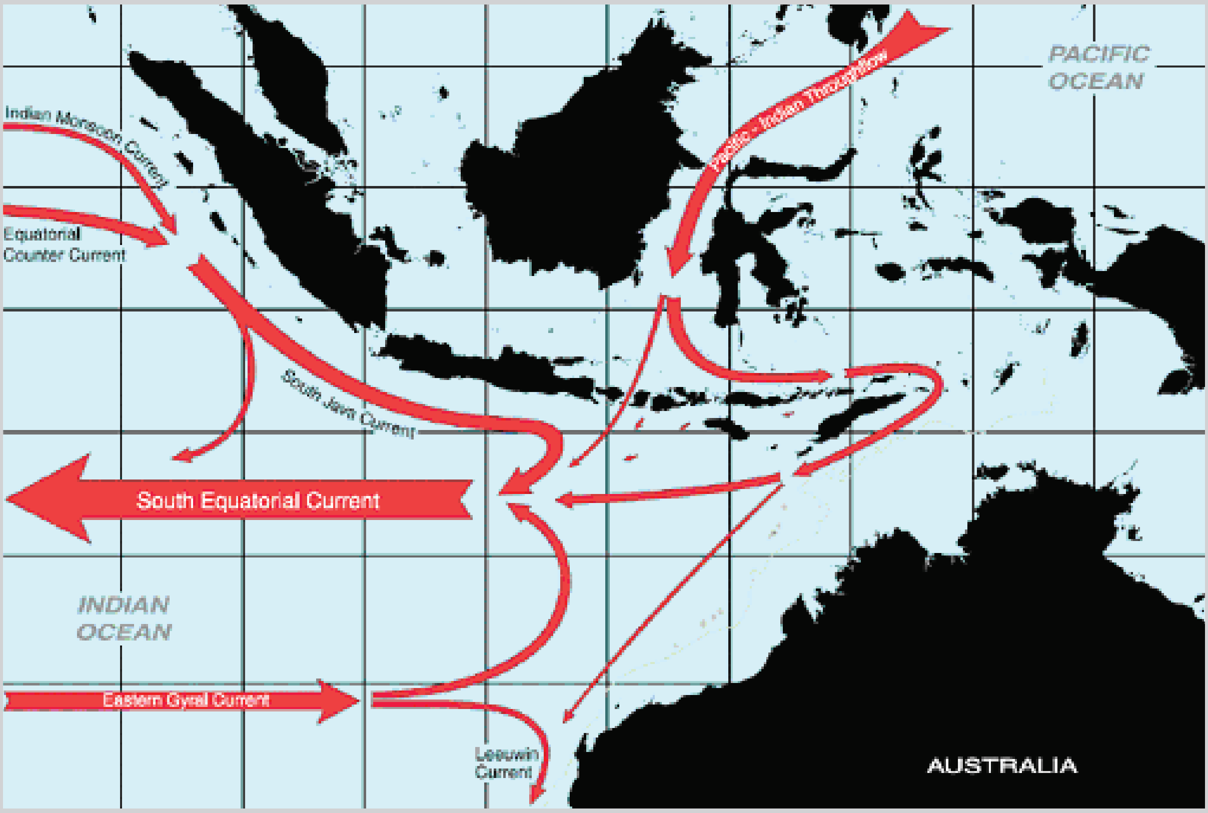
Farther to the north-west in the Sunda Arc, relatively young (40 million years) oceanic lithosphere subducts offshore Sumatra. The subduction of such young oceanic lithosphere in the Pacific Ocean is associated with most of the massive earthquakes that generate the huge tsunamis that pose a threat to the entire Pacific basin. Although there are no Australian observations on record of tsunamis excited by earthquakes off Sumatra, great thrust earthquakes occurred there in historic times, the most recent in 1833.

Equatorial Current (between 8° and 15° S latitude) and floods the NWS with relatively warm, low-salinity water.

Wind-induced currents occur due to local wind forcing at the surface and are most pronounced during tropical cyclones. After the passage of such strong events, transient oscillations in the ocean may arise called inertial currents. Local wind driven surface currents generally have amplitudes of 0.2 to 0.3 ms$^{-1}$ with maximum speeds of 0.6 ms$^{-1}$ during extreme monsoonal or trade wind surges (Heyward et al. 1997). The NWS region has semidiurnal tides, with a high tidal range between 3 m (neaps) and 10 m (springs) (Brewer et al. 2007).

Modelling of currents of the NWS region (CSIRO, 2007) has shown that instantaneous current patterns are strongly

### *Indo-Pacific Through Flow (ITF)*



*(Reproduced from CSIRO (2004). Note: ITF labelled as "Pacific-Indian Throughflow" on figure).*

The ITF drives the South Equatorial Current which is a major circulation feature during the south-west monsoon season. During the north-east monsoon, the South Equatorial Current loses strength and retreats south, whilst the Equatorial Counter current (locally the Java Current) enters from the west. Just south of Java it is drawn into the South Equatorial Current, which flows in the opposite direction. Reportedly there is some upwelling at the interface between the two current systems which is of some importance to the productivity of this part of the ocean. The deep overlying oligotrophic waters of the ITF are a major barrier to convective mixing up of nutrients hence turbulent mixing from other processes such as equatorial currents and internal tidal mixing critically control the nature of productive processes at the local, regional and collectively at the largest basin scale. The ITF appears to be subject to the pronounced inter-annual variations of the El Niño-Southern Oscillation events (Heyward et al. 1997).

dominated by tides and the spring neap cycle. However, longer-term transport over the inner and mid shelf is mainly controlled by wind-driven flow, which follows the seasonal switch from summer monsoon winds to south-easterly trades in winter. Over the outer shelf and slope the large-scale regional circulation also has a major influence.

Additional influences in the NWS region are from barotropic and baroclinic tidal currents. Barotropic tides result from a pressure gradient, caused by a change in the sea surface height due to wind or astronomical tidal oscillations, which drives the current motion in the water column. Astronomical tides are semi-diurnal and therefore the barotropic tide typically exhibits four current reversals per day.

Baroclinic tide (internal tides) may occur due to strong stratification of the water column and in areas of steeply sloping bathymetry. Baroclinic tidal currents are formed by the interaction of the oscillatory barotropic tide with both the vertical density structure and the underlying bathymetry. In regions such as the NWS where strong stratification is predominant, particularly in the summer months, baroclinic tides can play an important role in subsurface flows throughout the water column. Studies have indicated that strong turbulence and mixing is caused in NWS waters by breaking internal waves, bringing nutrients from below the thermocline to surface waters (Kasumata, 2006).

### *Waves*

Waves in the region of the development are composed of the following:

- Sea-waves: locally generated in response to wind conditions; and
- Swell-waves: result predominantly from storms in the Southern Ocean or southern portion of the Indian Ocean.

Local wind generated sea-waves have typical peak periods (time interval between arrival of consecutive crests at a stationary point) between 2 and 7 seconds and variable wave heights ranging between 0 to 4 m.

Indian Ocean swell arrives at the outer edge of the continental shelf from the southwest-west, then refracts across the shelf to become more north-westerly and even northerly nearshore. Indian Ocean swell periods tends to be higher during winter, with peak periods typically of the order of 12 to 18 seconds. Winter easterly swell, which arrives from the east-northeast, and swell waves generated by the westerly monsoon, typically have peak periods of 6 to 10 seconds.

High sea-wave conditions will normally occur within 250 km of tropical cyclones and swell-waves may occur at further distances (Heyward et al. 1997). Sea-waves can be generated with wave heights up to 7 m under extreme cyclones and swell waves, with peak periods of 6 to 12 seconds, can have significant wave heights between 0.5 and 9 m.

### *Temperature*

Sea-surface temperatures in the region have been recorded to range between 27°C and 30°C over a year, with a mean of 28.5°C (Brewer et al. 2007). Mean temperature in deeper waters (~150 m) has been reported to be 19.4°C (Brewer et al. 2007).

Sub-tropical water temperatures throughout the NWS region are largely derived from the influence of the ITF, which also controls the depth of the thermocline (Brewer et al. 2007). A permanent thermocline exists on the NWS, which isolates the lower portion of the water column from surface waters. Perturbations of the thermocline through internal tides can result in rapid changes in temperature in the region of 50-150 m depth.

The field survey, conducted at the project location in July 2008 (ERM, 2008), observed this thermocline at approximately 100 m depth. The survey identified two distinct water layers, with different temperature, oxygen and salinity characteristics. Little variation in sea temperatures were observed in the first 100m of the temperature profiles, indicating well mixed surface waters. Temperatures dropped rapidly below the thermocline to a minimum around 16°C at approximately 250 m depth (*Figure 5.6*).

### *Salinity and Specific Conductivity*

Surface seawater salinities in the tropics are generally between 34 and 35 ppt and vary little between seasons (Middleton, 1995). Sea salinity profiles measured at the project area in July 2008 found salinities to be similar among sampling locations and throughout the water column, ranging from 33.61 to 34.71 ppt, though slightly lower salinity levels were recorded in deeper waters (*Figure 5.6*). Specific conductivity followed a similar pattern to salinity and ranged from a minimum of 51.07 mS cm$^{-1}$ to a maximum of 53.28 mS cm$^{-1}$. Levels were similar to those expected for seawater of similar temperature and salinity (53.02 mS cm$^{-1}$) (NPL, 2008).

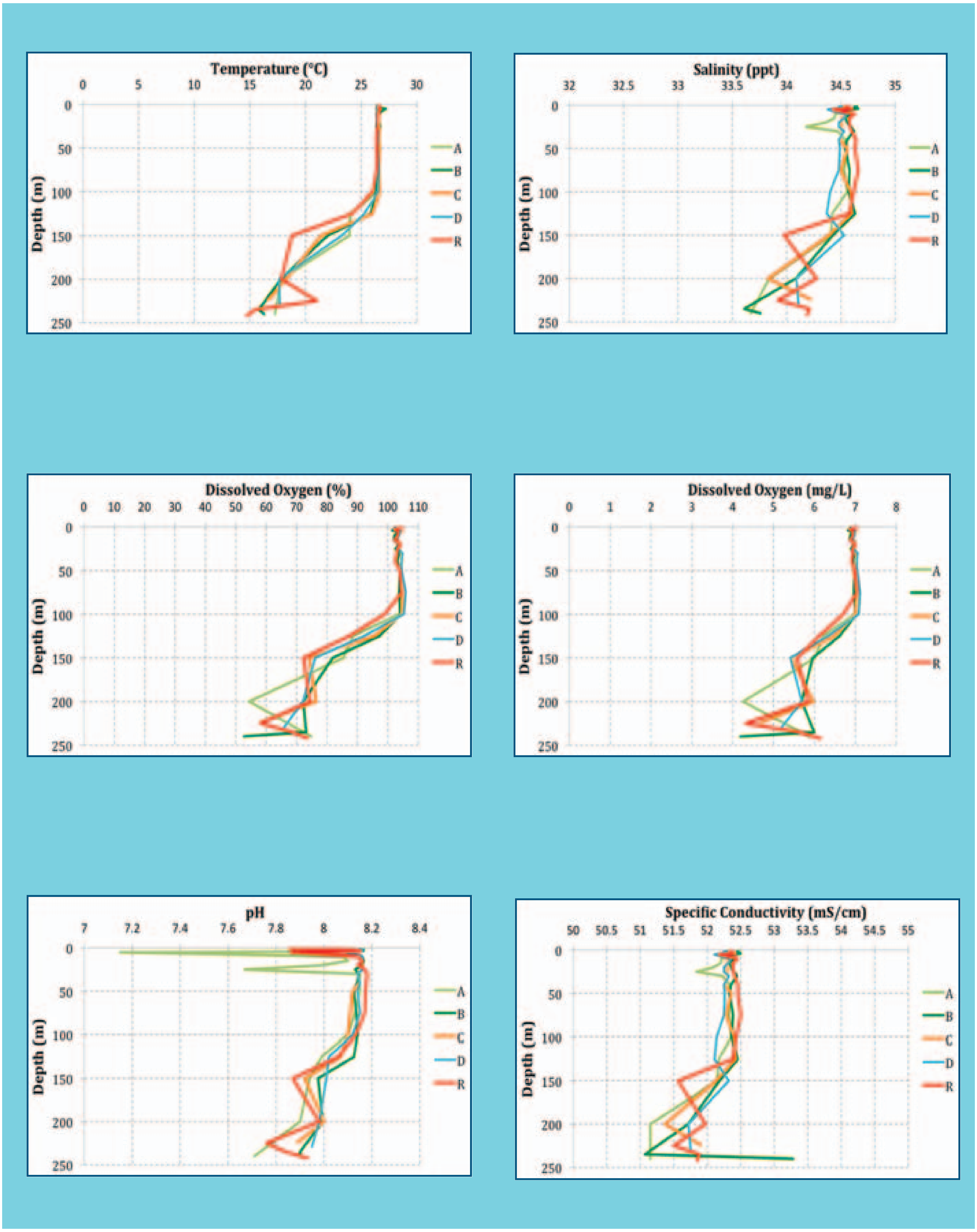
### *pH*

In-situ water measurements collected in and around the project area in July 2008 (*Figure 5.6*) found pH to be similar among sampling zones, ranging from a minimum of 7.15 to a maximum of 8.21. No clear vertical gradient in pH was observed.

### *Dissolved Oxygen*

Dissolved Oxygen was found to be similar among sampling locations, but varied with water depth. Concentrations ranged from a minimum of 4.19 mg L$^{-1}$ (53%) in bottom

*Figure 5.6 Water Properties Depth Profiles*



seawater recorded at the FLNG facility site (Zone B) to a maximum of 7.27 mg $L^{-1}$ (109%) in surface seawater recorded in the Reference Zone (R).

Dissolved oxygen concentrations showed a similar pattern to temperature. Concentrations were similar in the first 100 m water depth, with an average of 6.94 mg $L^{-1}$ ± 0.09 (103.29% ± 1.53), and then decreased with depth and became more variable, with an average of 5.97 mg $L^{-1}$ ± 0.74 (76.48% ± 11.87). Such variation of dissolved oxygen in the water column is often linked to higher photosynthetic activity at the seawater surface and wave and wind generated mixing, compared to deeper waters. The values recorded are typical of unpolluted seawater.

### 5.2.5 Water Quality

#### *Introduction*

This section describes water quality in the vicinity of the project area from water samples collected at depths of 5 m (surface), 150 m (mid depth) and 5 m above the seabed (bottom) in July 2008, which were analysed for the following parameters:

- nutrients (total nitrogen; nitrate and nitrite; total kjeldahl nitrogen);
- hydrocarbons (BTEX; TPH $C_6$-$C_{36}$); and
- dissolved metals (Ba, Ni, Fe, Zn, Cd, Cr, Pb, V, Hg).

Total Suspended Solids (TSS) measurements are from an INPEX study completed adjacent to the project area in September 2005 and May 2007.

#### *Nutrients*

Offshore NWS surface waters are typically oligotrophic (low in nutrients), which is confirmed by the low nitrate concentrations and low phytoplankton abundance measured in the project area in July 2008.

No spatial or vertical variation in seawater Total Kjeldahl Nitrogen[13] concentrations was observed from the water samples collected during the July 2008 fieldwork. Samples from all locations and depths were below the laboratory Limit of Reporting (LOR) (< 1.0 mg $L^{-1}$).

The region in general experiences an influx of comparably nutrient-rich waters at depth in summer and a variety of processes such as tidal currents, internal waves and cyclone mixing are known to carry these nutrients into the bottom waters of the shelf (Hallegraeff 1995). This can be seen in the results for nitrite/nitrate and total nitrogen. Nitrite/nitrate (as nitrogen) concentrations and total nitrogen concentrations in surface seawater were also below the laboratory LOR (<0.01 mg $L^{-1}$) in all sampling locations, apart from one sample from Zone R (reference site outside project area) which reported a total nitrogen concentration of 0.7 mg $L^{-1}$. Concentrations of nitrite/nitrate and total nitrogen generally increased with depth. Mean nitrite/nitrate for all the samples were 0.20 mg $L^{-1}$ (± 0.06) at 150 m and 0.31 mg $L^{-1}$ (± 0.05) at 5 m above the seabed. Mean total nitrogen concentrations were 0.18 mg $L^{-1}$ (± 0.07) at 150 m and 0.3 mg $L^{-1}$ (± 0.05) at 5 m above the seabed.

#### *Hydrocarbons*

Total petroleum hydrocarbons (TPH) concentrations in water samples collected during the July 2008 fieldwork are presented in *Table 5.6*. BTEX was not detected in concentrations above the laboratory LOR in any of samples.

TPH in the $C_6$-$C_9$ fraction was not detected in concentrations above the laboratory LOR in any of water samples. Longer chained TPH, however, were recorded in some water samples. The pattern is not simple with hydrocarbons detected at all sites and all depths but not in a consistent manner (*Table 5.6*). The source of the hydrocarbon is unknown. Water samples collected in the adjacent permit for INPEX did not observe any hydrocarbons concentrations above laboratory LOR.

#### *Heavy Metals*

Heavy metal concentrations in water samples collected during the July 2008 fieldwork are presented in *Table 5.7*.

---

[13] *the sum of organic nitrogen, ammonia and ammonium*

Samples did not contain chromium (Cr), lead (Pb), vanadium (V) or mercury (Hg) concentrations above the laboratory LOR. Cadmium (Cd) was only detected in samples collected at 150 m in Zones A, B and R (at a concentration of 0.002 mg L$^{-1}$).

There was little spatial or vertical variation in seawater barium (Ba), nickel (Ni), iron (Fe) and zinc (Zn) concentrations among sampling locations, although seawater from Zone A (proposed subsea infrastructure site) was found to have lower Fe concentrations in comparison to other locations.

Mean concentrations of metals in all sampling zones were below trigger values identified in the ANZECC Guidelines for marine water quality that could cause potential ecological risks (Ni, Zn, Cr and Hg) (ANZECC, 2000).

### *Total Suspended Solids (TSS)*

TSS data were obtained from a study conducted for INPEX in Exploration Permit WA-285-P (RPS, 2007b) located immediately adjacent to WA-371-P. Mean TSS values reported for offshore waters between March 2005 and May 2007 were 3.7, 5.0 and 3.8 mg L$^{-1}$ for near-surface, mid-depth and near-seabed waters respectively. This data represents relatively low suspended solid values as would normally be expected for offshore waters in the region.

### 5.2.6 Bathymetry and Seabed Features

WA-371-P is located in waters between 200 and 300 m depth. There are no significant topographical features in the region of the FLNG facility (*Figure 5.7* and *Figure 5.8*).

*Table 5.6 Mean TPH Concentrations in Seawater*

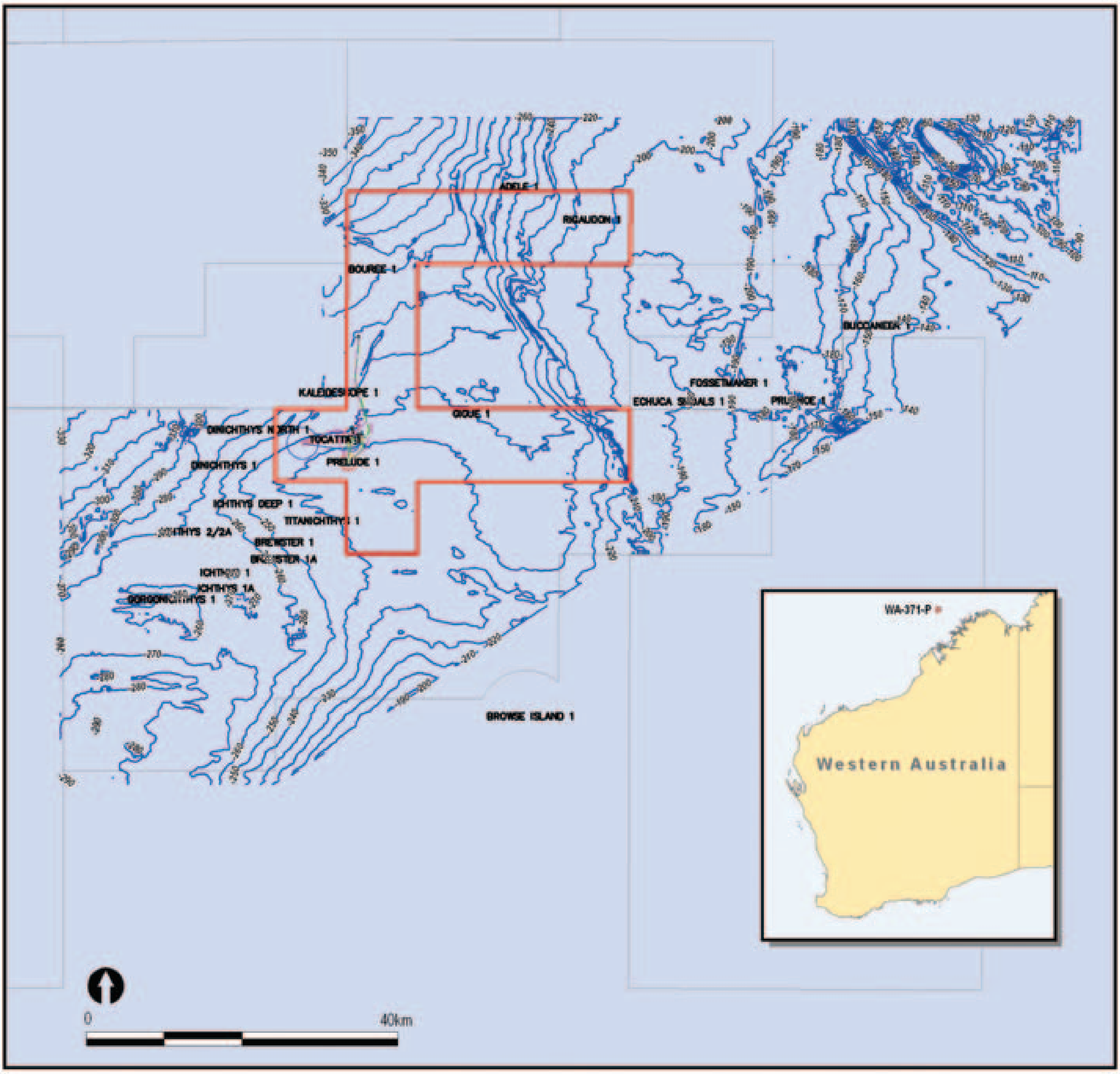
| Sampling Zones | Concentration (µg l$^{-1}$) | | |
|---|---|---|---|
| | Bottom | Mid-depth | Surface |
| $C_6 – C_9$ | | | |
| A | *10* | *10* | *10* |
| B | *10* | *10* | *10* |
| C | *10* | *10* | *10* |
| D | *10* | *10* | *10* |
| R | *10* | *10* | *10* |
| $C_{10} – C_{14}$ | | | |
| A | *25* | *25* | 60 |
| B | 37.5 | *25* | *25* |
| C | *25* | 60 | 90 |
| D | *25* | *25* | 50 |
| R | *25* | *25* | *25* |
| $C_{15} – C_{28}$ | | | |
| A | *50* | *50* | 100 |
| B | 150 | 75 | 125 |
| C | *50* | 100 | 100 |
| D | *50* | *50* | 100 |
| R | 150 | 117 | 100 |
| $C_{29} – C_{36}$ | | | |
| A | *25* | *25* | 70 |
| B | 47.50 | *25* | 37.50 |
| C | *25* | 60 | 80 |
| D | *25* | *25* | 60 |
| R | 36.67 | 33.33 | 36.67 |

*Table 5.7 Mean Metal Concentrations in Seawater*

| Sampling Zones | Concentration (mg L$^{-1}$) | | |
|---|---|---|---|
| | Bottom | Mid-depth | Surface |
| Barium (Ba) | | | |
| A | 0.007 | 0.006 | 0.006 |
| B | 0.008 | 0.006 | 0.005 |
| C | 0.007 | 0.006 | 0.006 |
| D | 0.006 | 0.006 | 0.005 |
| R | 0.007 | 0.006 | 0.006 |
| Nickel (Ni) | | | |
| A | 0.006 | 0.006 | 0.004 |
| B | 0.006 | 0.007 | 0.007 |
| C | 0.007 | 0.006 | 0.008 |
| D | 0.007 | 0.006 | 0.007 |
| R | 0.007 | 0.006 | 0.007 |
| Iron (Fe) | | | |
| A | 0.060 | 0.090 | *0.025* |
| B | 0.255 | 0.240 | 0.255 |
| C | 0.280 | 0.240 | 0.270 |
| D | 0.300 | 0.240 | 0.290 |
| R | 0.237 | 0.190 | 0.210 |
| Zinc (Zn) | | | |
| A | 0.008 | 0.009 | 0.006 |
| B | *0.003* | *0.003* | *0.003* |
| C | *0.003* | *0.003* | *0.003* |
| D | *0.003* | 0.006 | *0.003* |
| R | 0.004 | 0.008 | 0.008 |

*Note: Values in italics indicate calculated mean concentrations equal to half the achieved LOR indicating that the parameter was not detected in any samples.*

*Figure 5.7 Seafloor Bathymetry in the Project Vicinity*



Browse Island is the nearest seabed feature of significance, occurring approximately 40 km south-southeast from the project area. Two small subtidal seamounts, Heywood and Echuca Shoals, occur further away to the east of the title area. Both shoals rise out of approximately 150 m depth and peak at 10 to 15 m below mean sea level. Other islands/reefs in the region include Scott Reef and Sandy Islet (~ 140 km SW of project area), Seringapatam Reef (~ 80 km W), and Ashmore Reefs and Cartier Island (~ 140 km N).

Seabed sediment samples collected from the project area in July 2008 found substrates to comprise of fine clays, muds and sands, with little or no hard substrata or consolidated sediments (ERM, 2008). No reefs or areas of rocky substrate have been observed within the project area.

*Figure 5.8 Locations of Significant Seabed Features*

### 5.2.7 Sediment Quality

#### *Introduction*

This section describes sediment quality in the project area from direct measurements collected during the field survey in July 2008.

The following parameters were measured:

- particle size distribution;
- reduction/oxidation (redox) potential;
- heavy metals (Ba, Ni, Fe, Zn, Cd, Cr, Pb, V, Hg);
- hydrocarbons (BTEX, TPH $C_6$-$C_{36}$, oil and grease); and
- total organic carbon.

#### *Particle Size Distribution*

The seabed sediment samples collected in the July 2008 field survey indicated observable differences in particle size distribution between the development zones (Zones A-D) and reference site (Zone R). Samples from Zones A-D were composed primarily of silt (56.75% ± 9.06) and clay (29.89% ± 4.22). In contrast, substrate from the reference sites were dominated by sand (48.67% ± 23.74) and silt (32.29% ± 17.48), particularly to the south and the east of the development zones.

#### *Reduction Oxidation*

The Reduction Oxidation (Redox) potential in sediments from the vicinity of the project area ranged from a mean of -322.5mV (± 59.3) in Zone A to -38.9mV (± 9) in Zone D. Negative, anoxic values are characteristic of bottom deposits which consist largely of fine sediments. Redox potential, along with pH, can be one of the factors affecting the bioavailability of heavy metal contaminants in sediments (Gambrell et al. 1991; Pardue et al. 1988).

#### *Total Organic Carbon*

Total organic carbon concentrations in sediments from the project area were found to range from 0.06 to 2.9% wt, with an overall mean of 1.63% wt, which is considered as representative of a low percentage of organic material. There was no clear spatial pattern in mean total organic carbon concentrations between sampling zones.

#### *Hydrocarbons*

TPH concentrations in sediment samples collected during the July 2008 fieldwork are presented in *Table 5.8*.

Oil and grease, BTEX and TPH were generally not present in detectable concentrations in the seabed sediments across the Prelude FLNG Project area. Levels of oil and grease above the LOR (200 mg $kg^{-1}$) were found only in one sample from the site of the FLNG facility (Zone A: 3400 mg $kg^{-1}$) and two samples from the reference zone (Zone R: 530 and 1660 mg $kg^{-1}$). One sample collected from Zone A contained TPH levels above the laboratory LOR with concentrations of 470 mg $kg^{-1}$ for $C_{10}$–$C_{14}$ and 815 mg $kg^{-1}$ for $C_{15}$–$C_{28}$ recorded. The source of these hydrocarbons is unknown but all detectable TPH concentrations were well below ecological investigation levels identified for soil, which are the concentrations of a contaminant below which adverse impacts upon site-specific ecological values are unlikely to occur (DEP, 2003). Sediment samples collected in the adjacent permit for INPEX did not detect hydrocarbons above laboratory LOR.

#### *Heavy Metals*

Heavy metal concentrations in sediment samples collected during the July 2008 fieldwork are presented in *Table 5.9*.

*Table 5.8 Mean Concentrations of Hydrocarbon in seabed sediments (mg kg$^{-1}$)*

| **Zone** | **A** | **B** | **C** | **D** | **R** |
|---|---|---|---|---|---|
| Oil and Grease | **430** | **111** | 100 | 100 | **247.92** |
| **BTEX** | | | | | |
| Benzene | *0.1* | *0.1* | *0.1* | *0.1* | *0.1* |
| Toluene | *0.25* | *0.25* | *0.25* | *0.25* | *0.25* |
| Ethylbenzene | *0.25* | *0.25* | *0.25* | *0.25* | *0.25* |
| Xylene | *0.25* | *0.25* | *0.25* | *0.25* | *0.25* |
| **TPH** | | | | | |
| $C_6$ – $C_9$ | *5* | *5* | *5* | *5* | *5* |
| $C_{10}$ – $C1_4$ | **114** | *25* | *25* | *25* | *25* |
| $C_{15}$ – $C_{28}$ | **203** | *50* | *50* | *50* | *50* |
| $C_{29}$ – $C_{36}$ | *50* | *50* | *50* | *50* | *50* |

*Note: Values in italics indicate calculated mean concentrations equal to half the achieved LOR indicating that the parameter was not detected in any samples.*

*Table 5.9 Mean Metal Concentrations in Seabed Sediments (mg kg$^{-1}$)*

| Types of Metals | A | B | C | D | R |
|---|---|---|---|---|---|
| Barium (Ba) | 204 | 22.5 | 23 | 18.85 | 14.17 |
| Chromium (Cr) | 11 | 11.5 | 12.9 | 11.27 | 16.46 |
| Iron (Fe) | 3,405 | 3,205 | 3,475 | 3,800 | 5,830 |
| Nickel (Ni) | 9.3 | 9.8 | 10.3 | 8.69 | 11.21 |
| Vanadium (V) | 6.6 | 6.9 | 7.2 | 5.56 | 8.42 |
| Zinc (Zn) | 3.1 | 6.6 | 12.75 | 4.62 | 15.98 |
| Mercury (Hg) | 0.05 | 0.05 | 0.05 | 0.05 | 0.056 |

Concentrations of cadmium (Cd), lead (Pb) and mercury (Hg) were below the laboratory LOR.

Heavy metal concentrations in seabed sediments were found to be low across the project area, with no clear spatial pattern between sampling zones. All heavy metal concentrations were well below the ANZECC guideline values (ANZECC, 2000), with the exception of one sample collected from the reference Zone (R) which had an elevated mercury concentration of 0.2 mg kg$^{-1}$, which is 0.05 mg kg$^{-1}$ above the ANZECC trigger concentration.

## 5.3 ECOSYSTEMS, COMMUNITIES AND HABITATS

### 5.3.1 Introduction

This section outlines the ecosystems, communities and habitats present in the project area. It describes:

- underwater noise due to its significance to certain faunal groups;
- fish and pelagic communities;
- islands, reefs and shoals; and
- marine protected areas.

Individual species listed under the *EPBC Act*, including cetaceans and reptiles, are discussed in *Section 5.4*.

### 5.3.2 Noise Conditions

#### *Introduction*

Noise in the marine environment is both natural and anthropogenic in nature, as illustrated in *Figure 5.9*. Natural background sounds in the sea are produced by wind, waves, currents, rain, echo-location and communication noises generated by cetaceans, and other natural sources such as tectonic activity eg earthquake.

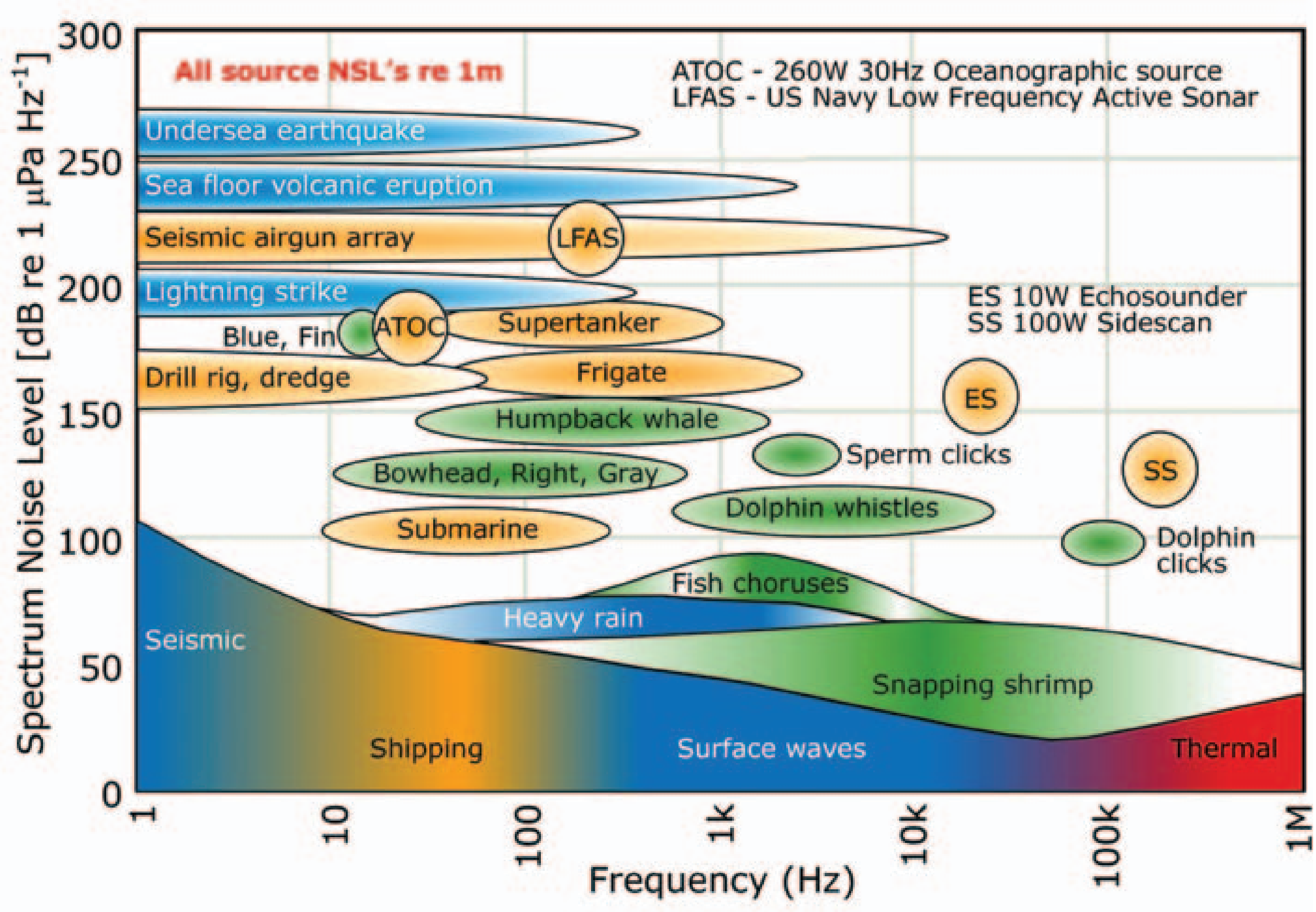
Background noise levels as documented in literature tend to be in the range 90 dB to 110dB (re 1uPa), representing the typical range for calm to windy conditions, though heavy rain can result in higher noise levels.

#### *Underwater Noise Logging*

An underwater baseline noise survey was conducted to characterise anthropogenic, biological and oceanic noise sources (Duncan and McCauley, 2008). Baseline noise logging was conducted over an extended period from September 2006 to August 2008, which is considered adequate to characterise both biological and regular anthropogenic sources. The noise logger was located 8.5 km southwest of the project area.

A selection of data from the recording sets has been displayed graphically on *Figure 5.10* to *Figure 5.13*. These figures only show broad scale temporal patterns due to the data averaging involved. The plots tend to highlight

*Figure 5.9 Noise Sources in the Marine Environment*



*Source: Seiche Ltd (www.seiche.com)*

signal types which are either intense and/or which persist across the 200s sample length either through a long signal duration or multiple signals within a sample. Signals which are short in relation to the sample length (200 seconds), such as humpback signals, may not displayed well in these figures but were detected and are discussed below and in *Section 5.4*.

These figures highlight the gross features of:

- Fish choruses – several regular fish choruses (schooling fish calling en masse) were evident, with one chorus at > 1 kHz and a second centred around 200 Hz evident.
- Great whales – several great whale calls were evident including humpback song, a low frequency possible great whale signal evident over 20-50 Hz, pygmy blue whale signals in late October 2006, possible minke whale signals and signals of unknown origin but consistent with great whale sources.
- Vessel noise - Persistent vessel noise from early November 2006 until the recordings end in mid 2008. Vessel noise is recorded on all 50 day plots.
- Seismic survey noise – Seismic survey signals, mostly distant but some very close, were persistent from April 2007 onwards.

To obtain an estimate of the lowest ambient noise, several periods largely free of vessel, seismic survey and whale noise were chosen. A selection of low-ambient noise curves are shown in *Figure 5.14*.

*Figure 5.10 Fifty day stacked sea noise spectra for 14 September 2006 to 22 December 2006*

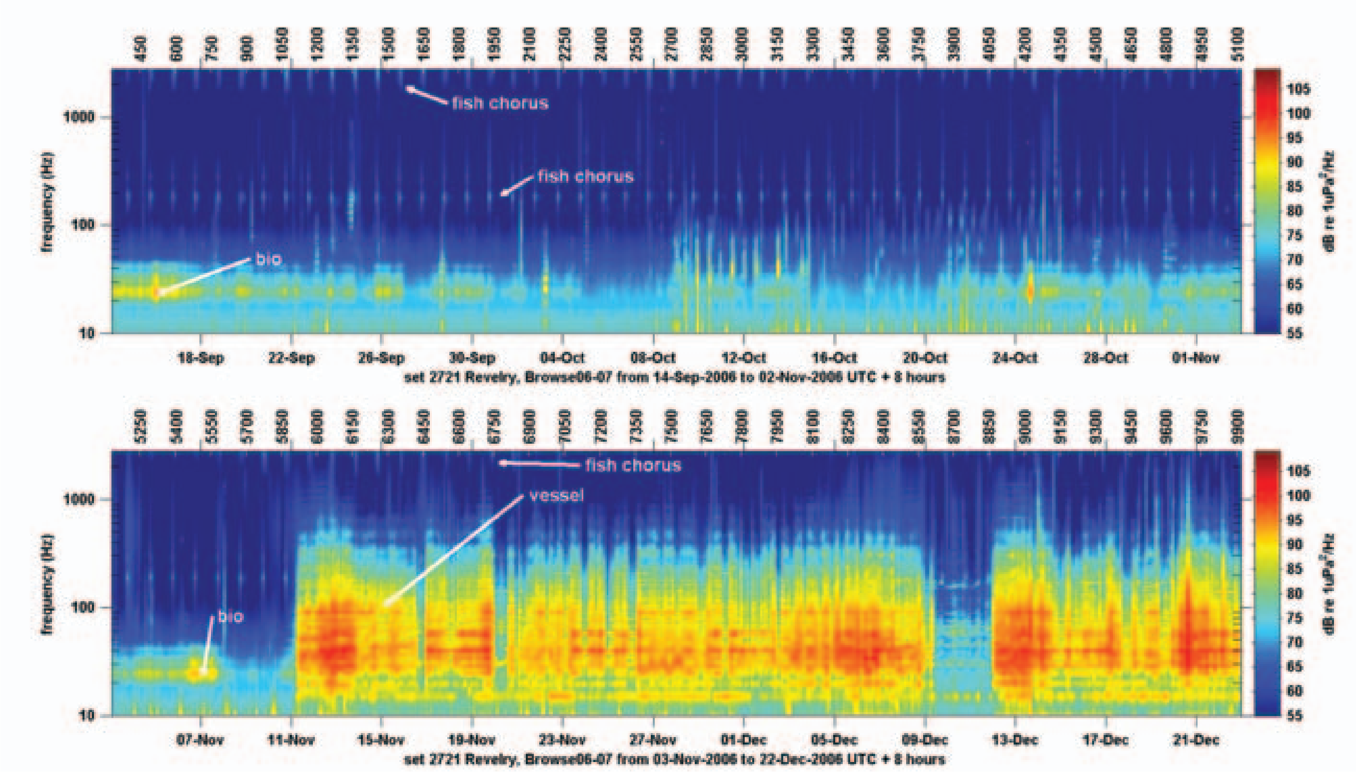


*Figure 5.11 Fifty day stacked sea noise spectra for 2 April 2007 to 10 July 2007*

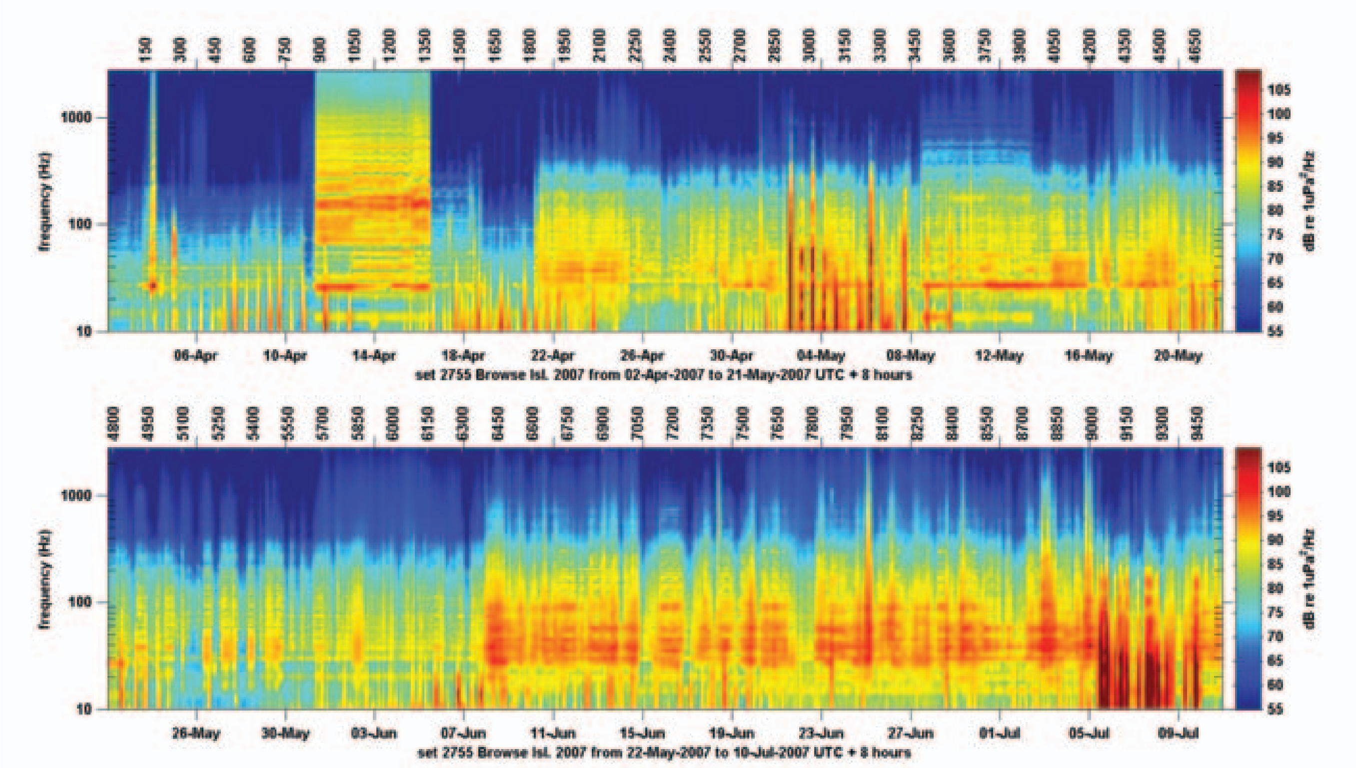


*Figure 5.12 Fifty day stacked sea noise spectra for 11 July 2007 to 18 October 2007*

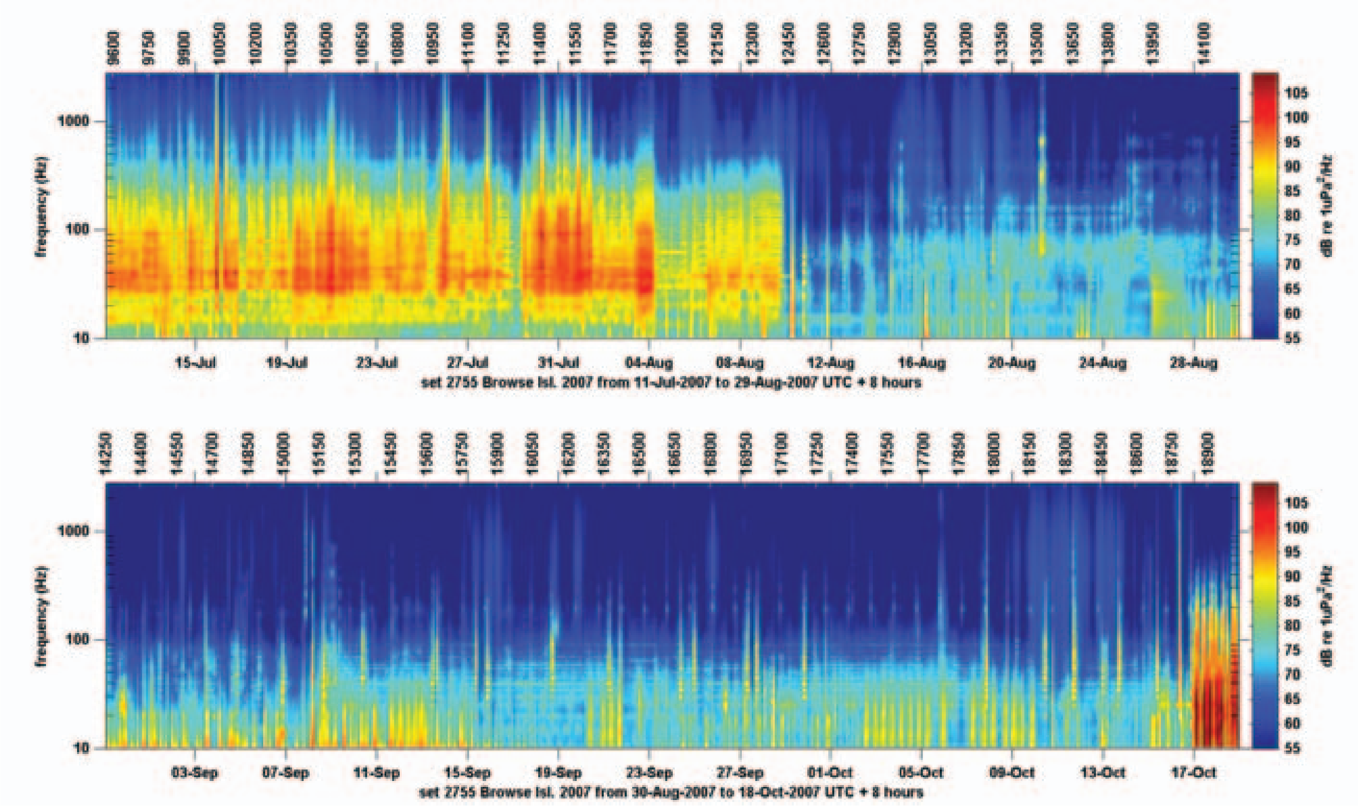


*Figure 5.13 Fifty day stacked sea noise spectra for 1 December 2007 to 9 March 2008*

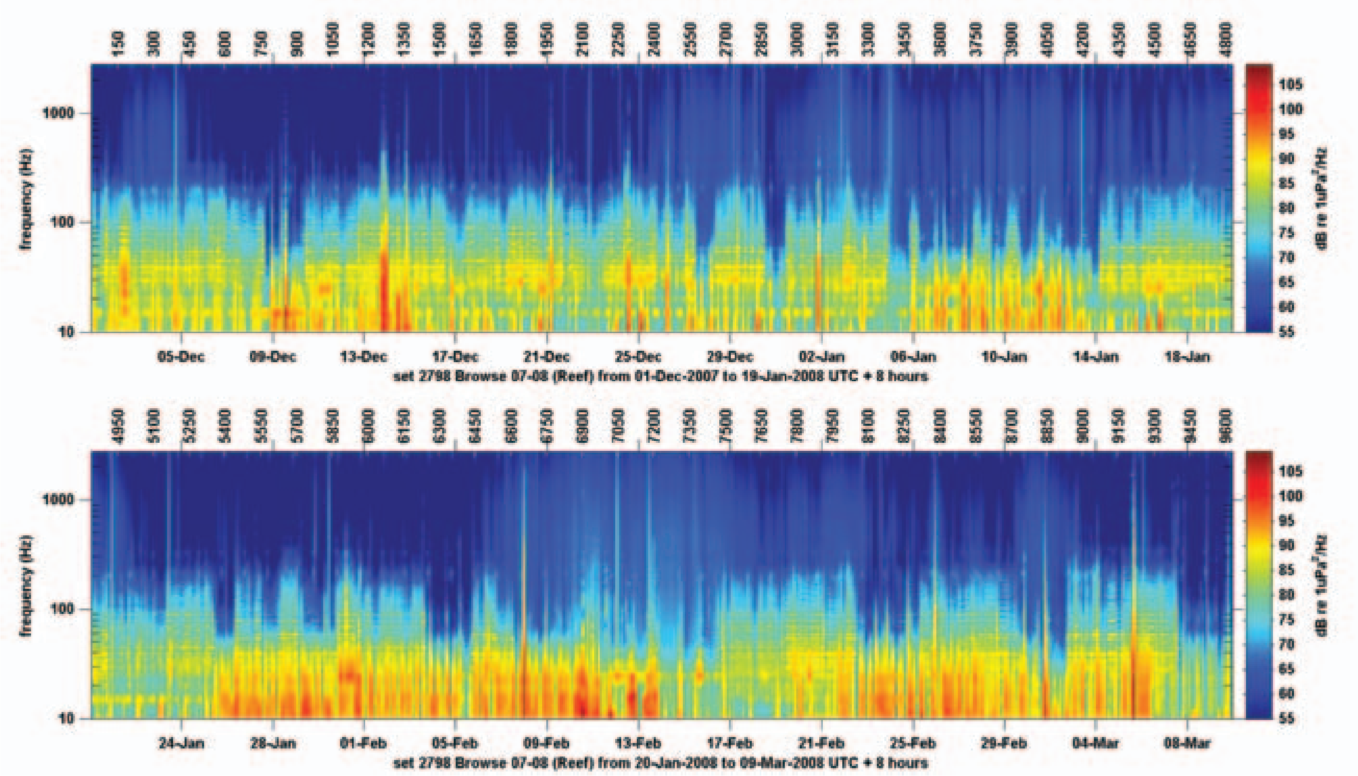
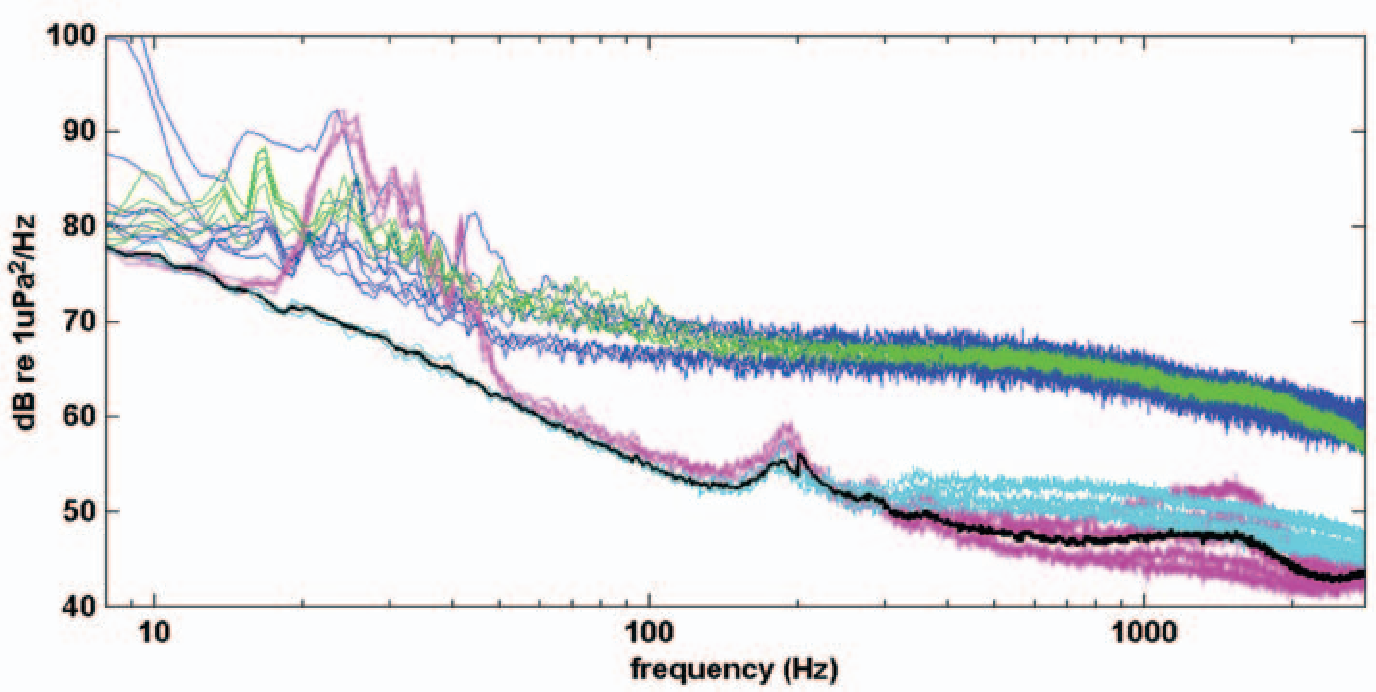


*Figure 5.14 Selection of Low-Ambient Noise Curves from the Browse Sea Noise Site*



It can be seen from *Figure 5.14* that:

- Many low frequency sources (< 60 Hz) were present, in the averaged spectra shown, with some spectra having contributions from a low frequency unidentified biological source and some from distant vessel noise;
- Above 10Hz there was as much as a 20 dB difference in ambient noise;
- Mostly fish and some distant humpbacks contributed to an ambient noise spike at 200 Hz for a selection of curves; and,
- No or little snapping shrimp noise was evident (energy at > 1800 Hz).

### 5.3.3 Fish and Pelagic Communities

#### *Fish, Sharks & Rays*

The Timor Sea supports a variety of bony and cartilaginous fish species of high conservation value as well as of commercial and recreational fishing importance. Key shark species that occur in the region include the endangered whale shark (*Rhincodon typus*) and threatened sandbar (thickskin) shark (*Carcharhinus plumbeus*). Pelagic sharks of commercial importance that may be found include hammerheads (*Sphyrnidae*), pigeye (*Carcharhinus amboinensis*) and tiger sharks (*Galeocerdo cuvier*). Demersal species include blacktip shark (*Carcharhinus spp.*), lemon shark (*Negaprion acutidens*), grey reef shark (*Carcharhinus amblyrhynchos*), shovelnose/fiddler rays (*Rhinobatidae/Rhynchobatidae*) and various skates, stingrays and eagle rays (*Rajidae, Dasyatidae, and Myliobatidae*). Most demersal shark and ray species, with the exception of deepwater skates, are unlikely to occur within the project area due to the lack of suitable habitat (ie reef associated species), however, some pelagic species including the whale shark (see *Section 5.4.8*) may occasionally transit the project area during seasonal migrations (DEWHA, 2008a).

Pelagic scalefish that occur in the region include billfish, tunas and mackerels. Key species are swordfish (*Xiphius gladus*), blue marlin (*Makaira mazara*), black marlin (*Makaira indica*), sailfish (*Istiophorus platypterus*), yellowfin tuna (*Thunnus albacares*), long tail tuna (*Thunnus tonggol*), grey mackerel (*Scomberomorus semifasciatus*) and spanish mackerel (*Scomberomorus commerson*).

Demersal species found in the region include red emperor (*Lutjanus sebae*), goldband snapper (*Pristipomoides* *multidens*) and a range of other snappers (*Lutjanidae*), emperors (*Lethrinidae*) and cods (*Serranidae*). It is unlikely that any large or significant populations of these species reside within the project area as these species are strongly associated with shallow environments such as nearshore shelf systems and off-shore reefs and atolls.

### *Plankton*

Samples collected in the vicinity of the project area in July 2008 provide a snapshot view of plankton abundance and assemblage composition.

Phytoplankton was found to be highly diverse but low in abundance. Phytoplankton abundance is, however, likely to be seasonal and higher densities may occur during the spring and summer. Key groups identified include dinoflagellates (Dinophyceae), diatoms (Bacillariophyceae) and Prasinophyceae. The most abundant species included *Prasinophyte sp* (Prasinophyceae); *Gyrodinium sp* and *Heterocapsa sp* (Dinophyceae); *Pseudo-nitzschia sp*, Cylindrotheca closterium, *Chaetoceros sp*, *Thalassionema frauenfeldii* and *Nitzschia longissima* (Bacillariophyceae). Phytoplankton in the wider NWS region is similar to that observed in the project area with relatively high diversity in certain groups recorded such as diatoms, dinoflagellates and coccolithophorids (Hallegraeff and Jeffrey, 1984; Hallegraeff, 1984).

Zooplankton samples collected in July 2008 found crustacean assemblages to be primarily dominated by copepod species. Overall densities of crustacean assemblages were relatively low and typical of low nutrient open ocean environments in the region. A few samples were dominated by Euphausiids or Chaetognaths. The fish larval assemblage was relatively diverse and relatively abundant; however species composition was primarily dominated by neritic species, which have little or no commercial value. Commercial species identified came from groups typical of a range of marine habitats including pelagic shelf systems and both coastal and deep sea demersal habitats. Larvae were identified from the following groups which have commercially targeted species: Berycidae, Carangidae, Lutjanidae, Serranidae, and Scombridae.

The findings of the July 2008 plankton survey are consistent with the results of a winter survey in the Timor Sea (450 km northwest of Darwin) conducted by BBG (2002) on behalf of Shell, which also found phytoplankton abundance to be low and zooplankton samples to be low in abundance but high in diversity of species.

## 5.3.4 Benthic Communities

### *Macrobenthos*

Macrobenthos are organisms which live within (infauna) or on (epifauna) the seabed sediments (eg polychaete worms, bivalves, prawns and crustaceans). They are an important component of the benthic community, serving as food sources for many demersal fish species. In shallower coastal waters of the continental shelf and on reefs and shoals in less than 50 m water depth, epibenthic communities (living on the sea floor not within the sediments) are abundant and diverse. However sea floor communities in deeper waters are generally less abundant and diverse. Absence of hard substrate is considered a limiting factor for the recruitment of epifauna. Typical infauna communities of soft marine sediments include worms, molluscs, and crustaceans. Across the northern continental shelf, the predominant infauna species are polychaetes and crustaceans. These two groups have been found to comprise 84% of the total species in sediment samples with a high diversity of species but a low abundance of each individual species (Heyward et al. 1997).

Macrobenthos composition was similar across the survey area. Macrobenthic abundance across the survey area was found to be low (overall mean abundance = 7.9 individuals/grab). A total of 632 individual organisms (> 0.5 mm in size) were found in 80 sediment samples (collected using a 0.1 $m^2$ grab). Individual and species abundance ranged from a mean of 14.4 individuals and 9.1 species per grab (in the vicinity of the proposed site of the subsea well structure) to a mean of 5.6 individuals and 3.8 species per grab (in the vicinity of the proposed site of subsea infrastructure).

Individuals were identified from nine Phyla (Annelida, Chordata, Cnidaria, Crustacea, Echinodermata, Mollusca, Nematoda and Sipuncula) from a total of 45 Families in 14 Classes. Annelid worms contributed the majority of individuals, accounting for ~80% of all individuals across the survey area. Class Malacostraca (Phylum Crustacea) ranked second with mean percentage abundances of 5 to

10%. Class Copepoda (Phylum Crustacea) also occurred in all sampling locations with lower percentages (< 5%). Macrobenthos in other classes occurred only at relatively low abundances.

The dominant species identified in the project area include polychaete worms from the Family Paraonidae (total >100 individuals), Family Phyllodocidae (total >100 individuals) and Family Syllidae (total ~60 individuals). Mud shrimps (Family Upogebiidae, Phylum Crustacea) were also abundant (total ~20 individuals).

### 5.3.5 Islands, Reefs and Shoals (Including Browse Island)

There are no known reefs within or in close proximity to the project area. The depth of water in the project area precludes the occurrence of seagrasses, macroalgae and scleratinian coral (reef building corals). The closest island or reef is Browse Island, located about 40 km from the project area. Shallow sub-tidal and intertidal habitats also occur further away at Ashmore Reef, Hibernia Reef, Seringapatam Reef, Scott Reef and Cartier Island. *Figure 5.8* identifies significant seabed features in relation to the project area.

#### *Browse Island*

Browse Island is located approximately 40 km south-southeast from the project area. The island and the waters surrounding it for a distance of three nautical miles are WA State Territorial Waters. It is a sand and limestone cay situated on a limestone and coral reef, covering an area of 13 ha. The remnants of historical phosphate mining on the island have left a significantly disturbed surface. The island represents an important turtle nesting site in the region for the green turtle (*Chelonia mydas*) (DEC, 2008). According to the Report of the Marine Parks and Reserves Selection Working Group (CALM 1994), it is an offshore platform reef of high scientific interest. To date, however, it has received little attention, most scientific research focusing on the larger offshore atolls.

Preliminary marine and intertidal surveys conducted for INPEX (INPEX, 2007) indicate that coral assemblages are the most important benthic primary producers in the Browse Island area. Coral assemblages generally support a high level of biodiversity, however no detailed studies have been completed at Browse Island to date.

#### *Adele Island*

Adele Island is located off the central Kimberley coast, around 100 km north of Cape Leveque and 175 km south of the project area. It became a nature reserve in 2001. The island, measuring 2.9 by 1.6 km with an area of 2.17 km², and its surrounding extensive sand banks sit atop a shallow-water limestone platform. It is an important site for breeding seabirds, with rookeries of Lesser Frigate Birds (*Fregata ariel*), Brown Booby (*Sula leucogaster*), Red-footed Booby (*Sula sula*) and Masked Booby (*Sula dactylatra*).

#### *Ashmore Reef and Cartier Island*

Ashmore Reef, located 140 km north of the title area, is an extensive 150 km$^2$ reef complex containing lagoons, large areas of drying flats, sand banks and limestone platform and three vegetated sandy cays: West Islet (32 ha), Middle Islet (13 ha) and East Islet (16 ha). The surrounding reef consists of a well-developed reef crest, most prominent on the south and east sides, and a broad reef flat that can be up to 3 km across. The three islands located within the lagoon are mostly flat, being composed of coarse sand with a few areas of exposed beachrock and limestone outcrops. West Island is the largest of the islands being about 1 km long.

Cartier Island is located 100 km north of the project area and 45 km from Ashmore Reef. The island is an unvegetated 44.5 ha sand cay surrounded by a wide platform and fringing coral reef. The surrounding reef flat rises steeply from the surrounding depths. The Cartier Island Marine Reserve includes Cartier Island and the surrounding reef, covering an area within a 4 nm radius of the centre of the island. A total area of 167 km$^2$ and including the substrata to a depth of 1000 m below the seafloor. Cartier Reef is considered an important biological stepping stone, fulfilling a role in linking the reef systems of Indonesia and the Philippines to those along the West Australian coasts (DEWHA, 2007).

There are a number of shoals, banks and submerged reefs in the region of Ashmore and Cartier Reefs. These include the Johnson Bank (27 km southeast from Ashmore Reef with an area 137 km²), Woodbine Bank (48 km southeast from Ashmore Reef covering 93 km²), Marlin Bank (12 km to the northwest of Ashmore Reef), Vee Shoal (94 km northeast from Ashmore Reef), Wave Governor Bank (6 km southeast from Cartier Island), Fantome Bank (73 km northeast from Cartier Island) and Barracouta Reef (54 km east from Cartier Island). Several large, unnamed, deep-water banks are also found within the area.

### *Hibernia Reef*

Hibernia Reef is located 160 km north of the project area. It is a less extensive reef complex with a deep central lagoon and drying sand flats.

### *Seringapatam Reef*

Located 140 km west-northwest of the project area, Seringapatam Reef is a small circular reef with a maximum dimension of 9.4 km. There are no emergent sand cays on Seringapatam Reef but the reef platform is exposed at low tide.

### *Scott Reef*

Scott Reef is located 150 km west of the project area and is comprised of two reefs. North Scott Reef is a pear-shaped reef with a maximum dimension of 17 km. South Scott Reef has a horseshoe shape with a breadth of 27 km. There is one emergent sand cay on South Scott Reef (WA State Territory along with the waters within a radius of 3 nm). Both reef platforms are exposed at low tide.

### 5.3.6 Existing and Proposed Marine Protected Areas

There are no known areas of environmental significance in the immediate vicinity of the project area. No endangered or vulnerable species are known to reside permanently in the project area although some may pass through on migratory routes.

Browse Island is the nearest island of significance, located approximately 25 km to the southeast of the southern limit of WA-371-P and about 40 km from the project area. Browse Island is currently a Western Australian Class C Reserve (No. 22697) vested with the Conservation Commission. The island is an important turtle and bird nesting site and is surrounded by extensive coral reefs.

### *Conservation Zones*

A number of declared Commonwealth Marine Protected Areas and Western Australian State marine parks and reserves occur in the North West Marine Bioregion, which includes the Browse Basin. This system of reserves has been established to help conserve regionally and internationally important species of marine reptiles, dugongs, and birds (including both migratory shorebirds and seabird species). The reefs (particularly Ashmore Reef) support the greatest number of coral species of any reefs off the West Australian coast (Commonwealth of Australia, 2002).

Scott Reef and Browse Island are the only existing terrestrial reserves in the offshore Browse Basin area. Both are Class `C' Nature Reserves under the Western Australian *Conservation and Land Management Act 1984* and the *Amendment (Marine Reserves) Act 1997*. They are administered by the WA Marine Parks and Reserves Authority. The major purpose of their conservation status is the protection of major nesting sites of the Green Turtle *(Chelonia mydas)*.

Ashmore and Cartier Reefs are Commonwealth Reserves under the *EPBC Act*. Ashmore Reef National Nature Reserve (declared in 1983) and Cartier Island Marine Reserve (declared in 2000) are part of the National Representative System of Marine Protected Areas (ANZECC, 1999).

The principal conservation value of Adele Island (a sand cay built on a coral rock platform) is as a major seabird rookery While Adele Island is Commonwealth freehold land, it is not currently included in the Australian Government estate of marine protected areas which are managed and protected under the *EPBC Act*.

## 5.4 KEY FLORA AND FAUNA SPECIES

### 5.4.1 Humpback Whale (*Megaptera novaengliae*)

Humpback whales are listed as vulnerable under the *EPBC Act*. The species has recently been downgraded from `vulnerable' to `least concern' in the cetacean update of the 2008 IUCN Red List of Threatened Species, indicating a global recovery in humpback whale numbers to a point where they are considered less threatened with extinction. The Commonwealth Government developed a five year Humpback Whale recovery plan in 2005 with the objectives of assisting the recovery and distribution of this species to population levels similar to pre-exploitation levels and to maintain the future protection of humpback whales from anthropogenic threats (DEH 2005a).

Humpbacks whales migrate seasonally through the waters of northwest Australia, from Antarctic summer feeding grounds to winter calving grounds off the Kimberley coast.

The northward migration is generally offshore (rather than nearshore) and the predominant migration route is understood to pass to the west of the Lacepede Islands and remain offshore until the whales reach Camden Sound. Northward migration patterns show marked segregation according to age, sex and stages of the breeding cycle. The first groups to migrate north include sexually immature adults and females at the end of lactation. Adult males tend to move north during the middle of the migration period with pregnant females leaving the Antarctic feeding grounds last, usually around July. The period of peak northern migration into the calving grounds is late-July to early-August (*Figure 5.15*).

Key congregation areas at the end of the northern migration include Pender Bay, Tasmanian Shoals (in the Bucanner Archipelago) and Camden Sound (Jenner et al. 2001). Coastwatch aerial sightings between 1994 and 1997, reported by Jenner et al. (2001), found scattered plots of humpbacks further north of Camden Sound, however no large aggregations north of Camden Sound were apparent. The project area is more than 200 km from all the congregation areas.

Southward migration from the calving grounds peaks around late-August to early September but can extend to as late as November in some years (Jenner et al. 2001). The pattern of migration south follows the same order as the northern migration with immature adults leaving first and pregnant females and mothers with newborn calves leaving last. The southward migration path is typically closer to the coastline, appearing to follow the coastline between Cape Leveque and Pender Bay before diverting west around the Lacepede Islands and then south. On this route whales tend to parallel the coast along the 20–30 m depth contour, approximately 20 nm west of Broome (Jenner et al. 2001; Environment Australia, 2001).

Observations from the 2006/07 study of cetaceans in the Browse Basin and inshore Kimberley region (see *Section 5.1*) found humpback whales to be more abundant in nearshore areas than offshore areas. The highest densities were recorded in Pender Bay and Camden Sound from late August to early September, which is consistent with Jenner et al.'s (2001) observations. Only 21 humpback whales (in 13 pods, one of which included calves) were recorded in the offshore Browse Basin during the surveys.

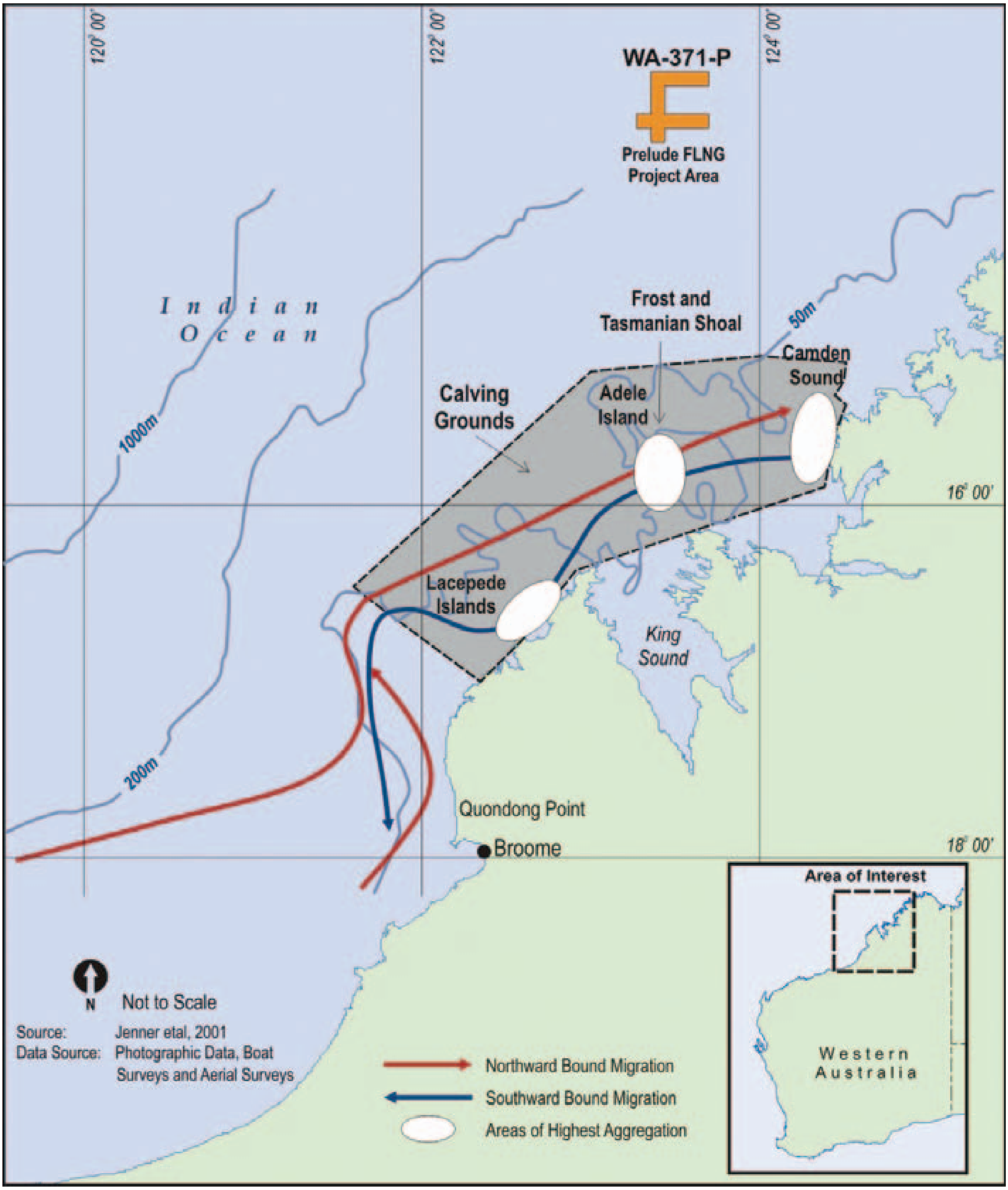
Humpback whales were recorded on acoustic loggers at both the inshore (near the Maret Islands) and offshore (near Browse Island) sites in 2006 and possibly again in the 06-08 study. Humpback vocalisations were not detected beyond late September by the inshore logger. Similarly, no humpback whales were observed during the vessel and aerial surveys in the Browse basin or at the Maret Islands after 3rd and 28th September 2006 respectively (although a few individuals were observed around Camden Sound and Pender Bay into mid-October). Humpback whales were present in the survey area up to 20th October in 2007.

The study is consistent with previous observations of humpback distribution and calving areas in the Kimberley (Jenner et al. 2001) in identifying Camden Sound and Pender Bay as the main calving areas for humpback whales in the Kimberley.

During the first vessel survey in 2006 two humpback whales were observed exhibiting swimming and diving behaviour that was consistent with feeding, which previously was thought only to occur in Antarctic waters. Humpbacks were again recorded feeding in 2007 (side-lunge feeding by sub-adult humpbacks). The 2006 observation was made where a 0.5°C temperature front and very high levels of bird, fish and other wildlife activity were recorded. This is consistent with observations that oceanographic features such as oceanic frontal and convergence zones typically support significant aggregations of macro zooplankton including krill (P. Gill, pers. comm.).

Observations from the 2008 cetacean survey (Jenner and Jenner, 2009) recorded 46 humpback whales between Willie Creek and the 50 m depth contour, 65 km north of the Lacepede Islands. All humpback whales were northbound and assumed to be swimming towards the Kimberley Calving Grounds (as described by Jenner et al., 2001).

*Figure 5.15 Humpback Whale Migratory Routes and Calving Grounds*



*Source: Jenner et al. 2001*

Humpback whales were also sighted on three occasions inside the Browse Basin study area (south of the project area) in approximately 250 m water depth.

### 5.4.2 Blue Whale (*Balaenoptera musculus*)

Blue Whales are listed as endangered under the *EPBC Act*. They have an extensive oceanic distribution and have been recorded from all Australian states. Australian migration paths are widespread and have not been observed to follow coastlines or oceanographic features (Bannister et al. 1996). Two sub-species occur in Australian waters, the southern hemisphere `true' blue whale (*Balaenoptera musculus intermedia*) and the `pygmy' blue whale (*Balaenoptera musculus brevicauda*). The `true' blue whale is listed as critically endangered and the `pygmy' blue whale as `data deficient' in the cetacean update of the 2008 IUCN Red List of Threatened Species. The current estimated population of southern hemisphere true blue whales is between 1,000 and 2,000 individuals. The most recent estimate for pygmy blue whales was made in 1996 (Bannister et al. 1996) which put this population at around 6,000 animals.

A Commonwealth Government recovery plan has been developed for blue whales in Australia (DEH 2005b) with the objectives of advancing and maintaining the recovery of these species utilising Australian waters. This plan identifies the Perth Canyon as a critical feeding area but does not designate any other areas along the WA coastline as being significant for the recovery of this group of whales.

Migratory patterns of both sub-species of blue whale are poorly understood, though the generally accepted view is that both species migrate annually between cold water, austral summer feeding grounds and warm water, austral winter breeding locations. During summer, the `true' blue whales mainly feed in the Antarctic but Pygmy blue whales are not generally found in the Antarctic and are thought to feed in productive regions in temperate waters (DEWHA, 2008b). Calving is believed to occur in tropical waters in winter, however, the exact mating and calving grounds of blue whales off Australia, and in the southern hemisphere, are not known (DEWHA, 2008b).

The Perth Canyon off Rottnest Island is the only recognised feeding area for blue whales in Western Australia (December to April), however, significant aggregations have also been observed nearby at Geographe Bay (DEH, 2005b). The blue whale is rarely present in large numbers outside recognised aggregation areas.

Branch et al. (2007) indicated that the WA continental slope, from the Perth Canyon (32°S) towards the Indonesian Archipelago, is a likely migratory path between feeding areas in the south and an undetermined northern calving area. It currently appears that pygmy blue whales migrate southwards past Exmouth between October and December each year and northward in June and July.

The 2006/07 study of cetaceans in the Browse Basin and inshore Kimberley region (see *Section 5.1*) recorded no observations of blue whales during the vessel or aerial surveys. Pygmy blue whales were recorded on an acoustic logger in the Browse Basin only once over a 2 year period (in late October 2006). At least two calling animals were present, indicating that several whales were probably in the area of the noise logger. Recordings of blue whales were absent from the acoustic logger located closer inshore.

A total of seven pygmy blue whales where observed during the 2008 cetacean study during eighty days of observation. One pygmy blue whale was sighted migrating north in an area east of Browse Island during June, while six Pygmy blue whales were sighted at Scott Reef, migrating south in October/ November.

The low numbers of sightings and low number of individuals recorded in these studies would suggest that while some pygmy blue whales pass through the region, the project area is unlikely to fall on a primary migration pathway.

### 5.4.3 Australian Snubfin Dolphin (*Orcaella heinsohni*)

Australian snubfin dolphins are listed as migratory under the *EPBC Act* and have been listed as near threatened in the cetacean update of the 2008 IUCN Red List of Threatened Species.

Australian snubfin dolphins (*Orcaella heinsohni*) were described as a separate species to the Asian Irrawaddy dolpins (*Orcaella brevirostris*) in 2005. Only marine populations are known from Australia, however, coastal, estuarine and riverine areas are important for *Orcaella* in other regions. Snubfin dolphins occur in shallow, tropical and subtropical areas up to 20 km from shore. The species has been reported to occur in Western Australia from Broome (18°S) northward. Abundance and distribution are little known, particularly along the West Kimberley Coast. No key localities, including calving areas, are known in Australian waters (Bannister et al. 1996). Group size is considered to be small, ranging from 1 to 14 animals (Ross, 2006).

### 5.4.4 Indo-Pacific Humpback Dolphin (*Sousa chinensis*)

Indo-Pacific Humpback dolphins are listed as migratory under the *EPBC Act* and listed as near threatened in the cetacean update of the 2008 IUCN Red List of Threatened Species.

The distribution of Indo-Pacific Humpback dolphins (*Sousa chinensis*) in Australia extends south to Ningaloo Reef on the west coast. These dolphins inhabit coastal, estuarine and occasionally riverine environments, in tropical and subtropical regions. The species occurs close to the coast, generally in less than 20 m depth. Information on the biology and ecology of the species in Australian waters is limited. The sparse data available for selected areas indicate that humpback dolphins occur in discrete, geographically localised populations (Parra et al. 2004). No calving areas are known in Australian waters (Bannister et al. 1996).

### 5.4.5 Other Cetaceans

In the 2006-2007 study of cetaceans and megafauna in the Browse Basin and inshore Kimberley region (RPS, 2007a) (see *Section 5.1* for details), large pods of offshore dolphins were commonly observed in the Browse Basin area. Small toothed whales were uncommon but included the false killer (*Pseudorca crassidens*), short-finned pilot (*Globicephala macrorhynchus*) and melon headed whales (*Peponocephala electra*). A single beaked whale (*Family Ziphiidae*) of undetermined species was seen on 23 August 2006 in the Browse Basin. Several unknown signals consistent with great whale calls were recorded by noise loggers located in the Browse Basin. See *Table 5.10* and *Table 5.11* for a summary of cetaceans observed during the Browse Basin and inshore surveys. The locations of sightings for other migratory cetacean species observed during the survey suggest that primary migration routes occur away from the title area.

### 5.4.6 Green Turtle (*Chelonia mydas*)

Green turtles are found in tropical and subtropical waters throughout the world and are the most common species of turtle observed in Western Australia. Green turtles are listed as vulnerable under the *EPBC Act* and endangered under the IUCN Red List of Threatened Species. Post hatchling and young juvenile green turtles are pelagic, moving to shallow benthic foraging habitat containing seagrass and/or algae at a size of around 30-40 cm curved carapace length. These habitats include coral and rocky reefs and inshore seagrass beds. Green turtles can make long reproductive migrations between foraging grounds and nesting beaches (Limpus et al. 1992). The project area does not contain any emergent land, shallow sub tidal features or other habitats frequented by green turtles.

The Prelude FLNG Project is located within the Commonwealth Government's North West Shelf Management Unit (NWSMU) for green turtles. The NWSMU is one of the four major breeding units recognised in Australia. Nesting in the region occurs between approximately October and February each year, with adult females laying an average of five clutches per breeding season (Limpus, 1995), each approximately 14 days apart. The females usually remain within 10 km of the nesting beach between nestings (Hays et al. 1999).

Key rookeries in this NWSMU occur at the North West Cape and Lacepede Islands. Smaller breeding populations are also supported on the beaches of North and South Maret islands, which are located approximately 200 km southeast of the project area. The nearest known turtle breeding, nesting, or feeding grounds are located 40 km to southeast of the project area on Browse Island. The island represents a regionally important turtle nesting site for green turtles (DEC, 2008).

Turtle surveys conducted in the Kimberley region for INPEX (RPS 2008) state the female turtle population of the Kimberley region in the 2006-07 peak nesting period to be between 3,808 and 13,057 individuals, with the offshore Lacepede Islands and Maret Islands supporting the largest rookeries in the region. Beach surveys in 2006 indicated

*Table 5.10 Numbers of Cetaceans recorded in the Browse Basin and Inshore Survey Areas during 2006-07 study (number of pods in brackets).*

| Group | Scientific name | Common name | Browse Basin | Maret Islands | Camden Sound | Pender Bay | Total |
|---|---|---|---|---|---|---|---|
| Inshore Dolphins | *Orcaella heinsohni* | Snubfin dolphin | – | 4 (2) | – | – | 22 (6) |
| | *Sousa chinensis* | Indo-Pacific humpback dolphin | – | – | – | 2 (1) | 4 (2) |
| | *Tursiops aduncus* | Indo-Pacific humpback dolphin | 192 (5) | 154 (4) | 52 (2) | 51 (5) | 487 (25) |
| Offshore Dolphins | *Delphinus capensis* | Long-beaked common dolphin | 200 (1) | – | – | – | 306 (3) |
| | *Delphinus delphis* | Short-beaked common dolphin | 58 (1) | – | 2 (1) | – | 60 (2) |
| | *Lagenodelphis hosei* | Fraser's dolphin | 12 (1) | – | – | – | 12 (1) |
| | *Stenella attenuata* | Pantropical spotted dolphin | 140 (1) | – | – | – | 150 (2) |
| | *Stenella coeruleoalba* | Striped dolphin | 50 (1) | 61 (1) | – | – | 136 (3) |
| | *Stenella longirostris* | Spinner dolphin | 434 (5) | 12 (1) | 40 (1) | – | 488 (8) |
| | *Stenella longirostris roseiventris* | Dwarf spinner dolphin | 337 (2) | – | – | – | 337 (2) |
| | *Tursiops truncatus* | Offshore bottlenose dolphin | 100 (1) | – | 7 (1) | – | 107 (2) |
| Small Toothed Whales | *Feresa attenuata* | Pygmy killer whale | – | – | 5 (1) | – | 5 (1) |
| | *Globicephala macrorhynchus* | Short-finned pilot whale | 12 (1) | – | – | – | 12 (1) |
| | *Mesoplodon sp.* | Beaked whale species | 1 | – | – | – | 1 (1) |
| | *Pseudorca crassidens* | False killer whale | 38 (2) | 22 (1) | 23 (1) | – | 83 (4) |
| | *Peponocephala electra* | Melon headed whale | 20 (1) | – | – | – | 20 (1) |
| Baleen Whales (non-humpback) | *Balaenoptera acutorostrata subsp.* | Dwarf minke whale | 4 (3) | – | – | – | 4 (3) |
| | *Balaenoptera acutorostrata* | Minke whale species | 3 (2) | – | – | – | 3 (2) |

*Source: RPS 2007a*

that green turtles were the predominant nesting species on Browse Island with evidence of low density mid-year nesting and hatching around the entire island.

### 5.4.7 Flatback Turtle (*Natator depressus*)

Flatback turtles are found only in the tropical waters of northern Australia, Papua New Guinea and Indonesia (DEWHA, 2008c). The Prelude FLNG Project site falls within the Federal Government's NWSMU for flatback turtles. The species is listed as vulnerable under the *EPBC Act* and data deficient under the IUCN Red List of Threatened Species. Nesting is only known to occur in Australia, with six major aggregations recognized, including the Kimberley region. Nesting sites are widely distributed along the mainland coast and among offshore islands. Flatback turtles make long reproductive migrations similar to other species of sea turtles, although these movements are restricted to the continental shelf. Nesting in the region occurs mainly in December and January. Females lay a mean of 2.8 clutches per season at an internesting interval of 15 days (Limpus, 1971). Flatback turtle internesting grounds are unknown for the NWS region but they are thought to favour soft bottom habitat close to nesting sites.

Post-hatchlings and juveniles do not have a wide dispersal phase in the oceanic environment like other sea turtles (Walker & Parmenter 1990). They are considered to follow a surface dwelling lifestyle over the continental shelf, feeding predominantly on macro-zooplankton (Limpus,

*Table 5.11 Recorded Numbers and Sightings of all Cetaceans Observed in the Browse Basin and Adjacent Marine Areas During the 2008 Cetacean Study (Jenner and Jenner, 2009).*

| Scientific Name | | Common Name | Number | Sightings |
|---|---|---|---|---|
| Family | Species | | | |
| Balaenopteridae | | | | |
| | *Balenoptera acutorostrata* | Dwarf minke whale | 1 | 1 |
| | *Like Balenoptera acutorostrata* | Undetermined minke whale | 1 | 1 |
| | *Balaenoptera musculus brevicauda* | Pygmy Blue whale | 7 | 4 |
| | *Balenoptera edeni* | Bryde's whale | 4 | 4 |
| | *Megaptera novaeangliae* | Humpback whale | 57 | 32 |
| | *Kogia sima* | Dwarf sperm whale | 1 | 1 |
| Delphinidae | | | | |
| | *Delphinus delphis* | Common bottlenose dolphin | 48 | 3 |
| | *Pseudorca crassidens* | False killer whale | 177 | 6 |
| | *Globicephala spp.* | Pilot whale spp. | 150 | 4 |
| | *Lagenodelphis hosei* | Frasers Dolphin | 80 | 1 |
| | *Delphinus capensis* | Long-beaked common dolphin | 46 | 1 |
| | *Tursiops aduncus* | Indo-pacific bottlenose dolphin | 4 | 1 |
| | *Stenella longirostris* | Long-snouted spinner dolphin | 1336 | 40 |
| | *Stenella attenuata* | Pantropical spotted dolphin | 10 | 4 |
| | *Grampus griseus* | Risso's dolphin | 70 | 7 |
| | *Delphinus delphis* | Short-beaked common dolphin | 450 | 2 |
| | *Tursiops spp.* | Tursiops spp. | 513 | 12 |
| | *Globicephala macrorhynchus* | Short-finned pilot whale | 25 | 4 |
| Unidentified Cetaceans | | | | |
| | - | Dolphin | 941 | 49 |
| | - | Whale | 14 | 8 |
| | - | Cetacean | 79 | 18 |

2007). Adults are known to inhabit soft bottom habitat and forage in turbid shallow near-shore water in areas 5 to 20 m deep (Limpus et al. 1983). However, there is sparse data available on the feeding grounds of Flatback turtles from the Kimberley region (Limpus, 2007). The Prelude FLNG Project area does not contain any emergent land or shallow sub tidal habitats that could be frequented by flatback turtles.

### 5.4.8 Whale Shark (*Rhincodon typus*)

Whale sharks are listed as vulnerable under the *EPBC Act* and the IUCN Red List of Threatened Species. Relatively limited information is available on population trends. Whale sharks have a broad distribution usually between latitudes 30°N and 35°S in tropical and warm temperate seas, both oceanic and coastal (DEH, 2005c). They are a wide ranging species, with individual animals known to migrate in the order of 12,000 km over the course of a year (DEWHA, 2008d). Studies using satellite telemetry have indicated that whale sharks swim an average of 24 km/day and have a minimum range of 200 km (Eckert et al. 2001; Eckert et al. 2002). Whale sharks are generally encountered singly, but occasionally occur in large aggregations. In Australia, whale sharks are known to aggregate seasonally in coastal waters off Ningaloo Reef between March and July, to a lesser extent at Christmas Island between December and January and in the Coral Sea between November and December (Wilson et al. 2001; DEH, 2005c). These aggregations are thought to be associated with feeding in the seasonally productive waters. There are no known mating areas in Australian waters.

Information on the distribution and migration patterns of whale sharks in Australia is based primarily on seasonal surveys at Ningaloo Marine Park, with very limited records collected elsewhere. Limited satellite tracking data collected by CSIRO suggests that whale sharks may migrate through the proposed project area (www.cmar.csiro.au/tagging/whale/ningaloo.html), however, there have been no studies conducted to date to determine if aggregation areas for this species may exist in the region. There are no oceanographic features in the vicinity of the project area which could encourage feeding aggregations.

### 5.4.9 Seabirds

Seabird feeding grounds, roosting and nesting areas are found on the offshore atolls of the NWS. The closest emergent land to the project area is Browse Island. A search of the Commonwealth DEWHA protected matters search tool conducted on 12 May 2008 indicated the Streaked Shearwater (*Calonectris leucomelas*, also known as *Puffinus leucomelas*), a migratory seabird species listed under the *EPBC Act*, may occur within the region. The Streaked Shearwater is a broadly distributed pelagic species which breeds and nests only in Japan and its offshore islands.

Individuals and flocks of both mixed and single seabird species have been observed in and near the project area during marine surveys conducted between 2006 and 2008 (RPS, 2007a; ERM, 2008; Jenner and Jenner, 2009). The largest bird group represented are the tern species consisting of bridled (*Sterna anaethetus*), crested (*S. bergii*), gull-billed (*S. niloteca*) and lesser crested (*S. bengalensis*) terns as well as common noddies (*Anous stolidus*). Other species commonly sighted in the region include Bulwer's Petrel (*Bulweria bulwerii*), Wilson's Storm petrels (*Oceanites oceanicus*) and Brown boobies (*Sula leucogaster*).

A number of other migratory seabirds may also pass through the project area, some of which are protected by international agreements (see *Section 5.4.10*).

### 5.4.10 JAMBA, CAMBA and ROKAMBA Species

Low densities of migratory shorebirds and seabirds protected under the Japanese-Australia Migratory Bird Agreement (JAMBA), China-Australia Migratory Bird Agreement (CAMBA) and Republic of Korea-Australia Migratory Bird Agreement (ROKAMBA) bilateral agreements may pass through the project area. Ashmore Reef, in particular, is an important site for both migratory birds and seabirds.

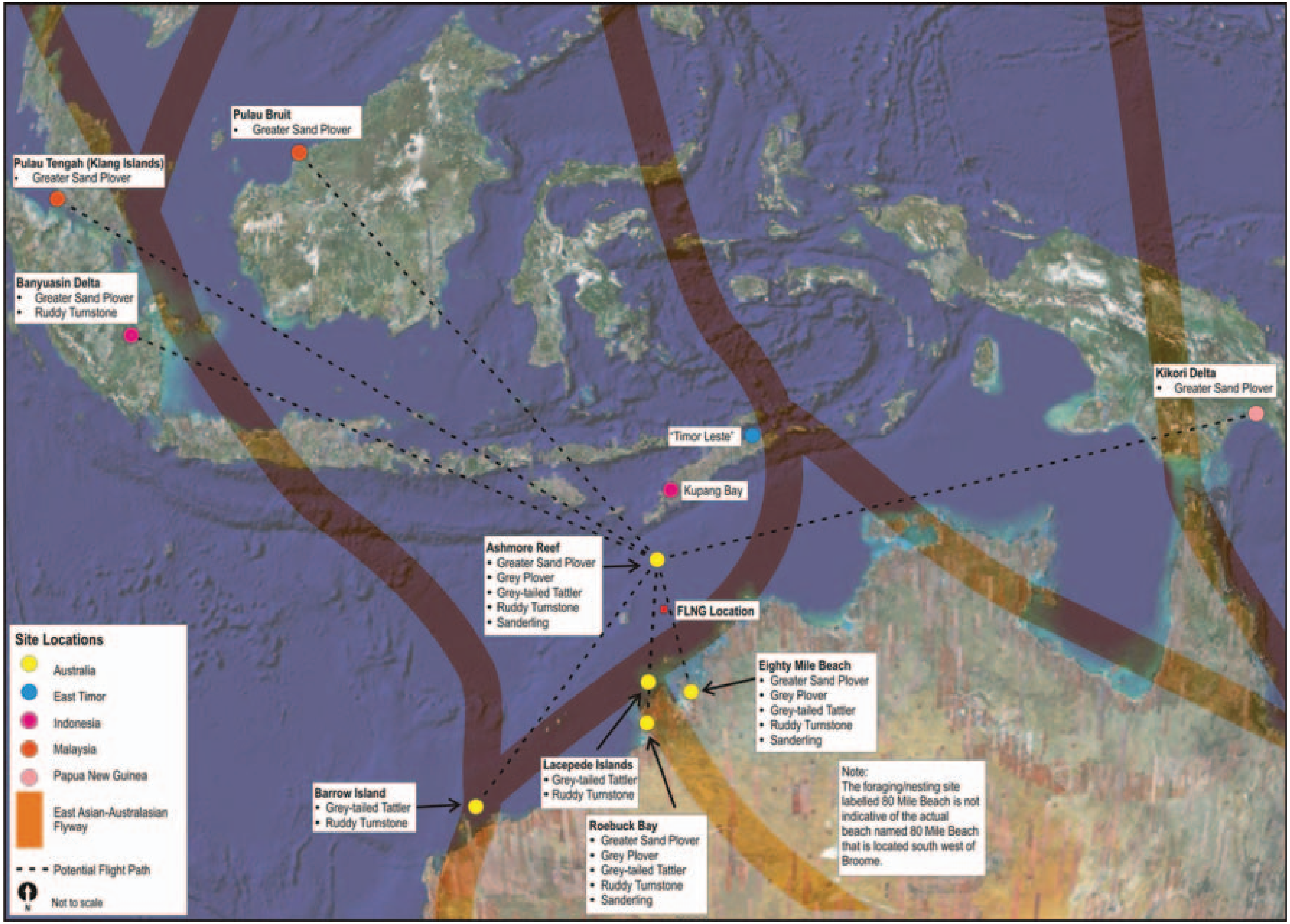
A recent review of migratory shorebirds has drawn together population estimates and identified internationally important sites of the East Asian-Australasian Flyway (EAAF) (Bamford et al. 2008). This study concluded that 54 species of migratory shorebirds are known to utilise the EAAF. One hundred and nineteen internationally important sites were recognised in Australia, with Roebuck Bay/80 Mile Beach (around 500 km south of the project area) recognised as a major site for over 30 species of migratory shorebirds. Ashmore Reef was also recognised as an internationally important site for five species (Ruddy Turnstone, Grey Plover, Greater Sand Plover, Sanderling and Grey-tailed Tattler), with a further nine sites identified in northern Western Australia and 11 sites in the southwest Western Australia.

The sand flats of Ashmore Reef and Cartier Islands are recognised as particularly important for feeding migratory shore birds during non-breeding periods. However, the Islands are also an important staging point during the migration between the Northern Hemisphere and Australia. During October to November and March to April large flocks of Eastern Curlews, Ruddy Turnstones, Whimbrels, Bar-Tailed Godwits, Common Sandpipers, Mongolian Plovers, Red-Necked Stints and Grey-tailed Tattlers occur at these islands as part of the migration (Commonwealth of Australia, 2002). These species are all listed under JAMBA, CAMBA and ROKAMBA.

The Ashmore Reef and Cartier Islands are also regarded as supporting some of the most important seabird rookeries on the NWS (Commonwealth of Australia, 2002). Species include Crested Terns, Bridled Terns and Common Noddies, which breed on East and Middle Islands, and are listed under JAMBA and CAMBA (Commonwealth of Australia, 2002).

*Figure 5.16* illustrates the locations of the internationally important shorebird sites identified by Bamford et al. (2008) in the context of the major flight paths of the EAAF (Milton, 2003). In addition, potential flight paths between the shorebird sites where species are known to occur in significant numbers have been identified. These flight paths

*Figure 5.16 Important Shorebird Sites and Potential Shorebird Flight Pathways.*



are illustrative only and assume that birds of the same species travel the most direct path.

### 5.4.11 Migratory Species

Key migratory species that may occur seasonally in the vicinity of the project area and for which migratory pathways are understood include humpback whales (*Section 5.4.1*), green turtles (*Section 5.4.6*) and migratory birds. Table 5.12 outlines the key periods when migratory species are most likely to be present in the locality of the project area.

### 5.4.12 Other Listed Species

Other listed threatened and migratory species that may occur in the region are listed in *Table 5.13*. All these species may be observed opportunistically but are not likely to have any site specific dependence within the Prelude FLNG Project area.

*Table 5.12 Key Periods of Migratory Species Activity in the Browse Basin*

| Species/ Activity | June | July | Aug | Sept | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Humpback whales/ migration and calving | ▨ Northern migration | ▨ | ■ Whales present in calving grounds | ▨ Southern migration | ▨ | | | | | | | |
| Migratory birds/ migration and feeding | | | ▨ | ■ Southern migration | ■ | ▨ | Migratory birds present in coastal feeding habitats. | | | ▨ | ■ Northern migration | ▨ |
| Green Turtles/ mating and nesting (Browse Island) | | | ▨ | ▨ | ▨ | ■ Aggregations of adult turtles present in nearshore areas off nesting beaches, including Browse Island | ■ | ■ | ▨ | | | |
| Green Turtles/ hatching (Browse Island) | | | | | | | ▨ | ■ Hatchling turtles present in nearshore areas and dispersed in the vicinity of nesting beaches, including Browse Island | ■ | ■ | ▨ | |

■ Peak activity/ presence reasonably reliable and predictable

▨ Lower level of activity/presence less predictable and may vary from year to year

*(Source of information: Jenner et al., 2001; Bamford et al., 2008 and DEC, 2008).*

*Table 5.13 EPBC Act Listed Species identified in the DEWHA Protected Matters Database that May Occur in the Vicinity WA-371-P*

| Species Name | Common Name | *EPBC Act* Listing Status | IUCN Status† |
|---|---|---|---|
| Antarctic minke whale | *Balaenoptera bonaerensis* | Migratory | Data Deficient |
| Bryde's whale | *Balaenoptera edeni* | Migratory | Data Deficient |
| Killer whale | *Orcinus orca* | Migratory | Data Deficient |
| Sperm whale | *Physeter macrocephalus* | Migratory | Vulnerable |
| Spotted bottlenose dolphin | *Tursiops aduncus* | Migratory | Data Deficient |
| Leathery Turtle | *Dermochelys coriacea* | Threatened | Critically endangered |

*† IUCN - International Union for the Conservation of Nature, Cetacean update of the 2008 Red List of Threatened Species*

Observations from the 2006/07 study of cetaceans in the Browse Basin and inshore Kimberley region (see *Section 5.1*) recorded spotted bottlenose dolphins during both inshore and offshore surveys (including some large pods of 50-100 individuals in the Browse Basin area). Seven minke whales, four of which were identified to belong to dwarf sub-species, were recorded during vessel surveys in the Browse Basin.

## 5.5 INTRODUCED MARINE SPECIES

Introduced Marine Species (IMS) are species that have been introduced to an area outside their natural range of occurrence by human activities. IMS can be introduced by a variety of vectors, including ballast water discharged by shipping and fouling on hulls. A two year study designed to identify introduced marine species within Australian waters found 129 non-native and 209 cryptogenic (of unknown origin) species established in Australian waters (Hayes et al. 2005).

The National Introduced Marine Pest Information System (Hewitt et al. 2002) identifies the presence of 44 IMS in the waters of Western Australia. A map of the number of introduced marine species produced for the National Oceans Office (2004) indicates no known introduced species in the northwest marine region, which includes the project area. However, wide-scale surveys of introduced IMS for the region are lacking. Due to the remoteness, low volume of shipping traffic, lack of hard substrate in shallow depths, open oceanic environment and depth of water in the vicinity of the survey area, it is unlikely that there has been successful establishment of introduced species into the project area.

## 5.6 EXTENT OF EXISTING DISTURBANCE

Oil exploration activities in the Timor Sea commenced in the late 1960s. Since this time numerous wells have been drilled throughout the region. Searches for new sources of hydrocarbons are actively being pursued in the region by a number of operators. The petroleum exploration and production industry is a significant user of offshore waters in the region, particularly within and adjacent to the Joint Petroleum Development Area between East Timor and Australia. *Figure 5.17* provides an overview of current discoveries and developments in the vicinity of the Browse Basin and the Prelude FLNG Project title area.

The Ichthys/Gorgonichthys/Brewster fields in Exploration Permit Area WA-285-P are immediately to the south of the WA-371-P title area and are the closest known fields.

## 5.7 SOCIO-ECONOMIC AND CULTURAL ENVIRONMENT

### 5.7.1 Introduction

This section provides details of the offshore socio-economic and cultural environment relevant to the Prelude FLNG Project. As the project area is located in the open ocean at considerable distance from the shoreline and more than 40 km distant from the Browse Island, there are no known cultural or heritage issues associated with the project.

An analysis of navigation data for the area shows that a few ships reported positions from within the project area during 2007. All of these ships appeared to be support vessels associated with the oil and gas industry. The project area may be traversed on occasion by mariners and fishermen but does not appear to overlap with any known and established sea lanes or fishing grounds.

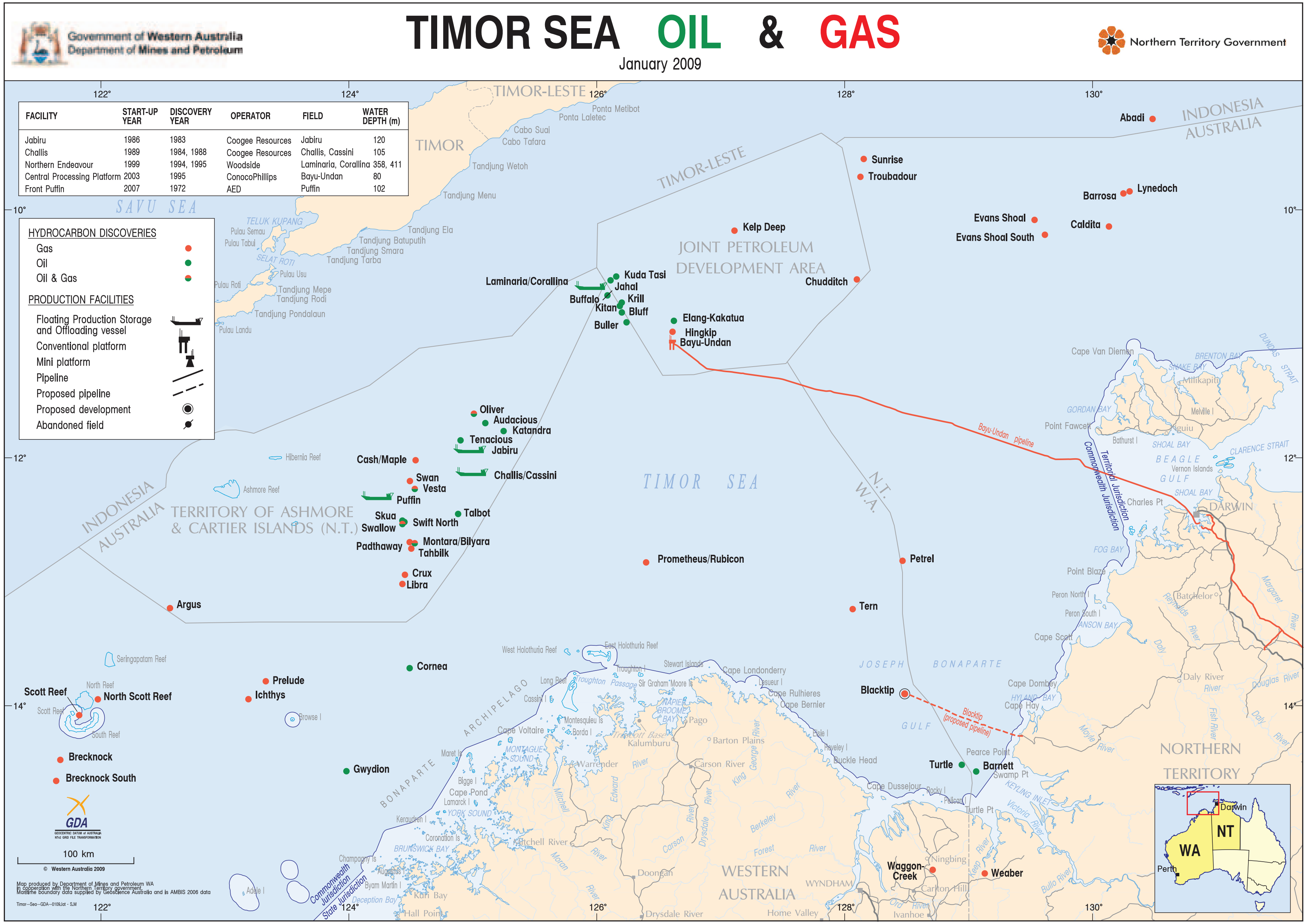
### 5.7.2 Shipping Routes

The Australia Ship Reporting System 2007 data are presented graphically in *Figure 5.18*. Attribute data for vessels classified as 'geological seismic', 'tug' or 'supply' have been screened out of the presentation, on the assumption that these vessels were likely to be engaged in exploration and development activities associated with Prelude and other exploration.

The remaining data show probable shipping lanes to the north and to the west of the proposed project area. The nearest major shipping lane to the west of the project area is 215 km distant. The nearest shipping lane to the north of the project area is approximately 100 km distant. Given the distances between the proposed project area and shipping lanes, the FLNG facility will pose a minimal navigational risk to commercial shipping.

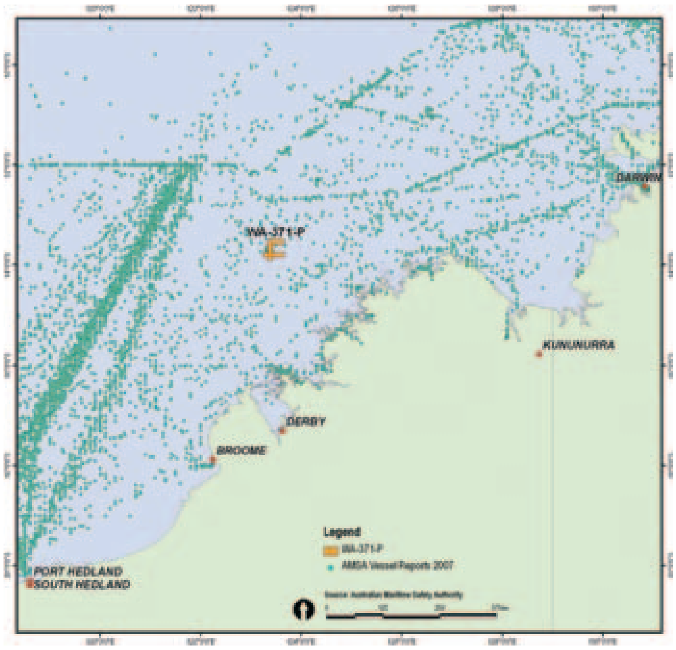
During the development phase of the project, which

*Figure 5.17 Oil & Gas Development Activities Timor Sea*



| FACILITY | START-UP YEAR | DISCOVERY YEAR | OPERATOR | FIELD | WATER DEPTH (m) |
|---|---|---|---|---|---|
| Jabiru | 1986 | 1983 | Coogee Resources | Jabiru | 120 |
| Challis | 1989 | 1984, 1988 | Coogee Resources | Challis, Cassini | 105 |
| Northern Endeavour | 1999 | 1994, 1995 | Woodside | Laminaria, Corallina | 358, 411 |
| Central Processing Platform | 2003 | 1995 | ConocoPhillips | Bayu-Undan | 80 |
| Front Puffin | 2007 | 1972 | AED | Puffin | 102 |

*Figure 5.18 Navigation Position Report for Large Vessels in Proximity to Project Area – 2007*



*Source: AMSA (2007)*

includes drilling of approximately eight wells within the project area, supply ships may be required to complete up to three weekly round-trip voyages between the project area and a shore base. During the operating phase of the project, the number of supply ship transits could drop to one per week or even one every two weeks.

### 5.7.3 Vessel Movements

#### *Vessel Movements in Broome*

During the 2006/07 year, the Port of Broome's outer berth and two smaller berths accommodated 1,626 vessel visits. Of the total number of visits almost 19% (308 vessels) were rig supply vessels, a growth of more than five times the number of visits from the previous year. *Table 5.14* shows that other major port users included pearling, fishing and charter vessels, which accounted for approximately 65% (1,052 vessels) (Broome Port Authority, 2007, p 22).

#### *Vessel Movements in Darwin*

*Table 5.15* shows that commercial wharves at the Port of Darwin received 5,408 visits in 2007/08 which was up 12% from the number of visits received during 2006/07.

Cruise vessel visits totalled 44 while defence vessels visited the port 55 times. Small craft represented the greatest proportion of visits to the Port of Darwin comprising 69.1% of all visits. The vast majority of these small craft are described as being a part of the fishing industry (82.2%) with 252 (6.7%) vessel visits from small pleasure craft (Darwin Port Authority, 2008). Other small craft included pearling, research and patrol vessels. (Darwin Port Corporation, 2008).

*Table 5.14 Vessel Types and Visits to the Port of Broome 2006/07*

| Type of Trade Vessel | Number of Visits |
|---|---|
| Cargo | 17 |
| Livestock | 29 |
| Fuel/Oil/Bitumen Tankers | 20 |
| Rig Supply Vessels | 308 |
| Cruise Ships | 19 |
| Pearling | 438 |
| Fishing | 293 |
| Charter | 321 |
| Navy | 27 |
| Other | 154 |
| *Total number of visits* | *1,626* |
| *Average weekly visits* | *31* |

*Source: Broome Port Authority (2007)*

*Table 5.15 Vessel Types and Visits to the Port of Darwin*

| Vessel Type | Number of visits 2007/08 | Number of visits 2006/07 |
|---|---|---|
| Small craft | 3,738 (69.1%) | 3,397 (70.6%) |
| Trading | 1,547 (28.6%) | 1,253 (26.0%) |
| Defence | 55 (1.0%) | 64 (1.3%) |
| Cruise | 44 (0.8%) | 44 (0.9%) |
| Container | 24 (0.4%) | 53 (1.1%) |
| *Total number of visits* | *5,408* | *4,811* |
| *Average weekly visits* | *104* | *93* |

*Source: Darwin Port Corporation (2007, 2008)*

The Port of Darwin is the location of a 3.5 mtpa LNG plant. Fifty two LNG Carrier calls were completed at the new Darwin LNG facilities in the Port of Darwin during 2006/07 and an increase in LNG movements was expected in 2007-8. (Darwin Port Corporation, 2007 and 2008).

### 5.7.4 Commercial, Traditional and Recreational Fishing

#### *Commercial fisheries*

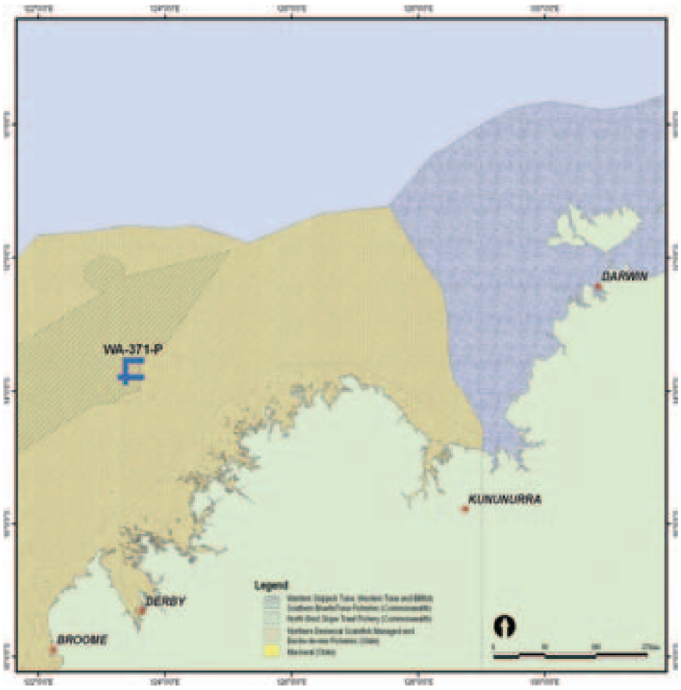
The project area overlaps with a variety of commercial fishing management areas. Commercial fisheries include tuna and tropical finfish, particularly high-value emperors, snappers and cods. Within the northwest region there are also significant commercial fisheries for Spanish mackerel, barramundi, threadfin salmon and shark. A number of wet line activities, including offshore demersal line fishing, also occur in the region (Department of Fisheries, 2007).

Extensive fisheries closures in the offshore waters around the project area have been introduced to manage finfish trawling by Australian vessels. The project area lies outside the boundary of the Northern Demersal Scalefish Managed Fishery, the most commercially valuable of the state managed finfish fisheries in Western Australia.

The number of licence holders and estimated catch value of the different fleets is presented in *Table 5.16*. *Figure 5.19* below provides a map of the licence areas for the commercial fleets relative to the project area.

*Figure 5.20* shows the best available information on actual commercial fishing activities in the general area of the proposed Prelude FLNG Project. The figure, which shows the fishing activities (effort) of the Northwest Slope trawl fleet between 2000 and 2006, indicates that the nearest recorded location for sustained fishing activity is outside the project area, and that this area attracted less than 200 hours of fishing effort between 2000 and 2006.

*Figure 5.19 Commercial Fishing Licence Areas*



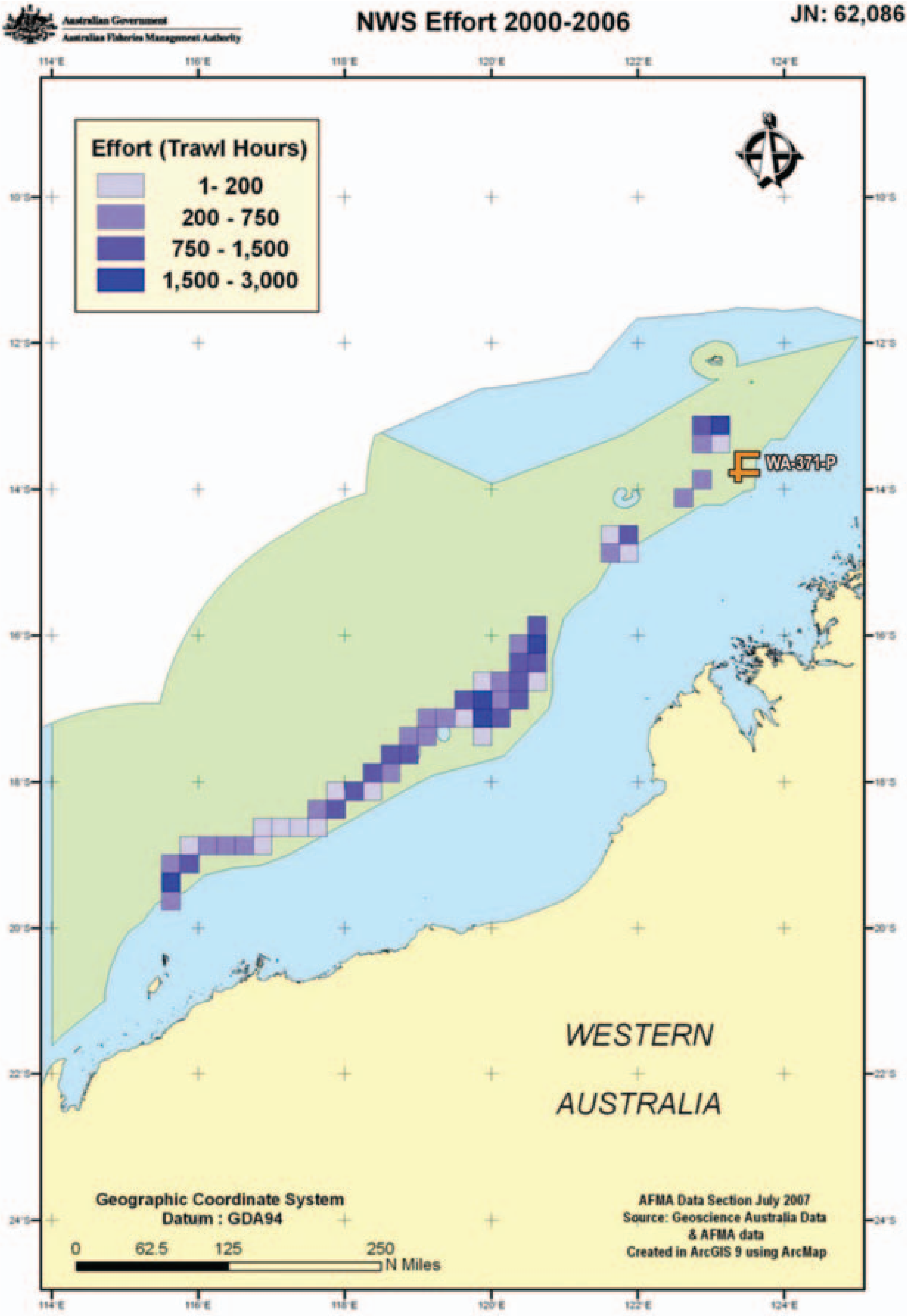
*Source: AFMA (2009)*

*Table 5.16 License Holders and Estimated Catch Value of Fishing Fleets*

| Fishery Type | No of permits/ licences | Value |
|---|---|---|
| **Commonwealth Managed Fisheries** | | |
| North West Slope Trawl Fishery | 7 | A$1.15 million (2004) |
| Western Skipjack Tuna Fishery | 13 | Maximum catch value 1997-2006 A$8.1 million |
| Western Tuna and Billfish | 110 | A$3.2m million (2006) (includes 446 tonnes of Skipjack) |
| Southern Bluefin Tuna Fishery | 98 | A$78 million (wild harvest) |
| **WA State Managed Fisheries** | | |
| Mackerel | 6 | A$2.65 million |
| Northern Demersal Scalefish Managed Fishery | 11 | A$4.6 million (2006) |
| Beche-de-mer Fishery | 6 | 56 tonnes |

*Source: Australian Fisheries Management Authority (2009) and Department of Fisheries (2007)*

*Figure 5.20 Fishing Effort for the Northwest Slope Trawl Fleet 2000 - 2006*



*Source: AFMA (2006)*

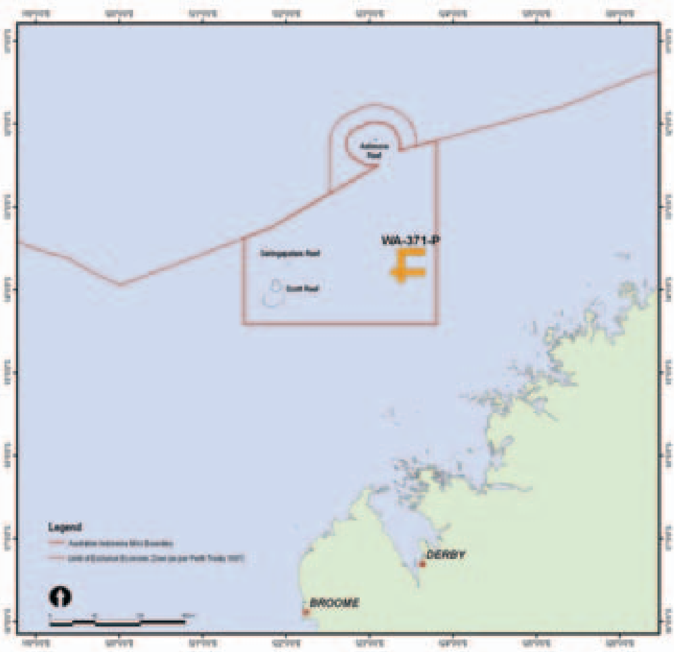
### *Traditional fisheries*

The project area lies within the area known as the 'MOU Box'. In 1974, Australia recognised access rights for traditional Indonesian fishers in shared waters to the north of Australia, granting long-term fishing rights in recognition of the long history of traditional Indonesian fishing in the area (Geoscience Australia, 2008b). The Memorandum of Understanding (MOU) enables Indonesian traditional fishers to continue their customary practices and to harvest species such as trepang, trochus, abalone and sponges in Australian waters. These are found on reef flats in shallow waters.

Every year boats leave Indonesia to fish within the MOU Box, shown below in *Figure 5.21*. Under the terms of the agreement, the Indonesian fishermen must rely on traditional fishing methods including the use of sail.

Traditional Indonesian fishers were seen at Browse Island during the 2007 fishing season. Browse Island is cited as a location for Trochus shell (Department of Fisheries, 2001), used for high quality buttons and crafts. Overfishing of Trochus in Western Australian waters has led to a collapse in the annual harvest and the Department of Fisheries has been conducting research into rebuilding populations on the reefs off the Kimberley coast.

*Figure 5.21 Boundary of Australian-Indonesian MoU Box*



*Source: Geoscience Australia (2008b)*

These traditional Indonesian fishermen are found in deepwater areas only during transit to and from the reef locations; therefore, they will be unaffected by the project.

### *Recreational fisheries*

According to the Western Australian Department of Fisheries, recreational fishing is experiencing significant growth along the north coast, with a distinct seasonal peak in winter when significant numbers of metropolitan and inter-state tourists travel through the area. The preferred areas for recreational fishing are near the coast at the Onslow, Dampier Archipelago and Broome sections of the coastline.

An internet search of recreational fishing charters in the northwest region of Western Australia did not reveal any advertised recreational fishing to Browse Island or to the project area.

## 5.7.5 Maritime Heritage

Australia protects its shipwrecks and associated relics older than 75 years through the *Historic Shipwrecks Act 1976* which applies to Australian waters that extend from the low tide mark to the end of the continental shelf and is administered by the Commonwealth in collaboration with the States, Northern Territory and Norfolk Island.

Information on historic shipwrecks is maintained in the National Shipwrecks database, a searchable database of Australian shipwrecks containing shipwreck records provided by the Australian State and Territory governments (DEWHA, 2008e). A search of the database revealed six shipwrecks within a distance of 50 km from the project area. All of the identified shipwrecks were located at or near Browse Island. The complete list of these wrecks is provided in *Table 5.17*.

## 5.7.6 Tourism

Whilst charter fishing companies frequent the broader region, there are no known tourist attractions or destinations within the project area. Tourism, however, has a much

*Table 5.17 Registered Shipwrecks in Vicinity of Project Area*

| Shipwreck Id | Name | Type | Date wrecked | Where wrecked | State |
|---|---|---|---|---|---|
| 7785 | Berteaux | Ship | 1885/11/12 | Browse Island | WA |
| 7867 | Carleton | Barque | 1878/03/11 | Browse Island | WA |
| 8141 | Florida | Schooner | 1887/09/12 | Near South Shore Browse Island | WA |
| 8486 | Matterhorn | Ship | 1878/03/11 | Browse Island | WA |
| 8736 | Runnymede | Barque | 1878/12/22 | Browse Island | WA |
| 8789 | Selina (Sulina) | Ship | 1879/01/22 | Browse Island | WA |

*Source: DEWHA (2008e)*

larger presence along the coast from Exmouth to Broome, particularly during the winter when visitors come to enjoy the mild subtropical climate. Approximately half of these visits are for the purpose of outdoor, nature or sporting activities that include whale watching, diving, fishing and wildlife tours.

### 5.7.7 Military / Defence

Customs Coastwatch, together with both Navy Fremantle class patrol boats and Customs Bay class vessels, undertake civil and maritime surveillance in and around the project area (McCormick, 2001). The primary purpose of the activity is to monitor the passage of suspect illegal entry vessels and illegal foreign fishing activity within the boundaries of the 'MOU Box' and the Australian Fishing Zone (an area extending roughly 200 nm from the mainland).

# 6 IMPACTS AND MANAGEMENT

## 6.1 SCOPE

This chapter describes and assesses the potential environmental, social and health impacts arising from the activities associated with the Prelude FLNG Project. The potential impacts from unplanned events such as a condensate spill are also considered. The measures that have been incorporated into the project design and the mitigation and management measures that Shell will implement in response to these potential impacts are presented.

The assessment covers the following project activities:

- offshore construction activities including development well drilling, preparation of the sea bed and installation of subsea infrastructure, mooring chain and anchor installation, and tow out and hook up of FLNG;
- commissioning, operation (including support and logistics) and maintenance of the FLNG facility and subsea infrastructure; and
- decommissioning the FLNG facility and subsea infrastructure (general outline and approach).

These sequential activities have been considered under each of the following categories of impact, which were identified during the Environment, Social, Health Impact Assessment (ESHIA) scoping phase (described in *Section 6.2.2* below) and in the guidelines issued by DEWHA for the draft EIS for the Prelude FLNG Project:

- physical impacts;
- lighting;
- noise;
- solid wastes;
- liquid wastes;
- emissions to atmosphere;
- unplanned events;
- socioeconomic impacts; and
- health impacts.

The chapter sections dealing with the impact categories each include:

- a description of the sources and characteristics of the potential impacts;
- a listing of receptors sensitive to potential impacts;
- a description and evaluation of impacts;
- the identification of safeguard and mitigation measures to reduce the potential impacts associated with project;
- a concluding statement regarding the significance of the identified impacts in relation to the relevant controlling provisions under the *EPBC Act* (Sections 18 and 18A: Listed threatened species and communities, Sections 20 and 20A: Listed migratory species and Sections 23 and 24A: Commonwealth Marine Environment); and
- a summary table.

## 6.2 IMPACT ASSESSMENT METHODOLOGY

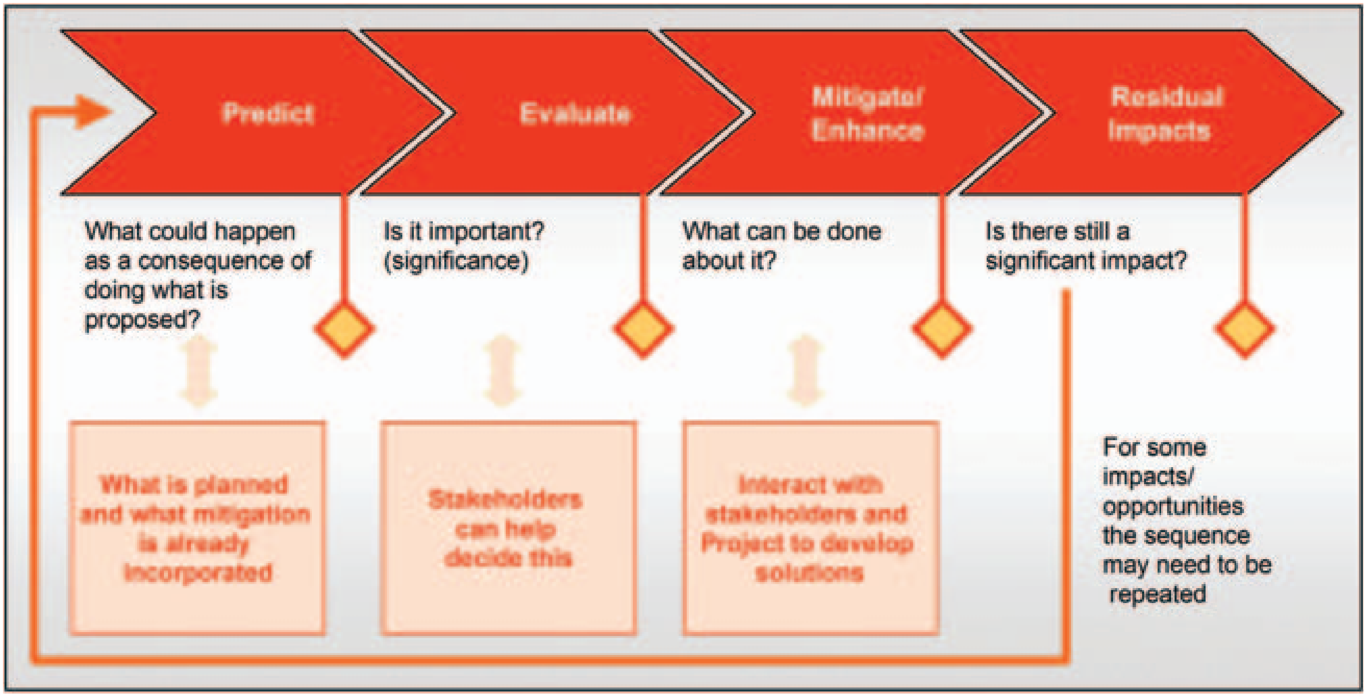
### 6.2.1 Environment, Social, Health Impact Assessment Process

The ESHIA process comprises a number of different phases as follows:

- project definition;
- scoping and information collection;
- prediction and assessment of potential impacts;
- development of management and mitigation measures; and
- communicating and reporting of results.

These phases are informed by the assessment team, the project engineering and management team and by stakeholder consultation throughout the ESHIA process. Further details of the stakeholder engagement program undertaken for the Prelude FLNG Project and its contribution to the project are provided in *Chapter 3*. An overview of the ESHIA process is shown in *Figure 6.1* and the activities in each phase are described below.

*Figure 6.1 Overall Impact Assessment Process*



### 6.2.2 Scoping

Scoping was the first phase undertaken during the ESHIA process and was done to set the boundary conditions for the study, to identify potential interactions between the project and environmental, social and health resources or receptors, and to prioritise these in terms of potential magnitude or significance (*Prelude* FLNG *Scoping Document- Revision 3 - May 2008*). Potential impacts were identified through a systematic process whereby each individual project activity (both planned and unplanned) was considered with respect to its potential to interact with an environmental, social or public health receptor. A summary of the project activity components are listed in *Table 6.1*.

*Table 6.1 Project Activities*

| Activities | Activity Components |
|---|---|
| Offshore Construction | • Drilling and installation of subsea infrastructure<br>• Tow-out and hook up<br>• Hydrotesting |
| Commissioning & Operations | • Well, flowline and riser operations<br>• FLNG facility routine activities<br>• FLNG facility non-routine activities<br>• Product export<br>• Maintenance |
| Unplanned Events | • Spills from FLNG facility and vessels |
| Decommissioning | • Well abandonment<br>• Removal of subsea facilities<br>• FLNG facility relocation |

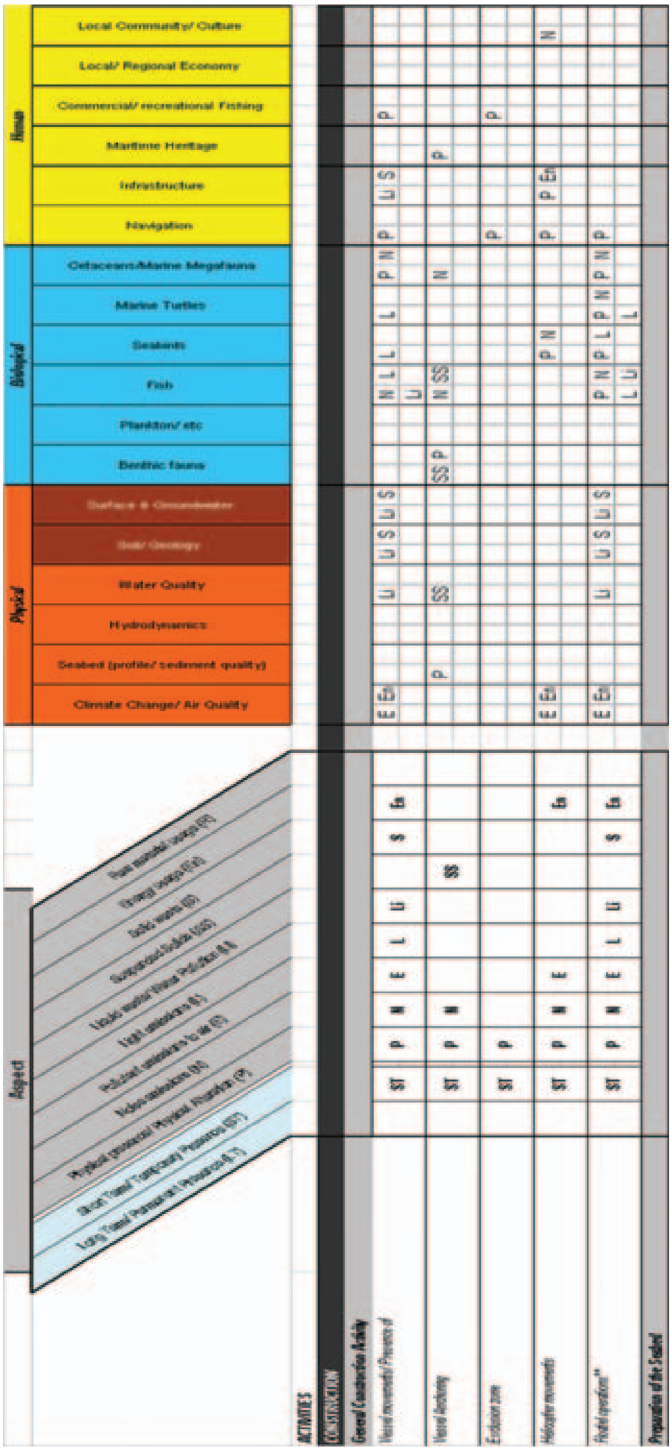
A *Scoping Matrix* was developed at the time of the impact assessment workshop to illustrate the identified interactions of activities and environmental, social and health resources in a consistent and robust manner. An example of the matrix is provided in *Figure 6.2*.

The process included a workshop involving ESHIA specialists and Shell project representatives (1 April 2008) during which project activities with the potential to affect an environmental or social resource or receptor were identified. These were listed down the vertical column (or 'y' axis) of the scoping matrix.

The horizontal (or 'x') axis comprises three components:

- an indication of the duration of the activity, namely 'short term' or 'long term';
- a list of aspects ie an element of an activity that will, or has the potential to, lead to an impact such as noise or air emissions, or the generation of solid and liquid wastes; and
- environmental and social resources and receptors that are susceptible to impacts, grouped into physical, biological and human components.

*Figure 6.2 Extract from the Prelude Issues Scoping Matrix*



Having identified the potential interactions, each activity was examined, drawing upon the experience of the reviewers and their understanding of the extent and nature of the project activities and the environmental and social setting, to ascertain:

- which aspects were relevant and if so, whether the interaction of the aspects with the receiving environments would result in a positive or negative impact; and
- which resources and receptors would potentially be affected by each activity and whether they would be impacted slightly or significantly.

The latter was recorded in the matrix cell at the intersection between an activity and an affected resource or receptor. As it is possible that an activity can affect a particular resource or receptor in more than one way (eg vessel activity may affect cetaceans from physical collisions and underwater noise), the type of effect was recorded in each cell.

### 6.2.3 Prediction and Assessment of Impacts

The prediction of impacts (risk assessment) was undertaken to determine what could potentially happen to the receptor (ie environment, socio-economic and health) as a consequence of the project and its associated activities. The diverse range of potential impacts considered in the ESHIA process resulted in a range of prediction methods being used including quantitative, semi-quantitative and qualitative methods.

The impact prediction and assessment process took into account measures that have been incorporated into the project design and the procedures that will be applied to the project in order to avoid or reduce potential impacts to ALARP levels; these measures are also summarised in *Chapter 7*.

### 6.2.4 Evaluation of Impacts

The purpose of impact evaluation is to identify those impacts which are of greatest significance and upon which the greatest attention should be focussed in terms of impact management and mitigation. In evaluating the significance (ie importance) of impacts, the following factors have been taken into consideration:

- **Impact Magnitude**: The magnitude or consequence of an impact is a function of a range of considerations (see *Section 6.2.6* and *Table 6.3*); and
- **Likelihood of Occurrence**: How likely is the impact to occur as a result of an activity, taking into account the nature of the activity and the control measures in place (see *Section 6.2.7* and *Table 6.4*).

It is important to emphasise that the resulting risk evaluation from these two elements is not the likelihood of the activity occurring, but rather it is the likelihood of that activity causing the impact described.

### 6.2.5 Nature of Impacts

In considering impacts related to this project, both negative and positive impacts have been identified. Furthermore, direct, secondary, indirect and cumulative impacts are also considered.

These are further defined in *Table 6.2*.

*Table 6.2 Nature of Impacts*

| Term | Definition |
|---|---|
| *Impact Nature* | |
| **Negative Impact** | • An impact that is considered to represent an adverse change from the baseline condition or introduces a new undesirable factor |
| **Positive Impact** | • An impact that is considered to represent an improvement on the baseline condition or introduces a new desirable factor |
| *Impact Type* | |
| **Direct Impact** | • Impacts that result from a direct interaction between a project activity and the receiving environment (eg between occupation of an area of seabed and the habitats which are lost) |
| **Secondary Impact** | • Impacts that follow on from the primary interactions between the project and its environment as a result of subsequent interactions within the environment (eg loss of part of a habitat affects the viability of a species population over a wider area) |
| **Indirect Impact** | • Impacts that result from other activities that are encouraged to happen as a consequence of the project (eg project implementation promotes service industries in the region) |
| **Cumulative Impact** | • Impacts that act together with other impacts to affect the same environmental resource or receptor |

### 6.2.6 Impact Magnitude

In evaluating the magnitude (positive or negative) of environmental or social or health impacts, the following factors have been taken into consideration:

- **Frequency and Duration of the Impact**: how often the impact will occur and for how long will it interact with the receiving environment;
- **Extent of Impacts**: whether the impact effects the local, regional or broader receiving environments; and
- **Sensitivity of Receiving Environment**: the nature, importance (ie whether of local, national, regional or international importance) and the sensitivity or adaptability to change of the receptors or resources that could be affected. This also takes account of any laws, regulations or standards aimed at protecting the receiving environment.

These are further defined in *Table 6.3*.

*Table 6.3 Magnitude Factors*

| *Term* | *Definition* |
|---|---|
| *Impact Frequency* | |
| **Rare** | • The interpretation of each frequency descriptor varies with the impact topic; a regular impact to water quality from wash down water, for example, may be a daily occurrence, whereas a regular underwater noise impact from offtake operations may occur weekly. |
| **Occasional** | |
| **Regular** | |
| *Impact Duration* | |
| **Short** | • The interpretation of these descriptors also varies according to the impact topic. For example, a short term impact to the seabed, such as the effects of levelling works, may last for a year, whereas a short term impact to water quality, such as effects from the discharge of water based mud, could involve a period of 12 to 24 hours. |
| **Moderate** | |
| **Long** | |
| *Impact Extent* | |
| **Local** | • The primary zone of influence of the project. In this instance the local region encompasses the area within a radius of 40 km around the facility, extending to the closest landfall, Browse Island. |
| **Regional** | • Impacts extend beyond project locality to impact on the region. The region in this instance would encompass the Kimberly and offshore waters. |
| **National** | • Impacts on a national scale (effects extend well beyond the region). |
| **Global** | • Impacts on a global scale (eg global warming). |
| *Sensitivity of Receiving Environment* | |
| **Low** | • Abundant/ common species/ environment and broadly distributed<br>• Robust in nature and proven to be adaptable to changing environments<br>• Valued, but not unique<br>• IUCN Category 1[14] |
| **Medium** | • Range/ abundance restricted to a limited number of areas<br>• Under pressure and showing some, but slow, adaptability to changing environment<br>• Valued locally and regionally as an important species or environment<br>• IUCN Category 2 to 3 |
| **High** | • Rare/ unique species/ environment<br>• Under significant pressure and likely to fail or be irreversibly damaged<br>• Valued globally as an important species or environment<br>• DEWHA listed species<br>• IUCN Category 4 to 6 |

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[14] *See http://www.unep-wcmc.org/protected_areas/categories/index.html for more information*

The outcomes from each of the above categories were then combined by the topic specialists using their professional judgement to decide an overall grading of the magnitude of a particular impact.

Where quantification of potential impacts is possible, the decision has been based on numerical values, representing regulatory limits, project standards or guidelines (eg noise and air quality impacts).

A number of environmental aspects such as ecology, landscape, visual impact and generally all social and health impacts require a more qualitative approach for determining magnitude. Semi-quantitative and/or qualitative methods have therefore been used whereby the criteria have been set according to magnitude factors as set out in *Table 6.3* above.

The magnitude has been summarised using the following scale:

- low;
- medium; and
- high.

### 6.2.7 Likelihood of Impact Occurrence

The likelihood (probability) of an impact occurring has been defined using the qualitative scale of probability categories in *Table 6.4*. Likelihood is estimated on the basis of experience and/or evidence that such an outcome has previously occurred.

*Table 6.4 Likelihood Categories*

| ***Likelihood*** | ***Definition*** |
|---|---|
| Unlikely | Impacts which are improbable or would be unusual during the project life. |
| Possible | These are impacts which may occur during the project lifetime but would only do so infrequently. They would be unplanned events and some unusual planned events (eg replacement of equipment due to failure). |
| Probable | This includes impacts which are likely to occur as a result of the project. In general this category covers planned construction, operational or decommissioning impacts of the project. |
| Certain | These are impacts that will result from the project that are inevitable should the project proceed. |

### 6.2.8 Assessing Impact Significance

For the potential impacts associated with the Prelude FLNG Project, the significance of each impact is determined by assessing the impact **magnitude** against the **likelihood** of the impact occurring as summarised in the impact significance assessment matrix provided in *Figure 6.3*.

### 6.2.9 Mitigation and Enhancement

Application of mitigation measures to reduce potential negative impacts and enhance the benefits of a proposed activity is achieved by the application of the following mitigation hierarchy:

*Figure 6.3 Environmental, Social & Health Impact Significance Assessment Matrix*

| | | Likelihood | | | |
|---|---|---|---|---|---|
| | | Unlikely | Possible | Probable | Certain |
| Magnitude | Low | Minor | Minor | Moderate | Moderate |
| | Medium | Minor | Moderate | Moderate | Major |
| | High | Moderate | Moderate | Major | Critical |

- **Avoid at Source/Reduce at Source**: Avoiding or reducing at source is essentially designing the project so that a feature causing a potential impact is designed out or altered.
- **Abate on Site**: This involves adding something to the basic design to abate the potential impact – pollution controls fall within this category.
- **Abate at Receptor**: If a potential impact cannot be abated on-site then measures can be implemented off-site.
- **Repair or Remedy**: Some potential impacts involve unavoidable damage to a resource. Repair involves restoration and reinstatement measures.

Residual impact is the remaining or mitigated impact level after all avoidance, design and management measures have been taken into account. Where the residual impacts are of more than minor significance, an explanation of why further mitigation is not practicable is provided.

### 6.2.10 Cumulative Impacts

A review of other potential works in the vicinity of a proposed project is undertaken to identify the potential for cumulative impacts that may arise from the interaction between those works and the project. The results of the assessment of cumulative impacts for the Prelude FLNG Project are presented in *Section 6.12*.

## 6.3 PHYSICAL IMPACTS

### 6.3.1 Source and Characteristics of Physical Presence

Potential physical impacts from the Prelude FLNG Project will arise from the installation of physical features such as wells and seafloor infrastructure, and from the presence of the FLNG facility, associated vessels and aircraft. A summary of the sources of physical impact during each phase is provided in *Table 6.5*.

### 6.3.2 Receptors

Species expected to inhabit or migrate through the project area include benthic fauna, cetaceans, turtles, fish and migratory birds.

#### *Benthic Fauna*

Impacts to soft sediment habitat as a consequence of drilling and the installation of the subsea infrastructure are likely to occur as a result of smothering or direct displacement. In addition, the presence of the FLNG facility, near surface

*Table 6.5 Aspects of Physical Presence of the Prelude FLNG Project*

| Phase | Activity Source | Source Type | Impact Duration |
|---|---|---|---|
| Drilling and Construction | Vessel movements | Presence | 2-3 per week for 2 years |
| | Vessel Anchoring | Presence/ Alteration | 2 years |
| | Helicopter movements | Presence | Daily for 2 years |
| | Levelling of seabed | Alteration | Permanent |
| | Well drilling | Presence/ Alteration | 2 years |
| | Subsea well infrastructure | Presence | 25 years |
| | Drill cuttings disposal | Alteration | Permanent |
| | Subsea well infrastructure | Presence | 25 years |
| | FLNG facility anchor points | Presence | 25 years |
| Operation/Maintenance | Presence of FLNG facility | Presence | 25 years |
| | Helicopter movements | Presence | Daily for 25 years |
| | Support/Supply/transfer vessel | Presence | Fortnightly for 25 years |
| | Export vessel movements | Presence | 1-2 per week for 25 years |
| Decommissioning | Vessel movements | Presence | 4 months |

infrastructure (such as risers and upper sections of the mooring lines) and subsea infrastructure provides hard substrate for the settlement of marine organisms that would not otherwise be successful in colonising the area.

### *Cetaceans*

Cetaceans that are likely to be present in the vicinity of the project are discussed in *Section 5.4*. These include two threatened species and five migratory species under the *EPBC Act*. The project area is not known to provide significant feeding or breeding habitat or migration routes for any cetaceans.

There is a potential for whales and vessel traffic to collide (Bannister et al., 1996). In the event that whales do not successfully avoid vessels or vice versa, collisions could result in injury or fatalities.

### *Seabirds and Migratory Birds*

Migratory shorebirds may pass in the vicinity of the Prelude FLNG Project area 'en route' between sites on mainland Australia and destinations on offshore islands or overseas. The EPBC Protected Matters Database indicates that the only listed migratory shorebird that may be found in the vicinity of the FLNG facility is the streaked shearwater (*Calonectris leucomelas, Puffinus leucomelas*) (DEWHA, 2008a).

Potential effects on seabirds include longer term behavioural changes, such as roosting on the FLNG structure and/or changed feeding patterns in nearby waters. This could potentially alter the size and composition of the seabird community in the local area.

Given their coastal habitat, no shorebirds or waders will be impacted by the FLNG Project.

### *Turtles*

Two species of marine turtle may migrate through the project area, the green turtle (*Chelonia mydas*) and the flatback turtle (*Natator depressus*). These turtle species are described in *Section 5.3*. There is a potential for collisions between vessels and turtles, particularly during construction when vessel activity will be highest. However, the project area does not contain any emergent land, shallow subtidal features or other habitats commonly frequented by turtles. The nearest known turtle breeding, nesting or feeding grounds are located 40 km to the southeast of the FLNG facility on Browse Island.

### *Fish*

Pelagic species are commonly attracted to fixed and drifting surface structures in areas of open-ocean (Lindquist et al. 2004). Fish may be attracted to the area through the creation of attractive artificial habitat or nutrient enriched waters.

## 6.3.3 Description and Evaluation of Impacts

### *Installation of Physical Structures*

Construction of the following components of the project will disturb areas of the seabed:

- subsea natural gas gathering system (eg drilling and installation of wells, manifolds and flowlines);
- FLNG facility anchor points; and
- subsea umbilicals.

During drilling and installation stages of the project, the MODU and some installation vessels will be held in place using anchors. The exact anchoring configuration will vary for each construction vessel. Physical disturbance of the seabed will mainly be associated with laying and retrieval of anchors and chains.

Seabed disturbance during construction will have a direct local impact on benthic communities within the infrastructure footprint. The area extent of disturbance is provided in *Table 6.6*. No listed marine threatened or migratory species will be affected.

From the above table, the total area directly affected will be approximately 8,000 $m^2$. If geosequestration was undertaken (see *Section 4.4.2)* then the area of seabed disturbed would increase to approximately 10,000 $m^2$. In addition, drill cuttings will also form areas of deposition on the seafloor (see *Section 6.6*).

The subsea structures including the FLNG facility hull, the anchors, mooring lines, exposed subsea flowlines and

*Table 6.6 Proposed Direct Disturbance to Seabed*

| **Facility** | **Approximate area of disturbance (m$^2$)** |
|---|---|
| FLNG facility suction anchors (4x6) | 1900 |
| Riser base manifolds (2) | 300 |
| Flowlines (4) | 4267 |
| Flowline end manifolds (4) | 100 |
| Umbilicals & controls | 762 |
| Drill centre manifolds (2) | 300 |
| Wells (8) | 72 |
| **Total** | **7,701** |

risers will provide substrate for encrusting fauna and flora that would not otherwise be successful in colonising the area. Colonisation of the structures over time can lead to the development of a fouling community. The potential for this is discouraged through the application of anti-fouling materials for those components of the subsea infrastructure whose functionality would be impaired, should they be colonised by marine organisms.

Where colonisation is permitted to occur, fish and other organisms may be attracted as food chains develop. The structures may also attract fish by providing protection and habitat not otherwise available (Swan et al. 1994). For those fish species preferring some structural habitat complexity, the presence of seabed structures is likely to have a beneficial impact. The provision of artificial habitat on the seabed is likely to influence the composition of the benthic community in the immediate vicinity due to altered predator-grazing pressures (Pollard and Matthews, 1985; Hixon and Beets, 1993). The environmental impacts associated with the provision of artificial habitat are locally increased biological productivity and diversity.

The seafloor benthic community local to the proposed FLNG facility, (described in *Section 5.3.4*), is broadly distributed, abundant and robust (low sensitivity). The likelihood of impacts is certain and the magnitude will be low. Hence the significance of the impact to benthic fauna is assessed as moderate. No impacts on listed species are anticipated.

At the end of the project life, the sea floor infrastructure will be decommissioned. The subsea production wells will be plugged and abandoned and the remaining subsea infrastructure will be removed if required.

| **Direct disturbance to seabed** | | | |
|---|---|---|---|
| **Impact** | **Magnitude** | **Likelihood** | **Significance** |
| Negative | Low | Certain | MODERATE |

### *Disturbance From Shipping Traffic*

Vessels transiting to and from the FLNG location pose a risk for cetaceans and marine turtles due to the potential for collisions. However, vessel activity will occur away from recognised whale feeding and aggregation areas (see *Sections 5.4.1* and *5.4.2*) and the number of whales in the area of the FLNG facility is expected to be low.

Vessel movements between the project area and the Maintenance Workshop may cross the humpback migration routes if a Broome workshop is chosen. The operations phase of the project will require support vessels travelling to and from the Maintenance Workshop every one to two weeks. Offloading of product will involve one LNG tanker every week, one LPG tanker per month and one condensate tanker per fortnight calling at the FLNG facility. However, these are unlikely to transit across known migration paths.

The increase in vessel activity due to the project, relative to existing vessel movements in the area, is minimal (*Sections 5.7.2* and *5.7.4*) and is not expected to materially increase the likelihood of collisions with whales.

At decommissioning, the FLNG facility will be towed to another location. The type and number of vessel movements associated with decommissioning are expected to be similar to those during installation; hence impacts are expected to be similar.

From the above, the likelihood of project related vessels colliding with whales is considered to be unlikely and the magnitude of the impact is low.

The likelihood and magnitude of turtles and project vessels colliding is also considered unlikely and low because the project related vessels will be displacement hull vessels travelling at relatively slow speeds, compared to high speed planning hull ‘speed’ boats which are known to strike and kill larger numbers of turtles in certain parts of the world (eg Florida). Vessel speed has been demonstrated as a key factor in collisions with turtles, with faster vessels exerting a greater collision risk than slower vessels (Hazel et al.

2007). The significance of the impact is hence assessed to be minor.

| Disturbance from shipping traffic | | | |
|---|---|---|---|
| Impact | Magnitude | Likelihood | Significance |
| Negative | Low | Unlikely | MINOR |

### *Disturbance From Helicopter Movements*

Helicopter movements have the potential to impact on seabirds through direct strike. However, given the high visibility and noise levels associated with helicopter movements, seabirds are expected to avoid collisions with helicopters. The number of helicopter flights is relatively low, averaging one inward and outward flight per day during the construction and operational phases of the project, with a peak of two per day during the four month commissioning period. Collisions are therefore considered unlikely and the magnitude is considered low. The overall potential impact from helicopter movements associated with the project is therefore assessed to be minor.

| Disturbance from helicopter movements | | | |
|---|---|---|---|
| Impact | Magnitude | Likelihood | Significance |
| Negative | Low | Unlikely | MINOR |

### *Antifouling Leachate*

Any object submersed in marine waters for a period of time provides a potential habitat for marine organisms. Vessel hulls not protected by anti-fouling systems (typically an anti-fouling paint and sometimes an impressed current cathodic protection system) may gather as much as 150 kg/m$^2$ of 'fouling' (unwanted growth of biological material eg barnacles) in less than 6 months at sea (Fremantle Ports, 2002).

Historically, the main concern associated with the application of antifouling paints on vessel hulls was that the main chemical component, tributyltin (TBT), an organotin compound, had toxic effects on non-target marine species. In light of this, in the 1990s most countries around the world introduced a ban on the use of TBT paints for small craft (less than 25 m). In 1989 Australia prohibited the use of TBT-based paints on vessels less than 25 m in length. The International Maritime Organisation (IMO) introduced a global ban on the presence of TBT paints on ships as of 1 January 2008. The most common anti-fouling paints being applied as replacements for TBT-based paints are formulations containing copper (ANZECC, 2000) and 'booster biocides', such as Irgarol 1051 (a triazine herbicide), diuron and zinc pyrithione. Booster biocides are designed to leach slowly from the paint to prevent fouling build-up. Other formulations that are based on Teflon or silicon and present a smooth surface that prevents marine organisms attaching to the hull or on other subsea infrastructure are also available.

The FLNG facility is not expected to be dry docked during its operational life at the Prelude field. The FLNG hull will be coated with non-TBT paint to control fouling by marine organisms. Anti-fouling will be selected with a preference for least environmental harm while meeting operational requirements. The concentrations of leachates in the surrounding waters or sediments will thus be extremely low and less than concentrations required to elicit detectable biological effects. Given the dynamic, open ocean environment, the likelihood of any impact is assessed as unlikely.

Any effects of anti-fouling leachate will be localised to the artificial habitat provided by the subsea structures associated with the project area and hence are considered to be of low magnitude. The potential overall impact to the environment from anti-fouling associated with the project is therefore assessed to be minor.

The use of anti fouling on vessels and subsea structures associated with the project will not cause any significant impacts to listed species, migratory species or the surrounding marine environment.

| Antifouling Leachate | | | |
|---|---|---|---|
| Impact | Magnitude | Likelihood | Significance |
| Negative | Low | Unlikely | MINOR |

### 6.3.4 Safeguard/Mitigation Measures

The following mitigation measures have been incorporated into the project design and the project has committed to the following management measures to reduce negative impacts from the physical presence of the Prelude FLNG Project:

### *Installation of Physical Structures*

Design Mitigation Measures:

- The selection of project development concept as FLNG, which has a smaller environmental footprint than an onshore LNG plant development (with associated offshore platform, export pipeline and coastal dredging).
- Positioning of the FLNG facility and associated infrastructure in an area that does not have any known significant environmental sensitivities.
- Screens will be installed on the cooling water riser inlets and inlet current speeds will be low (estimated at 0.5 m/s) to prevent the ingress of large marine fauna into the cooling water system (see *Section 6.7.5*).
- TBT antifouling will not be used on the FLNG facility or associated subsea infrastructure.

### *Presence of Vessels/Aircraft*

Management Mitigation Measures:

- Vessel cetacean interaction procedures will be developed and relevant drilling, construction and supply contractors engaged by Shell will be obliged to comply with these. The procedures will include the requirement to maintain a watch for cetaceans when transiting, to not knowingly approach within 500 m of cetaceans, to take actions to avoid cetaceans located within a distance of 500 m from the vessel when safe to do so and to complete a 'Whale and Dolphin Sighting Report Sheet' (DEWHA, 2009) in the event cetaceans are sighted.
- Helicopter operators engaged by Shell will be obliged to route flight paths to avoid Browse Island, to fly above an altitude of 1,000 metres within a 300 metre horizontal radius of observed whales (except for take-off and landings) and to comply with Civil Aviation Authority procedures to reduce the potential for bird strikes from helicopters.

### *Summary of Impacts*

*Section 6.3* is summarised in *Table 6.7* and *Table 6.8.*

### *Conclusion*

The environmental impact associated with physical impacts from all phases of the Prelude FLNG Project has been evaluated and is assessed to have minor significance, except for the potential impact associated with direct disturbance of the seabed which was assessed to have a moderate significance. Potential impacts to the seabed have been reduced to ALARP and the seabed footprint of FLNG is considerably smaller than a offshore platform/export pipeline/onshore LNG plant alternative. No significant impacts to *EPBC Act* listed species, migratory species or the surrounding marine environment as a result of the physical presence of project infrastructure, vessels or helicopters are expected.

## 6.4 LIGHTING

### 6.4.1 Background

A large number of natural biological cycles in the ocean are driven by light cues. For example, light is generally considered to play an important role in the timing of the daily vertical migration of plankton (Frank and Widder, 1997; Kamykowski et al. 1998).

Artificial light from activities associated with the Prelude FLNG Project will result in light spill. Current sources of light in the vicinity of the Prelude FLNG Project area are limited to occasional vessel movements and oil and gas exploration activities. Such sources are temporary and the baseline illumination of the project area; therefore; is mainly limited to starlight and the lunar phase and cycle.

The amount of light spill generated from infrastructure and vessels in the Prelude FLNG Project area will be dependent on the number of light sources, the wavelength and intensity of the light sources, the location and/or placement of light fittings and the method of light switching. Light intensity, similar to noise, attenuates with distance.

### 6.4.2 Explanation of Modelling

An investigation has been conducted to determine the potential zones of effect from artificial light emanating from the Prelude FLNG Project on sensitive receptors such as marine turtles and migratory birds (ERM, 2009b).

A line of sight assessment was used (see *Section 6.10.2*) to determine the potential extent of visibility of the proposed light sources for marine turtles and migratory birds. Three factors are required to calculate line of sight; the location

*Table 6.7 Summary of Predicted Impacts from Installation of Physical Structures*

| **Impact** | | **Impact from installation of physical structures** | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Receptors** | | Benthic fauna and flora | | | | | | | |
| **Receptor Sensitivity** | | ■ | Low | | Medium | | High | | |
| The subsea infrastructure and production wells will cover an area of approximately 8000m$^2$. Physical presence and disturbance caused by drilling and the installation of subsea facilities will result in localised impacts to benthic habitats. | | | | | | | | | |
| **Drilling and Construction** | **Impact Nature** | ■ | Negative | | Positive | | | | |
| | **Impact Extent** | ■ | Local | | Regional | | National | | Global |
| | **Impact Duration** | | Rare/ short | | Occasional/ moderate | ■ | Regular/ long | | |
| | **Impact Magnitude** | ■ | Low | | Medium | | High | | |
| | **Likelihood** | | Unlikely | | Possible | | Probable | ■ | Certain |
| | **Significance** | | Minor | ■ | Moderate[1] | | Major | | Critical |
| **Commissioning** | **Impact Nature** | ■ | Negative | | Positive | | | | |
| | **Impact Extent** | ■ | Local | | Regional | | National | | Global |
| | **Impact Duration** | | Rare/ short | | Occasional/ moderate | ■ | Regular/ long | | |
| | **Impact Magnitude** | ■ | Low | | Medium | | High | | |
| | **Likelihood** | ■ | Unlikely | | Possible | | Probable | | Certain |
| | **Significance** | ■ | Minor | | Moderate | | Major | | Critical |
| **Operation/ Maintenance** | **Impact Nature** | ■ | Negative | | Positive | | | | |
| | **Impact Extent** | ■ | Local | | Regional | | National | | Global |
| | **Impact Duration** | | Rare/ short | | Occasional/ moderate | ■ | Regular/ long | | |
| | **Impact Magnitude** | ■ | Low | | Medium | | High | | |
| | **Likelihood** | ■ | Unlikely | | Possible | | Probable | | Certain |
| | **Significance** | ■ | Minor | | Moderate | | Major | | Critical |
| **Decommissioning/ Abandonment** | **Impact Nature** | ■ | Negative | | Positive | | | | |
| | **Impact Extent** | ■ | Local | | Regional | | National | | Global |
| | **Impact Duration** | | Rare/ short | | Occasional/ moderate | ■ | Regular/ long | | |
| | **Impact wMagnitude** | ■ | Low | | Medium | | High | | |
| | **Likelihood** | ■ | Unlikely | | Possible | | Probable | | Certain |
| | **Significance** | ■ | Minor | | Moderate | | Major | | Critical |

*Note: [1] relates to benthic fauna only.*

and height above sea level of the light source, the distance between the light source and the viewing location and height (where the light is viewed from), and the curvature of the earth's surface. This calculation can be made using a Line of Sight Calculator (Mats Kagstrom, 2005).

### 6.4.3 Sources and Characteristics

Sources of artificial light from project activities during each phase of the development are identified in *Table 6.9*.

#### *FLNG Facility*

A detailed plan of lighting for the FLNG facility will be developed during the Front-End Engineering and Design (FEED) phase. However, the FLNG facility will require 24 hour external illumination to meet maritime and operational safety standards.

Illumination sources associated with the FLNG facility include generic illumination, visual berthing aids and navigation lights. Where possible external lighting (except

## *Table 6.8 Presence of Vessels and Aircraft*

| Impact | | Impact from presence of vessels and aircraft | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Receptors** | | Cetaceans, including two threatened species (humpback whale and blue whale) may transit the project area.<br>Turtles, two vulnerable species (green and flatback turtle) may transit the project area. Green turtles also nest on Browse Island (~ 40 km from the FLNG facility location).<br>Fish, including one known threatened species (whale shark) may transit the project area.<br>Birds, including one known migratory marine species (streaked shearwater) may transit the project area. Four potential flights path for migratory shorebirds occur within 150 km of project area.<br>Plankton and benthic fauna | | | | | | | |
| **Receptor Sensitivity** | | | | | | | | | |
| **Fish, benthic fauna and flora, plankton** | | ■ | Low | | Medium | | High | | |
| **Seabirds, shorebirds** | | | Low | ■ | Medium | | High | | |
| **Cetaceans, turtles** | | | Low | | Medium | ■ | High | | |
| The likelihood of collisions between vessels and marine fauna (eg cetaceans and turtles) is low in view of the location of the facility remote from cetacean migration paths and congregation areas, and the comparably low vessel speeds. Impacts from helicopter movements are also anticipated to be low given the low frequency of flights, low abundance of birds and their avoidance behaviour. | | | | | | | | | |
| **Drilling and Construction** | **Impact Nature** | ■ | Negative | | Positive | | | | |
| | **Impact Extent** | ■ | Local | | Regional | | National | | Global |
| | **Impact Duration** | ■ | Rare/ short | | Occasional/ moderate | | Regular/ long | | |
| | **Impact Magnitude** | ■ | Low | | Medium | | High | | |
| | **Likelihood** | ■ | Unlikely | | Possible | | Probable | | Certain |
| | **Significance** | ■ | Minor | | Moderate | | Major | | Critical |
| **Commissioning** | **Impact Nature** | ■ | Negative | | Positive | | | | |
| | **Impact Extent** | ■ | Local | | Regional | | National | | Global |
| | **Impact Duration** | ■ | Rare/ short | | Occasional/ moderate | | Regular/ long | | |
| | **Impact Magnitude** | ■ | Low | | Medium | | High | | |
| | **Likelihood** | ■ | Unlikely | | Possible | | Probable | | Certain |
| | **Significance** | ■ | Minor | | Moderate | | Major | | Critical |
| **Operation/ Maintenance** | **Impact Nature** | ■ | Negative | | Positive | | | | |
| | **Impact Extent** | ■ | Local | | Regional | | National | | Global |
| | **Impact Duration** | | Rare/ short | | Occasional/ moderate | ■ | Regular/ long | | |
| | **Impact Magnitude** | ■ | Low | | Medium | | High | | |
| | **Likelihood** | ■ | Unlikely | | Possible | | Probable | | Certain |
| | **Significance** | ■ | Minor | | Moderate | | Major | | Critical |
| **Decommissioning/ Abandonment** | **Impact Nature** | ■ | Negative | | Positive | | | | |
| | **Impact Extent** | ■ | Local | | Regional | | National | | Global |
| | **Impact Duration** | ■ | Rare/ short | | Occasional/ moderate | | Regular/ long | | |
| | **Impact Magnitude** | ■ | Low | | Medium | | High | | |
| | **Likelihood** | ■ | Unlikely | | Possible | | Probable | | Certain |
| | **Significance** | ■ | Minor | | Moderate | | Major | | Critical |

*Table 6.9 Sources of Artificial Light During the Phases of the Prelude FLNG Project*

| Phase | Activity Source | Source Type | Duration |
|---|---|---|---|
| **Drilling and Construction** | Vessels (installation, support and supply vessels) | Navigation and generic lighting | 2 years |
| | Drilling rig | Navigation and generic lighting | 2 years |
| **Commissioning, Operation and Maintenance** | FLNG facility | Navigation and generic lighting, and visual berthing aids | 25 years |
| | Vessels (offtake tankers, support and supply vessels) | Navigation and generic lighting | 1-2 per week for 25 years |
| | Flaring | Flame | Intermittent during start-up; planned maintenance programs and emergencies only during operations |
| **Decommissioning** | Vessel movements | Navigation and generic lighting | 4 months |

navigation lights and signals) will be designed to reduce light spill on to the ocean by limiting the effects of reflecting surfaces and locating luminaries in such a way that they are directed inwards on the facility or shielded, as far as practicable, from ocean view points.

The "no flaring" principle for disposal of hydrocarbon streams generated by normal plant operations limits the extent and duration of flaring, however, flaring will still occur during process upsets, start-up and shut-down procedures and in emergency situations. The FLNG facility flare stacks will be installed in a common structure, located on the bow of the facility. The highest point of the flare stacks is proposed to be 154 m above sea level.

Additionally, the FLNG facility will be accompanied at different times by offtake tankers and various support vessels (each with external illumination to meet maritime safety standards).

### *Vessels and Drilling Rig*

Functional lighting will also be required on rigs and vessels to meet navigation and safety requirements. Lighting associated with offshore construction vessels and activities typically consists of bright white (metal halide, halogen, florescent) lights. These lights will be used on a 24-hour basis in accordance with safety requirements. Support vessels will also require 24-hour lighting.

## 6.4.4 Description of the Impact

The presence of artificial lighting associated with activities during all phases of the Prelude FLNG Project has the potential to impact marine fauna and birds, particularly those that use visual cues for orientation, navigation, or other purposes. Impacts from artificial lighting associated with the Prelude FLNG Project may include the following:

- disorientation, attraction or repulsion;
- disruption to natural behavioural patterns and cycles; and
- secondary impacts such as increased predation and reduced fitness.

## 6.4.5 Receptors

Species expected to inhabit or migrate through the project area that are known to be susceptible to impacts from artificial light are described below. Potentially sensitive species include turtles, migratory birds and fish.

### *Turtles*

Two species of marine turtle may migrate through the project area; the green turtle (*Chelonia mydas*) and the flatback turtle (*Natator depressus*). Of these, only green turtles are known to nest in significant numbers on Browse Island (43 km to the southeast of the Prelude FLNG Project area) (see *Section 5.4*).

Light pollution on nesting beaches can alter critical nocturnal behaviours in adult and hatchling turtles. Research suggests that artificial lighting can disrupt or affect the choice of nesting location by female turtles, particularly light visible on the landward side of nesting beaches (Salmon, 2003). Extensive light attraction studies have also been conducted on turtle hatchlings, including recently at Barrow Island (Pendoley, 2005), approximately 1000 km southwest of the Prelude FLNG Project area. These studies demonstrated that hatchlings crawl away from tall, dark horizons (sand dunes and vegetation) towards lower and lighter horizons (the sea and stars), and that artificial lighting can alter this response. Once in the water, hatchling navigation is understood to be influenced predominantly by wave motion, currents and the earth's magnetic field (Lohmann and Lohmann, 1992), rather than light.

Studies also suggest that light generated by flares may not affect hatchlings as much as other light sources. Witherington and Bjorndal (1991) examined the roles of light wavelength and intensity in the sea-finding mechanisms of loggerhead and green turtle hatchlings, and found the most disruptive wavelengths to be in the range of 300 to 500 nanometers. Spectral analysis of flares on Thevenard Island on the NWS (Pendoley, 2000) suggests that flare light does not contain a high proportion of light wavelengths within this range.

### *Seabirds*

Studies conducted between 1992 and 2002 in the North Sea confirmed that artificial light was the reason that birds were attracted to and accumulated around lit offshore infrastructure (Marquenie et al. 2008) and that lights can attract birds from large catchment areas (Wiese et al. 2001). Birds may either be attracted by the light source itself or indirectly as structures in deep water environments tend to attract marine life at all trophic levels, creating food sources and shelter for seabirds (Surnam, 2002). The light from operating production facilities and flares may also provide enhanced capability for sea birds to forage at night.

Negative potential impacts to seabirds attracted by artificial lighting are limited but includes collisions with infrastructure and flares and alteration of normal behaviours.

### *Migratory Birds*

As discussed in *Section 5.4*, there are recognised sites of importance for migratory shorebirds on the coast of northwest Western Australia (Roebuck Bay, 80 Mile Beach and the Lacepede Islands) and at Ashmore and Cartier Islands (175 km north of the title area). Migratory birds may pass in the vicinity of the Prelude FLNG Project area 'en route' between these sites on mainland Australia and destinations on offshore islands or locations such as East Timor, Indonesia, Malaysia and Papua New Guinea.

Whilst little is known about how migratory birds navigate, particularly over oceans and in the absence of terrestrial landmarks, many are thought to use the Earth's magnetic field, stars, the Sun and polarised light patterns to determine their migratory direction. If migratory birds are reliant on visual cues such as ambient light, moonlight and starlight to navigate, then artificial light could alter their natural migratory patterns, particularly in the absence of terrestrial landmarks.

Light from offshore platforms has been shown to attract migrating birds and birds that migrate during the night are especially affected (Verheijen, 1985). Currently, very little research has been undertaken into why migrating birds are attracted toward artificially lit structures or the impact of this attraction on the population of the migratory birds. Gauthreaux and Belser (2006) discuss several hypotheses of why attraction occurs. The favoured hypothesis involves the possibility that artificial lighting over-rides the magnetic compass. In addition to possessing an internal magnetic compass, it is assumed that migrating birds use visual cues for orientation (Åkesson and Bäckman, 1999; Mouritsen and Larsen, 2001).

During studies conducted in the North Sea, Marquenie et al. (not dated) noted that birds travelling within a 5 km radius of illuminated offshore platforms deviate from their intended route and either circle or landed on the nearby platform. Beyond this distance, it is assumed that light source strengths were not sufficient to attract birds away from their preferred migration route.

Additional findings of this study, published by Van De Laar (2007), determined that birds are particularly sensitive and also attracted to the orange to red portion of the visible light spectrum. This equates to the wavelength range of roughly 590 – 750 nanometers within the electromagnetic spectrum. As most offshore infrastructure and vessels contain primarily white and orange (sodium vapour) coloured luminaries, a significant proportion of the total light emitted is within this range.

Van De Laar, (2007), documented that by replacing 152 of a possible 176 orange, red and white lights with primarily green and blue lights on an offshore oil platform, two to ten times fewer birds were noted to be attracted to and circled the platform. If all lights were to be replaced, it was estimated that 90% of all bird attraction could be eliminated.

Whilst attraction to light sources is well documented, the potential impacts on the population viability of migratory seabirds, if any, which result from this attraction to light sources is not well understood.

### *Fish and Invertebrates*

Fish and zooplankton may be directly or indirectly attracted to lights. 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 platforms' light fields.

The concentration of organisms attracted to light results in an increase in food source for predatory species and marine predators are known to aggregate at the edges of artificial light halos. Shaw et al. (2002), in a similar light trap study, noted that juvenile tunas (Scombridae) and jacks (Carangidae), which are highly predatory, may have been preying upon concentrations of zooplankton attracted to the light field of the platforms. This could potentially led to increased predation rates compared to unlit areas.

### *Cetaceans*

There is no evidence to suggest that artificial light sources impact on the migratory, feeding or breeding behaviours of cetaceans. Cetaceans predominantly utilize acoustic senses to survey their environment, rather than vision (Simmonds et al. 2004). It is therefore considered artificial lighting associated with the Prelude FLNG Project is unlikely to impact on cetacean species.

## 6.4.6 Evaluation of Impact

The impacts from artificial light from project activities have been evaluated below for each of the following project phases:

- drilling and construction;
- commissioning and operation and maintenance; and
- decommissioning.

### *Drilling and Construction*

The MODU and support vessels will be on location in the Prelude FLNG Project area for approximately 24 months, thereby limiting the duration of any lighting effects. Construction activities will be 40 km from the nearest turtle breeding location on Browse Island and are not expected to cause any disruption to normal breeding behaviour.

Lighting impacts from project activities during construction and installation are therefore expected to be unlikely and of low magnitude, and are evaluated as minor.

| Artificial Light During Drilling and Construction | | | |
|---|---|---|---|
| Impact | Magnitude | Likelihood | Significance |
| Negative | Low | Unlikely | MINOR |

### *Commissioning and Operation and Maintenance*

*Table 6.10* outlines the extent to which the light sources from the operational FLNG facility and the associated lighting impacts can be expected for the identified receptors (marine turtles and migratory birds).

*Table 6.10 Line of Sight Limits for Turtles and Migratory Birds*

| Proposed Light Source | Marine Turtles (limit of light visibility) | Migratory Birds (limit of light visibility) |
|---|---|---|
| Flare (when operating) | 51 km | 151 km |
| Processing Deck | 27 km | 127 km |
| Glow from combined luminaries | Effects expected to be minimal given the low levels of particulate matter in the air offshore | |

### a) Turtles

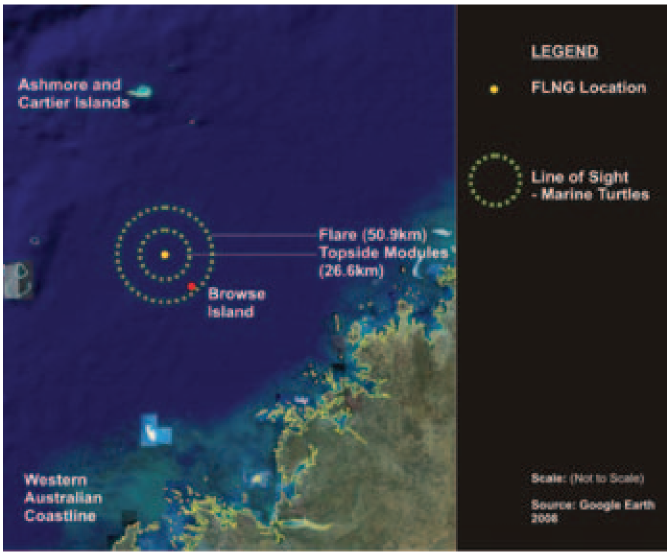
Turtles in the waters surrounding or on the beaches of Browse Island will not be able to see the lighting of the FLNG facility. However, the flare, only when in use, will be potentially visible to turtles out to a distance of 51 km from the FLNG facility (*Figure 6.4* and *Table 6.10*), which encompasses Browse Island.

The flare will be potentially visible from the northern beaches of Browse Island low on the seaward horizon with an intensity visually similar to a bright star. As the flare will be low on the horizon, the Island's landmass will block light from the flare to the southern beaches so that no beaches on Browse Island will be subjected to light from the flare on their landward horizon and the landward horizons will remain unaltered to nesting and hatchling turtles.

Given the limited amount of flaring that will occur, especially during the operational phase of the project, the distance of the FLNG facility from Browse Island and the unaltered landward horizon at Browse Island, the impacts on turtle hatchlings and adult turtles are considered to be of a low magnitude and are assessed to be of minor significance.

| Turtles From Artificial Lighting During Operations and Maintenance | | | |
|---|---|---|---|
| Impact | Magnitude | Likelihood | Significance |
| Negative | Low | Unlikely | MINOR |

*Figure 6.4 Limits of visibility for Marine Turtles*



Scale: (Not to Scale)

Source: Google Earth 2008

### b) Migratory Birds and Seabirds

When considering line of sight with respects to light assessment for migratory birds, three factors must be considered:

- The location and height of the light source (FLNG facility);
- The distance between the light source and the receptor; and
- The potential elevation of the receptor (migratory birds).

Migratory birds that have been identified as potential receptors to this light study are known to fly at altitudes of between 150 and 600 m. To be conservative, this assessment has used an elevation of 600 m as the potential maximum elevation of the migratory birds.

Based on a potential flying height of 600 m, the light from the FLNG facility will be visible to migratory birds out to a distance of approximately 151 km when the flare is operational or 127 km when the flare is not being used (*Figure 6.5*).

Within 151 km of the proposed FLNG facility there are four suspected migratory bird flight paths as described below. The flight paths are based on direct movement between known sites of importance for nesting and foraging in the region.

Each potential flight path (see *Figure 6.5*) is listed below in order of the proximity to the FLNG facility:

**Route 1:** Ashmore Reef and Cartier Islands to the site labelled 80 Mile Beach (proximity to FLNG facility: 20 km; approximate route length: 480 km). Note that the site labelled 80 Mile Beach is not the same as the beach with the same name.

**Route 2:** Ashmore Reef and Cartier Islands to the Lacepede Islands (proximity to FLNG facility: 34 km; approximate route length: 505 km).

**Route 3:** Ashmore Reef and Cartier Islands to Roebuck Bay (proximity to FLNG facility: 34 km; approximate route length: 620 km).

**Route 4:** Ashmore reef and Cartier Islands to Barrow Island (proximity to FLNG facility: 126 km; approximate route length: 1280 km).

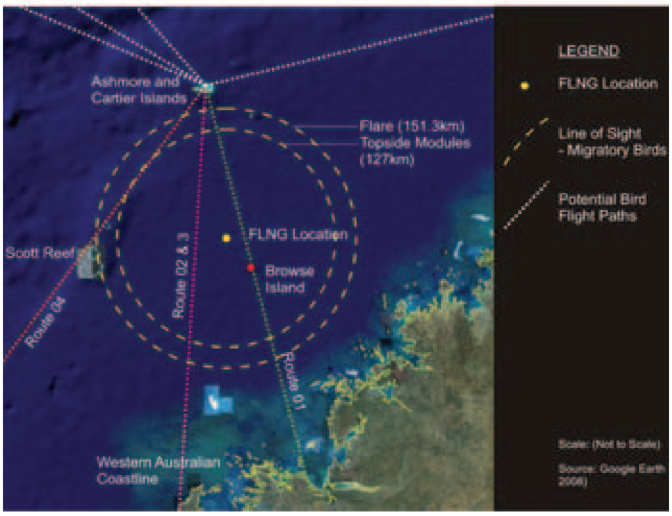
According to Bamford et al. (2008), of the 33 species of migratory birds that use East Asian-Australian Flyway (EAAF) four are expected to use the four identified potential flight paths located within 151 km of the FLNG facility. The four species and their abundance (percentage) within these four potential flight paths, relative to their estimated Australian population, are listed below:

- greater sand plover (2%);
- grey plover (12%);
- grey-tailed tattler (3%); and
- ruddy turnstone (11%).

The four migratory pathways located within 151 km of the FLNG facility are only used by a small percentage of the four species of migratory birds, with the vast majority of individuals belonging to these four species using other migratory pathways beyond the line of sight of the FLNG facility. The *EPBC Act* listed streaked shearwater bird was not identified as using the EAAF or the migratory pathways located within 151 km of the FLNG facility in Bamford's study.

As defined previously, the documented zone of attraction to light sources for migratory birds is two orders of magnitude smaller than the limit of visibility, at a radius of 5 km from an artificial light source.

*Figure 6.5 Limit of Visibility for Migratory Birds and Proximity of Potential Migratory Routes.*



The nearest potential route (Route 1) is approximately 20 km from the FLNG facility at its closest point. Whilst it is recognised that the exact routes are unknown and prevailing winds could result in deviations from the flight paths, given a distance range of 20 km between the nearest potential migratory bird route and the FLNG facility, it is considered unlikely that migratory birds will be attracted to the lighting of the FLNG facility in significant numbers.

Even with the worst case scenario assumption of all individuals using the migratory pathways located within 151 km of the FLNG facility being attracted to the FLNG facility, the magnitude of any impact is considered medium, and hence the significance of potential artificial lighting impacts on migratory birds is assessed to be minor. As discussed above, this worst case scenario is not considered credible so the magnitude of the predicted impact should be even less than the medium assessed in this ESHIA.

Seabirds may be attracted to lighting from the FLNG facility, partly due to enhanced night time feeding capability, and are likely to habituate to the presence of the FLNG facility. The likelihood of such a response is considered possible and the magnitude of the effect on the seabirds is considered low. The significance of artificial lighting on seabirds is therefore assessed to be minor.

<table>
<tr><th colspan="4">Migratory Birds From Artificial Lighting During Operations and Maintenance</th></tr>
<tr><td>Impact</td><td>Magnitude</td><td>Likelihood</td><td>Significance</td></tr>
<tr><td>Negative</td><td>Medium</td><td>Unlikely</td><td>MINOR</td></tr>
</table>

<table>
<tr><th colspan="4">Seabirds From Artificial Lighting During Operations and Maintenance</th></tr>
<tr><td>Impact</td><td>Magnitude</td><td>Likelihood</td><td>Significance</td></tr>
<tr><td>Negative</td><td>Low</td><td>Possible</td><td>MINOR</td></tr>
</table>

### c) Fish And Invertebrates

The range of attraction for fish and invertebrates to lighting from the FLNG facility is expected to be localised and the likelihood of impacts is considered to be unlikely and the magnitude low. The significance is therefore assessed to be minor.

| Fish and Invertebrates From Artificial Lighting During Operations and Maintenance | | | |
|---|---|---|---|
| Impact | Magnitude | Likelihood | Significance |
| Negative | Low | Unlikely | MINOR |

*Decommissioning*

Vessels involved in the decommissioning of infrastructure in the Prelude FLNG Project area will be on location for a brief length of time, thereby limiting any effects of lighting to nearby areas. Decommissioning activities will be distant from the nearest turtle breeding location on Browse Island and are not expected to cause any disruption to normal breeding behaviour. Lighting impacts from development activities during decommissioning are assessed as being unlikely and of low magnitude and therefore evaluated as a minor significance.

| Artificial Light During Decommissioning | | | |
|---|---|---|---|
| Impact | Magnitude | Likelihood | Significance |
| Negative | Low | Unlikely | MINOR |

### 6.4.7 Safeguard/Mitigation Measures

The following mitigation measures have been incorporated into the project design and the project has committed to the following management measures to reduce artificial lighting impacts from the Prelude FLNG Project:

Design Mitigation Measures:

- Locating the FLNG facility in an area that is distant to the closest known significant environmental sensitivities.
- Lighting of the FLNG facility will be designed with the objective of reducing light spill, subject to meeting all workplace health and safety, and navigational requirements. Design measures that will be considered will include:
    - limiting the effects of reflecting surfaces by assessing the location of luminaries and the use of low-reflective paints;
    - locating luminaries in such a way that they are shielded as far as practicable from direct line-of-sight from surrounding view points;
    - directing luminaries inwards on the FLNG facility and away from the ocean; and
    - the preferential use of low-impact spectrum illumination (including the use of green or blue lighting) over red, orange and white external lighting.
- The FLNG facility will be designed to reuse hydrocarbon waste streams generated by normal operations ("no flaring principle"), limiting the extent and duration of flaring.

*Management Mitigation Measures*

- Continuous illumination of work and accommodation areas on the FLNG facility and supply vessels will be limited wherever practicable to prevent attraction of marine and bird life, although any measures adopted will not compromise safety or navigational requirements.
- Procedures will be designed to limit the occurrence and duration of flaring to ALARP.

### 6.4.8 Summary

*Section 6.4* is summarised in *Table 6.11*.

### 6.4.9 Conclusion

The environmental impact associated with light emitted from all phases of the Prelude FLNG Project has been evaluated and is predicted to be minor. As a result, no significant impacts to *EPBC Act* listed species, migratory species or the surrounding marine environment are expected.

## 6.5 UNDERWATER NOISE

### 6.5.1 Explanation of Modelling

Underwater noise modelling of the likely extent of noise propagation into the marine environment from FLNG facility operations was undertaken by Curtin University's Centre for Marine Science and Technology (Duncan and McCauley, 2008). The proposed FLNG facility is the first of its type and therefore there are no direct underwater noise measurements for a similar facility available. The noise source model used for operation is therefore based on measurements of the underwater noise produced by an

*Table 6.11 Summary of Predicted Impacts from Artificial Lighting*

| Impact | | Impact from Artificial Lighting | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Receptors** | Cetaceans, including two threatened species (humpback whale and blue whale) may transit the project area.<br>Turtles, two vulnerable species (green and flatback turtle) may transit the project area. Green turtles also nest on Browse Island (~ 40 km from the FLNG facility location).<br>Fish, including one known threatened species (whale shark) may transit the project area.<br>Birds, including one known migratory marine species (streaked shearwater) may transit the project area. Four potential flights path for migratory shorebirds occur within 150 km of project area. | | | | | | | | |
| **Receptor Sensitivity** | | | | | | | | | |
| **Cetaceans** | | ■ | Low | ☐ | Medium | ☐ | High | | |
| **Fish** | | ☐ | Low | ■ | Medium | ☐ | High | | |
| **Turtles, birds** | | ☐ | Low | ☐ | Medium | ■ | High | | |
| Artificial lighting will be present through all stages of the project and has the potential to impact marine fauna that use visual cues for orientation, navigation etc. Potential impacts include disorientation or attraction/repulsion and disruption to natural patterns/cycles. The predominant effect of exposure to artificial light on turtles is moderation of natural behaviour, especially during nesting and hatchling. However, the nearest nesting beach to the project is Browse Island, 40 km from the FLNG facility, so lighting is not expected to disrupt breeding/nesting behaviour. The flaring from the FLNG facility is likely to be visible at the horizon from Browse Island. The appearance of the flare is not expected to affect nesting turtles or hatchlings due to its location on the horizon, not behind the nesting beaches. The FLNG facility is located near potential flight paths for migratory shorebirds and lighting may attract birds within a 5 km radius. FLNG facility lighting and colours will be designed to reduce light spill and flaring will be minimised. | | | | | | | | | |
| **Drilling and Construction** | **Impact Nature** | ■ | Negative | ☐ | Positive | | | | |
| | **Impact Extent** | ■ | Local | ☐ | Regional | ☐ | National | ☐ | Global |
| | **Impact Duration** | ■ | Rare/ short | ☐ | Occasional/ moderate | ☐ | Regular/ long | | |
| | **Impact Magnitude** | ■ | Low | ☐ | Medium | ☐ | High | | |
| | **Likelihood** | ☐ | Unlikely | ■ | Possible[1] | ☐ | Probable | ☐ | Certain |
| | **Significance** | ■ | Minor | ☐ | Moderate | ☐ | Major | ☐ | Critical |
| **Commissioning** | **Impact Nature** | ■ | Negative | ☐ | Positive | | | | |
| | **Impact Extent** | ■ | Local | ☐ | Regional | ☐ | National | ☐ | Global |
| | **Impact Duration** | ■ | Rare/ short | ☐ | Occasional/ moderate | ☐ | Regular/ long | | |
| | **Impact Magnitude** | ■ | Low | ☐ | Medium | ☐ | High | | |
| | **Likelihood** | ☐ | Unlikely | ■ | Possible[1] | ☐ | Probable | ☐ | Certain |
| | **Significance** | ■ | Minor | ☐ | Moderate | ☐ | Major | ☐ | Critical |
| **Operation/ Maintenance** | **Impact Nature** | ■ | Negative | ☐ | Positive | | | | |
| | **Impact Extent** | ■ | Local | ☐ | Regional | ☐ | National | ☐ | Global |
| | **Impact Duration** | ☐ | Rare/ short | ☐ | Occasional/ moderate | ■ | Regular/ long | | |
| | **Impact Magnitude** | ■ | Low | ☐ | Medium | ☐ | High | | |
| | **Likelihood** | ☐ | Unlikely | ■ | Possible[1] | ☐ | Probable | ☐ | Certain |
| | **Significance** | ■ | Minor | ☐ | Moderate | ☐ | Major | ☐ | Critical |
| **Decommissioning/ Abandonment** | **Impact Nature** | ■ | Negative | ☐ | Positive | | | | |
| | **Impact Extent** | ■ | Local | ☐ | Regional | ☐ | National | ☐ | Global |
| | **Impact Duration** | ■ | Rare/ short | ☐ | Occasional/ moderate | ☐ | Regular/ long | | |
| | **Impact Magnitude** | ■ | Low | ☐ | Medium | ☐ | High | | |
| | **Likelihood** | ☐ | Unlikely | ■ | Possible[1] | ☐ | Probable | ☐ | Certain |
| | **Significance** | ■ | Minor | ☐ | Moderate | ☐ | Major | ☐ | Critical |

*Note: [1] relates to sea birds only.*

FPSO facility, the *Cossack Pioneer* (McCauley, 2002), with sound levels extrapolated to those expected for the Prelude FLNG facility based on a comparison between the two facilities.

Modelling was conducted separately for the FLNG facility during 'normal' operations without product offtake and during offtake of LNG/LPG/condensate from the facility. Sound propagation modelling was carried out for four different seasons and no seasonal pattern of sound propagation was identified, therefore, underwater noise is not discussed further in the context of season.

The results of the modelling are summarised in the following sections, accompanied by an assessment and evaluation of the impacts.

### 6.5.2 Background

The definition of sound level depends on a number of factors, including the intensity of the sound wave, the frequency and the length of the sound exposure and whether the sound is propagating in air or in water. Sound is transmitted more efficiently through water, compared to air, and can therefore be detected at much greater distances from the source. The standard scientific approach is to describe underwater sound levels in terms of sound pressure. While a decibel (dB) is a relative measure of sound level, in order to make this measure meaningful for underwater sound, it is referenced to a standard 'reference pressure' of 1µPa (dB re 1µPa). Underwater noise is also measured over a specified frequency, usually either a 1Hz bandwidth (expressed in dB re 1µPa$^2$/Hz) or over a broadband that has not been filtered. Where the frequency has not been expressed, it may be assumed that the measurement is a broadband measurement.

### 6.5.3 Sources and Characteristics of Project Noise

Sources of underwater noise from activities during each phase of the project are identified in *Table 6.12*. These include vessels during all phases of the project, drilling, subsea facilities installation and operation of the FLNG facility.

#### *Vessels*

During the construction and installation phases of the Prelude FLNG Project, vessels operating in the project area will include support and installation vessels and drilling rigs. Vessel noise varies with the size, speed, engine type of the vessel and the activities being undertaken. Smaller, faster vessels typically produce higher-frequency sound at lower source levels than large, relatively slow-moving ships. The sound level from a given vessel is also highly dependent upon its speed, declining rapidly as a vessel slows from its normal cruising speed. Vessels may use thrusters for dynamic positioning or anchors to maintain position. If vessels use thrusters then the noise produced could be audible for many kilometres. Other sources of noise will be on-board cranes, compressors and generators. Shipboard sound are generally transmitted as continuous broad-band sounds through the hulls of the vessels (Sakhalin Energy, 2003).

*Table 6.12 Sources of Underwater Noise during the Phases of the Prelude FLNG Project*

| Phase | Activity Source | Duration |
|---|---|---|
| Drilling and Construction | Support vessel movements | 2-3 per week for 2 years |
| | Drilling and Subsea facilities installation | 2 years |
| | Helicopter movements | Daily for 2 years |
| Commissioning | Hook-up and commissioning of FLNG facility | 6 months |
| | Support vessel movements | Weekly for 6 months |
| | Helicopter movements | Twice daily for 6 months |
| Operation and Maintenance | FLNG facility normal operations | 25 years |
| | FLNG facility offtake operations | 1-2 vessels weekly for 25 years |
| | Support vessel movements | Fortnightly for 25 years |
| | Helicopter movements | Daily for 25 years |
| Decommissioning | Support vessel movements | 4 months |

Specialist installation vessels will be used to install the subsea infrastructure and tugs will be used to transport and manoeuvre the FLNG facility to its location within the Prelude field. Support vessels will be used routinely during all phases of the project. It is anticipated that the drilling rig will require a supply vessel call every two to three days during construction. During production, supplies to and wastes from the FLNG facility will be transported via purpose built supply vessels. It is anticipated that one supply vessel visit to the facility will be required per week. In addition, one support vessel will be required on standby at the facility at all times. Noise from offtake tankers and support tugs are discussed in conjunction with the FLNG facility below.

*Table 6.13* shows estimated noise source levels at 1 metre from a range of vessels. Received levels at a range of 50 m would be around 34 dB lower than at a 1 meter range. Support vessel sound emissions are generally dominated by low frequencies below 1kHz (Simmonds et al. 2004). Broadband source levels for most small ships underway are approximately 170-180 dB re 1µPa and drop with reduced speed (Richardson et al. 1995; Simmonds et al. 2004).

### *Drilling*

Noise produced from drilling ships and rigs is predominantly below 2 kHz, with peak frequencies below 500Hz with a wide range of broadband values (59 to 185db re 1µPa) (Simmonds et al. 2004). In the Otway Basin, Woodside (2002) measured ocean noise at a distance of approximately 5.1 km from a semi-submersible MODU over a period of 32 days. Drilling noise was dominated by sharp tones (<100 Hz) with little high frequency noise. The maximum broadband noise level recorded was 145 db re 1 µPa and noise levels exceeding 100 db re 1 µPa and 120 db re 1 µPa, 70.55% and 0.69% of the time respectively across the duration of the drilling operations (Woodside, 2002).

### *Helicopters*

It is anticipated that three return flights per week will be required from the operating base to the Prelude FLNG Project site during the drilling and construction phase. Six return flights per week are anticipated to be required during normal operations of the FLNG facility.

The main acoustic source associated with helicopters is the impulsive noise from the main rotor. The rotating blades produce tones with fundamental frequencies proportional to the rotation rate and number of blades. Dominant tones in noise spectra from helicopters are generally below 500 Hz (Richardson et al. 1995). There may be a large number of tones at many frequencies from the rotation of the blades and the engines.

Sound travelling from a source in the air to a receiver underwater is affected by both in-air and underwater propagation processes. Underwater noise from a passing helicopter is generally brief in duration, especially when compared with the duration of audibility in the air. The level of underwater sound from helicopters is affected by helicopter altitude, aspect and strength of noise emitted, and the receiver depth, water depth and other variables (Richardson et al. 1995).

*Table 6.13 Sound Frequencies and Source Levels Produced by Shipping Traffic.*

| Type of vessel | Frequency (kHz) | Source level (dB re 1µPa-m) | Reference |
|---|---|---|---|
| MODU support vessel (holding station) | Broadband | 182 | McCauley, 1998 |
| Tug pulling empty barge | 0.037 (tone)<br>1.0 (1/3 octave)<br>5.0 (1/3 octave) | 166<br>164<br>145 | Buck and Chalfant, 1972<br>Miles et al,. 1989 |
| Tug pulling loaded barge | 1.0 (1/3 octave)<br>5.0 (1/3 octave) | 170<br>161 | Miles et al,. 1989 |
| 34m twin diesel engine workboat | 0.63 (1/3 octave) | 159 | Malme et al. 1989 |
| Tanker (179m)<br>Supertanker (266m) | 0.06 (tone)<br>0.008 (tone) | 180<br>187 | Ross, 1976<br>Thilele and Ødengaard, 1983 |

*Source: Simmonds et al. 2004*

In general, the peak received level in the water as a helicopter passes directly overhead decreases with increasing altitude. Received level also diminishes with increasing receiver depth when the helicopter is directly overhead. However, when a helicopter is not directly overhead, helicopter noise can be stronger at mid-water than at shallow depths (Richardson et al, 1995). The angle at which a line drawn between an aircraft and underwater receiver intersects the water surface is important. In calm conditions, at angles greater than 13° from the vertical, much of the sound is generally reflected and does not penetrate the water (Richardson et al. 1995; NRC, 2003).

*Table 6.14* provides an example of noise levels from a Bell 212 helicopter, which is indicative of helicopters used to service offshore installations.

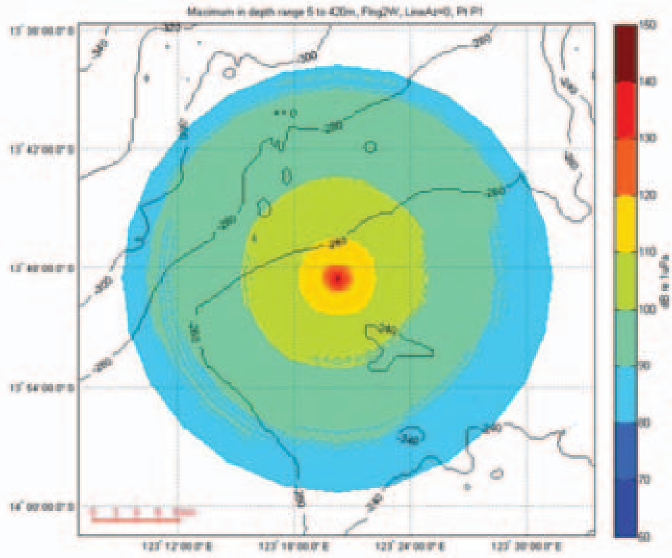
## *FLNG Facility*

### a) Normal operations with no product offtake activities

At times when the FLNG facility is not offloading to tankers, its underwater noise signature is expected to be dominated by the noise produced by the onboard plant. This includes the steam turbine generators, boilers, air compressors and pumps located within the hull and topsides process equipment including compressors and motors.

The resulting noise levels from the FLNG facility during normal operations are predicted to peak at 50 Hz and the overall source level in the frequency range 10 Hz to 2 kHz is predicted to be 189.1dB re 1µPa at one metre (compared with 180.61 dB re 1µPa at one metre for the *Cossack Pioneer*). *Figure 6.6* shows predicted maximum received noise levels from FLNG facility plant as described above.

*Figure 6.6 Predicted Maximum Received Noise Levels at Any Depth Due to Non-Offtake activities.*



### b) Normal operations concurrent with product offtake operations

The highest underwater noise levels produced during the operation of the FLNG facility are modelled to occur during the docking and undocking of the vessels that will offload the LNG and LPG.

It is anticipated that an LNG carrier will visit the FLNG facility on a weekly basis and an LPG tanker monthly. LNG and LPG vessels will moor alongside the FLNG facility and will be supported by two tugs. Offloading is expected to take 14 hours for a 155,000 $m^3$ LNG carrier and 28 hours for an 80,000 $m^3$ LPG carrier. Condensate tankers will be moored astern of the facility using only one tug and will take approximately 20 hours to load 100,000 $m^3$ of condensate.

*Table 6.14 Summary of noise from a Bell 212 helicopter*

| Frequency (Hz) | Altitude (m) | Received level (dB re 1µPa) | Estimated source spectral density level in dB re 1 (µPa-m)²/Hz at frequency (Hz) | | | |
|---|---|---|---|---|---|---|
| | | | 1000 | 2000 | 4000 | 8000 |
| 22 (tone) | 152 | 109 | 111 | 107 | 101 | 93 |
| | 305 | 107 | | | | |
| | 610 | 101 | | | | |

*Source: Richardson et al. 1995*

The alongside offloading configurations for the LNG and LPG carriers are likely to involve the simultaneous operation of thrusters on the FLNG facility, thrusters on the two high performance offshore support tugs and the main engines of the docking tanker. Thrusters on the FLNG facility and tugs will be generating high levels of thrust in poor flow conditions, resulting in significant propeller cavitation[16] and consequent high underwater noise levels. This will occur over an approximately 2 hour period during berthing and similarly during un-berthing operations.

The noise source model used for operation of the thrusters is based on measurements of underwater sound levels produced by a rig tender (*Pacific Ariki*) on dynamic positioning (McCauley, 1998). Levels have been extrapolated to those expected for offtake vessels.

The predicted noise levels peak in the frequency range 200 to 400Hz. The corresponding broadband source levels over 10 Hz to 2 kHz are predicted to be 188.9 dB re 1µPa at one metre for the FLNG facility and 189.7dB re 1 µPa at one metre for the combined effect of two tugs. If all sources are co-located, their combined source level is predicted to be 192.4 dB re 1µPa at 1 metre.

*Figure 6.7* shows the maximum predicted received level of noise at any depth as a function of range and azimuth for the different sources during offtake operations, as well as their combined effect. The seabed slope produces an asymmetry in the noise levels, with higher levels occurring in the down-slope (ie offshore) direction at a given distance and the lower levels up-slope (ie inshore direction). The highest received noise levels through the ocean depth profile are found at a depth of about 20 m.

### c) Maximum ranges for specific received levels

*Table 6.15* illustrates the maximum distances from the FLNG facility at which particular noise levels from normal operations and offtake operations are likely to be exceeded.

*Table 6.15 Maximum Distance from FLNG facility at which the Specified Received Levels are Exceeded.*

| Received Noise Level in 10 Hz to 2 kHz band (dB re 1 Pa) | Cavitation noise during offtake operations | Plant noise during normal operations |
|---|---|---|
| 160 | 60 m | (17 m) |
| 150 | 200 m | 50 m |
| 140 | 850 m | 190 m |
| 130 | 3.7 km | 600 m |
| 120 | 9 km | 1.3 km |
| 110 | 17 km | 4.5 km |
| 100 | 30 km | 10 km |
| 90 | 44 km | 20 km |

*Note: Value in brackets obtained by extrapolation.*

### 6.5.4 Description of the Impact

The use of sound in the underwater environment is important for marine animals, particularly cetaceans, to navigate, communicate and forage effectively. Underwater noise may impact on marine organisms in the following ways:

- disturbance, leading to behavioural changes or displacement from areas;
- masking or interference with other biologically important sounds such as communication or echolocation (used by certain cetaceans for location of prey and other objects);
- physical injury to hearing or other organs; and
- indirectly by inducing behavioural and physiological changes in predator or prey species.

The extent of the impacts of underwater noise on marine animals will depend upon the frequency range and intensity of the noise produced, and upon the hearing, vocalisation and other biological characteristics of the organism affected. The effects of sound on organisms have mostly been studied in cetaceans, with much less known about the effects of sound on other groups of animals.

Direct studies of hearing in marine animals are limited to a few species. Where direct measurements of hearing are not

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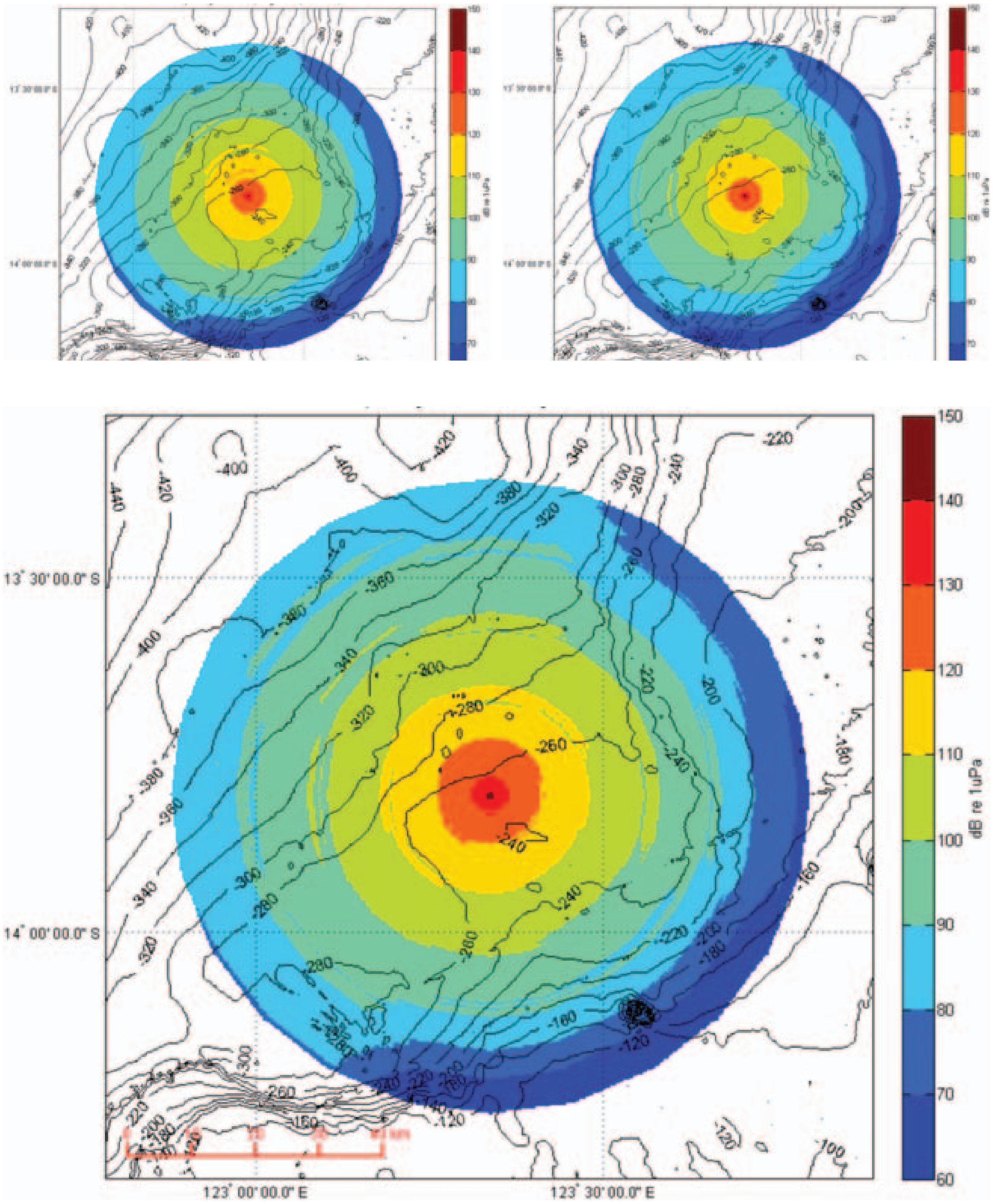
[16] *As a propeller rotates through the water, regions of low or negative pressure are created at the propeller tips. If and when these negative pressures become sufficiently strong, bubbles (cavities) form. These bubbles are short lived and a sharp pulse of sound is produced as the bubble collapses 'cavitation'.*

*Figure 6.7* *Predicted Maximum Received Noise Levels at Any Depth During Offtake Activities. Top Left shows FLNG Facility Only. Top Right shows 2 x Tugs only. Bottom shows noise levels generated by Combined Tugs and FLNG Facility.*



*Note: Change in scale compared to Figure 6.6* available, vocalisation frequencies can provide an indication of hearing sensitivities ie it is likely that marine animal hearing is particularly sensitive for sound frequencies that are the same as their social calls and echolocation clicks (Simmonds et al. 2004). Similarly, vocalisations can indicate the range of noise frequencies that has the potential to mask or interfere with communication.

### 6.5.5 Receptors

The receptors discussed in this section as being potentially impacted by underwater noise from project activities are:

- cetaceans;
- fish;
- marine turtles; and
- seabirds.

#### *Cetaceans*

Cetaceans that are likely to be present in the vicinity of the project are discussed in *Section 5.4*.

The use of sound has evolved to become the predominant long-range sensory method for cetaceans. Underwater sound is very important to effective marine mammal navigation, communication and foraging.

*Table 6.16* and *Figure 6.8* provide a comparison of sound frequencies and source levels expected from noise produced by project activities and the frequencies understood to be utilised by cetaceans.

Baleen whales (humpbacks, blue, minke etc) communicate by low frequency sounds and are therefore considered to be the most sensitive of the cetaceans to man-made low frequency noise. Southall et al. (2007) have estimated the hearing range for baleen whales to be between 7 Hz and 22 kHz, with dominance in the 16 Hz to 8 kHz range. Baleen whale vocalisations are predominantly at frequencies below 1 kHz and it is likely that the hearing of baleen whales is most sensitive to these frequencies (McCauley, 1994).

Hearing in toothed whales (dolphins, sperm whales, orcas etc) has been estimated to be between 150 Hz and 160 kHz (Southall et al. 2007), though predominantly within the 500 Hz to 130 kHz range. Research has indicated that toothed whales are most sensitive to sounds above approximately 10 kHz (NRC, 2003). Below about 10 kHz sensitivity deteriorates with decreasing frequency and below 1 kHz, sensitivity appears to be poor.

Observed disturbance responses to anthropogenic sound in cetaceans include altered swimming direction; increased swimming speed including pronounced 'startle' reactions; changes to surfacing, breathing and diving patterns; avoidance of the sound source area and other behavioural changes (NRC, 2003). The occurrence and intensity of such responses, however, are highly variable and depend on a range of factors relating to the organism and situation (NRC, 2003).

Underwater noise produced by the FLNG facility and associated operations may potentially interfere with the ability of marine animals to detect natural sounds. This effect is termed auditory masking and has the potential to interfere with animals' communication and socialisation, the detection of predators and prey, and navigation and orientation.

There is little information available regarding call masking in whales (Richardson et al. 1995), although it has been suggested that an observed lengthening of calls in response to low-frequency noise in humpback whales and orcas may be a response to auditory masking (Fristrup et al. 2003; Foote et al. 2004). As noted above, toothed whales hear and communicate at frequencies predominantly above those of the noise sources that will result from project related activities. They are therefore unlikely to be affected by auditory masking.

Physiological damage from noise, such as hearing loss, is only likely to result from close proximity to intense sound from high energy sources. The sound intensity from the range of construction, operation and decommissioning activities associated with the FLNG facility is highly unlikely to exceed the threshold peak impulse sound pressure that could result in direct physical trauma in cetaceans. This threshold is generally considered to be >200 dB re 1μPa (McCauley, 1994; Richardson et al. 1995).

#### *Fish*

Fish hearing sensitivity is a function of the inner ear, specialised auditory structures and the swimbladder (a gas-filled internal organ used to control buoyancy). Cartilaginous fish (such as sharks and rays) lack a swimbladder and are considered less sensitive to sound than bony fishes.

Fish use sound to communicate, locate prey, detect predators and as a cue for orientation (McCauley and Cato, 2000). The majority of fish have a hearing frequency range between 100 – 1000 Hz (with peak hearing from 100 – 400 Hz), although some 'hearing specialists' can detect sounds to over 3 kHz (Popper, 2003).

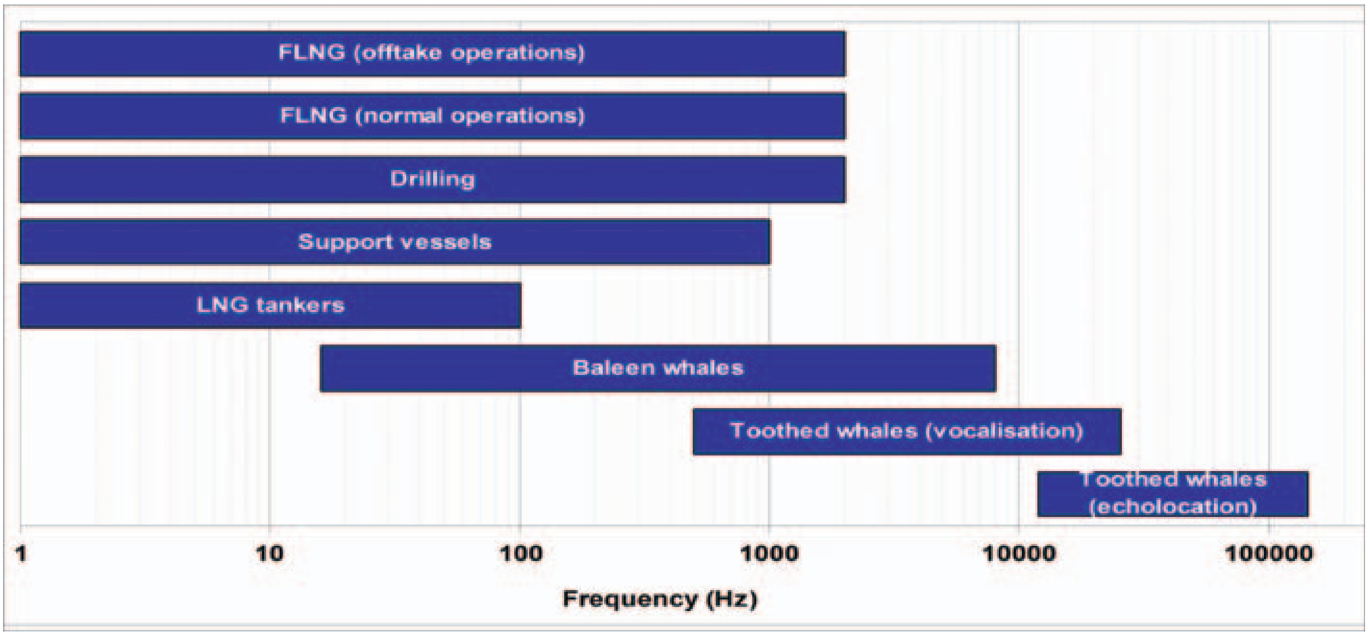
Fish have been shown to respond to high levels of man-made noise by changing schooling behaviour, moving away from the source of noise or in extreme situations, by becoming stunned and disoriented. Surface and mid water dwelling fishes may be initially affected by vessel movements and normal production noise. However, the accumulation of fish adjacent to operating facilities (Lindquist et al. 2005) indicates that in the absence of any associated threats, they can be expected to habituate to this noise.

*Table 6.16 Expected Sound Frequencies and Broadband Source Levels of Project Activities and Frequencies Utilised by Cetaceans*

| Source | Dominant Frequency Range (Hz) | Source levels (db re 1µPa-1m) |
|---|---|---|
| Baleen whales | 16 – 8,000 | _ |
| Toothed whales (vocalisation)<br>Toothed whales (echolocation) | 500 – 25,000<br>12,000 – 130,000 | _<br>_ |
| LNG tanker<br>Support vessels | <100<br><1,000 | 180-190<br>170-180 |
| Drilling<br>Helicopters | <2,000 (peak <500)<br><500 | 59 - 185<br>_ |
| FLNG facility<br>FLNG and tugs simultaneously using thrusters | <2,000 (peak 50)<br><2,000 (peak 200-400) | 189.1 (10-2,000 kHz)<br>192.4 (10-2,000 kHz) |

*Sources: Richardson et al. 1995; Simmonds et al. 2004 and Duncan and McCauley, 2008.*

*Figure 6.8 Expected Sound Frequencies of Project Noise Compared with Dominant Frequencies Utilised by Cetaceans*[17]



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[17] 'Based on data from Table 6.16. Where the lower boundary of the frequency range has not been reported in the literature, it has been assumed to be zero for the purposes of displaying the frequency range in this figure.

Intense sound wave vibrations (eg from blasting or piling) can cause fish swim bladders and auditory structures to be damaged or destroyed. However, sound intensities from project activities are unlikely to reach a level that would result in physical damage to fish.

### *Turtles*

Two species of marine turtles, green and flatback turtles, may occur in the vicinity of the project, with green turtles known to nest on Browse Island (approximately 40 km from the proposed FLNG facility location) (see *Section 5.4*).

There is little information available in relation to noise impacts on turtles. Turtles have been shown to respond to low frequency sound, with indications that they have the highest hearing sensitivity in the frequency range 100 – 700Hz (Bartol and Musick, 2003). Reported responses of turtles to high levels of man-made noise include increased swimming activity and erratic swimming patterns (McCauley et al. 2002).

## 6.5.6 Evaluation of Impact

### *Drilling and Construction*

The construction and installation vessels (including drill rig and support vessels) will be on location in the Prelude FLNG Project area for approximately 24 months. The noisiest activities expected during this phase will be intermittent and short term, involving the operation of the MODU while drilling, the support vessels using thrusters to maintain position, and the use of thrusters in positioning the FLNG facility for hook-up to the turret mooring system. The noise frequencies produced will overlap with hearing and vocalisation frequencies of baleen whales and to a lesser extent with those of toothed whales (see *Table 6.16* and *Figure 6.8*). Project activities during these activities therefore have the potential to mask sounds utilised by whales.

As the activities will be temporary and intermittent, and the project area is not known to provide significant habitat for any of the sensitive receptors, the likelihood of noise impacts is considered to be possible, and of low magnitude. Impacts from underwater noise to marine fauna during the drilling and construction period are therefore assessed to be minor.

Activities in the project area will be 40 km from the nearest turtle breeding location on Browse Island and are not expected to cause disruption to normal breeding behaviour.

| Underwater noise during and construction | | | |
|---|---|---|---|
| Impact | Magnitude | Likelihood | Significance |
| Negative | Low | Possible | MINOR |

### *Commissioning*

Impacts from noise generated during commissioning are expected to be similar to those from normal operation of the FLNG facility, as described below. Impact likelihood has been evaluated as possible and of low magnitude, such that the overall impact of underwater from commissioning activities is assessed to be minor.

| Underwater noise during commissioning | | | |
|---|---|---|---|
| Impact | Magnitude | Likelihood | Significance |
| Negative | Low | Possible | MINOR |

### *Operation and Maintenance*

As documented above, continuous broadband noise will be produced from onboard plant during operation of the FLNG facility. Source levels are expected to peak at 50 Hz, with an overall source level of 189.1 dB re 1µPa at one metre in the frequency range 10 Hz to 2 kHz.

During offtake operations, source levels are expected to increase over a similar frequency range to 192.4 dB re 1µPa at one metre when the FLNG facility and support tugs are simultaneously operating thrusters.

#### a. Cetaceans

The noise frequencies produced during operation of the FLNG facility will overlap with hearing and vocalisation frequencies of baleen whales and to a lesser extent with those of toothed whales (see *Table 6.16* and *Figure 6.8*).

A recent report by Southall et al. (2007) has summarised observed marine mammal response to anthropogenic noise according to category of marine mammal and type of noise. For low frequency hearing marine cetaceans (baleen whales such as blue, humpback and minke whales), limited or no response has generally been observed for anthropogenic sound levels of 90 – 120 dB re 1µPa. Increasing probability of avoidance and other behavioural effects have been reported for sound levels in the 120–160 dB re 1µPa range. No extreme behavioural responses have been reported. For mid frequency hearing cetaceans (toothed whales such as sperm whales and bottlenose dolphins), limited or no response has generally been observed for anthropogenic sound levels below 130 dB re 1µPa.

Based on these findings, it can be inferred that above 150 dB re 1µPa there will be increasing probability of responses to noise, while below 130 dB re 1µPa there will be no to minor response for both baleen and toothed whales.

The 150 dB re 1µPa level corresponds to a maximum distance of about 200 m from the Prelude FLNG facility during docking/undocking activities, which last for approximately 2 hours at a time, and about 30 m during normal operation of the FLNG facility (see *Table 6.15*).

The 130 dB re 1µPa level corresponds to a maximum distance of about 2 km during docking/undocking activities and about 700 m during normal operation of the FLNG facility.

The project area is not considered to provide significant feeding or breeding habitat for cetaceans, therefore, individuals in the area are expected to be transient. The main migration path for humpback whales is at least 150 km to the east of the project area, with key congregation areas in Pender Bay and Camden Sound approximately 200 km away. Given these separation distances between the FLNG facility and the nearest principal areas used by whale populations, in comparison to the distances to which the relevant noise levels are predicted to extend from the facility (*Table 6.15*), underwater noise impacts to whales are considered possible and of low magnitude.

Similarly the distances to which noise levels above 130 dB re 1µPa extend are very small in comparison to the geographic scale at which cetaceans operate and cetaceans, including baleen whales, are seen in close proximity to offshore structures which produce noise levels above the threshold values with no apparent discomfort. Therefore, potential impacts to cetaceans transiting the local area of the FLNG facility are expected to be possible but of a low magnitude, and hence are rated as minor.

The overall impacts of underwater noise on cetaceans during operation and maintenance of the FLNG are therefore assessed to be minor.

| **Cetaceans from underwater noise during FLNG operation and maintenance** | | | |
|---|---|---|---|
| Impact | Magnitude | Likelihood | Significance |
| Negative | Low | Possible | MINOR |

## b. Fish

The majority of fish have a hearing frequency range between 100 – 1000 Hz, which overlaps with the range from noise output from the FLNG facility. Studies have indicated, however, that the level at which behavioural effects (increased activity) start to appear is about 160 dB with the 'alarm' threshold at about 180 dB.

As outlined previously, noise levels are expected to exceed 150 dB re 1µPa within 200 m of the FLNG facility during the offloading activities and 30 m during normal operations. Given the areas of comparable habitat available to the fish, impacts from the FLNG operations are considered unlikely and of low magnitude, and hence are assessed to be minor.

| **Fish from underwater noise during FLNG operation and maintenance** | | | |
|---|---|---|---|
| Impact | Magnitude | Likelihood | Significance |
| Negative | Low | Unlikely | MINOR |

## c. Turtles

Turtles have been reported to increase their swimming activity at 155 dB re 1µPa and show more erratic swimming patterns at 164 dB re 1µPa. As noted above, noise levels are expected to exceed 150 dB re 1µPa within 200 m of the FLNG facility during offtake activities and 30 m during normal operations. Given the low abundance of turtles in the project area, the distance of the FLNG facility from Browse Island (40 km) and the extent of comparable habitat available to turtles, impacts from the FLNG operations are considered unlikely and of low magnitude, and hence are assessed to be minor.

| Turtles from underwater noise during FLNG operation and maintenance | | | |
|---|---|---|---|
| Impact | Magnitude | Likelihood | Significance |
| Negative | Low | Unlikely | MINOR |

### *Decommissioning*

Underwater noise from vessel activity in the area during decommissioning is expected to be similar to that during the construction phase, and hence underwater impacts are assessed to be minor.

| Underwater noise during decommissioning | | | |
|---|---|---|---|
| Impact | Magnitude | Likelihood | Significance |
| Negative | Low | Possible | MINOR |

### 6.5.7 Safeguards/Mitigation Measures

The following mitigation measures have been incorporated into the project design and the project has committed to the following management measures to reduce underwater noise impacts from the Prelude FLNG Project:

**Design Mitigation Measures:**

- Locating the FLNG facility in an area that is distant to the closest known significant environmental sensitivities.
- An acoustic design study will be undertaken during the Front-End Engineering and Design (FEED) phase to support the overall design process of the FLNG Facility.
- Locating the majority of the process equipment on the topsides of the FLNG facility, not in the hull, and mounting modules on elastomeric mounts or using other vibration isolation methods to reduce vibration where required.
- The FLNG facility will be designed to meet occupational health and safety noise limits.
- Supply vessels will be new, purpose-built vessels and will incorporate the latest design principles for energy efficiency which should help reduce vessel-generated underwater noise levels.

**Management Mitigation Measures:**

- A maintenance program will be developed for the FLNG facility and supply vessels which will include inspection and maintenance of noise suppression equipment to ensure occupational health and safety noise limits are met.
- Vessel cetacean interaction procedures will be developed and relevant drilling, construction and supply contractors engaged by Shell will be obliged to comply with these. The procedures will include the requirement to maintain a watch for cetaceans when transiting, to not knowingly approach within 500 m of cetaceans, to take actions to avoid cetaceans located within a distance of 500 m from the vessel when safe to do so and to complete a 'Whale and Dolphin Sighting Report Sheet' (DEWHA 2008) in the event cetaceans are sighted.
- Helicopter operators engaged by Shell will be obliged to route flight paths to avoid Browse Island, to fly above an altitude of 1,000 metres within a 300 metre horizontal radius of observed whales (except for take-off and landings) and to comply with Civil Aviation Authority procedures to reduce the potential for bird strikes from helicopters.

### 6.5.8 Summary

*Section 6.5* is summarised in *Table 6.17*.

### 6.5.9 Conclusion

The environmental impact associated with underwater noise generated from all phases of the Prelude FLNG Project has been evaluated and is predicted to be minor. No significant impacts from underwater noise to *EPBC Act* listed species, migratory species or the surrounding marine environment have been identified.

## *Table 6.17 Summary of Predicted Impacts from Underwater Noise*

| Impact | | Impact from Underwater Noise | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Receptors** | Cetaceans, including two threatened species (humpback whale and blue whale) may transit the project area.<br>Turtles, two vulnerable species ( green and flatback turtle) may transit the project area. Green turtles also nest on Browse Island (~ 40 km from the FLNG facility location).<br>Fish, including one known threatened species (whale shark) may transit the project area.<br>Birds, including one known migratory marine species (streaked shearwater) may transit the project area. Four potential flights path for migratory shorebirds occur within 150 km of project area. | | | | | | | | |
| **Receptor Sensitivity** | | | | | | | | | |
| **Turtles, fish, birds** | | ■ | Low | | Medium | | High | | |
| **Cetaceans** | | | Low | | Medium | ■ | High | | |
| Underwater noise will be produced through all stages of the project from construction activities, vessel movements and operation of the FLNG facility. Potential impacts include disturbance and behavioural changes, masking of other biologically important sounds (such as vocal communication or echolocation), or physical injury to hearing or other organs. Noise frequencies produced from the project will overlap with hearing and vocalisation frequencies of baleen whales and to a lesser extent with those of toothed whales. It is predicted that whales may show avoidance behaviour around the FLNG facility within a 2 km radius during tanker berthing/unberthing activities and 700 m during normal operations. However, individuals are likely to habituate to its presence and often observed in close vicinity to other petroleum facilities on NWS. Project noise may also cause some localised disturbance and behavioural changes to fish, turtles or seabirds in the vicinity but these animals often observed in close vicinity to other petroleum facilities. | | | | | | | | | |
| **Drilling and Construction** | **Impact Nature** | ■ | Negative | | Positive | | | | |
| | **Impact Extent** | ■ | Local | | Regional | | National | | Global |
| | **Impact Duration** | ■ | Rare/ short | | Occasional/ moderate | | Regular/ long | | |
| | **Impact Magnitude** | ■ | Low | | Medium | | High | | |
| | **Likelihood** | | Unlikely | ■ | Possible | | Probable | | Certain |
| | **Significance** | ■ | Minor | | Moderate | | Major | | Critical |
| **Commissioning** | **Impact Nature** | ■ | Negative | | Positive | | | | |
| | **Impact Extent** | ■ | Local | | Regional | | National | | Global |
| | **Impact Duration** | ■ | Rare/ short | | Occasional/ moderate | | Regular/ long | | |
| | **Impact Magnitude** | ■ | Low | | Medium | | High | | |
| | **Likelihood** | | Unlikely | ■ | Possible | | Probable | | Certain |
| | **Significance** | ■ | Minor | | Moderate | | Major | | Critical |
| **Operation/ Maintenance** | **Impact Nature** | ■ | Negative | | Positive | | | | |
| | **Impact Extent** | ■ | Local | | Regional | | National | | Global |
| | **Impact Duration** | | Rare/ short | | Occasional/ moderate | ■ | Regular/ long | | |
| | **Impact Magnitude** | ■ | Low | | Medium | | High | | |
| | **Likelihood** | | Unlikely | ■ | Possible | | Probable | | Certain |
| | **Significance** | ■ | Minor | | Moderate | | Major | | Critical |
| **Decommissioning/ Abandonment** | **Impact Nature** | ■ | Negative | | Positive | | | | |
| | **Impact Extent** | ■ | Local | | Regional | | National | | Global |
| | **Impact Duration** | ■ | Rare/ short | | Occasional/ moderate | | Regular/ long | | |
| | **Impact Magnitude** | ■ | Low | | Medium | | High | | |
| | **Likelihood** | | Unlikely | ■ | Possible | | Probable | | Certain |
| | **Significance** | ■ | Minor | | Moderate | | Major | | Critical |

*NOTE: Likelihood rated as Possible relate to cetaceans only, all others likelihoods are Unlikely*

## 6.6 SOLID WASTES

### 6.6.1 Sources and Characteristics of Solid Waste

Solid wastes will be generated during all stages of the Prelude FLNG Project as discussed in *Sections 4.7* and *Section 4.8*. Solid wastes produced by the project will consist of:

- drill cuttings (estimated 1,000 $m^3$ per well);
- non-hazardous materials from the production process such as sands and grit from pigging;
- general non-hazardous wastes including paper, rope, packaging timber, metal and plastic;
- hazardous waste from the production process, including used or spoilt water treatment chemicals, process sand and sludge, used lube oils, used molsieve and possibly used mercury absorbent; and
- general hazardous wastes including aerosol cans, batteries and oil filters.

### 6.6.2 Receptors

The following receptors may inhabit or migrate through the project area:

- cetaceans including two *EPBC Act* 'threatened' species: the humpback whale and blue whale;
- two species of turtles: the green turtle and the flatback turtle;
- fish including one *EPBC Act* 'threatened' species: the whale shark;
- seabirds including one *EPBC Act* 'migratory marine' species: the streaked shearwater; and
- benthic fauna and flora.

Improperly disposed of solid waste may reduce water quality, with subsequent impacts on the above marine flora and fauna. Benthic habitats may also be polluted or smothered by improperly disposed of solid waste, and marine fauna may become entangled or ingest discarded waste.

### 6.6.3 Description and Evaluation of Impact

#### *Non Hazardous Solid Wastes*

#### a. Drill Cuttings

Drill cuttings are the rock and sand particles removed from the well (bore hole) during the drilling operation. They are separated from the drilling fluid and deposited over the side of the rig. About 1,000 $m^3$ of cuttings will be produced per well, for a total of 8,000 $m^3$ from the eight wells to be drilled. The disposal of drilling muds is discussed separately in *Section 6.7*.

The environmental impact associated with the disposal of drill cuttings has been the subject of much scientific research globally across the oil and gas industry. This section is based on a comprehensive understanding of cuttings disposal issues published by industry organisations including APPEA, UKOOA, IPEICA and OGP.

Discharge of cuttings will lead to temporarily increased water turbidity in the vicinity of the discharge point, which may be discernible for one to two kilometres from the discharge point for the duration of the discharge (between 30 and 60 days for each well). Hinwood et al. (1994) point out that the plume created by the discharge of drill cuttings can be expected to dilute by a factor of at least 10,000 within 100 m of its point of discharge. As a result, given the generally low turbidity of the expected plume (reducing rapidly with distance from the discharge point), the limited area impacted and the short lived period of impact, the plume is not expected to impact photosynthetic activity measurably in the water column.

As the cutting particles fall through the water column they will be dispersed by currents. Minor alteration of benthic habitat characteristics (sediment particle size, element composition) may occur on the seafloor in the vicinity of the drilling rig. Mineralisation of cuttings is expected to be low and any metals present are unlikely to be in a bio-available or in a soluble form. Bottom-feeding organisms would be most susceptible to bioaccumulation of metals from cuttings. Benthic organisms are sparsely distributed in the area of the project and community types are likely to be widely spread in the region (*see Section 5.3.4*).

Impacts to water quality or marine benthic fauna from the disposal of drill cuttings to the seabed are therefore assessed as being certain and low in magnitude, such that the overall impact of the disposal of drill cuttings is assessed to be moderate.

| Drill cuttings disposal | | | |
|---|---|---|---|
| Impact | Magnitude | Likelihood | Significance |
| Negative | Low | Certain | MODERATE |

### b. Sand and Sludge

Oil-contaminated sand and sludge may be recovered with well production fluids during commissioning, well clean-up and normal operation of the facilities. It is not expected to be a considerable ongoing source of waste. Sand and sludge will be collected in a dedicated tank and then sent onshore for disposal at an appropriately licensed facility in accordance with the project's Waste Management Strategy (see *Chapter 7*) and will not impact the environment at the Prelude FLNG location.

| Sand and sludge management | | | |
|---|---|---|---|
| Impact | Magnitude | Likelihood | Significance |
| Negative | Low | Unlikely | MINOR |

### c. Food and Putrescibles

Food scraps and other putrescible wastes will be produced during all phases of the project from vessels and the FLNG facility. These will be macerated and passed through a 25 mm screen prior to discharge to sea as per standard industry practice. Potential impacts are related to reduced water quality and nutrient enrichment of the surrounding waters at the point of disposal. Some fish and oceanic seabirds may potentially be attracted to the FLNG facility and vessels by the discharge of food scraps either directly, in response to increased food availability, or indirectly, as a result of prey species being attracted to the vessels.

Discharge volumes of macerated food and putrescibles from the FLNG will typically be about 1L/person/day, equating to 100L/day during the well drilling and completion phase, a short term peak of up to 400L/day from multiple sources during the 6 month commissioning period, and 110L/day during the 25 year operational period. Wave action and currents are expected to rapidly disperse the discharge, which will have been macerated as described above, and hence impacts are assessed to be unlikely and of low magnitude. The impact of the discharge of food and putrescible wastes is therefore considered to be minor for all project phases.

| Food and putrescibles waste disposal | | | |
|---|---|---|---|
| Impact | Magnitude | Likelihood | Significance |
| Negative | Low | Unlikely | MINOR |

### d. General Non-Hazardous Solid Wastes

Non-hazardous general wastes will include paper, rope, various packaging, timber, metal and plastic which will be periodically transferred onshore for recycling or disposal. Potential impacts from the disposal of general non-hazardous solid wastes include accidental loss of material overboard, resulting in water pollution or injury to wildlife.

Non-hazardous wastes will be generated throughout the phases of the project and will be stored on board the MODU, the FLNG facility and vessels in appropriately labelled and sealed containers prior to transfer onshore for recycling or disposal.

With the application of an overall waste minimisation hierarchy for the project (*see Chapter 7*) and the appropriate management of non-hazardous solid waste arising as described above, impacts from non-hazardous solid waste disposal are considered to be unlikely and of low magnitude and are assessed to be minor.

| General non-hazardous solid waste | | | |
|---|---|---|---|
| Impact | Magnitude | Likelihood | Significance |
| Negative | Low | Unlikely | MINOR |

## *Hazardous Solid Wastes*

### e) General Hazardous Solid Wastes

Hazardous wastes generated during general operational and maintenance activities include spent lubricants and oils, aerosol cans, batteries and oil-contaminated materials (eg. sorbents, filters and rags).

Whilst currently not expected, if the Prelude feed gas contains mercury, the guard bed material used to remove it from the gas stream will be transferred to shore for prescribed disposal approximately every 5 years.

The main concerns associated with the management of hazardous wastes are their method of disposal and the potential for accidental loss to the marine environment. Throughout the project phases, hazardous wastes will be stored in clearly labelled sealed containers before being transferred to supply vessels for onshore disposal at an appropriately licensed facility in accordance with the project Waste Management Plan (see *Chapter 7*).

With the application of an overall waste minimisation hierarchy for the project (see *Chapter 7*) and the appropriate management of hazardous solid waste, impacts from the disposal of hazardous solid wastes are considered to be unlikely and of low magnitude, and are assessed to be minor.

| General hazardous solid wastes | | | |
|---|---|---|---|
| Impact | Magnitude | Likelihood | Significance |
| Negative | Low | Unlikely | MINOR |

### f. Drill Thread Lubricant (Pipe Dope)

Small quantities of grease known as 'pipe dope' are applied as a lubricant to the connecting threads of sections of drill pipe when they are screwed together during drilling. Pipe dope contains very fine particles of heavy metals. Whilst the pipe dope is mainly contained within the pipe threads, any excess dope is sloughed off during drilling and is ultimately discharged to the ocean with the drill cuttings. Assuming 10 mL of pipe dope is sloughed off from each connection on the 5,400 m length of drill string required for the total length of one of the Prelude wells, approximately 1.5L of pipe dope will be released during each run of drill pipe into the well.

Any impacts associated with discharge of these small amounts of pipe dope with drill cuttings will be very limited and localised. The impact likelihood is thus considered unlikely and of low magnitude, such that the overall impact is assessed to be minor.

| Drill thread lubricant (pipe dope) | | | |
|---|---|---|---|
| Impact | Magnitude | Likelihood | Significance |
| Negative | Low | Unlikely | MINOR |

## 6.6.4 Safeguard/Mitigation Measures

The following mitigation measures have been incorporated into the project design and the project has committed to the following management measures to reduce solid waste impacts from the Prelude FLNG Project:

### *Hazardous and Non-Hazardous Solid Wastes*

**Design Mitigation Measures:**

- The FLNG facility will be designed to include designated areas for segregation and collection of solid wastes.
- The FLNG facility will be fitted with a macerator that is able to macerate wastes to a diameter of less than 25 mm prior to overboard disposal.
- Sand and sludge generation will be reduced through the design of the production wells, including the installation of sand screens and traps if practicable.

**Management Mitigation Measures:**

- Waste Management Plans will be developed and adopted for the construction, operation and decommissioning phases of the Prelude FLNG project and contractors engaged by Shell will be obliged to implement these. The Waste Management Plans, will define the approved methods and locations for the transport and disposal of all wastes and will include documented waste consignment processes and licensing requirements for waste management services and facilities. These plans will also demonstrate how:
    - The principle of 'avoid, reduce, re-use and dispose in an environmentally responsible manner' will be adopted. One focus will be on avoiding waste at source. Waste segregation and storage facilities will be provided in line with the relevant Australian standards, MARPOL and the World Bank guidelines (see *Section 2.7*).
    - When selecting materials, non-hazardous solid materials that meet technical requirements and are as cost-effective as hazardous materials will be given preference.
    - Wastes will be segregated into waste streams and wastes not being disposed of overboard will be clearly labelled and appropriately stored on the FLNG facility for transport to onshore contractors, approved and registered with relevant authorities, for disposal or treatment.
        - o Cooking oils and greases from the support vessels and the FLNG facility will be collected and transported back to the mainland for disposal.
        - o Batteries will be collected and stored in separate (dedicated) containers; batteries will not be incinerated, but preferably

    - recycled and, if not possible, disposed of in a safe and controlled manner.
    - Disposal of spent adsorbent from the mercury removal unit shall be transported to an appropriately licensed treatment facility.
    - Lube and motor oils waste will be returned to a recycling plant or refinery.
    - Medical waste will be incinerated onshore; chemicals and solvents (eg AGRU fluids) will be returned to the supplier for recycling or to a suitable onshore waste disposal facility.
    - Sludges from the FLNG Facility will be collected and transported back to the mainland for disposal.
- Vessel vetting procedures will be developed and implemented to ensure that all vessels engaged by Shell can dispose of food scraps and other putrescible wastes in accordance with relevant legislation (eg *OPGGS Act* and MARPOL).
- Cuttings contaminated with synthetic based muds will be treated to achieve less than 6.9% synthetic based mud by weight prior to overboard discharge. Spent synthetic based mud will be collected on board and transported to shore for disposal.

### 6.6.5 Summary

*Section 6.7* is summarised in *Table 6.18.*

### 6.6.6 Conclusion

The environmental impacts associated with the disposal of solid wastes generated from the Prelude FLNG Project have been evaluated and are predicted to be minor, except for the potential impact associated with drill cuttings disposal which was assessed to have moderate significance. Standard Australian industry drilling practices will be followed which will ensure that potential impacts to the seabed associated with the disposal of drill cuttings are ALARP. As a result, no significant impacts to *EPBC Act* listed species, migratory species or the surrounding marine environment are expected.

## 6.7 LIQUID WASTES

### 6.7.1 Introduction

Liquid wastes will be generated during all stages of the project in varying quantities and contain both hazardous and non-hazardous chemicals. The liquid wastes generated during the various phases of the project are summarised in *Table 6.19.*

Modelling techniques have been used to assess the significance of potential impacts of the main liquid wastes discharged to the ocean. Where relevant, guidelines regarding allowable discharge concentrations (eg World Bank, ANZECC and MARPOL) have been adopted to evaluate potential impacts.

### 6.7.2 Overview of Key Liquid Effluents

#### *Drilling Fluids*

As described in *Chapter 4*, two types of drilling muds are used during drilling (refer *Section 6.6.3* for discussion on drill cuttings):

- *Synthetic Based Muds (SBMs)*: represent a potential risk to the environment and as such will be recovered and returned onshore for recycling or disposal. However, the nature of SBM recovery is such that small volumes of the SBM cannot be removed from drill cuttings prior to the discharge of the cuttings to the marine environment. It is estimated that about 36 $m^3$ of SBM per well will be discharged to sea with the cuttings.
- *Water Based Muds (WBMs)*: do not represent a risk to the environment and as such, the industry accepted practice is to discharge these to the sea at the end of the drilling program (APPEA 2008 and DOIR 2006).

#### *Hydrotest Fluids*

To ensure the integrity of the flow-lines, risers and the topside infrastructure prior to commissioning, it is necessary for them to be pressure tested (referred to as hydrostatic testing or hydrotesting). This is an important measure for avoiding and minimising the risk associated with potential releases of hydrocarbons. As described in *Section 4.8.3*, hydrotesting is achieved by filling the flow-lines, risers and topsides piping with sea water and such additives as oxygen scavenger,

*Table 6.18 Summary of Predicted Impacts from Solid Wastes*

| Impact | | Impact from Solid Wastes | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Receptors** | | Cetaceans, including two threatened species (humpback whale and blue whale) may transit the project area.<br>Turtles, two vulnerable species ( green and flatback turtle) may transit the project area. Green turtles also nest on Browse Island (~ 40 km from the FLNG facility location).<br>Fish, including one known threatened species (whale shark) may transit the project area.<br>Birds, including one known migratory marine species (streaked shearwater) may transit the project area. Four potential flights path for migratory shorebirds occur within 150 km of project area.<br>Benthic fauna and flora | | | | | | | |
| **Receptor Sensitivity** | | | | | | | | | |
| **Cetaceans, fish, benthic fauna and flora** | | ■ | Low | | Medium | | High | | |
| **Turtles, birds** | | | Low | ■ | Medium | | High | | |
| Solid wastes will be generated throughout all phases of the Prelude FLNG Project. Solid wastes that will be discharged to the marine environment (drill cuttings, food wastes) have the potential to have localised effects on water quality, toxicity effects, smothering of fauna, and risk of entanglement or ingestion by fauna. Any impacts are expected to be minor and highly localised. Hazardous solid wastes will be stored and transported to the mainland for appropriate onshore disposal. | | | | | | | | | |
| **Drilling and Construction** | **Impact Nature** | ■ | Negative | | Positive | | | | |
| | **Impact Extent** | ■ | Local | | Regional | | National | | Global |
| | **Impact Duration** | ■ | Rare/ short | | Occasional/ moderate | | Regular/ long | | |
| | **Impact Magnitude** | ■ | Low | | Medium | | High | | |
| | **Likelihood** | ■ | Unlikely | | Possible | | Probable | ■ | Certain[1] |
| | **Significance** | ■ | Minor | ■ | Moderate[1] | | Major | | Critical |
| **Commissioning** | **Impact Nature** | ■ | Negative | | Positive | | | | |
| | **Impact Extent** | ■ | Local | | Regional | | National | | Global |
| | **Impact Duration** | ■ | Rare/ short | | Occasional/ moderate | | Regular/ long | | |
| | **Impact Magnitude** | ■ | Low | | Medium | | High | | |
| | **Likelihood** | ■ | Unlikely | | Possible | | Probable | | Certain |
| | **Significance** | ■ | Minor | | Moderate | | Major | | Critical |
| **Operation/ Maintenance** | **Impact Nature** | ■ | Negative | | Positive | | | | |
| | **Impact Extent** | ■ | Local | | Regional | | National | | Global |
| | **Impact Duration** | | Rare/ short | | Occasional/ moderate | ■ | Regular/ long | | |
| | **Impact Magnitude** | ■ | Low | | Medium | | High | | |
| | **Likelihood** | ■ | Unlikely | | Possible | | Probable | | Certain |
| | **Significance** | ■ | Minor | | Moderate | | Major | | Critical |
| **Decommissioning/ Abandonment** | **Impact Nature** | ■ | Negative | | Positive | | | | |
| | **Impact Extent** | ■ | Local | | Regional | | National | | Global |
| | **Impact Duration** | ■ | Rare/ short | | Occasional/ moderate | | Regular/ long | | |
| | **Impact Magnitude** | ■ | Low | | Medium | | High | | |
| | **Likelihood** | ■ | Unlikely | | Possible | | Probable | | Certain |
| | **Significance** | ■ | Minor | | Moderate | | Major | | Critical |

*1: Certain and Moderate impacts during drilling relate only to drill cutting disposal.*

*Table 6.19 Liquid Waste during all Phases of the Prelude FLNG Project*

| Phase | Activity Source | Source Type | Duration |
|---|---|---|---|
| Construction and Installation | Vessels | Sewage and grey water | 2 years |
| | | Deck drainage | 2 years |
| | Well testing | Produced Formation Water* | 4 months * |
| | Anti-fouling protection | Anti -fouling leachate | 25 years |
| | Dewatering flowlines | Hydrotest fluids | 8 tests over 4 months |
| | Well Drilling | Drilling fluids | 8 months over 2 years |
| Commissioning and Operation | Presence of Structures | Subsea control fluids | 25 years |
| | Supply vessels | Sewage and grey water | 25 years |
| | | Deck drainage | 25 years |
| | FLNG facility | Sewage and grey water | 25 years |
| | | Anti-fouling leachate | 25 years |
| | | Desalination brine | 25 years |
| | | Deck drainage | 25 years |
| | | Cooling water | 25 years |
| | | Produced Formation Water* | 25 years * |
| | Export vessel movements | Ballast water | 1-2 per week for 25 years |
| Decommissioning | Vessel movements | Sewage and grey water | 4 months |
| | | Deck drainage | 4 months |

** As described in section 4.7.11, the likelihood of Produced Formation Water occurring is low. Nonetheless, this impact assessment has been conducted on the assumption that Produced Formation Water will exist and be discharged as a liquid waste at the maximum rate.*

corrosion inhibitor, dye and biocide. The infrastructure is then pressurised and monitored for any change in pressure over time (usually 24 hours).

On completion of the successful hydrotest of the subsea infrastructure, the hydrotest water will be processed through the FLNG facility's water treatment facilities and then directed to the slops tanks for storage until discharged to sea.

Based on the field layout described in *Section 4.8.3*, an estimated volume of about 1,500 m$^3$ of hydrotest fluid will be generated as a result of mandatory hydrotesting during commissioning. This is a small fraction of the hydrotest water volume required to test a long export pipeline from an offshore gas field to an onshore gas treatment plant.

### *Produced Formation Water*

Over a geological period of millions of years, seawater accumulates naturally in the porous sands of a subsurface reservoir, along with hydrocarbon deposits. Being denser than oil or gas, it lies below the hydrocarbons and may be drawn into a well during hydrocarbon extraction/recovery. This water is known as Produced Formation Water (PFW). In addition, water can condensate out of the gas as both pressure and temperature of the gas are reduced as the gas is produced from the reservoir. This is known as condensate water but for simplicity, both PFW and condensate water are collectively referred to as PFW in this draft EIS.

The PFW volumes associated with the Prelude FLNG Project are not expected to be significant. For the purpose of the assessment of potential risks associated with discharge of PFW:

- The FLNG produced water treatment design capacity volume of 2,200m$^3$ per day has been used, however actual water production rates for the Prelude field are expected to be much lower; and,
- A generic composition has been used based on other operations off the northwest coast of Australia as the composition of any Prelude PFW is yet to be confirmed.

Most PFWs are highly saline and contain a mixture of dissolved inorganic salts, dispersed oil, dissolved organic compounds, treatment and workover chemicals, dissolved gases (particularly hydrogen sulphide and carbon dioxide), bacteria and other living organisms, and dispersed solid particles. Naturally occurring radioactive materials (NORMs) have also been known to occur in PFW.

Only the elements that are expected to represent an environmental risk have been included in this impact assessment and are summarised as follows:

- BTEX compounds: benzene, toluene, ethylbenzene , xylene;
- NPD compounds: naphthalene, phenanthrene, dibenzothiophene;
- PAH compounds: polycylic aromatic hydrocarbon compounds, which include acenaphthylene, fluoranthrene and chrysene; and
- Production chemicals: methylethyl glycol (MEG).

The MEG is from two potential sources:

- Low concentrations of unrecoverable MEG within the PFW; and
- MEG sludge from the MEG regeneration unit (see *Section 4.7*), which has the capacity to produce up to 3.6 tonnes of MEG brine per day, a brine containing 10% MEG salt which will be discharged into the PFW discharge stream.

### *Subsea Control Fluids*

A water-based subsea hydraulic control fluid will be used to control wellhead valves on the Christmas tree remotely from the FLNG facility and will operate as an open-loop system (industry standard). The main properties required of a hydraulic control fluid are low viscosity, low compressibility, corrosion protection, resistance to microbiological attack, compatibility with seawater and biodegradable.

The proprietary brand that will be used for Prelude is not yet known, however industry standard subsea control fluids are freshwater-based with additives of mono-ethylene-glycol (typically about 40%), lubricants, corrosion inhibitors, biocides and surfactant.

Small amounts of control fluid are discharged near the seabed from the Directional Control Valves when they are open and closed. About 23 m$^3$ of the water-based hydraulic fluids are likely to be discharged to sea per year.

### *Cooling Water*

Seawater will be used as a heat exchange medium for the cooling of machinery engines and in the production process. Seawater will be drawn from the ocean and will flow counter current to closed circuit heat exchangers, transferring heat from the machinery or production process to the seawater via an intermediate circulating freshwater system. The heated seawater will then be discharged to the ocean at between 39°C to 42°C, which is 7.5°C to 16°C above the ambient seawater temperature depending on season. About 50,000 m$^3$ of cooling water will be discharged per hour.

As described in *Section 4.7.8*, chlorine in the form of sodium hypochlorite will be added to the cooling water to inhibit marine growth within the pipework of the cooling water system. There will be a residual hypochlorite concentration of 0.2 ppm in the cooling water discharged to sea.

### *Deck & Surfaces Drainage*

Potential impacts associated with deck drainage will be managed through design considerations for accidentally and continuously contaminated water (refer *Section 4.7.11*). Deck drainage will consist mainly of wash down water, seawater spray and rainwater and may contain small quantities of oil, grease and detergents present on the deck, which has the potential to create surface sheens and short-term, localised reduction in water quality. Deck and surface drainage will be generated not only from the FLNG facility but also from the support and supply vessels transiting to and from the FLNG facility during construction, commissioning and operation phases of the project.

Drainage from areas on the FLNG facility that have potential for small oil spills, such as under valves or machinery, will be directed to a sump which drains to an oily-water separation system. Once separated, the oil and grease will be reprocessed while the treated water will be discharged to sea. Non-oil contaminated deck drainage will be discharged directly overboard.

Areas on the deck where LPG or LNG are handled will not be bunded and deck drainage will be directed to the ocean as a design safety measure. In the unlikely event of a spill, the liquefied hydrocarbons would volatilise rapidly with minimal effect on the marine environment.

### *Desalination Brine*

The production of fresh water from seawater in the freshwater generators of all vessels results in a discharge of seawater with a slightly elevated salinity (around 10% higher than seawater). The volume of the discharge is dependent on the requirement for fresh (or potable) water. As per *Section 4.7.11*, standard requirements for freshwater for the FLNG facility will be approximately 70 tonnes/hr (~70 m$^3$/hr), however this figure may be up to 50% higher during commissioning and maintenance activities. The volume of elevated salinity seawater (termed desalination brine) expected to be discharged from the FLNG facility during normal operation of the desalination plant is 210 tonnes/hr (~210 m$^3$/hr) (*Section 4.7.11*).

### *Sewage & Greywater*

Treated sewage will be discharged to the ocean from the FLNG facility and supply/support vessels following onboard treatment, during all stages of the project. The FLNG facility sewage system uses freshwater in the sanitary system and will comprise two 50% units sized in total for 400 persons. The expected combined flow rate of sewage and greywater (laundry, galley, shower and basin water) is 30 m$^3$/day during commissioning and 10 m$^3$/day during operation.

Support vessels generally store their untreated sewage (blackwater) in holding tanks that is then transferred to sewage treatments facilities onshore via sucker tanks when the vessels return to port or discharge sewage and grey water overboard at sea in accordance with MARPOL.

## 6.7.3 Receptors

The following receptors that may potentially be impacted by liquid wastes have been identified:

- cetaceans including two *EPBC Act* 'threatened' species: the humpback whale and blue whale;
- two species of turtles: the green turtle and the flatback turtle;
- fish including one *EPBC Act* 'threatened' species: the whale shark;
- seabirds including one *EPBC Act* 'migratory marine' species: the streaked shearwater; and
- benthic fauna and plankton.

With the exception of seabirds, all of the above receptors are marine organisms that are reliant on suitable marine water quality in which to live, breed and move from one location to another. Liquid wastes have the potential to impact the physical, chemical and biological marine environment, which could pose a threat to the identified receptors. However, as described in *Section 5*, none of these receptors are abundant in or considered to be restricted to the project area.

## 6.7.4 Modelling of Liquid Waste

### *Overview*

Modelling of the major liquid discharges was undertaken to investigate potential impacts to the marine environment around the FLNG facility (ERM, 2009a). *Table 6.20* summarises the four waste streams which were modelled and their associate chemical constituents. These are discussed in detail in the sections below.

The above liquid wastes were selected for modelling as they represent those liquid wastes that have the largest volumes and/or the greatest potential for impact on the marine environment. As described in *Section 4.7.11*, very little PFW is expected to be produced from the reservoir, however provision has been made to treat and discharge up

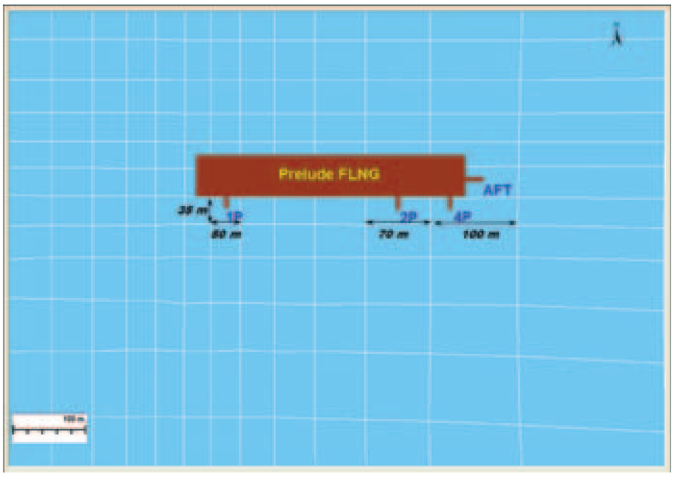
*Table 6.20 Summary of Modelled Impacts*

| Waste Stream | Constituents |
|---|---|
| PFW | • BTEX, NPD and PAH compounds |
| | • Residual MEG within the PFW that is not recovered through the MEG regeneration unit |
| | • MEG brine from the MEG regeneration unit |
| Cooling water | • Temperature |
| | • Chlorine |
| | • Dissolved oxygen (DO) |
| Wastewater (sewage/ grey water/drainage) | • Total Suspended Solids |
| | • Coliforms |
| | • Oil and grease |
| Implications associated with the combined effects of wastewater discharged and discharge of cooling water (deep water extraction) | • Nutrients |
| | • Oxygen demand |
| | • Chlorophyll-a |
| | • DO |

to 2,200 m$^3$ of PFW per day and the modelling undertaken was based on this worst case volume.

The hydrodynamic model chosen to assess the impacts of the FLNG facility on the physical marine environment is the Generalized Environmental Modelling System for Surface Waters (GEMSS®) using a nested grid covering a region of approximately 30 by 30 km, with finer resolution around the discharge locations (*Figure 6.9*) (ERM, 2009a).

*Figure 6.9 Near-field Grid close-up at the FLNG Facility showing Drain Locations*



### 6.7.5 Evaluation of Impacts

#### *Construction and Installation*

#### a. Drilling Fluids

The main environmental concerns associated with the discharge of drilling muds to the marine environment are:

- increased turbidity;
- alteration of sediment characteristics;
- contamination of sediments and associated toxicity to marine biota; and
- bioaccumulation and biomagnification.

Upon completion of the drilling program, bulk WBM will most likely be discharged from the MODU rig into the ocean as per industry practice. The discharge of drilling muds will result in a temporary discolouration and increased turbidity of water. The mud is anticipated to dilute and disperse with the tide and winds over a 6 to 12 hour period.

Given the lack of sensitivities in the marine environment at the project area and the use of low toxicity WBM, physical and/or biochemical impacts of the WBM discharge to the marine environment are predicted to be unlikely and of low magnitude, such that the impact is assessed to be minor (also see discussion in *Section 6.6.3*).

| WBM discharged to sea | | | |
|---|---|---|---|
| Impact | Magnitude | Likelihood | Significance |
| Negative | Low | Unlikely | MINOR |

SBM will only be used during the drilling of the deeper and more technically challenging portion of the production wells. The bulk of the SBM will be recovered in accordance with industry guidelines for subsequent re-use on other drilling programs or onshore recycling. A small amount of SBM will be lost, however, as a coating on the drill cuttings and will be discharged to sea. A combination of industry standard equipment including shale shakers and hydrocyclones will recover the SBM and dry the drill cuttings as far as practicable, leaving approximately 36 m$^3$ of SBM discharged to sea as a residual coating on the drill cuttings from each well.

Acute ecotoxicity testing is commonly used to predict the toxicity of drilling fluids in the marine environment. SBMs currently used in drilling operations in Australia range from slightly toxic to non-toxic (LC50 value of 1,000 to >100,000 mg/l), depending on the test organisms used (APPEA, 1998). This low toxicity can be attributed to two factors; the low solubility of SBMs in the water column and their low to negligible concentrations of aromatic hydrocarbons. SBMs currently in use in Australia are generally considered to have limited potential to bio-accumulate in aquatic organisms (APPEA, 1998).

A compilation and review of the findings of 75 studies relating to the discharge of non-aqueous drilling fluids (NADFs) by the International Association of Oil and Gas Producers (OGP, 2003) concluded that the numerous field studies conducted to measure the initial impacts and recovery from NADF discharge showed that benthic community disturbance is in general very localised and temporary. The effects on soft bottom communities from SBM cuttings discharges are rarely seen outside of 250-500 m (Jensen et al. 1999). Biodegradation of modern NADF can be relatively rapid, particularly when NADF concentrations are low to moderate, and where newer NADFs were used field studies show that recovery was underway within one year of cessation of discharges.

Given the depth of water at the drilling locations, the low toxicity and high degradability of the SBM, and the limited volume (on cuttings) to be discharged, impacts are considered of low magnitude and unlikely. The impact of SBM discharged to the marine environment on drill cuttings is therefore assessed to be minor.

| SBM on drill cuttings discharged to sea | | | |
|---|---|---|---|
| Impact | Magnitude | Likelihood | Significance |
| Negative | Low | Unlikely | MINOR |

### b. Hydrotest Fluids

The main risk associated with the discharge of hydrotest water is a localised and temporary reduction in water quality, oxygen depletion and potential toxicity to marine fauna and flora from the release of the chemically treated water.

Given the small volume of hydrotest fluid (1500 $m^3$), open ocean environment and depth of water in the receiving environment, adverse impacts on receptors is considered unlikely and of low magnitude, and hence the impact is assessed to be minor.

| Hydrotest water discharged to sea | | | |
|---|---|---|---|
| Impact | Magnitude | Likelihood | Significance |
| Negative | Low | Unlikely | MINOR |

## *Commissioning And Operation*

### c. PFW Discharge

Modelling was performed to determine fate and transport of PFW discharge, using the near-field hydrodynamic model coupled with the release of the following specific PFW constituents:

- BTEX, NPD and PAH compounds;
- Residual MEG within PFW that is not recovered through the MEG regeneration unit; and
- MEG brine from the MEG regeneration unit.

Concentrations over space and time were examined as the PFW constituents dispersed, diluted and degraded. Modelling was performed to estimate the water column concentration of the above referenced PFW constituents using the most conservative of the potential discharge scenarios (2,200 $m^3$/day of PFW).

Inclusion of the two MEG constituents were modelled using the following considerations:

- Low concentrations of unrecoverable MEG within the PFW; and
- Addition of a MEG sludge based on a maximum MEG production of 3.6 tonnes/day.

This model assumes a combined worst case scenario for the combined process MEG and MEG brine of 1,000 ppm at a flow rate of 800 $m^3$/day, which is equivalent to the maximum daily volume of the MEG regeneration unit.

All PFW discharges were assumed to be constant throughout the day. Ranges of degradation half-lives for aerobic aqueous conditions were obtained from Howard et al. (1991). Note that the averages of the ranges presented were chosen as the model inputs. Concentrations of each BTEX, NPD, and PAH constituent were obtained from the Blacktip Produced Formation Water Assessment report (IRC Environment, 2004). For the BTEX compounds, the highest individual concentration reported was used. For NPD and PAHs, the highest of each group's total concentration was used and applied to each individual compound ($\Sigma NPD = 0.67$ ppm, $\Sigma PAH = 0.021$ ppm). The degradation rates and discharge concentrations of the modelled constituents are summarised in *Table 6.21*.

According to ANZECC & ARMCANZ (2000) and French (2000), dissolved aromatics' 96-hour LC50 (the concentration killing 50% of exposed organisms within 96 hours of exposure) range between 100 to 1,000 ppb, with Low Reliability Triggers below which no toxic effects would be expected, one to two orders of magnitudes less. Accordingly, a value of 5 ppb was chosen as a 96-hour threshold for the model and discussion of the results. Nowever, it should be noted that this value of 5 ppb is extremely conservative as it is an order or two of magnitude less than the corresponding ANZECC & ARMCANZ (2000) 99% Level of Protection trigger values (*Table 6.22*).

MEG is slightly toxic (LC50 = 1000–10 000 mg/l) to almost non-toxic (LC50 = 10 000–100 000 mg/l) (Hinwood et al. 1994). A Low Reliability Trigger value of 50 mg/l was selected for MEG as the threshold for the modelling and discussion of the results.

A summary of the maximum and average concentrations in the model discharge cell for all of the constituents are listed below in *Table 6.22*. Model results indicate that total hydrocarbon concentrations in the PFW are mostly below the very conservative 5 ppb threshold applied. Of the 11 constituents modelled, toluene and BTEX showed exceedances of the 'no effect' concentrations over periods of two to four hours. However, as these exceedances are intermittent, whereas the threshold is based upon a continuous 96-hour exposure, the maximum concentrations are considered unlikely to give rise to an impact. The maximum instantaneous size of the plume under these exceedances is 50 m.

The outputs from the GEMMS modelling runs for BTEX and MEG are shown in *Figure 6.10* to *Figure 6.13*.

Modelling results for the 10 hydrocarbon compounds and for residual MEG indicated that potential environmental impacts associated with discharge of PFW to the marine

*Table 6.21 Degradation Rates and Initial Concentrations of Modelled Constituents*

| Chemical | Type | Half Life Range (hrs) | Half-Life Chosen (hrs) | Decay Rate (1/d) | Concentration (ppm) |
|---|---|---|---|---|---|
| Benzene | BTEX | 120 - 384 | 252 | 0.06601 | 7.3 |
| Toluene | BTEX | 96 - 528 | 312 | 0.05332 | 13 |
| Ethylbenzene | BTEX | 72 - 240 | 156 | 0.10664 | 0.8 |
| Xylene | BTEX | 168 - 672 | 420 | 0.03961 | 8.3 |
| Naphthalene | NPD | 12 - 480 | 246 | 0.06762 | 0.67 |
| Phenanthrene | NPD | 384 - 4800 | 2592 | 0.00642 | 0.67 |
| Acenaphthylene | PAH | 1020 - 1440 | 1230 | 0.01352 | 0.021 |
| Fluoranthrene | PAH | 3360 - 10560 | 6960 | 0.00239 | 0.021 |
| Chrysene | PAH | 8904 - 24000 | 16452 | 0.00101 | 0.021 |
| Methylethyl Glycol | MEG | * 89% - 98% deg after 24 hours | *91.5% deg after 24 hours | 2.4651 | 1000 |

** Not a half-life*

*Table 6.22 No Effect Concentrations versus Concentrations in Ambient Water*

| Chemical | Type | Maximum Concentration (mg/l) | Average Concentration (mg/l) | ANZECC 99 % Trigger Values (mg/l) |
|---|---|---|---|---|
| Benzene | BTEX | 0.003982 | 0.000772 | 0.5 |
| Toluene | BTEX | 0.007093 | 0.001375 | $0.5^1$ |
| Ethylbenzene | BTEX | 0.000436 | 0.000085 | $0.5^1$ |
| Xylene | BTEX | 0.004530 | 0.000878 | $0.5^1$ |
| BTEX | BTEX | 0.016041 | 0.003110 | $0.5^1$ |
| Naphthalene | NPD | 0.000365 | 0.000071 | 0.05 |
| Phenanthrene | NPD | 0.000366 | 0.000071 | $0.05^2$ |
| Acenaphthylene | PAH | 0.000011 | 0.000002 | $0.05^2$ |
| Fluoranthrene | PAH | 0.000011 | 0.000002 | $0.05^2$ |
| Chrysene | PAH | 0.000011 | 0.000002 | $0.05^2$ |
| Methylethyl Glycol | MEG | 0.215476 | 0.042710 | - |

*1- Value not available due to insufficient data -see ANZECC & ARMCANZ (2000). Value for Benzene used.*
*2- Value not available due to insufficient data -see ANZECC & ARMCANZ (2000). Value for Naphthalene used.*

environment are low in magnitude and unlikely to result in an adverse impact and therefore are assessed to be minor.

| PFW discharged to sea | | | |
|---|---|---|---|
| Impact | Magnitude | Likelihood | Significance |
| Negative | Low | Unlikely | MINOR |

### d. Cooling Water

Sea water (approximately 50,000 m$^3$/hr) will be required as a cooling medium for the production processes and power generation system on the FLNG facility. It will be drawn from the ocean at a depth of approximately 150 m where water temperatures are lower than at the surface.

The discharge of heated seawater could potentially cause alteration of the physiological processes (especially enzyme-mediated processes) of exposed biota. These alterations may cause a variety of effects ranging from behavioural response (including attraction and avoidance behaviour), to minor physiological stress through to potential mortality for prolonged exposure (Wolanski, 1994). Early studies (in the 1970s) of coastal thermal discharges found that fish avoided them in the warmer months and entered them in colder months and that phytoplankton photosynthesis and the breeding patterns of various invertebrates could be effected (Black et al., 1994).

Screens will be installed at the inlet of the cooling water risers and inlet current speeds will be low (estimated at 0.5m/s) to prevent the ingress of large marine organisms and debris into the system, hence impacts to larger organisms will be avoided. Black et al. (1994) suggest that cooling water intakes have detrimental effects on plankton that become entrained in the cooling water plume but that the impact is likely to be localised (Wolanski, 1994), especially given the low abundance of plankton at the intake depth.

The cooling water will be treated with chlorine to control fouling within the cooling system. Chlorine will be added to maintain a residual level of 0.2 ppm at the outlets, though manual shock dosing of up to 3 ppm could result in short-lived discharges containing 1 ppm chlorine. Modelling of the potential zones of affect for the cooling water discharge includes assessment of both temperature and chlorine. The temperature threshold used is the World Bank guideline which requires cooling water to be within

Figure 6.10 BTEX Surface Contour

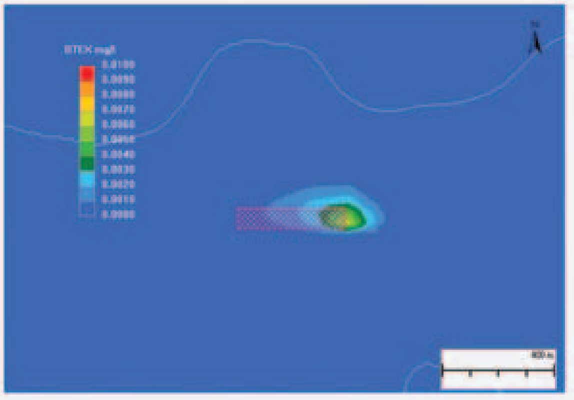


Figure 6.11 BTEX Vertical Slice

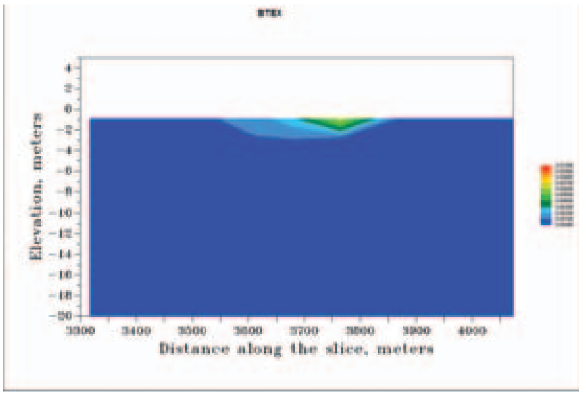


Figure 6.12 MEG Surface Contour

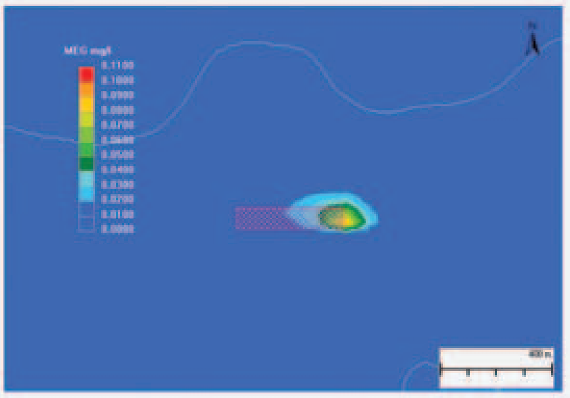
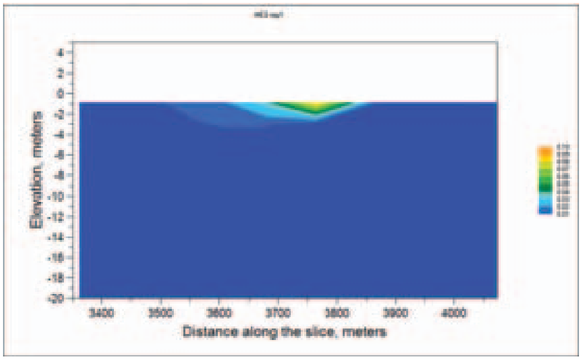


Figure 6.13 MEG Vertical Slice



6

3°C of the background temperature within a distance of 100 m from the discharge point (IFC, 2007). Modelling results are summarised below respectively.

### *Chlorine*

Free Residual Chlorine (FRC) concentrations will meet the World Bank guideline value (0.2 mg/l) at the end-of-pipe. Modelling shows that, as a worst case, FRC is diluted by an order of magnitude within 70 m from the discharge point. FRC consists of hypochlorous acid and hypochlorite ions, which have potential for a chemical and physical impact on marine organisms. However, modelling shows that they are diluted to less than 10% of the regulatory values used overseas and the impact area is limited.

Several chlorine by-products (CBPs) may also develop after discharge which have recently been recognized as constituents of concern because of their toxicity. Based on previous work (Adenekan et al., 2009), four CBP by-products were chosen for further investigation and modelling:

- bromoform;
- dibromoacetic acid (DBAA);
- dibromoacetonitrile (DBAN); and
- monochloroacetic acid (MCAA).

These four CPBs showed maximum concentrations of 4.9 µg/l for bromoform, 1.6 µg/l for DBAA, 0.9 µg/l for DBAN and 0.8 µg/l for MCAA. Currently there are no known standards for CBPs, however, toxicity studies compiled in the US EPA ECOTOX database (USEPA, 2009) have shown bromoform has an LC50 for fish in the range 4,600 µg/l to 36,000 µg/l. For DBAA, the LC50 ranged from 73,000 µg/l to 1,380,000 µg/l, while DBAN was reported in the literature to be more toxic with an LC50 ranging from 540 µg/l to 780 µg/l. No LC50 value was uncovered in the literature for MCAA, but lethality was reported when test organisms were exposed to concentrations ranging from 177,000 to 196,000 µg/l.

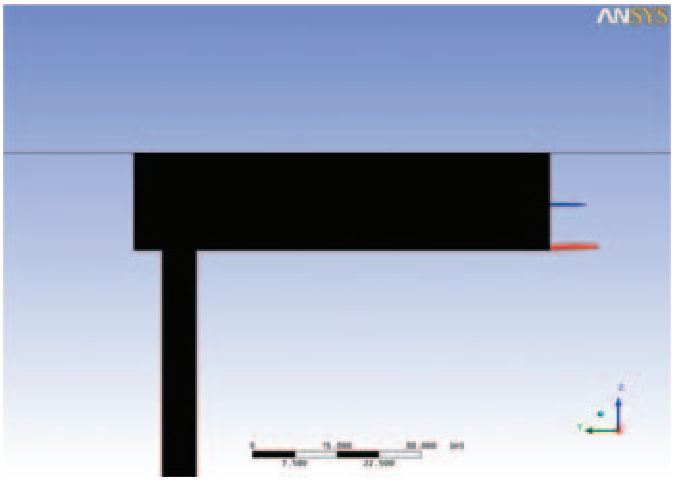
Maximum concentrations of these four CPBs in the cooling water discharge from the FLNG facility are several orders of magnitude below known toxic concentrations suggesting an impact is unlikely.

### *Increased temperatures*

To examine the near field behaviour of the outfall plumes, Deltares undertook extensive stationary computational fluid dynamic flow simulations for representative summer and winter conditions (Deltares, 2009). The simulations show that the dilution of the plumes is mainly governed by the outfall flow velocity and the temperature difference of the discharged cooling water compared to the surrounding ocean. The ambient hydrodynamic conditions (tidal currents and wind) have minimal affect on the initial mixing of the outfall plumes.

In summer, the temperature of the cooling water plume is less than 3°C warmer than the surrounding ocean within 20 m from the discharge point. During winter, the cooling water plume temperature is within 3°C of surrounding ocean water temperature within approximately 15 m. The zone of effect is smaller in winter because the temperature difference between the cooling water discharge and ocean is less than in summer when cooling requirements are greater. For both winter and summer conditions the World Bank guidelines (of a less than 3°C temperature increase at the end of the initial mixing zone or within 100 m) are comfortably fulfilled. *Figure 6.14* shows the extent of the 3°C plume for winter conditions.

*Figure 6.14* *Excess Temperature Plume associated with the Cooling Water Discharge.*



*Note: Figure is a cross-section view of the FLNG facility showing cooling water intakes below the starboard side and 4 cooling water discharges on the port, 3 located at 10 m depth and the fourth at 17 m depth. Excess temperature is defined as > 3 °C above background and shown in blue for the 3 discharges located at 10 m depth and in red for the discharge at 17 m depth.*

The potential for warm seawater, previously heated by the FLNG cooling water discharged, returning to the FLNG on the following tide and affecting temperature dilutions of subsequent cooling water discharges was also investigated. Modelling indicated that the maximum increase in background sea surface temperature in the vicinity of the FLNG facility, as a result of previous cooling water discharges, was 0.4°C. This occurs when tidal flows are low during summer. During winter, the temperature difference between the discharged cooling water and surrounding ocean is less so this temperature effect is reduced. This small increase in ambient temperature does not material affect the dilution of the cooling water discharge plume, estimated to cause an increase in the zone of effect of 3 m.

Given the very localised temperature changes compared to the size of the receiving environment and the very low concentrations of chlorine and chlorine by-products, the magnitude of impact from the discharge of cooling water is low and impacts are unlikely, the significance of impact is therefore assessed to be minor.

| Cooling water discharged to sea | | | |
|---|---|---|---|
| Impact | Magnitude | Likelihood | Significance |
| Negative | Low | Unlikely | MINOR |

### e. Sewage, Grey water and Drainage

Treated sewage, greywater and drainage water will be discharged during all stages of the proposed project. Non-oil contaminated deck drainage will be discharged directly overboard. Contaminated drainage will be diverted to the treatment system to remove hydrocarbons to meet the 30mg/l standard (*Petroleum (Submerged Lands) Management of the Environment Regulations 1999*) prior to discharge overboard. Modelling of sewage, greywater and contaminated drainage concentrated on three constituents; TSS, coliforms and oil/grease.

Model results show that TSS, coliforms, oil/grease and similar constituents modelled as a non-decaying "numerical dye" dilute rapidly upon discharge, and will meet UNEP (1999) standards within 70 m of their discharge (see *Figure 6.15*). TSS and oil/grease are to be controlled on the FLNG facility and discharged at concentrations that meet regulatory levels at the end-of-pipe. Other discharged compounds will dilute quickly, limiting potential impacts. Therefore, impacts from sewage and greywater discharge is predicted to be unlikely and of low magnitude, and is hence assessed to be minor.

| Sewage, greywater and contaminated drainage discharged to sea | | | |
|---|---|---|---|
| Impact | Magnitude | Likelihood | Significance |
| Negative | Low | Unlikely | MINOR |

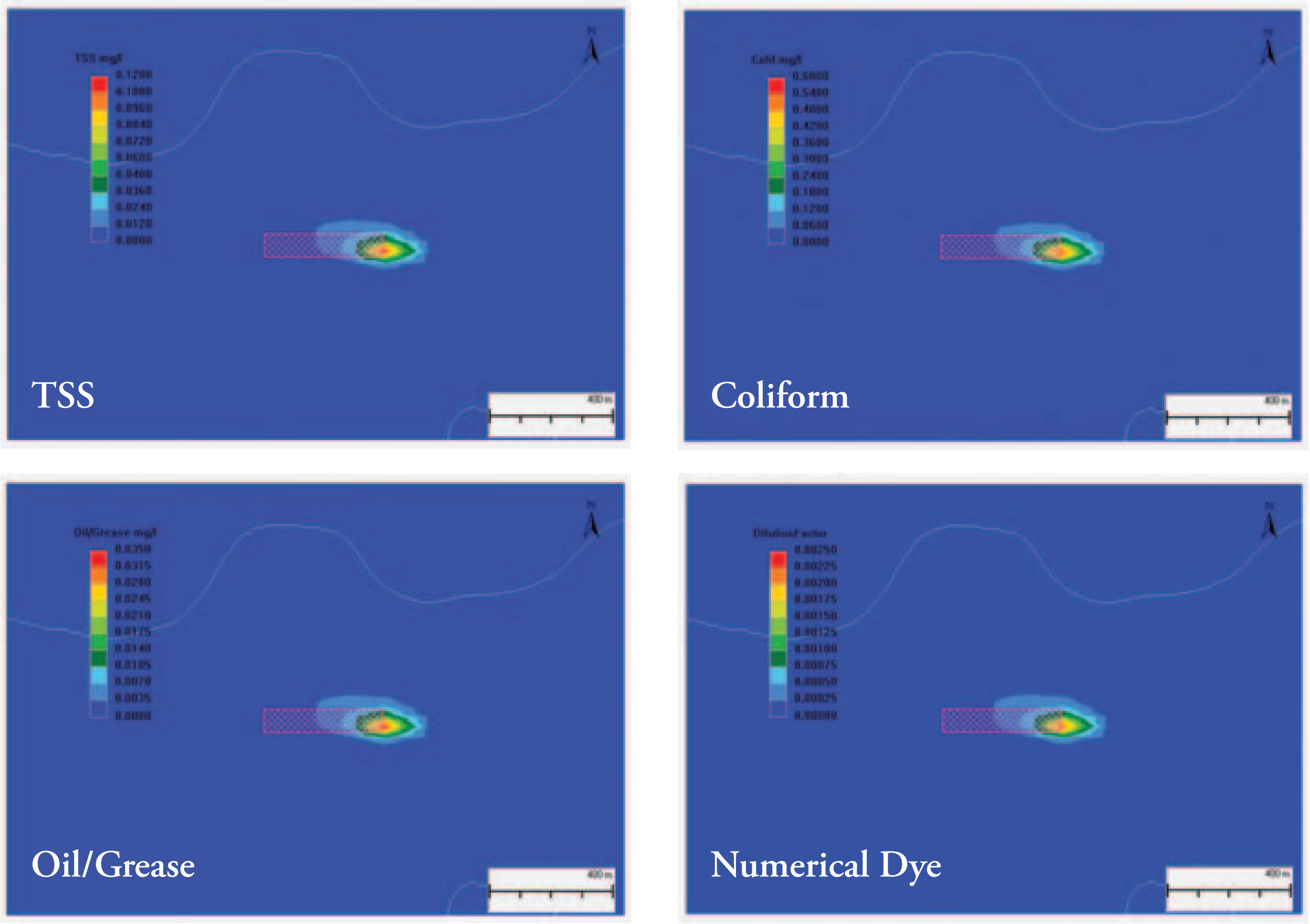
The combined impacts on surface water quality from the discharges of cooling water and grey water (sewage, galley scraps, and bilge water) were also investigated. Cooling water transfers a large quantity of water from deep below the FLNG facility to near the surface. Deeper water contains higher nutrients and lower Dissolved Oxygen (DO) concentrations. Increasing nutrients at the surface has the potential to support increased phytoplankton growth, which in turn has an effect on DO levels. At night, increased phytoplankton depresses DO levels through respiration, while during sunlight hours, the phytoplankton increase DO levels through photosynthesis. Transferring lower DO water from depth nearer to the surface also depresses DO concentrations around the discharge structures.

Grey water consists of sewage, galley scraps and bilge water and contains nutrients which, like the nutrient-rich bottom water, have the potential to depress DO levels and to spur phytoplankton growth. The purpose of the water quality model simulations was to assess the FLNG facility's impact on DO concentrations, which requires the modelling of nutrients, oxygen demand, chlorophyll-*a* as well as DO.

*Table 6.23 Waste Water Dilution Model Results*

| Component | End-of-pipe concentration | Average Concentration | Maximum Concentration | Dilution Factor (for maximum) |
|---|---|---|---|---|
| Numerical dye | 100 mg/l | 0.031 mg/l | 0.22 mg/l | 0.0022 |
| TSS | 50 mg/l | 0.015 mg/l | 0.1 1 mg/l | 0.0022 |
| Coliforms | 250col /100 ml | 0.076 mg/l | 0.54 mg/l | 0.0022 |
| Oil / Grease | 30 mg/l | 0.0092 mg/l | 0.066 mg/l | 0.0022 |

*Figure 6.15 TSS, Coliform, Oil/Grease and Numerical Dye concentrations*



ANZECC (2000) default trigger values for physical and chemical stressors for offshore marine waters in tropical Australia include:

- 0.5 to 0.9µg/l for chlorophyll-*a*; and
- 90% of DO saturation derived from daytime measurements.

The lower chlorophyll-*a* value is typical of clear coral dominated waters (Great Barrier Reef), while the higher value is typical of turbid macrotidal systems such as coastal, northern Western Australia.

Model results (see *Table 6.24* and *Table 6.25*) show that the chlorophyll-*a* and DO criteria will be met. *Figure 6.16* shows the time series of DO and chlorophyll-*a* at two discharge locations with and without FLNG discharges. The difference between the two time series are minimal showing negligible impact.

Since the water quality model was not calibrated to observed data, this evaluation is based on the small incremental changes in DO and chlorophyll-*a* due to proposed FLNG facility discharges, not the absolute DO and chlorophyll-*a* concentrations. The modelled maximum concentration of chlorophyll-*a* is lower than the clear water default trigger value (0.5 µg/l) and the modelled maximum DO difference is only 3% of the average value. Furthermore, the area of impact is very small, within 100 m of the discharge. Small plumes develop at each of the four discharge pipes and at the aft surface, where waves and currents quickly disperse and dilute the plumes. As, such potential impacts are assessed to be minor.

| Extraction and discharge of deepwater to surface marine environment | | | |
|---|---|---|---|
| Impact | Magnitude | Likelihood | Significance |
| Negative | Low | Unlikely | MINOR |

*Figure 6.16* *Time Series Showing modelled Dissolved Oxygen and Chlorophyll-a Concentrations for two of the four Discharge Locations with and without the FLNG Facility*

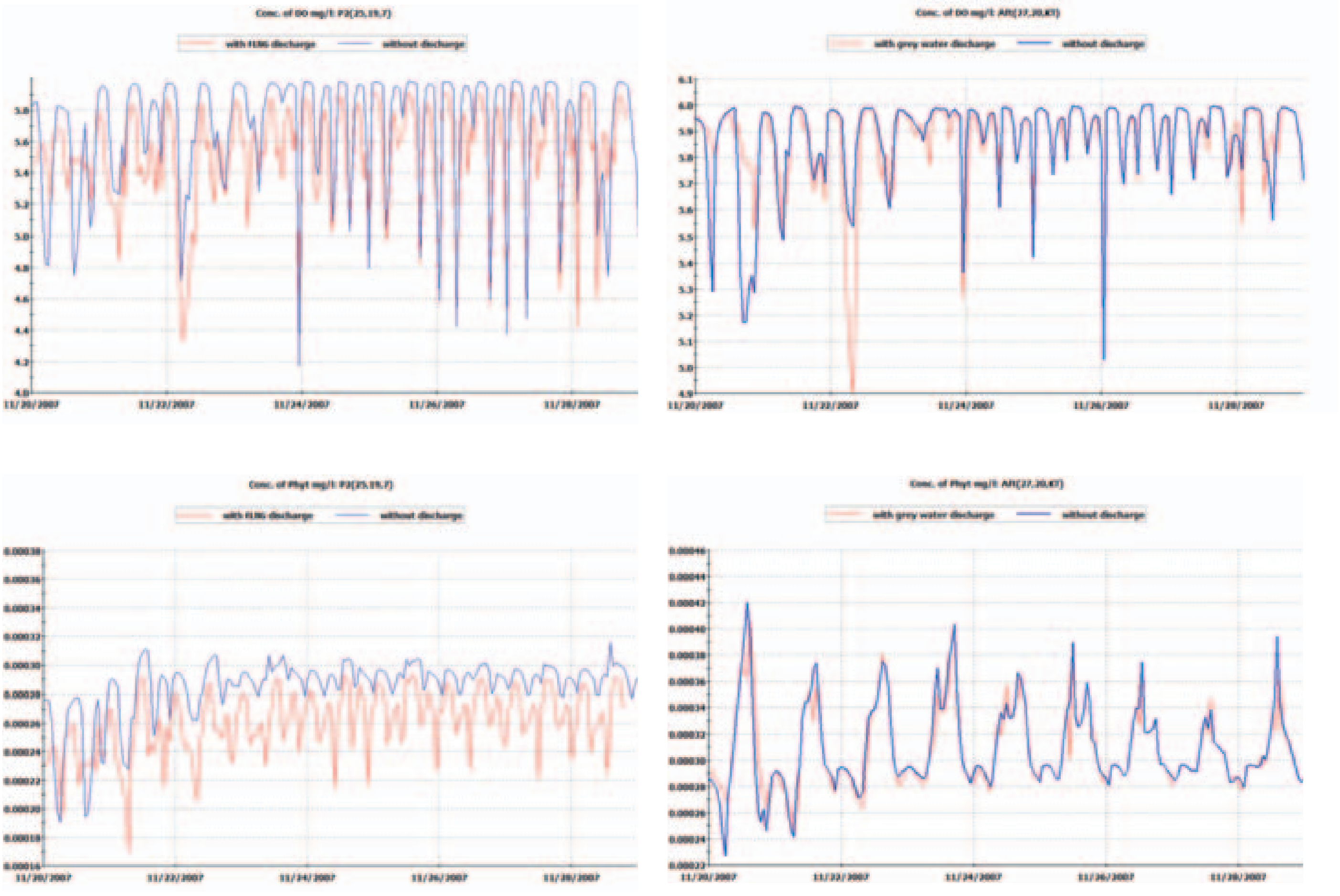


*Table 6.24* *Chlorophyll-a Concentrations for two of the four Discharge Locations with and without the FLNG Facility Discharges*

| Chl-a | Concentrations in µg/l | | |
|---|---|---|---|
| | Minimum | Maximum | Average |
| Chl-*a* at 2P discharge depth | | | |
| with FLNG facility | 0.17 | 0.293 | 0.261 |
| w/o FLNG facility | 0.19 | 0.350 | 0.286 |
| Difference | -0.02 | -0.067 | -0.027 (9.4%) |
| Chl-*a* at Aft water surface | | | |
| with Grey water | 0.246 | 0.404 | 0.309 |
| w/o Grey water | 0.227 | 0.420 | 0.309 |
| Difference | +0.019 | -0.000016 | 0.0 (0%) |

*Table 6.25* *Dissolved Oxygen Concentrations for two of the four Discharge Locations with and without the FLNG Facility Discharges*

| Dissolved Oxygen | Concentrations in mg/l | | |
|---|---|---|---|
| | Minimum | Maximum | Average |
| DO at 2P discharge depth | | | |
| with FLNG facility | 4.33 | 5.91 | 5.52 |
| w/o FLNG facility | 4.17 | 5.98 | 5.68 |
| difference | +0.16 | -0.07 | -0.16 (3%) |
| DO at Aft water surface | | | |
| with Grey water | 4.90 | 6.00 | 5.87 |
| w/o Grey water | 5.03 | 6.00 | 5.87 |
| difference | -0.13 | 0.00 | 0.00 (0%) |

### f. Subsea Control Fluids

Subsea control fluids are used to turn on or off wellhead valves. These systems are typically open-loop system with small volumes of subsea control fluids discharged each time a valve is operated. The control fluids that will be used are water soluble, have low toxicity and are used internationally, as well as on other Shell facilities. Potential effects are limited due to the small volumes used, infrequent use and rapid dilution in a non-sensitive environment. The magnitude of the impact is low and very localised and the potential for an impact to occur is considered unlikely. As such, potential impacts are assessed to be minor.

| Discharge of subsea control fluids to the seabed | | | |
|---|---|---|---|
| Impact | Magnitude | Likelihood | Significance |
| Negative | Low | Unlikely | MINOR |

### g. Desalination Brine

Desalination brine discharge is estimated to be about 210 tonnes/hr (~210 m$^3$/hr). Being of greater density than seawater, this will sink and disperse in the currents. The average salinity for the receiving water is approximately 34.5 ppt (ERM, 2008) and the largest increase of salinity experienced would be approximately 10% in the immediate vicinity of the discharge point. Most marine species are able to tolerate short-term fluctuations in the order of 20% to 30% (Walker and McComb, 1990). The biocide and anti-scale chemicals used are a low inherent toxicity suitable for use in potable water systems. Environmental impacts as a result of the discharge of desalination brine to sea are therefore rated as unlikely to occur and of low magnitude. As such, the impact significance is assessed to be minor.

| Discharge of desalination brine | | | |
|---|---|---|---|
| Impact | Magnitude | Likelihood | Significance |
| Negative | Low | Unlikely | MINOR |

### *Decommissioning*

Liquid waste discharges during decommissioning activities are expected to be localised, small in quantity and short in duration. They are expected to include water generated from the flushing of flowlines, which would be treated within the FLNG facility to meet statutory limits, ballast water discharge from decommissioning vessels, sewage, greywater and deck drainage. The impacts of these discharges to the receiving environment will be assessed in further detail during the process of developing a specific decommissioning management plan. However, given the discharges generated are broadly similar to the discharges generated during construction activities, environmental impacts from liquid waste discharges during decommissioning are expected to be unlikely to occur and of low magnitude. As such, the impact significance is assessed to be minor.

| Liquid waste discharges during decommissioning | | | |
|---|---|---|---|
| Impact | Magnitude | Likelihood | Significance |
| Negative | Low | Unlikely | MINOR |

## 6.7.6 Safeguard and Mitigation Measures

The following mitigation measures have been incorporated into the project design and the project has committed to the following management measures to reduce liquid waste impacts from the Prelude FLNG Project:

### *Drilling Fluids*

**Management Mitigation Measures:**

- Water Based Muds will be used for drilling the top hole sections of the wells.
- The Synthetic Based Muds (SBM) will be low toxicity and approved for use of by the regulator.
- Drilling fluids will be re-used and muds and cuttings separated using shale shakers or centrifuges as per standard industry practice. Spent synthetic based mud will be collected on board and transported to shore for disposal. Cuttings contaminated with SBM will be treated to achieve less than 6.9% SBM by weight prior to overboard discharge.

### *Hydrotest Water*

**Management Mitigation Measures:**

- The selection of chemicals to be added to the hydrotest water will involve a consideration of environmental performance as well as technical requirements.
- Hydrotest water will be discharged to sea through the FLNG facility, which allows greater control over storage times and discharge rates to ensure minimal environmental impacts.

### *Produced Formation Water*

**Management Mitigation Measures:**

- The selection of process chemicals will involve a consideration of environmental performance as well as technical requirements.
- The FLNG facility PFW treatment system will be designed to achieve hydrocarbon concentrations of 30 mg/l or less prior to disposal (to meet the requirements under the *OPGSS Act*).
- A maintenance program will be developed for the FLNG facility and supply vessels which will include inspection and maintenance of treatment systems to ensure discharge limits are met.
- Monitoring of the discharge stream will be undertaken prior to disposal and wastes not meeting specification will be diverted to storage tanks and returned to the PFW treatment system for retreatment. Provision will be made for the capacity to store onboard 2 to 3 days worth of produced water and contaminated drain water, to cater for the unlikely event of failure or poor performance of the treatment system.

### *Subsea Control fluids*

**Management Mitigation Measures:**

- The selection of subsea control fluids will involve a consideration of environmental performance as well as technical requirements.

### *Cooling Water*

**Design Mitigation Measures:**

- Automatic biocide dosing, quality control and feed-back systems will be incorporated into the FLNG facility design.

**Management Mitigation Measures:**

- A maintenance program will be developed for the FLNG facility and supply vessels which will include inspection and maintenance of treatment systems to ensure discharge limits are met.

### *Deck and Surface Drainage*

**Design Mitigation Measures:**

- Bunded areas will be incorporated on the FLNG facility around machinery using hydrocarbons to reduce risk of leaks reaching the ocean.
- The FLNG facility will be designed so that drainage water from deck areas that have the potential to be contaminated with oil or chemicals (excluding areas handling LNG or LPG) and water from areas which are likely to be contaminated with oil (sumps, bunds, machinery spaces, etc) are directed to the slop tanks for treatment.
- The FLNG facility will be designed so that water from areas accidentally contaminated with oils can be directed into the PFW system for treatment prior to disposal.
- The FLNG facility waste water treatment system will be designed to achieve hydrocarbon concentrations of 30 mg/l or less (to meet the requirements under the *OPGSS Act*). Monitoring of the discharge stream will be undertaken prior to disposal and wastes not meeting specification will be diverted to storage tanks and returned to the treatment system for retreatment. Provision will be made for the capacity to store onboard 2 to 3 days worth of produced water and contaminated drain water, to cater for the unlikely event of failure or poor performance of the treatment system

**Management Mitigation Measures:**

- Materials handling procedures will be developed for the FLNG facility and implemented to reduce the risk of spills and leaks.
- A maintenance program will be developed for the FLNG facility and supply vessels which will include inspection and maintenance of treatment systems to ensure discharge limits are met.
- Monitoring of the discharge stream will be undertaken and wastes not meeting specification will be diverted to storage tanks and returned to the treatment process.

### *Ballast water*

**Management Mitigation Measures:**

- Vessel vetting procedures will be developed and implemented to ensure that all vessels engaged by Shell meet the ballast water requirements of relevant legislation (eg *Quarantine Act* and MARPOL).
- All vessels engaged by Shell will be obliged to conduct ballast tank operations in line with IMO guidelines and, where applicable, comply with Australian Quarantine regulations.

### *Sewage and Greywater*

**Management Mitigation Measures:**

- Vessel/rig vetting procedures will be developed and implemented to ensure that all vessels engaged by Shell meet the obligations under the relevant legislation (eg *OPGGS Act*, *Protection of the Sea (Prevention of Pollution from Ships) Act 1983* and MARPOL).
  - For the MODU and FLNG facility, sewage and grey water will be disposed of in accordance with the *OPGGS Act*. Sewage will be passed through a macerator able to macerate wastes to a diameter of less than 25 mm prior to overboard disposal.
  - For all other vessels, sewage and grey water will be disposed of in accordance with international legal requirements under MARPOL 73/78 and the *Protection of the Sea (Prevention of Pollution from Ships) Act 1983.*

### 6.7.7 Summary

*Table 6.26* provides a summary table identifying the receptors and their sensitivity to liquid wastes. It also categorises the nature of the impacts associated with each of the four phases of the project.

### 6.7.8 Conclusion

Liquid waste discharges will include drilling fluids, hydrotest water, PFW (including process MEG and MEG brine from the regeneration facility), treated sewage and greywater, deck drainage, desalination brine, subsea hydraulic control fluids, cooling water and ballast water. These discharges will occur at different times throughout the lifecycle of the project. When discharged to sea, dispersion modelling completed for the largest liquid waste streams indicates that these discharges are rapidly diluted, dispersed and assimilated. No measurable impact to surrounding water quality, outside of very localised mixing zones, is expected based on the volumes of discharge within an open ocean environment. Therefore, the environmental impact to matters of NES, which includes species of marine cetaceans, fish, seabirds and marine turtles, from these discharges has been assessed as minor.

## 6.8 EMISSIONS TO ATMOSPHERE

This section assesses the impacts associated with emissions to atmosphere. It is structured into two sections. The first focuses on greenhouse gases (GHG) and the second on other emissions to atmosphere.

### 6.8.1 Greenhouse Gases

Climate change, as defined by the United Nations Framework Convention on Climate Change, is a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability. Changes to the world's climate can directly result in extreme weather, higher temperatures, more droughts and rising sea levels along with a range of serious indirect impacts. The scientific consensus is that the dramatic increase in atmospheric GHG, especially $CO_2$, which is largely attributable to the burning of fossil fuel, is contributing to global warming and hence to climate change.

Production of LNG and LPG are energy intensive processes that result in significant emissions of GHG. However, LNG has a significantly lower $CO_2$ emissions intensity than other fossil fuels, especially coal. As an example, to generate the same energy input to a power station as generated by Prelude's 3.6 mtpa of LNG requires 7 mtpa of black coal, which emits an additional 7 mtpa $CO_2$-e over and above that emitted by LNG (9.8 mtpa vs 16.8 mtpa: Source: National Greenhouse and Energy Reporting (Measurement) Determination 2008 (*Section 3.85*)).

### *Sources And Characteristics*

Emissions to atmosphere from the Prelude FLNG Project will arise from a number of activities, including:

- combustion of gas – for power generation, compression and flaring;
- discharge of separated reservoir $CO_2$;
- fugitive emissions from flanges etc;
- transportation – in this case supply vessels and tug support for operation of the FLNG facility; and
- diesel drivers (power generation, instrument air, fire water pump etc), which will run on an incidental basis.

## *Table 6.26 Summary of Impacts Associated with Liquid Wastes*

<table>
<tr><th colspan="2">Impact</th><th colspan="8">Impact from Liquid Wastes</th></tr>
<tr><td colspan="2"><b>Receptors</b></td><td colspan="8">Impact on water quality from liquid waste discharges at the FLNG facility resulting in behavioural response and physiological effects on marine species.<br>Cetaceans, including two threatened species (humpback whale and blue whale) may transit the project area.<br>Turtles, two vulnerable species ( green and flatback turtle) may transit the project area. Green turtles also nest on Browse Island (~ 40 km from the FLNG facility location).<br>Fish, including one known threatened species (whale shark) may transit the project area.<br>Birds, including one known migratory marine species (streaked shearwater) may transit the project area. Four potential flights path for migratory shorebirds occur within 150 km of project area.</td></tr>
<tr><td colspan="2"><b>Receptor Sensitivity</b></td><td>■</td><td>Low</td><td></td><td>Medium</td><td></td><td colspan="3">High</td></tr>
<tr><td colspan="10">Throughout the life of the FLNG facility, liquid wastes will be treated and discharged to the environment. Treated effluents have the potential to affect the marine environment through acute or chronic toxicity, oxygen depletion and thermal or salinity stress. It is considered that impacts here are generally of a localised nature.<br>Localised impacts to benthic fauna may result, for example, from subsea control fluid release over the long-term. However, due to the relatively low biological abundance and the wide distribution of similar community types throughout the region, the receiving environment is not considered sensitive and operation impacts are assessed to be minor.</td></tr>
<tr><td rowspan="6"><b>Drilling and Construction</b></td><td><b>Impact Nature</b></td><td>■</td><td colspan="3">Negative</td><td></td><td colspan="3">Positive</td></tr>
<tr><td><b>Impact Extent</b></td><td>■</td><td>Local</td><td></td><td>Regional</td><td></td><td>National</td><td></td><td>Global</td></tr>
<tr><td><b>Impact Duration</b></td><td>■</td><td>Rare/ short</td><td></td><td>Occasional/ moderate</td><td></td><td colspan="3">Regular/ long</td></tr>
<tr><td><b>Impact Magnitude</b></td><td>■</td><td>Low</td><td></td><td>Medium</td><td></td><td colspan="3">High</td></tr>
<tr><td><b>Likelihood</b></td><td>■</td><td>Unlikely</td><td></td><td>Possible</td><td></td><td>Probable</td><td></td><td>Certain</td></tr>
<tr><td><b>Significance</b></td><td>■</td><td>Minor</td><td></td><td>Moderate</td><td></td><td>Major</td><td></td><td>Critical</td></tr>
<tr><td rowspan="6"><b>Commissioning</b></td><td><b>Impact Nature</b></td><td>■</td><td colspan="3">Negative</td><td></td><td colspan="3">Positive</td></tr>
<tr><td><b>Impact Extent</b></td><td>■</td><td>Local</td><td></td><td>Regional</td><td></td><td>National</td><td></td><td>Global</td></tr>
<tr><td><b>Impact Duration</b></td><td>■</td><td>Rare/ short</td><td></td><td>Occasional/ moderate</td><td></td><td colspan="3">Regular/ long</td></tr>
<tr><td><b>Impact Magnitude</b></td><td>■</td><td>Low</td><td></td><td>Medium</td><td></td><td colspan="3">High</td></tr>
<tr><td><b>Likelihood</b></td><td>■</td><td>Unlikely</td><td></td><td>Possible</td><td></td><td>Probable</td><td></td><td>Certain</td></tr>
<tr><td><b>Significance</b></td><td>■</td><td>Minor</td><td></td><td>Moderate</td><td></td><td>Major</td><td></td><td>Critical</td></tr>
<tr><td rowspan="6"><b>Operation/ Maintenance</b></td><td><b>Impact Nature</b></td><td>■</td><td colspan="3">Negative</td><td></td><td colspan="3">Positive</td></tr>
<tr><td><b>Impact Extent</b></td><td>■</td><td>Local</td><td></td><td>Regional</td><td></td><td>National</td><td></td><td>Global</td></tr>
<tr><td><b>Impact Duration</b></td><td></td><td>Rare/ short</td><td></td><td>Occasional/ moderate</td><td>■</td><td colspan="3">Regular/ long</td></tr>
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<tr><td><b>Likelihood</b></td><td>■</td><td>Unlikely</td><td></td><td>Possible</td><td></td><td>Probable</td><td></td><td>Certain</td></tr>
<tr><td><b>Significance</b></td><td>■</td><td>Minor</td><td></td><td>Moderate</td><td></td><td>Major</td><td></td><td>Critical</td></tr>
<tr><td rowspan="6"><b>Decommissioning/ Abandonment</b></td><td><b>Impact Nature</b></td><td>■</td><td colspan="3">Negative</td><td></td><td colspan="3">Positive</td></tr>
<tr><td><b>Impact Extent</b></td><td>■</td><td>Local</td><td></td><td>Regional</td><td></td><td>National</td><td></td><td>Global</td></tr>
<tr><td><b>Impact Duration</b></td><td>■</td><td>Rare/ short</td><td></td><td>Occasional/ moderate</td><td></td><td colspan="3">Regular/ long</td></tr>
<tr><td><b>Impact Magnitude</b></td><td>■</td><td>Low</td><td></td><td>Medium</td><td></td><td colspan="3">High</td></tr>
<tr><td><b>Likelihood</b></td><td>■</td><td>Unlikely</td><td></td><td>Possible</td><td></td><td>Probable</td><td></td><td>Certain</td></tr>
<tr><td><b>Significance</b></td><td>■</td><td>Minor</td><td></td><td>Moderate</td><td></td><td>Major</td><td></td><td>Critical</td></tr>
</table>

Sources of emissions to atmosphere from project activities during each phase of the project are identified in *Table 6.27*.

*Table 6.27 Sources of Emissions during the phases of the Prelude FLNG Project*

| Phase | Activity Source | Duration |
|---|---|---|
| Construction and installation | Drill Rig | 2 years |
| | Vessels movements and vessel-based installation equipment (cranes etc) | |
| Commissioning and operation | FLNG facility operations | 25 years |
| | Vessels- FLNG facility offtake operations | 1-2 per week for 25 years |
| | Vessels (supply vessels) | Fortnightly for 25 years |
| Decommissioning | Vessel and vessel-based decommissioning equipment (cranes etc) | Fortnightly for 4 months |

### 6.8.2 Description And Likely Extent Of Impact

The operational phase of the Prelude FLNG Project generates the vast majority of emissions across the project life. Therefore, an estimate of emissions of GHG has been made for only for this phase of the project. Emissions associated with construction, commissioning and decommissioning are only minor contributions, over short periods, and have not been quantified.

#### *Emissions Inventory*

Emissions to atmosphere have been estimated for the operational phase of the project, based upon current best knowledge of the Prelude gas composition and the level of engineering definition for the project as outlined below. Shell does not expect significant emissions of Hydrofluorocarbons, Perfluorocarbons or Sulphur hexafluoride as there are no uses of these chemicals planned.

#### *Fuel Combustion*

Emissions from burning fuelgas on the FLNG facility includes recognition that some fuelgas used has not been treated in the AGRU and contains $CO_2$ from the reservoir. The emissions of methane and $N_2O$ associated with this combustion were calculated by applying the National Greenhouse and Energy Reporting (NGER) factors for kg $CO_2e$ per GJ of fuel for combustion of natural gas, as per below *Table 6.28*.

#### *Discharge of separated reservoir gas*

This is an almost pure $CO_2$ stream (99.8%) with less than 0.2 mol% methane content and zero $N_2O$.

#### *Flaring*

During start-up and shutdown, controlled flaring will be required as part of operational procedures. During normal operations, flaring will only be performed as necessary for safety reasons and otherwise be restricted according to Shell's commitment to its 'no flaring' principle.

Results of reliability and availability modelling have been used to forecast the number of planned and unplanned events and resultant flaring required to ensure safe operation. This estimate of flared gas enables a calculation of the $CO_2$ emissions. The emissions of methane and $N_2O$ have been calculated by applying factors for tonnes carbon dioxide equivalent ($CO_2e$) per tonne flared (see *Table 6.29)*.

#### *Fugitive Emissions*

Fugitive emissions of methane can arise from leaks from flanges, control valve seals, compressor seals and LNG/LPG loading couplings. At this stage of design, an estimate based upon equipment count is available.

#### *Greenhouse Gas Emissions*

Overall carbon dioxide equivalent emissions are presented in *Table 6.30*. This table shows that emissions of $CO_2e$ from the combustion of gas account for over 50% of the project emissions. These emissions are also presented in *Figure 6.17*.

A useful metric to compare efficiency of LNG projects is the tonnes of GHG emitted to the atmosphere for each tonne of LNG and LPG produced. This GHG intensity provides a benchmark by which to compare GHG emissions of various LNG facilities. GHG intensity of LNG facilities is influenced by a range of internal (technology) and external (environmental/geographic) factors.

### Table 6.28 Fuel Combustion Emission Factors

| Fuel combusted | Energy content factor (GJ/m$^3$ unless otherwise indicated) | Emission factor kg $CO_2$ e/GJ (relevant oxidation factors incorporated) | | |
|---|---|---|---|---|
| | | $CO_2$ | $CH_4$ | $N_2O$ |
| Natural gas distributed in a pipeline | 39.3 × 10 3 | 51.2 | 0.1 | 0.03 |

*Source: National Greenhouse and Energy Reporting (Measurement) Determination 2008 (Section 3.85)*

### Table 6.29 Flaring Emission Factors

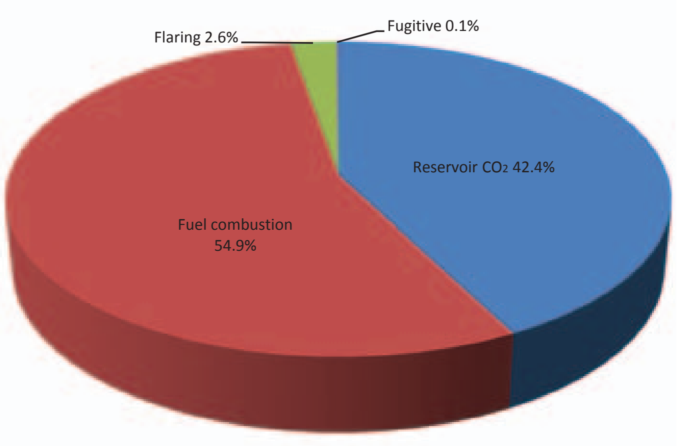
| Operation or process source | Emission factor (tonnes $CO_2$-e/tonnes flared) | | |
|---|---|---|---|
| | $CO_2$ | $CH_4$ | $N_2O$ |
| Gas flared | 2.7 | 0.1 | 0.03 |

*Source: National Greenhouse and Energy Reporting (Measurement) Determination 2008 (Section 3.85)*

### Table 6.30 Annual $CO_2$ equivalent Emissions from the Prelude FLNG Project

| Tonnes per year | $CO_2$ | $CH_4$ | $N_2O$ | $CO_2e$ | % |
|---|---|---|---|---|---|
| Reservoir $CO_2$ | 966 | 370 | 0 | 973,728 | 42.4 |
| Fuel combustion | 1,259,664 | 114 | 2.4 | 1,262,688 | 54.9 |
| Flaring | 57,792 | 101 | 2 | 60,480 | 2.6 |
| Fugitive | 0 | 101 | 0 | 2,016 | 0.1 |
| Total | 2,283,456 | 686 | 4.4 | 2,298,912 | 100 |

### Figure 6.17 GHG Emissions by Source for the Prelude FLNG Project



Technological and process factors that influence GHG intensity include:

- choice of liquefaction technology - simple $N_2$ cycle, cascade refrigeration, propane pre-cooled mixed refrigerant design or dual mixed refrigerant design;
- choice of driver for compressors and power generation – steam turbines, industrial gas turbines, aeroderivative gas turbines, electrical motors;
- choice of air cooling or water cooling or both;
- choice to produce separate LPG product stream;
- design reliability affecting the amount of flaring that may take place; and
- waste heat recovery applied.

The main environmental factors that have a significant impact on LNG Plant GHG efficiency are:

- the ambient air temperature at the LNG facility location and/or water temperature if water cooling is used. Gas combustion and refrigeration efficiency improves with cooler temperatures; and
- the composition of the feed gas for:
  - $CO_2$ - higher $CO_2$ content results in increased energy requirement to remove the $CO_2$ (which must be removed from the feed gas stream prior to the liquefaction process to avoid $CO_2$ solidifying and blocking the process) and an increased amount of separated reservoir $CO_2$ to be discharged to atmosphere;
  - $N_2$ - higher nitrogen content increases liquefaction energy requirement;
  - LPG - higher LPG content reduces liquefaction energy requirement; and
  - heavier components - extra condensate yield requires more energy for stabilisation.

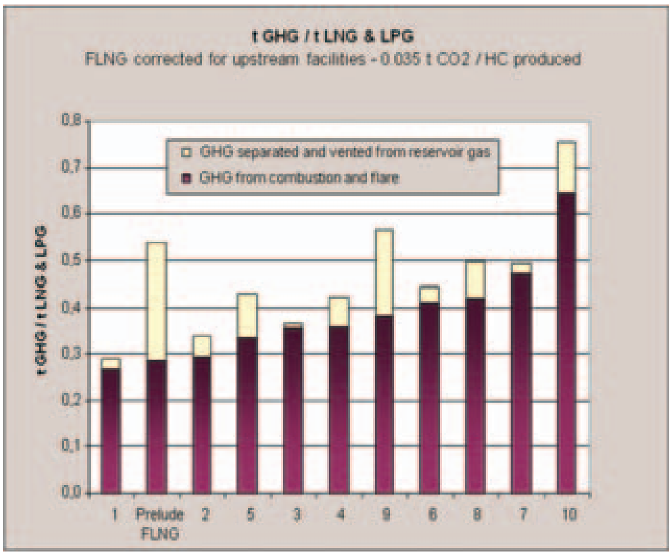
Notwithstanding these differences, benchmarking GHG intensity of the project against other LNG projects provides a comparison with GHG performance in the industry.

*Figure 6.18* presents a comparison of GHG intensity for a group of 10 existing world scale LNG facilities benchmarked against the Prelude FLNG facility. These ten LNG Plants account for about 70% of current total global LNG capacity ie about 140 mtpa LNG production.

LNG plants in this comparison are onshore and show emissions for the LNG plant only. They do not include emissions from their offshore platform operations eg offshore gas compression. The Prelude FLNG Project upstream emissions are expected to be considerably less than many other LNG projects, due to the proximity of the LNG facility to the reservoir. Nonetheless, so that a 'like for like' comparison is presented, the $CO_2$ emissions from upstream operations have been subtracted. In the case of Prelude, upstream emission were estimated at rate of 0.035 $tCO_2$/t HC, which is an order of magnitude smaller than the downstream emissions presented in *Figure 6.18*.

The Prelude FLNG facility is energy efficient in comparison to many land-based LNG plants because it uses cold seawater from 150 m depth for coolant, uses a dual mixed refrigerant liquefaction cycle and minimises LNG boil-off with short loading lines. It also reduces gas compression requirements as the facility is located over the gas field, though this is not included in the comparison presented in *Figure 6.18*. The FLNG facility has the second lowest GHG intensity (t $CO_2$/t LNG + LPG) of the LNG plants in the comparison.

*Figure 6.18 GHG Intensity Comparison*



However, Prelude has a relatively high amount of $CO_2$ in the feedgas at 9% volume which contributes to its overall $CO_2$-e footprint. When the vented reservoir derived $CO_2$ is combined with the combustion and flare emissions, the Prelude FLNG facility ranks ninth of 11 overall in terms of total operational $CO_2$ emissions.

In summary, during the production of 5.2 million tonnes per annum (mtpa) of hydrocarbons (including LNG, LPG and condensate), the facility is forecast to emit 2.3 mtpa of carbon dioxide equivalent ($CO_2$e). Approximately half the estimated annual emissions arise from combustion of fuel gas to power the liquefaction process. Nearly all of the remaining emissions arise from discharge of separated reservoir $CO_2$.

## *Assessment of Impacts*

The GHG impacts of the project have been considered in the context of their magnitude compared with Australia's and the world's emissions. The estimate of emissions from the Prelude FLNG Project is 2.3 mtpa $CO_2$e.

Emissions from the project contribute to the total Australian annual emissions. In 2006, annual GHG emissions were estimated for Australia at 576 million tonnes $CO_2$e[18] which represented 1.5% of global $CO_2$e emissions. Forecast emissions from the project represent approximately 0.4% of Australia's annual emissions in 2006.

It is difficult to risk assess the impact of Prelude GHG emissions in isolation, as the effects of global warming and associated climate change are the cumulative effect of many sources across the globe and it is the cumulative effects that ultimately bring about climate change. While

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[18] *Reporting year 2006, Kyoto framework, Australian Greenhouse Emissions Information System http://www.ageis.greenhouse.gov.au/*

Prelude GHG emissions will contribute on a cumulative basis to global GHG emissions, it is difficult to argue that Prelude GHG emissions will have any direct negative environmental impact on receptors, including matters of NES, in the project area of the Browse basin. Also, Prelude LNG $CO_2$ emissions intensity, when compared with like for like exploitation of other fossil fuels (eg coal) on a well to wheels basis, could potentially have a net positive impact, but only if the export of Prelude LNG displaces more carbon intensive fuels in power stations.

In an Australian context, the emissions generated by the project will increase pressure on all emitters in Australia in collectively meeting reduction targets. The Carbon Pollution Reduction Scheme (CPRS) represents the Australian Government's primary policy approach to reducing overall emissions of GHG from Australian industry and reducing the extent of climate change. The scheme sets an annual cap, which represents the total GHG emissions that can be emitted. This is designed to apply a cost to GHG emissions and thereby use market forces to encourage a reduction in emissions by improved energy efficiency and other cost effective carbon reduction technologies.

The key points in relation to reduction targets are:

- reduce emissions of GHG by 25 per cent below 2000 levels by 2020 if the world agrees to an ambitious global deal to stabilise levels of $CO_2$-e at 450 parts per million or lower by mid century; and
- confirmation of an unconditional 5% reduction in carbon pollution below 2000 levels by 2020, which represents a significant cut of around 27% on a per capita basis (Australian Government, 2008).

The Prelude FLNG Project will fall under the CPRS as scope 1 direct emissions from the project will exceed the 25,000 tonnes $CO_2$e annum threshold. Therefore, the Prelude FLNG Project will be required to purchase emission permits to cover GHG emissions and will increase the pressure on all emitters to achieve the Australian Government's GHG reduction targets. Therefore, the negative impact of Prelude FLNG Project GHG emissions are assessed to be moderate.

| GHG Emissions | | | |
|---|---|---|---|
| Impact | Magnitude | Likelihood | Significance |
| Negative | Medium | Probable | MODERATE |

### 6.8.3 Safeguards/Mitigation Measures

GHG emissions mitigation has been considered at all stages of the Prelude FLNG project to date, from concept selection and through preliminary design, as is outlined below:

*Activities already undertaken to minimise emissions*

The design of the FLNG facility has been developed with a high thermal efficiency to reduce the carbon footprint for a liquefaction facility as follows:

- Combining the offshore and onshore components into one integrated facility reduced the use of materials (steel, concrete) and disturbance (dredging, onshore land take) from wellhead to loaded LNG.
- By being located over the gas field, the FLNG facility avoids a long pipeline to shore which:
    - reduces the compression requirements during the later life of the field as the reservoir pressure declines, as gas does not have to be transported a long distance.
    - avoids the need for any additional processing requirements to remove water from the gas and condensate to make it suitable for transport in a carbon steel pipeline to shore.

The FLNG facility itself has a number of energy efficiency improvements over an onshore LNG Plant. The FLNG facility:

- uses cold seawater from 150 m water depth as coolant rather than coastal seawater or air cooling;
- uses reliable steam turbines, supplied with steam from multiple steam boilers fuelled by low pressure boil-off gas (recovered from the LNG storage);
- uses a dual mixed refrigerant liquefaction cycle to enable optimum thermodynamic efficiency for differing gas compositions and ambient temperatures and minimise the equipment count;
- minimizes LNG boil-off by avoiding long recirculating loading lines out to the end of jetties (as required for typical onshore LNG plants);
- recovers the boil-off gas generated from loading of LNG carriers instead of flaring it and compresses it to fuelgas which itself uses a lower pressure for firing steam boilers thereby reducing boil-off gas compression duty;
- uses $N_2$ to purge the flare stack rather than hydrocarbon gas;

- uses a three stage pre-cool system rather than two stage system in the liquefaction process to gain extra efficiency; and
- avoids the need to incinerate the acid gas vent stream by routing to the flare tip for safe dispersion.

*Additional studies that are planned to minimise emissions*

As part of the ongoing design process, studies will be undertaken to:

- further minimise flaring during cold and warm start-ups;
- investigate flow assurance requirements and the need for de-pressuring flowlines in a shutdown; and
- investigate process availability and reliability to maximise operational run lengths and reduce process trips and losses to flare.
- further investigate the feasibility of geosequestration (see *Section 4.4.2*)

### 6.8.4 Other Emissions

Emissions to atmosphere from the proposed development will arise primarily from the combustion of fossil fuels. The primary pollutants with potential human health implications are oxides of nitrogen, carbon monoxide, hydrocarbons and particulates. Oxides of nitrogen (NOx) are the most significant pollutant, therefore, they are the focus of this study. It is considered likely that impacts to ambient air from other primary pollutants will be of a lower magnitude than NOx.

It is not considered that there are any natural receptors in the vicinity of the FLNG which would be sensitive to changes in air quality. As a consequence and as agreed with DEWHA, no dispersal modelling of other emissions has been presented in this report. The information presented below is limited to a summary of other emission sources (including NOx, $H_2S$ and VOCs), estimated emission volumes and a confirmation of impacts.

*Emissions*

The main emissions with a potential impact on regional air quality will be oxides of nitrogen (NOx) from the combustion of fossil fuel. Emissions of Sulphur Oxides and Volatile Organic Compounds (VOC) – including hydrocarbon compounds such as, benzene, toluene ethyl benzene and xylene have also been estimated.

**a) Nitrogen Oxides**

Emissions of nitrogen oxides (NOx) arise from the thermal oxidation of gas in boilers and flares during operation of the facility.

The emission of NOx from boilers is based on fuel gas firing for which a maximum emission limit is applicable of 240 mg $Nm^{-3}$. This emissions limit has also been used to estimate emissions of NOx from flaring.

In addition, there are a number of diesel fuelled pieces of equipment within the FLNG facility. This equipment is typically operated on a 'back-up' basis. The emissions are therefore an order of magnitude smaller than the boilers and flaring contributions and have not been included in the emissions inventory.

Nitrogen oxide emissions are presented in *Table 6.31* below.

*Table 6.31 Annual NOx emissions from the Prelude FLNG Project*

| Pollutant | Source of emissions | Emissions (tonnes per annum) |
|---|---|---|
| NOx (as $NO_2$) | Boilers | 2144 |
| | Flare | 134 |

**b) Hydrogen Sulphide**

Hydrogen sulphide ($H_2S$) is present in the feed gas and is removed as part of gas processing in the Acid Gas Removal Unit (AGRU). Once removed from the gas stream, $H_2S$ is vented to atmosphere along with the $CO_2$. The total quantity of $H_2S$ emitted by this route is estimated at 171 tonnes per annum. Only a minor amount of $H_2S$ will remain in the fuel gas to the boilers to be converted into SOx (estimated to be less than 1 tonne per annum).

**c) VOC Emissions**

VOCs result from fugitive emission sources such as residual hydrocarbons emissions in $CO_2$ vent gas, un-combusted gas flared, condensate loading operations and other fugitive sources.

Emissions of VOCs from flaring are based on an estimated combustion efficiency of 97%. The condensate production will be offloaded onto oil tankers. As is similar practice for FPSOs, as the condensate fills up the receiving tanks on the oil tanker, it displaces the tank's vapour space to atmosphere, thereby releasing some VOCs. The quantity can vary according to the degree of inert atmosphere and pressure build allowed by different oil tankers. Estimates of the resultant VOC's are shown below. Other fugitive emission sources identified include valves, seal, and LNG and LPG loading arm couplings.

A summary of estimated annual emissions to atmosphere is presented in *Table 6.32* below.

*Table 6.32 Other Emissions from the Prelude FLNG Project*

| **Pollutant** | **Source of emissions** | **Emissions (tonnes per annum)** |
|---|---|---|
| $H_2S$ | Acid gas vent | 172 |
| Ethane | Acid gas vent, flare and fugitive emissions | 221 |
| Propane | Acid gas vent, flare and fugitive emissions | 37 |
| iButane | Acid gas vent, flare, and condensate storage tanks | 302 |
| Butane | Acid gas vent, flare, and condensate storage tanks | 1005 |
| Benzene | Acid gas vent and condensate storage tanks | 402 |
| Toluene | Acid gas vent and condensate storage tanks | 1106 |
| Xylene | Condensate storage tanks | 33 |

*Source: Prelude Air Emissions 1303091.doc*

### 6.8.5 Assessment of Impacts

Given the distance to the nearest environmental sensitive receptors, it is not anticipated that emissions from the facility will have an impact at any sensitive receptor locations. As such, dispersion modelling has not been undertaken as part of this assessment.

Prevention of emissions throughout the design process is the primary method through which emissions to air quality are controlled. The potential impacts of process emissions from the operational facility have been reviewed and modelled to confirm that no occupational health concerns from elevated air pollutant concentrations will exist for personnel working on the FLNG facility. This will be subject to further checks as the design specifications for the processes are established.

Given that emissions will not exceed occupational health limits and the distance of the FLNG facility from environmental sensitive receptors, impacts from non-GHG emissions are considered to be unlikely and of low magnitude, and therefore the impact significance is assessed to be minor.

| Non-GHG Emissions | | | |
|---|---|---|---|
| Impact | Magnitude | Likelihood | Significance |
| Negative | Low | Possible | MINOR |

### 6.8.6 Safeguard/Mitigation Measures

The following mitigation measures have been incorporated into the project design and the project has committed to the following management measures to reduce impacts from emissions to air from the Prelude FLNG Project:

**Design Mitigation Measures:**

- The selection of project development concept as FLNG, which has a smaller environmental footprint than an onshore LNG plant development (with associated offshore platform, export pipeline and coastal dredging).
- Locating the FLNG facility in an area that is distant to the closest known significant environmental sensitivities.
- Reducing the volume of emissions is the primary method through which emissions to air will be managed.
    - A 'no venting' principle with respect to the disposal of hydrocarbon streams from process units and other equipment has been applied to the Prelude FLNG Project. Some venting may be required, however, in special cases where routing to the flare is prohibited for safety or other reasons.
    - A 'no flaring' principle with respect to the disposal of hydrocarbon streams from normal operations has been applied to the Prelude FLNG Project. Some flaring will be required , however, for safety reasons during start up and shut down and process upsets.
- The FLNG facility will be designed to run efficiently,

whilst meeting reliability requirements, and equipment, flanges, seals and valves selection will involve consideration of fugitive emissions, with the objective of reducing emissions.
- The design of the FLNG facility will allow the installation of adequate equipment to monitor and record emissions for which regulatory limits exist and/or for which performance statistics are required.

**Management Mitigation Measures:**
- Procedures will be developed to limit the occurrence and duration of venting and flaring to ALARP.

*Table 6.33* and *Table 6.34* are summary tables identifying the receptors and their sensitivity to GHG and non-GHG emissions to air. It also categorises the nature of the impacts associated with each of the four phases of the project.

### 6.8.7 Conclusion

The overall GHG impacts of the project need to be considered in the context of their magnitude in respect of Australia's and the world's emissions. The estimate of emissions from the Prelude project is 2.3 mtpa $CO_2e$ which represents about 0.4% of total Australian GHG emissions.

The effects of global warming and associated climate change are the cumulative effect of many sources across the globe and it is the cumulative effects that ultimately bring about climate change. As such the negative impact of Prelude project GHG emissions are considered to be moderate.

## 6.9 UNPLANNED EVENTS

### 6.9.1 Introduction

Unplanned events are incidents or non-routine events that have the potential to trigger impacts that would otherwise not be anticipated during the normal course of construction, operation or decommissioning. The magnitude of impact from the unplanned events of concern can be greater than the magnitude of potential impacts associated with routine operations, however the probability of an unplanned event occurring is typically much lower.

Given the high potential magnitude of unplanned events, they require plans specifically designed to respond to the event as quickly and effectively as possible. In addition to mobilising the operator's resources, additional resources from external parties such as government agencies are often an inherent part of the incident response.

For the purpose of this assessment, the following unplanned events have been considered:
- hydrocarbon spills and leaks;
- non-hydrocarbon spills and leaks; and
- introduced marine species.

### 6.9.2 Hydrocarbon Spills and Leaks

#### *Sources and Characteristics*

Liquid hydrocarbons utilised and/or produced during the project phases are summarised below. These include diesel, lubricating and hydraulic oils, condensate and aviation fuel. Spills and leaks of LNG and LPG have not been considered below because both liquids are non-toxic and, as they vaporise quickly, they will have a minimal impact on the marine environment in the unlikely event of a spill.

#### a. Diesel

Marine diesel used in offtake and support vessels is a low viscosity distillate fuel. Diesel contains a high proportion of lighter hydrocarbons, such that evaporation is an important process contributing to the removal of spilt diesel from the sea surface. Evaporation will be enhanced by higher wind speeds and warmer sea and air temperatures. The general behaviour of diesel at sea can be summarised as follows:
- A slick of diesel will elongate rapidly in the direction of the prevailing wind and waves.
- Very rapid spreading of the low viscosity diesel will take place.
- Some diesel fuel oils may form an unstable emulsion at the thicker, leading edges of the slick.
- Speed of physical dispersion of the surface slick increases with wind speed. Up to 95% of a slick may disperse within about 4 hours of the spill in 15 knot winds, warm air and sea conditions.
- Evaporation of diesel is likely to be enhanced due to the warmer prevailing air and sea temperatures of the Prelude project area.

*Table 6.33 Summary of Predicted Impacts from GHG Emissions*

| Impact | | Impact from GHG emissions | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Receptors** | | GHG emissions from the project contribute to total Australian annual emissions. The effects of global warming and associated climate change are the cumulative effect of many sources across the globe and it is the cumulative effects that ultimately bring about climate change.<br>Relevant receptors for GHG emissions, therefore, are the global climate and environment. | | | | | | | |
| **Receptor Sensitivity** | | | | | | | | | |
| **Global climate and environment** | | | Low | | Medium | ■ | High | | |
| Based on the scientific evidence from the United Nations Intergovernmental Panel on Climate change (IPCC, 2007), the climate is sensitive to changes in the concentration of $CO_2$ in the atmosphere as a contributor to climate change and global warming. The IPCC have stated that they are 'highly confident' that increased concentrations of $CO_2$ in the atmosphere are 'human induced' and that this is responsible for a change in the global climate. These conclusions have been used in determining the impacts shown below. | | | | | | | | | |
| **Drilling and Construction** | **Impact Nature** | ■ | Negative | | Positive | | | | |
| | **Impact Extent** | | Local | | Regional | | National | ■ | Global |
| | **Impact Duration** | ■ | Rare/ short | | Occasional/ moderate | | Regular/ long | | |
| | **Impact Magnitude** | ■ | Low | | Medium | | High | | |
| | **Likelihood** | | Unlikely | | Possible | ■ | Probable | | Certain |
| | **Significance** | ■ | Minor | | Moderate | | Major | | Critical |
| **Commissioning** | **Impact Nature** | ■ | Negative | | Positive | | | | |
| | **Impact Extent** | | Local | | Regional | | National | ■ | Global |
| | **Impact Duration** | ■ | Rare/ short | | Occasional/ moderate | | Regular/ long | | |
| | **Impact Magnitude** | ■ | Low | | Medium | | High | | |
| | **Likelihood** | | Unlikely | | Possible | | Probable | | Certain |
| | **Significance** | ■ | Minor | | Moderate | | Major | | Critical |
| **Operation/ Maintenance** | **Impact Nature** | ■ | Negative | | Positive | | | | |
| | **Impact Extent** | | Local | | Regional | | National | ■ | Global |
| | **Impact Duration** | | Rare/ short | | Occasional/ moderate | ■ | Regular/ long | | |
| | **Impact Magnitude** | | Low | | Medium | ■ | High | | |
| | **Likelihood** | | Unlikely | | Possible | ■ | Probable | | Certain |
| | **Significance** | | Minor | ■ | Moderate | | Major | | Critical |
| **Decommissioning/ Abandonment** | **Impact Nature** | ■ | Negative | | Positive | | | | |
| | **Impact Extent** | | Local | | Regional | | National | ■ | Global |
| | **Impact Duration** | ■ | Rare/ short | | Occasional/ moderate | | Regular/ long | | |
| | **Impact Magnitude** | ■ | Low | | Medium | | High | | |
| | **Likelihood** | | Unlikely | ■ | Possible | | Probable | | Certain |
| | **Significance** | ■ | Minor | | Moderate | | Major | | Critical |

### b. Lubricating and Hydraulic Oil

Lubricating oils behave in a manner similar to marine diesel but are more viscous, slowing down the spread of the slick marginally. As lubricating oils are considerably refined, they do not contain the same quantity or ratio of light-end hydrocarbons. Hydraulic oils are medium oils of light to moderate viscosity. They have a rapid spreading rate and generally dissipate quickly, particularly in higher sea states. Lubricating and hydraulic oils are used in a variety of equipment on both rigs and vessels and stored in containers ranging from 20  to 1,000 L.

*Table 6.34 Summary of Predicted Impacts from non-GHG Emissions*

| **Impact** | | **Non GHG Emissions** | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Receptors** | | Browse Island visitors/rangers | | | | | | | |
| **Receptor Sensitivity** | | ■ | Low | ☐ | Medium | ☐ | High | | |
| **Drilling and Construction** | **Impact Nature** | ■ | Negative | ☐ | Positive | | | | |
| | **Impact Extent** | ■ | Local | ☐ | Regional | ☐ | National | ☐ | Global |
| | **Impact Duration** | ■ | Rare/ short | ☐ | Occasional/ moderate | ☐ | Regular/ long | | |
| | **Impact Magnitude** | ■ | Low | ☐ | Medium | ☐ | High | | |
| | **Likelihood** | ☐ | Unlikely | ■ | Possible | ☐ | Probable | ☐ | Certain |
| | **Significance** | ■ | Minor | ☐ | Moderate | ☐ | Major | ☐ | Critical |
| **Commissioning** | **Impact Nature** | ■ | Negative | ☐ | Positive | | | | |
| | **Impact Extent** | ■ | Local | ☐ | Regional | ☐ | National | ☐ | Global |
| | **Impact Duration** | ■ | Rare/ short | ☐ | Occasional/ moderate | ☐ | Regular/ long | | |
| | **Impact Magnitude** | ■ | Low | ☐ | Medium | ☐ | High | | |
| | **Likelihood** | ☐ | Unlikely | ☐ | Possible | ☐ | Probable | ☐ | Certain |
| | **Significance** | ■ | Minor | ☐ | Moderate | ☐ | Major | ☐ | Critical |
| **Operation/ Maintenance** | **Impact Nature** | ■ | Negative | ☐ | Positive | | | | |
| | **Impact Extent** | ■ | Local | ☐ | Regional | ☐ | National | ☐ | Global |
| | **Impact Duration** | ■ | Rare/ short | ☐ | Occasional/ moderate | ☐ | Regular/ long | | |
| | **Impact Magnitude** | ■ | Low | ☐ | Medium | ☐ | High | | |
| | **Likelihood** | ☐ | Unlikely | ■ | Possible | ☐ | Probable | ☐ | Certain |
| | **Significance** | ■ | Minor | ☐ | Moderate | ☐ | Major | ☐ | Critical |
| **Decommissioning/ Abandonment** | **Impact Nature** | ■ | Negative | ☐ | Positive | | | | |
| | **Impact Extent** | ■ | Local | ☐ | Regional | ☐ | National | ☐ | Global |
| | **Impact Duration** | ■ | Rare/ short | ☐ | Occasional/ moderate | ☐ | Regular/ long | | |
| | **Impact Magnitude** | ■ | Low | ☐ | Medium | ☐ | High | | |
| | **Likelihood** | ☐ | Unlikely | ■ | Possible | ☐ | Probable | ☐ | Certain |
| | **Significance** | ■ | Minor | ☐ | Moderate | ☐ | Major | ☐ | Critical |

### c. Condensate

Condensate comprises the fraction of the produced hydrocarbon that is a liquid at ambient temperature and pressure. Condensate may be encountered as liquid hydrocarbons produced from gas condensate reservoirs and may be similar in appearance to light crude oil. It is comprised of low molecular weight hydrocarbons and has similar characteristics as light diesel fuel. It is typically very volatile and will evaporate readily. However, the condensate anticipated for Prelude will have a significant waxy component which may persist after the volatile portion evaporates. Condensate spreads rapidly and may be impractical or difficult to contain in an open ocean environment. As described in *Section 4.7.10*, condensate will be offloaded from the FLNG to tankers as per conventional FPSO practice.

**d. Aviation Fuel (Jet A-1)**

Aviation fuel is volatile and evaporates and spreads quickly. Since the fuel will mostly evaporate, leaving little or no visible mass left on the surface within 24 hours, it is unlikely there would be sufficient time for cleanup operations in the event of a spill. Aviation fuel is used for refuelling helicopters that transport equipment and personnel to and from the FLNG and other offshore vessels to shore.

### *Description of the Impact*

Hydrocarbons vary in their impacts from highly toxic and less persistent to low toxicity and high persistence, depending on their respective chemical properties. To evaluate the consequences of hydrocarbon spills on natural resources it is important to understand the properties and chemistry of petroleum products. Petroleum, depending upon its form and chemistry, causes a range of physiological and toxic effects on wildlife and habitats. For example, the low molecular weight aliphatics can have anaesthetic properties and aromatic components, such as benzene, are known carcinogens and toxic to humans and wildlife. Some polynuclear aromatics are also carcinogenic and toxic and become concentrated in the food chain eg in the tissues of filter feeding shell fish such as mussels and oysters.

This compositional variation of petroleum also governs its behaviour, weathering and fate after being spilt in the marine environment. Toxicity and physical consequences are dictated by:

- volatility of hydrocarbons into the air from spilt petroleum;
- solubility of toxic components into seawater from the hydrocarbon slick;
- formation and stability of emulsions;
- rate of natural hydrocarbon dispersion;
- persistence;
- adherence to surfaces ("stickiness") and physical state; and
- rate of natural biodegradation.

Effects of hydrocarbon on habitats and wildlife can be summarised as:

- physical and chemical alteration of natural habitats;
- physical smothering effects on flora and fauna;
- physiological effect on wildlife;
- lethal or sub lethal toxic effects on flora and fauna;
- changes in biological communities resulting from hydrocarbons' effect on key organisms; and
- behavioural changes due to impact of hydrocarbon on habitats.

### *Receptors Potentially Affected*

The receptors discussed in this section are:

- fish;
- cetaceans;
- marine turtles; and
- seabirds and shorebirds.

**a. Fish**

A wide variety of fish species occur in the waters of the region with varying physiology, feeding behaviours and habitats. Eggs, larvae and young fish are comparatively sensitive to hydrocarbon (particularly dispersed oil), as demonstrated in laboratory toxicity tests. However, there is no definite evidence from case histories to suggest that hydrocarbon pollution has significant effects on fish populations in the open sea. This is partly because fish may take avoiding action and partly because the hydrocarbon-induced deaths of young fish are often of little significance compared with significantly larger natural losses each year through natural predation and fishing.

**b. Cetaceans**

Cetaceans that may be present in the vicinity of the project area are described in *Section 5.4*. Cetaceans surface to breathe air and are therefore vulnerable to exposure to an oil slick on the sea surface. These cetaceans are smooth-skinned and hairless so contact with oil may result in only minor adherence but there is potential for impact to eyes and airways.

**c. Turtles**

Two species of marine turtles, green and flatback turtles, may occur in the vicinity of the project, with green turtles known to nest on Browse Island 40 km away (see *Section 5.4*). Potential impacts from hydrocarbon spills on animals such as turtles that nest on land also include the disruption, alteration or destruction of their nesting sites and incubating young. If oiling is heavy and penetrates sediments, nests may be contaminated resulting in oil permeating through shell membranes and contaminating emergent hatchlings. At sea, if turtles surface in an oil slick to breathe, spilt petroleum will affect their eyes and potentially damage airways or lungs.

**d. Seabirds and shorebirds**

Many hydrocarbon spills have resulted in the death of a large number of shorebirds. This group is very sensitive to both internal and external effects. Sea birds and shorebirds have a high risk of contact with spilled hydrocarbons due to the amount of time they spend on or near the surface of the sea and on affected foreshores.

### *Modelling Methodology*

This section provides a summary of comprehensive modelling undertaken for a number of possible spill scenarios (ERM, 2009a). Spill modelling was performed for three types of hydrocarbon releases; condensate, marine diesel and Jet A-1 fuel and three spill sizes; 10, 100 and 1,000 MT, depending on the type of hydrocarbon. The purpose of the modelling was to assess the potential environmental impacts of a spill and was accomplished by examining:

- the spatial extent of potential spill scenarios over various meteorological conditions;
- the thickness of the surface oiling, to delineate when the oiling was considered sufficient to have an impact. The definition of significant oiling, based upon sufficient thickness to cause smothering of an organism, is 1 µm (French et. al., 1999). For a modelling threshold value with a safety margin, this classification was reduced by an order of magnitude to 0.1 µm thickness. This thickness corresponds to a surface oil coverage threshold of 0.1 $g/m^2$ for diesel and condensate and the start of a rainbow sheen based upon visibility/colour to thickness classifications (Koops, 1985).

Stochastic modelling, using the GEMSS Chemical/Oil Spill Impact Module, was performed to examine the variability in the fate and transport of each of the spill scenarios over a ten-day period. The model was run for the months of December and April to examine seasonal variability. December winds primarily come from the west, while April winds come from the north, east and south (see *Section 5.2.2*).

Dissolved concentrations of hydrocarbons, in particular the aromatics, are the components typically of concern to the aquatic biota in the water column during oil spills. A 96-hour toxicity threshold for aromatics was assumed to be 5 ppb, as described previously in *Section 6.7*. For shorter durations of exposure, the LC50 may be adjusted to a higher concentration required to produce the same mortality (French, 2002). French (2002) describes the uncertainty in the these calculations for durations less than 24 hours, especially durations of only a few hours, as the computed LC50 increase exponentially towards very high values. Based on the estimation methods in French (2002), the 5 ppb no effect threshold was increased to a range between 50 ppb and 100 ppb if the exposure is reduced from 96 hours to 4 to 6 hours.

### *Evaluation of Impact and Discussion of Modelling Results*

A 10 metric ton (MT) spill in the vicinity of the FLNG facility over a short period (assumed one hour) was modelled for diesel, jet-A1 fuel and condensate. For condensate, additional 100 MT and 1,000 MT spills were also modelled. These volumes represent reasonable worst case spill quantities identified by project engineers as follows:

- 10 MT based upon inadvertent disconnection of a transfer hose coupling and failure to contain spill onboard; and
- 100 and 1,000 MT for condensate offloading operation by floating hose. At a loading rate of 5,000 $m^3$ per hour, these quantities reflect a major loss of containment from rupture of loading hose and failure to respond inside 15 minutes.

The FLNG facility is double-hulled and has been designed to withstand loads encountered in extreme one in 10,000 year weather conditions so a larger spill, as a result of a catastrophic structural failure of the FLNG facility due to a collision or weather, is not considered a realistic scenario.

Only the 1,000 MT December condensate spill is presented here as it is the only modelled spill scenario that reached Browse Island and it represents the worst case spill scenario.

### *Discussion of 1,000 MT December Condensate Spill.*

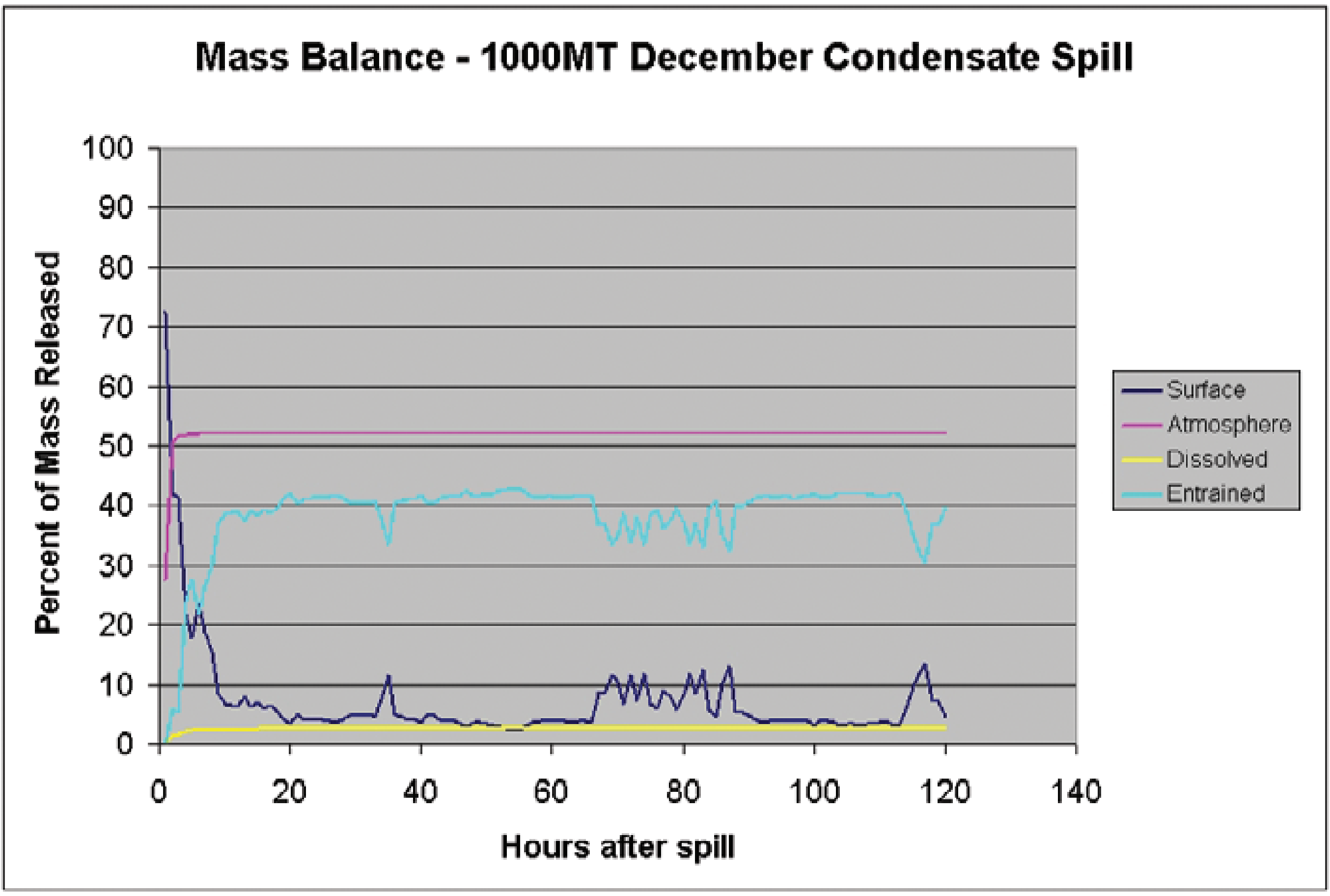
*Figure 6.19* shows the mass balance plot for a December 1,000 MT condensate spill. Condensate evaporates rapidly, initially at a faster rate than for diesel, and within 5 hours of the spill almost 52% of the condensate has evaporated. The entrainment of spilt condensate into the water column is higher in December, than in April, at around 40% due to the stronger December winds. Since most of the condensate is evaporated or entrained, very little (<20%) stays at the surface and only a small fraction (<5%) dissolves into the water column.

*Figure 6.20* shows the probability of surface oiling (>0.1 g/m²) from a 1,000 MT condensate spill. The stronger winds in December have increased the spread of spilt condensate compared to the same scenario in April. In December there is between 0.1 and a 1% probability of surface oiling contacting Browse Island following a 1,000 MT condensate spill, though it is important to realise that this surface oiling equates to a rainbow sheen of oil and is unlikely to have any significant impact upon the ecology of the island. All other modelled scenarios did not result in hydrocarbons at concentrations >0.1 g/m² contacting Browse Island.

*Figure 6.21* illustrates the water column concentration of the sum of aromatics (BTEX and PAH) over time for December 100 MT and 1,000 MT condensate spills. For the 1,000 MT scenario, the average aromatics concentration over the first 6 hours is 114 ppb. Based on the estimation methods in French (2002), the 5 ppb 96 hours no effect threshold was increased to a range between 50 ppb and 100 ppb if the exposure is reduced from 96 hours to 4 to 6 hours. This threshold is exceeded briefly and there is some potential risk of mortality from narcosis but only in the immediate vicinity to the spill location and only for a 7 hour period.

Modelling results indicate that the magnitude of the impact

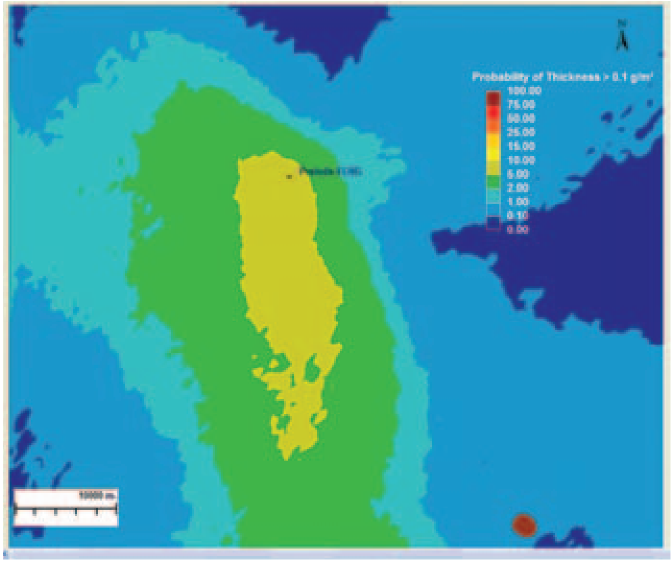
*Figure 6.19* *1,000 MT December Condensate Spill Mass Balance*



of a 1,000 MT spill would be medium and the likelihood of an impact occurring is unlikely, therefore, this scenario is assessed as minor.

A summary of all the modelling scenarios undertaken for the Prelude FLNG Project and the key results illustrated by the modelling is collated in *Table 6.35*.

*Figure 6.20 December 1,000 MT Condensate Spill Scenario – probability of significant (> 0.1 g/m²) surface oiling .*



| 1,000MT condensate spill in December | | | |
|---|---|---|---|
| Impact | Magnitude | Likelihood | Significance |
| Negative | Medium | Possible | MINOR |

## *Safeguard and Mitigation Measures*

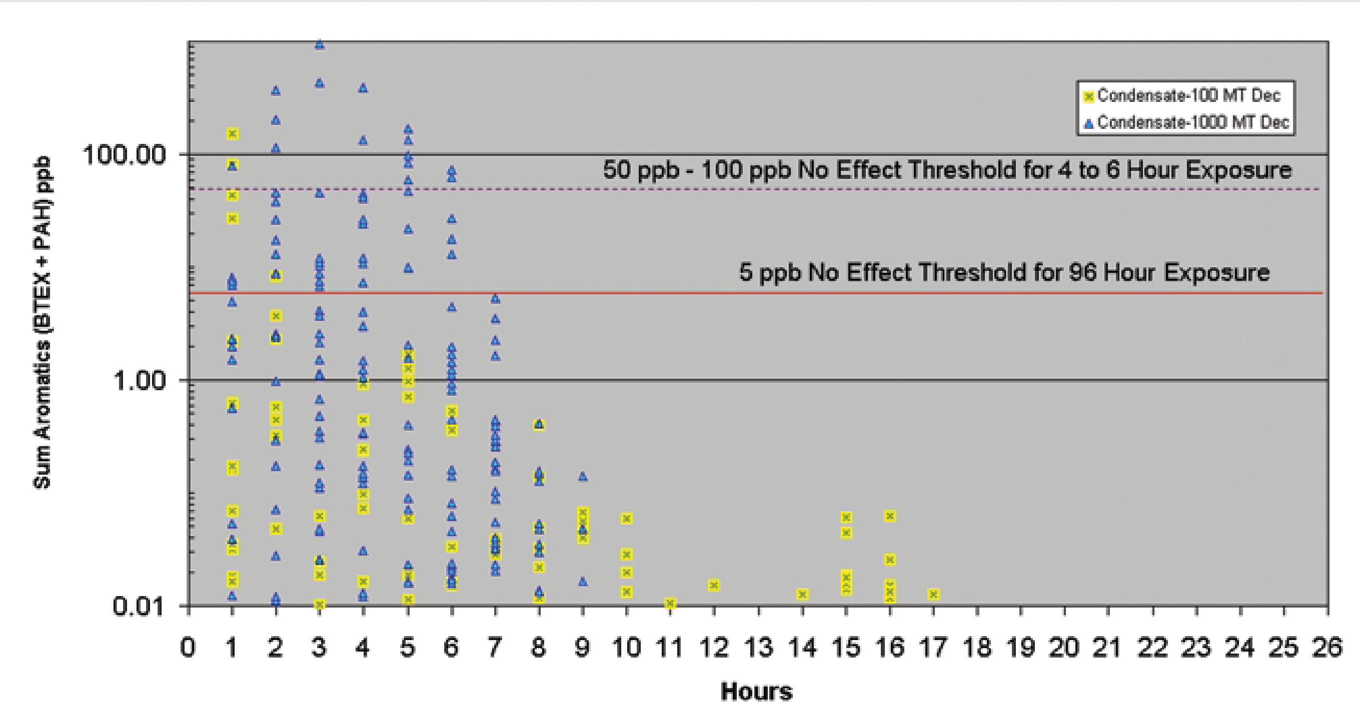
Mitigation measures associated with minimising the impact of hydrocarbon spills fall into two broad categories, those that are implemented to reduce the likelihood and/or volume of a spill and those associated with responding quickly and effectively should a spill occur.

The following mitigation measures have been incorporated into the project design and the project has committed to the following management measures with respect to hydrocarbon spills from the Prelude FLNG Project:

**Design Mitigation Measures:**

- The FLNG facility will be designed to withstand a 1 in 10,000 year weather event, with in-built facility integrity and will be double hulled.

*Figure 6.21 Water column concentrations for Aromatics (PAH + BTEX) for 100 MT and 1000 MT Condensate Spill in December*



- The FLNG facility will be designed with an emergency stoppage mechanism for the transfer of liquid products to and from the FLNG facility and quick disconnect couplings for transfer hoses/loading arms where appropriate.
- The main diesel and aviation fuel storage tanks on the FLNG facility will be fitted with high and low level alarms, level gauges and bunds and any overflow will routed to treatment.
- The FLNG facility will be designed so that drainage water from deck areas that have the potential to be contaminated with oil or chemicals (excluding areas handling LNG or LPG) and water from areas which are likely to be contaminated with oil (sumps, bunds, machinery spaces etc) are directed to the slop tanks for treatment.
- The FLNG facility will be designed so that water from areas accidentally contaminated with oils can be directed into the PFW system for treatment prior to disposal.
- Subsea equipment associated with the FLNG facility will be subject to "dropped object studies" to ensure that the potential risks posed by dropped objects are ALARP.

**Management Mitigation Measures:**

- The preparation of a government approved Oil Spill Contingency Plan (discussed further in *Chapter 7*) before any developments take place in the project area.
- Vessel and drill rig vetting procedures will be developed and implemented to ensure that all vessels engaged by Shell are able to comply with the relevant legislation and Shell standards including:
    - Vessels must meet the survey requirements for their class.
    - Vessels and rigs must have their own Ship Board Oil Pollution Emergency Plan (SOPEP) in compliance with MARPOL 73/78 and carry at least the minimum required oil response equipment.
    - Vessels must comply with the requirements of the Multifunctional Oil Spill Advisory Group 'Guidelines for Shell Companies on Preparedness, Response and Compensation for Oil and Chemical Spills.'
    - Drilling Rigs must be fitted with Blow Out Protectors suitable for the pressure expected to be encountered.
- Materials handling procedures will be developed to reduce the risk of spills and leaks and will include the definition of suitable sea states and times for transfers, operating and communication procedures to ensure

*Table 6.35 Scenario Summaries of Scenarios Modelled*

| Scenario | Modelling results |
|---|---|
| 1. Condensate, 1000 MT April | No hit for spill (> 0.1 g/m$^2$) to Browse Island<br>Exceedence of aromatic (BTEX and PAH) no effect threshold: No (too short a duration of exposure)<br>55% of condensate evaporates within first 5 hours of the spill |
| 2. Condensate, 100 MT December | No hit for spill (> 0.1 g/m$^2$) to Browse Island<br>Exceedence of aromatic (BTEX and PAH) no effect threshold: occasionally within 2 hours following spill<br>55% of condensate evaporates within first 5 hours of the spill |
| 3. Condensate 1000 MT December | <1% probability of a spill (> 0.1 g/m$^2$) reaches Browse Island after 43 hrs<br>Exceedence of aromatic (BTEX and PAH) no effect threshold: occasionally within 7 hours following spill<br>55% of condensate evaporates within first 5 hours of the spill |
| 4. Diesel 10 MT April | No hit for spill (> 0.1 g/m$^2$) to Browse Island<br>Exceedence of aromatic (BTEX and PAH) no effect threshold: No<br>65% of spill dissolved within 20 hours of the spill |
| 5. Diesel 10 MT December | No hit for spill (> 0.1 g/m$^2$) to Browse Island<br>Exceedence of aromatic (BTEX and PAH) no effect threshold: No<br>Approximately 50% of spill has evaporated within 5 hours of the spill |
| 6. JetA1 10 MT December | No hit for spill (> 0.1 g/m$^2$) to Browse Island<br>Exceedence of aromatic (BTEX and PAH) no effect threshold: No<br>Approximately 95% of spill has evaporated within 5 hours of the spill |
| 7. JetA1 10 MT April | No hit for spill (> 0.1 g/m$^2$) to Browse Island<br>Exceedence of aromatic (BTEX and PAH) no effect threshold: No<br>Approximately 95% of spill has evaporated within 5 hours of the spill |

close monitoring of offloading and fuel transfer operations, routine maintenance and inspection of loading equipment and storage facilities, and in place containment/recovery systems.

### *Summary*

*Table 6.36* provides a summary identifying the receptors and their sensitivity to hydrocarbon spills. The table also categorises the nature of the impacts associated with each of the four phases of the project. For the purposes of the summary table, the categorisation of impact has been recorded for the worst case spill (1,000 MT condensate spill in December).

### *Conclusion*

Apart from the open ocean itself that surrounds the FLNG facility, the closest location considered to have sensitive habitat is Browse Island, located about 40 km southeast of the proposed location of the facility. The modelling demonstrates that with the exception of a 1,000 MT condensate spill in December, no oiling (>0.1g/m$^2$) of Browse Island has been modelled to occur for any of the plausible spill scenarios conducted for this impact assessment. In the 1,000 MT case, there is a 1% probability that oiling (>0.1g/m$^2$ or equivalent to a rainbow sheen on the water surface) may reach Browse Island, with a brief (maximum 7 hours) aquatic impact possible in the vicinity of the FLNG facility from aromatic narcosis. In April, the possible spills were less likely to spread to the east or west of the FLNG site than in December, instead travelling primarily in either the north or south direction. The rate of travel, however, was similar for both seasons.

For all scenarios, evaporation to atmosphere reduces the volume of hydrocarbons left to interact with the marine environment and receptors within it. Subsequent degradation by wind and wave action further reduces the persistence of hydrocarbons on the sea surface.

The environmental impact associated with hydrocarbon spills and leaks from the Prelude FLNG Project has been evaluated and is assessed to be minor. As a result, no significant impacts to EPBC-listed species, migratory species or the surrounding marine environment have been identified.

## 6.9.3 Non Hydrocarbon Spills and Leaks

During the life of the project there is the potential for non-hydrocarbon spills and leaks to occur. Spills may result in localised impacts on water quality and toxicity effects on marine fauna and flora.

Non-hydrocarbon spills include chemical and synthetic drilling mud spills, accidental leakage of hydraulic fluid or chemical inhibitors used in the wells, or accidental release of chemicals during transfer between vessels.

A comprehensive list of chemicals will be developed in the FEED phase of the project. Bulk chemicals stored during the drilling, commissioning and operational phase of the project that are considered in this section are:

- Drilling:
    - Synthetic based drilling muds (560 m$^3$ storage capacity)
- Commissioning and operation:
    - Monodiethylamine (350 tonnes storage capacity)
    - Piperazine (60 tonnes storage capacity)
    - MEG (7,000 tonnes storage capacity)

### *Receptors*

Chemical spills may result in localised impacts on water quality and toxicity effects on marine fauna and flora. Specific effects on individual receptors would depend upon the type and volume of chemical released but are broadly similar to the receptors discussed in relation to hydrocarbon spills.

### *Description and Evaluation of Impact*

If released into the marine environment, chemical spills and leaks have the potential to cause physical and chemical alteration of natural habitats, including water quality, with the potential for lethal or sub-lethal toxic effects on flora and fauna. However, as described below, the design of the facility incorporates measures to reduce the likelihood of spill and leaks, and to contain those that do occur. As such, the likelihood of spills occurring is considered to be unlikely and the magnitude of any such event is expected to be low, therefore, the impact from spills of non-hydrocarbon is assessed to be minor.

## *Table 6.36 Summary of Impacts Associated with Hydrocarbon Spills and Leaks*

| Impact | | Impact from Hydrocarbon Spills | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Receptors** | | Cetaceans, including two threatened species (humpback whale and blue whale) may transit the project area.<br>Turtles, two vulnerable species ( green and flatback turtle) may transit the project area. Green turtles also nest on Browse Island (~ 40 km from the FLNG facility location).<br>Fish, including one known threatened species (whale shark) may transit the project area.<br>Birds, including one known migratory marine species (streaked shearwater) may transit the project area. Four potential flights path for migratory shorebirds occur within 150 km of project area.<br>Browse Island. | | | | | | | |
| **Receptor Sensitivity** | | | | | | | | | |
| **Fish** | | ■ | Low | | Medium | | High | | |
| **Turtles, cetaceans** | | | Low | ■ | Medium | | High | | |
| **Birds** | | | Low | | Medium | ■ | High | | |
| **Browse Island** | | | Low | | Medium | ■ | High | | |
| Apart from mobile receptors transiting the open ocean, the closest location considered to have sensitive habitat is Browse Island, located 40 km from the proposed location of the FLNG facility. In the worst case modelled scenario, a 1000 MT spill of condensate in December, there is less than a 1% probability of surface oiling in concentrations above 0.1 g/m$^2$ reaching Browse Island following a spill. This concentration is equivalent to a a rainbow sheen on the water surface. On this basis the overall environmental significance of the impact of hydrocarbon spills is considered minor. | | | | | | | | | |
| Drilling and Construction | **Impact Nature** | ■ | Negative | | Positive | | | | |
| | **Impact Extent** | ■ | Local | | Regional | | National | | Global |
| | **Impact Duration** | ■ | Rare/ short | | Occasional/ moderate | | Regular/ long | | |
| | **Impact Magnitude** | ■ | Low | | Medium | | High | | |
| | **Likelihood** | ■ | Unlikely | | Possible | | Probable | | Certain |
| | **Significance** | ■ | Minor | | Moderate | | Major | | Critical |
| Commissioning | **Impact Nature** | ■ | Negative | | Positive | | | | |
| | **Impact Extent** | ■ | Local | | Regional | | National | | Global |
| | **Impact Duration** | ■ | Rare/ short | | Occasional/ moderate | | Regular/ long | | |
| | **Impact Magnitude** | ■ | Low | | Medium | | High | | |
| | **Likelihood** | ■ | Unlikely | | Possible | | Probable | | Certain |
| | **Significance** | ■ | Minor | | Moderate | | Major | | Critical |
| Operation/Maintenance | **Impact Nature** | ■ | Negative | | Positive | | | | |
| | **Impact Extent** | | Local | ■ | Regional | | National | | Global |
| | **Impact Duration** | ■ | Rare/ short | | Occasional/ moderate | | Regular/ long | | |
| | **Impact Magnitude** | | Low | ■ | Medium | | High | | |
| | **Likelihood** | ■ | Unlikely | | Possible | | Probable | | Certain |
| | **Significance** | ■ | Minor | | Moderate | | Major | | Critical |
| Decommissioning/ Abandonment | **Impact Nature** | ■ | Negative | | Positive | | | | |
| | **Impact Extent** | ■ | Local | | Regional | | National | | Global |
| | **Impact Duration** | ■ | Rare/ short | | Occasional/ moderate | | Regular/ long | | |
| | **Impact Magnitude** | ■ | Low | | Medium | | High | | |
| | **Likelihood** | ■ | Unlikely | | Possible | | Probable | | Certain |
| | **Significance** | ■ | Minor | | Moderate | | Major | | Critical |

| Non-hydrocarbon spill | | | |
|---|---|---|---|
| Impact | Magnitude | Likelihood | Significance |
| Negative | Low | Unlikely | MINOR |

### *Safeguards/ Mitigation Measures*

The following mitigation measures have been incorporated into the project design and the project has committed to the following management measures to reduce the impacts of non-hydrocarbon spills from the Prelude FLNG Project:

**Design Mitigation Measures:**

- The FLNG facility will be designed so that drainage water from deck areas that have the potential to be contaminated with oil or chemicals (excluding areas handling LNG or LPG) and water from areas which are likely to be contaminated with oil (sumps, bunds, machinery spaces etc) are directed to the slop tanks for treatment.
- The FLNG facility will be designed so that water from areas accidentally contaminated with oils or chemicals can be directed into the PFW system for treatment prior to disposal.
- The bulk chemical containers on the FLNG facility will be designed to withstand collisions, using features such as recessed valves and metal cages.

**Management Mitigation Measures:**

- Materials handling procedures will be developed to reduce the risk of spills and leaks and will include definition of suitable sea states and times for transfers, operating and communication procedures to ensure close monitoring of offloading and fuel transfer operations, routine maintenance and inspection of loading equipment and storage facilities and in place containment/recovery systems.
- The selection of chemicals will involve consideration of environmental performance as well as technical requirements.
- Chemicals on the FLNG facility and supply vessels will be securely stored within bunded areas
- The FLNG facility and supply vessels will locate chemical spill recovery equipment near onboard chemical supplies.

### *Summary*

*Table 6.37* provides a summary table identifying the receptors and their sensitivity to non-hydrocarbon spills. The table also categorises the nature of the impacts associated with potential spills during each of the four phases of the project.

### *Conclusion*

The environmental impact associated with non-hydrocarbon spills from the Prelude FLNG Project has been evaluated and is predicted to be minor. As a result of this impact assessment, no significant impacts to EPBC-listed species, migratory species or the surrounding marine environment are expected.

## 6.9.4 Introduced Marine Species

Introduced marine species (IMS) are organisms which have been transported from their existing natural environment to a new host location. The National Introduced Marine Pest Information System (Hewitt et al. 2002) identifies 44 IMS in the waters of Western Australia. A map of the number of introduced marine species produced for the National Oceans Office (2004) indicates no known introduced species in the northwest marine region, which includes the project area. However, wide-scale surveys for introduced IMS in WA are lacking.

The most common transfer pathways for IMS are via the uptake and discharge of ballast water or the fouling of marine organisms on the hulls and other wetted areas of ships (eg chain locker, seawater intakes and sea chests).

Ballast water is seawater that is pumped into and from a vessel's ballast tanks to maintain the vessel's weight and stability in the ocean, so as to offset changes in load distribution in or on the vessel. Marine organisms may be taken onboard in one location in ballast water and released in another location if they survive during transport. Transfer via ballast water has become an increasing issue as vessels speeds increase and transport times between locations decrease.

Ballast water requirements for the MODU, specialist installation vessels and supply and support vessels are limited. The main source of ballast water will be the offtake tankers as they arrive at the FLNG facility without a full cargo, which is

*Table 6.37 Summary of Impacts Associated with Non-Hydrocarbon Spills and Leaks*

| Impact | | Impact from Non-Hydrocarbon Spills and leaks | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Receptors** | | Invertebrates<br>Cetaceans, including two threatened species (humpback whale and blue whale) may transit the project area.<br>Turtles, two vulnerable species ( green and flatback turtle) may transit the project area. Green turtles also nest on Browse Island (~ 40 km from the FLNG facility location).<br>Fish, including one known threatened species (whale shark) may transit the project area. | | | | | | | |
| **Receptor Sensitivity** | | ■ | Low | | Medium | | High | | |
| During the life of the project there is the potential for non-hydrocarbon spills and leaks to occur. Spills may result in localised impacts on water quality and toxicity effects on marine fauna and flora. Spill volumes, however, are likely to be small and impacts would therefore be localised and short-term. Potential impacts from non-hydrocarbon spills are therefore considered to be minor. | | | | | | | | | |
| **Drilling and Construction** | **Impact Nature** | ■ | Negative | | Positive | | | | |
| | **Impact Extent** | ■ | Local | | Regional | | National | | Global |
| | **Impact Duration** | ■ | Rare/ short | | Occasional/ moderate | | Regular/ long | | |
| | **Impact Magnitude** | ■ | Low | | Medium | | High | | |
| | **Likelihood** | ■ | Unlikely | | Possible | | Probable | | Certain |
| | **Significance** | ■ | Minor | | Moderate | | Major | | Critical |
| **Commissioning** | **Impact Nature** | ■ | Negative | | Positive | | | | |
| | **Impact Extent** | ■ | Local | | Regional | | National | | Global |
| | **Impact Duration** | ■ | Rare/ short | | Occasional/ moderate | | Regular/ long | | |
| | **Impact Magnitude** | ■ | Low | | Medium | | High | | |
| | **Likelihood** | ■ | Unlikely | | Possible | | Probable | | Certain |
| | **Significance** | ■ | Minor | | Moderate | | Major | | Critical |
| **Operation/ Maintenance** | **Impact Nature** | ■ | Negative | | Positive | | | | |
| | **Impact Extent** | ■ | Local | | Regional | | National | | Global |
| | **Impact Duration** | ■ | Rare/ short | | Occasional/ moderate | | Regular/ long | | |
| | **Impact Magnitude** | ■ | Low | | Medium | | High | | |
| | **Likelihood** | ■ | Unlikely | | Possible | | Probable | | Certain |
| | **Significance** | ■ | Minor | | Moderate | | Major | | Critical |
| **Decommissioning/ Abandonment** | **Impact Nature** | ■ | Negative | | Positive | | | | |
| | **Impact Extent** | ■ | Local | | Regional | | National | | Global |
| | **Impact Duration** | ■ | Rare/ short | | Occasional/ moderate | | Regular/ long | | |
| | **Impact Magnitude** | ■ | Low | | Medium | | High | | |
| | **Likelihood** | ■ | Unlikely | | Possible | | Probable | | Certain |
| | **Significance** | ■ | Minor | | Moderate | | Major | | Critical |

offset by a load of ballast water, and leave with a load of cargo which requires less ballast. The FLNG facility will also take up and discharge ballast water regularly as it produces cargoes and exports the products to offtake tankers but this ballast poses no threat as the FLNG facility is permanently moored and does not travel to or from other ports.

### *Receptors*

The introduction and establishment of new marine species can result in a localised impact on native marine fauna and flora. Such impacts include changes to habitat structure and availability, predation and/or changes to dominance in ecological communities.

### *Description and Evaluation of Impact*

The probability of successful establishment of an introduced species depends primarily on the following:

- frequency of arrival in the receiving environment (introduction); and
- post arrival mortality (survival).

The frequency of arrival will depend on the number of vessel movements (discussed below) and the numbers of new species/individuals present in ballast water or fouling communities. The post arrival mortality survival of new species introduced into the receiving environment is dependent on a number of factors including habitat suitability, water or larval retention times and predation and/or competition by native species. If the conditions of the receiving environment are favourable, the new species may survive and reproduce. This may lead to the species becoming invasive, out-competing native species and ultimately altering the dominance of existing ecological communities. Given the oceanic environment, habitat suitability for coastal species (from other ports around the world) and larval retention times are likely to be very low in the project area, significantly reducing the likelihood of successfully introducing exotic species.

There is the potential for the introduction of marine species to occur at all stages of the Prelude FLNG Project as vessels will be arriving in the area regularly during the lifespan of the project, although risks are marginally increased, once the turret and FLNG facility are installed as these provide the only long-term solid substrate in the top 20 m of the water column.

During the operational phase of the project, offtake tankers will regularly visit the FLNG facility. It is anticipated that a LNG carrier will visit on a weekly basis, an oil tanker fortnightly and an LPG tanker monthly, all of which have the potential to have originated from non-Australian waters.

To reduce the likelihood of the transmital of exotic marine species, AQIS requires that all salt water taken up in ports and coastal waters outside Australia's territorial sea not be discharged within Australia's territorial sea (12 nm limit). This recognises that coastal species found in ports and coastal waters are very unlikely to survive in open ocean environments. AQIS requires that ballast exchanges must be conducted outside the Australian territorial sea, beyond the 12 nm limit and they recommended that ballast exchanges be conducted as far away as possible from any land mass and in water at least 200m deep.

The FLNG facility is located outside Australia's territorial sea, 40 km from the closest landfall (Browse Island) and in water depths in excess of 200 m. Therefore, any exotic species introduced in ballast water or on the hulls of vessels would be unlikely to survive to become established. As such, impacts are considered to be unlikely and of low magnitude, and are assessed as minor.

| Introduced Marine Species | | | |
|---|---|---|---|
| Impact | Magnitude | Likelihood | Significance |
| Negative | Low | Unlikely | MINOR |

### *Safeguard/Mitigation Measures*

The following mitigation measures have been incorporated into the project design and the project has committed to the following management measures to reduce the risk of introduction of exotic marine species to the project area or elsewhere. These measures will be implemented for vessel movements during all phases of the project:

**Design Mitigation Measures:**

- The selection of the project development concept as FLNG, which removes the need for onshore export facilities.
- Positioning of the FLNG facility outside Australia's territorial sea, 40 km from the nearest land and in water depths of 250 m.
- To control fouling by marine organisms, the outer hull of the FLNG facility will be coated with anti-fouling paint (TBT free) and the cooling water system will be treated with hypochlorite.

**Management Mitigation Measures:**

- Vessel vetting procedures will be developed and implemented to ensure that all vessels engaged by Shell meet the requirements of the relevant legislation. Under the International Convention for the Control and Management of Ship's Ballast Water and Sediments 2004, ships are required to implement a ballast water and sediment management plan and ships must carry a Ballast Water Record Book. A number of Guidelines are provided by the IMO (2004) which include the following requirements:

- the uptake of ballast shall be avoided where practicable in shallow water and at night when the number of marine organisms in the water column may increase due to the rise of bottom dwelling organisms, and also in ports where populations of harmful organisms are known to occur;
- avoiding the unnecessary discharge of ballast;
- regular cleaning of ballast tanks; and
- implementing ballast water management procedures which include replacing ballast at sea with clean open ocean water (marine species taken on in port areas are unlikely to survive in the open ocean due to the different conditions).

### *Summary*

*Table 6.38* provides a summary table identifying the receptors and their sensitivity to introduced marine species. The table also categorises the nature of the impacts associated with each of the four phases of the project.

### *Conclusion*

The environmental impact associated with introduced marine species from the Prelude FLNG Project has been evaluated and is assessed to be minor. No significant impacts to EPBC-listed species, migratory species or the surrounding marine environment are expected.

# 6.10 SOCIOECONOMIC IMPACTS

## 6.10.1 Overview

This section assesses the potential socioeconomic and cultural impacts of the Prelude FLNG Project. The socioeconomic and cultural impacts of the project refers to the effects that the Prelude FLNG project will have on the lives and circumstances of Australian people, their families and their communities.

Accepted practice in socioeconomic impact assessment is to establish a primary zone of influence for the activity being studied. The primary zone of influence is the geographic location within which the lives and circumstances of people, their families and their communities could be directly affected by a project. In the case of the Prelude FLNG Project, this location is offshore, over 200 km from the nearest human habitation and 475 km from the nearest large community (Broome). Therefore, potential direct negative impacts on the Kimberley region are very limited. Most of the workforce is likely to have their permanent homes outside the region so they will not place significant new demands on local educational, health and other government and community infrastructure and services.

### *Sources and Characteristics*

Socioeconomic effects at the project location will be generated throughout the life of the project, from pre-installation through to de-commissioning. The socio-economic effects expected to be produced during all phases of the project may be experienced by people associated with:

- recreational fishing, including charter fishing;
- commercial and traditional fishing;
- commercial shipping; and
- industry and commerce.

The potential sources of the impacts that will be experienced during each phase of the project are shown in *Table 6.39*.

## 6.10.2 Description and Likely Extent of Impacts

### *Resource Access and Use*

The *EPBC Act* requires an assessment of impacts caused by any short, medium and long-term changes, interruption, alteration or curtailment of anthropogenic activities and uses of the area due to the proposed project, including changes affecting traditional uses, recreational uses, conservation and tourism. Currently, the only known uses directly associated with the area are petroleum exploration and development. The area has no other known traditional uses, recreational uses, conservation and tourism at this time and there are no known plans for these or other uses of the project area in the future.

The project area may be traversed on occasion by mariners and fishermen on route from one location to another, including Indonesian fishermen in small boats. Under Commonwealth legislation, a safety and security zone extending 500 m from any part of offshore oil and gas

*Table 6.38 Summary of Impacts Associated with Introduced Marine Species*

| **Impact** | | **Impact from Introduced Marine Species** | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Receptors** | | Marine biota | | | | | | | |
| **Receptor Sensitivity** | | ■ | Low | | Medium | | High | | |
| Throughout the life of the project, LNG, LPG and condensate tankers, support and supply vessels have the potential to introduce species through ballast water and hull fouling. Due to the remoteness of the Prelude FLNG Project area and the depth of water in the vicinity of the project, there is a low likelihood that there would be successful establishment of IMS. | | | | | | | | | |
| **Drilling and Construction** | **Impact Nature** | ■ | Negative | | Positive | | | | |
| | **Impact Extent** | ■ | Local | | Regional | | National | | Global |
| | **Impact Duration** | | Rare/ short | | Occasional/ moderate | ■ | Regular/ long | | |
| | **Impact Magnitude** | ■ | Low | | Medium | | High | | |
| | **Likelihood** | ■ | Unlikely | | Possible | | Probable | | Certain |
| | **Significance** | ■ | Minor | | Moderate | | Major | | Critical |
| **Commissioning** | **Impact Nature** | ■ | Negative | | Positive | | | | |
| | **Impact Extent** | ■ | Local | | Regional | | National | | Global |
| | **Impact Duration** | | Rare/ short | | Occasional/ moderate | ■ | Regular/ long | | |
| | **Impact Magnitude** | ■ | Low | | Medium | | High | | |
| | **Likelihood** | ■ | Unlikely | | Possible | | Probable | | Certain |
| | **Significance** | ■ | Minor | | Moderate | | Major | | Critical |
| **Operation/ Maintenance** | **Impact Nature** | ■ | Negative | | Positive | | | | |
| | **Impact Extent** | ■ | Local | | Regional | | National | | Global |
| | **Impact Duration** | | Rare/ short | | Occasional/ moderate | ■ | Regular/ long | | |
| | **Impact Magnitude** | ■ | Low | | Medium | | High | | |
| | **Likelihood** | ■ | Unlikely | | Possible | | Probable | | Certain |
| | **Significance** | ■ | Minor | | Moderate | | Major | | Critical |
| **Decommissioning/ Abandonment** | **Impact Nature** | ■ | Negative | | Positive | | | | |
| | **Impact Extent** | ■ | Local | | Regional | | National | | Global |
| | **Impact Duration** | | Rare/ short | | Occasional/ moderate | ■ | Regular/ long | | |
| | **Impact Magnitude** | ■ | Low | | Medium | | High | | |
| | **Likelihood** | ■ | Unlikely | | Possible | | Probable | | Certain |
| | **Significance** | ■ | Minor | | Moderate | | Major | | Critical |

installations (and connected off take tankers) is established around all installations which project above the sea. Vessels of all nations are required to respect the zone and it is an offence to enter the zone without permission. The 500 m zone is consistent with allowances for coastal states under the United Nations Convention on the Law of the Sea (Department of Resources, Energy and Tourism, 2008).

The impact magnitude of the exclusion zone on mariners and fishermen is predicted to be low and impacts are considered unlikely due to the low usage of the area and its small size, relative to the surrounding ocean. Therefore, the potential impact has been assessed to be minor.

*Table 6.39 Summary of Socio-Economic Impact Sources by Development Phase*

| Phase | Activity Source | Source Type | Type (+/-) | Activity Duration |
|---|---|---|---|---|
| **Construction and installation** | Drill rig<br>Vessel movements (support and supply) | Shipping hazard | - | 2 years |
| | FIFO workers | Economic | + | 2 years |
| **Commissioning and operation** | Vessel movements (support and export tankers) | Shipping hazard | - | 25 years |
| | FLNG normal operations | Exclusion zone | - | 25 years |
| | FIFO workers | Economic | + | 25 years |
| | LNG/LPG and condensate sales | Economic | + | 25 years |
| **Decommissioning** | Decommissioning seabed infrastructure and relocation of FLNG | Shipping hazard | - | ~ 4 months |
| | FIFO workers | Economic | + | ~ 4 months |

Due to the low usage of the project area and its distance from known recreational, conservation and tourism areas, no avoidance or mitigation measures regarding access and use are being proposed.

| Resource Access and Use | | | |
|---|---|---|---|
| Impact | Magnitude | Likelihood | Significance |
| Negative | Low | Unlikely | MINOR |

### *Recreational Fishing, Including Charter Fishing*

Recreational fishing refers to non-commercial fishing activities enjoyed by residents and visitors to the area in proximity to the project site. Currently, there are no known recreational fishing activities in the project area as the site is too far from shore to be accessed by recreational fishermen in small boats. Even at relatively high speed (30 km/hour), it would take at least fifteen hours for a recreational boat to reach the project area from the nearest port of Broome.

Charter fishing activities, which typically extend over several days and take place in large live-aboard vessels, could potentially reach the project area. Chartered fishing vessels already operate to Scott Reef from Broome, a distance of approximately 420 km. However, none of the known charter operators in the region currently offer fishing charters to Browse Island and its surrounding waters (approximately 475 km from Broome).

Because the project area is remote from known recreational fishing areas and there are no established charter fishing activities in the area, impacts of the project on recreational and charter fishing is considered to be unlikely and of low magnitude and hence the impact significance is assessed to be minor.

| Recreational fishing including charter fishing | | | |
|---|---|---|---|
| Impact | Magnitude | Likelihood | Significance |
| Negative | Low | Unlikely | MINOR |

### *Commercial and Traditional Fishing*

As described in *Section 5.7.4*, the project area overlaps with a variety of permitted commercial fishing areas and is also located within the MOU Box that permits Indonesian traditional fishers to continue their customary practices in Australian waters. The project therefore has the potential to impact on these activities.

Examination of information on existing commercial activities directly in or adjacent to the project area indicates very low commercial fishing effort; less than 100 kg per 100 km$^2$ per year (DEWHA, 2008f, p.160). Information on the fishing effort of the northwest Slope Trawl fleet indicated activity in the vicinity of the project area but at some distance from the project area and at low levels (see *Section 5.7.4*). Based on this information, the project is not expected to have any direct and immediate impacts on the existing fishing activities of the Australian commercial fleet.

Indonesian fishers are known to enter the waters around Browse Island and to use Browse Island as a base to fish for species allowed under the MOU with Indonesia. Nearly all traditional fishing activities are reef based. The project area is located too far from Browse Island and in waters that are too deep to compromise the reef based fishing activities of the Indonesian fishermen.

The likelihood of impacts occurring has been rated unlikely, due to the lack of sustained fishing effort in the vicinity of the project, and the impact magnitude as low. As a consequence, the significance of the impact of the project on commercial and traditional fishing is assessed to be minor.

| Commercial and Traditional Fishing | | | |
|---|---|---|---|
| Impact | Magnitude | Likelihood | Significance |
| Negative | Low | Unlikely | MINOR |

### *Commercial Shipping and Navigation*

The physical presence of the FLNG facility in Australian waters could be a potential hazard to shipping during the lifetime of the operation. Navigation data obtained from the Australian Maritime Safety Authority (AMSA) indicates that a variety of different shipping vessels pass through the area, although the FLNG facility is not located on any established shipping lanes. The movement of the supply vessels and off take tankers loading at the FLNG also increases the potential and collision risk to shipping when they are present.

The movement of the supply vessels also potentially increases collision risk at the Port of Broome and/or Port of Darwin during transit. The degree of increased risk changes with the development phase and the choice of home port for the supply vessels. During the project's two-year drilling phase, three supply vessel transits per week to a drill ship in the development location are expected. As the project moves into the operating phase, supply ship movements decrease to once a fortnight and the potential hazard to shipping diminishes accordingly. However, the increase in shipping traffic generated by the Prelude FLNG Project through the ports of Broome and/or Darwin only represent a small incremental increase in the overall shipping activity of these ports.

During operations, potential hazards to other shipping from tanker traffic arriving at or departing from the FLNG facility are not expected to be greater than that from other shipping in the area. The facility is not located within close proximity to any major shipping lanes (See *Section 5.7.2*) and the annual number of off take tanker visits is low (weekly LNG; monthly LPG and condensate every 2-3 weeks).

Given the FLNG facility's considerable size and visibility, and its location remote from established commercial shipping routes, impacts arising from the project on commercial shipping and navigation are expected to be unlikely and of low magnitude, so that the impact significance is assessed as minor.

| Commercial Shipping and Navigation | | | |
|---|---|---|---|
| Impact | Magnitude | Likelihood | Significance |
| Negative | Low | Unlikely | MINOR |

### *Industry and Commerce*

The expenditure associated with the project will impact positively on local, state and national industry and commerce. This impact will be in the form of employment, opportunities for local businesses and contractors, and increased spending. This includes:

- opportunities for local businesses, contractors and employees to take part in the approximately $2 billion AUD capital expenditure and $5 billion AUD operating expenditure that may occur in Australia through to 2040;
- Australian employment reaching more than 500 during the installation, commissioning and start-up, and around 320 long term jobs for Australian sourced staff; and
- substantial tax revenue to the Australian Government through company tax and the Petroleum Resource Rent Tax.

These impacts are likely to result in indirect impacts on the broader economy, including increased GDP, increased exports, a reduced current account and increased net employment.

Indirect impacts could include:

- indirect employment, with relevant employment multipliers indicating that up to seven (Johnson, 2001) indirect jobs can be created for every direct job involved in the oil and gas projects in the region; and
- positive impacts on the broader economy through a multiplier effect as spending by Shell, project participants and employees increases economic activity.

Because the likelihood of positive economic impacts of the project are considered to be certain and the magnitude of the benefits are considered to be low, the significance of the impacts is assessed to be moderate.

| Industry and Commerce | | | |
|---|---|---|---|
| Impact | Magnitude | Likelihood | Significance |
| Positive | Low | Certain | MODERATE |

### *Visual and Aesthetic Values and Impacts to Tourism*

The Zone of Visual Influence (ZVI) defines the area within which the FLNG facility could be viewed by a receptor. This has been determined using the Line of Sight Calculator (Mats Kagstrom, 2005). *Figure 6.22* illustrates this calculation. This process involves the calculation of the highest point of the FLNG facility (top of flare stack 154 m) in relation to the eye height of the receptor and the curvature of the earth. For a person travelling on a small vessel, the ZVI has been calculated as a distance of 56 km (ERM, 2009b) which encompasses Browse Island (*Figure 6.23*).

*Figure 6.22 Line of Sight Calculation*

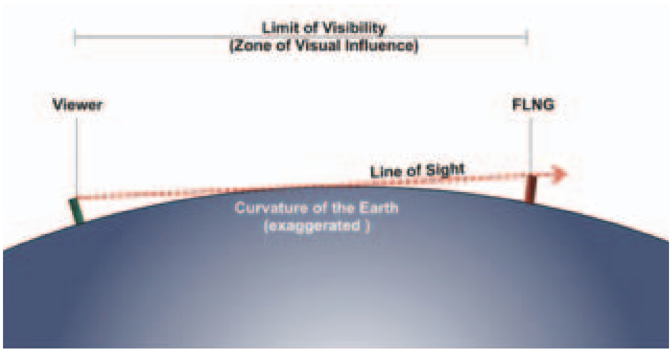
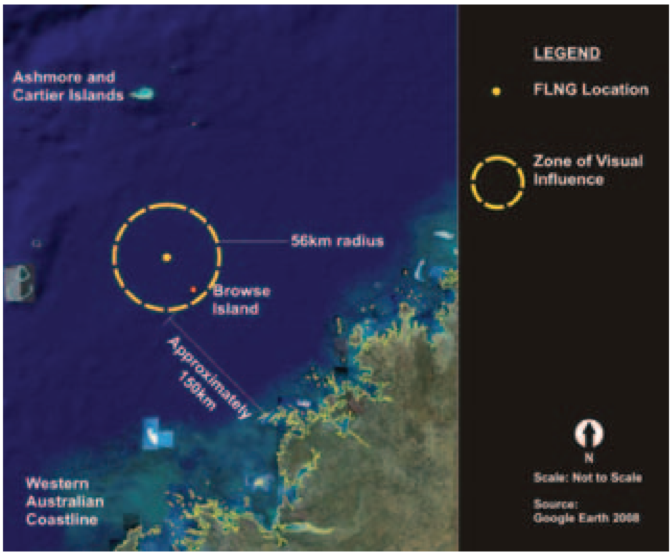


*Figure 6.23 Zone of Visual Influence for human receptors*



The proposed FLNG facility location is approximately 200 km offshore from the Kimberley Landscape Region, and (as a part of Australian Territory) can be included within the Kimberley Plateau Character Type (as classified by Stuart-Street and Revell, 1994).

Browse Island is the only landform that exists within the ZVI and due to its location within the Timor Sea and isolation from other landforms, is rated as of high scenic quality. This is determined by the description by Stuart-Street and Revell (1994) in *Reading the Remote: Landscape Characters of Western Australia* (see *Table 6.40*).

*Table 6.40 Landscape Character – Frame of Reference*

| Visual Significance | Landform | Vegetation Patterns | Water-form |
|---|---|---|---|
| High | Islands, reefs and other off-shore features which become focal points. | Single plants or groups of plants which become focal points due to shape, colour, isolation, or position in landscape. | Unusual ocean shoreline motion and colour due to islands, reefs and shoreline configurations. |

As described previously within this chapter, there is no human habitation in the project area and passages through the area are very infrequent. Additionally, the 40 km proximity of Browse Island to the project area would result in very low visibility of the FLNG facility because it will be low on the horizon. As such, impacts to the 'viewed' visual amenity of Browse Island and the surrounding ocean within the project area are unlikely and of low magnitude, therefore, the potential impact significance has been assessed to be minor.

The perceived visual amenity is slightly different and is dependant on the extent of stakeholders that are cognisant of the project area and the existing landscape character. As Browse Island is not a known tourist destination, nor is it visited with any regularity by the Australian public, the likelihood of impacts occurring is considered unlikely and the magnitude of any effects is considered to be low.

The presence of the FLNG facility, its support vessels and offtake tankers is predicted to have a low impact on visual and aesthetic values or tourism. From Browse Island, the facility would only be just visible on the horizon. The significance of the perceived impacts to tourism is therefore assessed to be minor.

| Visual and Aesthetic Values and Impacts to Tourism | | | |
|---|---|---|---|
| Impact | Magnitude | Likelihood | Significance |
| Negative | Low | Unlikely | MINOR |

### *Sites of Historical and Cultural Significance Including Shipwrecks*

The project will be located within the administration area for the *Historic Shipwrecks Act 1976* but construction and operation of the project are not expected to have any impacts on known, or unknown, shipwrecks. The known shipwrecks are approximately 40 km from the project area and the probability of an unknown shipwreck being located in the project area is low because of the water depth and absence of reefs or shoals on which a ship could founder. The project area does not lie within a protected or no-entry zone established under the *Historic Shipwrecks Act 1976.*

No sites of cultural or heritage significance will be impacted by the project. There are no Aboriginal heritage sites in or around the proposed project area. The project area has not been the subject of a native title claim and no procedures related to native title claim are in preparation.

Potential impacts from the project on sites of indigenous or non indigenous heritage are avoided due to the location of the proposed project far out at sea and the placement of the facility at considerable distance from Browse Island. No impacts to any sites of historical or cultural significance are anticipated.

| Historical and Cultural Significance | | | |
|---|---|---|---|
| Impact | Magnitude | Likelihood | Significance |
| Negative | Low | Unlikely | MINOR |

### 6.10.3 Safeguard/Mitigation Measures

The key safeguard/mitigation measure inherent in the project is its distance from shore. The location of the facility far out to sea and away from areas of human habitation or activity effectively limits the negative socioeconomic and cultural impacts of the project without compromising its positive economic impacts.

The positive socioeconomic impacts of the Prelude FLNG Project on industry and commerce are rated moderate. The assessment methodology requires that positive and moderate impacts are enhanced through the implementation of conventional management measures. The proposed management measure for the positive socioeconomic impacts of the Prelude FLNG Project is an Industry Participation Plan (IPP). Details for the IPP are provided in *Chapter 7.*

With the exception of economic effects, the significance of all of the other assessed socioeconomic and cultural impacts of the project are 'minor'.

### *Recreational Fishing, Including Charter Fishing*

There is not expected to be any need for safeguard or mitigation measures with respect to recreational or charter fishing at this time due to the absence of these fishing activities in the project area.

### *Commercial and Traditional Fishing*

A range of measures will be put in place regarding commercial fisheries and operators of commercial fishing boats with licences to operate in the vicinity of the project area. These include:

- gazetting the FLNG facility and its 500 m safety and security exclusion zone and requesting that it be included on navigational charts;
- issuing a "Notice to Mariners" through the Australian Hydrographic Service describing the facility, its operations and coordinates (including the position, size and direction of subsea gas gathering infrastructure that could pose a potential hazard to draggers or long-line trawlers);
- contacting the fishery licence groups that operate in the project area, providing them with detailed information on the nature of the undersea infrastructure that could potentially pose a snagging or collision hazard to their members; and
- lighting the FLNG facility and support vessels as required under the *Navigation Act 1912* and maintaining a watch for shipping activity in the project area.

With regard to traditional Indonesian fishermen operating in the MOU Box, Shell will:

- distribute information to the FLNG facility crew on the fishing rights and practices of the Indonesians under the MOU and procedures for dealing with boats

that might enter the 500m safety and security exclusion zone; and
- have materials in Bahasa Indonesian/and or a recorded voice message on board the FLNG facility and supply vessels for communicating with fishermen who approach the FLNG facility.

### *Commercial Shipping and Navigation*

A range of management and mitigation measures will be put in place regarding commercial shipping including:
- installing an anti-collision radar on the FLNG facility, assigning responsibility to designated personnel for monitoring and response and providing training on these responsibilities;
- lighting the FLNG facility and support vessels as required under the *Navigation Act 1912* and maintaining a watch for shipping activity in the project area;
- gazetting the FLNG facility and its 500 m safety and security exclusion zone;
- issuing a “Notice to Mariners” through the Australian Hydrographic Service describing the facility, its operations and coordinates;
- establishing and making available (as required) a schedule of regular vessel movements to and from the FLNG facility; and
- ensuring that radio communication and safety protocols are established for communication with vessels entering the safety and security zone around the FLNG facility.

### *Summary*

*Section 6.10* is summarised in *Table 6.41* and *Table 6.42.*

### *Conclusion*

Overall, the socioeconomic effects associated with the Prelude FLNG Project are assessed to be positive. The negative socioeconomic effects are unlikely and of low magnitude and are assessed as minor.

The positive impacts of the project are economic. The project could directly create more than 500 jobs during construction and around 320 Australian jobs during operations for up to 25 years. Most of those jobs will be held by FIFO workers on the FLNG facility. The project is expected to employ support crews and logistics personnel in Broome and/or Darwin. Indirectly, the project can be expected to support employment in local small business and revenue for local merchants and service suppliers. Further, the project will create a long-term revenue stream for the Commonwealth government.

As a result of this impact assessment, no significant negative impacts to economic and social matters arising under the *EPBC Act* have been identified.

## 6.11 HEALTH IMPACTS

This section assesses the potential health impacts of the project on local communities of the Kimberley including Broome. The anticipated health impacts associated with the Prelude FLNG Project with potential to affect the onshore communities are expected to be minor as a result of the following:
- the majority of construction and operation activities are offshore, 475 km from Broome and approximately 800 km from Darwin;
- the logistical arrangements for transiting workers aims to minimise overnight stays in onshore hubs; and
- existing industrial areas will be utilised for bases in Broome and/or Darwin.

### 6.11.1 Sources and Characteristics of Health Impacts

The project presents a number of potential hazards that may have occupational health consequences for workers if not managed appropriately. In particular, the potential for exposure to hazardous materials, equipment, air emissions and excessive noise levels which could result in injury or fatality. These risks do not extend to onshore communities due to the distance of the FLNG facility from coastal communities. The risks to workers associated with the project and the appropriate workplace health and safety arrangements are addressed through Shell’s OHS policies and procedures, and NOPSA requirements, and are not dealt with further in this section.

Onshore LNG projects, in particular during construction, typically have some local impact on healthcare facilities and services. This is usually due to project drawing on the local healthcare system to meet worker needs for, among other things, health checks, medical examinations and vaccinations.

This demand will be much less for the Prelude FLNG project as onshore construction activities are limited. Workers that

*Table 6.41 Summary of Economic Impacts*

| Impact | | Economic Effects | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Receptors | Industry, commerce and Government. | | | | | | | | |
| Receptor Sensitivity | | | | | | | | | |
| Industry | | ■ | Low | | Medium | | High | | |
| Commerce | | ■ | Low | | Medium | | High | | |
| Government | | ■ | Low | | Medium | | High | | |
| Expenditures and tax revenues associated with the project have the potential to impact positively on local, state and national industry and commerce. Impact will be in the form of employment, opportunities for local businesses and contractors and increased government tax revenues generated by the project. | | | | | | | | | |
| Drilling and Construction | Impact Nature | | Negative | ■ | Positive | | | | |
| | Impact Extent | | Local | ■ | Regional | | National | | Global |
| | Impact Duration | | Rare/ short | ■ | Occasional/ moderate | | Regular/ long | | |
| | Impact Magnitude | ■ | Low | | Medium | | High | | |
| | Likelihood | | Unlikely | | Possible | | Probable | ■ | Certain |
| | Significance | | Minor | ■ | Moderate | | Major | | Critical |
| Commissioning | Impact Nature | | Negative | ■ | Positive | | | | |
| | Impact Extent | ■ | Local | | Regional | | National | | Global |
| | Impact Duration | ■ | Rare/ short | | Occasional/ moderate | | Regular/ long | | |
| | Impact Magnitude | ■ | Low | | Medium | | High | | |
| | Likelihood | | Unlikely | ■ | Possible | | Probable | | Certain |
| | Significance | ■ | Minor | | Moderate | | Major | | Critical |
| Operation/ Maintenance | Impact Nature | | Negative | ■ | Positive | | | | |
| | Impact Extent | | Local | | Regional | ■ | National | | Global |
| | Impact Duration | | Rare/ short | | Occasional/ moderate | ■ | Regular/ long | | |
| | Impact Magnitude | ■ | Low | | Medium | | High | | |
| | Likelihood | | Unlikely | | Possible | | Probable | ■ | Certain |
| | Significance | | Minor | ■ | Moderate | | Major | | Critical |
| Decommissioning/ Abandonment | Impact Nature | | Negative | ■ | Positive | | | | |
| | Impact Extent | | Local | ■ | Regional | | National | | Global |
| | Impact Duration | ■ | Rare/ short | | Occasional/ moderate | | Regular/ long | | |
| | Impact Magnitude | ■ | Low | | Medium | | High | | |
| | Likelihood | | Unlikely | ■ | Possible | | Probable | | Certain |
| | Significance | | Minor | ■ | Moderate | | Major | | Critical |

## *Table 6.42 Summary of Marine Social Effects*

| Impact | Resource access, navigational changes and occupational hazards | | | | | |
|---|---|---|---|---|---|---|
| **Receptors** | Vessel operators, recreational boaters and fishing crews (Australian and traditional Indonesian) | | | | | |
| **Receptor Sensitivity** | | | | | | |
| **Industry** | ■ | Low | | Medium | | High |
| **Commerce** | ■ | Low | | Medium | | High |
| **Government** | ■ | Low | | Medium | | High |

The physical presence of the FLNG facility and the movement of the vessels may affect current navigational practices and potentially increase navigation and collision hazards.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Drilling and Construction** | **Impact Nature** | ■ | Negative | | Positive | | | | |
| | **Impact Extent** | ■ | Local | | Regional | | National | | Global |
| | **Impact Duration** | | Rare/ short | ■ | Occasional/ moderate | | Regular/ long | | |
| | **Impact Magnitude** | ■ | Low | | Medium | | High | | |
| | **Likelihood** | ■ | Unlikely | | Possible | | Probable | | Certain |
| | **Significance** | ■ | Minor | | Moderate | | Major | | Critical |
| **Commissioning** | **Impact Nature** | ■ | Negative | | Positive | | | | |
| | **Impact Extent** | ■ | Local | | Regional | | National | | Global |
| | **Impact Duration** | ■ | Rare/ short | | Occasional/ moderate | | Regular/ long | | |
| | **Impact Magnitude** | ■ | Low | | Medium | | High | | |
| | **Likelihood** | ■ | Unlikely | | Possible | | Probable | | Certain |
| | **Significance** | ■ | Minor | | Moderate | | Major | | Critical |
| **Operation/ Maintenance** | **Impact Nature** | ■ | Negative | | Positive | | | | |
| | **Impact Extent** | ■ | Local | | Regional | | National | | Global |
| | **Impact Duration** | | Rare/ short | | Occasional/ moderate | ■ | Regular/ long | | |
| | **Impact Magnitude** | ■ | Low | | Medium | | High | | |
| | **Likelihood** | ■ | Unlikely | | Possible | | Probable | | Certain |
| | **Significance** | ■ | Minor | | Moderate | | Major | | Critical |
| **Decommissioning/ Abandonment** | **Impact Nature** | ■ | Negative | | Positive | | | | |
| | **Impact Extent** | ■ | Local | | Regional | | National | | Global |
| | **Impact Duration** | ■ | Rare/ short | | Occasional/ moderate | | Regular/ long | | |
| | **Impact Magnitude** | ■ | Low | | Medium | | High | | |
| | **Likelihood** | ■ | Unlikely | | Possible | | Probable | | Certain |
| | **Significance** | ■ | Minor | | Moderate | | Major | | Critical |

cannot be adequately treated offshore will be brought to the nearest onshore health facility for treatment. Local healthcare services could also be called upon in the event of an emergency or non routine event such as a serious offshore incident involving multiple workers requiring immediate medical treatment; however, the likelihood of this is low.

### *Community Health Services*

As the project is largely offshore, community interaction with the project will be limited. The use of health facilities and services such as doctors, dentists, chemists and hospital beds by the onshore workforce in Broome or Darwin is likely to be minimal as only a small number may need to access local health facilities and services during their roster. Offshore FIFO workers are not expected to be in the local onshore communities for any length of time and are unlikely to seek elective healthcare services locally. There will be medical workers on board the FLNG facility, the minimum requirements for which are specified the *OPGGS Act*.

The social receptors that could be affected by additional demands on community health services are the local onshore communities, tourists visiting the area and regional communities. In the event of a major non routine event requiring major assistance, the Royal Flying Doctors, GPs, paramedics and other local healthcare professionals will be called upon.

The impacts from a major event would be felt more in Broome than Darwin due to the smaller base population, remoteness and smaller scale of existing health facilities. Darwin can provide at least local tier three support.

Because of its proximity to the project area, Broome is more likely to be impacted by an emergency arising at the project. In the event of an offshore incident or transportation accident of significant size, the emergency services in Broome and surrounding region may struggle to meet the emergency healthcare needs of both the project and the local community as health service ratios in Broome are already below the Australian average (Broome Community Guide, ABS and other sources).

Should a non-routine event occur, access for Broome residents to both regular and emergency health services could be reduced. The effects of the service reduction would be limited in duration but could be highly disruptive for local residents and service providers. Shell's Emergency Planning will therefore include early discussions with the Broome health authorities on arrangements for triage, coordination of emergency response and maintenance of health services for local residents. Community health impacts associated with the project are expected to be unlikely and of medium magnitude for a major non-routine event, and hence their significance has been assessed to be minor.

| Community health services | | | |
|---|---|---|---|
| Impact | Magnitude | Likelihood | Significance |
| Negative | Medium | Unlikely | MINOR |

### 6.11.2 Safeguards/Mitigation Measures

### *Workplace Health and Safety*

Shell will hold early discussions with Broome Health Authorities on coordinating emergency response requirements in a manner that also maintains health service for local residences. Shell will prepare detailed Workplace Health and Safety and Emergency Management Plans to meet all regulatory and Shell Group requirements (See *Chapter 7*). Workplace health and safety of the workforce is of the utmost importance to Shell. This is observed in Shell's HSE Policy which promotes the goal of no harm to people. This policy includes contractors working on the Prelude FLNG Project.

### *Summary*

*Section 6.11* is summarised in *Table 6.43*.

### *Conclusion*

The health impacts associated with all phases of the Prelude FLNG Project have been evaluated and are assessed to be minor. As a result of this impact assessment, no significant health impacts with a bearing on economic and social matters arising under the *EPBC Act* have been identified.

## 6.12 CUMULATIVE IMPACTS

Whilst individually the effects of activities may be judged to be acceptable, in combination with others they have the

## *Table 6.43 Summary of Health Impacts*

| Impact | Health Services |
|---|---|
| **Receptors** | Local community (Broome/Darwin), tourists visiting the area and regional communities trying to access health services in Broome/Darwin |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Receptor Sensitivity** | | | | | | |
| **Local Community** | | Low | ■ | Medium | | High |
| **Tourists** | ■ | Low | | Medium | | High |
| **Regional Communities** | | Low | ■ | Medium | | High |
| Offshore workers will not rely on local health services for routine procedures but could require emergency services. Local community health services are limited in Broome and could be overwhelmed if a major incident were to occur offshore. | | | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Drilling and Construction** | **Impact Nature** | ■ | Negative | | | | Positive | | |
| | **Impact Extent** | ■ | Local | | Regional | | National | | Global |
| | **Impact Duration** | ■ | Rare/ short | | Occasional/ moderate | | Regular/ long | | |
| | **Impact Magnitude** | ■ | Low | | Medium | | High | | |
| | **Likelihood** | ■ | Unlikely | | Possible | | Probable | | Certain |
| | **Significance** | ■ | Minor | | Moderate | | Major | | Critical |
| **Commissioning** | **Impact Nature** | ■ | Negative | | | | Positive | | |
| | **Impact Extent** | ■ | Local | | Regional | | National | | Global |
| | **Impact Duration** | ■ | Rare/ short | | Occasional/ moderate | | Regular/ long | | |
| | **Impact Magnitude** | ■ | Low | | Medium | | High | | |
| | **Likelihood** | ■ | Unlikely | | Possible | | Probable | | Certain |
| | **Significance** | ■ | Minor | | Moderate | | Major | | Critical |
| **Operation/ Maintenance** | **Impact Nature** | ■ | Negative | | | | Positive | | |
| | **Impact Extent** | ■ | Local | | Regional | | National | | Global |
| | **Impact Duration** | ■ | Rare/ short | | Occasional/ moderate | | Regular/ long | | |
| | **Impact Magnitude** | ■ | Low | | Medium | | High | | |
| | **Likelihood** | ■ | Unlikely | | Possible | | Probable | | Certain |
| | **Significance** | ■ | Minor | | Moderate | | Major | | Critical |
| **Decommissioning/ Abandonment** | **Impact Nature** | ■ | Negative | | | | Positive | | |
| | **Impact Extent** | ■ | Local | | Regional | | National | | Global |
| | **Impact Duration** | ■ | Rare/ short | | Occasional/ moderate | | Regular/ long | | |
| | **Impact Magnitude** | ■ | Low | | Medium | | High | | |
| | **Likelihood** | ■ | Unlikely | | Possible | | Probable | | Certain |
| | **Significance** | ■ | Minor | | Moderate | | Major | | Critical |

potential to be of significance. As such, cumulative impacts are the result of the effects of an action associated with one project or activity combining with those of another. Hence, in assessing the overall acceptability of a project, it is important that potential cumulative impacts are considered. There are three general types of cumulative impact:

- Additive impacts, where effects from multiple sources act additively to increase the level of impact on the environment;
- Interactive impacts, where multiple sources interact and introduce a new form of impact; and
- Spin-off impacts whereby a project action leads to another form of impact that is not directly related to the project.

While project or activities generally give rise to cumulative impacts, the use of the FLNG concept for the development of the Prelude field reduces or avoids a number of potential cumulative impacts to the wider Kimberley region, relative to those from a land based LNG development option, by not contributing to cumulative impacts such as landtake, coastal ecology or heritage impacts that could result from land based development in the region. The FLNG concept also reduces cumulative impacts to the physical resource base by avoiding the need for additional materials associated with constructing infrastructure such as delivery pipelines, jetty structures and additional offshore platforms.

### 6.12.1 Scope of the Assessment

The scope of the cumulative impact assessment is based upon the draft EIS Guidelines issued by the Commonwealth DEWHA. *Section 5.7* states:

"This section must include…Cumulative impacts, where potential project impacts are in addition to existing impacts of other activities, (including those known potential future expansions or developments by Shell and other proponents in the vicinity), should also be identified and addressed. Where relevant to the potential impact, risk assessment should be conducted and documented. The risk evaluation should include known potential future expansions or developments by Shell and other proponents."

For the consideration of the Prelude FLNG Project, the scope of the cumulative assessment has been defined by considering the type of activities, their spatial scale and time span and hence their potential to interact with the Prelude FLNG Project.

#### *Relevant Activities*

Candidate activities for inclusion in the cumulative assessment were considered by applying the following criteria:

- Activities that already exist, or have a high degree of certainty of proceeding in the future, such as those under construction or for which approvals and budget have been obtained, were considered;
- Conceptual activities were excluded;
- Activities for which Shell had insufficient information to undertake an assessment to a reasonable standard were excluded; and
- Non-oil and gas related activities such as fishing, tourism, shipping and recreational activities were considered to be beyond the scope of this draft EIS and were not considered.

With regard to the first criterion, the Prelude FLNG Project is located within the Northern Browse Basin, a proven hydrocarbon province. It lies within Petroleum Exploration Permit Area WA-371-P, which is one of a mosaic of title areas within the basin. As such, it can be expected that these areas will come to be developed over time, and the Prelude facility may in the future be located in the vicinity of other offshore developments. Currently, however, the form and timing of the development proposals for these title areas are not fully known.

Referring to the oil and gas development activities identified in *Section 4.5*, the Ichthys development proposal, the closest currently proposed development, involves a semi-submersible platform and an FPSO, expected to be located approximately 25-30 km to the southwest of the Prelude FLNG facility, with a subsea pipeline to an onshore gas liquefaction plant at Blaydin Point, Darwin. The project is understood to be at an early design stage and a contract for FEED for the offshore facilities has been awarded (media release www.inpex.com.au, posted 30 April 2009). As such, information regarding the project is limited (it is understood that an Environmental Impact Statement under the *EPBC Act* is in preparation) and it is not considered further here beyond noting the substantial buffer distance between the Ichthys development and the Prelude FLNG Project makes cumultive impacts unlikely.

The Woodside Browse development is located within a cluster of Petroleum Exploration Permit Areas approximately 140 km to the south-southwest of the Prelude FLNG location. It has yet to receive government approval and is undergoing the approval process at the present time. In view of its approval status and very large separation distance from the Prelude FLNG, it is not considered further. Similarly, the Nexus Crux field development, located approximately 140 km northeast of the Prelude FLNG project, has received a production licence but due to separation distance from the Prelude FLNG, it is not considered further.

### 6.12.2 Identification and Assessment of Cumulative Effects

Given the large separation distances between the closest proposed development and the Prelude FLNG Project, cumulative effects at a local scale (as defined in *Table 6.4*) are not anticipated. At a regional scale, cumulative socioeconomic impacts may arise as higher levels of ship and small aircraft movements between Broome or Darwin and offshore destinations, and higher passenger levels at Broome or Darwin airport. In view of the number of vessel and passenger movements involved, as described in *Section 4.8.4* and *Section 6.1.1*, the cumulative impact is anticipated to be minor.

$CO_2$ emissions from the Prelude FLNG Project contribute to total Australian annual emissions. The effects of global warming and associated climate change are the cumulative effect of many of such sources across the globe and it is the cumulative effects that ultimately bring about climate change. Accordingly, the cumulative impacts from $CO_2$ emissions from the Prelude FLNG Project have been assessed as a moderate impact. The Prelude FLNG facility incorporates a number of technological and process efficiencies which results in an energy efficient LNG plant design and the Prelude project has been designed and developed in the full knowledge of an impending CPRS. The costs associated with GHG emissions generated by the Prelude FLNG project have formed part of the criteria for assessing project process and equipment selection.

### 6.12.3 Conclusion

The Prelude FLNG project will not give rise to cumulative impacts on a local scale. Minor cumulative socioeconomics impacts regionally have been identified as a result of Prelude's contribution to vessel and passenger movements in the northern Kimberley. $CO_2$ emissions have been assessed as a moderate impact at a global scale.

The project will not give rise to significant cumulative impacts to EPBC listed species, migratory species or the marine environment.

## 6.13 SUMMARY OF IMPACTS

A summary of all the potential impacts identified and evaluated in this chapter is included in *Table 6.44*. The significance of each of these impacts, as derived from applying the impact's likelihood and magnitude according to the matrix included in *Section 6.2.8*, is reported and a final statement regarding whether the evaluated impact is considered to trigger the *EPBC Act's* legal definition of significance in regards to matters of NES is also included.

For each of the impact categories, the significance of the environmental risk is described separately for each of the four project phases; drilling and construction, commissioning, operations and maintenance, and decommissioning.

No negative impacts have been categorised as major or critical, meaning that all impacts are either:

- minor, which can be managed through effective standard operating procedures; or
- moderate, which can be mitigated to ALARP through the implementation of conventional mitigation measures.

The categorisation of the impact significance presented throughout this chapter is based on the residual impact, after all identified safeguard and mitigation measures are applied. A consolidated list of all safeguard and mitigation measures is included in *Chapter 7,* along with information relating specifically to the management framework for the project.

*Table 6.44* *Summary of Impacts*

| Action | Receptors | Impact Description | Mitigated Impact Significance | | | | NES Implications |
|---|---|---|---|---|---|---|---|
| | | | Drilling | Commission | Operation | Decommis-sioning | |
| **Physical Impacts** | Cetaceans<br>Turtles<br>Fish<br>Birds<br>Plankton<br>Benthic fauna | (i) There is potential for collisions between vessels and marine fauna (eg whales and turtles). The operations phase of the project will require one support vessel travelling to and from the facility per week, one LNG tanker visit every week, one condensate tanker per fortnight and one LPG Tanker per month.<br>ii) The physical presence of subsea infrastructure and production wells will cover an area of approximately 8,000m$^2$. Installation of subsea facilities will cause localised impacts to benthic habitats. | Minor<br>Moderate | Minor<br>Moderate | Minor<br>Moderate | Minor<br>Moderate | Not significant |
| **Presence of Vessels and Aircraft** | Cetaceans<br>Turtles<br>Fish<br>Birds | Collisions between vessels and marine fauna (eg cetaceans and turtles) is considered unlikely in view of the remote location of the facility from cetacean migration paths and congregation areas, and the avoidance capabilities of turtles. Impacts from helicopter movements are anticipated to be low given the low frequency of flights, choice of flight path and avoidance behaviour by birds. | Minor | Minor | Minor | Minor | Not significant |
| **Artificial Lighting** | Turtles<br>Fish<br>Birds | Artificial lighting will be present through all stages of the project and has the potential to particularly impact marine fauna that use visual cues for orientation, navigation etc.<br>The predominant effect of exposure to artificial light on turtles is moderation of natural behaviour, eg light pollution on nesting beaches can alter critical nocturnal behaviours in adult and hatchling turtles. However, the nearest nesting beach to the project is Browse Island (~40 km from the FLNG facility), and FLNG facility lighting is not expected to disrupt breeding/nesting behaviour.<br>The project is located adjacent to potential flight paths for migratory shorebirds, and lighting may attract birds within a 5 km radius. As the FLNG facility is 20 km from the nearest potential flight path at its closest point it is expected to result in a low level of light attraction. | Minor | Minor | Minor | Minor | Not significant |

*Table 6.44 Summary of Impacts (continued)*

| Action | Receptors | Impact Description | Mitigated Impact Significance | | | | NES Implications |
|---|---|---|---|---|---|---|---|
| | | | Drilling | Commission | Operation | Decommissioning | |
| **Underwater Noise** | Cetaceans<br>Turtles<br>Fish | Underwater noise will be produced through all stages of the project from construction activities, vessel movements and operation of the FLNG facility. Potential impacts include disturbance and behavioural changes, masking of other biologically important sounds (such as vocal communication or echolocation), or physical injury to hearing or other organs. Noise frequencies produced from the project will overlap with hearing and vocalisation frequencies of baleen whales and to a lesser extent with those of toothed whales. Underwater noise from the FLNG operations reach levels at which cetaceans show minor or no response at 2 km radius from the facility during offtake activities and 700 m during normal operations. Project noise may cause very localised disturbance to fish or turtles within 200m of the facility during offtake activities and 30m during normal operations. However, individuals are likely to habituate to the FLNG facility. | Minor | Minor | Minor | Minor | Not significant |
| **Solid Waste** | Cetaceans<br>Turtles<br>Fish<br>Birds<br>Benthic fauna and flora | Solid wastes will be generated throughout all phases of the Prelude FLNG Project – a hazardous waste plan will be developed to meet all statutory requirements. Solid wastes discharged to the marine environment have the potential to have localised effects on water quality, and risk of entanglement or ingestion by fauna.<br>Non-hazardous solid wastes discharged to sea are predicted to have localised short term effects and impacts are predicted to be minor, and moderate for drill cuttings disposed to the sea floor.<br>Hazardous solid waste will be collected for transport and disposal at a licensed on shore facility and hence impacts are predicted to be minor. | Minor<br>Moderate (for drill cuttings) | Minor | Minor | Minor | Not significant |
| **Liquid Waste** | Cetaceans<br>Turtles<br>Fish<br>Birds<br>Benthic fauna and flora<br>Plankton<br>Water Quality | Liquid effluents have the potential to damage the marine environment through acute or chronic toxicity, oxygen depletion, thermal or salinity stress. Throughout the life of the FLNG facility, liquid wastes will be treated prior to discharge to sea , and it is expected that any impacts will be local to the discharge point. Given the mobility of receptors such as fish and whales and their potential short-term exposure, the level of impact from these discharges is considered low. Localised impacts to benthic fauna may result, for example, from subsea control fluid release over the long-term. However, due to the relatively low biological abundance and the wide distribution of similar community types throughout the region, the impact is expected to be minor. | Minor | Minor | Minor | Minor | Not significant |

*Table 6.44 Summary of Impacts (continued)*

| Action | Receptors | Impact Description | Mitigated Impact Significance | | | | NES Implications |
|---|---|---|---|---|---|---|---|
| | | | Drilling | Commission | Operation | Decommissioning | |
| **GHG emissions** | Global climate and environment | Atmospheric emissions will be routinely generated during the installation and commissioning, production and decommissioning phases of the Prelude FLNG Project.<br>During production of 5.3 million tonnes per annum (mtpa) of hydrocarbons (including LNG, LPG and condensate), the facility is forecast to emit 2.3mtpa of carbon dioxide ($CO_2$). Approximately half the estimated annual emissions arise from combustion of fuel gas to power the liquefaction process. The remaining emissions arise from venting of reservoir $CO_2$. | Minor | Minor | Moderate | Minor | Not significant |
| **Other Air Emissions** | Browse Island | Given the distance to the nearest sensitive receptors it is not anticipated that emissions from the facility will have an impact at any sensitive receptor locations.<br>Reduction of emissions throughout the design process is the primary method through which emissions to air quality have been controlled. The facility has been designed to run as efficiently as possible. | Minor | Minor | Minor | Minor | Not significant |
| **Unplanned Events: Hydrocarbon Spill and Leaks** | Turtles, Cetaceans, Fish, Birds | Apart from mobile receptors transiting the open ocean in the area, the closest location considered to have sensitive habitat is Browse Island, located 40 km from the proposed location of the FLNG facility. Hydrodynamic spill modelling has established that in the worst modelled scenario, a 1000MT spill of condensate in December, there are no regions in which the likelihood for visible surface oiling is greater than a 10% probability. There is a less than 1% probability of a rainbow sheen reaching Browse island. On this basis, the overall environmental significance of the impact of hydrocarbon spills is considered minor. | Minor | Minor | Minor | Minor | Not significant |
| **Unplanned Events: Introduced Marine Species** | Marine biota | Throughout the life of the LNG, LPG and condensate tankers, support and supply vessels have the potential to introduce species through ballast water and hull fouling. However, any marine species taken up by the vessels are unlikely survive the hostile ballast environment due to the remoteness of the Prelude FLNG Project area and the depth of water in the vicinity of the project. | Minor | Minor | Minor | Minor | Not significant |

*Table 6.44* *Summary of Impacts (continued)*

| Action | Receptors | Impact Description | Mitigated Impact Significance | | | | NES Implications |
|---|---|---|---|---|---|---|---|
| | | | Drilling | Commission | Operation | Decommissioning | |
| **Socio-Economic Effects** | Industry<br>Commerce<br>Government<br>Heritage<br>Tourism | i) Expenditures and tax revenues associated with the project have the potential to impact positively on local, state and national industry and commerce. Impact will be in the form of employment, opportunities for local businesses and contractors and increased spending by government from tax revenues generated by the project. | Moderate (+ve) | Minor (+ve) | Moderate (+ve) | Minor (+ve) | Not applicable |
| | | ii) Interruption of commercial and recreational fishing through presence of safety exclusion zone. | Minor | Minor | Minor | Minor | |
| | | iii) Visual and aesthetic values and impacts on tourism. | Minor | Minor | Minor | Minor | |
| | | iv) Damage of disruption to sites of cultural and historical significance. | Minor | Minor | Minor | Minor | |
| | | v) The physical presence of the FLNG facility and the movement of the supply vessels and off take tankers affects current navigational practices and increases potential navigation and collision hazards. | Minor | Minor | Minor | Minor | |
| **Health Services** | Offshore workers<br>Local community<br>Tourists<br>Regional communities | i) Offshore workers will not rely on local health services for routine procedures but could require emergency services. Local community health services are limited in Broome and could be overwhelmed if a major incident were to occur offshore or during flights transporting workers to and from the project location, however contingency plans will be developed to accommodate such a situation. | Minor | Minor | Minor | Minor | Not applicable |
| | | ii) Impacts on the local communities arising from work place health and safety incidents. | Minor | Minor | Minor | Minor | |

# 7 FRAMEWORK ENVIRONMENTAL MONITORING AND MANAGEMENT PLAN

## 7.1 INTRODUCTION

This Chapter presents a framework Environmental Management and Monitoring Plan (EMMP) for the Prelude FLNG Project. The purpose of this framework is to demonstrate Shell's delivery mechanism for the commitments made in this draft EIS and outline the monitoring that will be undertaken throughout project execution. The Prelude FLNG project is being developed with the environmental objectives presented in *Table 7.1*.

Identifying impacts began in the earliest phases of the project design and will continue throughout the lifecycle of the project. The Impact Assessment methodology undertaken during this draft EIS provides a robust and public process for the identification of potential impacts, prediction of their significance and development of the mitigation and ongoing management measures.

The Impact Assessment process undertaken for this draft EIS has concluded that planned and unplanned operations of a FLNG facility do not represent a significant risk to any listed or migratory species, threatened ecological communities, nor the marine, socio-economic or cultural environment if the documented design and mitigation measures are implemented.

## 7.2 MITIGATION & MANAGEMENT MEASURES

This section provides an overview of Shell's approach to the ongoing management of potential impacts to ALARP levels through the life cycle of the Prelude FLNG Project. These impacts have been identified through the impact assessment process detailed in *Chapter 6* of this draft EIS. The process of managing potential impacts will be addressed through the following:

- Designed Mitigation Measures: Avoiding or reducing at source through engineering/design so that a feature that may potentially cause an impact is designed out or altered;
- Management Measures: Establishing and implementing operational procedures to reduce the likelihood and/or severity of an impact occurring through actions or activities.
- Monitoring of Management Measures: Set in place monitoring procedures to provide verification of the overall design and effectiveness of the mitigations measures and thereby allow for adjustment accordingly.

*Table 7.1 Environmental Aspects and Management Objectives*

| Aspect | Objectives |
|---|---|
| Marine Environment | • Maintain biodiversity, species distribution and function of marine ecosystem.<br>• Ensure that potential risks to significant marine communities and species are avoided or mitigated and controlled.<br>• Avoid significant impacts to *EPBC Act* listed species (as defined in *EPBC Act* Policy Statement 1.1). |
| Air Quality/ GHG Emissions | • Reduce emissions through the use of technological efficiencies.<br>• Minimise flaring and venting to only that required for safety reasons.<br>• Reduce GHG emissions to ALARP levels within the context of the development restrictions of this project, through the: 1) Decision to implement FLNG as the means of hydrocarbon extraction and production; and, 2) Technological efficiencies. |
| Noise | • Reduce noise impacts to ALARP levels.<br>• Manage noise through the use of technological efficiencies and design mitigation measures. |
| Light | • Reduce light spill to ALARP levels through design measures and selection of technologies. |
| Waste and effluent | • Treat effluent prior to discharge to accepted industry and regulatory standards.<br>• Reduce the pollutant load of controlled water discharges from operations.<br>• Handle and dispose of waste in a manner as to control loss to environment.<br>• Implement a "minimise, segregate, recycle and reuse" approach to the project as appropriate. |
| Hydrocarbon/ chemical release | • Reduce risks of accidental discharge through design measures and handling practices. |
| Workforce and public health | • Ensure risks to health and safety are reduced to ALARP levels through good design of facilities, development of appropriate procedures, strict vetting of logistics providers and sufficient competency of workforce and contractors by recruitment and training programs. |
| Engagement | • Open communication and implement transparent feedback mechanisms with relevant stakeholders. |
| Economic Development | • Optimise the opportunities for economic benefits to the local and regional community provided by the project. |

As described in *Chapter 4*, the Prelude FLNG Project has been designed with an intent to mitigate potential impacts of an LNG facility development to ALARP. As the project progresses through the further design, engineering, construction, installation, operation and finally decommissioning phases of the project, Shell will continue to strive to avoid or minimise all adverse environmental, socioeconomic and health impacts. To achieve this, Shell will develop a systematic approach to the management of their operations which will include monitoring, measuring performance and taking corrective actions where necessary.

In accordance with the *EPBC Act* and *Sections 5.8* and *Section 5.11* of the DEWHA guidelines for this draft EIS, Shell has developed a framework environmental monitoring and auditing plan for the project, which is discussed in *Section 7.6*. The monitoring requirements associated with the proposed mitigation and management measures are summarised in *Table 7.4* The design and procedural mitigations measures outlined in *Chapter 6* are summarised in *Table 7.2*.

## 7.3 SHELL'S MANAGEMENT SYSTEM

The design and mitigation commitments made in this draft EIS will be implemented, along with other project commitments, through a project specific HSE-MS. The components of the management system, and how the draft EIS process fits into and is delivered by the management system, are described below.

*Table 7.2* *Mitigation & Management Measures*

| Aspect | Mitigation and Management Measures | Responsible Party | Timing |
|---|---|---|---|
| Cetaceans | Vessel cetacean interaction procedures will be developed and relevant drilling, construction and supply contractors engaged by Shell will be obliged to comply with these. The procedures will include the requirement to maintain a watch for cetaceans when transiting, to not knowingly approach within 500 m of cetaceans, to take actions to avoid cetaceans located within a distance of 500 m from the vessel when safe to do so and to complete a 'Whale and Dolphin Sighting Report Sheet' (DEWHA 2008) in the event cetaceans are sighted. | Shell will develop procedures, all vessel contractors to implement procedures | All Phases |
| | Helicopter operators engaged by Shell will be obliged to fly above an altitude of 1,000 m within a 300 m horizontal radius of observed whales (except for take-off and landings). | Helicopter contractor | All Phases |
| Birds and Turtles | Helicopter operators engaged by Shell will be obliged to route flight paths to avoid Browse Island and to comply with Civil Aviation Authority procedures to reduce the potential for bird strikes from helicopters. | Helicopter contractor | All Phases |
| | Lighting of the FLNG facility will be designed with the objective of reducing light spill, subject to meeting all workplace health and safety, and navigational requirements. The FLNG facility will be designed to reuse hydrocarbon waste streams generated by normal operations ("no flaring principle"), limiting the extent and duration of flaring -see lighting section below for further details. | EPC Contractor for FLNG facility | Design and FLNG Construction |
| Physical Presence | Selection of project concept as FLNG and positioning of FLNG facility and associated infrastructure in an area that does not have any known significant environmental sensitivities. | Shell | Design |
| | Screens will be installed on the cooling water riser inlets and inlet current speeds will be low (estimated at 0.5 m/s) to prevent the ingress of large marine fauna into the cooling water system.<br>TBT antifouling will not be used on the FLNG facility or associated subsea infrastructure. | EPC Contractor for FLNG facility | Design and FLNG Construction |
| Lighting<br>• Lights<br>• Flaring | Locating the FLNG facility in an area that is distant to the closest known significant environmental sensitivities. | Shell | Design |
| | Lighting of the FLNG facility will be designed with the objective of reducing light spill, subject to meeting all workplace health and safety, and navigational requirements. Design measures that will be considered will include:<br>• limiting the effects of reflecting surfaces by assessing the location of luminaries and the use of low-reflective paints;<br>• locating luminaries in such a way that they are shielded as far as practicable from direct line-of-sight from surrounding view points;<br>• directing luminaries inwards on the FLNG facility and away from the ocean; and<br>• the preferential use of low-impact spectrum illumination (including the use of green or blue lighting) over red, orange and white external lighting.<br>The FLNG facility will be designed to reuse hydrocarbon waste streams generated by normal operations ("no flaring principle"), limiting the extent and duration of flaring. | EPC Contractor for FLNG facility | Design and FLNG Construction |
| | Continuous illumination of work and accommodation areas on the FLNG facility and supply vessels will be limited wherever practicable to prevent attraction of marine and bird life, although any measures adopted will not compromise safety or navigational requirements. | Shell and Supply vessel contractor | All Phases |
| | Procedures will be designed to limit the occurrence and duration of flaring to ALARP. | Shell | Operations |

*Table 7.2 Mitigation & Management Measures (continued)*

| Aspect | Mitigation and Management Measures | Responsible Party | Timing |
|---|---|---|---|
| Noise | Locating the FLNG facility in an area that is distant to the closest known significant environmental sensitivities. | Shell | Design |
| | An acoustic design study will be undertaken during the Front-End Engineering and Design (FEED) phase to support the overall design process of the FLNG Facility.<br>Locating the majority of the process equipment on the topsides of the FLNG facility, not in the hull, and mounting modules on elastomeric mounts or using other vibration isolation methods to reduce vibration where required.<br>The FLNG facility will be designed to meet occupational health and safety noise limits. | EPC Contractor for FLNG facility | Design and FLNG Construction |
| | Supply vessels will be new, purpose-built vessels and will incorporate the latest design principles for energy efficiency which should help reduce vessel-generated underwater noise levels.<br>A maintenance program will be developed for the FLNG facility and supply vessels which will include inspection and maintenance of noise suppression equipment to ensure occupational health and safety noise limits are met. | Shell and Supply vessel contractor | Design<br>Operations |
| Wastes<br>Hazardous and non-hazardous solid wastes<br>Liquid Wastes<br>• Drilling fluids<br>• Hydrotest<br>• PFW and other process waters<br>• Subsea control fluids<br>• Cooling water<br>• Drainage<br>• Ballast water<br>• Sewage and grey water | The FLNG facility will be designed so that drainage water from deck areas that have the potential to be contaminated with oil or chemicals (excluding areas handling LNG or LPG) and water from areas which are likely to be contaminated with oil (sumps, bunds, machinery spaces, etc) are directed to the slop tanks for treatment. Bunded areas will be incorporated on the FLNG facility around machinery using hydrocarbons to reduce risk of leaks reaching the ocean.<br>The FLNG facility will be designed so that water from areas accidentally contaminated with oils can be directed into the PFW system for treatment prior to disposal.<br>FLNG facility PFW and waste water treatment system designed to achieve hydrocarbon concentrations of 30 mg/l or less as requirements under the *OPGSS Act*. Monitoring of the discharge stream will be undertaken prior to disposal and wastes not meeting specification will be diverted to storage tanks and returned to the PFW treatment system for retreatment. Provision will be made for the capacity to store onboard 2 to 3 days worth of produced water and contaminated drain water, to cater for the unlikely event of failure or poor performance of the treatment system.<br>The FLNG facility will be designed to include designated areas for segregation and collection of solid wastes.<br>The FLNG facility will be fitted with a macerator that is able to macerate wastes to a diameter of less than 25 mm prior to overboard disposal. | EPC Contractor for FLNG facility | Design and FLNG Construction |

## Table 7.2 Mitigation & Management Measures (continued)

| Aspect | Mitigation and Management Measures | Responsible Party | Timing |
|---|---|---|---|
| Wastes<br>Hazardous and non-hazardous solid wastes<br>Liquid Wastes<br>• Drilling fluids<br>• Hydrotest<br>• PFW and other process waters<br>• Subsea control fluids<br>• Cooling water<br>• Drainage<br>• Ballast water<br>• Sewage and grey water | Waste Management Plans will be developed and adopted for the construction, operation and decommissioning phases of the Prelude FLNG project and contractors engaged by Shell will be obliged to implement these. The Waste Management Plans, will define the approved methods and locations for the transport and disposal of all wastes and will include documented waste consignment processes and licensing requirements for waste management services and facilities. These plans will also demonstrate how:<br>• The principle of 'avoid, reduce, re-use and dispose in an environmentally responsible manner' will be adopted. One focus will be on avoiding waste at source. Waste segregation and storage facilities will be provided in line with the relevant Australian standards, MARPOL and the World Bank guidelines.<br>• When selecting materials, non-hazardous solid materials that meet technical requirements and are as cost-effective as hazardous materials will be given preference.<br>• Wastes will be segregated into waste streams and wastes not being disposed of overboard will be clearly labelled and appropriately stored on the FLNG facility for transport to onshore contractors, approved and registered with relevant authorities, for disposal or treatment.<br>- Cooking oils and greases from the support vessels and the FLNG facility will be collected and transported back to the mainland for disposal.<br>- Batteries will be collected and stored in separate (dedicated) containers; batteries will not be incinerated, but preferably recycled and, if not possible, disposed of in a safe and controlled manner.<br>- Disposal of spent adsorbent from the mercury removal unit shall be transported to an appropriately licensed treatment facility.<br>- Lube and motor oils waste will be returned to a recycling plant or refinery.<br>- Medical waste will be incinerated onshore; chemicals and solvents (eg AGRU fluids) will be returned to the supplier for recycling or to a suitable onshore waste disposal facility.<br>- Sludges from the FLNG Facility will be collected and transported back to the mainland for disposal. | Shell will develop plans, Shell and contractors to implement procedures | All Phases |
| | Sand and sludge generation will be reduced through the design of the production wells, including the installation of sand screens and traps if practicable. | Shell | Design |
| | Drilling fluids will be re-used and muds and cuttings separated using shale shakers or centrifuges as per standard industry practice. Water Based Muds will be used for drilling the top hole sections of the wells.<br><br>The Synthetic Based Muds (SBM) will be low toxicity and approved for use of by the regulator. Cuttings contaminated with synthetic based muds will be treated to achieve less than 6.9% synthetic based mud by weight prior to overboard discharge. Spent synthetic based mud will be collected on board and transported to shore for disposal. | MODU Contractor | Drilling |
| | Selection of chemicals for hydrotest, process chemicals and subsea control fluids will involve consideration of environmental performance as well as technical requirements.<br><br>Hydrotest water will be discharged to sea through the FLNG facility, which allows greater control over storage times and discharge rates to ensure minimal environmental impacts.<br><br>A maintenance program will be developed for the FLNG facility and supply vessels which will include inspection and maintenance of treatment systems to ensure discharge limits are met.<br><br>Materials handling procedures will be developed and implemented to reduce the risk of spills and leaks. | Shell | Installation and Operations |

*Table 7.2* *Mitigation & Management Measures (continued)*

| Aspect | Mitigation and Management Measures | Responsible Party | Timing |
|---|---|---|---|
| Wastes<br>Hazardous and non-hazardous solid wastes<br>Liquid Wastes | Vessel/rig vetting procedures will be developed and implemented to ensure that all vessels engaged by Shell meet the obligations under the relevant legislation (eg *OPGGS Act*, *Protection of the Sea (Prevention of Pollution from Ships) Act 1983* and MARPOL).<br>• For the MODU and FLNG facility, sewage and grey water will be disposed of in accordance with the *OPGGS Act*. Sewage will be passed through a macerator able to macerate wastes to a diameter of less than 25 mm prior to overboard disposal.<br>• For all other vessels, sewage and grey water will be disposed of in accordance with international legal requirements under MARPOL 73/78 and the *Protection of the Sea (Prevention of Pollution from Ships) Act 1983*<br>• All vessels engaged by Shell will be obliged to conduct ballast tank operations in line with IMO guidelines and, where applicable, comply with Australian Quarantine regulations. | Shell | All Phases |
| Emissions<br>• Flaring<br>• Venting<br>• Combustion<br>• Fugitive | The selection of project development concept as FLNG, which has a smaller environmental footprint than an onshore LNG plant development (with associated offshore platform, export pipeline and coastal dredging).<br>Locating the FLNG facility in an area that is distant to the closest known significant environmental sensitivities. | Shell | Design |
| | Reducing the volume of emissions is the primary method through which emissions to air will be managed.<br>• A 'no venting' principle with respect to the disposal of hydrocarbon streams from process units and other equipment has been applied to the Prelude FLNG Project. Some venting may be required, however, in special cases where routing to the flare is prohibited for safety or other reasons.<br>• A 'no flaring' principle with respect to the disposal of hydrocarbon streams from normal operations has been applied to the Prelude FLNG Project. Some flaring will be required , however, for safety reasons during start up and shut down and process upsets.<br>The FLNG facility will be designed to run efficiently, whilst meeting reliability requirements and flanges, pumps, seals and valves to be used on the facility will be selected with the objective of reducing emissions.<br>The design of the FLNG facility will allow the installation of adequate equipment to monitor and record emissions for which regulatory limits exist and/or for which performance statistics are required. This monitoring and recording will be based on automatic on-line technology, where available and practical. | EPC Contractor for FLNG facility | Design and FLNG Construction |
| | Procedures will be designed to limit the occurrence and duration of venting and flaring to ALARP.<br>As part of the ongoing design process, studies will be undertaken to:<br>• further minimise flaring during cold and warm start-ups;<br>• investigate flow assurance requirements and the need for de-pressuring flowlines in a shutdown; and<br>• investigate process availability and reliability to maximise operational run lengths and reduce process trips and losses to flare. | Shell | Operation<br>Design |

**Table 7.2** *Mitigation & Management Measures (continued)*

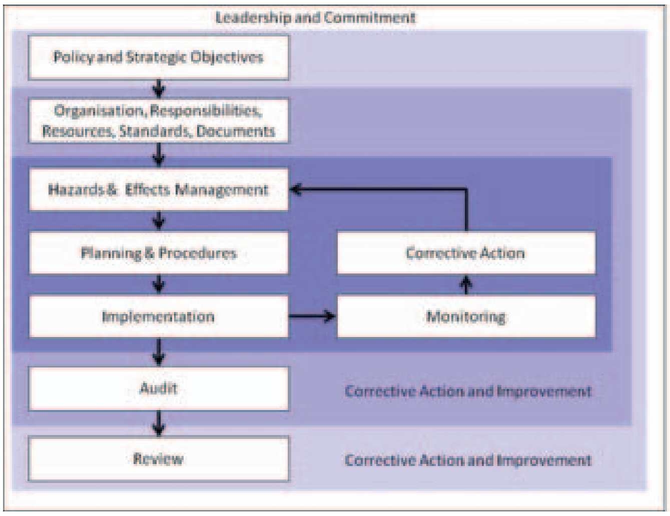
| Aspect | Mitigation and Management Measures | Responsible Party | Timing |
|---|---|---|---|
| Spills<br>Hydrocarbon spills<br>Non-hydrocarbon spills | The FLNG facility will be designed to withstand a 1 in 10,000 year weather event, with in-built facility integrity and will be double hulled.<br>The FLNG facility will be designed with an emergency stoppage mechanism for the transfer of liquid products to and from the FLNG facility and quick disconnect couplings for transfer hoses/loading arms where appropriate.<br>The main diesel and aviation fuel storage tanks on the FLNG facility will be fitted with high and low level alarms, level gauges and bunds and any overflow will routed to treatment.<br>The FLNG facility will be designed so that drainage water from deck areas that have the potential to be contaminated with oil or chemicals (excluding areas handling LNG or LPG) and water from areas which are likely to be contaminated with oil (sumps, bunds, machinery spaces etc) are directed to the slop tanks for treatment.<br>The FLNG facility will be designed so that water from areas accidentally contaminated with oils can be directed into the PFW system for treatment prior to disposal. | EPC Contractor for FLNG facility | Design and FLNG Construction |
| | Subsea equipment will be subject to dropped object studies to ensure that the risks posed by dropped objects are 'ALARP'. | Shell | Design |
| | Vessel and drill rig vetting procedures will be developed and implemented to ensure that all vessels engaged by Shell are able to comply with the relevant legislation and Shell standards including:<br>• Vessels must meet the survey requirements for their class.<br>• Vessels and rigs must have their own Ship Board Oil Pollution Emergency Plan (SOPEP) in compliance with MARPOL 73/78 and carry at least the minimum required oil response equipment.<br>• Vessels must comply with the requirements of the Multifunctional Oil Spill Advisory Group 'Guidelines for Shell Companies on Preparedness, Response and Compensation for Oil and Chemical Spills.'<br>• Rigs must be fitted with Blow Out Protectors suitable for the pressure expected to be encountered.<br>Preparation of a government approved Oil Spill Contingency Plan before any developments take place. | Shell | All Phases |
| | Materials handling procedures will be developed to reduce the risk of spills and leaks and will include the definition of suitable sea states and times for transfers, operating and communication procedures to ensure close monitoring of offloading and fuel transfer operations, routine maintenance and inspection of loading equipment and storage facilities and in place containment/recovery systems.<br>The selection of chemicals will involve consideration of environmental performance as well as technical requirements The bulk chemical containers on the FLNG facility will be designed to withstand collisions, using features such as recessed valves and metal cages.<br>Chemicals on the FLNG facility and supply vessels will be securely stored within bunded areas<br>The FLNG facility and supply vessels will locate chemical spill recovery equipment near onboard chemical supplies. | Shell | Operations |

*Table 7.2* *Mitigation & Management Measures (continued)*

| Aspect | Mitigation and Management Measures | Responsible Party | Timing |
|---|---|---|---|
| Introduced Marine Species | Selection of project concept as FLNG removes the need for coastal export facilities. Positioning of FLNG facility outside Australia's territorial sea, 40 km from the nearest land and in water depths of 250m. | Shell | Design |
| | Vessel vetting procedures will be developed and implemented to ensure that all vessels engaged by Shell meet the requirements of the relevant legislation. Under the *International Convention for the Control and Management of Ship's Ballast Water and Sediments 2004*, ships are required to implement a ballast water and sediment management plan and ships must carry a Ballast Water Record Book. A number of Guidelines are provided by the IMO (2004) which include the following requirements:<br>• the uptake of ballast shall be avoided where practicable in shallow water and at night when the number of marine organisms in the water column may increase due to the rise of bottom dwelling organisms, and also in ports where populations of harmful organisms are known to occur;<br>• avoiding the unnecessary discharge of ballast;<br>• regular cleaning of ballast tanks; and<br>• implementing ballast water management procedures which include replacing ballast at sea with clean open ocean water. (Marine species taken on in port areas are unlikely to survive in the open ocean due to the different conditions.) | Shell | All Phases |
| | To control fouling by marine organisms, the outer hull of the FLNG facility will be coated with anti-fouling paint (TBT free) and the cooling water system will be treated with hypochlorite. | EPC Contractor for FLNG facility | Design and FLNG Construction |
| Social-Economic<br>• Fisheries<br>• Navigation and Shipping<br>• Workplace Health and Safety | Gazetting the FLNG facility and its 500 metre safety and security exclusion zone.<br>Issuing a "Notice to Mariners" through the Australian Hydrographic Service describing the facility, its operations and coordinates (including the position, size and direction of subsea gas gathering infrastructure that could pose a potential hazard to draggers or long-line trawlers);<br>Contacting the fishery licence groups that operate in the project area, providing them with detailed information on the nature of the undersea infrastructure that could potentially pose a snagging or collision hazard to their members.<br>Lighting the FLNG facility and support vessels as required under the *Navigation Act 1912* and maintaining a watch for shipping activity in the project area.<br>Distribute information to the FLNG facility crew on the fishing rights and practices of the Indonesians under the MOU and procedures for dealing with boats that might enter the 500m safety and security exclusion zone and having materials in Bahasa Indonesian/and or a recorded voice message on board the FLNG facility and supply vessels for communicating with fishermen who approach the FLNG facility.<br>Ensuring that radio communication and safety protocols are established for communication with vessels entering the safety and security zone around the FLNG facility. | Shell | Installation<br>Operation |
| | Providing anti-collision radar on the FLNG facility;<br>Lighting the FLNG facility and support vessels as required under the *Navigation Act 1912*. | EPC Contractor for FLNG facility | Design and FLNG Construction |
| | Shell will hold early discussions with Broome Health Authorities on coordinating emergency response in a manner to maintain health service for local residences.<br>Shell will prepare detailed Workplace Health and Safety and Emergency Management Plans to meet all Shell's and regulatory requirements . | Shell | All Phases |

The HSE-MS is a tool used by Shell to ensure and demonstrate that HSE objectives are met and that continuous improvement is achieved. Each Shell Company is required to implement such a system and to report its progress to Shell Group level. The key elements of the Shell HSE-MS are outlined in *Figure 7.1*.

*Figure 7.1 HSE Management System Structure*



In short, the HSE-MS comprises:

- organisational aspects, including strategic objectives, definition of responsibilities for HSE management, required standards and how documents will be managed;
- the Hazards and Effects Management Process (HEMP), which aims to identify and assesses hazards and effects, and drives the development of measures to control or manage them and
- the plan-do-check-feedback 'loop' to ensure that lessons learned from the management of hazards and effects are fed back into the HEMP in an effort to prevent reoccurrence or escalation.

The aim of the HSE-MS is to ensure environmental management is integrated throughout the organisation from senior management to individual staff, contractors and suppliers. The audit and review function of the HSE-MS seeks to ensure that the system is being fully implemented and to identify areas for improvement.

As an integral part of Shell's Global HSE-MS, Shell have established a number of standards and targets which all Shell companies must abide with, in addition to local regulatory requirements. These are included in Shell's *Global Environmental Standards* (Shell, 2007) which seek to ensure that environmental performance in all Shell companies meet both local and international standards of environmental management. These standards are translated by each business unit into HSE business performance indicators. Shell companies therefore have to monitor and report their performance against these indicators.

### 7.3.1 EIS and the Prelude HSE-MS

The relationship between the EIS process and the HSE-MS is shown in *Figure 7.2*.

The figure illustrates the two parallel processes for the management of potential environmental impacts associated with the Prelude development:

- **Statutory Requirements:** The requirements associated with the *EPBC Act* and the *OPGGS Act*, including the commitments made in the draft EIS and EPs.
- **Shell Requirements:** Incorporating the environmental management measures from the draft EIS, the EMMP and the EPs into the HSE-MS that will be developed for this project.

## 7.4 GUIDELINES FOR MITIGATION, MANAGEMENT AND MONITORING

### 7.4.1 Shell Commitment and Policy

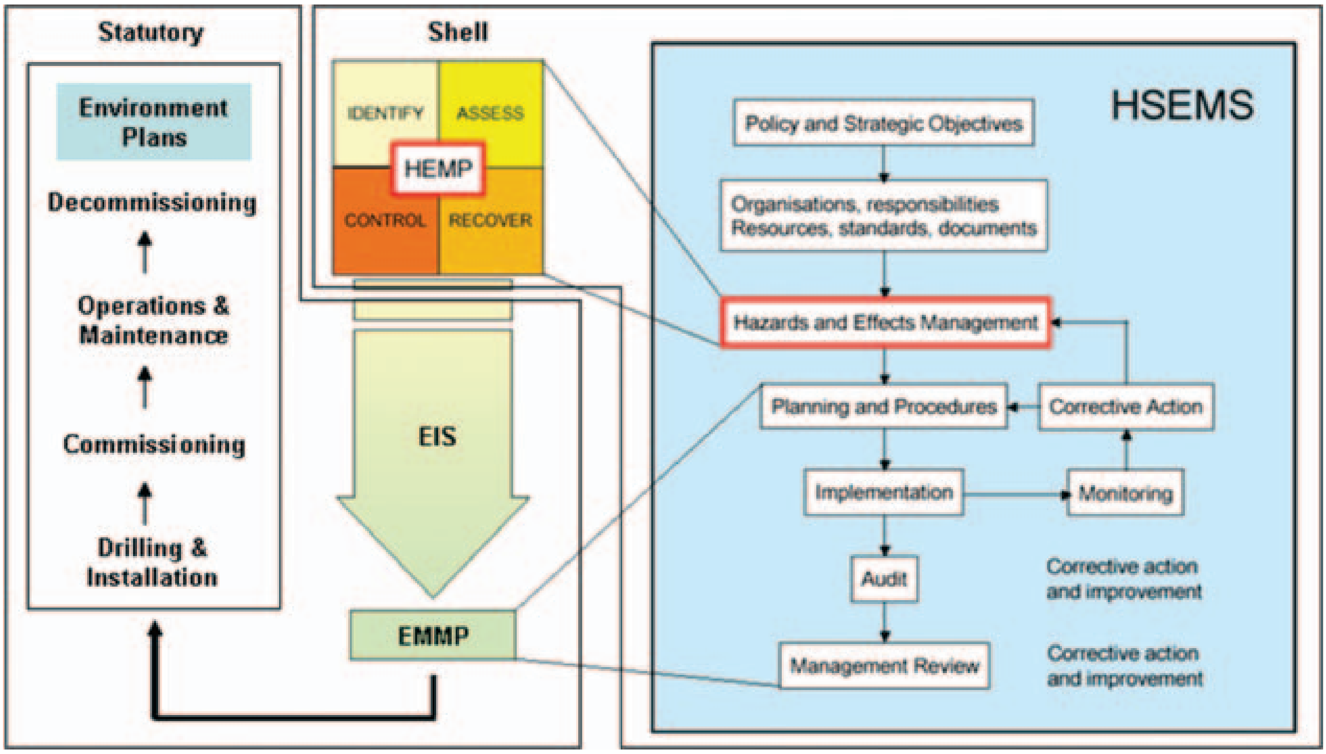
The Shell Group operates under a common set of business principles, supported by policies, standards and business controls which are implemented throughout the organisation structure. In support of the business principles, there is a Group Health, Safety and Environment Policy which requires every Shell Company to manage HSE in a systematic manner.

A copy of the Policy, endorsed and adopted by Shell Australia, is presented in *Figure 7.3*. The policy illustrates the commitment made by the senior management and all staff of Shell to achieve not only compliance with environmental standards set by the Company and by the Australian Commonwealth Government but also to seek continual improvements in HSE performance.

Additionally, Shell's management commitment towards

7

*Figure 7.2 Relationship between the EIS, EPs and HSE-MS*



HSE is reflected by the following:

- Communicating HSE expectations to employees and contractors to drive the process for HSE excellence;
- Prioritising HSE matters on the agenda of meetings, from the Board downwards;
- Demonstrating commitment to implementing the HSE measures and achieve external certification of the system (eg. ISO 14001) by ensuring that the necessary resources, milestones and reviews are allocated with the Business Plan;
- Recognising achievement and holding staff and contractors accountable for knowingly violating HSE standards and procedures;
- Communicating the importance of HSE considerations in business decisions and in communication with stakeholders;
- Demonstrating active personal participation in HSE activities such as training, reward and recognition schemes, industry/contractor workshops, conferences and audits;
- Leading high potential incident investigations;
- Championing HSE activities, such as contractors' HSE workshops and HSE toolbox meetings, champion activities associated with achieving sustainable development;
- Seeking internal and external views on HSE;
- Senior Shell personnel being directly involved in improvement efforts identified from management reviews and audits;
- Director accountability for Group HSE Policy and reporting on the status of such implementation; and
- Providing sufficient resources and training to supervise contractors and their taking accountability for actions of contractors under their control.

### 7.4.2 Adopted Standards for the HSE-MS

The Prelude HSE-MS will be developed to comply with:

- Commonwealth and any relevant State statutory requirements;
- Shell corporate requirements;
- The international standard on environmental management systems ISO 14001; and
- Internationally recognised best practice procedures and protocols including:
  - World Bank/IFC Performance Standard 1 and

Figure 7.3 Shell Health, Safety and Environment Commitment and Policy

# Health, Safety, Security and Environment

Shell in Australia has a HSSE performance we can be proud of. At Shell we commit to:

- pursuing the goal of no harm to people;
- protecting the environment;
- using materials and energy efficiently to provide our products and services;
- developing energy resources, products and services consistent with these aims;
- publicly reporting on our performance;
- playing a leading role in promoting best practice in our industries;
- managing HSSE matters as any other critical business activity;
- promoting a culture in which all Shell employees share this commitment; and
- creating a secure business environment that minimises economic loss and business disruption, safeguarding Shell's people, integrity and reputation.

In this way we aim to earn the confidence of customers, shareholders and society at large, to be a good neighbour and to contribute to sustainable development.

Every Shell company:

- has a systematic approach to HSSE management designed to ensure compliance with the law and to achieve continuous performance improvement;
- sets targets for improvement and measures, appraises and reports performance;
- requires contractors to manage HSSE in line with this policy;
- requires business partners under its operational control to apply this policy and uses its influence to promote it in its other ventures; and
- includes HSSE performance in the appraisal of all employees and rewards accordingly.

Each of us has a right and duty to intervene with unsafe acts and conditions or when activities are not in compliance with this policy.

Russell Caplan
Chairman, Shell Companies in Australia

February 2006

SHELL IN AUSTRALIA

  Guidance Note: Social and Environmental Assessment and Management Systems;
- World Bank/IFC EHS Guidelines for Liquefied Natural Gas Facilities;
- World Bank/IFC EHS Guidelines – Offshore Oil and Gas Development;
- Australian Petroleum Production and Exploration Association Guidelines;
- The Oil and Gas Industry: Operating in Sensitive Environments 2003 – International Petroleum Industry Environmental Conservation Association (IPIECA); and
- UNEPs Environmental Management in Oil and Gas Exploration and Production and the Oil Industry International Explorations and Production Forum (E&P Forum).

The HSE-MS will be audited against the ISO 14001 standard, by an accredited independent third party, to achieve certification to this standard.

### 7.4.3 Environment Plans

The development and approval of activity-specific EPs prior to key stages of the Prelude FLNG Project is a legislative requirement under the *Petroleum (Submerged Lands) (Management of Environment) Regulations 1999*. EPs will detail the implementation of objectives, commitments and practices defined for the project at each progressive stage of project development (ie drilling and installation, commissioning, operations and maintenance, and decommissioning). Each EP will outline specific strategies to avoid, mitigate or reduce potential environmental impacts. The plans will be used to inform the workforce of the monitoring, auditing, reporting and corrective action requirements. The EPs will also identify the roles and responsibilities of key individuals/positions from the company and/or contractor teams.

## 7.5 HSE-MS IMPLEMENTATION AND REVIEW

### 7.5.1 Introduction

Potential impacts arising from the development and operation of the Prelude FLNG Project have been assessed and mitigation and management measures identified. These are detailed in *Chapter 6* of this draft EIS and summarised in *Table 7.2*. Mitigation and management measures will be delivered through the Prelude HSE-MS and the statutory EPs.

### 7.5.2 Responsibilities

#### *Role of the Shell Project Team*

As operator of the Prelude FLNG Project, Shell holds responsibility for the environmental performance of the overall project through all its phases, including the monitoring of contractors' performance. Shell also holds responsibility for:

- reviewing the environment, social and community health management elements of the Engineering, Procurement and Construction (EPC) Contractors' bids;
- reviewing the selected EPC Contractor's HSE plans and procedures; and
- monitoring the performance of the EPC Contractor to ensure that the overall objectives of the HSE-MS and statutory EPs are met.

Shell will provide sufficient and suitably qualified resources to fulfil its management function throughout the life of the Prelude FLNG Project. This will be through the development of an HSE team, which will comprise an HSE manager and advisors with links to specialist technical advisors as appropriate. While the EPC Contractor(s) will be responsible, through their contractual terms, for assuring that the design, procedures, procurement, construction and commissioning adhere with all environmental, socio-economic and health controls and mitigation measures specified in this draft EIS and subsequent statutory EPs, as detailed through the HSE MS, Shell holds ultimate responsibility.

The EPC Contractor(s) will be required to demonstrate to the satisfaction of the Project Team, how compliance with the draft EIS, EPs and the HSE-MS requirements will be achieved through the development of detailed HSE plans, procedures and method statements. The EPC Contractor's HSE plans, procedures and method statements will be submitted for review and approval by Shell and will be the basis for open discussion to promote an appropriate management regime for the project. The EPC Contractor(s) will be required to undertake regular inspections and to provide related reports to the Shell Prelude HSE team, thereby enabling Shell to monitor and evaluate performance against the measures and objectives established in this draft EIS and the statutory EPs. Shell will also undertake regular audits of the EPC Contractor(s) to ensure compliance with agreed objectives and targets - *see Section 7.5.4*.

Shell will lead ongoing consultation and communication with all stakeholders. Part of this engagement process will be focused on encouraging feedback from government and other interest groups on the performance of the project in order to quickly identify and resolve any issues or grievances, should they arise.

Before commencing each of the project phases within Australian jurisdiction, Shell must submit to the Designated Authority (WA Department of Mines and Petroleum (DMP)) an EP for that phase and have it approved. Similarly, Shell will be required to develop and have accepted a safety case for the FLNG facility. NOPSA has responsibility for administering the safety requirements of the *OPGGS Act* and its associated regulations. Before the DMP may grant the 'Consent to Construct and Install', NOPSA must have accepted a Facility Description, a Formal Safety Assessment and those parts of the Safety Management System that relate to construction and installation. A Safety Case must have been accepted by NOPSA for the granting of the 'Consent to Use'.

### 7.5.3 Competence

All personnel required on the project shall be employed on the basis they are competent to do the job. Additionally, all personnel will be given an induction prior to the commencement of the work to ensure that they are aware of their obligations and commitments.

Comprehensive training programs will be developed which will address both administrative and technical environmental management procedures. These programs will be developed and implemented prior to the commencement of each project phase. The programs will be tailored to meet the specific requirements of various roles that employees and contractors undertake for the project.

### 7.5.4 Reporting & Feedback

#### *Shell Expectations*

In accordance with Shell HSE-MS requirements, regular HSE audits will be undertaken by Shell and Shell Corporate auditors.

The HSE-MS will also undergo a process of regular internal audits and external audits which are required by the ISO 14001 certification conditions. Assessing the operational aspects and monitoring, audits will investigate compliance with agreed objectives and targets, the effectiveness of the HSE-MS and its implementation. The HSE-MS will therefore be subject to ongoing review and development to ensure that it remains appropriate for all aspects of the project.

All audit findings will be reviewed by the Project Manager and HSE Manager and, where corrective actions are deemed necessary, specific plans (with designated responsibility and timing) will be developed aimed at achieving continuous improvement in the environmental performance of the facility.

Corporate Environmental Performance Targets are set by Shell Group and are approved by the HSE Committee. The targets are cascaded down to the Business. These targets are aimed at driving continuous improvements in performance. Reporting against environment parameters identified in the Shell Group Performance Monitoring and Reporting standard will take place each quarter using the Shell Data Loader. This data is used as the basis for an annual Shell Group external HSE report (Shell Sustainability Report), which is publicly and externally reported.

### 7.5.5 Incident Investigation and Reporting

#### *Shell Requirements*

Shell requires that all environmental incidents are reported and investigated using Shell's incident reporting and investigation procedures. Contractors will also be required to report incidents to the Prelude HSE Manager in accordance with the Shell incident reporting procedure.

### *Reporting under the Petroleum Legislation*

**Reporting Arrangements**

Shell is required to report performance to the DMP and as such the HSE-MS and the EPs will include arrangements for:

- recording, monitoring and reporting information about the activity (including information required to be recorded under the *OPGGS Act*, the regulations and any other environmental legislation applying to the activity) sufficient to enable the DMP to determine whether the environmental performance objectives and standards in the EPs are met; and
- reporting at intervals agreed with the DMP, but not less often than annually (*Clause 15, Petroleum (Submerged Lands) Management of Safety Offshore Facilities Regulations 1996*).

**Reportable Incidents**

Under legislation *(Petroleum (Submerged Lands) (Management of Safety Offshore Facilities) Regulations 1996* and the *P(SL)A* Specific Requirements as to Offshore Petroleum Exploration and Production), the DMP must be notified of all Reportable Incidents.

Reportable Incidents are defined as:

- "an incident mentioned in the environment plan for the activity that has caused, or has the potential to result in, moderate to catastrophic environmental consequences as categorised by the risk assessment process undertaken as part of the preparation of the environmental plan"; and
- "an escape or discharge into the area of more than 80L of petroleum (not being a discharge into the sea of petroleum in a mixture of petroleum and water where the concentration of petroleum in a mixture of petroleum and water is not greater than 50 mg/L)."

DMP will be notified of and provided written reports of reportable incidents in accordance with Regulations 26 and 26A of the *Petroleum (Submerged Lands) (Management of Safety Offshore Facilities) Regulations 1996*. The written report must contain:

- all material facts and circumstances concerning the reportable incident that the operator knows or is able, by reasonable search or enquiry, to find out;
- any action taken to avoid or mitigate any adverse environment impacts of the reportable incident; and
- the corrective action that has been taken, or is proposed to be taken, to prevent a similar reportable incident.

**Recordable Incidents**

A Recordable Incident for an operator of petroleum activity, as defined in the *Petroleum (Submerged Lands) (Management of Safety Offshore Facilities) Regulations 1996*, is an incident arising from the activity that:

- breaches a performance objective or standard in the environment plan that applies to the activity; and
- is not a Reportable Incident.

DMP will be notified of all Recordable Incidents, according to the requirements of Regulation 26B of the *Petroleum (Submerged Lands) (Management of Safety Offshore Facilities) Regulations 1996*.

The report will comprise:

- a record of all Recordable Incidents that occurred during the calendar month;
- all material facts and circumstances concerning the Recordable Incidents that the operator knows or is able, by reasonable search or enquiry, to find out;
- any action taken to avoid or mitigate any adverse environment impacts of the Recordable Incidents; and
- the corrective action that has been taken, or is proposed to be taken, to prevent similar Recordable Incidents.

The Prelude HSE Manager will report on a monthly basis to DMP.

### *Spill Reporting Obligations*

Other key legislative drivers for reporting incidents include those listed in *Table 7.3*. Reporting of accidents and dangerous occurrences as defined by the *Petroleum (Submerged Lands) (Management of Safety Offshore Facilities) Regulations 1996* will be in accordance with Clause 4b of those regulations.

### 7.5.6 Records

The following records will be kept through the life of the Prelude FLNG Project:

*Table 7.3 Oil Spill Reporting Requirements*

| Quantity | Jurisdiction | Authority | Legislation |
|---|---|---|---|
| All discharges not in accordance with MARPOL | WA State Waters | DPI | *Pollution of Waters by Oil and Noxious Substances Act 1987* |
| All discharges not in accordance with MARPOL | Commonwealth waters | AMSA | *Prevention of Pollution by Ships 1983* |
| Spills >80 litres or uncontrolled vapour releases >1kg | Commonwealth/ State waters | NOPSA | *P(SL) (Management of Safety on Offshore Facilities) Regulations 1996* |
| Spills >80 litres | State waters | DMP | *Petroleum (Submerged Lands) Act 1982* |
| All spills | Port | Port Authority | *Port Authority Act 1999* |

- attendance of employees and contractors at the HSE induction;
- occurrence of any environmental incidents and any actions undertaken to control environmental impact as a result of the incident;
- reports of any Regulatory Authority inspection and any actions undertaken to rectify any issues raised by either audit or inspection;
- internal and external audit reports;
- non-conformance with Environmental Performance Objectives and Activities;
- waste log and manifests;
- effluent discharge log;
- fuel use and emission calculations;
- GHG emissions;
- upset or non-routine conditions; and
- marine notices and broadcasts.

## 7.6 ENVIRONMENTAL MONITORING FRAMEWORK

Monitoring is required in order to demonstrate compliance with legal limits and Shell's project requirements (compliance monitoring) established in this draft EIS. Monitoring will also provide verification of the overall design and effectiveness of the implemented control measures. The key objectives of Shell's proposed monitoring activities are as follows:

- to monitor discharges and emissions to ensure compliance with relevant standards and Shell's environmental objectives;
- to provide an early indication that any of the environmental control measures or practices are failing to achieve acceptable standards;
- to determine whether environmental changes are attributable to the project activities, other activities or as a result of natural variation; and
- to provide a basis for continuous review and improvement to the operational monitoring program.

In developing the monitoring program, the following considerations and strategies have been applied:

- statutory requirements;
- internationally accepted industry best practice;
- responsiveness to the detection of environmental changes/ trends;
- logistically practical; and
- cost effective.

*Table 7.4* outlines the recommended monitoring framework during:

- drilling and installation; and
- commissioning and operational/maintenance phases of the project.

This framework will be further developed prior to initiation of the above phases as part of the statutory EPs and HSE-MS, and will be updated throughout the project lifecycle as appropriate. Monitoring requirements for decommissioning will be developed at a later stage.

In addition to the routine monitoring outlined in *Table 7.4*, Shell will develop and undertake the environmental studies listed below within the first five years of operation, to confirm the impact assessments made within this draft EIS and to contribute to the knowledge base for future FLNG developments:

- Underwater Noise monitoring will be undertaken to expand on the database of whale activity in the project area and measure noise levels generated by the FLNG Facility and during LNG/LPG tanker berthing and offloading.
- Cooling Water dilution and chemical composition will be measured and compared against the results of the modelling presented in this draft EIS.

- An identification guide and monitoring program will be developed to document the composition and abundance of birds, including listed species, which land on or frequent the area around the FLNG facility.

## 7.7 GREENHOUSE GAS MANAGEMENT PLAN

The Greenhouse Gas Management Plan will incorporate and co-ordinate the following project requirements; the Shell Greenhouse Gas Management Standard, project commitments and Australian Federal Government reporting requirements.

This will include the management, measurement and recording of:
- energy use;
- greenhouse gas emissions;
- transport activities; and
- waste management.

### *Reduction opportunities to be considered*

Opportunities will continue to be explored during the FEED design phase to reduce GHG emissions during the operational phase of the Prelude FLNG Project.

Final project design is still ongoing and therefore not all reduction opportunities have been quantified but the following are being considered as part of the FLNG design process:
- studies to minimise flaring during cold and warm start-ups;
- flow assurance studies to avoid need for de-pressuring flowlines in a shutdown;
- availability/reliability studies to maximise run lengths with optimum efficiency operation and reduce trips and losses to flare; and
- maintenance philosophy to balance maintenance onboard the FLNG facility versus the onshore Maintenance Workshop, trying to optimise plant availability and minimise the number of supply vessel movements.

Geosequestration of the Prelude reservoir $CO_2$ has significant cost and technical uncertainties. Therefore, reservoir $CO_2$ will be safely vented once it has been separated from the feedgas (see *Section 4.4.2*). Nonetheless, Shell believes geosequestration will be a key technology to combat climate change and will continue to investigate other opportunities to implement Carbon Capture and Storage.

## 7.8 SOCIAL COMMITMENTS AND ENGAGEMENT

### 7.8.1 Social and Health Commitments

Shell reinforces health and safety as a core value. Emphasis is placed upon encouraging a safety culture in the workplace, by setting clear expectations, improving safety training and encouraging people at all levels to be leaders in safety. Shell supplements engineering driven safety procedures with behavioural safety programs. This involves staff in the development of plans and actions to further improve safety.

Shell is developing an Australian Industry Participation Plan that aims to maximise opportunities for Australian industry to benefit from the Prelude FLNG Project. By providing full, fair and reasonable opportunities for local companies to compete on price, performance and suitability, local benefits of the project can be maximised. Engagement with large projects such as the Prelude FLNG Project can improve the capacity of local businesses to compete globally.

Shell invests in the communities where it has businesses. Shell's social investment program targets investments that assist community organisations to achieve their goals, with a focus on health, education and the environment. Shell recently entered into a three year agreement with *Indigenous Community Volunteers* to assist their expansion into the Kimberley. As the Prelude FLNG Project proceeds, Shell will be evaluating opportunities to work with and invest in local communities.

### 7.8.2 Stakeholder Engagement

Stakeholder engagement is a core Shell policy and will continue throughout the development and operation of the Prelude FLNG Project, informing and guiding development planning. There will be focused briefing programs in the lead-up to all project milestones, so that stakeholders are aware of and can comment on proposed activities. Shell's Stakeholder Engagement Plan for Prelude will be regularly

*Table 7.4* *Monitoring Framework*

| Aspect | Source | Parameters | Monitoring Frequency | Reporting | Responsible Party |
|---|---|---|---|---|---|
| Drilling/ Installation | | | | | |
| Waste | Hazardous and non-hazardous wastes stored and transported for onshore disposal | • *Inventory:*<br>- Quantity of waste generation<br>- Quantity of waste disposal<br>- Location of waste disposal site<br>• *Waste Consignment Notes* | Internal: continuously<br>External: As per legal obligations | Internal | Shell/ Contractors |
| Marine Environment | Unplanned Event resulting in hydrocarbon or non-hydrocarbon spill | • Number and volume of accidental spills:<br>- As per Shell corporate requirements<br>- If over 10 t, report to AMSA<br>- If over 80 L, report to NOPSA<br>- If consequence of spill categorised as moderate or higher on risk assessment in EP, report to DMP.<br>• Root cause of non-routine events, spills and accidents | As required | Internal<br>External to relevant agencies<br>Refer *Section 7.5.5* | Shell |
| Marine Environment | Discharge of Drilling wastes | • Type of drilling fluids used<br>• Quantity of WBM and SBM discharged to sea<br>• Efficiency of solids control system<br>• Quantity of bulk WBM and SBM and cement discharged to sea<br>• Quantity of SBM returned to shore for disposal<br>• Quantity and type of drilling chemicals<br>• Lithology and estimated volume of cuttings generated | Continuously during drilling | Internal | Shell |
| Marine Environment | Support vessels | • Observation of cetaceans numbers and locations in vicinity of vessels during transit<br>• Record behaviours | During transit | Whale and Dolphin Sighting Report to DEWHA via email to Cet_sightings@deh.gov.au | Shell/Contractors |
| Air emissions and GHG | Generators on MODU rig and other emission sources | • Inventory of fuel used and associated emissions | Daily (calculation) | Internal<br>Annual National Greenhouse and Energy Reporting (NGER) and Carbon Pollution Reduction Scheme (CPRS) reporting | MODU Contractor |

*Table 7.4 Monitoring Framework (continued)*

| Aspect | Source | Parameters | Monitoring Frequency | Reporting | Responsible Party |
|---|---|---|---|---|---|
| Commissioning/ Operation/ Maintenance | | | | | |
| Waste | Hazardous and non-hazardous wastes stored and transported for onshore disposal | • *Inventory:<br>- Quantity of waste generation<br>- Quantity of waste disposal<br>- Location of waste disposal site<br>• *Waste consignment Notes<br>* As a minimum, monitoring and recording of hazardous/ scheduled waste must be in accordance with Western Australian legislative requirements | Internal: continuously<br>External: As per legal obligations | Internal | Shell/Contractors |
| Marine Environment | Unplanned Event resulting in hydrocarbon or non-hydrocarbon spill | • Number and volume of accidental spills:<br>- As per Shell corporate requirements<br>- If over 10 t, report to AMSA<br>- If over 80 L, report to NOPSA<br>- If consequence of spill categorised as moderate or higher on risk assessment in EP, report to DMP.<br>• Root cause of non-routine events, spills and accidents | Continuously | Internal<br>External to relevant agencies<br>Refer *Section 7.5.5* | Shell |
| Marine Environment | Release of subsea fluid controls | • Type of fluid used<br>• Inventory calculation to understand period volume lost to marine environment | Continuously, via product consumption records | Internal | Shell |
| Marine Environment | Liquid discharges (PFW, cooling water, desal brine, meg brine, sewage/ grey water) | • Volumes discharged<br>• In-line monitoring of temperature, oil in water and chlorine to ensure average daily discharge does not exceed limits<br>• Performance of monitoring equipment associated with PFW discharges (Clause 29A P*(SL) Management of Environment Regulations* | Continuously, via product consumption records | As agreed with DMP, likely to be monthly | Shell |
| Air emissions and GHG | Operation emissions | • Inventory of fuel used and associated emissions<br>• Inventory of production to calculate $CO_2$ vented | Daily (calculation) | Internal<br>Annual NGER and CPRS reporting obligations | Shell |
| | None routine events | • Flaring duration<br>• Calculation of emissions through volume of product/ duration of flaring | As required | As agreed with DMP, likely to be monthly | Shell |

reviewed and updated, and targeted engagement plans will be developed around specific project milestones or issues.

Shell prefers to engage directly with stakeholders but will also include new tools such as a Prelude FLNG Project website in 2009. The website will not only provide the latest information on the project for the public but will also alert contractors to opportunities as they arise. To complement the website, a series of supplier workshops to outline potential opportunities are planned.

## 7.9 FRAMEWORK EMERGENCY RESPONSE PLANS

### 7.9.1 Introduction

An Emergency Response Plan will be developed to manage unplanned events and emergencies. The plan will include procedures to deal with the following events (as a minimum):

- hydrocarbon spills (detail provided in *Section 7.9.2* below);
- chemical spills;
- damage to wells, pipes, flowlines and other subsurface, surface or suspended structures;
- fires and explosions;
- security issues or terrorism;
- medical evacuation;
- extreme weather conditions; and
- traffic or transport accidents.

The Emergency Response Plan will follow industry best practice, legislative requirements and Shell standards and procedures and will satisfy the following key requirements:

- it receives the approval of the relevant authorities;
- staff are trained in its activation and implementation;
- it is backed-up by the necessary resources, equipment and facilities;
- it is known to external agencies that may be called upon to respond; and
- drills are conducted and evaluated.

### 7.9.2 Hydrocarbon Spill Response

The Prelude FLNG facility hydrocarbons inventory relevant to spill response planning comprises condensate, diesel and aviation fuel. It does not include LNG and LPG as these refrigerated products evaporate quickly and completely during a spill event.

Shell has a range of controls in place to reduce the risk of a hydrocarbon spill and to respond effectively in the event of a spill. These are based on standard industry practice in preventing any unplanned discharge of hydrocarbons. Examples of operational prevention measures are:

- quick disconnect couplings for transfer hoses;
- storage tanks fitted with level gauges and high and low level alarms;
- overflow lines from storage tanks typically discharge to the drains system;
- in place containment/recovery systems; and
- real-time monitoring of transfer volumes and loading rates.

Other controls take the form of procedural measures such as:

- training and protocols;
- close visual monitoring of product/fuel transfer operations;
- no product transfer outside defined weather limits; and
- regular maintenance checks, including testing and changeover of floating hoses used for condensate transfer.

In addition to these operational mitigation measures, Shell manages hydrocarbon loss of containment through comprehensive Spill Contingency Planning arrangements.

#### *Oil Spill Contingency Plans*

Under the Commonwealth *Petroleum (Submerged Lands) (Management of the Environment) Regulations 1999*, an Oil Spill Contingency Plans (OSCP) is required as part of the proposal's Implementation Strategy. In the event of a hydrocarbon spill from petroleum operations affecting the environment, Shell is required to notify the Government and to implement Shell's OSCP.

Additionally, Shell is party to the following National, State and Industry arrangements for the prevention of, and response to, uncontrolled releases of hydrocarbons at sea.

- The National Plan to combat Pollution of the Sea by Oil and Noxious Substances (NATPLAN). NATPLAN has been developed by Commonwealth and State governments and Industry. It is administered by the Australian Maritime Safety Authority (AMSA). This plan combines the efforts and resources of the Commonwealth and State Governments and the Oil/Gas and Shipping Industry to combat oil spills in the marine environment. NATPLAN provides stock piles of oil spill response equipment around Australia in collaboration with State and Industry bodies. Western Australia is currently well provisioned with two of the largest stockpiles in Dampier and Fremantle and a more recent relocation of resources to the Port of Broome to strengthen industry resources in the Browse Basin.
- West Plan – Marine Oil Pollution (WestPlan-MOP). Supporting NATPLAN is the WestPlan-MOP, which details the arrangements between the WA State government agencies and industry to combat marine oil pollution within WA. It prescribes responsibilities and procedures, and provides a basis for coordination of resources for responding to spills offshore. The Western Australian NATPLAN State Committee and the operational arm of this committee, the Executive Response Group, administer WestPlan-MOP.
- AMOSPlan. AMOSPlan is managed by the Australian Marine Oil Spill Centre (AMOSC). The AMOSPlan will be activated by Shell when the response to an oil spill incident is regarded by Shell to be requiring resources beyond those of the company itself. This group coordinates the participation of the oil industry in NATPLAN. AMOSC's role includes the:
    - provision of oil spill response personnel and equipment on 24 hour stand-by;
    - provision of oil spill training services at the training centre in Geelong; and
    - administration of the oil industry mutual aid arrangements where industry oil spill response resources are available to NATPLAN, through AMOSC.

### *Spill Categories*

For the purposes of response planning, spills are divided into three categories depending on the spill size. The categories also act as triggers for the activation of the National Plan, WestPlan-MOP, AMOSPlan and Shell's own response plan (*Table 7.5*).

*Table 7.5 Tiered Response and Escalation Triggers.*

| | Tier 1 | Tier 2 | Tier 3 |
|---|---|---|---|
| Spill Size | <10 tonnes | 10-1,000 tonnes | >1,000 tonnes |
| Incident Control | Shell responsible for the management of the oil spill. | Request for assistance will be made directly to AMOSC. | Assistance will be requested from AMSA and NATPLAN. |
| Potential Impact | Low | Moderate | High |
| Indicative Resources Mobilised | | | |
| Shell | ■ | ■ | ■ |
| AMOSC/ Industry | | ■ | ■ |
| WA State | | ■ | ■ |
| AMSA | | ■ | ■ |
| International | | | ■ |

### *Training and Exercises*

As part of Shell's spill response preparedness, regular training will be conducted with appropriate staff. Exercises are a regular facet of Shell's spill response either through notification exercises involving regulators and other industry bodies, or through regular desktop emergency scenarios. Shell staff have participated in State and National exercises and maintain an ongoing commitment to manage the response to oil spills.

## 7.9.3 Cyclones

The operations philosophy during adverse weather is similar to other operators in the area. Key cyclone design and operational controls considered for the FLNG facility during the operations phase are described below.

- The FLNG facility is not self-propelled and has been designed so that is does not need to be decoupled from the turret mooring system during a cyclonic event. The turret structure and its associated mooring chains and suction anchors have been designed to resist loads due to hull deflections, mooring loads and direct slamming loads that may be encountered in extreme 10,000 year weather conditions.
- Major maintenance campaigns and equipment overhauls requiring large numbers of additional

personnel to be accommodated on the FLNG facility will be preferentially undertaken outside the cyclone season.

- The FLNG facility will have clearly defined weather operational criteria. On the approach of cyclonic weather, the core production crew will remain on board but all non-essential personnel will be down-manned in accordance with established "Offshore Cyclone Down-manning and Up-manning Coordination" procedures. All loading and unloading operations will be discontinued once the weather operational limits are reached and the vessels sent away to a safe location. The FLNG will continue production until such time that wind speeds above 70 knots are predicted to reach the facility within the time required to shut-in the facility. This is known as the critical path duration.

## 7.10 ENVIRONMENTAL OFFSETS

Environmental offsets are actions taken outside the area of influence of a particular project that compensate for potentially major or critical impacts that arise from the development and operation of the project. Environmental offsets provide an opportunity to achieve long term conservation outcomes while providing flexibility to project proponents who wish to undertake activities that may have environmental impacts.

*Section 5.9* of the EIS guidelines issued by DEWHA for the Prelude FLNG Project points out that environmental offsets may be appropriate when they:

- are necessary or convenient to protect or repair impacts to a protected matter;
- relate specifically to the matter (for example, species) being impacted; and
- seek to ensure that the health, diversity and productivity of the environment is maintained or enhanced.

This draft EIS demonstrates that there are no significant environmental impacts predicted to arise from the Prelude FLNG Project and that FLNG has a smaller environmental footprint than the alternative LNG development scenarios as outlined in *Section 4.3.1*. As such, environmental offsets are not required for the project.

## 7.11 CONCLUSION

Shell is committed to protecting the environment during all stages of the Prelude FLNG Project. To assist in meeting this commitment a HSE-MS will be developed in accordance with Shell Company requirements, which will capture legislative requirements, commitments developed in this draft EIS as well as commitments made in the EPs required under the *OPGGS Act*. Monitoring will be carried out in order to demonstrate compliance and will be used to provide verification of the overall design and effectiveness of the implemented control measures. Adequate resources will be committed to the HSE-MS and contractors will be contractually obliged to meet the requirements of the HSE-MS.

# 8 CONCLUSION

Shell is proposing to develop and export the gas and condensate from the Prelude field within title area WA-371-P, which is located in Commonwealth waters, 200 km offshore Western Australia in a water depth of about 250 m. Shell examined a range of options to develop the Prelude field including 'do nothing', a traditional onshore Liquefied Natural Gas (LNG) plant at a number of proposed locations and a technically innovative offshore Floating LNG (FLNG) solution. A FLNG facility was determined to be the most appropriate. Compared to a conventional onshore LNG development, FLNG notably reduces several potential environmental impacts by restricting the disturbance area to within the immediate location of the remote gas field and removes the need for construction and operation of a subsea pipeline, an onshore processing facility and export jetties with the associated dredging.

This draft EIS has been prepared in accordance with the requirements of the *EPBC Act* (1999), including the principles of ecologically sustainable development, and the 'Guidelines For An Environmental Impact Statement For The Proposed Prelude Floating Liquefied Natural Gas Facility Western Australia (EPBC 2008/4146).'

Particular focus has been placed upon those aspects which relate to the three controlling provisions under which the project was identified as a controlled action:

- Sections 18 and 18A (Listed threatened species and communities);
- Sections 20 and 20A (Listed migratory species); and
- Sections 23 and 24A (Commonwealth marine environment).

The project area is remote and in deep water. The environment of the project area is typical of the ocean on Australia's North West Shelf and the sea floor contains no significant features. The nearest potential sensitive environment is Browse Island, located some 40 km to the SSE, and the Humpback Whale migration routes and calving grounds off the Kimberley coast are located some 200 km south of the project area.

Potential impacts from noise, light, emissions and spills have been investigated and analysed, using technical assessment and modelling studies where appropriate. All potential impacts which could arise from the Prelude FLNG Project were assessed as a minor risk with the exception of:

- disturbance to the seabed through the establishment of subsea infrastructure and drill cutting discharge during the construction phase is assessed as a moderate negative impact. The potential impacts associated with these activities will be managed to 'As Low As Reasonably Practicable' by the application of management measures outlined in this draft EIS;
- greenhouse gas emissions assessed in an Australian context as a moderate negative impact during the operations phase. The FLNG facility is 15-25% less $CO_2$ intensive than a conventional onshore LNG plant but has a carbon footprint of 2.3 million tonnes per year of GHG gases emitted at full throughput (compared to

a total of 576 million tonnes per year for Australia); and
- economic impacts which were assessed as a moderate positive impact. The project could directly create more than 500 Australian jobs during construction and 320 direct jobs for 25 years during operations. Most of the operational jobs will be held by FIFO workers on the FLNG facility. The project is also expected to employ support crews and logistics personnel in Broome and/or Darwin. Indirectly, the project can be expected to support employment in local small business and revenue for local merchants and service suppliers.

A management framework has been presented in this draft EIS, centred on Shell's Health Safety and Environment Management System (HSE-MS). A Prelude specific HSE-MS will be developed and along with the Environment Plans required under the *Petroleum (Submerged Lands) (Management of Environment) Regulations 1999*, will operationalise procedures and practices to ensure site construction, commissioning, operation and eventually decommissioning will all be executed in a manner that ensures the ongoing effectiveness of the mitigation and management measures presented in this draft EIS, and that the predicted low impact will be achieved.

In summary, the major conclusions of the draft EIS are:
- the drilling of development wells, installation of seabed infrastructure, and routine operations of a FLNG facility do not represent a significant risk to any listed or migratory species, threatened ecological communities, or the marine, socio-economic or cultural environment; and
- in the unlikely event that a non-routine incident occurs, modelling has illustrated that under worst case conditions the potential environmental impacts will be minor.

Overall, it is concluded that by implementing the design features and the mitigation measures, including the environmental, socio-economic and health management measures described within this draft EIS, the Prelude FLNG Project will have no significant impacts upon the environment or upon listed threatened species and communities, listed migratory species or upon the Commonwealth marine environment, as defined under the *EPBC Act (1999)*.

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# INFORMATION SOURCES

This report has been prepared in conjunction with an independent consultant, Environmental Resources Management (ERM).

All external reports produced for this draft EIS have been reviewed for accuracy and content by the contracted external agencies responsible for the reports, prior to issuing these reports to Shell. Shell personnel with relevant expertise have then reviewed the documents prior to using the information in this report.

External reports used in this report include:

| Name of Report | Author | Date |
|---|---|---|
| Ambient sea noise sources from near Browse Island, Kimberley, 2006-2008. (Underwater Noise Baseline Report) | Centre for Marine Science and Technology – Curtin University | December 2008 |
| Prediction of underwater noise associated with the proposed Shell Prelude development Floating Liquefied Natural Gas facility. (Underwater Noise Modelling Report) | Centre for Marine Science and Technology – Curtin University | December 2008 |
| Prelude Marine Baseline Survey Report | Environmental Resources Management | December 2008 |
| A description of cetacean distribution and abundance in the Scott Reef/ Browse Basin development areas during the Austral winter of 2008 | Centre for Whale Research (WA) Inc. | March 2009 |
| Cooling Water Dispersion Prelude | Deltares | January 2009 |
| Light Impact Assessment Draft Report | Environmental Resources Management | April 2009 |
| Hydrodynamic and Water Quality Modelling Report | Environmental Resources Management | March 2009 |
| Prelude FLNG Project Economic Impact Assessment | Environmental Resources Management | June 2009 |

Literature resources used in this report are cited in the relevant References section.

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# APPENDIX A
## *DEWHA Guidelines*

**Australian Government**

**Department of the Environment, Water, Heritage and the Arts**

***Environment Protection and Biodiversity Conservation Act 1999***

# GUIDELINES FOR AN ENVIRONMENTAL IMPACT STATEMENT FOR THE PROPOSED PRELUDE FLOATING LIQUEFIED NATURAL GAS FACILITY
# WESTERN AUSTRALIA

## SHELL DEVELOPMENT (AUSTRALIA) PTY LTD
## (EPBC 2008/4146)

**July 2008**

# 1 PREAMBLE

Shell Development (Australia) Pty Ltd (hereafter referred to as Shell) proposes to develop and locate a floating Liquefied Natural Gas (LNG) Facility in the Prelude Gas field in Western Australia. The gas field is approximately 450 km north-north east of Broome, in petroleum permits WA-371-P. The operating life of the proposed facilities is expected to be greater than 25 years.

The components of the floating LNG facility will consist of two main components, the upstream facilities and the Floating LNG facility, as illustrated in **Figure 1**. Within those areas, the exact positioning and type of associated infrastructure will be decided when the final location of the facility is determined.

The major components of the upstream facilities are expected to include:

- Subsea wells
- Subsea or platform based wellheads
- Steel tubed umbilicals

The major components of the Floating LNG facility include:

- Offshore processing facilities
- Storage for LNG LPG and condensate
- Product loading facilities
- Integrated power plant
- Refrigerant compressors
- Effluent treatment plant
- Turret mooring for weathervaning

A Referral under the EPBC Act was submitted for the upstream development proposal on 8th April 2008. The assessment process commenced following a determination on 7 May 2008 by the delegate of the Commonwealth Minister for the Environment, Heritage and the Arts that the proposed development was a controlled action under the provisions of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). On the same day, the delegate of the Minister determined that an Environmental Impact Statement (EIS) would be required for the proposal. The controlling provisions for the action under the EPBC Act are:

- Sections 18 and 18A (Listed threatened species and communities);
- Sections 20 and 20A (Listed migratory species); and
- Sections 23 and 24A (Commonwealth Marine environment).

The Guidelines identifies the issues the Government expects the proponent to address in the EIS.

# 2 ENVIRONMENTAL ASSESSMENT AND APPROVAL PROCESS

## 2.1 BACKGROUND

The proposed development requires assessment under Commonwealth legislation. On 7 May 2008, the delegate of the Commonwealth Minister for the Environment, Heritage and the Arts determined that the proposal was a controlled action under the provisions of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The controlling provisions under the EPBC Act are listed threatened species, migratory species, and Commonwealth marine area. On the same day, the delegate also determined that an Environmental Impact Statement (EIS) would be required for the proposal.

## 2.2 PURPOSE OF GUIDELINES / ISSUES PAPER

The purpose of the Guidelines / Issues Paper is to:

- communicate to the relevant stakeholders the Government's guidelines for the preparation of an EIS;
- obtain input on issues relating to the proposed floating LNG facility;
- enable the Commonwealth to consider that input when developing the Final Guidelines.

This document is intended to set the scope of environmental, social, and economic studies required in the EIS to allow for an assessment and decision on the appropriateness of the Prelude Floating LNG facility.

## 2.3 OPPORTUNITIES FOR PUBLIC INPUT

There are a number of opportunities for public input throughout the environmental impact assessment process.

The following are statutory requirements for public input:

- when the Project EPBC Act Referral was lodged on 8 April 2008 to the Commonwealth Department of the Environment, Water, Heritage and the Arts (Commonwealth DEWHA) and placed on the Commonwealth DEWHA web site;
- during the period for public comment when the Draft EIS has been completed and submitted to the Commonwealth Government.

In addition to the above statutory requirements, the proponent may seek to engage the community in consultation throughout the development of the EIS. The nature and level of this engagement is at the discretion of the proponent.

# 3 DESCRIPTION OF THE PROJECT

It is proposed that a floating LNG facility be located over the Prelude gas field which is situated within Petroleum Permit Area WA-371-P in the northern Browse Basin. The floating LNG facility will be purpose built to provide a technically innovative solution to developing a small gas field located far offshore. The exact location of the proposed floating LNG facility is yet to be determined but will be located within WA-371-P in water depth of 250m. The floating LNG facility is expected to be anchored at a radius of approximately 2-5km from either a well head platform or a subsea drilling centre. All processing will be carried out in the facility and the products will be transported by LNG, LPG and oil tankers.

## 3.1 THE PROPOSED PROJECT AREA

The Prelude gas field is located in the northern Browse basin approximately 450km north-northeast of Broome off Western Australia. The Prelude gas field is located in a water depth of between 200m and 250m. The permit area has little sea floor topography such as sea canyons or carbonate mounds. The approximate development footprint for the Notional Areas (dependent on final appraisal and engineering feasibility studies) are as follows;

- Floating LNG facility with a length of 480m and a width of 70-80m;
- Turret;
- Subsea wells; and
- Flowlines and flexible risers.

## 3.2 DESCRIPTION OF PROPOSED ACTIVITIES

*Drilling Wells*

Shell proposes to drill subsea wells prior to installation of the subsea facilities. Wellhead platform wells can only be drilled once a wellhead platform is installed. Two options will be explored for the wellhead platform;

- A piled steel jacket wellhead platform launched from an installation barge and lowered into place on the seabed and then secured using piles.
- A hybrid concept wellhead platform, with a concrete base floated to the location and lowered into place and allowed to settle for an extended time period, followed by a steel tower launched from an installation barge and lowered into place on the concrete base and secured by grouted connections.

Shell proposes to install the majority of the subsea facilities prior to the arrival of the facility into the field. Specialised installation vessels are expected to be used in installing the subsea flowlines, umbilicals and flexible risers. Crane vessels will also be used to install the subsea manifolds. The wells, subsea system, flowlines and umbilicals will be hooked up and connected using a subsea construction vessel. The umbilicals will require the assistance of divers to install the turret/umbilical latching interface.

*Installation of floating and fixed facilities*

The floating LNG facility will be towed from an overseas integration yard by tugs to its location within the Prelude gas field. The facility will be moored to the seabed by four suction pile anchor groupings equally spaced, with multiple anchor lines per grouping. This will be subject to further geotechnical investigation prior to the final selection and design of the anchoring system.

*Subsea and pipeline installation*

Once the floating LNG facility has been moored on location, the flexible risers and subsea umbilicals will be installed. Pressure testing, pre-commissioning and commissioning of the overall production system from the wells through to and including the facility will then be conducted from the facility.

*Commissioning*

Umbilical commissioning will displace storage fluid with a buffer, and the buffer with the final chemical to make it ready for startup. Displacement of the storage, buffer and small amounts of system chemicals will be put into the flowline and hence back to the Floating LNG facility for handling.

*Operations*

The facility is anticipated to operate for at least 25 years. The facility will be operated from the central control room and will include: start-up, ramp-up and shut down of individual wells. The well-streams will be injected with chemicals for management of hydrates and wax. Maintenance will consist of monitoring of the pressure, temperature and flow rates from individual wells. The wells will be tested and pigging operation in the flowlines will be carried out to scour and run internal checks on the integrity of the line.

Shell anticipates that approximately 270 personnel aboard the floating LNG facility will carry out operations, maintenance and/or provide support functions. In addition to the personnel staff another 200 day staff located ashore locally and/or in Perth will be required to provide other technical and administrative support. Supplies to, and wastes from the facility to the onshore supply base will be transported via purpose designed supply craft. Personnel will be transported to and from the facility by helicopter and/or fast ferry.

A certain amount of in-situ maintenance and equipment cleaning capability will be incorporated into the facilities on-board the facility. Shell has proposed to provide additional accommodation on the facility and have suggested the use of a visiting maintenance flotel for both scheduled and unscheduled maintenance events.

Emissions from the operation of the facility will be primarily related to turbine exhaust emissions and waste water. Waste waters generated will include, process waste water, storm water and sewage. The majority of these waste waters will be treated and then disposed of in deep water locations. The facility will also release up to 60,000 $m^3$ of cooling water per hour which will be treated with sodium hypochlorite and heated through use. Non-putrescible solid wastes will be returned to the mainland for subsequent disposal at suitable facilities.

*Decommissioning*

Shell states that at the end of the facility life, the facilities will be fully decommissioned, in accordance with all relevant national legislation and the terms of the environmental approvals set out for the project.

## 3.3 TIMEFRAME

Shell has stated that the proposed project life of the facility is approximately 25 years. The Prelude gas field is proposed to be abandoned in 2037.

# 4 INFORMATION AND ADVICE RELATED TO THE PREPARATION OF THE ENVIRONMENTAL IMPACT STATEMENT

## 4.1 THE OBJECTIVES OF AN ENVIRONMENTAL IMPACT STATEMENT

Environmental impact assessment depends on adequately defining those elements of the environment that may be affected by a proposed development, and on identifying the significance, risks and consequences of the potential impacts of the proposal at a local, regional and national level. The EIS will be a significant source of information on which the public and government decision makers will assess the potential environmental impacts of the proposal.

It is expected that additional ecological work may have to be undertaken to provide sufficient information for the EIS. The nature and level of investigations should be related to the likely extent and gravity of potential impacts (including worse case scenarios). All potentially significant impacts of the proposal on the environment are to be investigated an analysed, and commitments to mitigate any adverse impacts are to be detailed in the EIS.

This document provides guidelines (or terms of reference) for the drafting of the EIS based on the formal requirements for the contents of a EIS provided in Section 97 of the EPBC Act and Schedule 4 of the EPBC Act Regulations 2000 (**Attachment 1**).

In preparing the EIS the proponent should bear in mind the following aims of the EIS and public review process:

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

The proponent should ensure that the EIS discusses compliance with the objectives of the Act and the principles of Ecologically Sustainable Development as set out in the EPBC Act (**Attachment 2**).

The draft EIS prepared by the proponent must be approved for publication by the Minister prior to it being published in accordance with the Regulations. An invitation for anyone to give the proponent comments relating to the draft report within the period specified must also be published. After the period for comment, the proponent must take account of the comments received in finalising the EIS, which is then provided to the Minister. An assessment report is then prepared by the Department of Environment, Water, Heritage and the Arts. Following this, in accordance with Part 9, Division 1 of the EPBC Act, the Minister will decide whether to approve the proposal and attach any conditions required.

It is the responsibility of the proponent preparing the EIS to identify and address, as fully as possible, all matters relevant to this proposal and its potential impacts.

The EIS should provide a description of the existing environment in the area and of the operations proposed for this proposal. All potentially significant impacts on the environment are to be investigated and analysed. The EIS should present an evaluation of the potential environmental impacts using a thorough risk-based methodology and describe proposed measures to avoid or minimise the expected, likely, or potential impacts to as low as reasonably practicable. Particular attention should be paid to potential impacts on listed threatened species and communities and listed migratory species under the EPBC Act. Any prudent and feasible alternatives should be discussed in detail and the reasons for selection of the preferred option should be clearly given.

These guidelines are not necessarily exhaustive and should not be interpreted as excluding from consideration matters deemed to be significant, but not incorporated in them, or matters (currently unforseen) that emerge as important from environmental studies or otherwise during the course of the preparation of the EIS.

**The specific requirements to be addressed in the EIS are provided in Section 5. It is on these requirements that public comment is sought, with the earlier sections of this document providing the context.**

## 4.2 GENERAL ADVICE

The EIS should be a stand-alone document. It should contain sufficient information from any studies or investigations undertaken to avoid the need to search out previous or supplementary reports.

The EIS should enable interested stakeholders and the assessing agency to understand the environmental consequences of the proposed development. Information provided in the EIS should be objective, clear, succinct and, where appropriate, be supported by maps, plans, diagrams or other descriptive detail. The body of the EIS is to be written in style that is easily understood by the general reader. Technical jargon should be avoided wherever possible and a full glossary included. Cross-referencing should be used to avoid unnecessary duplication of text.

Detailed technical information studies or investigations necessary to support the main text should be included as appendices issued with the EIS. Any additional supporting documentation and relevant studies, reports or literature not normally available to the public from which information has been extracted should be made available at appropriate locations during the period of public display of the EIS.

If there is a necessity to make use of material that is considered to be of a confidential nature, for instance information obtained in regard to traditional use or of a commercial nature, the proponent may request that such information remain confidential and not be included in any publicly available document.

An executive summary should be provided in the EIS and made available separately for public information.

The EIS should state the criteria adopted in assessing the proposal and its potential impacts, such as: compliance with relevant legislation, policies and standards; community acceptance; maximisation of environmental benefits (if any); and minimisation of risks and harm.

Any and all unknown variables or assumptions made in the assessment must be clearly stated and discussed. The extent to which the limitations, if any, of available information may influence the conclusions of the environmental assessment should be discussed.

The EIS should comprise three elements:

- The executive summary;
- The main text of the document, which should be written in a clear and concise manner so as to be readily understood by general readers; and
- Appendices containing:
  a) A copy of these guidelines;
  b) Detailed technical information or other sensitive commercial or cultural information.

Part 5 of these guidelines details the required content of the EIS and has been set out in a manner that may be adopted as the format for the EIS. This format need not be followed where the required information can be more effectively presented in an alternative way. However, all requirements set out in the EPBC Act and Regulations must still be addressed.

The EIS should be written so that any conclusions reached can be independently assessed. To this end all sources must be appropriately referenced.

# 5 SPECIFIC CONTENT REQUIREMENTS

Schedule 4 of the EPBC Act Regulations 2000, which sets out the matters that must be addressed in an EIS, is provided at **Attachment 1**. The following content requirements are based on these matters with the addition of directions specific to the proposed action and the receiving environment; and additional advice on presentation and consultation that have proven valuable in communicating with members of the public and specific interest groups.

## 5.1 EXECUTIVE SUMMARY

An executive summary that outlines the key findings of the EIS should be provided. The executive summary should briefly:

1. State the background and the need for the proposal;
2. Discuss alternatives to the proposal and the reasons for selecting the preferred option and rejecting the alternatives;
3. Summarise the pre-operational, operational and post-operational activities associated with putting the proposal into practice;
4. State the proposed schedule for key activities and the expected duration of the proposal;
5. Provide an overview of the existing regional and local environments, summarising the features of the physical, biological, social and economic environment relating to the proposal and associated activities;
6. Describe the expected, likely and potential impacts of the proposal on the environment during pre-operational, operational and post-operational phases;
7. Summarise the environmental protection measures and safeguards, monitoring and decommissioning procedures to be implemented for the proposal;
8. Provide an outline of the environmental record of Shell Development (Australia) Pty Ltd.

## 5.2 GENERAL INFORMATION

A description of the background of the proposal (or action) including:

1. The title of the action;
2. The full name and postal address of the designated proponent;
3. A clear outline of the objectives of the action;
4. The location of the action;
5. The background to the development of the action;
6. How the action relates to any other actions (of which the proponent should reasonably be aware) that have been, or are being, taken or that have been approved in the region affected by the action;
7. The current status of the action;
8. The consequences of not proceeding with the action;
9. A brief explanation of the scope, structure and legislative basis of the EIS;
10. The specific EPBC matters affected by the action, and any additional approvals needed under the EPBC Act; and
11. A description of government planning policies and statutory controls which will influence the Project. All applicable jurisdictions and areas of responsible authorities within the area should be listed and shown on maps at appropriate scales.

## 5.3 CONSULTATION

Provide details of any consultation about the action, including:

1. Consultation that has already taken place;
2. If there has been consultation about the proposed action — any documented response to, or result of, the consultation; and
3. Any further proposed consultation about potential impacts of the action

Identify and consult with affected parties and communities, including any native title claimants and relevant indigenous stakeholders, and describe their views. Describe consultation methodologies adopted and skills and techniques used to ensure effective communication of the nature and detail of the proposal. This should include the means used to identify concerns and to gauge and negotiate mitigation strategies. It is recommended that an open community consultation process be carried out, in addition to the legislated environmental impact assessment process.

## 5.4 ALTERNATIVES TO THE PROPOSAL

This section should describe, to the extent reasonably practicable, any prudent and feasible alternatives to the action, including:

1. If relevant, the alternative of taking no action;
2. A comparative description of the adverse and beneficial impacts of each alternative infrastructure and location on the matters protected by the controlling provisions for the action;
3. Sufficient detail should be provided to make clear why any alternative is preferred to another;
4. The reasons for choice of the preferred location and option should be explained, including a comparison of the adverse and beneficial effects used as a basis for selection, and compliance with the objectives of the EPBC Act (including ESD principles);
5. The advantages and disadvantages of alternatives when considered against relevant matters protected under the EPBC Act must be specifically addressed;
6. Short, medium and long-term advantages and disadvantages of the options should be considered.

## 5.5 THE PROPOSAL DESCRIPTION

This section should describe the proposal in sufficient detail to allow an understanding of all stages and components, and assist in determining potential environmental impacts associated with the proposal. Those elements with potential implications for matters protected under Part 3 of the EPBC Act must be highlighted.

The description should include the use of aerial photographs, maps, figures and diagrams, where appropriate. A general location map should be provided that illustrates the distances of the Notional Development Areas and any proposed facilities from the shoreline of the Kimberley and Broome. The map should include the location of known potential future expansions or new developments by Shell and other proponents in the vicinity, such as the Inpex Ichthys Development. Reference should be made to detailed technical information in appendices where relevant.

### 5.5.1 PROJECT DETAILS

The description of the action should cover:

1. The environmental principles on which the action will be managed;
2. All the components of the action including:

   - a. Site selection;
   - b. Site preparation (including any action that may result in the modification of the natural surface of the sea-bed);
   - c. Development options;
   - d. Construction;
   - e. Commissioning;
   - f. Operation;
   - g. Related onshore activities; and
   - h. Decommissioning.

3. The location of works to be undertaken, structures to be built or other elements of the action that may have relevant impacts. This should include (as appropriate):
   - a. Production wells and any water or gas disposal wells;
   - b. Sub-sea well-head completions and sub-sea pipelines;
   - c. Processing facilities and offloading facilities;
   - d. Proposed locations of any port or facility for vessel based supply of offshore facilities.
4. How the works are to be undertaken and design parameters for those aspects of the structures or elements of the action that may have relevant impacts. This should include:
   - a. An explanation of the anticipated timetable for the construction, commissioning, operation and decommissioning;
   - b. Details of the construction, commissioning, operational and decommissioning equipment to be used;
   - c. Details of the operations of the proposal throughout its lifespan, including details of anticipated exclusion zones required for the project;
5. Origin and nature of solid, liquid and gaseous waste produced during the construction, commissioning, operations and decommissioning phases, including;
   - a. Volumes of all anticipated solid, liquid and gaseous waste produced including produced formation water and atmospheric emissions of pollutants, such as oxides of nitrogen, sulphur dioxide and volatile organic compounds throughout the life cycle of the project. The proponent should quantify all anticipated emissions throughout the life cycle of the project. All emissions sources (combustion, process, fugitive etc) should be discussed;
   - b. Estimates of the maximum emissions of greenhouse gases resulting from the proposal as specified in **Attachment 3**;
   - c. As far as predictable, proposals for waste reduction, treatment, reuse and disposal;
6. Information on other potentially hazardous materials to be used throughout the proposal life, including methods of transport, storage and disposal; and
7. Number and source of staff, and training for staff involved for all phases of the project.

### 5.5.2 DECOMMISSIONING

This section should outline the planned decommissioning of the proposal and address the decommissioning objectives and goals.

The discussion on decommissioning may be best addressed in table form, identifying the original environment, procedures for decommissioning and rehabilitation, time frame and planned final environment. This section should also identify the time scale for determination of compliance with, and progressive or final release from requirements of the appropriate authorities. Information which should also be addressed includes:

1. Integration of the decommissioning and rehabilitation program with design, construction and operation;
2. Options for the removal of all infrastructure; and
3. Final use for the project area, taking into account environmental and economic regime of the region.

## 5.6 The Existing Environment

This section should provide a description of the project area including its marine physiography, flora and fauna, and relevant socio-economic considerations. It should link the existing environment to the proposal's requirements, potential impacts, as well as proposed mitigation measures throughout construction, operation and decommissioning.

### 5.6.1 Physical Environment

This section should describe the following elements of the environment within all Notional Development Areas and Zones:

1. Climate and atmospheric characteristics (air quality, seasonal temperatures, humidity, wind, evaporation and rainfall);
2. Oceanographic conditions, especially those which may have a bearing on the proposal. Include information on seasonal variation, waves, tides, currents, water salinity, clarity, temperature and depths. Discuss frequency and severity of extreme weather conditions, such as storms and cyclones, for the 2, 10 and 100 year conditions;
3. Bathymetric and geotechnical information, any proposed flowline routes, and any other affected areas. Discuss the seismic stability of these areas;
4. Flora and fauna, including baseline information/maps on communities and individual species types in the immediate and surrounding areas that may be subject to likely or potential impacts, as determined by literature search, survey and sampling programs.

The EIS should provide an overall evaluation of the flora and fauna communities identified above with reference to:

1. Habitat values in a local, regional and national context;
2. Presence of endemic species;
3. Local and regional representation;
4. Conservation and biodiversity values;
5. Economic and cultural values of species;
6. Migratory species, and
7. Unique habitats.

Particular attention should be given to the

The likely presence of any unique, rare, threatened, endangered or vulnerable fauna species or listed migratory cetaceans, listed marine species (under Part 4 of the EPBC Act). The EIS should also consider smaller cetaceans such as snub-fin and humpback dolphins occurring in the area. An evaluation of the significance, occurrence (including conservation status, distribution, population viability and habitat requirements) should also be included in this section. Particular reference should be made to species and ecological communities listed as threatened under the EPBC Act (but should not be limited to such species and communities) that (through analysis) may potentially be disturbed by the project.

Species to be addressed in the EIS must include, but not be limited to;

| | |
|---|---|
| Humpback whale | *Megaptera novaengliae* |
| Blue whale | *Balaenoptera musculus* |
| Green turtle | *Chelonia mydas* |
| Whale shark | *Rhincodon typus* |
| Green turtle | *Chelonia mydas* |
| Flatback turtle | *Natator depressus* |
| Streaked Shearwater | Calonectris leucomelas<br>*Puffinus leucomelas* |

All migratory shorebird species listed under JAMBA, CAMBA and ROKAMBA.

All other listed migratory cetaceans and relevant listed threatened species should also be addressed.

A broader description of the biodiversity and biogeography of the receiving environment should be included. Sensitive environments should be identified along with key ecological relationships and interdependencies (eg coral spawning, fish spawning aggregations, flora and fauna relationships etc) with particular attention to the environment around Browse Island and Surrounds.

The extent of existing disturbance to flora and fauna, and the incidence of introduced pest species should be discussed.

Identification of any existing or proposed reserves in, or neighbouring, the project and their status. Include the reserve characteristics, status, IUCN category, and values and relevant management strategies.

### 5.6.2 SOCIO-ECONOMIC AND CULTURAL ENVIRONMENT

Discussion of the socio-economic and cultural environment should provide:

1. A description of all existing uses and users of the Notional Development Areas and Zones of the sea and the sea floor. Include discussion of scientific research, tourism, commercial, traditional and recreational fishing (where relevant), military areas and shipping routes;
2. A description of government planning policies and statutory controls which will influence the project, surrounding areas of future, planned and current use. All applicable jurisdictions and areas of responsible authorities within the area should be listed and shown on maps at appropriate scales.
3. Any places with known or anticipated heritage, social or cultural values, such that they have been recognised with listing or recording under relevant Commonwealth legislation or are anticipated to be listed under such legislation; and
4. A description of any historic shipwrecks within the area pursuant to the *Historic Shipwrecks Act 1976*, including locations.

## 5.7 RELEVANT IMPACTS OF THE ACTION

This section must include:

1. A description of all relevant potential impacts of the action;
2. A detailed assessment of the nature and extent of the potential short term and long term relevant impacts including on listed threatened species and communities and listed migratory species and on listed marine species (under part 4 of the EPBC Act) including whales and other cetaceans (under part 3 of EPBC Act);
3. A statement whether any relevant potential impacts are likely to be unknown, unpredictable or irreversible;
4. Analysis of the significance of the relevant potential impacts; and
5. Any technical data, any sources of authority, and other information used or needed to make a detailed assessment of the relevant potential impacts. Reliability of forecasts and predictions, confidence limits and margins of error should be indicated as appropriate.

In discussing the potential impacts of the proposal, particular emphasis is to be given to providing details on the potential impacts to the receiving environment's unique flora and fauna as identified and to any protected areas in the vicinity.

Cumulative impacts, where potential project impacts are in addition to existing impacts of other activities, (including those known potential future expansions or developments by Shell and other proponents in the vicinity), should also be identified and addressed. Where relevant to the potential impact, risk assessment should be conducted and documented. The risk evaluation should include known potential future expansions or developments by Shell and other proponents.

In particular, the EIS should address the matters described in the following paragraphs.

### 5.7.1 GENERAL IMPACTS

1. Discuss the effects of the overall action on the functioning of the marine environment, including effects to the marine environment surrounding the proposed development;
2. Identify the source of potential impacts, e.g. artificial lighting, noise, ship-movements;
3. Discuss potential impacts which may arise through the transportation, storage and use of dangerous goods (if any), fuels and chemicals, such as accidental spills;
4. Consider potential impacts caused by the need for waste disposal and management of emissions, refuse, effluent and hazardous waste (if any);
5. In discussing potential impacts, consider how the interaction of extreme environmental events and any related safety response may impact on the environment; and
6. Consider potential impacts throughout the life of the proposal – from construction, commissioning and operation through to decommissioning.

### 5.7.2 PHYSICAL AND BIODIVERSITY IMPACTS

1. Consider potential impacts to the sea floor through anchoring and direct placement, sediment disturbance, as well as any impacts of removal. The zone of likely seabed disturbance should be identified;
2. Consider potential impacts to fauna and flora species (composition and population densities), considering changes to overall communities, community types, propagation of species and potential barriers to species movement or gene flow;
3. Consider potential impacts to macrobenthic species, fish and larger marine fauna species (composition and population densities), including changes to communities, breeding success, habitat, potential barriers or disturbances to migration or migratory patterns and other wildlife movements;
4. Consider potential impacts, if any, on rare, threatened, or otherwise valuable flora and fauna, communities (particularly listed threatened species and communities, listed marine species including whales and other cetaceans and listed migratory species) and habitat, conservation areas and protected areas, in particular Browse Island and surrounds.
5. Consider the potential impacts on cetaceans and marine turtles from increased ship movement from facility and the potential for ship strike;
6. Consider the potential impacts from anticipated illumination of the facility and flaring on seabirds, marine turtles and other migratory species, including bird strike, nesting and disorientation.
7. Consider the potential impacts, from underwater noise during construction and operation (including associated shipping and support vessels) and what levels may be received in the surrounding environment including nearby feeding/calving/resting areas;
8. Provide a full evaluation of the frequency and amplitude of all generated noises including any temporal patterns that may be expected. Modelling of the likely extent of noise propagation into the marine environment and a strategy to reduce/minimise mechanical, low frequency noise generated to minimise adverse effects on marine biota;
9. Outline details of a strategy to reduce/eliminate illumination of the proposed facility and reduce/minimise flaring, especially during migratory period of birds and the hatching periods of turtles, particularly on dark nights; and
10. Consider potential impacts arising from the introduction and/or spread of exotic pest species.

### 5.7.3 AIR AND WATER POLLUTION IMPACTS

1. As a minimum, model emissions of NOx, $SO_2$, CO, VOCs, particulates and toxics and discuss the potential impact of solid, liquid and gaseous emissions and waste produced by the operation, including greenhouse gas emissions and the potential for geosequestration;
2. Outline a strategy to reduce/minimise the discharge of sewage, galley scraps and bilge water into the marine environment. Include discussion on the eventual fate of the waste and what effect the discharge of treated sewage and grey water into nutrient-poor tropical waters will have on the marine environment;

3. Provide a full evaluation of Produced Formation Water (PFW) discharge. Include anticipated composition of PFW, modelling of the mixing zones and discuss the potential impacts of discharge, including the spatial and temporal impacts of discharged PFW on marine biota. Consider the potential impacts of water clarity, salinity and temperature changes with specific reference to stratification of the water column. Discuss potential impacts related to the discharge of sewage, sullage and other production related discharges from the Proposal.
4. Discuss impacts of potential spillage of hydrocarbons related to construction, production, storage and shipping. Modelling of spills should take into account seasonal variations throughout the year. Modelling should also take into account proximity to sensitive marine areas, in particular Browse Island and Surrounds. The evaluation of the potential impacts of oil spills is to be carried out using a thorough risk-assessment methodology;
5. information on the discharge of warm water, the extent of dispersion and mixing of the water, the concentrations of sodium hypochlorite and the potential effects of water extraction from depth for cooling purposes.

### 5.7.4 SOCIO-ECONOMIC AND CULTURAL IMPACTS

Section 528 of the EPBC Act defines the environment as including:
(a) ecosystems and their constituent parts, including people and communities; and
(b) natural and physical resources; and
(c) the qualities and characteristics of locations, places and areas; and
(d) the social, economic and cultural aspects of a thing mentioned in paragraph (a), (b) or (c).

Discussion of the potential socio-economic and cultural impacts of the proposal as they relate to the above, this should include a description and discussion of potential impacts (both positive and negative):

1. Caused by any short, medium and long-term changes, interruption, alteration or curtailment of activities and uses of the area due to the proposed action, including changes affecting traditional uses, recreational uses, conservation and tourism;
2. On sites of historical or cultural significance, including places entered in the Register of the National Estate and other significant sites and unknown or unsurveyed sites;
3. On existing industry and commerce affected by the proposal;
4. To employees in terms of workplace health and safety;
5. On shipping and any potential traffic hazards;
6. On visual and aesthetic values, impacts to tourism and access for conservation purposes; and
7. To historic shipwrecks in the area, including potential impacts on, as yet, unknown shipwrecks or those in unsurveyed areas

## 5.8 SAFEGUARDS, MITIGATION MEASURES AND MONITORING

### 5.8.1 SAFEGUARDS AND MITIGATION MEASURES

This section should explain the proposed safeguards and mitigation measures to be put in place for every phase of the proposed action to deal with relevant (potential and anticipated) impacts of the action. This must include:

1. A consolidated list of mitigation measures proposed to be undertaken to prevent, minimise or treat the relevant potential impacts of the action (impacts upon matters protected under Part 3 of the EPBC Act and as discussed in Section 6 ), including any mitigation measures proposed to be taken by State governments, local governments or the proponent;
2. A description, and an assessment of the expected or predicted effectiveness of, the mitigation measures;
3. Any statutory or policy basis for the mitigation measures; and
4. The name of the agency responsible for endorsing or approving each mitigation measure or monitoring program.

Particular focus should be given to:

1. Determining factors in the planning of the proposal so as to avoid damage to the environment;
2. Measures to avoid or minimise damage to the marine environment;
3. Measures to avoid or minimise disturbance to fauna found around and within the proposal area (particularly listed threatened species and listed migratory species);
4. Measures to minimise atmospheric emissions, with particular reference to greenhouse emissions (refer to **Attachment 3** for more detail); and
5. Staff training, including training in relation to environmental issues.

### 5.8.2 MONITORING AND REPORTING

Appropriate baseline data requirements will be identified as part of the EIS to form the basis for baseline measurement and ongoing monitoring of environmental parameters. It must be demonstrated that the proposed methods for baseline measurements and subsequent monitoring are scientifically and statistically sound. This section should identify parameters to be monitored and their response trigger values and response activities.

This section will also identify and describe monitoring programs, procedural and compliance audit programs and reporting requirements and arrangements which will demonstrate the effectiveness of management and monitoring (linked to EMS/EMP procedures – see below).

The proponent must, in addition to outlining proposed programs, clearly identify what is to be monitored and why. Monitoring programs should be designed to provide objective evidence regarding activities associated with the proposal and if these activities are adversely impacting on the environment in the short, medium and long term.

Monitoring programs should demonstrate consideration of:

1. Ecosystems and habitats, flora and fauna (particularly listed threatened species and listed migratory species and Browse Island and Surrounds), and water quality issues;
2. Measuring the effectiveness of rehabilitation measures;
3. Management and operation of facilities;
4. Documenting the difference between predicted and actual impacts;
5. Methods for identification of non-predicted impacts and appropriate reporting and remedial measures;
6. Application and effectiveness of emergency and contingency plans; and
7. Review of consultation and management arrangements with regulatory authorities and the community.
8. Identification of any negative impacts upon the effectiveness of community infrastructure and services.

## 5.9 OFFSETS

Environmental offsets' are broadly understood to mean actions taken by developers to compensate for the adverse impacts of their developments. The Australian Government defines environmental offsets as 'actions taken outside a development site that compensate for the impacts of that development - including direct, indirect or consequential impacts'. Environmental offsets provide an opportunity to achieve long-term conservation outcomes whilst providing flexibility for proponents seeking to undertake development which will have environmental impacts.

This section should outline plans to offset the potential impacts of the action. Environmental offsets may be appropriate when they:

- are necessary or convenient to protect or repair impacts to a protected matter – i.e. a matter of national environmental significance or the environment more broadly;
- relate specifically to the matter (for example, species) being impacted; and

- seek to ensure that the health, diversity and productivity of the environment is maintained or enhanced.

## 5.10 ENVIRONMENTAL MANAGEMENT SYSTEM

The overall environmental management philosophy to be applied to the areas affected by the proposal is to be enunciated. An outline of the proposed Environmental Management System (EMS) is to be contained in the EIS document. It should include summary details of audit protocols and reporting procedures.

Reference should be made within the outline of the EMS to consultation, relevant legislation, standards adopted, safeguards planned, management practices, monitoring programs and emergency contingency plans, including the management of facilities in the event of cyclones. Management plans to manage impacts on listed threatened species and communities and listed migratory species and on listed marine species (under part 4 of the EPBC Act) including whales and other cetaceans (under part 3 of EPBC Act).

EMP outlines are to be presented in this section of EIS. It should, as a minimum, detail:

1. Monitoring arrangements;
2. Reporting arrangements; and
3. Feedback of monitoring results into project management.

Details of requirements for the preparation of Environmental Management Plans under other relevant legislation should be provided. In an effort to minimise duplication, areas of consistency between separate requirements should also be highlighted.

## 5.11 OTHER APPROVALS AND CONDITIONS

This must include the following:

1. A description of any approval that has been obtained from a State, Territory or Commonwealth agency or authority (other than an approval under the Act), including any conditions that apply to the action;
2. A statement identifying any additional approval that is required;
3. A description of the monitoring, enforcement and review procedures that apply, or are proposed to apply, to the action.
4. Details of any local or State government planning scheme, or plan or policy under any local or State government planning system (including licensing and permitting requirements) that deals with the proposed action, including:
    a. What environmental assessment of the proposed action has been, or is being, carried out under the scheme, plan or policy;
    b. How the scheme provides for the prevention, minimisation and management of any relevant potential impacts.

## 5.12 ENVIRONMENTAL RECORD

The environmental record of the person proposing to take the action must be provided. This should include details of any proceedings under a Commonwealth, State or Territory law for the protection of the environment or the conservation and sustainable use of natural resources against the person proposing to take the action. If the person proposing to take the action is a corporation, details of the corporation's environmental policy and planning framework must be provided.

Information relating to the persons environmental record should also include any accreditations (for example ISO 14001), environmental awards, and other recognition for environmental performance.

## 5.13 CONCLUSION

An overall conclusion as to the environmental acceptability of the proposal should be provided, including discussion on compliance with the objectives and requirements of the EPBC Act including the principles of ESD (see **Attachment 2**). Reasons justifying undertaking the proposal in the manner proposed should be outlined. The conclusion should highlight measures proposed or required by way of mitigating any unavoidable impacts on the environment.

## 5.14 INFORMATION SOURCES

This section will describe consultations and studies undertaken in the course of proposal formulation and preparation of the draft EIS, and sources of information and technical data. For information given the section must state:

1. The source of the information; and
2. How recent the information is; and
3. How the reliability of the information was tested; and
4. What uncertainties (if any) are in the information?

Any further or ongoing consultations or studies should be outlined here.

## 5.15 REFERENCE LIST AND BIBLIOGRAPHY

This should be accurate and concise and include the address of any internet pages used as data sources.

## 5.16 APPENDICES AND GLOSSARY

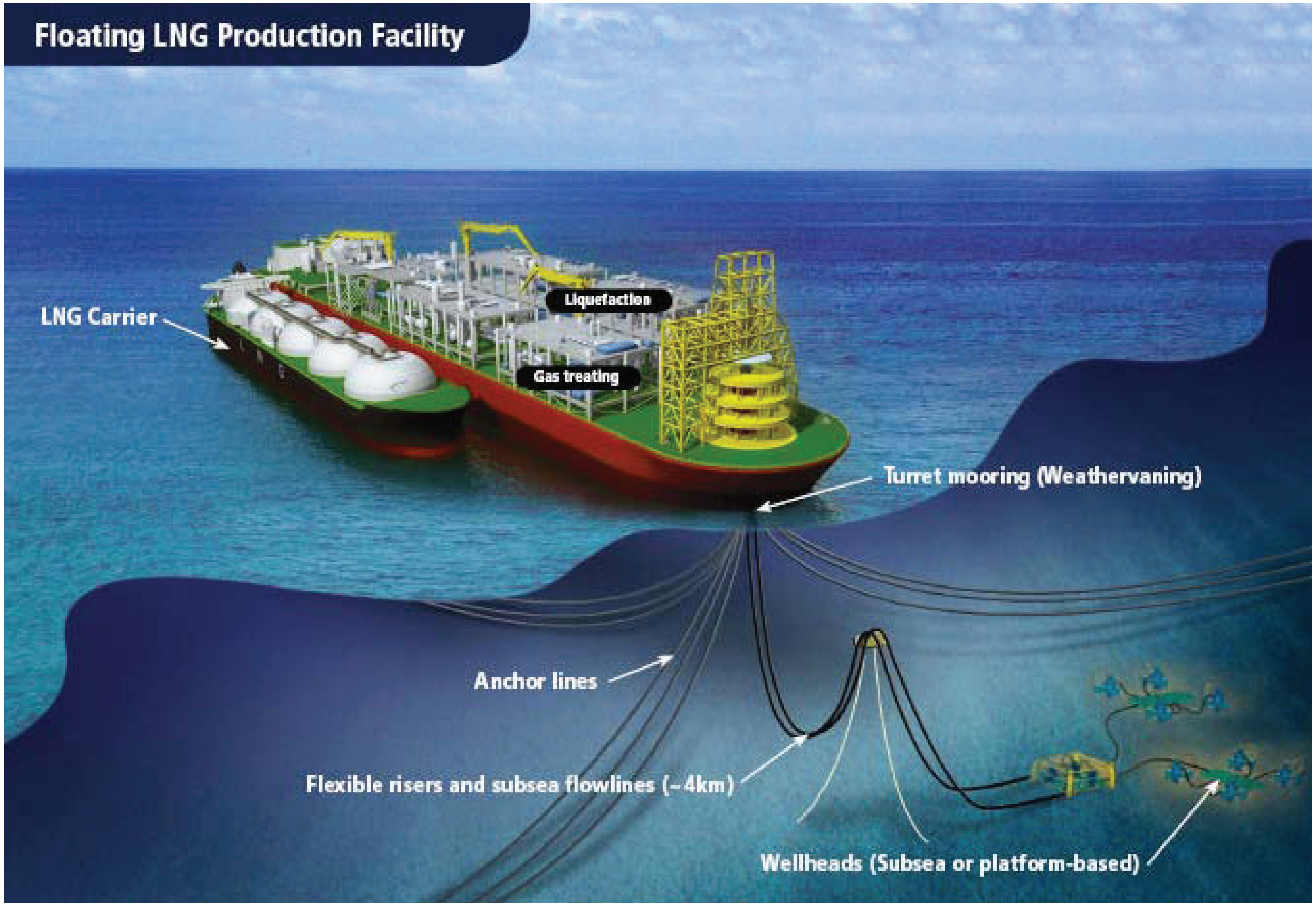
Detailed technical information studies or investigations necessary to support the main text of the EIS, but not suitable for inclusion in the main text should be included as appendices; for example, detailed technical or statistical information, maps, risk assessment, baseline data, supplementary reports etc. A copy of the Guidelines should also be included. A glossary defining technical terms and abbreviations used in the text should be included to assist the general reader.

## 5.17 ADDITIONAL SOCIAL AND ECONOMIC MATTERS

Section 136(1)(b) of the EPBC Act requires the Minister for the Environment, Heritage and the Arts to consider economic and social matters when deciding whether to grant approval to the proposed action under Part 9 of the EPBC Act. The requirements under s136(1)(b) encompass a broad range of matters that may be considered than those addressed during the assessment of the potential impacts of a controlled action. Accordingly, information should be provided on the broad social and economic impacts (positive or negative) of the proposal for the purposes of the Part 9 decision on approval.

As the matters protected by the controlling provisions for this action include "the environment", there is the potential for an overlap between the information provided in response to this, and the information requested in the main body of the guidelines in relation to social, economic and cultural aspects within the definition of the environment. The latter set of information need not be repeated if it will be contained in the body of the EIS.

Figure 1: Location of Proposed Floating LNG facility Development Areas



# ATTACHMENT 1: MATTERS THAT MUST BE ADDRESSED IN AN EIS (SCHEDULE 4 OF THE EPBC ACT REGULATIONS 2000)

## 1. General information

1.01 The background of the action including:
(a) the title of the action;
(b) the full name and postal address of the designated proponent;
(c) a clear outline of the objective of the action;
(d) the location of the action;
(e) the background to the development of the action;
(f) how the action relates to any other actions (of which the proponent should reasonably be aware) that have been, or are being, taken or that have been approved in the region affected by the action;
(g) the current status of the action;
(h) the consequences of not proceeding with the action.

## 2. Description

2.01 A description of the action, including:
(a) all the components of the action;
(b) the precise location of any works to be undertaken, structures to be built or elements of the action that may have relevant impacts;
(c) how the works are to be undertaken and design parameters for those aspects of the structures or elements of the action that may have relevant impacts;
(d) relevant impacts of the action;
(e) proposed safeguards and mitigation measures to deal with relevant impacts of the action;
(f) any other requirements for approval or conditions that apply, or that the proponent reasonably believes are likely to apply, to the proposed action;
(g) to the extent reasonably practicable, any feasible alternatives to the action, including:
(i) if relevant, the alternative of taking no action;
(ii) a comparative description of the impacts of each alternative on the matters protected by the controlling provisions for the action;
(iii) sufficient detail to make clear why any alternative is preferred to another;
(h) any consultation about the action, including:
(i) any consultation that has already taken place;
(ii) proposed consultation about relevant impacts of the action;
(iii) if there has been consultation about the proposed action — any documented response to, or result of, the consultation;
(i) identification of affected parties, including a statement mentioning any communities that may be affected and describing their views.

## 3. Relevant impacts

3.01 Information given under paragraph 2.01 (d) must include
(a) a description of the relevant impacts of the action;
(b) a detailed assessment of the nature and extent of the likely short term and long term relevant impacts;
(c) a statement whether any relevant impacts are likely to be unknown, unpredictable or irreversible;
(d) analysis of the significance of the relevant impacts;
(e) any technical data and other information used or needed to make a detailed assessment of the relevant impacts.

## 4. Proposed safeguards and mitigation measures

4.01 Information given under paragraph 2.01 (e) must include:
(a) a description, and an assessment of the expected or predicted effectiveness of, the mitigation measures;

(b) any statutory or policy basis for the mitigation measures;
(c) the cost of the mitigation measures;
(d) an outline of an environmental management plan that sets out the framework for continuing management, mitigation and monitoring programs for the relevant impacts of the action, including any provisions for independent environmental auditing;
(e) the name of the agency responsible for endorsing or approving each mitigation measure or monitoring program;
(f) a consolidated list of mitigation measures proposed to be undertaken to prevent, minimise or compensate for the relevant impacts of the action, including mitigation measures proposed to be taken by State governments, local governments or the proponent.

### 5. Other Approvals and Conditions

5.01 Information given under paragraph 2.01 (f) must include:
(a) details of any local or State government planning scheme, or plan or policy under any local or State government planning system that deals with the proposed action, including:
  (i) what environmental assessment of the proposed action has been, or is being, carried out under the scheme, plan or policy;
  (ii) how the scheme provides for the prevention, minimisation and management of any relevant impacts;
(b) a description of any approval that has been obtained from a State, Territory or Commonwealth agency or authority (other than an approval under the Act), including any conditions that apply to the action;
(c) a statement identifying any additional approval that is required;
(d) a description of the monitoring, enforcement and review procedures that apply, or are proposed to apply, to the action.

### 6. Environmental record of person proposing to take the action

6.01 Details of any proceedings under a Commonwealth, State or Territory law for the protection of the environment or the conservation and sustainable use of natural resources against:
(a) the person proposing to take the action; and
(b) for an action for which a person has applied for a permit, the person making the application.

6.02 If the person proposing to take the action is a corporation — details of the corporation’s environmental policy and planning framework.

### 7. Information sources

7.01 For information given the EIS must state:
(a) the source of the information; and
(b) how recent the information is; and
(c) how the reliability of the information was tested; and
(d) what uncertainties (if any) are in the information.

# ATTACHMENT 2: THE OBJECTS OF THE ENVIRONMENT PROTECTION AND BIODIVERSITY CONSERVATION ACT 1999 ACT

3. Objects of the Act

(a) to provide for the protection of the environment, especially those aspects of the environment that are matters of national environmental significance
(b) to promote ecologically sustainable development through the conservation and ecologically sustainable use of natural resources
(c) to promote the conservation of biodiversity
(d) to promote a co-operative approach to the protection and management of the environment involving governments, the community, land-holders and indigenous peoples
(e) to assist in the co-operative implementation of Australia's international environmental responsibilities
(f) to recognise the role of indigenous people in the conservation and ecologically sustainable use of Australia's biodiversity; and
(g) to promote the use of indigenous peoples' knowledge of biodiversity with the involvement of, and in co-operation with, the owners of the knowledge.

3A. Principles of Ecologically Sustainable Development

The following principles are principles of ecologically sustainable development:

(a) decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations;
(b) if there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation;
(c) the principle of inter-generational equity – that the present generation should ensure that the health , diversity and productivity of the environment is maintained or enhanced for the benefit of future generations;
(d) the conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making;
(e) improved valuation, pricing and incentive mechanisms should be promoted.

# ATTACHMENT 3: GUIDELINES FOR GREENHOUSE GAS EMISSIONS

The Commonwealth seeks transparent and accurate information to support decision making. This framework is provided to assist proponents in detailing the greenhouse implications of development proposals. To aid assessment of greenhouse gas emissions resulting from the proposed Shell development (EPBC 2008/4146), the following information is required:

## 1. Inventory of annual emissions

The proponent must provide data on maximum annual emissions of the six greenhouse gases listed in the Kyoto Protocol (carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride). This includes both on-site (Scope 1) and upstream (Scope 2) emissions, as such all operational boundaries should be established including any on-shore development where relevant.  The inventory should include:

(a) an estimate of emissions on a gas by gas basis;
(b) a summary table of emissions on a gas by gas basis;
(c) a summary table listing emissions on a carbon dioxide equivalent basis; and
(d) a table which includes gross emissions, emission reduction due to both offsets and mitigation, and net emissions.

As far as is practicable an inventory of cumulative emissions should be included (with regards to known potential future expansions or developments by Shell and other proponents in the vicinity

## 2. Mitigation

The proponent must include a full description of mitigation measures, including analysis of a full range of alternatives to the proposed project. This should include methods by which greenhouse gas emissions could be mitigated, including:

(a) analysis of the likely greenhouse gas reductions as a result of mitigation efforts (to the same level of detail as described in the section 1.1 above);
(b) analysis of costs, both financial and output related, of mitigation; and
(c) identification of any relevant voluntary partnerships between government and the proponent; such as Greenhouse Challenge and their links to mitigation.

## 3. Methodologies

The proponent must identify, in a transparent manner, the methodology used in making the estimate. In preparing estimates:

(a) the most recent National Greenhouse Gas Inventory (NGGI) methodology should be used (http://www.greenhouse.gov.au/inventory/index.html);
(b) if the relevant industry is not covered by the NGGI methodology, IPCC (Intergovernmental Panel on Climate Change) methodology should be substituted (http://www.ipcc.ch/pub/guide.htm); or
(c) if no methodology exists in either format, a methodology reflecting the principles of the NGGI and IPCC will be developed and agreed by the proponent and the Department of the Environment, Water, Heritage and the Arts.

Uncertainty in variables and parameters from the methodologies used should be quantified and reported.

## 4. Supporting Data

The following supporting data must be provided:

(a) the proponent must provide details on the emission factors used, and an explanation where a proponent chooses to use alternative emission factors to that provided in the methodology.
(b) the project's emission factors need to be compared with similar projects, including both Australian and international best practice. This analysis should include projects that use alternative fuel sources, processes, and technologies.

## 5. Offsets

The proponent should provide information on the range of offsets (eg sinks or off-site energy efficiency measures) that may be pursued. The following information should be provided:

(a) likely greenhouse gas reductions as a result of the offsets (to the same level of detail as described in the inventory section above);

(b) description of proposed offsets and a qualitative assessment of their impact on other matters of environmental, economic, or social significance; and

(c) analysis of costs, both financial and other related to offsets.

# APPENDIX B

# *GLOSSARY*

## DEFINITIONS

Acute toxicity – any poisonous effects from the short term exposure of a toxic substance. Acute effects often occur immediately after exposure.

Acid Gas Removal Unit (AGRU) – a processing unit that removes acid gases (hydrogen sulphide and carbon dioxide) from the recovered gas resource to prevent freezing and subsequent blockages in the liquefaction unit.

Acoustic loggers – Measure the velocity of soundwaves within geological formations. Acoustic logging is predominantly carried out to determine the porosity of the formations, differentiating between liquid-bearing zones and gas-bearing zones.

Additive impacts – where effects from multiple sources act additively to increase the level of impact on the environment.

Advection – the horizontal transfer of condensate spills.

Aliphatics – a class of petrochemical (the other being aromatic).

Annulus – the space between the outer surface of the steel casing and the wall of the well.

Anoxic – deficient in oxygen.

Anthropogenic – induced by man.

Anti-fouling paints – paints that inhibit growth of fouling species.

Aromatics – a class of petrochemical consisting of a carbon ring structure.

Artificial light halo – the glow coming from artificial lighting on Prelude equipment.

Australian Fishing Zone (AFZ) – an area extending roughly 200 nautical miles from the mainland where the Commonwealth Government of Australia possesses the right to control domestic and foreign access to fish resources.

Austral Winter/Summer – Winter/Summer in the Southern Hemisphere.

Avian – refers to birds.

Ballast water – Water used to increase stability and prevent capsizing. Concern exists in Australia regarding the risk of introducing harmful aquatic organisms into Australia's marine environment through ship's ballast water.

Bathymetry – the study of underwater depths. Bathymetry maps show underwater depths at various locations.

Benthic – the seafloor environment. Benthic fauna are animals that live in or on seafloor sediment.

Berthing – parking a ship to a docking facility.

Bilge water – water in the bilge/lower compartment of a ship. Bilge water is dissimilar to Ballast water as it is unintentionally taken on board and often in smaller volumes.

Bioaccumulation – the amount of a substance that is absorbed by an organism through all means of exposure (epidermal, inhalation, ingestion).

Bioavailable – the ability for a chemical to be circulated and absorbed within the body, reaching the organs and tissues of the body.

Biodegradation – where organic materials are broken down by microorganisms.

Biodiversity – relates to the level/range of living organisms available to a certain region or environment.

Biocides – a chemical substance capable of destroying a living organism.

Bioluminescent – where a living organism produces and emits light through a chemical reaction.

Biomagnification – when contaminants in organisms at the low end of the food chain (low tropic level) are magnified in organisms at higher tropic levels.

Biota – all organisms that can be found in a particular region.

Black water – waste water containing untreated sewage.

Blowdown – the process of removing hydrocarbons from the FLNG facility using pressure.

Brine – concentrated saline water from the desalination unit.

Bund – containment mechanism to capture spills before loss to the environment.

Caisson – a watertight structure that allows for construction underwater.

Capping – the seal used to prevent gases escaping.

Carbon Capture and Storage (CCS) – the capture of greenhouse gases (see Greenhouse gases) followed by storage of these gases within the earth.

Carbon dioxide equivalent ($CO_2$-e) – measures the global warming potential of the six greenhouse gases (see Greenhouse Gases), equivalent to the global warming potential of the greenhouse gas, carbon dioxide.

Carbon Pollution Reduction Scheme (CPRS) – an Australian Government initiative to reduce greenhouse gas emissions from large corporations using an emissions trading scheme (see GHG cap and trade scheme).

Casing – a steel pipe screwed together and cemented into a recently drilled well bore. Casings are used to prevent the bore from caving in; water and other fluids from entering the bore; and to maintain the circulation of drilling fluids.

Cathodic protection system – a system designed to prevent corrosion of facility infrastructure.

Centrifuge – a spinning devise that is used to separate drill cuttings from drilling mud.

Cetaceans – whales, dolphins, porpoises.

Chemical hazards – contamination with chemicals that are potentially harmful.

Chemical inhibitors – a substance used to retard a chemical reaction.

Chlorophyll-a – a substance found in photosynthesising organisms.

Chlorine by-products (CBPs) – chlorinated chemical compounds that are made when using the electro-chlorination system (see Electro-chlorination system).

Chronic toxicity – any poisonous effects from prolonged or repeated exposure of a toxic substance. Chronic effects have the potential to occur some time after exposure.

Coliforms – harmless bacteria of an environmental origin.

Commissioning – includes the testing of equipment used in operations to ensure readiness to begin.

Computational fluid dynamics (CFD) – the numerical approach to improving fluid flows.

Condensate – a mixture of liquid hydrocarbons that are extracted during gas production.

Condensate fraction – the broken down compounds of a hydrocarbon for example, pentane, hexane, heptane.

Contamination – to pollute a substance with another, unwanted, substance.

Copepod – herbivorous aquatic crustaceans that are often microscopic. For example, plankton.

Crepuscular – animals that feed at dawn and dusk.

Critical impact – an impact of concern which requires mitigation that provides high levels of assurance of achieving As Low As Reasonably Practicable (ALARP). Requires the adoption of management or mitigation measures.

Critical Ratio - the amount by which the intensity of a sound must exceed the background noise to be audible to an organism.

Crustaceans – arthropods such as crabs, barnacles and prawns that have jointed appendages and hard outer shells.

Cryptogenic species – of unknown species/origin.

Cryogenic equipment – Equipment used for handling and storing fluids at sub zero temperatures.

Cumulative impacts – whilst the effects of individual activities may be judged to be acceptable, in combination with others they have the potential to be of significance due to a contributing effect of each impact.

Current account – a measure of a nation's trade surplus (or deficit).

Cuttings – debris (pieces of sand, gravel and rock) that are brought to the surface from the well during drilling.

Decommissioning – withdrawing the facility from active service.

Dehydration (of the gas and condensate) – removal of water.

Demersal species – those species found on or near the sea floor.

Derrick – a pyramid shaped structure mounted over a bore hole and used to raise and lower equipment (see Drawworks).

Designed mitigation measures – avoiding or reducing at source through engineering/ design so that a feature that may potentially cause an impact is designed out or altered.

Diel cycles – 24 hour cycles of day and night.

Directional Control Valves (DCV) – DCVs control the flow of hydraulic fluid to various field valves, enabling them to open and close.

Dissolved oxygen – the amount of oxygen dissolved in water and available to marine life.

Diurnal (animals) – animals that are active during the day. (Antonym – Nocturnal).

Double hulled condensate offtake vessel – a carrier vessel with an internal, protective hull that is used to decrease the likelihood of a hydrocarbon spill.

Down-slope direction – direction moving away from shore.

Drawworks – a mechanism used to hoist drilling equipment above a rig (also see Derrick).

Drilling fluids (drilling muds) – are used to control subsurface pressures, lubricate the drill bit, stabilise the well bore and carry the cuttings to the surface. Well drilling for the Prelude development will use two types of muds, classified by their base fluid; water based mud (WBM) and synthetic based mud (SBM), with synthetic based muds being used on the deeper and more challenging well sections.

Echolocation pulses – noises used by certain marine mammals for location of prey and other objects through use of echoes. Often created by cetaceans (See Cetaceans).

Electro–chlorination system – a purification system used, in Prelude's case, to prevent marine growth forming in facility's cooling systems.

Employment multiplier – the number used to determine how many jobs will be created indirectly from the Prelude project per position of direct employment.

Encrusting epibiota – organisms that grow over subsea equipment (see Epibenthic).

Environmental Impact Statement (EIS) – a comprehensive study that is required by state and federal laws to accompany a development proposal that is likely to impact on the environment.

Environmental Management Plan (EMP) – a strategy that outlines mitigation and monitoring measures. Each measure is set to a timeline and has an allocated person/group of people responsible for implementation and follow up actions.

Epibenthic – organisms living on the surface of the sea floor but not within the sediments.

Epifauna – see Macrobenthic organisms.

Exclusion zone – area in which vessels are prohibited from entering.

External hydrophone – sound recorders used in the process of seismic surveys (see Seismic Surveys).

Flaring – the safe burning of excess/unwanted gases.

Flexible riser – a flexible connector between the FLNG facility and the sea floor which carries wellstream fluid and allows for movement due to sea conditions.

Flocculating agent – a chemical used to increase the clumping of suspended solids.

Flowlines – pipes that allow for contained flow between two points.

Fouling – the growth of organisms on marine infrastructure such as the hull of ships or on the FLNG facility itself.

Front End Engineering Design (FEED) – the design phase of the project.

Fugitive emissions – the unintended escape of greenhouse gas emissions (see Greenhouse gases).

Geosequestration – the storage of climate perturbing carbon in underground geological formations.

Greenhouse gases (GHG) – Includes the six greenhouse gases recommended by the Intergovernmental Panel on Climate Change: carbon dioxide ($CO_2$), methane ($CH_4$), nitrous oxide ($N_2O$), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride ($SF_6$).

GHG cap and trade scheme/emissions trading scheme – a scheme that places a cap on carbon pollution by issuing a set number of carbon permits. Organisations that take part in the scheme are then able to trade permits, placing a price on carbon (see CPRS).

Grey water – waste water generated from domestic activities, for example, from used dishwashing water.

Half-life – the time necessary for a substance to decay to half its initial volume or strength.

Hazardous substance – solid, liquid or gas that has the potential to harm living organisms, infrastructure and/or the environment.

Heat inleak – refers to external heat leaking into cryogenic equipment (see Cryogenic equipment).

Hookup – the process of connecting equipment.

Hydraulic oils – are medium oils of light to moderate viscosity used to operate valves and control systems.

Hydrocarbons – compounds that contain only hydrogen and carbon molecules. Petroleum based products such as LNG, LPG and condensate (See Condensate) all contain hydrocarbons.

Hydroclones – a piece of equipment used to remove the water content from the condensate.

Hydrotest – the fillings of equipment with water to test for any losses of pressure through leaks.

Impact – to have an effect upon a stakeholder or the surrounding environment.

Indo-Pacific Through Flow (ITF) – a warm ocean current that travels south through Indonesia and drives the South Equatorial Current, which is a major circulation feature during the south-west monsoon season.

Infauna – see Macrobenthic organisms.

Installation – the process whereby equipment is set up in preparation for operations.

Interactive impacts – where multiple sources interact and introduce a new form of impact.

Internesting – time interval between clutches laid.

Intertidal region – the area exposed at low tide.

Introduced marine species (IMS) – are organisms which have been transported from their existing natural environment to a new host location. These species may include small invertebrates, microbes and the eggs and larvae of a variety of species.

Jackup drilling rigs – rigs that use extendable legs to raise the rig above sea level.

Leachate – any liquid that percolates through a permeable substance.

Life of field production licence – A production licence that is granted for an indefinite term.

Light spill – the area in which the light halo/glow extends to.

Limit of Reporting (LOR) – the level as set by the laboratory during sample analysis that is the minimum level recognised.

Lipid – oily substances that are not soluble in water.

Liquefaction – the process by which the natural gas is cooled to -162°C to condense it to a liquid.

Lithology – the physical characteristics of the sediment below Prelude. This can include sediment colour, rock/grain size and mineralogy.

Luminaire – a light fixture, used to create artificial illumination.

Macrobenthic organisms (and Macrobenthos) – refers to organisms that live within (infauna) or on (epifauna) the seabed sediments (eg polychaete worms, bivalves, prawns and crustaceans).

Macro Porous Polymer Extraction (MPPE) – eliminates dissolved and diffuse hydrocarbons using an extraction process whereby the macro-porous polymer particle immobilises and extracts the hydrocarbon liquid.

Macrotidal – large tidal range.

Main Cryogenic Heat Exchanger (MCHE) – cools and liquefies natural gas to a temperature of -162°C.

Major impact - may require particular or combinations of mitigation measures to achieve ALARP. Requires the adoption of management or mitigation measures.

Manifolds – Subsea system for collecting multiple wellstream flows from flowlines.

Material Safety Data Sheets (MSDS) – summary sheets detailing safety hazards and procedures for safe handling.

Megafauna – large animals such as whales, dolphins and porpoises.

Memorandum of Understanding (MOU) Box - permits Indonesian traditional fishers to continue their customary practices in Australian waters.

Metocean – the combined study of meteorology and oceanography.

Micro-organisms – microscopic organisms.

Minor impact - impact which can be managed through effective standard operating procedures. Requires the adoption of management or mitigation measures.

Moderate impact – those impacts that can be mitigated to ALARP through the implementation of conventional mitigation measures. Requires the adoption of management or mitigation measures.

Molsieve unit (Molecular sieve unit) – separates molecules of different sizes, filtering through smaller molecules, which are adsorbed by the molsieve bed material. Used in gas dehydration to remove water.

National environmental significance (NES) – as defined by the EPBC matters include (as they relate to the Prelude development) listed threatened species and communities; listed migratory species; and the Commonwealth marine environment.

National Greenhouse and Energy Reporting System (NGERS) – a mandatory reporting system implemented by the Commonwealth Government of Australia. Under the system large corporations need to report and publicly disclose on their GHG emissions, energy consumption and production (Also see Carbon Pollution Reduction Scheme).

Nautical mile – a measurement of distance equal to 1,852 m.

Neap tides – where the range between high and low tides are smallest. Neap tides occur at the first and third moon quarters.

Neritic species – species that reside over the continental shelf.

Niskin water sampler – a device for collecting water.

Nocturnal – relates to fauna that are active at night.

Oil Discharge Monitor (ODM) – measures oil-in-water content and is used as an alert for unintentional discharges.

Oil in water (OIW) – the level of oil content in water, usually expressed in mg/L.

Oil Spill Contingency Plan (OSCP) – a pre-emptive plan for combating unexpected oil spills.

Oligotrophic – an environment that unsuitable for the sustenance of life.

Operations – the period where gas is being extracted, processed and exported.

Organotin compound – a tin to hydrocarbon bonded compound (see Tributyltin).

Oxygen scavengers – used to reduce the oxygen content in air or water to slow the process of corrosion.

Pelagic species – those species that live in the open sea. That is those species whose habitat is at the surface or middle depths of the water body.

Phytoplankton – see Plankton.

Pipe dope - Small quantities of grease applied as a lubricant to the connecting threads of drill strings during drilling. Pipe dope contains potentially toxic heavy metals.

Plankton – microscopic marine animals (zooplankton) or plants (phytoplankton) that drift in the open ocean.

Photic zone – region where light is still available.

Photo-oxidation – oxidation that occurs under the influence of light.

Photopositive – organisms that are attracted to light.

Photosynthesis – the metabolic generation of energy using solar radiation.

Phyla – a classification of organisms used in taxology.

Physico-chemical properties – relating to physical and chemical properties.

Pigging – refers to the practice of using pipeline inspection gauges or ‘pigs’ to perform various operations on a pipeline, such as cleaning and inspection, without stopping the flow of the product in the pipeline.

Polychaetes – marine worms whose bodies consist of a series of segments with bristles along the body.

Primary zone of influence –the geographic location within which the lives and circumstances of people, their families and their communities could be directly affected by the Project.

Produced formation water (PFW) – the water trapped in the oil and rocks and brought to the surface during operations.

Propeller cavitation – As a propeller rotates through the water, regions of low or negative pressure are created at its tips. If and when these negative pressures become sufficiently strong, bubbles (cavities) form. These bubbles are short lived and a sharp pulse of sound is produced as the bubble collapses “cavitation”.

Petroleum production licence – the licence required for offshore petroleum production facilities.

Procedural mitigation measures – establishing and implementing operational procedures to reduce the risk of an impact occurring through actions or activities.

Putrescibles – substances that are liable to spoil.

Receptor – an organism (including humans) that is sensitive to a certain activity.

Redox – reduction-oxidation potential.

Saprogenic – associated with organic materials, resulting from or causing decay.

Satellite telemetry – transmission of information via satellite.

Scale formation – the formation of calcium deposits on the hull of a ship.

Scuppers – deck drain holes.

Seismic survey – a method used to determine subsurface geological structures by emitting soundwaves toward the seabed. Detectors located at the sea surface are used to record the reflected soundwaves.

Shaleshakers – a series of sieves used to remove drill cuttings from the drilling muds (See Drilling muds).

Shorebirds – birds that frequent the edges of water bodies.

Significant impact - The *EPBC Act* defines a 'significant impact' as an impact which is important, notable, or of consequence, having regard to its context or intensity. Whether or not an action is likely to have a significant impact depends upon the sensitivity, value, and quality of the environment which is impacted, and upon the intensity, duration, magnitude and geographic extent of the impacts.

Sites of cultural or heritage significance – areas of land or water that hold significant cultural/heritage importance to a certain group of people.

Socioeconomic impact assessment – an analysis of the likely effects that a change/development will have on a community's way of life.

Spin-off impacts – whereby a project action leads to another form of impact that is not directly related to the project.

Splitter boxes – separates potentially hazardous waste from non-hazardous wastes sending spills or leaks (hazardous) to the slops tank, diverting high volumes of run off water directly overboard.

Spring tides - where the range between high and low tides are largest. Spring tides occur at the second and fourth moon quarters.

Stakeholders – a person or group of persons that is affected by a change and/or holds an interest in the outcomes of a project.

Stakeholder engagement – the act of communicating with stakeholders issues and opportunities regarding a certain activity.

Stochastic analyses – the analysis of random occurrences/variances.

Stratification – layers of water with varying densities that can act as barriers to mixing.

Subsea flow lines – used in the transportation of hydrocarbons from the wells to the processing facility. Subsea flow lines may also be used to reinject water or gas into the reservoir.

Subtidal region – a region that lies just below low tide and is almost always submerged.

Sullage – see Greywater.

The Sunda Arc – a volcanic arc that has produced the islands of Sumatra and Java and the Sunda Strait and the Lesser Sunda Islands. The Sunda Arc poses the greatest tsunami threat to Australia's northwest coast.

Sweet gas – gas that has been treated to remove acid gases such as carbon dioxide and hydrogen sulphide.

Swimbladder – a gas-filled internal organ used to control buoyancy.

Temperature inversion events – where denser, cooler air displaces warmer air and forms a lower layer of cool air.

Thermal oxidation – the incineration/flaring of pollutants.

Thermocline – a layer of rapid temperature change.

Threshold concentration – the level below which no toxic effects would be expected.

Thrusters – propellers that are capable of rotating on a horizontal plane and in turn steer a vessel.

Total Organic Carbon (TOC) – the total amount of organic carbon found in an organic compound. The TOC has been used to describe the seafloor environment surrounding the FLNG facility.

Total Suspended Solids (TSS) – a measurement of water quality that investigates the level of suspended solids in milligrams per litre (turbidity).

Toxicant – a chemical compound that has an effect on organisms.

Traditional Owners – a local descent group of indigenous persons who have common spiritual affiliations to a site and are entitled by indigenous tradition to forage as of right over the land.

Trophic – of or involving the feeding habits or food relationship of different organisms in a food chain.

Tributyltin – the main chemical component of some antifouling paints on vessel hulls that has toxic effects on non-target marine species.

Turbidity – a measure of the degree to which the water looses its transparency due to the presence of suspended particulates.

Turret – the permanent mooring system which allows the FLNG facility to weathervane with the prevailing conditions.

Van Veen benthic grab – a lightweight sampler designed to take large samples in soft bottoms.

Viscosifier – a product for increasing the viscosity of the drilling muds.

Viscosity – a measure of a fluid's resistance to flow. A fluid with low viscosity flows easily.

Volatile – evaporates readily at normal temperatures and pressures.

Wader – wading bird.

Well or well bore – the hole drilled to obtain the gas.

Wellhead – the topmost point of a well and the structure built over it.

Zone of Visual Influence (ZVI) – the area within which the FLNG facility could be viewed by the human eye.

Up-slope direction – direction moving towards the shore.

Zooplankton – see Plankton.

# ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| AGRU | Acid gas removal unit |
| ALARP | As low as reasonably practicable |
| AMDEA | Activated monodiethylamine |
| AMOSC | Australian Marine Oil Spill Centre |
| AMOSPlan | Australian Marine Oil Spill Plan |
| AMSA | Australian Maritime Safety Authority |
| ANZECC | Australian and New Zealand Environment and Conservation Council |
| AOC | Accidentally oil contaminated water |
| API | American Petroleum Institute |
| APPEA | Australian Petroleum Production & Exploration Association |
| AQIS | Australian Quarantine and Inspection Service |
| AUD | Australian dollar |
| AUSREP | Australian ship reporting system |
| BOM | Australian Bureau of Meteorology |
| BTEX | Benzene, toluene, ethylbenzene and xylene |
| CAMBA | China Australia Migratory Bird Agreement |
| CBP | Chlorine by-product |
| CCS | Carbon Capture and Storage |
| Chl-a | Chlorophyll-a |
| CMST | Centre for Marine Science and Technology (Curtin Univeristy) |
| $CO_2$ | Carbon dioxide |
| $CO_2$-e | Carbon dioxide equivalent |
| COC | Continuously oil contaminated water |
| CPRS | Carbon Pollution Reduction Scheme |
| CSIRO | Commonwealth Scientific and Industrial Research Organisation |
| CTD | Conductivity, temperature and pressure (Depth) |
| DEWHA | Commonwealth Department of Water, Heritage and the Environment |
| DMP | Department of Mines and Petroleum |
| DMR | Dual Mixed Refrigerant |
| DO | Dissolved oxygen |
| DoIR | Western Australian Department of Industry and Resources |
| DRET | Department of Resources, Energy and Tourism |
| DSD | Department of State Development |
| EAA | East Asian-Australasian Flyway |
| EEO | Energy efficiency and opportunities |
| EFG | End flash gas |
| EIS | Environmental Impact Statement |
| EMMP | Environmental Monitoring and Management Plan |
| EMS | Environmental Management System |
| ENSO | El Niño-Southern Oscillation |
| EP | Environment Plan |

| | |
|---|---|
| EPA | Environment Protection Authority |
| EPBC Act | Environmental Protection and Biodiversity Conservation Act |
| EPC | Engineering, Procurement and Construction |
| EPT | Environmental performance target |
| ERM | Environmental Resources Management Australia |
| ERP | Emergency response plan |
| ESD | Ecologically sustainable development |
| ESHIA | Environmental, Social, and Health Impact Assessment |
| ESHMP | Environmental, Social and Health Management Plan |
| FEED | Front end engineering design |
| FID | Final investment decision |
| FIFO | Fly in, fly out |
| FLNG | Floating liquified natural gas |
| FPSO | Floating production, storage and offloading |
| FRC | Free residual chlorine |
| FY | Financial year |
| GDP | Gross domestic product |
| GEMSS | Generalized Environmental Modelling System for Surface Waters |
| GES | Global Environmental Standards |
| GHG | Greenhouse gases |
| $H_2S$ | Hydrogen sulphide |
| HEMP | Hazards and Effects Management Process |
| HP | High pressure (fuel gas) |
| HSE | Health, Safety and Environment |
| HSE-MS | Health Safety and Environment Management System |
| IFC | International Finance Corporation |
| IMO | International Maritime Organisation |
| IMS | Introduced marine species |
| IPP | Industry Participation Plan |
| ISO | International Organisation for Standardisation |
| ITF | Indo-Pacific Through Flow |
| IUCN | International Union for Conservation of Nature |
| JAMBA | Japan Australia Migratory Bird Agreement |
| KLC | Kimberley Land Council |
| LNG | Liquefied natural gas |
| LOR | Limit of reporting |
| LPG | Liquid petroleum gas |
| MARPOL | Marine pollution |
| MCAA | Monochloroacetic acid |
| MCHE | Main cryogenic heat exchanger |
| MEG | Mono-Ethylene Glycol |
| MODU | Mobile offshore drilling unit |
| MOSAG | Multifunctional Oil Spill Advisory Group |

| | |
|---|---|
| MOU Box | Memorandum of Understanding Box |
| MPPE | Macro porous polymer extraction |
| MSDS | Material safety data sheets |
| MW | Megawatts |
| NADF | Non-aqueous drilling fluids |
| NATA | National Association of Testing Authorities |
| NDT | Northern Development Taskforce |
| NES | National Environmental Significance |
| NGERS | National Greenhouse and Energy Reporting System |
| NGL | Natural gas liquids |
| NGO | Non-government organisation |
| NOPSA | National Offshore Petroleum Safety Authority |
| NORM | Naturally occurring radioactive materials |
| NOx | Nitrogen oxides |
| NPDs | Naphtalenes, phenanthrenes, dibenzothiophenes |
| NT | Northern Territory |
| NWS JEMS | North West Shelf Joint Environmental Management Study |
| NWS | North West Shelf |
| NWSMU | North West Shelf Management Unit |
| OBM | Oil based muds |
| ODM | Oil discharge monitor |
| OECD | Organisation from Economic Cooperation and Development |
| OHS | Occupational health and safety |
| OIM | Offshore installation manager |
| OIW | Oil in water |
| OPGGS Act | Offshore Petroleum and Greenhouse Gas Storage Act 2006 |
| OSCP | Oil Spill Contingency Plan |
| P(SL)A | *Petroleum (Submerged Lands) Act* |
| PAHs | Polyaromoatic hydrocarbons |
| PFW | Produced formation water |
| PMR | Pre-cool mixed refrigerant |
| ROKAMBA | Republic of Korea Australia Migratory Bird Agreement |
| ROV | Remotely Operated Vehicle |
| SBM | Synthetic based mud |
| SDA | Shell Development Australia |
| SEP | Stakeholder Engagement Plan |
| SOx | Sulphur oxides |
| SPP | Social Performance Plan |
| TBT | Tributyltin |
| TECOP | Technical, Environmental, Commercial, Organisational and Political |
| TEG | Tetra-ethylene glycol |
| TKN | Total Kjeldahl Nitrogen |
| TOC | Total organic carbon |

| | |
|---|---|
| TPH | Total petroleum hydrocarbons |
| TSS | Total suspended solids |
| UNCLOS | United Nations Convention on the Law of the Sea 1982 |
| VOC | Volatile organic compounds |
| WA | Western Australia |
| WB | World Bank |
| WBM | Water based mud |
| WWF | World Wildlife Fund |
| WWTP | Wastewater treatment plant |
| ZVI | Zone of Visual Influence |

# MEASUREMENTS

| | |
|---|---|
| µm | micrometre |
| bbl | barrel |
| dB (re 1 uPa) | decibels referenced at one micro Pascal |
| ha | hectare |
| hr | hour |
| Hz | hertz |
| kHz | kilohertz |
| km | kilometre |
| kt | knots |
| ktpa | kilo-tonnes per annum |
| m | metre |
| mg/L | milligrams per litre |
| MMscf | million standard cubic feet |
| mS cm$^{-1}$ | milli Siemens per centimetre |
| MT | metric ton |
| mtpa | million tonnes per annum |
| mV | mega Volts |
| ng/Sm$^{3}$ | nanograms per Siemens cubic metre |
| nm | nautical mile |
| pH | potential of hydrogen |
| PJ | petajoules |
| ppm | parts per million |
| s | second |
| scfd | Standard Cubic Feet/Day |
| TJ | terajoules |
| tpsd | tonnes per stream day |
| tpa | tonnes per annum |
| tcf | trillion cubic feet |

# APPENDIX C

# *DRAFT EIS GUIDELINES CROSS REFERENCE TABLE*

| EIS Chapter | Executive Summary |
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| Exec Summary | An executive summary that outlines the key findings of the EIS should be provided. The executive summary should briefly: |
| Exec Summary | State the background and the need for the proposal; |
| Exec Summary | Discuss alternatives to the proposal and the reasons for selecting the preferred option and rejecting the alternatives; |
| Exec Summary | Summarise the pre-operational, operational and post-operational activities associated with putting the proposal into practice; |
| Exec Summary | State the proposed schedule for key activities and the expected duration of the proposal; |
| Exec Summary | Provide an overview of the existing regional and local environments, summarising the features of the physical, biological, social and economic environment relating to the proposal and associated activities; |
| Exec Summary | Describe the expected, likely and potential impacts of the proposal on the environment during pre-operational, operational and post-operational phases; |
| Exec Summary | Summarise the environmental protection measures and safeguards, monitoring and decommissioning procedures to be implemented for the proposal; |
| Exec Summary | Provide an outline of the environmental record of Shell Development (Australia) Pty Ltd. |
| | **General Information** |
| | A description of the background of the proposal (or action) including: |
| 1.1 | The title of the action; |
| 1.6 | The full name and postal address of the designated proponent; |
| 1.3 & 4.2.2 | A clear outline of the objectives of the action; |
| 1.2 | The location of the action; |
| 1.8 | The background to the development of the action; |
| 4.5 | How the action relates to any other actions (of which the proponent should reasonably be aware) that have been, or are being, taken or that have been approved in the region affected by the action; |
| 1.8 | The current status of the action; |
| 4.3 | The consequences of not proceeding with the action; |
| 1.4 & 2.3.2 | A brief explanation of the scope, structure and legislative basis of the EIS; |
| 2.3.2 | The specific EPBC matters affected by the action, and any additional approvals needed under the EPBC Act; and |
| 2.1, 2.2, 2.3.2, 2.3.3 & 2.4 | A description of government planning policies and statutory controls which will influence the Project. All applicable jurisdictions and areas of responsible authorities within the area should be listed and shown on maps at appropriate scales. |
| | **Consultation** |
| | Provide details of any consultation about the action, including: |
| 3.2 | Consultation that has already taken place; |
| 3.3 & 3.4 | If there has been consultation about the proposed action - any documented response to, or result of, the consultation; and |
| 3.5 | Any further proposed consultation about potential impacts of the action |

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| 3.2, 3.3 & 3.4 | Identify and consult with affected parties and communities, including any native title claimants and relevant indigenous stakeholders, and describe their views. Describe consultation methodologies adopted and skills and techniques used to ensure effective communication of the nature and detail of the proposal. This should include the means used to identify concerns and to gauge and negotiate mitigation strategies. It is recommended that an open community consultation process be carried out, in addition to the legislated environmental impact assessment process. |
| | **Alternatives to the Proposal** |
| | This section should describe, to the extent reasonably practicable, any prudent and feasible alternatives to the action, including: |
| 4.3.1 | If relevant, the alternative of taking no action; |
| 4.3.2 | A comparative description of the adverse and beneficial impacts of each alternative infrastructure and location on the matters protected by the controlling provisions for the action; |
| 4.3.1 | Sufficient detail should be provided to make clear why any alternative is preferred to another; |
| 4.3.1 | The reasons for choice of the preferred location and option should be explained, including a comparison of the adverse and beneficial effects used as a basis for selection, and compliance with the objectives of the EPBC Act (including ESD principles); |
| 4.3.1 | The advantages and disadvantages of alternatives when considered against relevant matters protected under the EPBC Act must be specifically addressed; |
| 4.3.1 | Short, medium and long-term advantages and disadvantages of the options should be considered. |
| | **The Proposal Description** |
| 4.6-4.8 | This section should describe the proposal in sufficient detail to allow an understanding of all stages and components, and assist in determining potential environmental impacts associated with the proposal. Those elements with potential implications for matters protected under Part 3 of the EPBC Act must be highlighted. |
| 1, 1.2, 4.5-4.8 | The description should include the use of aerial photographs, maps, figures and diagrams, where appropriate. A general location map should be provided that illustrates the distances of the Notional Development Areas and any proposed facilities from the shoreline of the Kimberley and Broome. The map should include the location of known potential future expansions or new developments by Shell and other proponents in the vicinity, such as the Inpex Ichthys Development. Reference should be made to detailed technical information in appendices where relevant. |
| | **Project Details** |
| | The description of the action should cover: |
| 2.5, 2.7, 2.8, 4.3 & 7.4 | The environmental principles on which the action will be managed; |
| | All the components of the action including: |
| 1.2 | a. Site selection; |
| 4.6.2 & 4.6.3 | b. Site preparation (including any action that may result in the modification of the natural surface of the sea-bed); |
| 4.3 | c. Development options; |
| 4.6, 4.8.1 & 4.8.2 | d. Construction; |
| 4.8.3 | e. Commissioning; |
| 4.8.4 | f. Operation; |
| 4.2.1 | g. Related onshore activities, and |
| 4.8.6 | h. Decommissioning. |
| 1.2 & 4.2 | The location of works to be undertaken, structures to be built or other elements of the action that may have relevant impacts. This should include (as appropriate): |
| 1.2 & 4.2 | a. Production wells and any water or gas disposal wells; |
| 1.2 & 4.2 | b. Sub-sea well-head completions and sub-sea pipelines; |

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| 1.2 & 4.2 | c. Processing facilities and offloading facilities; |
| 4.2.1 | d. Proposed locations of any port or facility for vessel based supply of offshore facilities. |
| 4.6 - 4.8 | How the works are to be undertaken and design parameters for those aspects of the structures or elements of the action that may have relevant impacts. This should include: |
| 4.2.2 | a. An explanation of the anticipated timetable for the construction, commissioning, operation and decommissioning; |
| 4.6-4.8 | b. Details of the construction, commissioning, operational and decommissioning equipment to be used; |
| 4.6-4.8 | c. Details of the operations of the proposal throughout its lifespan, including details of anticipated exclusion zones required for the project; |
| 6.6-6.8 | Origin and nature of solid, liquid and gaseous waste produced during the construction, commissioning, operations and decommissioning phases, including; |
| 6.6-6.8 | a. Volumes of all anticipated solid, liquid and gaseous waste produced including produced formation water and atmospheric emissions of pollutants, such as oxides of nitrogen, sulphur dioxide and volatile organic compounds throughout the life cycle of the project. The proponent should quantify all anticipated emissions throughout the life cycle of the project. All emissions sources (combustion, process, fugitive etc) should be discussed; |
| 6.8 & 6.13 | b. Estimates of the maximum emissions of greenhouse gases resulting from the proposal as specified in Attachment 3; |
| 6.6.4, 6.7.6 & 6.8.6 | c. As far as predictable, proposals for waste reduction, treatment, reuse and disposal; |
| 6.6.4 & 6.6.5 | Information on other potentially hazardous materials to be used throughout the proposal life, including methods of transport, storage and disposal; and |
| 4.7.12 & 7.5.3 | Number and source of staff and training for staff involved for all phases of the project. |
| | **Decommissioning** |
| 4.8.6 | This section should outline the planned decommissioning of the proposal and address the decommissioning objectives and goals. |
| 4.8.6, 6, 6.3.3, 6.4.6, 6.5.6 & 6.7.5 | The discussion on decommissioning may be best addressed in table form, identifying the original environment, procedures for decommissioning and rehabilitation, time frame and planned final environment. This section should also identify the time scale for determination of compliance with, and progressive or final release from requirements of the appropriate authorities. Information which should also be addressed includes: |
| 6 & 7 | Integration of the decommissioning and rehabilitation program with design, construction and operation; |
| 4.8.6 & 6.3.3 | Options for the removal of all infrastructure; and |
| 4.8.6 | Final use for the project area, taking into account environmental and economic regime of the region. |
| | **The Existing Environment** |
| 5 | This section should provide a description of the project area including its marine physiography, flora and fauna, and relevant socio-economic considerations. It should link the existing environment to the proposal's requirements, potential impacts, as well as proposed mitigation measures throughout construction, operation and decommissioning. |
| | **Physical Environment** |
| | This section should describe the following elements of the environment within all Notional Development Areas and Zones: |
| 5.2.2 | Climate and atmospheric characteristics (air quality, seasonal temperatures, humidity, wind, evaporation and rainfall); |
| 5.2.3-5.2.5 | Oceanographic conditions, especially those which may have a bearing on the proposal. Include information on seasonal variation, waves, tides, currents, water salinity, clarity, temperature and depths. Discuss frequency and severity of extreme weather conditions, such as storms and cyclones, for the 2, 10 and 100 year conditions; |

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| 5.2.4, 5.2.6 & 5.2.7 | Bathymetric and geotechnical information, any proposed flowline routes, and any other affected areas. Discuss the seismic stability of these areas; |
| 5.3 | Flora and fauna, including baseline information/maps on communities and individual species types in the immediate and surrounding areas that may be subject to likely or potential impacts, as determined by literature search, survey and sampling programs. |
| | The EIS should provide an overall evaluation of the flora and fauna communities identified above with reference to: |
| 5.3.6 | Habitat values in a local, regional and national context; |
| 5.3 & 5.4 | Presence of endemic species; |
| 5.3 & 5.4 | Local and regional representation; |
| 5.3 & 5.4 | Conservation and biodiversity values; |
| 5.7 | Economic and cultural values of species; |
| 5.3 & 5.4 | Migratory species, and |
| 5.3 | Unique habitats. |
| | Particular attention should be given to the: |
| 5.4 | The likely presence of any unique, rare, threatened, endangered or vulnerable flora and fauna species and communities or listed migratory cetaceans, listed marine species (under Part 4 of the EPBC Act). The EIS should also consider smaller cetaceans such as snub-fin and humpback dolphins occurring in the area. An evaluation of the significance, occurrence (including conservation status, distribution, population viability and habitat requirements) should also be included in this section. Particular reference should be made to species and ecological communities listed as threatened under the EPBC Act (but should not be limited to such species and communities) that (through analysis) may potentially be disturbed by the project. |
| | Species to be addressed in the EIS must include, but not be limited to; |
| 5.4.1 | Humpback whale *Megaptera novaengliae* |
| 5.4.2 | Blue whale *Balaenoptera musculus* |
| 5.4.6 | Green turtle *Chelonia mydas* |
| 5.4.8 | Whale Shark *Orcaella brevirostris* |
| 5.4.7 | Flatback turtle *Natator depressus* |
| 5.4.9 | Streaked Shearwater *Calonectris leucomelas (Puffinus leucomelas)* |
| 5.4.10 | All migratory shorebird species listed under JAMBA, CAMBA and ROKAMBA |
| 5.4.11 & 5.4.12 | All other listed migratory cetaceans and relevant listed threatened species should also be addressed. |
| 5.3, 5.3.5 | A broader description of the biodiversity and biogeography of the receiving environment should be included. Sensitive environments should be identified along with key ecological relationships and interdependencies (eg coral spawning, fish spawning aggregations, flora and fauna relationships etc) with particular attention to the environment around Browse Island and Surrounds. |
| 5.5 & 5.6 | The extent of existing disturbance to flora and fauna, and the incidence of introduced pest species should be discussed. |
| 5.3.6 | Identification of any existing or proposed reserves in, or neighbouring, the project and their status. Include the reserve characteristics, status, IUCN category, and values and relevant management strategies. |
| | **Socio-Economic and Cultural Environment** |
| | Discussion of the socio-economic and cultural environment should provide: |
| 5.7 | A description of all existing uses and users of the Notional Development Areas and Zones of the sea and the sea floor. Include discussion of scientific research, tourism, commercial, traditional and recreational fishing (where relevant), military areas and shipping routes; |
| 2.3.2, 2.3.3 & 2.4 | A description of government planning policies and statutory controls which will influence the project, surrounding areas of future, planned and current use. All applicable jurisdictions and areas of responsible authorities within the area should be listed and shown on maps at appropriate scales. |

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| 5.7 | Any places with known or anticipated heritage, social or cultural values, such that they have been recognised with listing or recording under relevant Commonwealth legislation or are anticipated to be listed under such legislation; and |
| 5.7.5 | A description of any historic shipwrecks within the area pursuant to the Historic Shipwrecks Act 1976, including locations. |
| | **Relevant Impacts of the Action** |
| | This section must include: |
| 6 | A description of all relevant potential impacts of the action; |
| 6 | A detailed assessment of the nature and extent of the potential short term and long term relevant impacts including on listed threatened species and communities and listed migratory species and on listed marine species (under part 4 of the EPBC Act) including whales and other cetaceans (under part 3 of the EPBC Act); |
| 7 | A statement whether any relevant potential impacts are likely to be unknown, unpredictable or irreversible; |
| 6 | Analysis of the significance of the relevant potential impacts; and |
| 6 | Any technical data, any sources of authority, and other information used or needed to make a detailed assessment of the relevant potential impacts. Reliability of forecasts and predictions, confidence limits and margins of error should be indicated as appropriate. |
| 6 | In discussing the potential impacts of the proposal, particular emphasis is to be given to providing details on the potential impacts to the receiving environment's unique flora and fauna as identified and to any protected areas in the vicinity. |
| 6.12 | Cumulative impacts, where potential project impacts are in addition to existing impacts of other activities, (including those known potential future expansions or developments by Shell and other proponents in the vicinity), should also be identified and addressed. Where relevant to the potential impact, risk assessment should be conducted and documented. The risk evaluation should include known potential future expansions or developments by Shell and other proponents. |
| | In particular, the EIS should address the matters described in the following paragraphs. |
| | **General Impacts** |
| 6 | Discuss the effects of the overall action on the functioning of the marine environment, including effects to the marine environment surrounding the proposed development; |
| 6 | Identify the source of potential impacts, e.g. artificial lighting, noise, ship-movements; |
| 6.9.2 & 6.9.3 | Discuss potential impacts which may arise through the transportation, storage and use of dangerous goods (if any), fuels and chemicals, such as accidental spills; |
| 6.6, 6.7 & 6.8 | Consider potential impacts caused by the need for waste disposal and management of emissions, refuse, effluent and hazardous waste (if any); |
| 6.9, 4.4.5 & 5.2.3 | In discussing potential impacts, consider how the interaction of extreme environmental events and any related safety response may impact on the environment; and |
| 6 | Consider potential impacts throughout the life of the proposal - from construction, commissioning and operation through to decommissioning. |
| | **Physical and Biodiversity Impacts** |
| 6.3 | Consider potential impacts to the sea floor through anchoring and direct placement, sediment disturbance, as well as any impacts of removal. The zone of likely seabed disturbance should be identified. |
| 6 | Consider potential impacts to fauna and flora species (composition and population densities), considering changes to overall communities, community types, propagation of species and potential barriers to species movement or gene flow. |
| 6 | Consider potential impacts to macrobenthic species, fish and larger marine fauna species (composition and population densities), including changes to communities, breeding success, habitat, potential barriers or disturbances to migration or migratory patterns and other wildlife movements. |
| 6 | Consider potential impacts, if any, on rare, threatened, or otherwise valuable flora and fauna, communities (particularly listed threatened species and communities, listed marine species including whales and other cetaceans and listed migratory species) and habitat, conservation areas and protected areas, in particular Browe Island and Surrounds. |

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| 6.3 | Consider the potential impacts on cetaceans and marine turtles from increased ship movement from facility and the potential for ship strike; |
| 6.4 | Consider the potential impacts from anticipated illumination of the facility and flaring on seabirds, marine turtles and other migratory species, including bird strike, nesting and disorientation. |
| 6.5 | Consider the potential impacts, from underwater noise during construction and operation (including associated shipping and support vessels) and what levels may be received in the surrounding environment including nearby feeding/calving/resting areas; |
| 6.5 | Provide a full evaluation of the frequency and amplitude of all generated noises including any temporal patterns that may be expected. Modelling of the likely extent of noise propagation into the marine environment and a strategy to reduce/minimise mechanical, low frequency noise generated to minimise adverse effects on marine biota; |
| 6.4.7 & 7 | Outline details of a strategy to reduce/eliminate illumination of the proposed facility and reduce/minimise flaring, especially during migratory period of birds and the hatching periods of turtles, particularly on dark nights, and |
| 6.9.5 | Consider potential impacts arising from the introduction and/or spread of exotic pest species. |
| | **Air and Water Pollution Impacts** |
| 6.8 | As a minimum, model emissions of NOx, $SO_2$, CO, VOCs, particulates and toxics and discuss the potential impact of solid, liquid and gaseous emissions and wasted produced by the operation, including greenhouse gas emissions and the potential for geosequestration; |
| 6.6.4, 6.7.6 & 7 | Outline a strategy to reduce/minimise the discharge of sewage, galley scraps and bilge water into the marine environment. Include discussion on the eventual fate of the waste and what effect the discharge of treated sewage and grey water into nutrient-poor tropical waters will have on the marine environment; |
| 6.7 | Provide a full evaluation of Produced Formation Water (PFW) discharge. Include anticipated composition of PFW, modelling of the mixing zones and discuss the potential impacts of discharge, including the spatial and temporal impacts of discharged PFW on marine biota. Consider the potential impacts of water clarity, salinity and temperature changes with specific reference to stratification of the water column. Discuss potential impacts related to the discharge of sewage, sullage and other production related discharges from the Proposal. |
| 6.9.2 | Discuss impacts of potential spillage of hydrocarbons related to construction, production, storage and shipping. Modelling of spills should take into account seasonal variations throughout the year. Modelling should also take into account proximity to sensitive marine areas, in particular Browse Island and Surrounds. The evaluation of the potential impacts of oil spills is to be carried out using a thorough risk-assessment methodology. |
| 4.7.8, 6.7.2, 6.7.3 & 6.7.4 | Information on the discharge of warm water, the extent of dispersion and mixing of the water, the concentrations of sodium hypochlorite and the potential effects of water extraction from depth for cooling purposes. |
| | **Socio-Economic and Cultural Impacts** |
| | Section 528 of the EPBC Act defines the environment as including: |
| | (a) ecosystems and their constituent parts, including people and communities; and |
| | (b) natural and physical resources; and |
| | (c) the qualities and characteristics of locations, places and areas; and |
| | (d) the social, economic and cultural aspects of a thing mentioned in paragraph (a), (b) or (c). |
| | Discussion of the potential socio-economic and cultural impacts of the proposal as they relate to the above, this should include a description and discussion of potential impacts (both positive and negative): |
| 6.10.2 | Caused by any short, medium and long-term changes, interruption, alteration or curtailment of activities and uses of the area due to the proposed action, including changes affecting traditional uses, recreational uses, conservation and tourism; |
| 6.10.2 | On sites of historical or cultural significance, including places entered in the Register of the National Estate and other significant sites and unknown or unsurveyed sites; |
| 6.10.2 | On existing industry and commerce affected by the proposal; |
| 6.11.2 | To employees in terms of workplace health and safety; |

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| 6.10.2 | On shipping and any potential traffic hazards; |
| 6.10.2 | On visual and aesthetic values, impacts to tourism and access for conservation purposes; and |
| 6.10.2 | To historic shipwrecks in the area, including potential impacts on, as yet, unknown shipwrecks or those in unsurveyed areas |
| | **Safeguards, Mitigation Measures and Monitoring** |
| | **Safeguards and Mitigation Measures** |
| | This section should explain the proposed safeguards and mitigation measures to be put in place for every phase of the proposed action to deal with relevant (potential and anticipated) impacts of the action. This must include: |
| 7 | A consolidated list of mitigation measures proposed to be undertaken to prevent, minimise or treat the relevant potential impacts of the action (impacts upon matters protected under Part 3 of the EPBC Act and as discussed in Section 6 ), including any mitigation measures proposed to be taken by State governments, local governments or the proponent; |
| 6 | A description, and an assessment of the expected or predicted effectiveness of, the mitigation measures; |
| 6 & 7 | Any statutory or policy basis for the mitigation measures; and |
| 6 & 7 | The name of the agency responsible for endorsing or approving each mitigation measure or monitoring program. |
| | Particular focus should be given to: |
| 8 | Determining factors in the planning of the proposal so as to avoid damage to the environment; |
| 6 & 7 | Measures to avoid or minimise damage to the marine environment; |
| 6 & 7 | Measures to avoid or minimise disturbance to fauna found around and within the proposal area (particularly listed threatened species and listed migratory species); |
| 6.8.6 & 7 | Measures to minimise atmospheric emissions, with particular reference to greenhouse emissions (refer to Attachment 3 for more detail); and |
| 7.5 | Staff training, including training in relation to environmental issues. |
| | **Monitoring and Reporting** |
| 2.4.6, 5, 5.1.1, 5.1.2 & 7.6 | Appropriate baseline data requirements will be identified as part of the EIS to form the basis for baseline measurement and ongoing monitoring of environmental parameters. It must be demonstrated that the proposed methods for baseline measurements and subsequent monitoring are scientifically and statistically sound. This section should identify parameters to be monitored and their response trigger values and response activities. |
| 6 & 7 | This section will also identify and describe monitoring programs, procedural and compliance audit programs and reporting requirements and arrangements which will demonstrate the effectiveness of management and monitoring (linked to EMS/EMP procedures - see below). |
| 7.6 | The proponent must, in addition to outlining proposed programs, clearly identify what is to be monitored and why. Monitoring programs should be designed to provide objective evidence regarding activities associated with the proposal and if these activities are adversely impacting on the environment in the short, medium and long term. |
| | Monitoring programs should demonstrate consideration of: |
| 7.6 | Ecosystems and habitats, flora and fauna (particularly listed threatened species and listed migratory species and Browse Island and Surrounds), and water quality issues; |
| 6 | Measuring the effectiveness of rehabilitation measures; |
| 7.6 | Management and operation of facilities; |
| 6 | Documenting the difference between predicted and actual impacts; |
| 6 | Methods for identification of non-predicted impacts and appropriate reporting and remedial measures; |
| 6 | Application and effectiveness of emergency and contingency plans; and |
| 6 | Review of consultation and management arrangements with regulatory authorities and the community. |
| 6 | Identification of any negative impacts upon the effectiveness of community infrastructure and services. |

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| | **Offsets** |
| 7.10 | Environmental offsets are broadly understood to mean actions taken by developers to compensate for the adverse impacts of their developments. The Australian Government defines environmental offsets as 'actions taken outside a development site that compensate for the impacts of the development - including direct, indirect or consequential impact'. Environmental offsets provide an opportunity to achieve long-term conservation outcomes whilst providing flexibility for proponents seeking to undertake development which will have environmental impacts. |
| 7.10 | This section should outline plans to offset the potential impacts of the action. Environmental offsets may be appropriate when they:<br>• are necessary or convenient to protect or repair impacts to a protected matter - i.e. a matter of national environmental significance or the environment more broadly;<br>• relate specifically to the matter (for example, species) being impacted; and<br>• seek to ensure that the health, diversity and productivity of the environment is maintained or enhanced. |
| | **Environmental Management System** |
| 2.4.5, 2.4.6 & 7 | The overall environmental management philosophy to be applied to the areas affected by the proposal is to be enunciated. An outline of the proposed Environmental Management System (EMS) is to be contained in the EIS document. It should include summary details of audit protocols and reporting procedures. |
| 2.4.5, 2.4.6 & 7 | Reference should be made within the outline of the EMS to consultation, relevant legislation, standards adopted, safeguards planned, management practices, monitoring programs and emergency contingency plans, including the management of facilities in the event of cyclones. Management plans to manage impacts on listed threatened species and communities and listed migratory species and on listed marine species (under part 4 of the EPBC Act) including whales and other cetaceans (under part 3 of the EPBC Act). |
| | EMP outlines are to be presented in this section of EIS. It should, as a minimum, detail: |
| 2.4.5, 2.4.6 & 7.6 | Monitoring arrangements; |
| 2.4.5, 2.4.6 & 7.6 | Reporting arrangements; and |
| 2.4.5, 2.4.6 & 7.6 | Feedback of monitoring results into project management. |
| 2.4.5 & 2.4.6 | Details of requirements for the preparation of Environmental Management Plans under other relevant legislation should be provided. In an effort to minimise duplication, areas of consistency between separate requirements should also be highlighted. |
| | **Other Approvals and Conditions** |
| | This must include the following: |
| 2 | A description of any approval that has been obtained from a State, Territory or Commonwealth agency or authority (other than an approval under the Act), including any conditions that apply to the action; |
| 2 | A statement identifying any additional approval that is required; |
| 2 | A description of the monitoring, enforcement and review procedures that apply, or are proposed to apply, to the action. |
| 2 | Details of any local or State government planning scheme, or plan or policy under any local or State government planning system (including licensing and permitting requirements) that deals with the proposed action, including: |
| N/A | a. What environmental assessment of the proposed action has been, or is being, carried out under the scheme, plan or policy; |
| N/A | b. How the scheme provides for the prevention, minimisation and management of any relevant potential impacts. |
| | **Environmental Record** |
| 1.7 | The environmental record of the person proposing to take the action must be provided. This should include details of any proceedings under a Commonwealth, State or Territory law for the protection of the environment or the conservation and sustainable use of natural resources against the person proposing to take the action. If the person proposing to take the action is a corporation, details of the corporation's environmental policy and planning framework must be provided. |
| 1.7 | Information relating to the persons environmental record should also include any accreditations (for example ISO 14001), environmental awards, and other recognition for environmental performance. |

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| | **Conclusion** |
| 8 | An overall conclusion as to the environmental acceptability of the proposal should be provided, including discussion on compliance with the objectives and requirements of the EPBC Act including the principles of ESD (see Attachment 2). Reasons justifying undertaking the proposal in the manner proposed should be outlined. The conclusion should highlight measures proposed or required by way of mitigating any unavoidable impacts on the environment. |
| | **Information Sources** |
| Information Sources | This section will describe consultations and studies undertaken in the course of proposal formulation and preparation of the draft EIS, and sources of information and technical data. For information given the section must state: |
| Information Sources | The source of the information; and |
| Information Sources | How recent the information is; and |
| Information Sources | How the reliability of the information was tested; and |
| Information Sources | What uncertainties (if any) are in the information? |
| Information Sources | Any further or ongoing consultations or studies should be outlined here. |
| | **Reference List and Bibliography** |
| References | This should be accurate and concise and include the address of any internet pages used as data sources. |
| | **Appendices and Glossary** |
| References | Detailed technical information studies or investigations necessary to support the main text of the EIS, but not suitable for inclusion in the main text should be included as appendices; for example, detailed technical or statistical information, maps, risk assessment, baseline data, supplementary reports etc. A copy of the Guidelines should also be included. A glossary defining technical terms and abbreviations used in the text should be included to assist the general reader. |
| | **Additional Social and Economic Matters** |
| 6.10 | Section 136(1)(b) of the EPBC Act requires the Minister for the Environment, Heritage and the Arts to consider economic and social matters when deciding whether to grant approval to the proposed action under Part 9 of the EPBC Act. The requirements under s136(1)(b) encompass a broader range of matters that may be considered than those addressed during the assessment of the potential impacts of a controlled action. Accordingly, information should be provided on the broad social and economic impacts (positive or negative) of the proposal for the purposes of the Part 9 decision on approval.<br>As the matters protected by the controlling provisions for this action include "the environment", there is the potential for an overlap between the information provided in response to this, and the information requested in the main body of the guidelines in relation to social, economic and cultural aspects within the definition of environment. The latter set of information need not be repeated if it will be contained in the body of the EIS. |
| | **Appendix 3: Greenhouse Gas Emissions** |
| | **1. Inventory of annual emissions**<br>The proponent must provide data on maximum annual emissions of the six greenhouse gases listed in the Kyoto Protocol (carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride). This includes both on-site (Scope 1) and upstream (Scope 2) emissions, as such all operational boundaries should be established including any on-shore development where relevant. The inventory should include: |
| 6.8.2 | (a) an estimate of emissions on a gas by gas basis; |
| Table 6.30 | (b) a summary table of emissions on a gas by gas basis;<br>(c) a summary table listing emissions on a carbon dioxide equivalent basis; and |
| 4.4.2, Table 6.30 | (d) a table which includes gross emissions, emission reduction due to both offsets and mitigation, and net emissions. |
| N/A | As far as is practicable an inventory of cumulative emissions should be included (with regards to known potential future expansions or developments by Shell and other proponents in the vicinity |

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| 4.4.2 | **2. Mitigation**<br>The proponent must include a full description of mitigation measures, including analysis of a full range of alternatives to the proposed project. This should include methods by which greenhouse gas emissions could be mitigated, including:<br>(a) analysis of the likely greenhouse gas reductions as a result of mitigation efforts (to the same level of detail as described in the section 1.1 above);<br>(b) analysis of costs, both financial and output related, of mitigation; and<br>(c) identification of any relevant voluntary partnerships between government and the proponent; such as Greenhouse Challenge and their links to mitigation. |
| 6.8.2 | **3. Methodologies**<br>The proponent must identify, in a transparent manner, the methodology used in making the estimate. In preparing estimates:<br>(a) the most recent National Greenhouse Gas Inventory (NGGI) methodology should be used (http://www.greenhouse.gov.au/inventory/index.html);<br>(b) if the relevant industry is not covered by the NGGI methodology, IPCC (Intergovernmental Panel on Climate Change) methodology should be substituted (http://www.ipcc.ch/pub/guide.htm); or<br>(c) if no methodology exists in either format, a methodology reflecting the principles of the NGGI and IPCC will be developed and agreed by the proponent and the Department of the Environment, Water, Heritage and the Arts. Uncertainty in variables and parameters from the methodologies used should be quantified and reported. |
| | **4. Supporting Data**<br>The following supporting data must be provided: |
| 6.8.2 | (a) the proponent must provide details on the emission factors used, and an explanation where a proponent chooses to use alternative emission factors to that provided in the methodology. |
| Figure 6.18 | (b) the project's emission factors need to be compared with similar projects, including both Australian and international best practice. This analysis should include projects that use alternative fuel sources, processes, and technologies. |
| 4.4.2 | **5. Offsets**<br>The proponent should provide information on the range of offsets (eg sinks or off-site energy efficiency measures) that may be pursued. The following information should be provided:<br>(a) the proponent must provide details on the emission factors used, and an explanation where a proponent chooses to use alternative emission factors to that provided in the methodology.<br>(b) description of proposed offsets and a qualitative assessment of their impact on other matters of environmental, economic, or social significance; and<br>(c) analysis of costs, both financial and other related to offsets. |