Ichthys Gas Field Development Project

DRAFT ENVIRONMENTAL IMPACT STATEMENT

Ichthys Gas Field Development Project: draft environmental impact statement

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The Draft EIS has been prepared for this purpose only, and no one other than the ministers and their delegated representatives should rely on the information contained in the Draft EIS to make any decision.

In preparing the Draft EIS, INPEX has relied on information provided by specialist consultants, government agencies and other third parties identified in the document. INPEX has not verified the accuracy or completeness of this information except where expressly acknowledged in the Draft EIS.

INPEX

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Invitation to comment

All members of the public, businesses and interest groups are invited to comment on this Draft Environmental Impact Statement (Draft EIS).

This document presents the case for the environmental acceptability of the Ichthys Gas Field Development Project. The Project proposes to construct offshore extraction and processing facilities in the Browse Basin off the Western Australian coast, a subsea pipeline to onshore processing facilities at Blaydin Point in Darwin Harbour, and product offloading facilities, including a jetty and a shipping channel, adjacent to Blaydin Point. The Project will produce around 8.4 million tonnes of liquefied natural gas per annum, together with liquefied petroleum gases and condensate as secondary products.

The proposal is being jointly assessed by the Australian and Northern Territory governments under the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth) and the *Environmental Assessment Act* (NT) respectively.

This Draft EIS is available for public review and comment for a period of eight weeks, which is advertised in the national and Northern Territory press. This period will take into account public holidays in both the Australian Capital Territory and the Northern Territory.

HOW TO MAKE A SUBMISSION

A submission may include comment, additional information, or an opinion relevant to the information provided in the Draft EIS, or in a general way related to the proposed development.

Submissions must be made in writing and respondents should note the following points:

- Refer to the project title (the *Ichthys Gas Field Development Project*).
- Each matter raised should refer to the relevant section and page number of the Draft EIS (e.g. Chapter 7, Section 7.1.2, page 383).
- Supporting factual information and/or references should be provided for each point raised.
- The name and address of the respondent(s) and the date of submission should be included.
- The submission should be delivered by no later than 5.00 p.m. on the final day of the advertised review period at the nominated electronic or postal address below.
- All written submissions should be signed[1].

Submissions may be lodged electronically or by post.

Electronic submissions may be dispatched directly to INPEX online via the INPEX web site (www.inpex.com.au) or e-mailed directly to inpex_eis@inpex.com.au.

Postal submissions should be addressed to:

Ichthys Gas Field Development Project
Draft EIS Comment
PO Box Z5023
St Georges Tce WA 6831

INPEX will forward an acknowledgment of receipt for all submissions received prior to the close of the review period and will record and collate all submissions and provide copies to the relevant government assessment agencies.

1 Each submission will be treated as a public document unless delivered in confidence.

ACCESSING THE DOCUMENT

The Draft EIS can be viewed online at www.inpex.com.au and at the following locations:

Northern Territory

- **Department of Natural Resources, Environment, the Arts and Sport**
  Level 2, Darwin Plaza, 41 Smith Street Mall, Darwin
- **Development Assessment Services Department of Lands and Planning**
  Ground floor, Cavenagh House,
  38 Cavenagh Street, Darwin
- **Minerals and Energy InfoCentre Department of Resources**
  Level 3, Paspalis Centrepoint Building,
  Smith Street Mall, Darwin
- **Northern Territory Library**
  Parliament House, Bennett Street, Darwin
- **Darwin City Council libraries:**
  Casuarina Library
  17 Bradshaw Terrace, Casuarina
  City Library
  Civic Centre, Harry Chan Avenue, Darwin
  Karama Library
  Karama Shopping Centre, Karama
  Nightcliff Library
  10-12 Pavonia Place, Nightcliff
- **Palmerston City Library**
  Goyder Square, The Boulevard, Palmerston
- **Katherine Public Library**
  First floor, Randazzo Building, Katherine Terrace, Katherine
- **Tennant Creek Public Library**
  Civic Centre, Peko Road, Tennant Creek
- **Alice Springs Public Library**
  Corner of Leichhardt Terrace and Gregory Terrace, Alice Springs
- **The Environment Centre NT**
  Unit 3, 98 Woods Street, Darwin
- **Northern Land Council**
  45 Mitchell Street, Darwin
- **Larrakia Nation Aboriginal Corporation**
  Unit 4/1 Pavonia Place, Nightcliff
- **Litchfield Council**
  7 Bees Creek Road, Freds Pass
- **Environment Hub**
  Shop 9, Rapid Creek Business Village
  48 Trower Road, Millner
- **INPEX Darwin Office**
  Level 8, Mitchell Centre
  59 Mitchell Street, Darwin

Australian Capital Territory

- **The Library of the Department of the Environment, Water, Heritage and the Arts**
  John Gorton Building, King Edward Terrace, Parkes, Canberra

Western Australia

- **State Library of Western Australia**
  Alexander Library Building
  25 Francis Street, Perth
- **INPEX Perth Office**
  Level 22, 100 St Georges Terrace, Perth

Hard copies can be obtained by submitting a request by e-mail to inpex_eis@inpex.com.au or by telephone to 1800 705 010.

Additional information can be obtained directly from the government regulator web sites provided below:

Commonwealth Government: Department of the Environment, Water, Heritage, and the Arts (DEWHA) at <http://www.environment.gov.au/>

Northern Territory Government: Department of Natural Resources, Environment, the Arts and Sport (NRETAS) <http://www.nt.gov.au/nreta/>.

Foreword

On behalf of INPEX Browse, Ltd. and in cooperation with our joint venturer, Total E&P Australia, I am pleased to present this draft environmental impact statement (Draft EIS) for the proposed Ichthys Gas Field Development Project.

INPEX has been a member of the Australian business community since 1986. In 2000 INPEX discovered the giant Ichthys gas and condensate field and since then we have worked continuously toward developing this world-class resource in a manner that is technically and economically viable, and environmentally and socially responsible.

This document presents a comprehensive description of the Ichthys Project, the natural and socio-economic environment in which it will be developed and the actual and potential impacts it will have. As the cleanest of all fossil fuels, LNG is an energy source appropriate for today's carbon-constrained world. It is my belief that this Draft EIS demonstrates a sound case supporting approval of the Ichthys Project.

The commercial development of the Ichthys Project promises to deliver substantial social and economic benefits to the people of Darwin, the Northern Territory and Australia through the creation of employment and training opportunities, improved infrastructure, and the significant economic stimulus it will provide.

In designing the Ichthys Project, INPEX and its contractors have carried out comprehensive environmental surveys in and around Darwin Harbour, at the Ichthys Field and along the subsea pipeline route from the field to Darwin. Extensive socio-economic studies have also been undertaken to identify the benefits that will flow from this development.

In addition, this Draft EIS has been prepared through a process of extensive consultation with relevant government agencies and non-government organisations, as well as through engagement with the broader community at public forums and briefings.

As both the Northern Territory Government and Australian Government regulators decided on a joint assessment process, the Draft EIS addresses the requirements of both jurisdictions and has been prepared in accordance with the published guidelines.

I thank all those who have contributed to this process to date and I would now like to invite all members of the Northern Territory and broader Australian communities to review this document and provide feedback on the proposed Ichthys Project.

Your contribution to the evaluation of the Ichthys Project Draft EIS will be very welcome and can only improve the quality and integrity of the assessment process leading to better outcomes for all.

Seiya Ito
Managing Director
INPEX Browse, Ltd.

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1 Introduction

1 INTRODUCTION

INPEX Browse, Ltd. (INPEX), as Operator of the Ichthys Gas Field Development Project (the Project), is seeking the approval of the Northern Territory and Commonwealth governments to develop the Ichthys gas and condensate field (the Ichthys Field) to produce liquefied natural gas (LNG), liquefied petroleum gases (LPGs) and condensate for export to markets in Japan and elsewhere.

The Ichthys Field is located in the Browse Basin, around 450 km north-north-east of Broome and 820 km west-south-west of Darwin. The field encompasses an area of approximately 800 km^2 in water depths ranging from 235 to 275 m. Appraisal drilling and development studies suggest that the P_{50} resources[1] of the Ichthys Field are 12.8 tcf (trillion cubic feet) of sales gas and around 527 MMbbl (million barrels) of condensate[2,3], split between a Cretaceous reservoir in the Brewster Member and a Jurassic reservoir in the Plover Formation.

INPEX intends to install a floating central processing facility (CPF) for the extraction of natural gas and condensate at the Ichthys Field. The bulk of the condensate will be exported directly from the field at an average rate of 85 000 barrels per day (at the start of LNG production) after processing on a floating production, storage and offtake (FPSO) facility moored some distance from the CPF. Natural gas from the field will be directed through a gas export pipeline from the field to onshore facilities at a site zoned for industrial development at Blaydin Point in Darwin Harbour in the Northern Territory. The gas will be processed through a two-train 8.4-Mt/a LNG processing plant. This production rate represents the average plateau rate over the first 23 years of the Project. Thereafter, LNG production will gradually decline as the Project slowly runs out of gas but continues to produce LNG at rates below 8.4 Mt/a. Total annual production will vary from year to year depending on factors such as the composition of the gas from the reservoir and the duration and frequency of maintenance activities.

1 In the oil & gas industry, P_{50} resources (often called “proved plus probable”) are in effect a median estimate of the resources expected to be extracted from a hydrocarbon field. A P_{50} estimate refers to a value which has a 50% probability of being exceeded.

2 Note: the hydrocarbon resources reported in this document are based upon the “Statement of Hydrocarbon Resources” which was registered with Western Australia’s Department of Mines and Petroleum on 27 March 2009. The P_{50} resources notified were 12.8 tcf of sales gas and 527 MMbbl of condensate. These figures were INPEX’s best estimates at the time of preparation of this document, but are subject to subsequent review. Modelling and emission estimates are based upon the registered 2009 figures.

3 In metric measure this equates to 361 Gm^3 of gas and 83 GL of condensate.

The onshore processing plant will also produce up to approximately 1.6 Mt/a of LPGs and a residual 15 000 barrels per day of condensate which will be carried to the plant with the gas stream.

The construction phase of the Project will cover a period of 5 to 6 years from the final investment decision (FID) to the export of the first cargo of gas approximately five years later. Approval for the construction and operation of the Project requires environmental assessment by both the Commonwealth Government and the Northern Territory Government. It does not require assessment under Western Australia’s *Environmental Protection Act 1986* as Western Australia’s jurisdiction does not extend beyond the state’s coastal waters zone (which extends only 3 nautical miles seaward of the territorial sea baseline).

1.1 Project proponent

INPEX’s parent company INPEX CORPORATION has been involved in the development of oil and gas resources for more than four decades and has been steadily increasing its exploration and development activities in many countries around the world. It is, for example, currently taking part in a number of projects in Australian waters. These include the Van Gogh and Ravensworth oil extraction projects in the southern part of the North West Shelf in Western Australia, and, until it ceased production in October 2009, the nearby Griffin Fields oil & gas project. INPEX is also a partner in the Bayu–Undan oil & gas project in the Timor Sea Joint Petroleum Development Area (JPDA).

In early 1998, INPEX CORPORATION (as Indonesia Petroleum, Ltd.) bid for a petroleum exploration permit for permit area WA-285-P in the northern Browse Basin about 200 km off Western Australia’s Kimberley coast, at the western edge of the Timor Sea. This petroleum exploration permit was awarded to INPEX CORPORATION on 19 August 1998. The subsidiary company INPEX Browse, Ltd. was established immediately after the grant of the permit and became the permit holder, 100% equity holder and Operator.

The company’s drilling program from March 2000 to February 2001 in the north-western portion of the permit area resulted in the significant gas and condensate discovery in the Ichthys Field. Shortly afterwards INPEX commenced the Ichthys Gas Field Development Project.

In August 2004 the original permit expired and a new permit, WA-285-P R1, was issued for a reduced area of 3041 km^2.

In 2006 INPEX transferred a 24% participating interest in the Project to Total E&P Australia (Total). Total has had a long-standing partnership with INPEX elsewhere in the world and also has extensive experience and expertise with LNG and LPG projects in many countries.

In September 2009 Retention Lease WA-37-R was awarded to INPEX as the Operator of the Ichthys Field. The area covered by the lease is approximately 912 km^2.

Since the initial drilling program commenced in 2000, INPEX has drilled eight appraisal wells at the Ichthys Field and has operated two years of boat-based field studies at the Maret Islands off the Kimberley coast. These were undertaken without any reportable environmental incidents. INPEX has also been acknowledged by the Australian Petroleum Production & Exploration Association (APPEA) which awarded its 2008 Environmental Award (exploration company category) to INPEX for its low-environmental-impact approach to geotechnical drilling activities on the Maret Islands.

During this extensive exploration, INPEX has operated under well-developed management systems and has not experienced any major environmental incidents. INPEX reports on its global environmental performance annually through its corporate sustainability report.

Contact details

The addresses of INPEX's offices in Australia are as follows:

Perth	**Darwin**
INPEX Browse, Ltd.	INPEX Browse, Ltd.
Level 22	Level 8, Mitchell Centre
100 St Georges Terrace	59 Mitchell Street
PERTH WA 6000	DARWIN NT 0800

1.2 Environmental assessment process

The Northern Territory Minister for Natural Resources, Environment and Heritage determined that the Project would require formal assessment under the *Environmental Assessment Act* (NT) (EA Act). In May 2008 INPEX referred its project proposal to the Commonwealth's Department of the Environment, Water, Heritage and the Arts (DEWHA) and the Northern Territory's Department of Natural Resources, Environment and the Arts (now NRETAS)[4]. Both agencies determined that the Project should be formally assessed at the EIS (environmental impact statement) level.

The Project was assessed by the DEWHA as having the potential to cause a significant impact on the following "matters of national environmental significance" that are protected under Part 3 of the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth) (EPBC Act):

- listed threatened species and ecological communities (sections 18 and 18A)
- migratory species protected under international agreements (sections 20 and 20A)
- the Commonwealth marine environment (sections 23 and 24A).

In order to ensure that these and other potential environmental, social and economic impacts from the Project are adequately investigated, in September 2008 the DEWHA and NRETAS developed a set of guidelines (*Guidelines for preparation of a draft environmental impact statement: Ichthys Gas Field Development Project*) to direct INPEX's production of a single environmental impact assessment document, the *Ichthys Gas Field Development Project: draft environmental impact statement* (Draft EIS). This is designed to satisfy the requirements of both the Commonwealth Government and the Northern Territory Government.

The EIS guidelines and a cross-referencing document comparing the EIS guidelines with this Draft EIS have been provided in Appendix 1 and Appendix 2. In addition, a cross-reference of the Draft EIS content against the requirements of the EPBC Act has been provided in Appendix 3.

Assessment of the Draft EIS will be undertaken in accordance with the Commonwealth's EPBC Act and the Northern Territory's EA Act. This combined environmental assessment process will be undertaken in stages as described in the following sections. The whole process, from initial proposal to final approval, is presented graphically in Figure 1-1.

1.2.1 Scope of the Draft EIS

The Draft EIS includes assessment of the following Project components:

- offshore infrastructure and activities at the Ichthys Field
- the gas export pipeline from the Ichthys Field to Darwin Harbour
- nearshore infrastructure, including the pipeline shore crossing and associated activities within Darwin Harbour and at the proposed offshore spoil disposal ground north of the Harbour
- onshore infrastructure on Blaydin Point, and Middle Arm Peninsula and associated activities that could cause off-site impacts, such as air emissions and traffic.

4 The Northern Territory's Department of Natural Resources, Environment and the Arts (NRETA) became the Department of Natural Resources, Environment, the Arts and Sport (NRETAS) in August 2008.

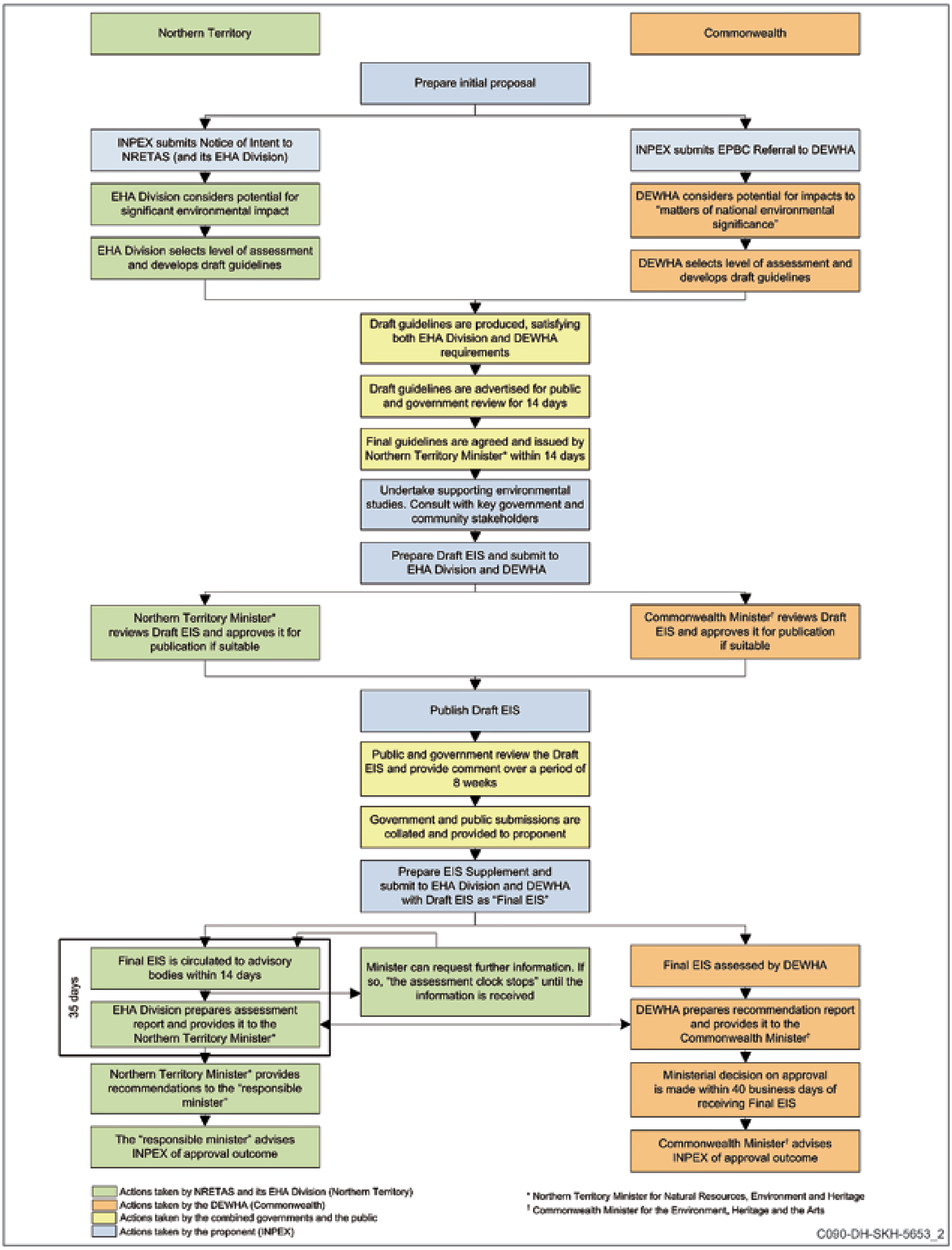

Figure 1-1: Environmental assessment process for the Project

As the accommodation village for the construction phase of the Project needs to be completed and available prior to commencement of works at Blaydin Point, a series of approvals separate from this Draft EIS are being sought. These approvals require the assessment of a range of environmental and social factors. However, the potential social and traffic impacts associated with introducing a construction workforce into the Darwin region are discussed in this Draft EIS.

An expansion of the production capacity beyond two LNG trains would be subject to future regulatory-authority approval but will depend on further gas reserves being identified as well as on market and supply variables. Consideration of any such expansion is therefore not within the scope of this Draft EIS.

1.2.2 Initial referrals

A "notice of intent" (NOI) for the Project was submitted to NRETAS in May 2008 to initiate the assessment process under the EA Act. The NOI provided an outline of the proposed development and its key potential environmental impacts to assist the Northern Territory Minister for Natural Resources, Environment and Heritage, on advice from NRETAS, in determining the appropriate level of environmental assessment. The NOI was also provided for public review on the department's web site.

A referral for the Project was also submitted to the DEWHA in May 2008 to commence the assessment process under the EPBC Act. The referral provided an outline of the Project with particular reference to its potential impacts on matters of national environmental significance. The purpose of the referral was to enable the Commonwealth Minister for the Environment, Heritage and the Arts, on advice from the DEWHA, to determine whether the Project, a "proposed action" under the Act, should be considered a "controlled action". A "controlled action" is one that is considered likely to have a significant impact on one or more matters of national environmental significance. The Minister would then identify an appropriate level of environmental assessment. This referral was provided for public review on the EPBC Act web site.

1.2.3 Level of assessment set for the Ichthys Project

The Northern Territory Minister determined that the Project should be formally assessed under an EIS, which is the highest level of assessment that can be undertaken under the Territory's EA Act. The key environmental issues contributing to this decision included the following:

- visual amenity and public interest
- potential impacts from dredging
- the potential for disturbance to marine and terrestrial biodiversity
- the potential for disturbance of maritime heritage sites
- the increased shipping movements in the Port of Darwin
- potential impacts associated with the construction of new wharf facilities
- discharge of process wastewater to Darwin Harbour
- air emissions, including greenhouse gases.

On 16 July 2008 a representative for the Commonwealth Minister advised INPEX that the Project would be assessed through an EIS under the EPBC Act. This decision was taken because of the potential impacts of the Project on three matters of national environmental significance.

1.2.4 Public review of guidelines and assessment level

As noted above, the DEWHA and NRETAS adopted a joint approach to the preparation of a set of EIS guidelines for the development of a Draft EIS. The purpose of the guidelines is to identify matters of concern and to establish the scope of the environmental, social and economic studies required to properly assess the potential impacts of the Project and make a final decision on its acceptability.

A draft of the EIS guidelines was presented for public review for 15 business days. This public review period provided an opportunity for stakeholders to comment on issues relating to the Project and enabled the DEWHA and NRETAS to consider this input when finalising the guidelines. This review period also allowed INPEX to clarify the requirements of the draft guidelines in consultation with the DEWHA and NRETAS.

The DEWHA and NRETAS finalised the guidelines in September 2008 and provided them to INPEX to guide its preparation of this Draft EIS.

1.2.5 Stakeholder consultation

In order to identify the environmental and socio-economic aspects that could be affected by the Project and to investigate these potential impacts with appropriate rigour, INPEX undertook a stakeholder consultation process. This was initiated early in the assessment process, after submission of the initial referrals, and has continued throughout the development of the EIS guidelines and the Draft EIS.

The complete stakeholder engagement process associated with the environmental assessment process is described in Chapter 2 *Stakeholder consultation*.

1.2.6 Preparation of the Draft EIS

In order to assess the impacts from the Project and characterise the baseline conditions, a number of targeted environmental studies and surveys were undertaken by a range of specialists contracted by INPEX. In order to discuss and decide the scope of these studies and surveys, INPEX undertook a two-day workshop with NRETAS in April 2008.

Participants in the workshop included government experts from various divisions of NRETAS, some representatives from other Northern Territory government agencies (such as the Department of Planning and Infrastructure[5]), the INPEX environmental team and engineers, and environmental consultants. This process enabled the identification of significant environmental values in the Project area, a high-level assessment of relevant existing knowledge, and agreement on the scope and methods of further investigations to be carried out by INPEX. The complete list of studies and surveys undertaken is presented in Table 1-1.

This Draft EIS documents the outcome of the environmental impact assessment carried out by INPEX and, in doing so, demonstrates that the company has achieved the following:

- It has studied and understood the existing environment in enough detail to predict changes that could occur as a result of the Project.
- It has undertaken a risk assessment of the impact of predicted changes to the existing environment.
- It has incorporated environmental management controls into the design and planning phases of the Project to avoid or minimise impacts on the environment through all phases of the Project—construction, commissioning, operations and, where appropriate, decommissioning.
- It has generated and documented sufficient detail about the Project to allow appropriately informed feedback to be submitted by interested parties through the Draft EIS's public review period.
- It has generated and documented sufficient detail to allow appropriately informed recommendations to be developed by the Northern Territory Government's NRETAS and the Commonwealth Government's DEWHA for transmission to their respective responsible ministers.

5 The Northern Territory's Department of Planning and Infrastructure was restructured in December 2009 and its functions transferred to two new departments, the Department of Lands and Planning and the Department of Construction and Infrastructure.

Table 1-1: Studies conducted for the environmental impact assessment of the Project

Study	Organisation	Study components	Study period	Study areas
Offshore marine environment				
Marine sediments and water quality	RPS Australia, Perth University of Western Australia, Perth Marine and Freshwater Research Laboratory, Murdoch University, Perth CSIRO laboratories URS Australia, Perth	Water quality	March and September 2005 October and December 2006 May and June 2007 December 2008	Ichthys Field Pipeline route
		Sediment quality	September 2005 May 2007 December 2008	Ichthys Field Pipeline route
		Infauna	September 2005 March 2007 December 2008	Ichthys Field Pipeline route
Marine ecology	RPS Australia, Perth URS Australia, Perth	Subtidal habitats and communities	September 2005 October–November 2006 March–April 2007 December 2008	Ichthys Field Pipeline route
Cetaceans and other megafauna	Centre for Whale Research (Western Australia), Perth Centre for Marine Science and Technology, Curtin University of Technology, Perth RPS Australia, Perth	Marine megafauna	August–October 2006 July–September 2007	Browse Basin
Underwater noise	Centre for Marine Science and Technology, Curtin University of Technology, Perth SVT Engineering Consultants, Perth	Underwater noise	September 2006 – February 2009	Ichthys Field
Oceanography and oceanic discharges	RPS MetOcean Engineers, Perth Asia-Pacific Applied Science Associates (APASA), Perth	Acoustic Doppler current profiling (ADCP) measurements Wind and wave monitoring Oil-spill trajectory modelling Produced-water discharge modelling	July–December 2006 January 2007 – February 2009	Ichthys Field Pipeline route Darwin Harbour
Oil-spill risk	Environmental Risk Solutions (ERS), Perth	Primary risk assessment	October 2008 – February 2009	Ichthys Field Pipeline route
Condensate weathering	Geotechnical Services, Perth	Laboratory tests on weathering process and ecotoxicity of Ichthys Field condensate	August 2007	Ichthys Field condensate

Table 1-1: Studies conducted for the environmental impact assessment of the Project (continued)

Study	Organisation	Study components	Study period	Study areas
Nearshore marine environment				
Marine ecology	URS Australia	Marine and intertidal habitats and communities	April–June 2008	Subtidal and intertidal areas adjacent to Blaydin Point, around Middle Arm Peninsula, and throughout Darwin Harbour
		Marine sediment quality	March 2008	Darwin Harbour
Marine water quality	URS Australia	Water quality	April–August 2008	East Arm and Middle Arm, Darwin Harbour
		Light attenuation and turbidity	April–August 2008	East Arm and Middle Arm, Darwin Harbour
Underwater noise	SVT Engineering Consultants	Establishment of underwater noise baseline	March 2009	East Arm, Darwin Harbour
Oceanography, coastal processes and oceanic discharges	Asia-Pacific Applied Science Associates (APASA), Perth URS Australia, Perth	Local currents, waves and tides	April–December 2008	East Arm Wharf, Darwin Harbour and offshore spoil disposal ground
		Oil-spill trajectory modelling Wastewater discharge modelling	April 2008 – March 2009	Darwin Harbour
Hydrodynamic and sediment-fate modelling	HR Wallingford, United Kingdom Asia-Pacific Applied Science Associates (APASA), Perth	Modelling of dredge sediment movement and spoil disposal	August 2009 – January 2010	Darwin Harbour and offshore spoil disposal ground
Oil-spill risk	Environmental Risk Solutions (ERS), Perth	Primary risk assessment	October 2008 – February 2009	Darwin Harbour, East Arm and Middle Arm
Onshore terrestrial environment				
Geographic studies	URS Australia, Darwin	Topography, geology, geomorphology and soils	May–June 2008	Blaydin Point and Middle Arm Peninsula
Hydrology and hydrogeology	URS Australia, Darwin	Existing surface and groundwater	April–July 2008	Blaydin Point
Terrestrial ecology	GHD, Darwin	Plant and animal life	November 2007 – June 2008	Blaydin Point and Middle Arm Peninsula
Biting insects	Medical Entomology Section (Centre for Disease Control), Darwin	Mosquitoes and biting midges	October–December 2007	Blaydin Point and Middle Arm Peninsula
Socio-economic				
Airborne noise assessment	SVT Engineering Consultants, Perth	Ambient noise measurements and noise modelling	May 2008	Darwin and Palmerston
Traffic	URS Australia, Melbourne	Traffic surveys and modelling of traffic routes	June–October 2008	Blaydin Point and Darwin region
Visual amenity	URS Australia, Darwin ERM Australia, Perth	Simulation of the visual impact of the Project's onshore facility in Darwin	June–March 2009	Darwin

Table 1-1: Studies conducted for the environmental impact assessment of the Project (continued)

Study	Organisation	Study components	Study period	Study areas
Heritage (non-Aboriginal)	URS Corporation, Gaithersburg, Maryland, USA Begnaze Pty Ltd, Wanguri, Northern Territory	Maritime non-Aboriginal heritage (World War II wrecks)	April–August 2008	Darwin Harbour
Archaeology and historical cultural heritage	Begnaze Pty Ltd, Wanguri, Northern Territory	Cultural heritage archaeological site surveys and desktop studies	June 2007 – June 2008	Wickham Point and Blaydin Point on Middle Arm Peninsula
Sacred sites	Aboriginal Areas Protection Authority (AAPA), Darwin	Sacred-site survey	September 2007 – January 2009	Wickham Point, Darwin Harbour and around Cox and Shoal Bay peninsulas, subsea pipeline route
Public safety	Advantica (formerly British Gas Research and now Germanischer Lloyd Industrial Services), United Kingdom	Quantitative risk assessment of the safety of the onshore processing plant and pipeline	September 2008 – ongoing assessments	Blaydin Point, Darwin Harbour, Darwin region
Social impacts assessment	URS Australia, Melbourne	Interviews with stakeholders	May–June 2008	Darwin and Palmerston
Economic impacts assessment	URS Australia, Melbourne	Economic modelling	April–November 2008	Darwin, Northern Territory and Australian economies
Regional climate				
Air quality	Sinclair Knight Merz (SKM), Perth	Climate and meteorology	June–September 2008	Darwin region
		Existing air quality	June–February 2009	Darwin region
		Atmospheric emissions dispersion modelling	June–February 2009	Darwin region
Local meteorology	Asia-Pacific Applied Science Associates (APASA), Perth	Local meteorology	April–October 2008	Darwin Harbour

1.2.7 Government and public review of the Draft EIS

Following review of an earlier version of the Draft EIS, the DEWHA and NRETAS confirmed that the document complies with the EIS guidelines described in Section 1.2.3 *Level of assessment set for the Ichthys Project*, that it addresses all issues required, and that the document is suitable for publication and public review.

Permission to publish was granted to INPEX by NRETAS and the Commonwealth Minister for the Environment in early May 2010.

In accordance with statutory processes, this Draft EIS is available for public review and comment for a period of 8 weeks. During this period, any individual, business, or organisation may submit comments on the Project and associated impacts directly to INPEX (refer to "Invitation to Comment" at the front of this document for submission instructions).

1.2.8 Preparation of the Final EIS

Each issue raised during the public review and comment period will be addressed by INPEX in a separate document, the "EIS Supplement", either by a simple clarification or through further investigations and studies. The time frame for development of the "Final EIS", (which will consist of two documents, the original Draft EIS and the EIS Supplement), is therefore dependent on the volume and nature of issues raised through the public comment process.

1.2.9 Government assessment and final approval

When INPEX submits the Final EIS, the DEWHA and NRETAS will begin the final stages of environmental assessment for the Project.

Assessment under the EPBC Act

As required by Section 104 of the EPBC Act, within 10 business days of INPEX's submission of the Final EIS to the DEWHA the company must make the Final EIS available to the general public by announcing its publication and availability in an advertisement in a national newspaper. It will also be distributed for public viewing in the same locations used for the Draft EIS and it will be accessible on INPEX's Internet web site.

The Commonwealth Minister has 40 business days to make a decision on whether to grant approval for the Project. The DEWHA will prepare a "recommendation report" for the Minister during this 40-day period, with a suggested approval decision and any conditions that should apply to the approval.

Assessment under the EA Act

Under the Northern Territory assessment process, INPEX will submit the Final EIS to NRETAS for circulation to relevant government advisory groups. Within 35 days NRETAS will prepare an "assessment report" to advise the Northern Territory's Minister for Natural Resources, Environment and Heritage on whether the Project should be approved and, if so, under what conditions such an approval should be granted.

The Northern Territory Minister for Natural Resources, Environment and Heritage will then provide his/her advice to the responsible minister. The minister makes the ultimate decision on whether the Project should be approved and, if approval is granted, sets the environmental licence conditions for the Project.

The responsible minister will provide a final assessment report to INPEX. This report is likely to include some or all of the recommendations made by NRETAS and it will be made available to the public by various means such as through distribution to selected public libraries or viewing sites and by posting on the NRETAS web site on the Internet.

1.3 Other government approvals

A range of approvals have already been obtained for the Project in order to characterise the Ichthys Field and to provide preliminary information on the environmental and geotechnical characteristics of the development areas. These are summarised in Table 1-2.

Table 1-2: Government approvals already obtained for the Ichthys Project

Type of permit	Relevant legislation and agency	Purpose
Offshore		
Drilling	*Petroleum (Submerged Lands) Act 1967* (Cwlth)[6]; Western Australia's Department of Industry and Resources (now the Department of Mines and Petroleum)	Permission to conduct exploratory drilling in the WA-285-P permit area
Licence to take fauna for scientific purposes	*Wildlife Conservation Act 1950* (WA); Western Australia's Department of Conservation and Land Management (now the Department of Environment and Conservation)	Permission to conduct capture-and-release activities with marine turtles during baseline environmental surveys at Browse Island
Authority to enter Department of Conservation and Land Management land and/or waters	*Conservation and Land Management Regulations 2002* (WA); Western Australia's Department of Conservation and Land Management (now the Department of Environment and Conservation)	Permission to conduct capture-and-release activities with marine turtles during baseline environmental surveys at Browse Island
Access authorities (various)	*Petroleum (Submerged Lands) Act 1967* (Cwlth), *Petroleum (Submerged Lands) Act 1982* (WA) and *Petroleum Act 1967* (WA); Western Australia's Department of Industry and Resources (now the Department of Mines and Petroleum)	Permission to conduct geophysical surveys at the Ichthys Field, to inform the design of offshore infrastructure
Onshore and nearshore		
Permissive occupancy (various)	*Planning Act* (NT); Northern Terrritory's Department of Planning and Infrastructure (now the Department of Lands and Planning)	Permission to conduct preliminary geotechnical, geological, environmental and engineering studies at Blaydin Point
Authority certificates (various)	*Northern Territory Aboriginal Sacred Sites Act* (NT); Northern Terrritory's Aboriginal Areas Protection Authority	Determine the location(s) of any Aboriginal sacred sites in the nearshore and onshore development areas
Permit to take wildlife for commercial purposes	*Territory Parks and Wildlife Conservation Act* (NT); Northern Terrritory's Parks and Wildlife Commission	Permission to clear cycads (*Cycas armstrongii*) during preliminary physical surveys at Blaydin Point
Development permits (various)	*Planning Act* (NT); Northern Terrritory's Department of Planning and Infrastructure (now the Department of Lands and Planning)	Permission to clear vegetation and conduct minor earthworks at Blaydin Point, for preliminary geotechnical, geological, environmental and engineering studies
Bore construction permits	*Water Act* (NT); Northern Terrritory's Department of Natural Resources, Environment, the Arts and Sport	Permission to develop groundwater bores at Blaydin Point, to inform design of the onshore development area
Occupation licence	*Crown Lands Act* (NT); Northern Terrritory's Department of Planning and Infrastructure (now the Department of Lands and Planning)	Permission to access Blaydin Point and part of Middle Arm Peninsula for preliminary physical surveys
Road reserve work permit	*Control of Roads Act* (NT); Northern Terrritory's Department of Planning and Infrastructure (now the Department of Lands and Planning)	Permission to work in the road reserves of Wickham Point Road and Channel Island Road to conduct preliminary physical surveys
Crossing gas pipeline	*Energy Pipelines Act* (NT); NT Gas Pty Limited	Permission to drive vehicles across an existing onshore gas pipeline during preliminary physical surveys

In addition, there are other statutes and regulations under which the Project will operate and for which approvals or licences may be required. These include those summarised in Table 1-3.

6 Note that the *Petroleum (Submerged Lands) Act 1967* (Cwlth) was superseded by the *Offshore Petroleum Act 2006* (Cwlth) on 1 July 2008. This was superseded in turn by the *Offshore Petroleum and Greenhouse Gas Storage Act 2006* (Cwlth) on 21 November 2008.

Table 1-3: Government approvals that may be required for the Ichthys Project

Approval required	Legislation	Comments
Production licence	*Offshore Petroleum and Greenhouse Gas Storage Act 2006* (Cwlth)	This Act governs the exploration and development of petroleum resources in Commonwealth waters.
Infrastructure licence	*Energy Pipelines Act* (NT) Energy Pipelines Regulations (NT)	This Act and these Regulations apply to the construction and operation of pipelines for the purposes of hydrocarbon transportation in the Northern Territory.
Pipeline licence Pipeline management plan (offshore)	*Offshore Petroleum and Greenhouse Gas Storage Act 2006* (Cwlth) Petroleum (Submerged Lands) (Pipelines) Regulations 2001 (Cwlth) *Petroleum (Submerged Lands) Act* (NT) *Energy Pipelines Act* (NT) Energy Pipelines Regulations (NT)	These Acts and Regulations relate to the construction, operation and maintenance of pipelines for the transport of petroleum.
Environment plan approval required	Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009 (Cwlth)[7]	These Regulations ensure that operations are carried out in accordance with the relevant approved environment plan.
Development approval	*Planning Act* (NT)	This Act requires the developer to obtain a development approval from the appropriate local-government authority.
Building licence	*Building Act* (NT) Building Regulations (NT)	This Act and these Regulations ensure that buildings are designed to comply with the health, safety and structural provisions of relevant legislation, building codes and standards.
Major hazard facility safety report and licence Dangerous goods transport licence	*Dangerous Goods Act* (NT) Dangerous Goods Regulations (NT) *Dangerous Goods (Road and Rail Transport) Act* (NT) Dangerous Goods (Road and Rail Transport) Regulations (NT)	These Acts and Regulations impose controls for the storage and handling of dangerous and explosive goods.
Security plan approval required	*Maritime Transport Security Act 2003* (Cwlth) Maritime Transport and Offshore Facilities Security Regulations 2003 (Cwlth)	This Act and these Regulations require all gazetted port operators to prepare a maritime security plan in accordance with the provisions outlined in the Act and Regulations.
Clearance of development area for Aboriginal sacred sites or archaeological sites	*Northern Territory Aboriginal Sacred Sites Act* (NT) *Heritage Conservation Act* (NT) Heritage Conservation Regulations (NT)	These Acts and Regulations apply to the protection of registered archaeological, anthropological and historical sites and objects important to people of Aboriginal descent in the Northern Territory.
Approval required to interfere with any historic shipwreck covered by Commonwealth legislation	*Historic Shipwrecks Act 1976* (Cwlth)	This Act protects shipwrecks over 75 years old.
Shipping management	*Marine Act* (NT)	This Act regulates shipping in the Northern Territory and provides for the application to the Territory of the Commonwealth's *Uniform Shipping Laws Code*.
Licences or approvals from the minister responsible for the environment may be required for possible interference with protected species of plants or animals	*Territory Parks and Wildlife Conservation Act* (NT) Territory Parks and Wildlife Conservation Regulations (NT)	This Act and these Regulations provide for the protection of native plant and animal species.

7 Note that the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009 (Cwlth) superseded the Petroleum (Submerged Lands) (Management of Environment) Regulations 1999 (Cwlth) on 17 December 2009.

Table 1-3: Government approvals that may be required for the Ichthys Project (continued)

Approval required	Legislation	Comments
Environmental protection approval Environmental protection licence	*Waste Management and Pollution Control Act* (NT) Waste Management and Pollution Control (Administration) Regulations (NT)	This Act and these Regulations provide for the protection of the environment through the encouragement of effective waste management and pollution prevention and control practices. The environmental protection approval is required for construction and the environmental protection licence is required for operations.
Weed management during construction and operations	*Weeds Management Act 2001* (NT) Weeds Management Regulations (NT)	This Act and these Regulations protect the Northern Territory's economy, community, industry and environment from the adverse impact of weeds.
Road reserve work permit	*Control of Roads Act* (NT); Northern Terrritory's Department of Lands and Planning	This Act governs the obtaining of permits to work in road reserves such as those of Wickham Point Road and Channel Island Road.
Waste discharge licence	*Water Act* (NT) Water Regulations (NT)	This Act and these Regulations provide for the investigation, allocation, use, control, protection, management and administration of water resources. This includes the management of dredging and dredge spoil disposal.

1.4 Structure of the document

This Draft EIS is structured generally in accordance with the *Guidelines for preparation of a draft environmental impact statement: Ichthys Gas Field Development Project*, which were prepared by the DEWHA and NRETAS. (The guidelines are attached to this Draft EIS as Appendix 1.) The Draft EIS has 12 chapters:

- Chapter 1 *Introduction* introduces the proponent and the Project concept and briefly describes the environmental assessment requirements for the Commonwealth and Northern Territory governments.
- Chapter 2 *Stakeholder consultation* describes the involvement of stakeholders in the planning of the Ichthys Project.
- Chapter 3 *Existing natural, social and economic environment* describes the physical, biological, cultural and socio-economic environment in which the Project will operate.
- Chapter 4 *Project description* describes the Project, its major components and activities through each of its phases from construction to decommissioning. This includes discussion of the criteria used in the design of Project components.
- Chapter 5 *Emissions, discharges and wastes* describes the volumes and characteristics of the air emissions, liquid discharges and the solid and liquid wastes that will be produced by the Project.
- Chapter 6 *Risk assessment methodology* provides the risk assessment methodology used to identify and categorise the environmental risks associated with the Project.
- Chapter 7 *Marine impacts and management* describes the potential impacts of the Project upon the marine environment and outlines the management controls to be undertaken by INPEX.
- Chapter 8 *Terrestrial impacts and management* describes the potential impacts of the Project upon the terrestrial environment and outlines the management controls to be undertaken by INPEX.
- Chapter 9 *Greenhouse gas management* describes the greenhouse gas emissions from the Project and the measures being investigated to manage these emissions.
- Chapter 10 *Socio-economic impacts and management* describes the potential socio-economic impacts of the Project and the management controls to be undertaken by INPEX.
- Chapter 11 *Environmental management program* outlines the proponent's Health, Safety and Environmental Management Process and includes a suite of provisional environmental management plans.
- Chapter 12 *Commitments register* provides the key environmental management commitments made by INPEX for the Ichthys Project.

Technical reports supporting the Draft EIS are provided as appendices to the main document.

2 Stakeholder Consultation

2 STAKEHOLDER CONSULTATION

2.1 Introduction

INPEX recognises stakeholder consultation as an important and ongoing process in the Ichthys Gas Field Development Project (the Project). From the outset, INPEX has embarked on a program of consultation and communication with a broad range of government, industry and community stakeholders[1]. Such consultation is a vital part of the environmental assessment process for the Project which adds to the formal input that will be provided by government and the public in response to this draft environmental impact statement (Draft EIS).

INPEX intends to deliver a major contribution to the economy and people of the Northern Territory through its commitment to the Ichthys Project over the next 40 years. This chapter describes components of the Stakeholder Communication Plan that has been developed to guide INPEX's communication strategy.

INPEX has developed a stakeholder communication plan to facilitate a considered and coordinated approach to its engagement with all stakeholders. This is described in further detail below.

2.2 Stakeholder Communication Plan

The purpose of the Stakeholder Communication Plan is to outline a process to ensure that there is effective involvement of stakeholders throughout the Project's 40-year production lifespan, from the approvals phase through to the construction, commissioning, operations and decommissioning phases.

As described in the plan, INPEX's approach is as follows:

- to identify the full range of stakeholders with an interest in the Project
- to establish and maintain a consistent and coordinated approach for communication with local communities, government agencies, special-interest groups and industry
- to provide stakeholders with information about the Project, the approvals process and overall Project timelines
- to identify known and emerging environmental, social and cultural heritage aspects of the Project which might be of interest or concern to stakeholders
- to inform stakeholders about the key environmental, social and cultural heritage factors associated with the Project, the potential impacts of Project activities, and the management strategies to be put in place to minimise or mitigate such impacts
- to consider stakeholder concerns during the Project decision-making process
- to ensure that there is timely and accurate feedback and provision of information on how INPEX will manage any impacts and issues.

The plan also outlines the engagement and consultation activities that have taken place since the formal commencement of the environmental impact assessment process in May 2008 and provides a summary of what is proposed for the future. In order to maintain its relevance over the long term, the Stakeholder Communication Plan will be updated as required.

2.2.1 The purpose of community communication

It is important to achieve effective communication with a wide range of stakeholders in order to create a shared understanding of issues and concerns. Once issues are identified, INPEX will further consult and cooperate with stakeholders to improve its decision-making process in achieving mutually beneficial management outcomes for specific aspects of the Project. This will assist in obtaining both the necessary regulatory approvals and the "social licence to operate", as well as demonstrating INPEX's application and adherence to its stated commitments.

INPEX recognises that stakeholder consultation does not necessarily produce solutions that are acceptable to all parties or that will resolve all differences of opinion. However, effective stakeholder consultation does offer transparency and ensures that all issues impacting on stakeholders are thoroughly understood and appropriately responded to.

2.2.2 Statutory, regulatory and legal requirements

The current relevant statutory and/or regulatory documents outlining the Project's stakeholder communication obligations are listed below:

- The Project Development Agreement (PDA) between the Northern Territory Government and the Joint Venture Parties (INPEX and Total E&P Australia) was prepared for the purpose of securing land tenure at the Blaydin Point site on Middle Arm Peninsula in Darwin Harbour. Section 24.1 of the PDA requires the Joint Venture Parties to engage widely with stakeholders and the community, as reasonably required, regarding the impact of the Project on the community. Section 24.4 also requires INPEX, as Operator of the Project, to provide briefings to the Northern Territory Government on the progress of the Project periodically or as requested.

1 A stakeholder is defined here as any organisation, government agency, group or person that has an interest in or may be affected by a project or by the activities or decisions of an organisation.

- The *Guidelines for preparation of a draft environmental impact statement: Ichthys Gas Field Development Project*[2] (provided as Appendix 1 to this Draft EIS) state that a stakeholder communication plan is to be included in the Draft EIS to facilitate consultation, information-sharing and involvement with government and the local community during the planning, construction, operations and decommissioning of the Project.
- The *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth) requires INPEX to outline the consultation undertaken with relevant stakeholders in the Draft EIS. The Commonwealth and Northern Territory government reviews of the Draft EIS and the subsequent review period for public comment will provide an opportunity for all interested parties to have formal input into the environmental approvals process for the Project. INPEX is required to address the issues raised by stakeholder submissions to the Draft EIS through a supplement to the document before the responsible Commonwealth and Northern Territory ministers make a determination on the Project.

2.2.3 Industry best practice and precedents

Incorporating stakeholder concerns into project decision-making processes is considered a best-practice approach. Identifying and communicating with stakeholders on a range of environmental, economic and social issues can create value for a project through the development of a common understanding of issues and a collaborative approach to problem-solving.

Several Australian and international industry bodies and government agencies provide best-practice guidelines for community consultation which have helped to define the program for the Ichthys Project. These guideline documents include the two listed below:

- *Principles of conduct*. This document is published online by the Australian Petroleum Production & Exploration Association (APPEA) and defines one of its core principles as "open and effective engagement with the communities in which we operate" (APPEA 2003).
- *Principles for engagement with communities and stakeholders*. This document is published online by the Ministerial Council on Mineral and Petroleum Resources (MCMPR) and states that "effective engagement with the community and stakeholders is essential for any successful enterprise. It can also result in a more efficient use of financial resources" (MCMPR 2005).

While the community may not be aware of what constitutes industry best practice, it nevertheless has an expectation that the Project will operate at best-practice level when conducting its business. Community expectations with respect to the types and level of stakeholder communication are not necessarily generally agreed and are certainly not static: they will shift according to the social, economic and environmental conditions of the day. It is INPEX's responsibility to be alert and sensitive to any changes in public perceptions of the Project and to investigate, define and discuss each issue with the stakeholders in the communities in which the company operates.

2.2.4 Stakeholder identification and communication methods

INPEX has compiled a database of key stakeholders. This records each stakeholder's profile, a description of each stakeholder's views on the Project, and the history of discussions with the stakeholder with comments on what has been found to be the best means of communication. In compiling the database, INPEX has used a range of communication methods, including individual briefings, group meetings, external Project working groups, workshops, community forums and phone and web-site feedback arrangements.

The level of consultation undertaken with each stakeholder is based on the level of interest and the preferred communication style. Table 2-1 provides a summary of key stakeholder groups and the communication methods used in INPEX's dealings with them.

2 This document was prepared in September 2008 by the Commonwealth's Department of the Environment, Water, Heritage and the Arts (DEWHA) and the Northern Territory's Department of Natural Resources, Environment, the Arts and Sport (NRETAS).

Table 2-1: Stakeholders and communication to date

Stakeholder type	Stakeholder	Communication to date
Commonwealth Government	Department of the Environment, Heritage, Water and the Arts (DEWHA)	• Regular formal meetings • Teleconferences
	Minister for Resources and Energy	• Meetings
	Minister for Climate Change and Water	• Meetings
	Minister for Infrastructure, Transport, Regional Development and Local Government	• Meetings
	Minister for Employment and Workplace Relations; Minister for Education	• Meetings
	Parliamentary Secretary for Regional Development and Northern Australia	• Meetings
	Department of Defence	• Meetings • Briefing on milestone events
	Minister for Families, Housing, Community Services and Indigenous Affairs	• Meetings
Northern Territory Government and public services	Department of Natural Resources, Environment, the Arts and Sport (NRETAS)	• Regular formal meetings • Briefing on milestone events • Teleconferences
	Department of the Chief Minister	• Meetings • Regular briefings • Teleconferences
	Major Projects Group	• Regular briefings
	Department of Resources (formerly the Department of Regional Development, Primary Industry, Fisheries and Resources) (DoR)	• Socio-economic impact assessment interview

Table 2-1: Stakeholders and communication to date (continued)

Stakeholder type	Stakeholder	Communication to date
Northern Territory Government and public services	Department of Lands and Planning (formerly the Department of Planning and Infrastructure)	• Socio-economic impact assessment interview • Briefing on milestone events
	Northern Territory Gas Taskforce	• Meetings
	Northern Territory Treasury	• Socio-economic impact assessment interview
	Department of Education and Training (DET)	• Socio-economic impact assessment interview • Briefing on milestone events
	Department of Health and Families	• Briefing on accommodation village site • Consultation regarding biting insects
	Department of Business and Employment	• Socio-economic impact assessment interview
	Land Development Corporation	• Socio-economic impact assessment interview • Meetings • Presentation to the corporation's board
	Darwin Port Corporation	• Regular meetings • Socio-economic impact assessment interview • Collaboration on "Notice to Mariners"
	Tourism NT	• Socio-economic impact assessment interview
	NT WorkSafe	• Briefing on milestone events
	Department of Housing, Local Government and Regional Services (formerly the Department of Local Government and Housing)	• Socio-economic impact assessment interview
	The Leader of the Opposition	• Meetings • Briefings on milestone events
	Independent Member of Parliament for the constituency of Nelson	• Meetings • Regular briefings and updates • Briefings on milestone events
	Northern Territory Police, Fire and Emergency Services	• Briefings on milestone events
Local government and services	Darwin City Council	• Socio-economic impact assessment interview • Regular meetings • Briefings on milestone events
	Palmerston City Council	• Socio-economic impact assessment interview • Regular meetings • Briefing of the Executive and Council • Briefings on milestone events
	Litchfield Council	• Socio-economic impact assessment interview • Briefing of the Executive and Council • Briefings on milestone events
	Northern Territory Police, Palmerston	• Briefing on accommodation village site

Table 2-1: Stakeholders and communication to date (continued)

Stakeholder type	Stakeholder	Communication to date
Businesses and business associations	ConocoPhillips	• Meetings
	Telstra	• Briefing on accommodation village site
	Australia Post	• Briefing on accommodation village site
	Howard Springs local businesses	• Briefing on accommodation village site
	Real Estate Institute of Northern Territory Inc.	• Socio-economic impact assessment interview • Briefing on accommodation village site
	The Taxi Council of the Northern Territory	• Briefing on accommodation village site
	Australian Petroleum Production & Exploration Association Limited (APPEA)	• Meetings
	Northern Territory Resources Council	• Socio-economic impact assessment interview • Briefings
	Northern Territory Industry Capability Network (NTICN)	• Socio-economic impact assessment interview • Meetings • Briefing on milestone events
	Chamber of Commerce Northern Territory	• Socio-economic impact assessment interview • Regular meetings • Briefings on milestone events
	Palmerston Regional Business Association	• Briefings on milestone events • Presentation to members
	Property Council of Australia, Northern Territory Division	• Briefings on milestone events
	Northern Territory Seafood Council	• Socio-economic impact assessment interview • Briefing of CEO and Executive • Group meetings
	International Business Council (of the Chamber of Commerce Northern Territory)	• Group meetings
	Northern Territory Business Council	• Group meetings
	Civil Contractors Federation, Northern Territory	• Group meetings
	Engineers Australia (Institution of Engineers Australia)	• Meetings
	Palmerston Recreation Centre (YMCA of the Top End)	• Briefing on site of the accommodation village

Table 2-1: Stakeholders and communication to date (continued)

Stakeholder type	Stakeholder	Communication to date
Non-government organisations	Darwin Harbour Advisory Committee	• Meetings • Regular briefings and updates • Meetings regarding specific issues and Project phases
	Harbour and Port Coordination Subcommittee	• Meetings regarding specific issues
	Amateur Fishermen's Association of the Northern Territory (AFANT)	• Socio-economic impact assessment interview • Regular briefings • Advice provided on significant announcements • Briefing of AFANT Board • Presentation to members at annual general meeting
	Environment Centre Northern Territory	• Project update briefings • Regular meetings • Site visits • Phone and e-mail contact about specific issues and Project phases
	Australian Marine Conservation Society	• Project update briefings • Regular meetings • Phone and e-mail contact about specific issues and Project phases
	National Trust	• Meetings
	Planning Action Network Inc. (PLan)	• Briefings
Aboriginal organisations	Northern Land Council	• Socio-economic impact assessment interview
	Larrakia Development Corporation	• Socio-economic impact assessment interview • Meetings with CEO, Chairman and Larrakia Advisory Committee • Briefings on milestone events • Involvement in key announcements
Media	Northern Territory radio, print and television (various)	• Media conferences at Project milestones • Media releases • Interviews on specific issues
	National media (various)	• Media conferences at Project milestones • Media releases
	Industry and business media (various)	• Media conferences at Project milestones • Industry forum • Media releases
Communities of the Northern Territory	Residents of the City of Darwin	• Community forums • Media
	Residents of the City of Palmerston	• Community forums • Media
	Residents of Litchfield Municipality	• Community forums • Media
	Residents of Howard Springs	• One-on-one briefings regarding the accommodation village site • Media

2 Stakeholder Consultation

2.2.5 Implementation of the Stakeholder Communication Plan

Since the formal commencement of the environmental assessment process in May 2008, issues raised during consultation have been entered into an "issues register" as discussed in Section 2.2.6 *Issues identified by stakeholders*. The key issues raised are provided in Annexe A to this chapter.

Consultation undertaken to date has included the following:

- open community forums in Darwin and Palmerston that were advertised in the local media
- presentations to a wide range of community and business groups, including an industry forum in Darwin
- regular formal meetings with a wide range of community and business groups, including an industry forum in Darwin
- discussions with Aboriginal groups, including the Northern Land Council and the Larrakia Development Corporation
- formal meetings with training and education providers to identify opportunities for sponsorship and capacity-building.
- sponsorship and representation at events such as the Freds Pass Rural Show and the Palmerston Festival
- regular formal meetings and presentations to elected and executive representatives of the Darwin, Palmerston and Litchfield councils
- socio-economic impact assessment interviews
- regular formal meetings with Northern Territory and Commonwealth government agencies

In addition, consultation was undertaken with the Northern Territory Government, local government, local businesses and the local community during February 2009 to seek support for the planning process for the development of INPEX's proposed accommodation village at Howard Springs. Environmental and social impacts for this development are assessed under a separate approvals process.

Consultation for specific Project activities

INPEX provides regular briefings and Project updates to both the Commonwealth Government and the Northern Territory Government. In addition to these regular briefings, meetings are held with government and other relevant stakeholder groups to provide advice on significant Project activities. For example, stakeholder interviews were carried out as part of the socio-economic impact assessment, consultation was carried out for the Darwin Harbour refraction survey and geotechnical programs, and consultation was undertaken on the potential social and environmental impacts associated with the proposed accommodation village. These consultation processes are described further below.

Socio-economic impact assessment interviews

In August 2008 socio-economic impact assessment interviews were carried out with key stakeholders to help identify issues that could have a social or economic impact on the community. The stakeholders consulted are included in Table 2-1 and the outcomes of these interviews are described in Chapter 10 *Socio-economic impacts and management*.

Darwin Harbour refraction survey consultation process

A refraction survey was carried out in Darwin Harbour during December 2008 and January 2009 to map the subsurface features of the Harbour. The survey was preceded by a stakeholder consultation program involving presentations to the DEWHA and NRETAS, the issuing of public notices, and consultation with the Northern Territory Seafood Council, the Darwin Port Corporation, local businesses and recreational organisations. Feedback from this consultation process was incorporated into environmental plans for the survey, specifically with regard to the management of the potential impacts of underwater noise on cetaceans in the Harbour.

Community forums

INPEX held its first four open community forums in Darwin and Palmerston in November 2008 (see Figure 2-1). The forums were run in a workshop format with company personnel providing an introduction to INPEX and the Project followed by a question-and-answer session and a chance for attendees to talk informally to staff.

Figure 2-1: Community forum held in Darwin in November 2008

The forums were designed to encourage stakeholder participation by presenting the key aspects of the Project, the likely impacts, and the proposed management controls. The controls are presented as provisional management plans in the annexes to Chapter 11 *Environmental management program* in this Draft EIS.

Key issues discussed are listed in Annexe A and include the following:

- employment and training opportunities associated with the Project
- potential accommodation shortages and pressure on infrastructure during the peak employment period
- the dredging program and its potential impact on other Harbour users
- the visual impact of the development on the Harbour
- access to waters adjacent to the onshore processing plant for recreational users
- air emissions and their impact on air quality
- liquid discharges and their impact on water quality.

In addition to the community forums, company representatives attend relevant community events and briefings in order to address public concerns or questions relating to the Project. Further public forums are scheduled to coincide with the public release of this Draft EIS.

Consultation with traditional owners

INPEX's goal is to establish and maintain sustainable and mutually advantageous relationships with traditional owners in the Darwin region, including the original inhabitants of the Blaydin Point area, the Larrakia people. It aims to achieve this by adopting the following measures:

- consulting relevant Aboriginal communities to promote an understanding of each other's concerns and aspirations
- helping relevant Aboriginal communities manage any issues and challenges they might face in relation to INPEX's proposed operations
- consulting with Aboriginal communities and other appropriate organisations to increase the pool of potential employees for the company
- offering a range of school- and community-level initiatives
- supporting partnerships that make a positive difference to Aboriginal communities.

INPEX believes that sustainable employment and economic development are prerequisites for improving the living standards and quality of life for Aboriginal people, and will collaborate with organisations such as the Larrakia Development Corporation to implement an engagement plan and achieve positive social and economic outcomes from the Project.

The establishment of a strong and positive relationship with this group has evolved through the following measures:

- reporting on outcomes of environmental studies
- incorporating Aboriginal heritage issues into the Project
- holding meetings with the Northern Land Council and the Larrakia Development Corporation to keep them advised of the progress and outcome of Project feasibility studies
- holding discussions on how local Aboriginal people can benefit from the Project.

2.2.6 Issues identified by stakeholders

Issues and recurring questions raised by stakeholders have been captured in an issues register which is a regularly updated document. The register ensures that all issues are documented and that an INPEX representative is assigned the responsibility for responding to each issue.

The key issues raised by stakeholders are provided in Annexe A to this chapter, together with a comment on INPEX's position on each. Project positions may change throughout each phase of the development and this will be communicated to stakeholders.

Input from the stakeholders has provided INPEX with valuable feedback which will be incorporated to varying degrees in the design, management and environmental impact assessment of the Project.

2.2.7 Ongoing consultation initiatives

The Commonwealth and Northern Territory government reviews of this Draft EIS and the subsequent period for public review and comment will offer an opportunity to all interested parties to provide input into the environmental assessment as required by the formal environmental assessment process. INPEX will address the issues raised by stakeholder submissions and provide comment on each through a supplement to the Draft EIS.

Comprehensive stakeholder communication will continue throughout the life of the Project as INPEX continues to consult with key stakeholders about the progress of the Project and opportunities for local involvement during its construction, operations, and decommissioning phases. Table 2-2 outlines INPEX's ongoing stakeholder communication initiatives. The Stakeholder Communication Plan will be updated to incorporate stakeholder feedback and expectations as the Project progresses.

Table 2-2: Stakeholder communication initiatives

Strategy	Activity	Project phase(s)	Status
Maintain an up-to-date stakeholder database.	Ensure that information on relevant government, community and other stakeholders is up to date.	All	Ongoing
Increase public awareness of the Project and access to information.	Establish a Darwin office to increase local presence and improve access to information through various means, including the following: • information telephone line: 1800 705 010 • Internet site: <www.inpex.com.au> • enquiries e-mail: <enquiries@inpex.com.au> • media statements.	All	Darwin office established in April 2009 Information line, enquiries e-mail address and web site are active
Liaise with community groups and individuals on key issues throughout all phases of the Project.	Identify opportunities for engagement. Ensure that open communication lines are maintained. Ensure that feedback and responses to enquiries are followed through in a timely and appropriate manner. Maintain a community issues register and incorporate feedback into decision-making and future plans.	All	Ongoing
Develop communication plans for specific Project activities.	Develop communications and community consultation plans to support Project activities as required.	All	Ongoing

Table 2-2: Stakeholder communication initiatives (continued)

Strategy	Activity	Project phase(s)	Status
Distribute Project information to the public in a timely manner.	Maintain up-to-date information for all key aspects of the Project. Produce approved material as required for public distribution (e.g. brochures, DVDs, images, newsletters, and fact sheets). Distribute information through media releases and the INPEX web site at <www.inpex.com.au>.	All	Ongoing
Undertake community and stakeholder presentations.	Organise and manage community and stakeholder presentations and events. Prepare support materials for presentations. Record proceedings as appropriate. Hold Project information sessions in Darwin and Palmerston to provide updates and to listen to stakeholder concerns. Ensure that feedback on issues and concerns raised in public forums is provided in a timely manner.	All	Ongoing
As part of the Project's Industry Participation Plan (IPP), establish a robust process for communicating and engaging with industry and government stakeholders.	Establish early and transparent communication with industry and government stakeholders regarding Project opportunities, utilising, for example, the following communication means: • bulletin boards (e.g. Project Gateway at <www.inpex.icn.org.au>) for contract and procurement opportunities • supplier forums.	All	Ongoing
	Provide qualitative and quantitative feedback to industry and government stakeholders related to supplier performance, and general feedback related to industry gaps, barriers, trends and opportunities.	Construction and operations	
Establish and maintain a community consultation reporting mechanism.	Establish and maintain a community consultation reporting mechanism by the following means: • maintain a database of e-mail and telephone enquiries • carry out quantitative and qualitative analyses of media coverage • maintain records of meetings.	All	Complete
	Provide summary reports as required, particularly in relation to the Draft EIS public-comment period.		Ongoing
	Provide periodic briefings to the Northern Territory Government on the progress of the Project, including community consultation matters as required by the PDA.		Ongoing
Maintain an up-to-date Stakeholder Communication Plan.	Carry out an ongoing review of this plan, including stakeholder communication priorities and engagement methods as the Project evolves through its approvals, construction, commissioning, operations and decommissioning phases.	All	Ongoing

2.3 References

APPEA—*see* Australian Petroleum Production & Exploration Association Limited.

Australian Petroleum Production & Exploration Association Limited. 2003. *Principles of conduct*. Australian Petroleum Production & Exploration Association Limited, Canberra, ACT. Viewed online on 1 March 2010 at <http://www.appea.com.au/images/stories/Publications/CodeOfConductfinal.pdf>.

MCMPR—*see* Ministerial Council on Mineral and Petroleum Resources.

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National Environment Protection Council. 2003. *National Environment Protection (Ambient Air Quality) Measure*. National Environment Protection Council, Canberra, ACT. Viewed online on 1 March 2010 at <http://www.ephc.gov.au/sites/default/files/AAQ_NEPM__Ambient_Air_Quality_NEPM_Varied_scaleplus_Final_200305_1.pdf>.

NEPC—*see* National Environment Protection Council.

Annexe A: Key issues raised relevant to the environmental approvals process

Key issues	INPEX response	Reference within the Draft EIS	Issue source
Clearing of land on Middle Arm Clearing of mangroves, cycads and monsoon vine forest	INPEX has worked closely with environmental groups, providing briefings and site visits. The extent of clearing will be clearly marked out to ensure that no unapproved clearing takes place. Plant and animal species will be described and potential impacts described. Measures taken to minimise identified impacts on species, communities and habitats will be discussed. The provisional vegetation clearing, earthworks and rehabilitation management plan included in this Draft EIS outlines management controls to minimise the potential impacts of clearing in the onshore development area.	Chapter 3 *Existing natural, social and economic environment* Chapter 7 *Marine impacts and management* Chapter 8 *Terrestrial impacts and management* Chapter 11 *Environmental management program*—Annexe 15: *Provisional vegetation clearing, earthworks and rehabilitation management plan*	Consultation with: • local government • Environment Centre Northern Territory • Australian Marine Conservation Society • Larrakia Development Corporation • AFANT • Darwin Harbour Advisory Committee Community forums held in November 2008
Discharges into Darwin Harbour and impacts on water quality and marine ecology	Reuse of some treated wastewater on site will be considered. Where discharges to the Harbour are necessary, they will be treated to comply with regulatory-authority requirements. The provisional liquid discharges, surface water runoff and drainage management plan included in this Draft EIS outlines management controls to minimise potential impacts of discharges into the Harbour.	Chapter 5 *Emissions, discharges and wastes* Chapter 7 *Marine impacts and management* Chapter 11 *Environmental management program*—Annexe 10: *Provisional liquid discharges, surface water runoff and drainage management plan*	Consultation with: • Australian Marine Conservation Society • Environment Centre Northern Territory Community forums held in November 2008
Impacts of noise and vibration on cetaceans and other large marine animals	INPEX has consulted with the DEWHA and NRETAS to identify sensitive receptors for noise and vibration and incorporated feedback from discussions into management measures to minimise potential impacts. The provisional piledriving and blasting management plan in this Draft EIS outlines management controls to minimise potential impacts of piledriving and blasting.	Chapter 7 *Marine impacts and management* Chapter 11 *Environmental management program*—Annexe 12: *Provisional piledriving and blasting management plan* Chapter 11 *Environmental management program*—Annexe 4: *Provisional cetacean management plan*	Consultation with: • DEWHA • NRETAS
Introduction of pest and exotic species	The provisional quarantine management plan in this Draft EIS outlines controls to minimise and manage exotic species introduction and spread.	Chapter 7 *Marine impacts and management* Chapter 8 *Terrestrial impacts and management* Chapter 11 *Environmental management program*—Annexe 13: *Provisional quarantine management plan*	Consultation with: • Northern Territory Seafood Council • Paspaley Pearling Company • Australian Marine Conservation Society • Environment Centre Northern Territory

Annexe A: Key issues raised relevant to the environmental approvals process (continued)

Key issues	INPEX response	Reference within the Draft EIS	Issue source
Dredging and dredge spoil disposal	INPEX has carried out modelling of dredge plume dispersal; the report is provided as an appendix to this Draft EIS and the results have been incorporated into Chapter 7. The provisional dredging and dredge spoil disposal management plan in this Draft EIS outlines management controls aimed at minimising the impacts of dredging and dredge spoil disposal. The proposed dredge spoil disposal ground was decided on after consultation with key stakeholders to identify areas to be protected, e.g. navigation channels, fishing grounds and sensitive coastal receptors.	Chapter 7 *Marine impacts and management* Chapter 11 *Environmental management program*—Annexe 6: *Provisional dredging and dredge spoil disposal management plan* Appendix 13	Consultation with: • DEWHA • NRETAS • AFANT • Environment Centre Northern Territory • Department of Planning and Infrastructure • Darwin Port Corporation • Department of the Chief Minister Community forums held in November 2008
Greenhouse gas (GHG) emissions	INPEX is committed to reducing GHG emissions from its operations and has commenced a process to identify technical abatement and offset opportunities to reduce GHG emissions. Quantification of GHG emissions has been conducted for all onshore and offshore activities associated with the Project. INPEX's environmental policy requires the company to actively promote the reduction of GHG emissions in a safe and technically and commercially viable manner. The provisional greenhouse gas management plan in this Draft EIS outlines management controls to reduce GHG emissions.	Chapter 9 *Greenhouse gas management* Chapter 11 *Environmental management program*—Annexe 8: *Provisional greenhouse gas management plan*	Consultation with: • Environment Centre Northern Territory • local government • Darwin Harbour Advisory Committee
Air quality	Emissions have been determined and quantified from point sources, and atmospheric modelling has been undertaken for these sources. This modelling demonstrates how emissions from the gas-processing plant will comply with the National Environment Protection (Ambient Air Quality) Measure (NEPC 2003). A validation program will be developed for air-quality modelling. Management controls to minimise impacts have been provided in the provisional air emissions management plan in this Draft EIS.	Chapter 5 *Emissions, discharges and wastes* Chapter 8 *Terrestrial impacts and management* Chapter 11 *Environmental management program*—Annexe 2: *Provisional air emissions management plan*	Consultation with: • Environment Centre Northern Territory • local government • Darwin Harbour Advisory Committee Community forums held in November 2008

Annexe A: Key issues raised relevant to the environmental approvals process (continued)

Key issues	INPEX response	Reference within the Draft EIS	Issue source
Impacts to heritage values	INPEX is working to limit damage to any maritime heritage sites of significance, including the Catalina flying-boat wrecks, heritage shipwrecks, Aboriginal sacred sites and listed heritage sites. Measures are being taken to avoid these sites in the design of pipeline routes, jetty locations and anchor points. Representatives of the Larrakia people have conducted comprehensive heritage and sacred site surveys and prepared a heritage management plan over INPEX's area of interest onshore. The provisional heritage management plan in this Draft EIS provides management controls to minimise the potential impacts on marine and terrestrial heritage sites.	Chapter 10 *Socio-economic impacts and management* Chapter 11 *Environmental management program*—Annexe 9: *Provisional heritage management plan*	Consultation with: • Larrakia Development Corporation • NRETAS • Darwin Port Corporation Community forums held in November 2008
Access to Middle Arm Peninsula: loss of traditional hunting, camping and food-gathering sites	INPEX will work with the Larrakia people to manage this issue.	Chapter 10 *Socio-economic impacts and management*	Consultation with: • Larrakia Development Corporation • Environment Centre Northern Territory • local government Community forums held in November 2008
Site-selection process	The Northern Territory Government identified the Blaydin Point industrial site as its preferred location for the onshore component of the Project and proposed it to INPEX.	Chapter 4 *Project description*	Consultation with: • Environment Centre Northern Territory • Darwin Harbour Advisory Committee • local government Community forums held in November 2008
Infrastructure issues: • increased road use and traffic congestion • pressure for housing and for release of industrial and residential land • pressure on power and water services	The potential impacts on public amenities are addressed in the socio-economic chapter of this Draft EIS. Bus transport will be provided between the accommodation village and the onshore processing plant at Blaydin Point to minimise use of vehicles on the road. Development of an accommodation village will alleviate some of the pressure on housing availability.	Chapter 4 *Project description* Chapter 8 *Terrestrial impacts and management* Chapter 10 *Socio-economic impacts and management* Chapter 11 *Environmental management program*—Annexe 14: *Provisional traffic management plan* Appendix 22	Consultation with: • Northern Territory Government • local government Community forums held in November 2008 Accommodation village interviews carried out in February 2009
Impacts on Darwin Harbour and concerns about further development	INPEX recognises the sensitivities associated with the Harbour as a multi-use location and with the effects of development on the Harbour.	Chapter 7 *Marine impacts and management* Chapter 10 *Socio-economic impacts and management*	Consultation with: • Darwin Harbour Advisory Committee • AFANT • local government • Environment Centre Northern Territory Community forums held in November 2008

Annexe A: Key issues raised relevant to the environmental approvals process (continued)

Key issues	INPEX response	Reference within the Draft EIS	Issue source
Impacts on visual amenity	The potential impacts on the visual amenity of the proposed development from the perspective of agreed viewing points around Darwin Harbour have been described in this Draft EIS. The viewing points were determined in consultation with NRETAS.	Chapter 10 *Socio-economic impacts and management* Appendix 23	Consultation with: • Environment Centre Northern Territory • AFANT • PLan
Impacts on recreational fishing	INPEX will continue consulting with relevant stakeholders regarding the impact of jetty construction and operations on recreational fishing zones. INPEX understands the importance of access to Cossack Creek and Lightning Creek ("Catalina Creeks 1 and 2") and, where possible, is incorporating stakeholder requirements in the design of nearshore infrastructure configurations. Public safety remains a key consideration for INPEX.	Chapter 10 *Socio-economic impacts and management*	Consultation with: • Paspaley Pearling Company • Northern Territory Seafood Council • AFANT Community forums held in November 2008
Maximising economic development and employment opportunities in Darwin	INPEX will be a long-term employer; the Project will have a life of over 40 years. The active promotion and provision of full, fair and reasonable opportunities for Northern Territory and Australian companies is a core business value for INPEX. INPEX will consult with relevant Aboriginal organisations to identify opportunities for members of Darwin's Aboriginal community to find employment.	Chapter 10 *Socio-economic impacts and management*	Consultation with: • Northern Territory Business Council • Chamber of Commerce Northern Territory • Larrakia Development Corporation Community forums held in November 2008
Security of onshore and offshore facilities Public safety	INPEX is consulting with Commonwealth and Northern Territory agencies regarding security planning. Required exclusion zones around components of Project infrastructure are outlined in Chapter 4 *Project description*. Offshore oil & and gas industry security is addressed through the *Maritime Transport Security Act 2003* (Cwlth) and managed by the Commonwealth's Department of Infrastructure, Transport, Regional Development and Local Government. Quantitative risk assessments have been and will continue to be undertaken to assess risks to public safety.	Chapter 4 *Project description* Chapter 10 *Socio-economic impacts and management*	Community forums held in November 2008
Increase in prevalence of biting insects	Biting-insect surveys have been carried out on Blaydin Point by the Northern Territory's Department of Health and Families. Management measures to minimise the creation of breeding habitat for biting insects are outlined in the provisional liquid discharges, surface water runoff and drainage management plan in this Draft EIS.	Chapter 8 *Terrestrial impacts and management* Chapter 11 *Environmental management program—* Annexe 10 *Provisional liquid discharges, surface water runoff and drainage management plan* Appendix 21	*Guidelines for preparation of a draft environmental impact statement: Ichthys Gas Field Development Project* Consultation with: • Department of Health and Families

3 Existing Natural, Social and Economic Environment

3 EXISTING NATURAL, SOCIAL AND ECONOMIC ENVIRONMENT

3.1 Introduction

This chapter of the draft environmental impact statement (Draft EIS) for the Ichthys Gas Field Development Project (the Project) describes the key physical, biological, social and economic features of the existing environment in the areas to be affected by the Project. A description of the regional environment is also included in order to provide context for the significance of the habitats, resources and socio-economic conditions that currently exist in and around the development areas. The area affected by the Project can be divided into three main components—the offshore, nearshore and onshore development areas—as described in Section 3.1.1 *Development areas*.

A number of scientific surveys and technical studies have been undertaken to characterise the existing environment and to fill gaps in current knowledge. A description of the scoping process for these investigations and a complete list of the studies carried out are provided in Chapter 1 *Introduction*.

3.1.1 Development areas

For the purpose of describing the environment in which the Project will operate, the development area can be divided into three main components:

- the offshore development area, which includes the Ichthys Field in the Browse Basin off the coast of north-western Australia as well as the pipeline route from the field to the mouth of Darwin Harbour
- the nearshore development area, which includes the pipeline route from the mouth of Darwin Harbour south to the waters around Blaydin Point and Middle Arm Peninsula as well as the offshore spoil disposal ground about 15 km north of the entrance to Darwin Harbour
- the onshore development area, which includes the site proposed for the onshore processing plant at Blaydin Point and the onshore pipeline corridor from the shore crossing south of Wickham Point to the Blaydin Point plant.

The major environmental features of each are described below, while a detailed description of the Project infrastructure in each area is provided in Chapter 4 *Project description*.

Offshore development area

The Ichthys Field is located approximately 220 km north-west of the Kimberley coast of Western Australia in the northern Browse Basin at the western edge of the Timor Sea. It is located in Retention Lease WA-37-R, which was granted to INPEX and Total E&P Australia (the Joint Venture Parties) on 21 September 2009 in a portion of petroleum exploration permit area WA-285-P R1 (see Figure 3-1). The offshore waters in the Ichthys Field area are between 235 m and 275 m deep while the waters across the whole permit area are between 100 m and 340 m deep. Browse Island is located 33 km south-east of the field and Echuca Shoal is approximately 55 km to the east. The edge of the continental shelf is located around 20 km west of the field.

The offshore development area also includes the subsea pipeline route, which will extend from the Ichthys Field to the shore-crossing area south of Wickham Point on Middle Arm Peninsula in Darwin Harbour, a distance of around 885 km. Approximately 852 km of the pipeline is in the offshore development area. Most of this route is distant from land, with the exception of the eastern end of the route that curves around Cox Peninsula just before it enters Darwin Harbour. In the eastern third of the route the pipeline will cross the Northern Australia Exercise Area (NAXA), a maritime military zone administered by the Australian Defence Force (ADF).

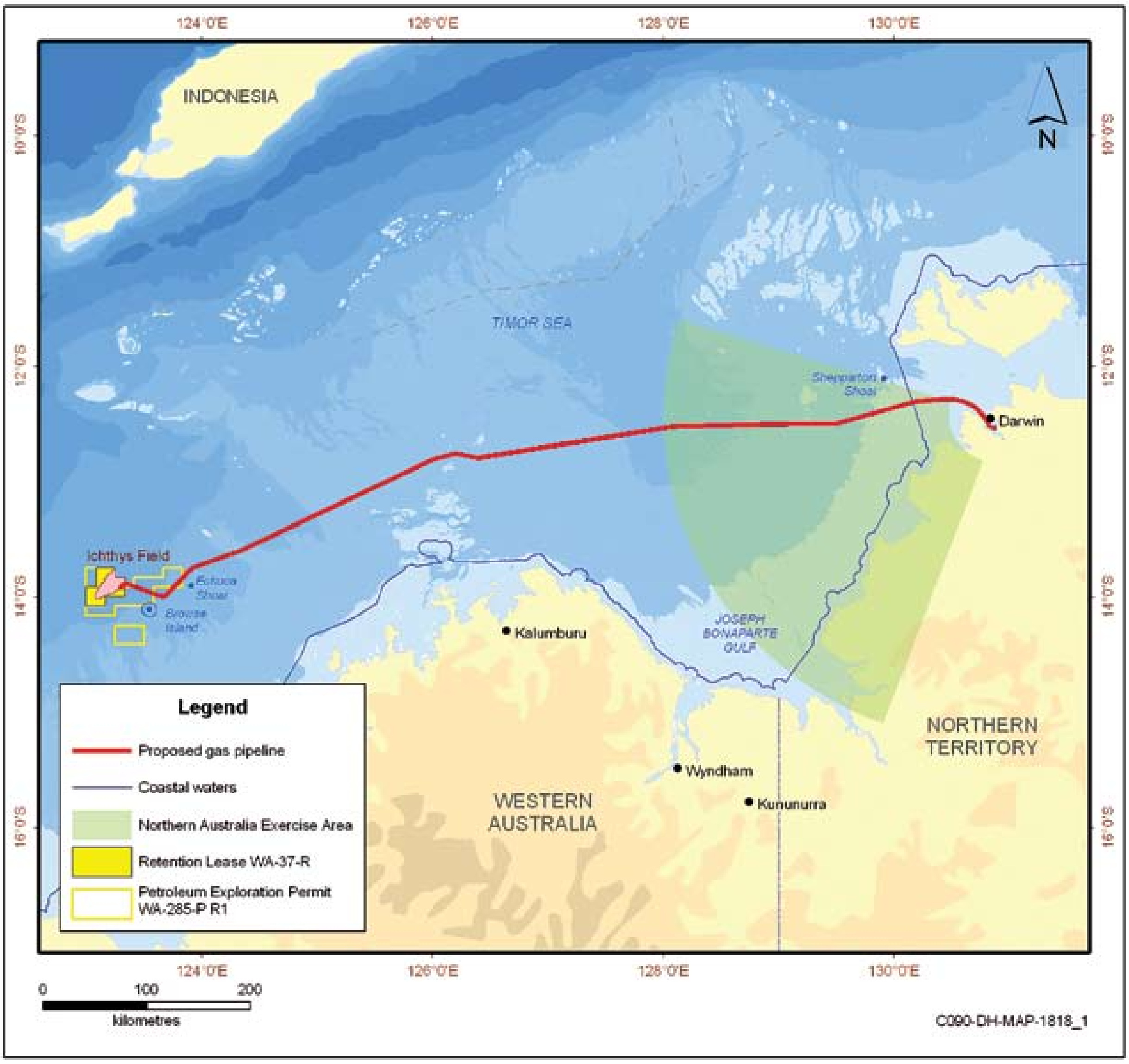


Figure 3-1: The Ichthys Project's offshore development area

Nearshore development area

The nearshore portion of the pipeline route, some 27 km long, extends from the mouth of Darwin Harbour through the Harbour to the low-water mark at the pipeline shore crossing south of Wickham Point on the western shore of Middle Arm Peninsula (see Figure 3-2). The pipeline route for the Project runs adjacent and parallel to the existing Bayu–Undan Gas Pipeline which feeds the Darwin Liquefied Natural Gas plant (Darwin LNG plant) operated by ConocoPhillips. Seabed features near the pipeline route include Kurumba Shoal, Plater Rock and Weed Reef to the west of the alignment. Channel Island is located in Middle Arm, around 1.5 km south-west of the proposed pipeline shore crossing.

The nearshore development area also includes the marine environment below the low-water mark around Blaydin Point. This area is located on the southern bank of East Arm, downstream of the Elizabeth River.

The existing harbour facility of East Arm Wharf lies on the northern side of East Arm. Subsea features of this area include South Shell Island and Old Man Rock. Immediately to the west of Blaydin Point on Middle Arm Peninsula are two narrow tidal creeks known as Lightning Creek and Cossack Creek (known until March 2008 as "Catalina Creeks 1 and 2"), both of which are utilised for recreational fishing.

An offshore site 15–20 km north of the mouth of Darwin Harbour is also considered to be part of the nearshore development area for the purposes of this description. This will be used as a disposal area for material resulting from INPEX's nearshore dredging operations in Darwin Harbour. The site is described in detail in Chapter 4 and in Chapter 7 *Marine impacts and management*.

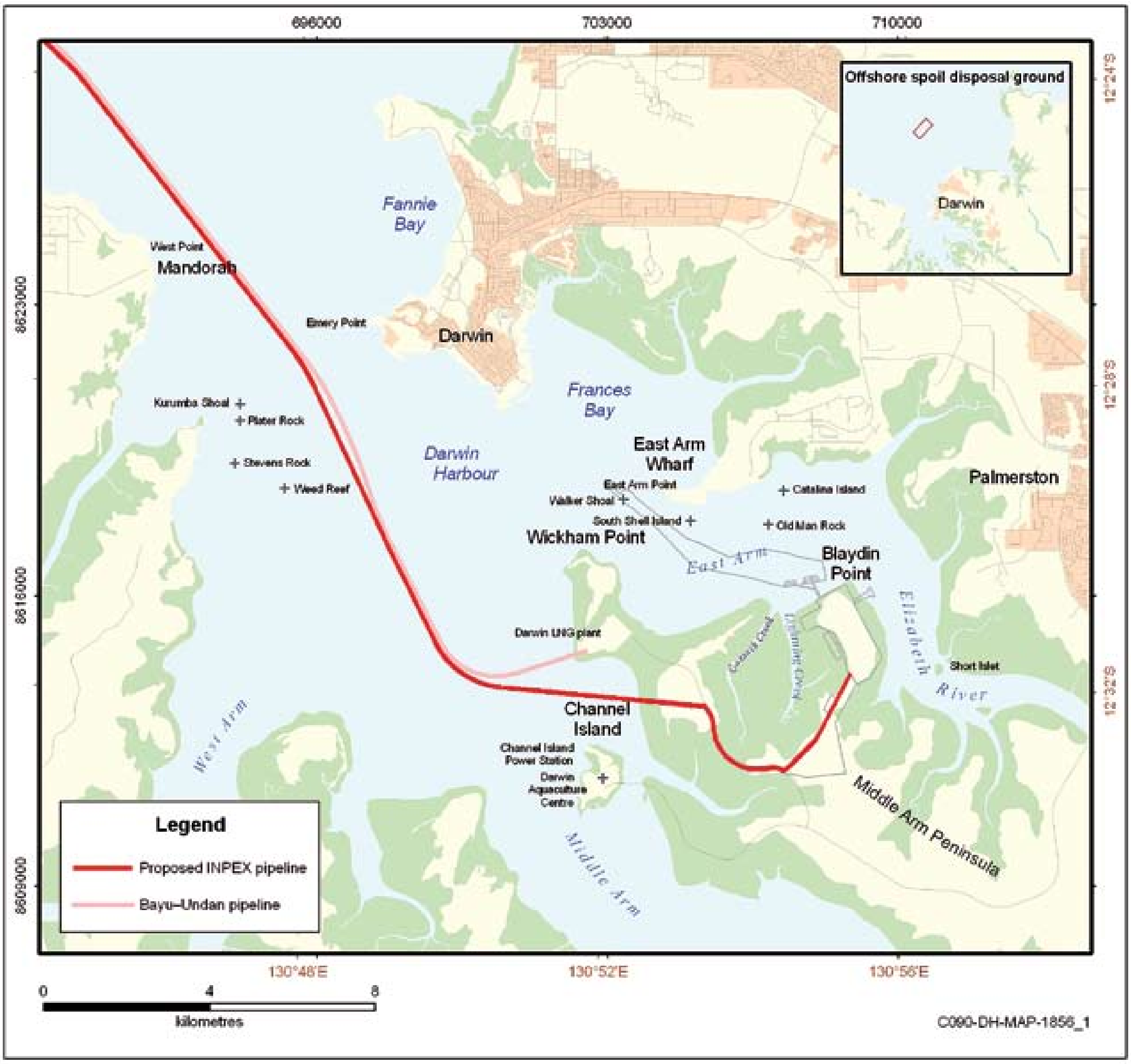


Figure 3-2: The nearshore development area in Darwin Harbour

Onshore development area

The proposed onshore development area will be on Blaydin Point on the northern side of Middle Arm Peninsula above the low-water mark (see Figure 3-3). Blaydin Point is a parcel of land that is linked to the main peninsula by a salt flat except at extreme high tide when the salt flat becomes inundated to a depth of approximately 1 m for periods of up to an hour. Blaydin Point is currently undeveloped. The onshore development area also extends on to the main area of Middle Arm Peninsula and includes the proposed onshore pipeline corridor leading from the western shore of the peninsula across country to Blaydin Point.

Middle Arm Peninsula is currently traversed by a road and services corridor leading to the Darwin LNG plant at Wickham Point as well as to a power station and an aquaculture centre on Channel Island.

3.2 Offshore marine environment

The offshore development area is made up of two parts: the Ichthys Field in Retention Lease WA-37-R in the Browse Basin off the north-western Australian coast and the subsea pipeline corridor from the Ichthys Field to the mouth of Darwin Harbour.

3.2.1 Oceanography and hydrodynamics

Broad-scale oceanography in the north-west Australian offshore area is complex, with the large-scale currents of the Timor and Arafura seas dominated by the Indonesian Throughflow current system (illustrated in Figure 3-4). This current, which is associated with water movement from the Pacific Ocean to the Indian Ocean between the land masses of Indonesia, Australia and Papua New Guinea, is generally strongest during the south-east monsoon from May to September (Qiu, Mao & Kashino 1999).

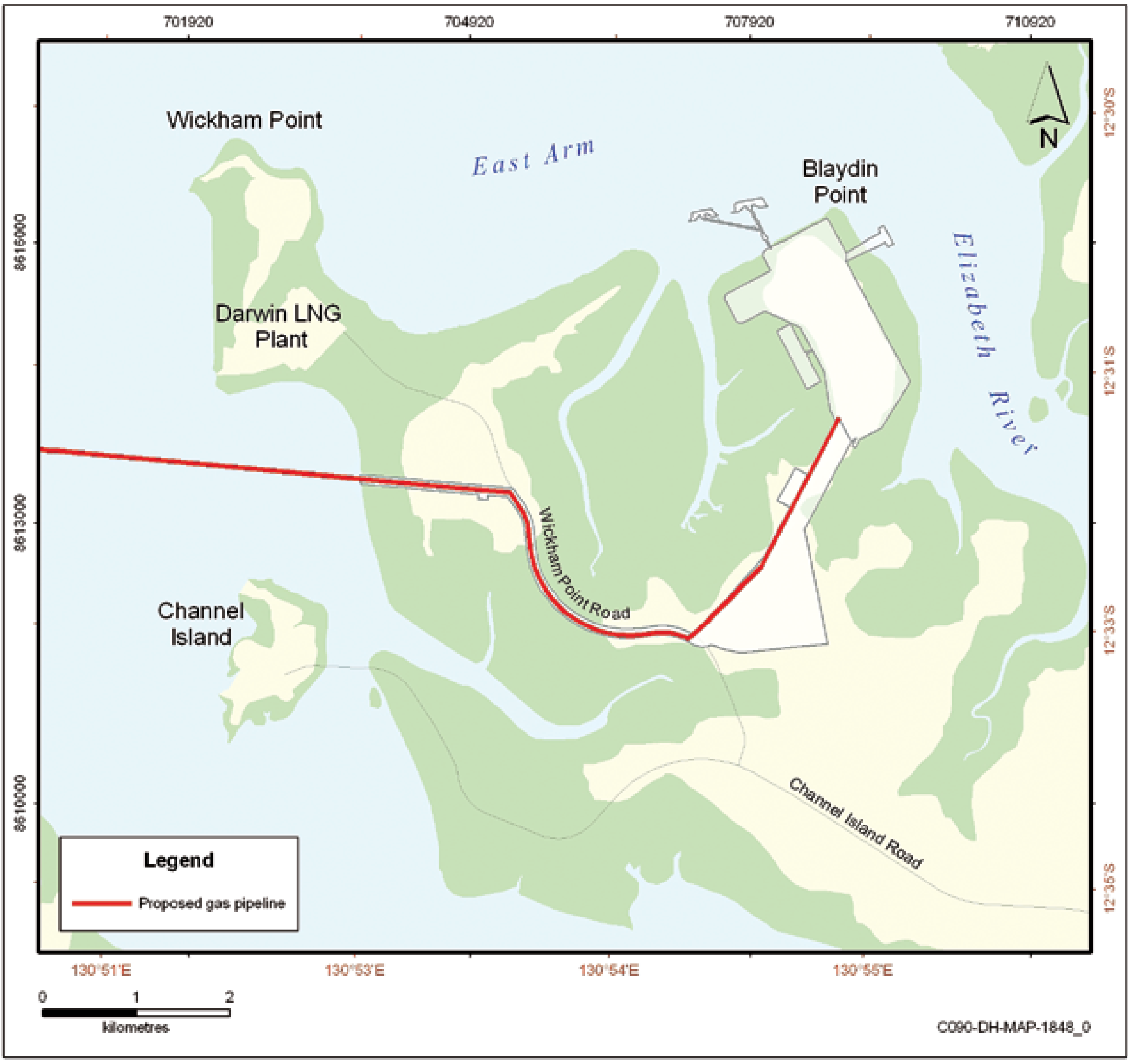


Figure 3-3: The onshore development area

On the outer parts of the continental shelf there are seasonally reversing currents and locally formed water masses characterised by peak south-westward or northward flows and strong meso-scale variability, causing interleaving and mixing of peripheral water masses (Cresswell et al. 1993); Retention Lease WA-37-R is located in this transitional region.

The Browse Basin generally experiences large tides and tidal currents. Mean sea level at the Ichthys Field is about 2.7 m above Lowest Astronomical Tide (LAT), with a spring tidal range of about 5.0 m. Tides are semidiurnal, with two daily high tides and two low tides. Barotropic tidal currents predominantly flow in the cross-shelf direction at the shelf break and in the along-shelf direction when approaching the coast (McLoughlin, Davis & Ward 1988).

This diurnal tide results in relatively short migrations of the thin water-surface layer; longer-term drift is more highly dependent upon the forces of the prevailing winds (see Appendix 7 to this Draft EIS). Meteorological conditions in the offshore development area are described in Section 3.5.1 *Meteorology*.

Southern Ocean swell (also sometimes called Indian Ocean swell) approaches the outer edge of the continental shelf from the south and south-west before refracting over shallower parts of the shelf and approaching the coast from the west, north-west or even north. In the Browse Basin, the swell tends to be higher during winter (with typical significant wave heights about 0.8 m) than in summer (with typical significant wave heights about 0.7 m), because the swell-generating storms move further north in winter. Swell periods are generally of the order of 12–18 s.

In areas of the north-west continental shelf where there is more than 200 km of "fetch" (open water for the wind to blow across), the winter easterly winds

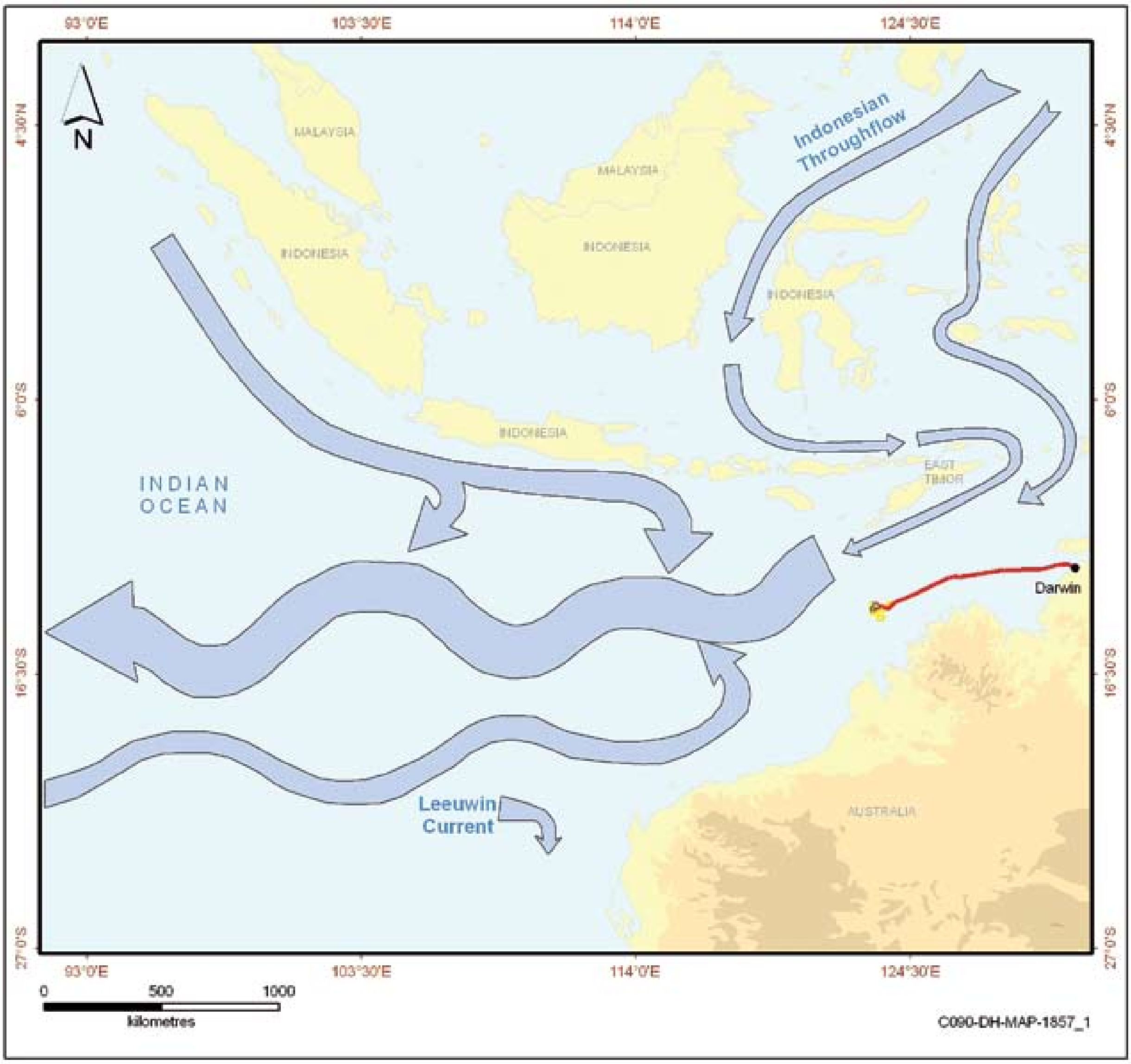


Figure 3-4: Large-scale currents of north-west Australia

generate east-north-easterly swells with a wave period of 6–10 s. In summer, the westerly winds generate west-north-westerly swells with the same period. Such swells may have some influence in the outer-shelf portions of the north-west continental shelf region with significant wave heights[1] of 1–2 m.

Summertime tropical cyclones generate waves propagating radially out from the storm centre. Depending upon the storm size, intensity, relative location and forward speed, tropical cyclones may generate swell with periods of 6–18 s from any direction and with wave heights of 0.5–9.0 m. During severe tropical cyclones, which can generate major short-term fluctuations in current patterns and coastal sea levels (Fandry & Steedman 1994; Hearn & Holloway 1990), current speeds may reach 1.0 m/s and occasionally exceed 2.0 m/s in the near-surface water layer. Such events are likely to have significant impacts on sediment distributions and other aspects of the benthic habitat.

1 "Significant wave height" is calculated as the average of the highest one-third of all of the wave heights during a defined sampling period.

3.2.2 Biogeographical setting

The Integrated Marine and Coastal Regionalisation of Australia (IMCRA) has been developed by the Commonwealth's Department of the Environment, Water, Heritage and the Arts (DEWHA) as a regional framework for planning resource development and biodiversity conservation (DEH 2006a). The IMCRA divides Australian marine areas into two types of bioregion:

- benthic bioregions, provinces and transitions based on the diversity and richness of demersal fish species
- meso-scale (intermediate scale) bioregions, defined by biological and physical information and geographic distance along the coast.

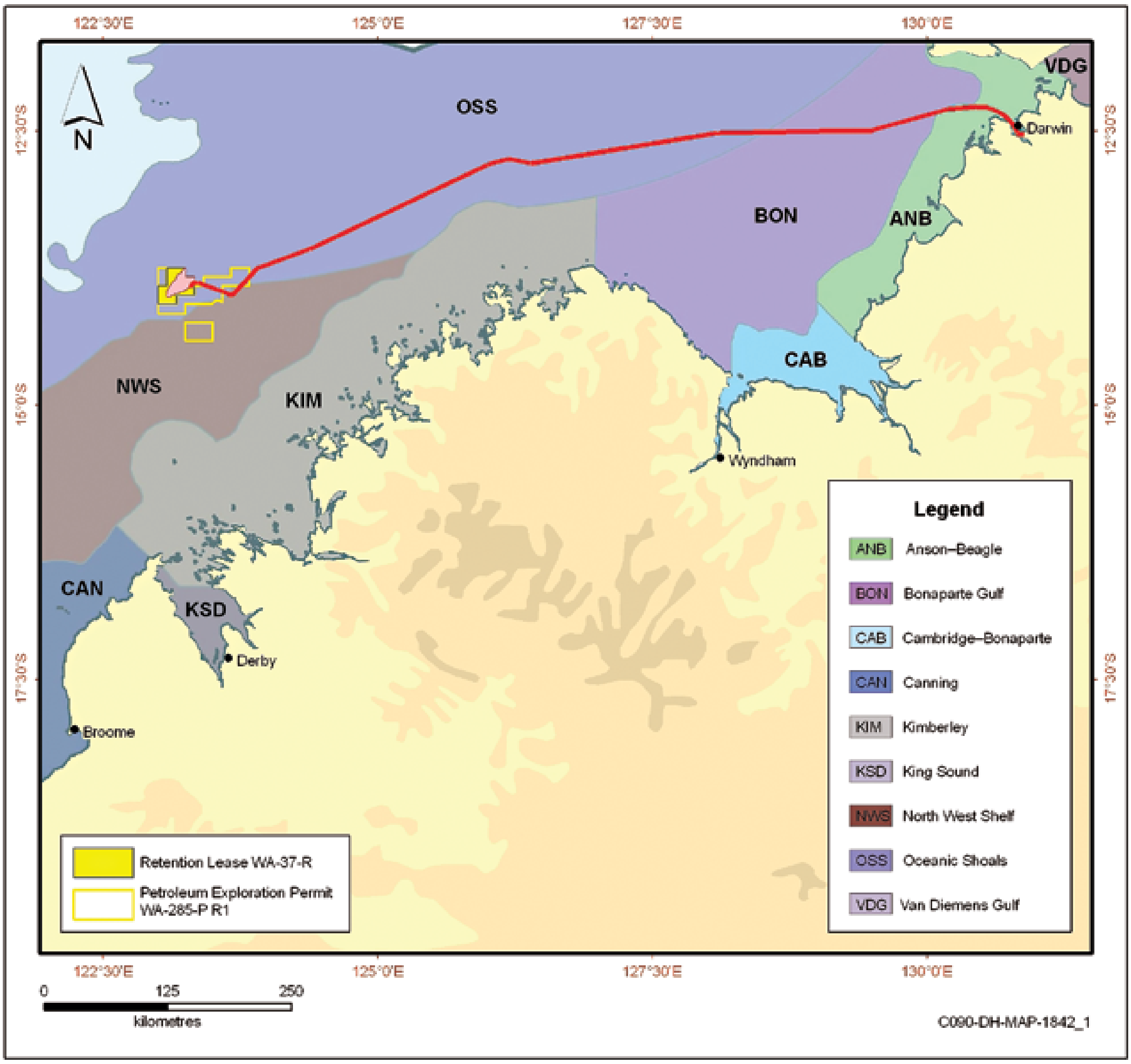


Figure 3-5: Meso-scale bioregions of north-west Australia

Benthic bioregions

The demersal fish provinces are defined by the levels of endemism in the local fish populations: a well-defined demersal fish province has a high occurrence of endemic species and/or a broad geographic coverage, while a weak province has few endemics which are often narrowly distributed. Transitions are areas of species overlap and faunal mixing, where species distributions from the adjacent provinces overlap and few (or no) endemic species occur (Heap et al. 2005).

The offshore development area (in Retention Lease WA-37-R) is located in the Timor Province for demersal fish species, which is considered to be a strong province with a high degree of endemism. The greater part of the proposed pipeline route from the Ichthys Field to Blaydin Point traverses the North-West Transition, a large biogeographic region of mixing and low endemism (Heap et al. 2005).

Meso-scale bioregions

The meso-scale bioregions are defined using biological and physical information, including the distribution of demersal fishes, marine plants and invertebrates; seafloor geomorphology and sediments; and oceanographic data (DEH 2006a).

The offshore development area is located in the Oceanic Shoals Bioregion. A small portion of the permit area is also located in the North West Shelf Bioregion. The proposed subsea pipeline route traverses the Oceanic Shoals, Bonaparte Gulf and Anson–Beagle bioregions from west to east (Figure 3-5). The characteristics of each bioregion are explained in the following sections.

North West Shelf

The IMCRA Technical Group (1998) provides the following information on the North West Shelf Bioregion.

It is located on the outer part of the North West Shelf off the Pilbara and Kimberley coasts, between about the 30-m bathymetric contour and the shelf edge. The southern portion of the North West Shelf is a wide continental platform bordered by the Australian continent on one side and by an abyssal plain on the other. Sediments are predominantly calcareous, with little sediment currently being supplied to this region.

Ocean current speeds in the area are generally high, particularly in deep waters, and are influenced by the poleward-flowing Leeuwin Current. Wave energy is typically moderate but can be extreme during cyclones. Tides are macrotidal with a spring-tide range exceeding 5 m.

The North West Shelf Bioregion has diverse benthic invertebrate communities and a rich pelagic and demersal fish fauna.

Oceanic Shoals

The Oceanic Shoals Bioregion comprises the Australian shelf margin in the easternmost part of the Indian Ocean, the Timor Sea, and the western part of the Arafura Sea, including the continental shelf and the outer part of the continental slope from about Port Hedland in Western Australia to the Cobourg Peninsula in the Northern Territory. It covers the eastern portion of the north-west continental shelf of Australia known as the Sahul Shelf (see also Appendix 4 to this Draft EIS).

In addition to the benthic habitats of the outer shelf and shelf slope, the bioregion is characterised by a chain of biohermic banks, atolls and shoals along the shelf edge rising from the continental slope and by several platform reefs rising from the seafloor of the outer shelf. To the south-west, the Seringapatam, Scott and Rowley Shoals reef systems persist as a disjunct line of near-surface or emergent reefs. Other reefs are emergent and have sandy cays forming small islands, such as Ashmore Reef with its three islets, which support sparse vegetation. None of the islands are inhabited (see Appendix 4).

The extent to which the coral reefs of the Oceanic Shoals Bioregion are interconnected and interrelated in regard to larval recruitment is unknown. The chain of reefs and banks along the shelf edge lies in the path of the south-westerly-flowing current that originates in the Indonesian Throughflow. However, seasonal reversals of flow on the shelf associated with changes in the direction of the prevailing wind have been noted (Cresswell et al. 1993) and larval recruitment may then be supplied from elsewhere. There are also local effects within oceanic currents: in May, during the time of strong shelf-edge flow toward the south-west, there is a reversal of flow on the shelf nearer the coast with currents flowing “almost against the prevailing south-east winds” (Cresswell et al. 1993). This latter effect is likely to be especially important on mid-shelf reefs like that surrounding Browse Island. Interconnectedness is likely to be a complex matter, depending on each reef’s position relative to the seasonal current patterns and the breeding methods and seasonalities of the different species (see Appendix 4).

The plant and animal assemblages of these coral reef systems are typical of oceanic reefs in the Indo-West Pacific region, with some endemism present in the northern sectors. The coral, other invertebrate, and fish faunas are species-rich. The islands support seabird breeding colonies that in some cases are regionally significant. Marine turtles, cetaceans and dugong occur and are also known to breed throughout this bioregion.

The Oceanic Shoals Bioregion is subject to cyclonic activity between December and April. Strong easterly to south-easterly trade winds blow at 15–20 knots almost continuously from May to October. Waters are generally clear and warm (24–30 °C), with moderate wave energy except when the region is influenced by cyclones. Tides are macrotidal to 6 m in the north of the bioregion.

The geology of the bioregion indicates that the continental shelf edge has been rapidly subsiding since the mid-Miocene as a consequence of the collision of the Australian and Asian blocks. The sequence of reef growth in the bioregion is likely to coincide with the postglacial rise in sea level, which stabilised at its present level about 6000 years ago.

Bonaparte Gulf

The Bonaparte Gulf Bioregion consists of the waters in the Bonaparte Gulf deeper than the 30-m isobath and is bordered to the north by the reef complexes of the Oceanic Shoals Bioregion.

This bioregion is characterised by sediments of biogenic gravels and sands, grading to biogenic muds offshore. Biological knowledge of the area is poor, except for trawl bycatch data which indicate that fish assemblages are distinctly different from those of the Arafura Region to the east (IMCRA Technical Group 1998).

The climate of the bioregion is monsoon tropical. Oceanic currents are influenced by the Indonesian Throughflow and the South Equatorial Current. Nearshore currents are generally westerly in the dry season (May to September) and easterly in the wet season (October to March). Waters are generally of low turbidity, with a microtidal range offshore (2–3 m variation) rising to mesotidal inshore (3–4 m variation).

Anson–Beagle

The Anson–Beagle Bioregion comprises the inshore waters of the western Top End coast, including the Beagle Gulf and the southern shores of the Tiwi Islands (Melville Island and Bathurst Island) between the high-water mark and the 30-m isobath—a width of approximately 25 km (IMCRA Technical Group 1998).

The climate in the bioregion is monsoon tropical, with high rainfall in the monsoon season from November to March; cyclones occur with low to moderate frequency. Riverine discharge from wet-season runoff can be significant from the Daly, Finniss and Adelaide rivers. As a result of this discharge, seafloor sediments in Darwin and Bynoe harbours in the east of the bioregion are dominated by coarse sands and gravels of terrigenous origin. In the offshore western part of the bioregion benthic sediments are dominated by biogenic sands and muds.

The major geomorphological features in the Anson–Beagle Bioregion are the ria[2] shorelines in Darwin and Bynoe harbours, the Vernon Islands reef complex on the eastern boundary, and sandy beaches backed by chenier ridge systems and low-cliffed headlands (less than 10 m high) on the western coast. Numerous rocky reefs and shoals are scattered throughout the region. Coralline fringing reefs and patch reefs are sparsely distributed, generally occurring in association with coastal rocky outcrops. The Peron Islands, two extensive sand cays overlying Permian sandstones and siltstones, are located 1 km offshore in the south-west of the bioregion (IMCRA Technical Group 1998).

Other than the extensive fringing mangrove communities of the nearshore area, significant habitat in the Anson–Beagle Bioregion includes wading-bird habitats, turtle feeding and nesting beaches, seagrass beds grazed by dugong, and some hard coral reefs where clear water occurs (IMCRA Technical Group 1998).

Ocean currents exert only a minor influence over this bioregion owing to the breadth of the continental shelf. In the dry season, from May to September, a general south-westerly drift is associated with south-easterly winds, the Indonesian Throughflow and the South Equatorial Current. Wet-season circulation is dominated by north-easterly drift generated by north-westerly monsoonal winds. The Beagle Gulf is dominated by strong internal circulation with little oceanic interaction. Tides range from 6 to 8 m and monsoon conditions can generate turbulent wave action and high turbidity along this coast during the wet season (IMCRA Technical Group 1998).

2 A ria is a drowned river valley, formed as a result of a rise in sea level relative to the land, either by an actual rise in global sea level or by the land sinking.

3.2.3 Seabed and bathymetry

Ichthys Field

The seabed and bathymetry of the Ichthys Field in the area proposed for the development of subsea wells have been characterised through sidescan sonar and multibeam bathymetry surveys undertaken by Fugro Survey Pty Ltd (Fugro) in September and October 2005 and further surveys by Neptune Geomatics in October 2008. These surveys revealed an almost featureless seabed varying in depth between 235 m in the north-east of the area to 270 m depth over the centre and shelving slightly to 260 m to the south-west of the area. All seabed slopes are less than one degree, except where local variations in the seabed bathymetry occur in the north-east and south-west portions where sand waves are present.

The four distinct seabed types in the Ichthys Field may be characterised as follows:

- featureless soft sandy silt
- loose fine-to-medium calcareous sand, generally in the form of sand waves
- loose medium-to-coarse gravelly sand, generally in the form of sand waves
- loose coarse gravelly sand with shell fragments, generally in the form of sand waves.

In general, the seabed sediments grade from soft featureless sandy silts in the north to gravelly sand in the south. Sand forms a cover over the silt, and is generally represented in the form of sand waves. The distribution of seabed type shows some correlation with the water depth—as it becomes deeper to the south the sediments become coarser (Fugro 2005).

Sand-wave crests on the seafloor are aligned in north-east to south-west bands and vary in height and wavelengths. Typical heights are 0.5–1.0 m with wavelengths in the order of 10–25 m. The sand waves are likely to be mobile and overlie the flat-lying sandy silt (Fugro 2005).

During surveys of the field, no obstructions were noted on the seafloor and no features such as boulders, reef pinnacles or outcropping hard layers were identified (Fugro 2005).

The Ichthys Field seabed is suggestive of strong near-seabed currents and mobile sediments that do not favour the development of diverse epibenthic communities. The areas of mud and fine sand on the seabed suggest that it is a depositional area where fine sediments and detritus accumulate. Soft substrates are typical of deep continental shelf seabeds and this habitat is very widely distributed in the deeper parts of the Browse Basin (see Appendix 4).

Pipeline route

The seabed along the pipeline route from the Ichthys Field to Darwin Harbour was characterised through geophysical and geotechnical surveys by Neptune Geomatics between July and November 2008. The survey methods included sidescan sonar and swath bathymetry to provide information on seabed morphology.

The surveys recorded featureless, unconsolidated clay–silt sands along the greater part of the pipeline route (>98%), with the most dominant seabed features being areas of pockmarks and sand waves. Rock subcrop occurred in some areas and exposed outcrop was very rare. Descriptions of sections of the seabed along the pipeline route are provided below. The sections are referred to in terms of their distance (as a "kilometre point" (KP)) from the Ichthys Field, for example KP 0 is located at the Ichthys Field where the survey commenced and KP 860 is near Darwin Harbour where the survey was completed. The seven main sections may be described as follows:

- **KP 0 to KP 97:** The greater part of the gently upward-sloping seabed (around 250–136 m deep) between these points consists of rippled fine-to-coarse sands with an occasional gravelly matrix occurring as a veneer overlying more consolidated cemented calcarenite. Areas of megaripples up to 5 m high are present in this zone.
- **KP 97 to KP 213:** The seabed here is dominated by fine-to-coarse sands with areas of both low-density (<10 per hectare) and high-density (≥10 per hectare) pockmarks between 5 and 10 m in diameter. The seabed in this section slopes gently upwards from a depth of 136 m to 84 m.
- **KP 213 to KP 331:** The seabed is characterised by featureless fine-to-coarse sands with occasional patches of a gravelly matrix and dense (≥10 per hectare) pockmarks.
- **KP 331 to KP 481:** The seabed is characterised by gently sloping, featureless fine-to-coarse sands. Occasional areas of ridged calcarenite subcrop up to 3.4 m high occur between KP 361 and KP 374. A scarp slope with a maximum gradient of 7.2° around KP 379 forms the western side of a 3-km-wide palaeochannel where the water depth reaches nearly 90 m. There are isolated outcrop areas within the palaeochannel.
- **KP 481 to KP 513:** Calcarenite subcrop causes the seafloor to be very rugged in places, with an 11-km-wide palaeochannel between KP 483 and KP 484 that reaches depths of 80–85 m. Small outcrops are present in the shallower waters (at depths of 70–75 m) on either side of the palaeochannel. The subcrop areas are flanked by clay–silt sand, interspersed with sandy gravel patches with a few pockmarks >5 m in diameter.
- **KP 513 to KP 706:** The seabed here is characterised by featureless clay–silt sands dominated by low-density pockmarks (≤10 per hectare) 5–10 m in diameter. Water depths vary from 110 m to 63 m.
- **KP 706 to KP 862:** The seabed is mostly characterised by featureless clay–silt sands with areas of megaripples (KP 799 to KP 804) and sand waves up to 4.9 m high. Water depths vary between 70 m and 11 m (URS 2009a).

In summary, the greater part of the proposed pipeline route (>98%) is made up of featureless, unconsolidated clay–silt sands with the most dominant seabed features being areas of pockmarks and sand waves. The only substantial areas of subcrop are to be found between KP 361 and KP 374 and between KP 482 and KP 513. Exposed outcrop was very rare along the route with only small areas encountered at KP 36, KP 187 and between KP 360 and KP 372 (URS 2009a).

3.2.4 Underwater noise

Ambient noise in the Ichthys Field was measured using a sea-noise logger deployed at a depth of 240 m on the seabed 45 km north-west of Browse Island. The measurements were carried out from September 2006 to August 2008 by the Centre for Marine Science and Technology at Curtin University. The monitoring revealed an average ambient noise level of 90 dB re 1 μPa under low sea states, with inputs of low-frequency energy from the Indian Ocean (McCauley 2009).

Three exploratory drilling programs were conducted by INPEX in the Ichthys Field during the noise-monitoring period. When these operations were under way, low-frequency noise (<1 kHz) was dominated by vessel noise from rig tenders moving slowly, holding station or in dynamically positioned mode. Third-party seismic surveys 136 km to the south-west of the Ichthys Field were also recorded on the noise logger (McCauley 2009).

Biological noise sources recorded in the Ichthys Field included regular fish choruses (one at >1 kHz and another at around 200 Hz), infrequent calls from individual nearby fish, and several whale calls from humpback whales, pygmy blue whales, minke whales and other unidentifiable species (McCauley 2009).

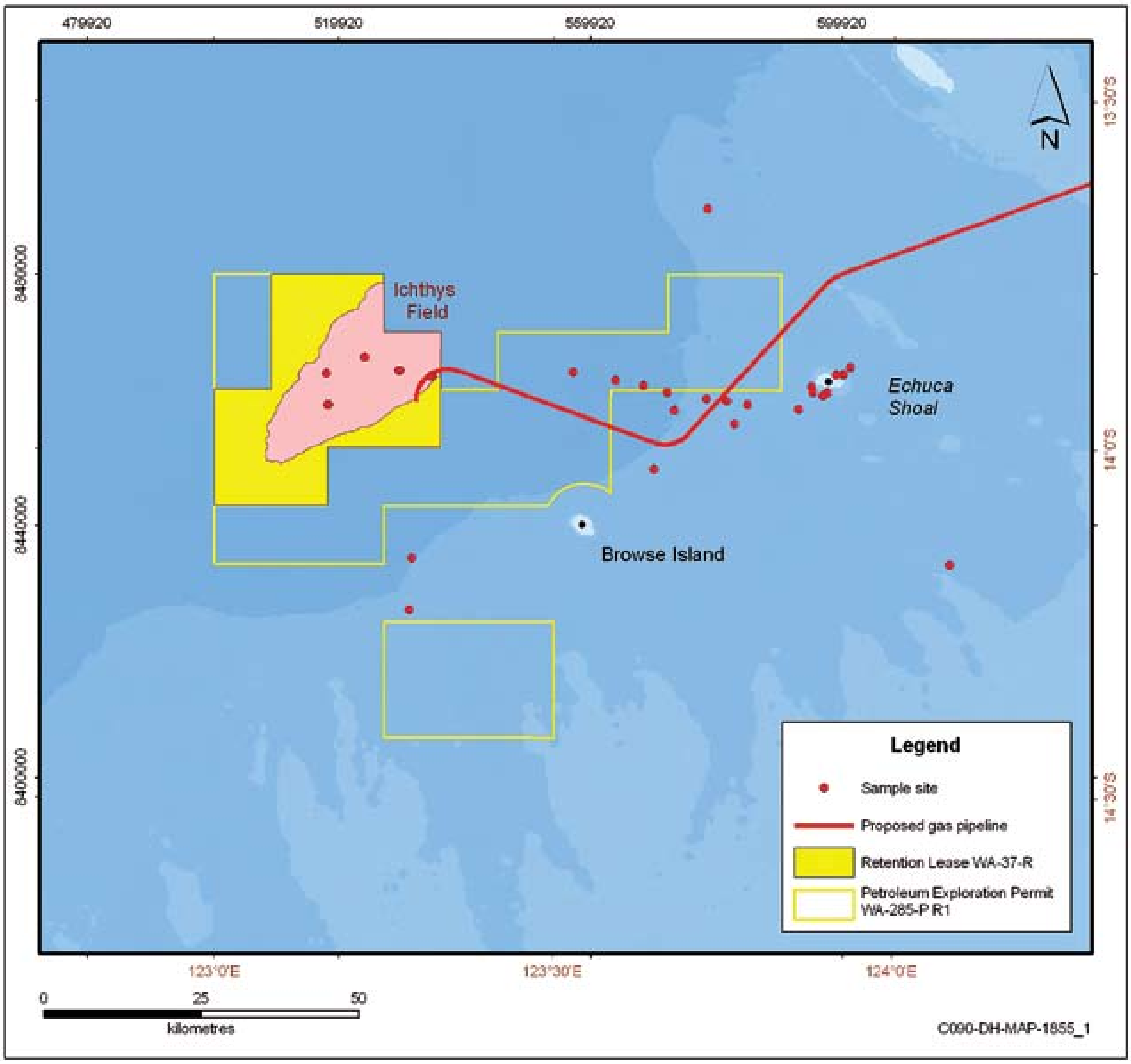


Figure 3-6: Water-quality and marine-sediment sampling sites in the offshore development area

3.2.5 Water quality

Water-quality sampling was conducted by RPS Environmental Pty Ltd in the offshore development area in March 2005 in order to describe the natural conditions of the waters at the Ichthys Field before development commenced and to compare the results with existing applicable guidelines. The most relevant for the marine environment are the Australian and New Zealand guidelines for fresh and marine water quality (ANZECC & ARMCANZ 2000a) and the Australian guidelines for water-quality monitoring and reporting (ANZECC & ARMCANZ 2000b). These form part of the National Water Quality Management Strategy to which the federal, state and territory governments of Australia are committed.

The water-quality survey investigated a range of physico-chemical properties with sampling to a depth of around 93 m, using in situ instrumentation as well as laboratory analysis. The survey included assessment of the following analytes:

- nutrients: total phosphorus, total nitrogen, ammonium (NH_4^+), orthophosphate (PO_4^{3-}), nitrate (NO_3^-) and nitrite (NO_2^-)
- chlorophyll: chlorophyll-*a*, -*b* and -*c* from phytoplankton samples
- metals: arsenic, cadmium, chromium, cobalt, copper, lead, mercury, nickel, zinc
- hydrocarbons: total petroleum hydrocarbons, polycyclic aromatic hydrocarbons, and BTEX (benzene, toluene, ethylbenzene and xylenes)
- radionuclides: radium-226, radium-228, uranium and thorium.

Twenty-seven offshore locations were sampled at the Ichthys Field, Echuca Shoal and their surrounds as shown in Figure 3-6. The results of the study are summarised below and provided in greater detail in Appendix 4.

Additional information on conductivity, temperature and dissolved oxygen in offshore waters was collected by INPEX in July 2008 during exploratory drilling in petroleum exploration permit area WA-344-P, approximately 10 km north-east of the Ichthys Field. These data were acquired using a probe attached to a remotely operated vehicle (ROV) and reached depths of 250 m. Equipment and data analyses were provided by the SERPENT ("Scientific and Environmental ROV Partnership using Existing iNdustrial Technology") project.

Near-seabed temperature and salinity profiles were also obtained along the proposed pipeline route from the Ichthys Field to Darwin Harbour during geophysical and geotechnical surveys conducted by Neptune Geomatics between August and October 2008.

Temperature

Surface-water temperatures recorded in and around the Ichthys Field were consistent across sampling sites at about 30 °C in summer (March) and 26–27 °C in winter (July).

Offshore waters in the region are typified by thermal stratification that varies in strength according to the season (IMCRA Technical Group 1998) (see also Appendix 4). Major thermoclines were encountered at all sites, which may indicate separate subsurface current streams. Depth to the thermocline appeared to increase in winter, with cooler subsurface water encountered at just 30–50 m in summer (March) and at 70–120 m in winter (August). Extreme weather events, such as cyclones and monsoons, may also promote temporary mixing of water layers across the thermocline.

Below the thermocline, water temperatures decreased by roughly 1 °C per 10 m depth (see Appendix 4). Temperatures as low as 12 °C were recorded by INPEX at a depth of 250 m.

Along the pipeline route, water temperatures near the seabed were as low as 15 °C in the deeper waters (150–250 m) at the Ichthys Field. However, in the shallower waters (20–100 m) along the greater part of the pipeline route, the temperatures remained relatively constant at around 25 °C (Neptune Geomatics 2009).

Salinity

Salinity was spatially and temporally consistent at 34–35 ppt across all offshore sampling sites, as expected for locations that are distant from major freshwater discharges. Minor variations in the salinity profile were associated with water layers at depth, particularly in the transitional mixing zone at the thermocline (see Appendix 4).

Seabed salinity levels along the greater part of the proposed pipeline route varied little, with a range of between 34.4 and 34.8 ppt. A slight increase in seabed salinity to 34.9 ppt was recorded in the approaches to Darwin Harbour; this can most likely be attributed to the leaching of terrestrial minerals into the marine environment (Neptune Geomatics 2009).

Dissolved oxygen

Dissolved oxygen concentrations in the offshore development area mirrored water temperatures, with constant levels of 6.0–6.5 ppm recorded at or above the thermocline in both summer and winter. In the cooler waters below the thermocline, however, dissolved oxygen decreased with increasing depth, with levels as low as 4.5–5.0 ppm recorded at a depth of 93 m (see Appendix 4) and 3 ppm at a depth of 250 m (INPEX data, August 2008). This indicates that mixing of the surface and subsurface water layers is limited because of the strong thermal stratification (see Appendix 4).

pH

The average pH of waters in the offshore development area was approximately 8.4, which is slightly higher (more alkaline) than normally encountered in the marine environment and is above the default criteria given in the *Australian and New Zealand guidelines for fresh and marine water quality* (ANZECC & ARMCANZ 2000a). The reason for this elevated pH level is unknown.

Turbidity and light attenuation

Turbidity was consistent between the profiles, decreasing marginally at all sites with increasing depth. Light attenuation coefficients (LACs) calculated from photosynthetically active radiation (PAR) measurements ranged from 0.026 to 0.043 in October and December 2006, but were higher in June 2007, ranging from 0.048 to 0.109. These were within reported "typical" levels for the region (see Appendix 4).

Nutrients, phytoplankton and total suspended solids

Relatively low concentrations of nutrients and chlorophyll are common in the surface mixed layer on the north-west continental shelf (Condie & Dunn 2006). In the mid- and outer-shelf waters the concentration of nitrate is high below the thermocline and the phytoplankton biomass tends to be concentrated at this depth and in the benthic mixed layer (see Appendix 4).

The median concentration of many forms of nutrients in the offshore development area approached or exceeded guidelines for slightly disturbed tropical ecosystems in northern Australia, particularly with increasing water depth (ANZECC & ARMCANZ 2000a). This trend has also been revealed in previous studies near Scott Reef and Browse Island, and in the Pilbara region of Western Australia. The source of these nutrients has not been determined—they may be transported from distant deeper sources via upwelling currents (this is known to occur elsewhere on Australia's north-west continental shelf) or they may be derived from the local seabed sediments (see Appendix 4).

Chlorophyll-*a* concentrations were low throughout the water-column profile but were similar to concentrations reported previously for the north-west continental shelf. This low concentration indicates a lack of enhanced production and probably reflects the trapping of nutrient-rich waters below the thermocline. However, this effect may also be attributable to the greater dispersion of phytoplankton during winter (when sampling was undertaken) or may suggest that the greater part of the phytoplankton lies well beneath the surface at the base of the thermocline or in the mixed layer near the seafloor where high nitrate levels exist (see Appendix 4).

Phytoplankton surveys conducted at the Ichthys Field recorded densities of 87–610 cells per 50 L (average density 249 cells per 50 L) (Dalcon Environmental 2008). These plankton densities are considered to be very sparse and are indicative of offshore waters where no significant nutrient sources exist. The most common class recorded from the samples was the Prasinophyceae (68%), followed by the Bacillariophyceae (30%), the Dinophyceae (1%) and the Cryptophyceae (<1%), all of which are common throughout the region.

Petroleum hydrocarbons

No traces of petroleum hydrocarbons were detected during offshore water-quality sampling.

Radionuclides

Water-column sampling for radionuclides in the offshore development area indicated activity concentrations of radium-226 from below "lower limits of reporting" (LLR) to 0.034 (±0.012) Bq/L, and of radium-228 from below LLR to 0.167 (±0.128) Bq/L. With the exception of one mid-depth sample, all samples returned gross alpha-particle and gross beta-particle radiation levels below the Australian Drinking Water Guidelines (ADWG) screening criterion of 0.5 Bq/L provided by the National Health and Medical Research Council (NHMRC) and the Natural Resource Management Ministerial Council (NRMMC) (NHMRC & NRMMC 2004).

Metals

Total metal concentrations in offshore waters were below the 99% species protection level for marine waters (ANZECC & ARMCANZ 2000a), with the exception of zinc and cobalt at one site each. The reason for these two slightly elevated readings is unknown.

Ultra-trace-level analysis methods were used to assess metal concentrations in surface waters because ANZECC and ARMCANZ (2000a) guideline trigger values at the 99% species protection level are lower than the limits of standard laboratory methods. Mercury was the only metal not detected above the LLR, while cobalt was marginally above the LLR at only one site. Concentrations of arsenic, nickel, chromium and zinc were consistent across all sites, but the concentrations of cadmium, copper and lead showed greater variability (see Appendix 4).

3.2.6 Marine sediments

Ichthys Field and offshore areas

Sampling of marine sediments in the offshore development area was conducted by RPS Environmental in September 2005 and May 2007 at 10 sites. The results of these surveys are described briefly below and are provided in detail in Appendix 4. The sampling sites are shown in Figure 3-6.

Physical

Background data on marine sediments in the region are scanty because of the remoteness of the location and the fact that there has been minimal exploration and development activity there by the oil & gas industry. The seabed in offshore locations on the continental shelf is known to consist of generally flat, relatively featureless plains characterised by soft sandy-silt marine sediments that are easily resuspended. Similarly, the substrate of the Scott Reef – Rowley Shoals Platform, located immediately south-west of the Ichthys Field in depths of 200–600 m, is considered to be a depositional area with predominantly fine and muddy sediments.

The composition of sediments varied across the offshore development area, with the most variation occurring in the vicinity of the Echuca Shoal close to the eastern boundary of the permit area. In this area sediments consisted mainly of calcareous shell grit and coral debris along with varying minor proportions of silts and fine-to-medium sands. In general, the proportion of silts, clays and fine sands increased rapidly with increasing distance from the shoal (see Appendix 4).

Chemical

No petroleum hydrocarbons were detected in sediment samples: all concentrations of alkanes were below LLR. Concentrations of metals were consistent across all samples and were well below "ISQG-Low" ("interim sediment quality guideline – low") trigger levels (ANZECC & ARMCANZ 2000a).

Radium-226 was detected at one site in the offshore development area, but all other samples were below LLR for each radium isotope. The concentration of uranium and thorium was consistent across all sites.

The sediment samples were assessed for total nitrogen, total phosphorus and total organic carbon. All nutrient concentrations were low, with total organic carbon consistently below LLR (see Appendix 4).

Pipeline route

Seabed sediments along the pipeline route were assessed during a geophysical survey conducted by Neptune Geomatics in 2008. Sampling was carried out using drop-core and piston-core sampling at 110 locations along the pipeline route, at approximately 10-km intervals.

In general, the seabed sediments along the pipeline route can be allocated to one of four types:

- very soft to stiff sandy mud
- very loose to dense muddy silty sand
- fine to coarse (occasionally gravelly) sand overlying a crust of variably cemented sediments
- consolidated bedded muds, silts, and sands intersected by a series of palaeochannels (Neptune Geomatics 2009).

Along the pipeline route from the Ichthys Field (KP 0) to Darwin Harbour (KP 860), the shallow geology can be categorised into three depositional settings and sedimentary classifications:

- **KP 0 to KP 235:** This section is within the Browse Basin and is characterised by a low-energy marine depositional environment, with surface sediments that are very loose and very soft to soft. These overlie horizontal interbedded muds, silts and sands, and a prominent, stiff, sandy mud unit at depth.
- **KP 235 to KP 391:** This section traverses the Yampi Shelf and Londonderry Rise and is characterised by a moderate- to high-energy marine depositional environment with very loose to loose sands and very soft to soft sandy mud surface sediments. These overlie consolidated massive to bedded sands.
- **KP 391 to KP 859:** This section traverses the Joseph Bonaparte Gulf and the Petrel Sub-basin. It is a high-energy fluvial depositional environment consisting of very loose to loose sands and very soft to soft sandy mud surface sediments overlying well to poorly bedded discontinuous beds of muds, silts and sands. This sequence of sediments is frequently intersected by a series of palaeochannels infilled with cross-bedded, poorly sorted sediments (Neptune Geomatics 2009).

3.2.7 Marine benthic habitats and communities

The benthic communities at the Ichthys Field were characterised by RPS Environmental in 2007 using sidescan sonar and bathymetric surveys, ROV surveys and sampling of infauna. Intertidal and subtidal habitats at Browse Island (the closest island to the offshore development area) and subtidal habitats at Echuca Shoal (the closest subtidal shoal to the development area) were also surveyed. Study methods included drop-camera surveys of subtidal habitats, intertidal transect surveys, and sampling of corals and fish. The results of this survey are summarised below while the more detailed results are provided in Appendix 4.

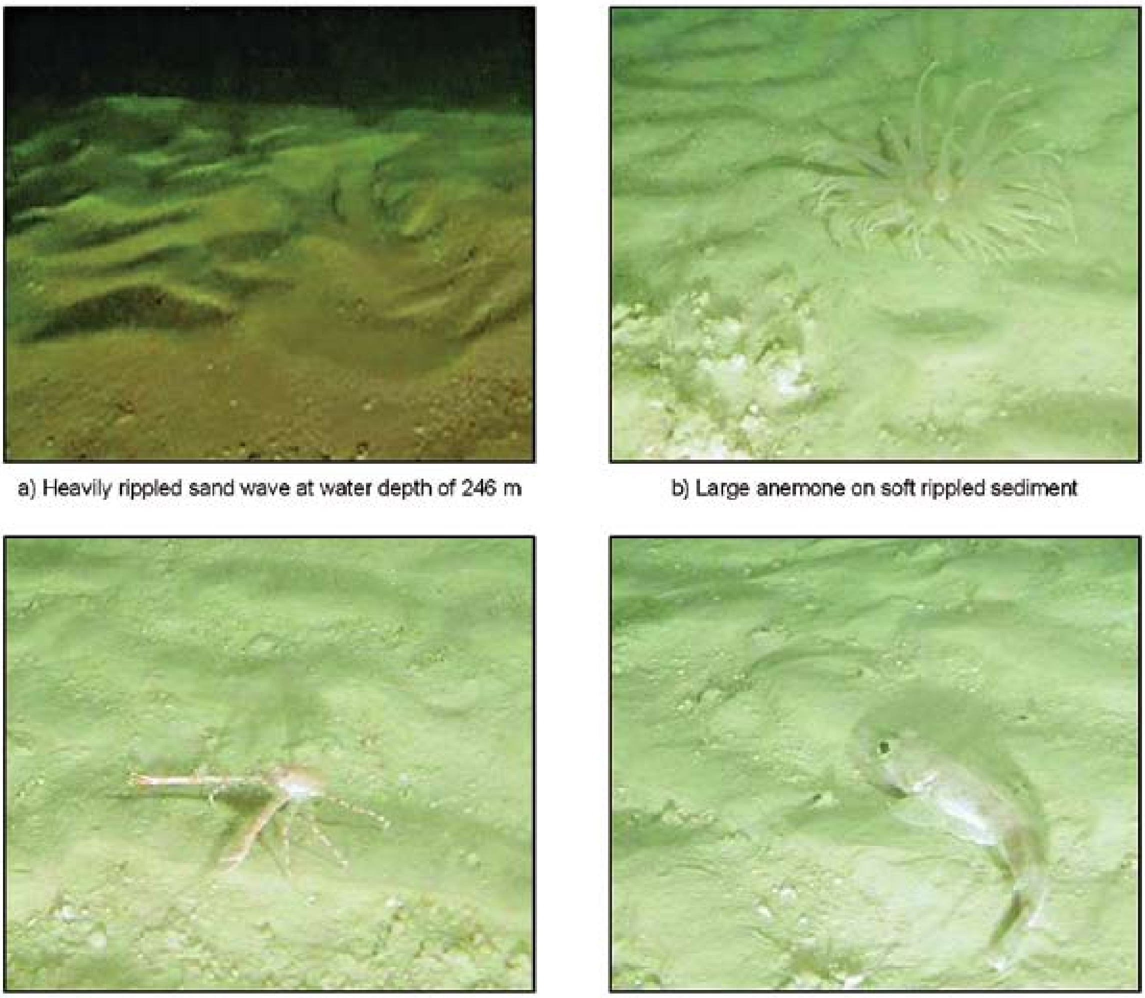
Ichthys Field

Investigations in the central portion of the petroleum exploration permit area WA-285-P R1 were undertaken in water depths of around 250 m. They recorded bare substrates with heavily rippled sand waves approximately 10 m apart (Figure 3-7). Very few epibenthic organisms were observed and the appearance of the seabed was suggestive of very strong currents and mobile sediments that do not favour the development of diverse epibenthic communities (see Appendix 4).

In the south-eastern portion of the permit area, the seabed was described as pavement reef with sand veneer, including low-cover (<40%) filter-feeding communities with sponges, gorgonians (sea whips and sea fans), soft corals, hydroids, bryozoans (lace corals), fan worms and other polychaetes. This area is around 10 km north of Browse Island, with water depths of approximately 190–220 m.

The seabed at the Ichthys Field is well below the photic zone and consequently no benthic macrophytes can be expected in this area.

The infauna in offshore marine sediments was sampled in September 2005 (when 117 species were recorded) and again in May 2007 (when 94 species were recorded).



a) Heavily rippled sand wave at water depth of 246 m

b) Large anemone on soft rippled sediment

c) A galatheid crab

d) Small olive-tailed flathead (*Rogadius asper*)

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Figure 3-7: The Ichthys Field seabed with a sample of its animals

The infauna assemblages were dominated by polychaete worms and crustaceans which contributed around 70% of the animal species in both sampling exercises. The polychaetes consisted of tube-dwelling deposit feeders and surface deposit feeders. The crustacean assemblage was made up of small shrimplike species.

Species richness and abundance decreased with increasing distance from land and with increasing water depth. The composition of the infauna also appeared to be related to sediment particle size, the sites with high sand fractions having a suite of species different from those found at sites dominated by clay or silt sediments, regardless of the distances between the sites and differences in water depth. These observations were consistent with those noted in previous studies.

The low dissolved-oxygen levels at depth in the offshore development area (see Section 3.2.5 *Water quality*) are likely to limit the diversity and composition of infauna assemblages (see Appendix 4).

Browse Island

Browse Island is an isolated sandy cay surrounded by an intertidal reef platform and shallow fringing reef. The reef complex is an outer-shelf, biohermic structure rising from a depth of approximately 200 m. It is a flat-topped, oval-shaped platform reef with a diameter of 2.2 km at its widest point. Rocky-shore habitat around the island is represented only by exposed beach rock and there are no intertidal sandflats. The reef platform is high and conspicuously barren in many places. The reef crest and seaward ramp habitats around the edge of the reef support moderately rich assemblages of molluscs, while the shallow subtidal zone is narrow and supports relatively small areas of well-developed coral assemblages (see Appendix 4).

Intertidal habitats around Browse Island include the following:

- a sandy beach zone of coarse coral sand. Turtles are known to nest here, but the sand does not provide suitable habitat for invertebrates such as bivalves and gastropods
- beach rock, especially on the southern and western sides. A modest invertebrate fauna was recorded in the lower parts of this habitat, including barnacles and marine snails
- a lagoon with sand and coral rubble substrates, supporting macroalgae and live corals such as *Acropora* spp. and *Porites* spp. Very few other invertebrate animals, such as burrowing bivalves or gastropods, were recorded in this habitat
- a reef platform, which is widest on the southern and western sides. Most of this habitat is exposed at low tide and contains areas of sand and coral rubble. There is some exposed limestone supporting sparse algal turf and there are many barren shallow pools
- the reef crest. This supported the highest diversity of molluscs of all the habitats, of both surface-dwelling and cryptic species. Hard corals of the family Faviidae (such as *Goniastrea* spp.) were also recorded in this habitat
- a seaward ramp, which is wave-swept except during very low tides and has a ragged edge. Plant and animal life includes some algal cover and live corals of species similar to those found in the lagoon and on the reef platform and reef crest (see Appendix 4).

The width of the shallow subtidal zone (<20 m depth) outside the reef at Browse Island ranges from 50 m to 200 m. The greater part of the oceanic swell appears to impact the island from a north to south-west direction, leaving mainly bare limestone. The most diverse coral communities were recorded in raised coral reefs in shallower areas around the island, including some large monospecific thickets of branching *Hydnophora rigida* along with tabular *Acropora* and occasional large *Porites* colonies.

The benthic habitats and biotic assemblages at Browse Island are characteristic of coral platform reefs throughout the Indo-West Pacific region. The small area of intertidal habitat at Browse Island, the elevation of the reef platform, and the constrained shallow subtidal area appear to have limited the development of benthic communities, including coral communities, around the island.

Coral diversity was greater on the reef faces and in the shallow lagoons, but these areas are of very limited extent. The molluscan assemblage was limited and strongly dominated by widespread Indo-West Pacific species. Macrophytes such as seagrasses and macroalgae of the genus *Sargassum* do not appear to occur in intertidal or shallow subtidal areas at Browse Island (see Appendix 4).

Echuca Shoal

Benthic surveys at Echuca Shoal encountered substantial areas of hard bottom substrate with its associated epibenthic fauna. Seabed substrates are dominated by coral rubble, reflecting impacts from high-energy waves and swells generated during tropical storms and cyclones.

The shallow shoal areas are dominated by a flat "reef" platform comprising hard corals (particularly large *Porites* and *Platygyra* colonies), feather stars (class Crinoidea), sea whips and other soft corals (including species of *Junceella*, *Sarcophyton* and *Dendronephthya* and black corals of the genus *Antipathes*). The largest features observed in the shallows were the remains of large coral colonies, which were heavily eroded and covered in encrusting and boring sponges. All the taxa recorded are common in tropical Western Australian reef habitats.

With increasing depth (25–80 m), soft corals (particularly of the genus *Dendronephthya*) and sponges (particularly barrel sponges of the genus *Xestospongia*) become increasingly dominant, with limited hard-coral abundance because of decreasing light levels. At greater depths the density of epibenthic fauna decreases dramatically, with sea whips and sea fans dominant (particularly between 80 and 100 m). Below the drop-off of the slope at the edge of Echuca Shoal (at depths of 180–200 m), bare sand is the dominant substratum, with sponges, feather stars and occasional echinoderms, sea whips and sea fans present (see Appendix 4).

Pipeline route

Benthic habitats at 18 sites along the pipeline route (Figure 3-8) were characterised by drop-camera surveys conducted by URS in December 2008 (see Appendix 4). Survey sites were selected based on the results of geophysical and geotechnical surveys of the route (see Section 3.2.3 *Seabed and bathymetry*), which identified areas of hard substrate along the route that could be of ecological interest.

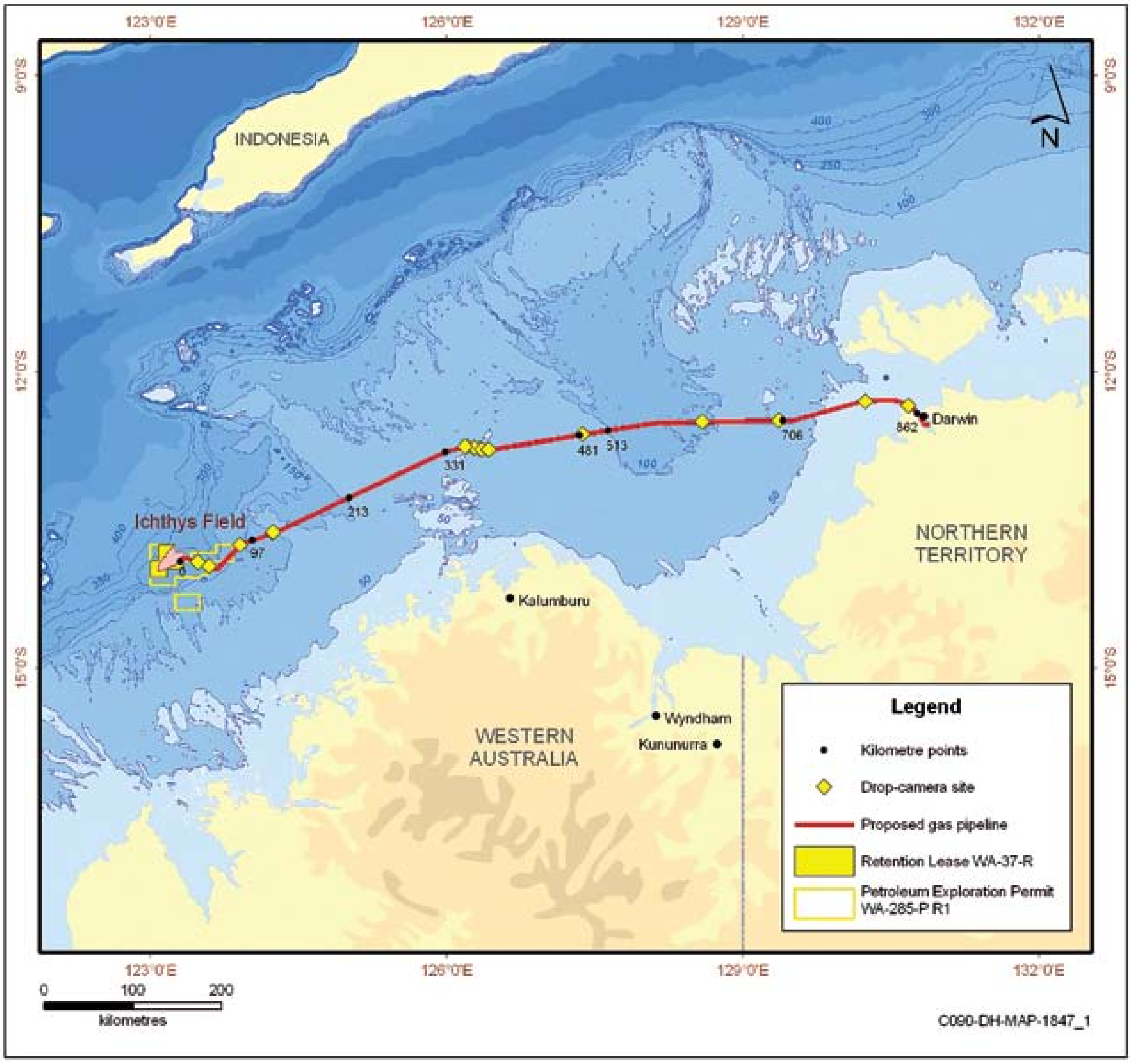


Figure 3-8: Survey sites for epibenthic communities along the proposed pipeline route

The benthic communities recorded along the pipeline route can be described in relation to the seven sections of seabed types identified through the geophysical survey from the Ichthys Field (KP 0) to Darwin Harbour (KP 860) as described in Section 3.2.3. Benthic biota recorded in the drop-camera investigations were as follows:

- **KP 0 to KP 97:** A single calcarenite outcrop 3 m high, approximately 600 m long and 200 m wide at KP 36 was the only notable hard substrate area recorded in this section during the geophysical surveys. This feature was not captured during the drop-camera survey. Occasional sea pens (family Pteroeididae) and sea whips were recorded on the clay–silt substrate at KP 36 and KP 81.
- **KP 97 to KP 213:** An isolated area of megaripples (with a crest height of 0.15 m and a wavelength of around 9 m) is present between KP 112 and KP 120, with some small patches of low-relief subcrop. Drop-camera surveys at KP 120 recorded sea fans and sea whips (*Junceella* spp.), feather stars, bryozoans, soft corals (*Dendronephthya* spp.), starfish or sea stars (class Asteroidea) and sponges.
- **KP 213 to KP 331:** No substantial areas of outcrops or hard substrate are present, so no drop-camera surveys were conducted in this section.
- **KP 331 to KP 481:** Eight drop-camera survey sites were included in this section (between KP 352 and KP 379) in order to investigate the various areas of hard substrate. Rocky outcrops supported epibenthic fauna at relatively high abundances, particularly feather stars. Sea pens, sea fans, sea whips, soft corals of the genus *Dendronephthya*, bryozoans, hydroids, and sponges were also recorded.

- **KP 481 to KP 513:** The subcrops in this area are flanked by clay–silt sand and interspersed with sandy gravel patches. A drop-camera survey at KP 484 recorded sea fans, sea whips, feather stars, soft corals of the genus *Dendronephthya* and sponges at low densities.
- **KP 513 to KP 706:** A small number of feather stars and a grinner fish (family Synodontidae) were recorded at KP 617. The drop-camera survey at KP 701 did not record any epibenthic animals, though the fine-sand substrate was peppered with small holes (<50 mm in diameter) indicative of burrowing invertebrates such as bivalves, shrimps and polychaete worms.
- **KP 706 to KP 862:** Drop-camera surveys at KP 848 recorded a sparse epibenthic fauna, predominantly made up of colonial hydroids with some sea pens, feather stars and ascidians (sea squirts of the class Ascidiacea). Similar species were recorded at KP 799, along with sparse sea whips, bryozoans and starfish (URS 2009a).

Pockmarks with diameters between 5 and 10 m were recorded along approximately a quarter (23%) of the total length of the pipeline route during the geophysical survey (Neptune Geomatics 2009). Pockmark density varied, with more than 10 pockmarks per hectare being considered to be "high" density. These features were also recorded in benthic surveys along the route of the Bayu–Undan Gas Pipeline in the Timor Sea (LeProvost, Dames & Moore 1997).

Pockmarks may be a focal point for benthic fauna in some instances, although the mechanisms and time-scale of their formation are not well defined (Brothers et al. 2009). Because pockmarks are widely distributed, any disturbance to them as a result of pipe-laying for the Ichthys Project is not considered to pose a threat to these benthic habitats on a regional scale.

In summary, benthic communities along the pipeline route are sparsely distributed and are mainly associated with hard substrates. Epibenthic species in the communities surveyed are common throughout north-west Australian offshore waters and are not considered to be of particular significance in the context of the Project.

3.2.8 Protected species

A number of threatened marine species that may be present in the offshore development area are protected under Commonwealth legislation, Northern Territory legislation or international agreements.

Commonwealth and Northern Territory legislation

The *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth) (EPBC Act) provides a legal framework to protect and manage nationally and internationally threatened plants and animals—defined as "matters of national environmental significance". Threatened species may be listed under the EPBC Act in one of several categories depending on their population status (e.g. "critically endangered", "endangered", "vulnerable", and "conservation dependent"). In addition, a range of marine and migratory species are protected under the EPBC Act as they are listed in international treaties and conventions for the protection of wildlife (described below).

All cetaceans and many other large marine animals are protected under the EPBC Act. The Act also established the Australian Whale Sanctuary, which encompasses the portion of Australia's exclusive economic zone (EEZ) outside state waters—generally to 200 nautical miles from the coast, but further in some areas to include offshore territorial waters around islands such as Christmas, Cocos (Keeling), Norfolk, Heard and McDonald islands. The Ichthys Field lies inside the Australian Whale Sanctuary. It is an offence to kill, injure, take, trade, keep, move or interfere with a cetacean in the sanctuary.

The assessment of the conservation status of each wildlife species in Northern Territory waters is undertaken by the Biodiversity Conservation Unit of the Department of Natural Resources, Environment, the Arts and Sport (NRETAS) under Section 29 of the *Territory Parks and Wildlife Conservation Act* (TPWC Act). The Northern Territory's Threatened Species List classifies threatened species under a number of categories, including "critically endangered", "endangered", "vulnerable", "near threatened", "data deficient" and "not threatened in the Northern Territory".

Table 3-1 lists threatened marine species that may be present in or near the offshore development area and that are listed as "critically endangered", "endangered" or "vulnerable" under the EPBC Act, TPWC Act or international conventions. It should be noted that other marine species that fall under less critical conservation categories (such as listed "cetacean" or "migratory" species, or "near threatened" species) also occur in the offshore development area; key species from these categories are discussed further in this section.

International protection and conservation status

Species of marine animals that are considered to be globally under threat of extinction may be listed on *The IUCN Red List of Threatened Species* maintained by the International Union for Conservation of Nature and Natural Resources (IUCN). They may otherwise be protected by the Convention on International Trade in Endangered Species of Wild Fauna and Flora ("CITES") or by the Convention on the Conservation of Migratory Species of Wild Animals ("the Bonn Convention"). Species that are protected by such conventions and laws are listed in Table 3-1. In the case of the IUCN Red List, only those species that are listed as vulnerable, endangered or critically endangered have been included.

Table 3-1: Protected species that may be present in or near the offshore development area and along the proposed pipeline route

Scientific name	Common name	Conservation status				
		Commonwealth*	Northern Territory†	IUCN‡	Bonn Convention§	CITES#
Cetaceans: whales						
Balaenoptera musculus	Blue whale	E	–	E	I	I
Megaptera novaeangliae	Humpback whale	V	–	V	I	I
Reptiles						
Caretta caretta	Loggerhead turtle (pipeline route only)	E	E	E	I	I
Chelonia mydas	Green turtle	V	–	E	I	I
Dermochelys coriacea	Leatherback turtle	E	V	CR	I	I
Eretmochelys imbricata	Hawksbill turtle (pipeline route only)	V	–	CR	I	I
Lepidochelys olivacea	Pacific ridley turtle** (pipeline route only)	E	–	E	I	I
Natator depressus	Flatback turtle	V	–	–	II	I
Cartilaginous fish: sharks						
Pristis zijsron	Green sawfish (pipeline route only)	V	V	CR	–	I
Rhincodon typus	Whale shark	V	–	V	II	II
Ray-finned fishes						
Hippocampus kuda	Spotted seahorse	–	–	V	–	–
Hippocampus planifrons	Flat-faced seahorse	–	–	V	–	–
Hippocampus spinosissimus	Hedgehog seahorse	–	–	V	–	–

Sources: DEWHA 2009a; NRETAS 2007a; IUCN 2009a, 2009b; Bonn Convention 2009a; CITES 2009b.

* Commonwealth Government—*Environment Protection and Biodiversity Conservation Act 1999* (Cwlth).
E = Endangered; V = Vulnerable.

† Northern Territory Government—*Territory Parks and Wildlife Conservation Act* (NT).
E = Endangered; V = Vulnerable.

‡ International—IUCN: The IUCN Red List of Threatened Species.
CR = Critically Endangered; E = Endangered; V = Vulnerable.

§ International—Bonn Convention: Appendices I and II of the Convention on the Conservation of Migratory Species of Wild Animals.
I = Appendix I Endangered Migratory Species; II = Appendix II Migratory Species.

\# International—CITES: Convention on International Trade in Endangered Species of Wild Fauna and Flora.
I = Appendix I lists species threatened with extinction; II = Appendix II includes species not necessarily now threatened with extinction, but that may become so unless trade involving them is closely controlled.

** The Pacific ridley turtle is also known as the olive ridley turtle.

Cetaceans

Cetaceans that occur in the North West Shelf and Oceanic Shoals bioregions include baleen whales, toothed whales and dolphins. In order to characterise the baseline abundance and diversity of marine mammals in the offshore development area, vessel-based cetacean surveys were conducted by the Centre for Whale Research (CWR) between August and November 2006 and in July and August 2007. To provide a broader, inter-regional context, aerial and vessel-based cetacean surveys were also conducted in the Kimberley Bioregion, at Camden Sound, Pender Bay and the Maret Islands (Figure 3-9). All surveys were timed to coincide with the period of peak seasonal presence of humpback whales and with pygmy blue whale migrations. The results of these studies are described briefly below, while more detail is provided in Appendix 4.

In addition, an acoustic logger was deployed by Curtin University's Centre for Marine Science and Technology near the northern edge of the WA-285-P permit area from September 2006 to September 2008 to record vocalising cetaceans and other marine noise (see Section 3.2.4 *Underwater noise*).

Humpback whales

Humpback whales are the most common whale species observed in the North West Shelf Bioregion, and are seasonally abundant between August and October.

Australia has two discrete populations of humpback whales, one migrating along the west coast and the other migrating along the east coast. The humpback whale stock that winters off Western Australia is known as the Group IV (Breeding Stock D) population (Jenner, Jenner & McCabe 2001), and is thought to have a total population of between 30 000 and 38 000 whales (Branch 2006).

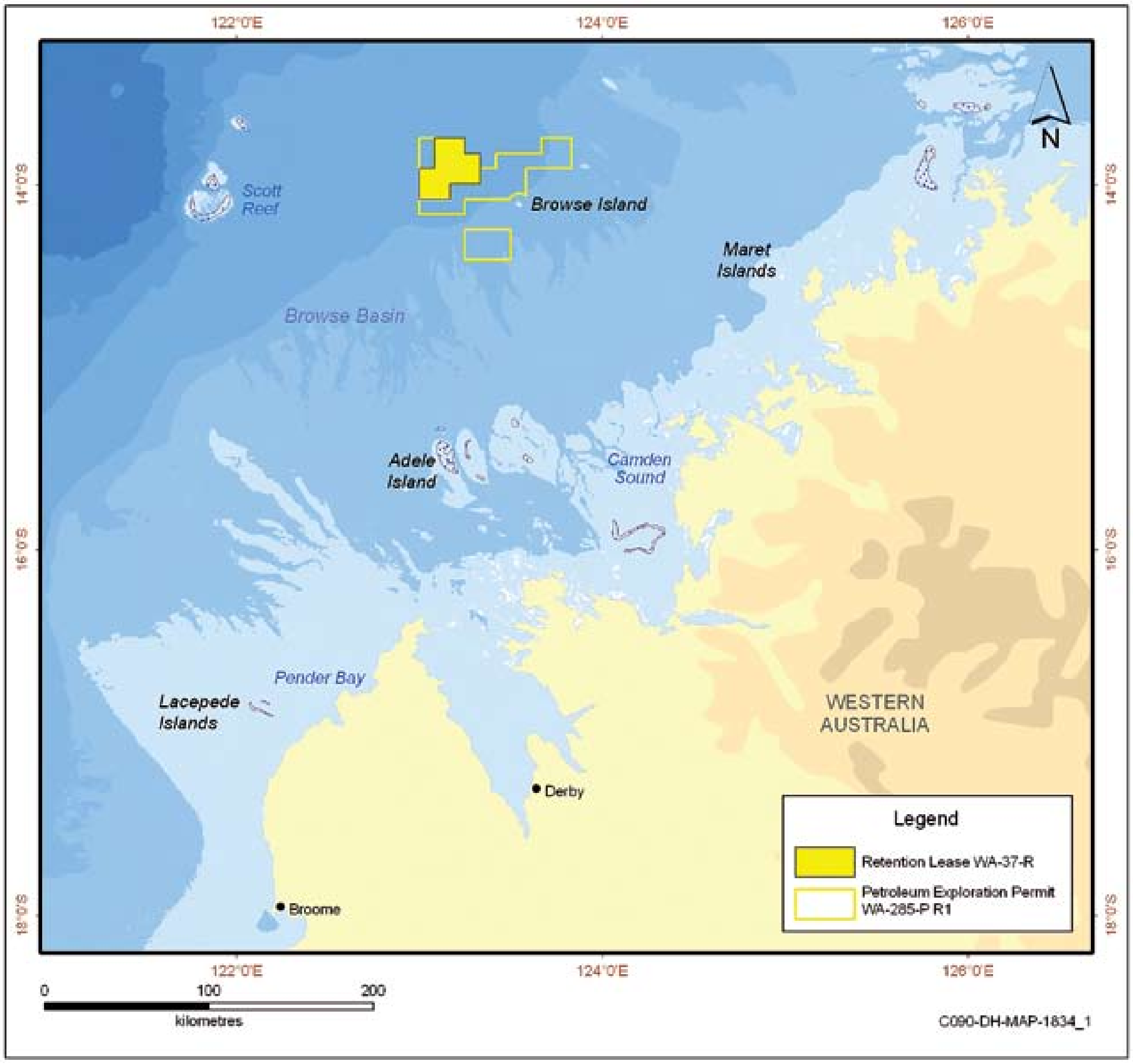


Figure 3-9: The Kimberley coast of Western Australia and the Ichthys Project's offshore development area

Stock D humpback whales migrate annually from their Antarctic feeding grounds to their breeding and calving areas off the Kimberley coast. The known calving area for Stock D humpback whales covers approximately 23 000 km^2 from the Lacepede Islands in the south to Adele Island in the north and to Camden Sound in the east (Jenner, Jenner & McCabe 2001). Calving occurs between June and November, with the peak of the southbound migration between late August and early September; cow-and-calf pairs trail the main migratory movement by three to four weeks (Chittleborough 1965).

Two humpback whales were recorded in vessel surveys south of Browse Island exhibiting swimming and diving behaviour that is consistent with feeding. These observations were considered unusual as humpback whales are thought to fast during their northern migration. This event coincided with a +0.5 °C temperature front and very high levels of bird, fish and other wildlife activity in the area. Pilot whales also appeared to be feeding in the same area (see Appendix 4).

Underwater noise logging suggested that humpback whales visited the offshore development area between July and September each year, with peak numbers recorded in mid-August (McCauley 2009).

There is no evidence from this study that the offshore development area is a calving ground for humpback whales, although the nearshore waters of the Kimberley Bioregion are known to be used for calving and resting. Humpback whale densities recorded in the field surveys were significantly higher in Camden Sound and Pender Bay than in the Browse Basin (Table 3-2). Whales observed in Pender Bay exhibited passive behaviour at the surface suggesting that the area is used for resting. Cow–calf pods appear to congregate in the area between Pender Bay and the Lacepede Islands during mid-September, using the area as a staging point and resting place prior to beginning their southern migration (see Appendix 4).

Table 3-2: Total humpback whales recorded during six vessel surveys in 2006 and 2007

	Browse Basin	Camden Sound	Pender Bay
Whales	21	486	263
Pods	13	325	182
Pods with calves	1	25	18

Source: see Appendix 4.

Blue whales

Two subspecies of blue whale are found in the southern hemisphere: the “true” blue whale (*Balaenoptera musculus intermedia*) and the pygmy blue whale (*Balaenoptera musculus brevicauda*). Pygmy blue whales have been observed on many occasions during the winter months in locations such as the Savu Sea west of Timor (B. Kahn, Apex Environmental, pers. comm. 22 February 2006) and have been recorded along the far northern Kimberley coast of Western Australia at Cape Londonderry (Dr Deborah Thiele, Deakin University, pers. comm. 15 April 2007). While pygmy blue whales have been recorded in the Kimberley region, true blue whales are uncommon north of 60°S (Branch et al. 2007).

Like other rorquals (baleen whales of the family Balaenopteridae), pygmy blue whales are assumed to breed in the tropical north. Previous studies on the distribution of pygmy blue whales and blue whales in the southern hemisphere suggest that the Western Australian continental slope is a likely migratory path between a southern feeding area and a northern calving area; the location of this northern breeding ground is currently unknown (Branch et al. 2007). There is no consensus on the size of the pygmy blue whale population (DEH 2005a), but in 1996 the Australian Nature Conservation Agency estimated there to be 6000 animals in the southern hemisphere (Bannister, Kemper & Warneke 1996).

No blue whales or pygmy blue whales were observed in vessel surveys of the offshore development area (see Appendix 4). Noise from a pod of around six pygmy blue whales was recorded within a 75-km radius of the offshore development area on one occasion (in October 2006) during the two-year noise-logging study. Based on this and other noise-logging studies in the north-west of Australia, pygmy blue whales are believed to utilise an offshore migration path in water depths of around 500 m (McCauley 2009). These depths occur around 90 km north-west of the Ichthys Field.

Minke whales

Antarctic minke whales appear to migrate from southern feeding grounds in the summer to northern tropical feeding grounds in winter months. However, the detailed pattern of migration is still unclear and may be quite complex. In the north-east Pacific, for instance, it has been suggested that some minke whales are migratory while others form a resident population. In Australia, it is known that dwarf minke whales occur broadly from Victoria to northern Queensland between March and October, with the maximum number of sightings on the northern Great Barrier Reef in June and July.

A small number of minke whales (seven) were recorded in the offshore development area during vessel surveys. One was positively identified as the dwarf subspecies (see Appendix 4). Noise from minke whales of both the dwarf and Antarctic subspecies was recorded at the offshore development area in August and September 2006 (McCauley 2009).

Toothed whales and dolphins

Information on toothed whale and dolphin species off the Kimberley coast is limited, especially in offshore waters. In total, 21 species of toothed whale and dolphin could occur in the offshore development area (DEWHA 2009a). Species recorded by Jenner, Jenner and McCabe (2001) in the Kimberley region included false killer whales, dwarf spinner dolphins, spinner dolphins, bottlenose dolphins and Australian snubfin dolphins. Sperm whales have also been recorded in the Kimberley (Townsend 1935). Fifteen species of dolphins and toothed whales were observed in vessel surveys in the offshore development area. In particular, large numbers of Indo-Pacific bottlenose dolphins, long-beaked common dolphins, spinner dolphins, dwarf spinner dolphins, pantropical spotted dolphins and offshore bottlenose dolphins were recorded, along with smaller numbers of false killer whales, melon-headed whales and short-finned pilot whales (see Appendix 4).

The Australian distribution of short-finned pilot whales is not well known. This species prefers deep water and is found at the edge of the continental shelf and over deep submarine canyons (Bannister, Kemper & Warneke 1996). The short-finned pilot whale is not particularly migratory but inshore–offshore movements are determined by squid spawning patterns and the species is found inshore primarily during the squid season (see Appendix 4).

The false killer whale is also an oceanic species and has been reported to be widely distributed in deep tropical, subtropical and temperate waters globally. Although tending to prefer warmer waters, it is reported to live in water temperatures ranging from as low as 9 °C to up to 31 °C (Stacey, Leatherwood & Baird 1994).

The number of cetacean species observed in the surveys of the offshore development area is relatively high compared with previous studies in other regions of Western Australia. The very large pods of oceanic dolphins, for example, suggest that there is a substantial underlying food web in the area (see Appendix 4).

Dugongs

The dugong (*Dugong dugon*) has a range that extends from East Africa around the Indian Ocean to the western Pacific. In Australia, the species occurs along the northern coastline from Shark Bay in Western Australia to Moreton Bay near Brisbane, Queensland (NRETAS 2009a).

Dugongs are herbivorous and demonstrate a strong dietary preference for seagrasses, although they will also eat algae (Anderson 1982; Marsh 1999; Marsh et al. 2002). Dugongs are usually found in coastal areas such as shallow protected bays and mangrove channels and in the lee of large inshore islands where seagrass grows (Heinsohn, Marsh & Anderson 1979). However, they have also been recorded further offshore in areas where the continental shelf is wide, shallow (up to 37 m deep), and protected (Lee Long, Mellors & Coles 1993; Marsh et al. 2002).

Given that water depths in the Project's offshore development area range from 190 to 250 m, the presence of feeding habitat for dugongs is limited. During vessel surveys only one dugong was observed in the vicinity of the Ichthys Field. Dugongs were recorded more commonly in aerial and vessel-based surveys throughout the coastal survey areas (see Appendix 4).

In Northern Territory waters, aerial surveys in the Anson–Beagle Bioregion have recorded large numbers of dugongs around the Vernon Islands and Gunn Point, 30–50 km north-east of Darwin Harbour. Satellite-tracking data showed that dugongs can move long distances (e.g. 300 km) and dugongs tagged around the Vernon Islands spent time in Darwin Harbour, around the Tiwi Islands and as far west as Cape Scott and Cape Ford south of the Peron Islands, 100–120 km south-west of Darwin (Whiting 2003). Seagrass habitat is rare in this bioregion and dugongs have instead been observed foraging on intertidal rocky reef flats that support sponges and algae (Whiting 2008).

Dugongs also occur in waters off the Gulf of Carpentaria and Arnhem Land (NRETAS 2009a). Areas identified by the Parks and Wildlife Service of the Northern Territory (PWSNT) as key sites for the conservation of dugong and seagrass habitat include the north coast of the Tiwi Islands and Cobourg Peninsula, and Blue Mud Bay, Limmen Bight and the Sir Edward Pellew Islands on the east coast of Arnhem Land (PWSNT 2003).

Recent genetic research indicates that there is a significant level of gene flow in the dugong populations around the tropical Australian coast. Management units are consequently difficult to define. There also appears to be gene flow between the dugong populations in Australia and those in neighbouring countries (McDonald 2005).

Turtles

Six species of marine turtle are known to occur in the waters of northern Western Australian and the Northern Territory—the green turtle, flatback turtle, hawksbill turtle, loggerhead turtle, leatherback turtle and the Pacific ridley turtle. Of these, the green, leatherback and flatback turtles could occur in the vicinity of the Ichthys Field, while all six species could occur along the subsea pipeline route (Table 3-1) (DEWHA 2009a).

The green turtle is the most common turtle species found in Western Australia, and occurs from as far south as Rottnest Island, north through Shark Bay and the Houtman Abrolhos islands to coastal beaches in the Gascoyne and Pilbara regions, Barrow Island and some islands of the Montebello Islands and the Dampier Archipelago. In the Kimberley Bioregion (and offshore to the North West Shelf and Oceanic Shoals bioregions) green turtles nest on the Lacepede Islands, with smaller, regionally important nesting stocks visiting Browse Island and the Scott and Ashmore reefs (DEC 2009). Browse Island and Scott Reef have been gazetted as nature reserves primarily because of their importance as green turtle habitat.

Turtle populations on the Kimberley coast and offshore islands, including the Maret Islands, Montalivet Islands, Lacepede Islands and Browse Island, were studied by RPS Environmental in the 2006–07 nesting season. Green turtles were by far the most common species recorded, with the largest rookeries identified on the Lacepede Islands and Maret Islands (see Figure 3-9). Green turtles were also observed nesting at Browse Island, but in fewer numbers than on islands closer to the mainland (see Appendix 4).

A brief tag-and-release program conducted at Browse Island in November 1991 recorded 59 green turtles nesting on the beaches on one night and 40 turtles on the following night; 11 of these were the same individuals. While this period was in advance of the expected peak of seasonal nesting activity, these green turtle densities were considered a reasonable guide to usage of Browse Island, and indicative of a nesting attendance of hundreds of female green turtles for that summer (Bob Prince, Senior Research Scientist, Department of Environment and Conservation, Western Australia, pers. comm. November 2009).

Green turtles are not known to nest in the Anson–Beagle Bioregion in the western Northern Territory, the species rather utilising nesting areas in north-eastern Arnhem Land. The northern Western Australian and eastern Northern Territory groups of green turtles appear to represent two distinct “management units” that are separated geographically (see Appendix 4). However, subadult green turtles are known to use an important feeding area within the island reefs at the northern end of Fog Bay approximately 80 km south-west of Darwin Harbour (Chatto & Baker 2008).

Flatback turtles migrate over long distances along the northern Western Australian coastline from rookeries in the Pilbara region into the Kimberley region, and as far as the Northern Territory. They generally forage in turbid, shallow inshore waters in depths of 5–20 m. Flatback turtle nests were recorded on beaches in the Maret, Montalivet and Lamarck islands in the field surveys and the population of female turtles nesting at these islands was estimated at 218–251 individuals. The species was not recorded in surveys of Browse Island or the Ichthys Field (see Appendix 4).

Flatback turtles are abundant throughout the Anson–Beagle Bioregion, with significant nesting areas located at North Peron Island, Five Mile Beach, Bare Sand Island, Quail Island and Indian Island (see Figure 3-10). Beaches around the Cox Peninsula are also utilised, although to a lesser extent, with informal observations suggesting a nesting density of about 20 nests per year (Dr M. Guinea, marine biologist, Charles Darwin University, pers. comm. September 2008). Similarly, flatback turtles nest in low densities on Casuarina Beach, which is located close to residential areas of Darwin’s northern suburbs. While important from the perspective of public education, Casuarina Beach is not considered a significant breeding area for marine turtles on a bioregional scale (Chatto & Baker 2008).

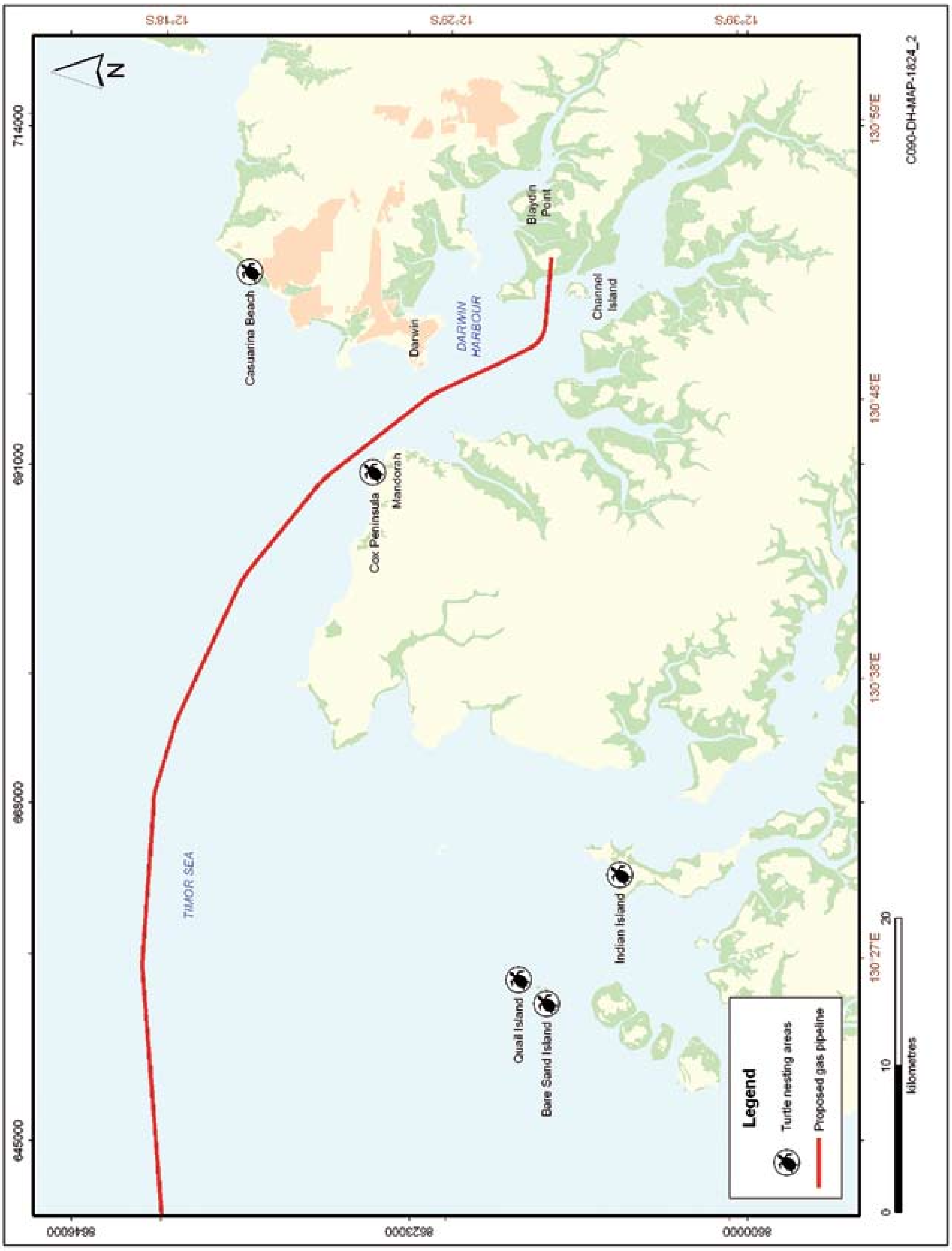


Figure 3-10: Turtle nesting beaches of the Anson–Beagle Bioregion

Leatherback turtles are presumed to migrate to Australian waters from nesting populations in Indonesia, Papua New Guinea and the Solomon Islands. Little is known of the biology of leatherback turtles in Australia: no major rookeries are known and mating has not been recorded, although sightings of the species have been made near Cape Leveque in the Kimberley Bioregion. Leatherback turtles were recorded off Browse Island during vessel-based whale surveys, and the species was occasionally observed in the survey of the Maret Islands and surrounds. No leatherback turtle nesting areas were identified in field surveys (see Appendix 4). Leatherback nesting activity is not known to occur in the Anson–Beagle Bioregion (Chatto & Baker 2008).

The mating and foraging behaviour of hawksbill turtles in Western Australia is not well known, and hawksbill tracks were recorded rarely in the field surveys of the Maret Islands and surrounds. Hawksbill turtles were not observed in offshore waters of the Browse Basin during field surveys. Nesting activity for this species is not known to occur in the Anson–Beagle Bioregion, but there is a significant hawksbill feeding area within the island reefs at the northern end of Fog Bay (Chatto & Baker 2008).

Pacific ridley turtles are not known to nest in Western Australia and were not recorded in field surveys in the Maret Islands and surrounds. The species does nest occasionally in the Anson–Beagle Bioregion, at Indian Island and Bare Sand Island (Figure 3-10), but in low numbers. More significant nesting areas for Pacific ridley turtles are located on the Tiwi Islands and in eastern Arnhem Land (Chatto & Baker 2008).

No mating or nesting of loggerhead turtles is known in the Kimberley Bioregion or the Anson–Beagle Bioregion. Loggerhead turtles were spotted during aerial surveys in the Maret Islands and the surrounding areas, but not during surveys of the Browse Basin (see Appendix 4).

Ray-finned fishes

Three seahorse species (family Syngnathidae) that appear on the IUCN's Red List (see Table 3-1) could potentially occur in the offshore development area; however, the distribution ranges of these are not well known. The flat-face seahorse has only been recorded previously in Shark Bay and Broome, and the presence of the hedgehog seahorse in Australian waters has not been confirmed (Seahorse Australia 2008). The spotted seahorse inhabits sheltered bays and estuaries from Onslow in Western Australia's Pilbara region, northwards across the Indo-Pacific region (Allen & Swainston 1988).

None of these seahorse species were recorded in surveys of an intertidal pool at Browse Island (see Appendix 4).

Seabirds

Seabirds in the offshore area around the Ichthys Field and Browse Island, and to the west as far as Scott Reef, were recorded during vessel surveys conducted by the CWR in June and July and in October and November 2008. Seabirds observed included frigatebirds, boobies, terns, noddies, tropicbirds, petrels, shearwaters and gulls, with the brown booby the most common species recorded. Of the species recorded, a number are migratory species listed under the EPBC Act, including the streaked shearwater, brown booby, masked booby, lesser frigatebird, Wilson's storm-petrel, bridled tern, lesser crested tern and little tern (see Appendix 4). These migratory species can be expected to pass through the offshore development area in low numbers.

Within the region, the Roebuck Bay – Eighty Mile Beach area on the Kimberley coast (approximately 450 km south-south-west of the Ichthys Field) is identified as an internationally important site for migratory birds that utilise the East Asian – Australasian Flyway. Hundreds of thousands of shorebirds have been recorded there, arriving during the southern migration period between August and November and with many birds staying through the non-breeding period from December to February (Bamford et al. 2008). Flight paths between key foraging and resting areas in the region are not well known and may vary between species. Ashmore Reef (around 160 km north of the Ichthys Field) is also recognised as regionally important for seabirds, with 16 species known to breed there; there are, for example, large nesting colonies of sooty terns, common noddies, bridled terns and crested terns (Milton 2005).

3.2.9 Other marine megafauna

Vessel surveys by RPS Environmental and the CWR and acoustic loggers utilised for cetacean surveys also provided data on fish, sharks, rays and seasnakes in the Ichthys Field area. Seasnakes were observed in the offshore development area but were not close enough to identify to species level. Observations included a leopard shark, a mako shark, two hammerhead sharks and one whale shark, as well as 22 manta rays. Large numbers of flying fish and jellyfish were also recorded (see Appendix 4).

Fish surveys in an intertidal pool at Browse Island identified 32 species, including *Abudefduf vaigiensis* (family Pomacentridae), *Ecsenius oculus* and *Cirripectes filamentosus* (family Blenniidae) and a *Gymnothorax* sp. (family Muraenidae). All of the species identified are common in the Indo-Pacific region (see Appendix 4).

3.3 Nearshore marine environment

As described in Section 3.1.1, the nearshore development area includes the marine area from the entrance of Darwin Harbour to the coastal waters around Blaydin Point and Middle Arm Peninsula below the low-water mark (see Figure 3-2).

3.3.1 Darwin Harbour bathymetry

Darwin Harbour is a large ria system about 500 km^2 in extent. In its southern and south-eastern portions the Harbour has three main components—East Arm, West Arm and Middle Arm—that merge into a single unit, along with the smaller Woods Inlet, before joining the open sea. Freshwater inflow to the Harbour occurs from January to April, when estuarine conditions prevail in all areas (Hanley 1988).

Over the 6000–8000 years since the Harbour was formed by rising sea levels, erosion from the adjoining terrestrial environment has carried substantial quantities of sediment into its waters. This sediment now forms much of the intertidal flats that veneer the bedrock.

The proposed onshore development area is situated on land at the eastern end of Middle Arm Peninsula in the Harbour, between East Arm and Middle Arm. Both arms are the estuaries of rivers that drain the hinterland behind Darwin and Palmerston during the wet season. Elizabeth River flows into East Arm, while the Darwin and Blackmore rivers flow into Middle Arm.

The main channel of the Port of Darwin is around 15–25 m deep, with a maximum depth of 36 m (Figure 3-11). The channel favours the eastern side of the Harbour, with broader shallower areas occurring on the western side. Intertidal flats and shoals are generally more extensive on the western side of the Harbour than on the eastern side.

The channel continues into East Arm, towards Blaydin Point, at water depths of more than 10 m below LAT; the bathymetry in this area has been modified by dredging for the development of East Arm Wharf.

A slightly deeper channel extends into Middle Arm, up to the western side of Channel Island. A shallower channel (generally 10–15 m below LAT) separates Wickham Point from Channel Island.

3.3.2 Oceanography and hydrodynamics

Darwin Harbour is characterised by a macrotidal regime. Tides are predominantly semidiurnal (two highs and two lows per day), with a slight inequality between the successive tides during a single day. For a two-day period during neap tides there are nearly diurnal tide conditions (one high and one low per day). The lowest spring tides of the year occur during October, November and December. Mean sea level is approximately 4.0 m above LAT. Spring tides can produce tidal ranges of up to 7.5 m (0.0 m LAT at low tide to 7.5 m above LAT at high tide), while the neap-tide range can be as low as 1.4 m (3.1 m above LAT at low tide to 4.5 m above LAT at high tide) (Australian Hydrographic Service 2008).

Tidal excursions range from 8 to 15 km during spring tides and 2 to 8 km during neap tides (Hanley & Caswell 1995; Semeniuk 1985). The large tidal ranges produce strong currents that peak at speeds of up to 2–2.5 m/s. Tidal flows are also large: peak spring-tide flows have been measured along a line from East Point to Mandorah and are in the order of 120 000 m^3/s. Over a spring tide up to 1000 GL/s can pass through this area (Williams & Wolanski 2003). The major currents in the Harbour are illustrated for ebb tide and flood tide in figures 3-12 and 3-13 respectively.

The Harbour is considered to be well protected, with the majority of waves generated within the Harbour or in Beagle Gulf (Byrne 1988). The ambient wave climate during the summer months could reach heights of up to 1 m, although average wave height would be less than 0.5 m with periods of 2–5 s (Byrne 1988; GHDM 1997). Average wave conditions during the winter months are predicted to be even lower. It is considered that tsunamis and swell waves (long-period waves) are unlikely to occur in Darwin Harbour as a consequence of its orientation and the protection from ocean swells afforded by the Tiwi Islands (GHDM 1997).

Extreme wave conditions were modelled by GHDM using wind data from Cyclone Tracy in 1974. Waves with a "significant wave height" of 4.5 m and average periods of around 7.5 s were found to occur at the entrance to the Harbour. However, these waves were found to be affected by bathymetry and reduced to a height of around 0.7 m in shallower waters in the inner parts of the Harbour (GHDM 1997).

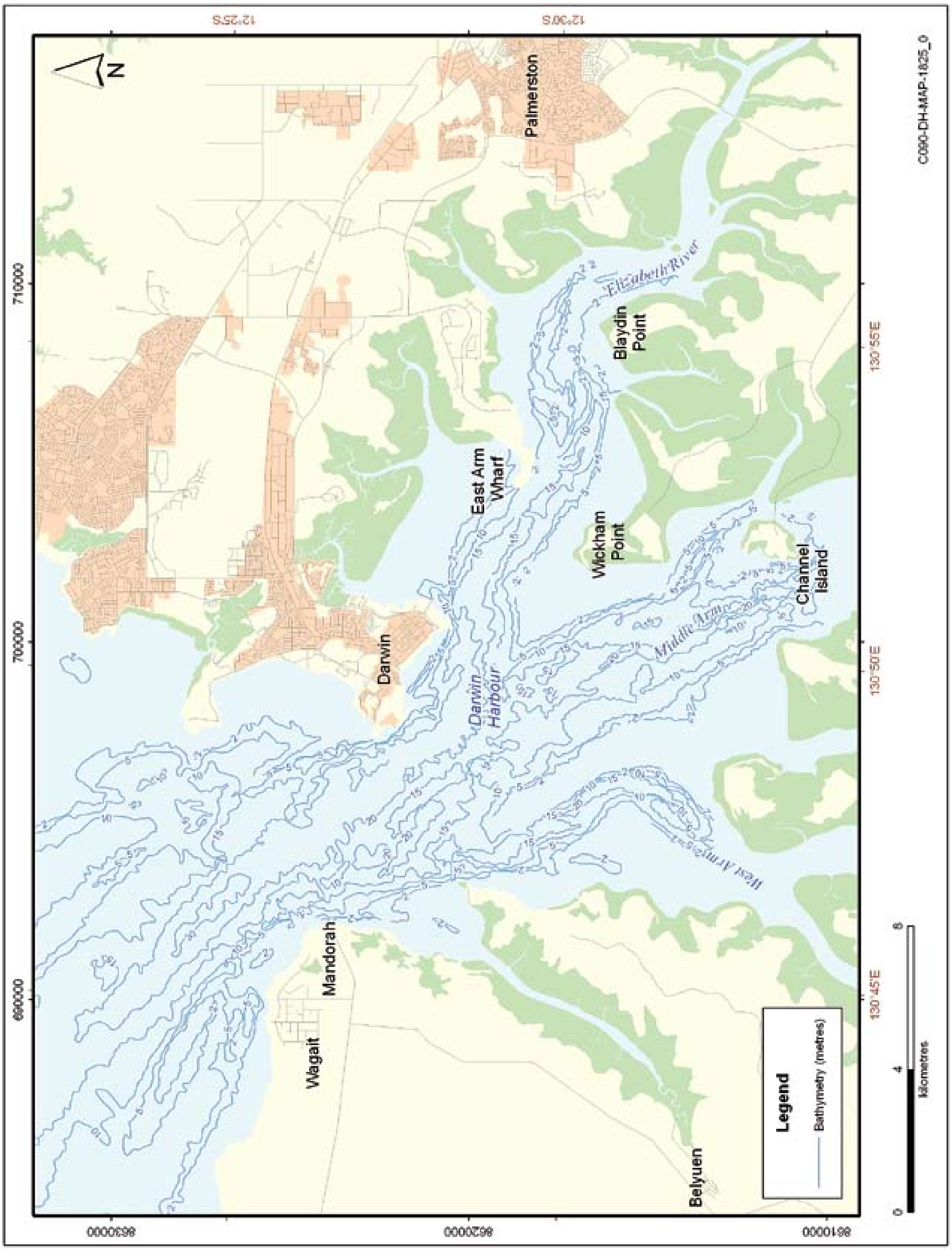
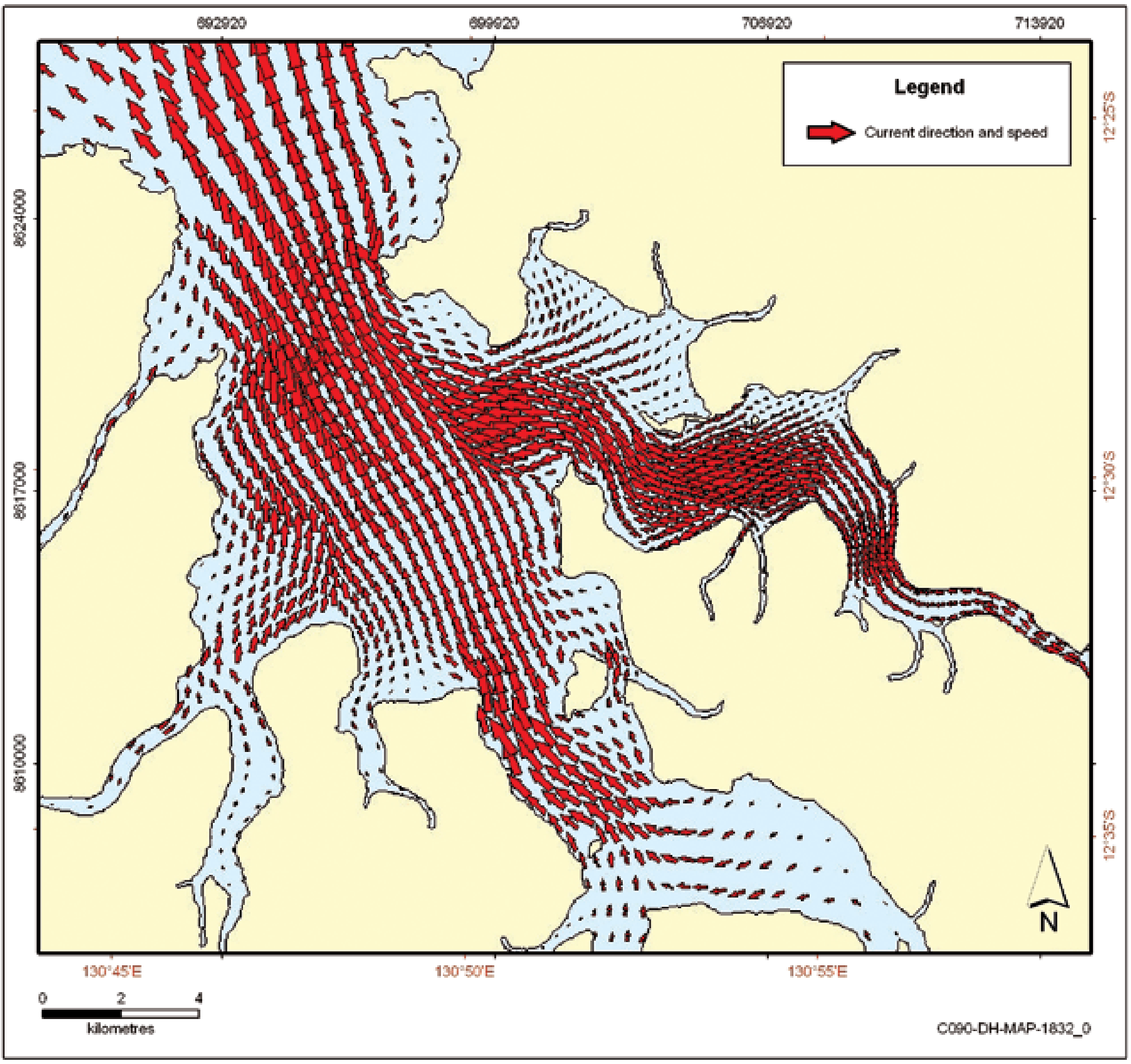


Figure 3-11: Bathymetry of Darwin Harbour



Source: APASA 2010.

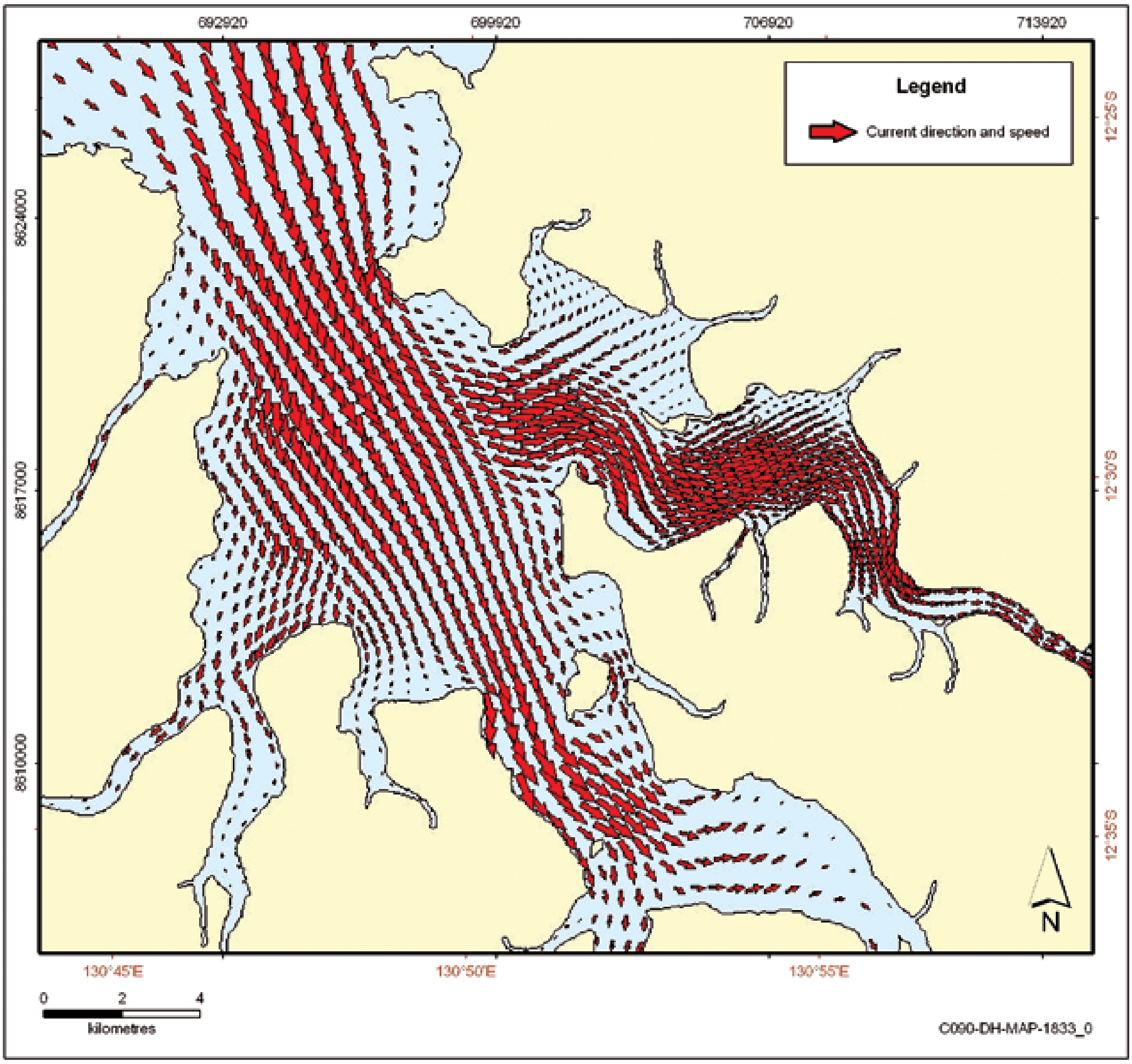
Figure 3-12: Major currents during ebb tide in Darwin Harbour

Storm tide predictions—which take into account cyclone storm surges together with the effects of frequent breaking waves ("wave set-up") and the influence of astronomical tide—indicate that temporary increases in sea level would occur during cyclone conditions at sites around Middle Arm Peninsula and East Arm (Table 3-3). The largest storm tide expected over a 100-year period (a 1-in-100-year event) is 4.9–5.1 m above mean sea level. As mean sea level is estimated at 4 m above LAT, this storm tide would therefore bring nearshore waters to a height of 8.9–9.1 m above LAT. Predictions over longer return periods, for 1-in-1000- and 1-in-10 000-year events, indicate even higher storm tides (Hennessy et al. 2004).

Table 3-3: Predicted storm tide heights for locations in the nearshore development area

Location	Storm tide height (m) relative to mean sea level (4 m above LAT)		
	1 in 100 years	1 in 1000 years	1 in 10 000 years
West Arm	5.1	6.4	7.6
Channel Island	5.1	6.4	7.7
Wickham Point	5.1	6.4	7.7
East Arm Wharf	4.9	6.0	7.0

Source: Hennessy et al. 2004.



Source: APASA 2010.

Figure 3-13: Major currents during flood tide in Darwin Harbour

3.3.3 Underwater noise

Underwater noise in Darwin Harbour is influenced by existing shipping traffic as well as by biological sources and weather (e.g. heavy rain). In order to characterise the acoustic environment in the nearshore development area, SVT Engineering Consultants conducted underwater noise monitoring in 2009 using hydrophones (SVT 2009a).

The readings obtained during the monitoring program can be broadly broken into three general frequency spectra:

- 0–50 Hz
- 50–2000 Hz
- >2000 Hz.

Within the 0–50 Hz spectrum most of the noise recorded was below 20 Hz. This is below the hearing range of most of the marine animals that occur in Darwin Harbour. Baleen whales are able to hear at this low frequency, but visit the Harbour very rarely.

The mid-frequency spectrum between 50 and 2000 Hz shows very wide variations in the ambient noise levels recorded, which is a result of the acoustic complexities of the area. Factors such as shallow water, variable depth of water, high tidal range (and the turbulence created by tidal flows), and variable seabed types cause wide variations in the propagation of noise through the water column. It was noted that sound pressure levels in the Elizabeth River were distinctly lower than those in the broader parts of East Arm (around 100 dB re 1 $\mu Pa^2/Hz$, compared with around 150–170 dB re 1 $\mu Pa^2/Hz$), as the shallower water, more complex landform and soft-bottom substrate in the river all reduce noise propagation.

The high-frequency >2000 Hz spectrum of ambient noise in the Harbour is dominated by the sound of snapping shrimp. This has a typical peak frequency of 5–7 kHz.

Targeted recordings of three tugboats under way in the Harbour (the *Marrakai*, *Ginga* and *Larrakia*) were typical of small diesel-powered vessels. These tugs generated point-source noise from propellers in the range 30–100 Hz, from their diesel engines in the range 100–1000 Hz, and from broadband propeller cavitation noise mainly up to 15 kHz, but extending as high as 96 kHz (the maximum for the hydrophone) at very close range (SVT 2009a).

Measurements of tugboats working alongside an LNG tanker (the *Energy Progress*) from a distance of 230 m recorded broadband noise at around 10 kHz, which is expected to have extended to much higher frequencies at closer range. Received levels of noise from this distance reached about 205 dB re 1 μPa (SVT 2009a).

Other prominent sources of noise in the nearshore marine environment include thunderstorms, lightning strikes and heavy wet-season rains, which generate noise at significant intensities. However, it is noted that these natural noise sources occur only seasonally, while vessel traffic in Darwin Harbour is active throughout the year.

3.3.4 Water quality

The Water Quality Protection Plan for Darwin Harbour was initiated in 2006 as part of the National Water Quality Management Strategy, a long-term plan developed by the Commonwealth, state and territory governments in 1992 to ensure that there would be a sustainable and nationally consistent approach to water-quality management (NRETAS 2007b). The plan aims to maintain the current quality of water resources in Darwin Harbour, and a key component of this management strategy has been the development of water-quality guidelines and objectives (NRETAS 2009b). These are based on the "declared beneficial uses" under the *Water Act* (NT), which are defined for the Harbour as "the protection of aquatic ecosystems, recreational water quality and aesthetics" (NRETA 2007a).

The range of water-related studies in Darwin Harbour is diverse with respect to the objectives, time frames, water-quality variables measured, and locations. The majority of these studies are descriptive and of short-term duration (less than one year) where the objectives have been to obtain baseline information. Most of the other studies are associated with environmental monitoring in response to potential impacts such as dredging, sewage discharge and runoff (Padovan 2003).

The first comprehensive water-quality study of Darwin Harbour was undertaken during 1990–91 for the main body of the Harbour and the entrances to East Arm, West Arm and Middle Arm. More recent comprehensive water-quality monitoring of the Harbour, from 2001 to 2005, expanded the range of locations to include the upper reaches of East Arm and Middle Arm, tidal creeks and Shoal Bay (WMB 2005).

Water quality in the Harbour is generally high, although naturally turbid most of the time. Water-quality parameters vary greatly with the tide (spring versus neap), the location of sampling (inner versus outer Harbour), and with the season (wet season versus dry season). The Darwin wet season extends from November to March and its effects on Harbour water quality (from high levels of surface runoff from the land) can last until April or May depending on the amount of rainfall received. Dry-season climate conditions prevail from May to September.

Tides have a marked effect on water clarity in the Harbour, with waters of neap tides being the clearest while spring tides carry quantities of sediment from the fringing mangroves (DHAC 2007) and bring fine sediments from the Harbour floor into suspension. The areas with the highest natural sedimentation are in the upper reaches of East Arm and Middle Arm. Medium levels of sedimentation occur in the seaward end of West Arm and the lowest levels are in the more open water areas such as East Arm Wharf, Larrakeyah and the seaward boundary (DHAC 2006). It is estimated that 60% of the Harbour's sediments originate from offshore. The remainder is deposited by rivers and creeks, derived predominantly from erosion of channel walls. Direct contribution to the Harbour from sheet erosion is likely to be limited because of the very low hill-slope gradients adjacent to the Harbour (DHAC 2006).

There is no evidence of widespread water or sediment pollution in the Harbour, although there is some localised pollution (Padovan 2003). Anthropogenic influences on Harbour water quality include the port operations at East Arm Wharf, historical industrial activities at Darwin Waterfront and Sadgroves Creek, and wastewater outfalls (URS 2004). The Power and Water Corporation discharges untreated macerated sewage to the Harbour from a sewage plant at Larrakeyah near the Darwin central business district (CBD) at rates of around 80 000 to 130 000 kL per month. Nutrient loads associated with these monthly discharges range between 3.16 t and 6.98 t of total nitrogen and 0.72 t and 1.36 t of total phosphorus (Power and Water Corporation 2006a).

There are increased levels of nutrients in Buffalo Creek and metals in the sediments at Iron Ore Wharf (near Fort Hill Wharf); however the ecological significance of these localised impacts is unclear. In addition, there is no evidence of hydrocarbon or pesticide pollution in the Harbour (DHAC 2007).

A summary of the seasonal, spatial and tidal processes affecting water quality in Darwin Harbour is presented in Table 3-4.

Table 3-4: Summary of processes affecting water quality in Darwin Harbour

Parameter	Influencing factors	
	Open Harbour	Tidal creeks
Temperature	Season	Season
Salinity	Season, location	Season, tide
Dissolved oxygen	Tide (minor)	Tide
pH	(none)	Season, tide
Turbidity and light attenuation	Season (minor), tide	Tide
Nutrients	(none)	Location

Source: Padovan 2003.

In order to characterise the existing conditions in the nearshore development area a water-quality survey was undertaken by URS from April to August 2008, designed to capture the effects of both the wet and the dry seasons. The study included measurement of physico-chemical water-quality parameters in the water column as well as assessment of total suspended solids (TSS). Sampling sites included in the survey are shown in Figure 3-14, while a summary of the average levels recorded is provided in Table 3-5. The results of the study are discussed below, with the full technical report (URS 2009b) provided as Appendix 9 to this Draft EIS.

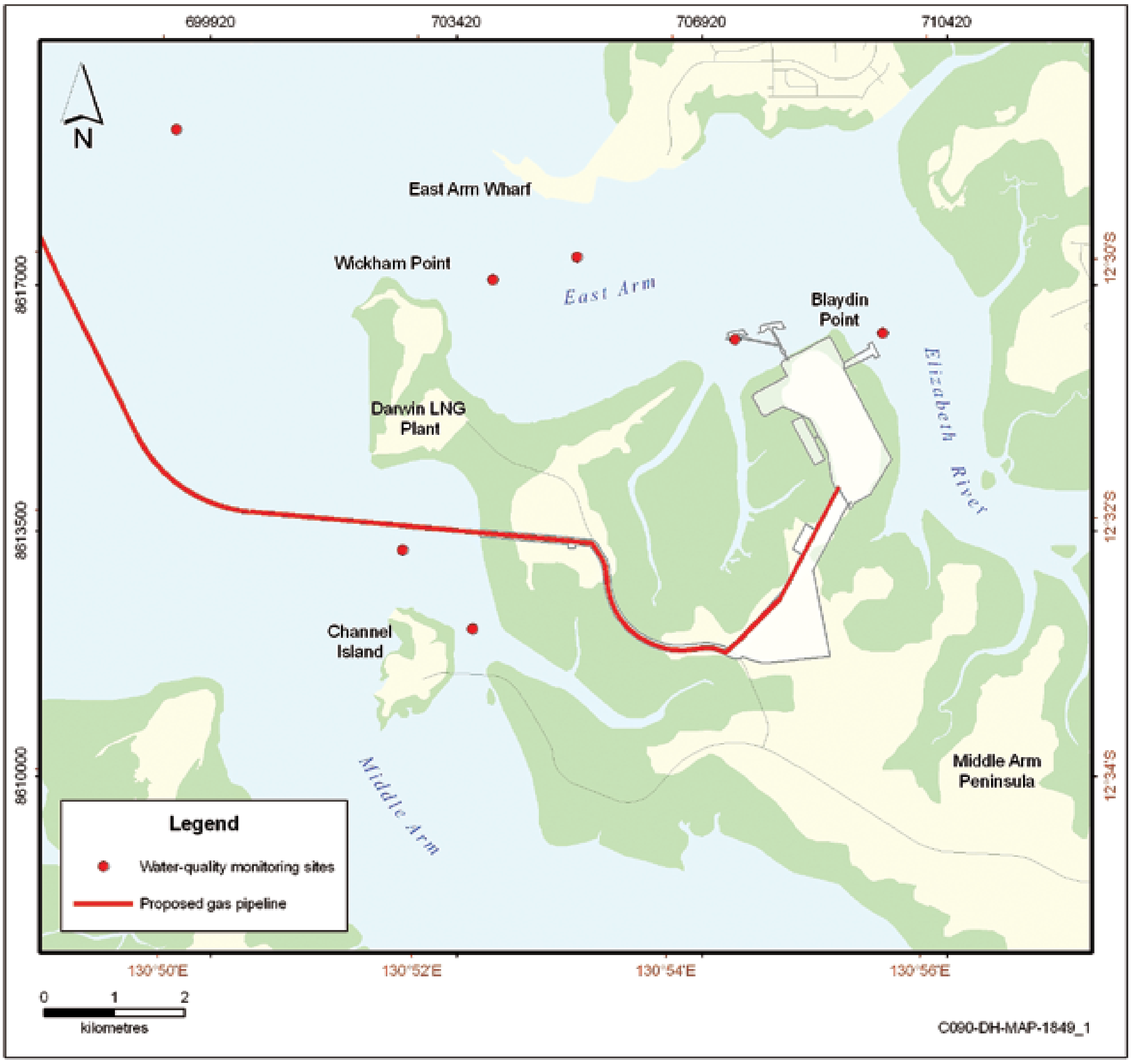


Figure 3-14: Nearshore water-quality sampling sites

Table 3-5: Mean water-quality levels recorded in the nearshore development area

Parameter	Dry season	Wet season
Temperature	24.5 °C	30.6 °C
Salinity	35.5 ppt*	29 ppt*
Dissolved oxygen	93.3%	87.8%
pH	8.4	8.1
Turbidity	3.0 NTU†	10.5 NTU†
Total suspended solids (TSS)	14.0 mg/L	14.1 mg/L

Source: URS 2009b.
* ppt = parts per thousand.
† NTU = nephelometric turbidity units.

Water temperature

Water temperatures in Darwin Harbour are typically high, and some seasonal variations do occur. Temperatures are lowest (23 °C) in June and July and highest (33 °C) in October and November (Padovan 1997).

Water temperatures measured in the nearshore development area by URS (2009b) ranged from 23.5 to 32.7 °C, with an average temperature of 30.6 °C in the wet season and 24.5 °C in the dry season. Comparison between sites over both the wet and dry seasons found that the water temperature was elevated by about 5 °C in the wet season. These distinct seasonal variations in sea-surface temperature have been shown in previous studies of the Harbour, for example by Michie, Grey and Griffin (1991). No significant difference in temperature was observed at any site as a result of either water column position (surface or bottom) or tidal flow (ebb or flood). Spatial uniformity in the Harbour has also been found to occur at sites located both in the upper reaches of Middle Arm and close to the Darwin CBD (Michie, Grey & Griffin 1991).

Salinity

Salinity in Darwin Harbour varies considerably during the year, particularly in East Arm, Middle Arm and West Arm where freshwater influence is greatest during the wet season. Sea water has a global average salinity of 35 parts per thousand (ppt) (DEH 2008). Salinities throughout the Harbour however are about 37 ppt during the dry season, with surface and bottom layers having similar levels. Salinity tends to be higher in harbours in the dry season owing to increased evaporation and less freshwater inflow. At the height of monsoonal inflow during February and March, areas in the middle of the Harbour such as Weed Reef can experience salinity levels as low as 27 ppt (Parry & Munksgaard 1995).

Salinities in the arms, which are strongly influenced by freshwater inflow, can drop as low as 17 ppt. The water at this time is highly stratified, with freshwater input from land-based catchments flooding the Harbour and overlying the intrusion of more dense and higher-salinity water from outside the Harbour, forming a classic “salt wedge” that is typical of estuarine systems. Parry and Munksgaard (1995) reported salinities on the bottom of the Harbour to be as much as 12 ppt higher than on the surface. As the rains cease, runoff decreases and salinities return to their higher dry-season levels (Parry & Munksgaard 1995).

Salinity levels recorded in the East Arm area by URS (2009b) ranged from 19.1 to 36.3 ppt. Mean salinity levels in the Harbour were lower in the wet season than in the dry season (Table 3-5). Under dry-season conditions, salinity was higher in upstream areas than downstream, but this trend was reversed in the wet season with freshwater input to the arms from rainfall. These variations in salinity according to location in the Harbour and according to season have also been previously reported by Michie, Grey and Griffin (1991) and Padovan (1997). No significant differences in salinity levels attributable to position in the water column were observed (URS 2009b)—this may have been a result of water sampling occurring in April and not earlier in the wet season when a significant salt wedge underlying a freshwater lens would likely have been present. Tidal flushing and a lack of major rainfall events during the wet-season sampling period may also have assisted with sufficient mixing of the water column at the sampling sites.

Dissolved oxygen

Harbour waters remain well oxygenated throughout the year, with levels typically ranging from 74% to 96% saturation, averaging around 84%. In a study by Padovan (1997) no seasonal effects were observed, and there were minor changes in oxygen levels with location in the main body of the Harbour. Dissolved-oxygen levels at sites closest to the Harbour’s mouth were slightly higher than sites further into the estuary. In addition, oxygen levels during a spring-tide cycle were 7% higher at high tide than at low tide (Padovan 1997).

Dissolved-oxygen levels in tidal creeks fluctuate with the tidal cycle, with oxygen concentrations lowest during low tide. Oxygen levels in Blessers Creek (on the west side of, and adjacent to, East Arm Wharf) at low neap tide have been recorded at 60% saturation, compared with 90% at high tide (Parry & Munksgaard 1996). This indicates a certain oxygen demand in tidal creeks, probably from mangrove root systems and sediment infauna.

To date there are no reports of anoxia in undisturbed tidal creeks, and it is not known whether the conditions under which anoxia is most likely to occur have ever been sampled. These conditions are during small tidal movements in October and November when temperatures are highest and calm conditions prevail (Padovan 2003).

Dissolved-oxygen levels measured in the nearshore development area by URS (2009b) ranged from 74.4% to 103.0%[3], with an average saturation of 93%. Overall, dissolved oxygen was generally found to be higher in the dry season and in the main body of the Harbour, with decreasing levels further upstream. Higher dissolved-oxygen levels were recorded nearer the surface than at the bottom of the water column. No significant differences in dissolved-oxygen levels were observed between flood and ebb tides (URS 2009b).

pH

The pH of Darwin Harbour waters generally remains within a narrow range (8.3–8.6 with a mean of 8.5) throughout the main waterbody. Padovan (1997) found no seasonal or spatial effects on pH, and no tidal effects.

The pH of tidal creeks varies to a greater degree than the open Harbour waters and is affected predominantly by tide and season. During the dry season or periods of no freshwater inflow, the pH of Blessers Creek and Middle Arm was 0.3 pH units lower at low tide than at high tide (Parry & Munksgaard 1996). This indicates that processes occur in the mangrove environment that result in the slight acidification of inflowing waters.

Measurements recorded in the nearshore development area by URS (2009b) recorded a mean pH of 8.4 and a range from pH 7.8 to 8.5. In the upper reaches of Middle Arm and East Arm, mean pH levels were found to be lower (more acidic), with pH levels increasing (becoming more alkaline) in the main body of the Harbour in both wet- and dry-season sampling. No significant difference in pH attributable to water-column position or tidal state was observed (URS 2009b).

3 Percentage dissolved oxygen is derived using standard calculations between water temperature and dissolved-oxygen concentrations (e.g. in mg/L). Water-quality sampling probes perform this conversion automatically. However, this “standard” calculation is not accurate across all environmental conditions and, as a result, dissolved-oxygen levels greater than 100% can occur.

Turbidity and light attenuation

Light levels reaching the sea surface in the Harbour are very high. However, because of the high levels of suspended solids in the water column the light is rapidly dissipated and even within a depth of a few metres light levels can be greatly reduced. Turbidity is a measure of this “light-scattering” effect, and is measured in nephelometric turbidity units (NTU).

The most important factors affecting turbidity are the tidal cycle and location within the Harbour (Padovan 1997). Turbidity is highest during spring tides when current velocity, and therefore the capacity of the water to move sediment, is greatest (DHAC 2005). During the spring-tide cycle, turbidity is greatest at the midpoint between high and low water and least at slack water.

Turbidity is higher in the wet season than the dry season because of the influx of terrigenous sediments to Harbour waters through the rivers and, to a lesser extent, from surface-water sheetflow. Even at a depth of only 3 m below the surface, light levels during the wet season can be as low as 7.7% of surface levels. Light levels at the bottom of the Harbour can be as low as 1% of surface levels during the wet season (Padovan 1997).

In analysing turbidity data from the East Arm Wharf development, Munksgaard (2001) found statistically significant effects of season where turbidity was highest during the wet season. However, the mean change in turbidity was relatively minor: from 4 to 12 NTU over the range of conditions analysed. These differences are much lower than the range typically found in the Harbour, that is, between 1 and 35 NTU (Padovan 1997). It can be concluded that season has only a minor effect on turbidity in the main body of the Harbour. There have been no studies on turbidity in the upper reaches of East Arm and Middle Arm where the Harbour is most affected by freshwater inflows during the wet season. Seasonal effects on turbidity, if present, would most likely be found here (Padovan 2003).

Turbidity levels recorded in the nearshore development area by URS (2009b) were up to 73.6 NTU, with a mean reading of 6.9 NTU. Predictably, higher NTU values were found at the bottom of the water column than at the surface, with higher levels also being recorded in the wet season when compared with the dry season. During ebb tides turbidity levels were higher upstream than in the Harbour; this was reversed during flood tides (see Appendix 9).

Total suspended solids

Measurements of TSS and turbidity both indicate the levels of solids suspended in the water column, whether mineral (e.g. soil particles) or organic (e.g. algae). However, TSS measures an actual weight of material per volume of water, while turbidity, as described above, measures the amount of light scattered.

Water-quality sampling in Darwin Harbour in 2002 and 2003 by the Australian Institute of Marine Science (AIMS) recorded an annual TSS average of 10.3 mg/L, with a minimum of 3.1 mg/L and a maximum of 73.5 mg/L (AIMS 2008). TSS levels around Blaydin Point measured by URS ranged from 1.5 to 83 mg/L, with an average of 15 mg/L. Elevated TSS levels were found to occur in the wet season at the bottom of the water column on a flood tide at all sites. Generally, TSS levels were not as high in Harbour waters as in East Arm and Middle Arm. No clear distinction was found between wet- and dry-season TSS levels at the surface (see Appendix 9).

Nutrients and phytoplankton

Studies on nutrients in the sediments of Darwin Harbour have been few and their scopes have been limited. Padovan (1997, 2002) and Sly, Marshall and Williams (2002) found total nitrogen in the main body of the Harbour to be between 0.2 and 0.6 mg/L. The concentration of total nitrogen in most of the inflowing river waters was similar to that found in the Harbour and therefore wet-season inflows are not expected to affect nitrogen concentrations in the main waterbody (Padovan 1997, 2003).

Phytoplankton is an important water-quality measure as its abundance and composition is directly influenced by environmental factors, including nutrients and light. The abundance of phytoplankton is typically quantified through the enumeration of cell numbers and through the measurement of chlorophyll-*a*, the main light-absorbing pigment used in photosynthesis.

Planktonic organisms, along with mangrove plant and animal communities, can form the basis of the food web in coastal marine ecosystems. About 250 different species of phytoplankton have been found in Darwin Harbour, which is typical of tropical, oceanic waters in northern Australia (WMB 2005). Results from the monitoring study by WMB (2005) demonstrated that for most of the year the amount of phytoplankton in the Harbour was very low (<2 µg/L of chlorophyll-*a*), though some measurements in the Blackmore River were up to ten times higher than this.

No seasonal or inter-annual changes in concentrations of chlorophyll-*a* in the Harbour have been found, though concentrations vary with tide cycle (Padovan 1997, 2002). Concentrations were highest during the midpoint of a spring tide, suggesting the resuspension of algal cells from the bottom. Overall, the concentrations measured in the Harbour are similar to those found in other north Australian waters (Padovan 1997).

Algal blooms, which are symptomatic of excessively nutrient-rich water, have not been recorded in Darwin Harbour (WMB 2005).

3.3.5 Marine sediments

Surface sediments

Michie (1988) divided Darwin Harbour sediments into four types:

- terrigenous gravels, which occur primarily in the main channel
- calcareous sands with greater than 50% biogenic carbonate, which are among or close to the small coral communities at East Point, Lee Point and Channel Island. Carbonate sediments, largely derived from molluscan shell fragments, also occur in spits and shoals close to the Harbour mouth
- terrigenous sands on beaches and spits, with 10–50% carbonate, largely derived from molluscs. This type of sediment is predominantly quartz and clay
- mud and fine sand on broad, gently inclined intertidal mudflats that occur in areas characterised by low current and tidal velocities, such as in Kitchener Bay (prior to the construction of the Darwin City Waterfront).

Soft surfaces with varying amounts of gravel and sand are found in the main channels around reefs, on beaches and on spits and shoals near the mouth of the Harbour. The spatial extent of these surfaces is sometimes difficult to determine because of the gradual transition between muddy, sandy and coarser sediments and sediment movement associated with large tidal influences (Fortune 2006).

The physical and biotic structure of soft substrates is governed by grain size, oxygen state and sediment chemistry. The rate of sediment chemistry processes (e.g. the carbon, nitrogen and sulfur cycles) and the plant and animal composition in and on the sediment are linked (e.g. see Kristensen & Blackburn 1987; Pearson & Rosenberg 1978). However, the extent to which the sediment biogeochemistry determines flora and fauna assemblages, and vice versa, is largely unknown for Darwin Harbour (Smit 2003).

Coarser material appears to be located in the central channels of tributaries and the main body of the Harbour as opposed to the landward margins, demonstrating the influence of tidal movement, bathymetry and potential transport capacity in these regions (Fortune 2006).

In 2008, URS sampled surface marine sediments at 151 sites in the nearshore development area (Figure 3-15) using grab sampling. The surface sediments were analysed for a range of substances: a suite of metals occurring both naturally and as a result of man-made contamination (namely aluminium, antimony, arsenic, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, silver and zinc); tributyltin compounds; nutrients (nitrogen and phosphorus); total organic carbon; total petroleum hydrocarbons; polycyclic aromatic hydrocarbons; and the BTEX compounds. In addition, organochlorine pesticides, polychlorinated biphenyls and radionuclides were investigated at some sites. All surface sediments were also assessed for particle size distribution and for their acid sulfate soil (ASS) potential.

Subsurface sediments (>0.5 m below surface level) were sampled through piston coring and borehole drilling at 18 sites in the nearshore development area during geotechnical investigations (Figure 3-15). The majority of the subsurface sediment samples were only assessed for metals concentrations and ASS potential, as the sampling depth was considered to preclude the possibility of anthropogenic contamination.

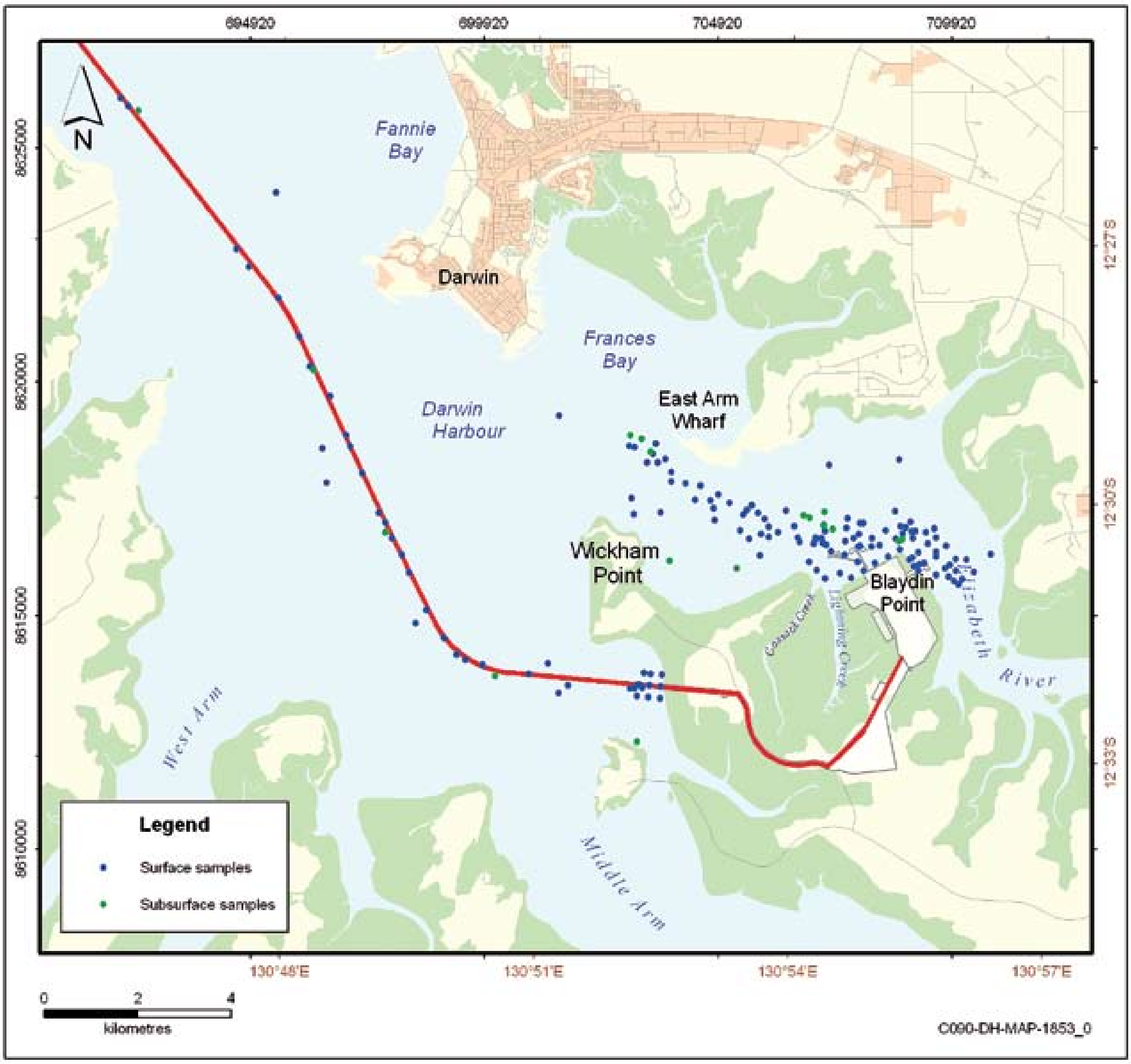


Figure 3-15: Nearshore sediment sampling sites

The sediment quality surveys were undertaken in accordance with the *National ocean disposal guidelines for dredged material* (NODGDM)[4] developed by Environment Australia (2002). These provide “screening level” concentrations for a range of contaminants below which toxic effects on organisms are not expected, as well as “maximum” concentrations at which toxic effects on organisms are probable if the contaminant is in biologically available form.

The results of the URS sediment survey are discussed below, while the full technical report is provided in Appendix 9.

Metals

Sediments play a key role in the geochemical and biological processes of an estuarine ecosystem such as Darwin Harbour. Sediments can act as sinks for metals and organics that enter the Harbour. However, the following physical factors may bring about the exchange of heavy metals between water and sediments:

- hydrodynamic effects that may cause sediment suspension at the sediment–water interface
- bioturbation in sediments that may tend to redistribute heavy metals in the profile
- the salinity of the interstitial water in the sediments (Fortune 2006).

The NODGDM provided guideline concentrations for many heavy metals that could affect environmental health. Previous studies of heavy-metal concentrations in Darwin Harbour sediments (e.g. Currey 1988; Hanley & Caswell 1995; Padovan 2002; Parry & Munksgaard 1995; Peerzada 1988; and Peerzada & Ryan 1987) all recorded levels below the guideline screening levels. More recently, Fortune (2006) undertook a detailed study of heavy-metal concentrations in sediments throughout the Harbour and recorded elevated metals levels at a number of sites. Arsenic was the only metal notably higher in the East Arm area; this, however, is likely to be a consequence of local geology rather than of anthropogenic contamination.

Metals concentrations in surface sediments recorded by URS were fairly consistent across sites throughout East Arm, Middle Arm and the main body of Darwin Harbour. Arsenic concentrations were regularly recorded above NODGDM screening levels (20.0 mg/kg) and occasionally above maximum levels (70.0 mg/kg), both in surface and subsurface sediments. Overall, the mean sediment concentration of arsenic was 34.5 mg/kg. Because of these consistently high arsenic concentrations, further testing was undertaken using a 1-M hydrochloric acid[5] digest. This indicated that only a very small proportion of the arsenic would dissolve into bioavailable forms. Arsenic from sediments is therefore unlikely to be toxic in the marine environment. Its presence in both surface and subsurface layers also suggests that the arsenic occurs naturally in these marine sediments and is not the result of anthropogenic contamination.

Sediment chromium and mercury concentrations were recorded above screening levels at a small number of sites in East Arm (10 for chromium and 2 for mercury, out of 109 sampling sites), and along the pipeline route (4 sites out of 30 for chromium only). Neither was recorded at concentrations above guideline maximum levels and, when averaged across the total samples taken, the resulting mean and 95% upper confidence level (UCL) concentrations for these metals were below the guideline screening levels. No further testing (e.g. for bioavailability) was warranted, in accordance with guideline protocols. Whether these slightly elevated metals levels are a result of anthropogenic pollution is unknown and the marine sediments are not considered “contaminated” based on these occasional deviations from guideline screening levels.

Hydrocarbons

Potential sources of hydrocarbons around Darwin Harbour include those listed below:

- seasonal stormwater inflow from Darwin and Palmerston stormwater drainage networks
- the Naval Fuel Installation at Stokes Hill
- the former fuel storage at the Channel Island Power Station
- the bulk hydrocarbon storage at East Arm Wharf
- the bulk hydrocarbon storage at the Darwin LNG plant
- inventories in recreational and commercial vessels and ships.

4 The *National ocean disposal guidelines for dredged material* (Environment Australia 2002) were formally replaced by the *National assessment guidelines for dredging 2009* (DEWHA 2009b) in May 2009, although the two sets of guidelines are very similar. The marine sediments study was completed in 2008 and referenced the NODGDM.

5 A 1-M (one molar) solution contains one mole of solute per litre of solution.

A survey by URS (2004) sampled 12 sites around the Darwin Wharf Precinct and at one reference site in the Elizabeth River approximately 6 km upstream of East Arm Wharf. The highest concentrations of petroleum hydrocarbons (11–16 mg/kg) were found at sites in Kitchener Bay, Fort Hill Wharf and landward of the Iron Ore Wharf. Concentrations at the remaining sites were between 6 and 10 mg/kg. Petroleum hydrocarbons were also present at the reference site, though the concentration (4.9 mg/kg) was lower than in any of the samples from the Darwin Wharf Precinct sites.

Petroleum hydrocarbons were assessed in surface sediments at 151 sites in the sampling program for the nearshore development area. In the majority of samples, including all samples near the pipeline shore crossing, hydrocarbons were not recorded above the minimum laboratory detection limit.

In East Arm, petroleum hydrocarbons were recorded with maxima of 10 mg/kg for the C_{10}–C_{14} hydrocarbon fraction, 42 mg/kg for the C_{15}–C_{28} fraction, and 24 mg/kg for the C_{29}–C_{36} fraction. Similar results were recorded at sites along the proposed pipeline route, with maxima of 5 mg/kg for the C_{10}–C_{14} hydrocarbon fraction, 31 mg/kg for the C_{15}–C_{28} fraction and 31 mg/kg for the C_{29}–C_{36} fraction (see Appendix 9). Total petroleum hydrocarbon concentrations were well below the screening level of 550 mg/kg given in the *National assessment guidelines for dredging 2009* (DEWHA 2009b), and are likely to be the result of historical industrial and port operations around East Arm.

The BTEX compounds were not recorded above laboratory detection limits at any site. Polycyclic aromatic hydrocarbons were recorded below laboratory detection limits at 103 out of 109 sites, and where detectable concentrations were recorded these were well below guideline screening levels (see Appendix 9).

Tributyltin

Tributyltin compounds (TBTs) are chemicals that contain the $(C_4H_9)_3Sn$ group; they form the main active ingredients in broad-spectrum biocides. In the late 1960s, TBTs, especially tributyltin oxide, came into widespread use as antifoulant additives to marine paints applied to the hulls of vessels. The leaching of TBT from the paint was effective in preventing the growth of fouling organisms on hulls, but also had detrimental environmental effects on biota in the surrounding waters. These compounds are persistent organic pollutants that biomagnify up the marine food chain and also tend to accumulate in sedimentary environments, particularly in fine sediments. In port sediments, TBTs are typically associated with paint flakes, which may be dislodged from vessel hulls during berthing or while alongside wharves.

In 1999, the International Maritime Organization initiated the development of a legally binding instrument to address the harmful effects of antifouling systems used on ships throughout the world. That instrument, the International Convention on the Control of Harmful Anti-fouling Systems on Ships, was adopted in 2001 and entered into force in September 2008. Australia became a party to the Convention in January 2007 and the Commonwealth Government has reinforced its commitment to the control of harmful antifouling compounds by passing the *Protection of the Sea (Harmful Anti-fouling Systems) Act 2006* (Cwlth) which also came into force in September 2008. The Convention prohibits the use of harmful organotins in antifouling paints used on ships and establishes a mechanism to prevent the potential future use of other harmful substances in antifouling systems.

A survey of marine sediment quality by URS (2004) found that there were elevated levels of TBTs across Darwin Harbour. However, although they were detected at most sites, the guideline screening level for TBT (5 ng/g) was exceeded at only one location—Fort Hill Wharf, which has received large numbers of vessels since the late 1960s.

Recent sampling of marine sediments in the nearshore development area did not record TBTs above the laboratory detection limit at any of the sampling sites (see Appendix 9).

Total organic carbon

Total organic carbon has a major influence on both the chemical and biological processes that take place in sediments. At very low total organic carbon levels, little food is available for consumers, resulting in a low-biomass community. At very high total organic carbon levels, enhanced sediment respiration rates lead to oxygen depletion and accumulation of potentially toxic reduced chemicals. Hyland et al. (2000) found that total organic carbon levels below 0.05% w/w (0.5 mg/g) and above 3.0% w/w (30 mg/g) were related to decreased benthic abundance and biomass.

Total organic carbon levels recorded in the nearshore development area averaged 0.3% w/w (3 mg/g) in East Arm and the main body of the Harbour, and 0.5% w/w (5 mg/g) in Middle Arm at the pipeline shore crossing (see Appendix 9). These levels are within the range supporting normal biomass growth.

Nutrients

Nitrogen and phosphorus are major plant nutrients and their availability in marine systems most often determines the limits on plant growth. An overabundance of bioavailable nitrogen and phosphorus can lead to the eutrophication of waterways and the proliferation of macroalgae and phytoplankton, which can choke estuaries and other confined marine systems. Large quantities of these nutrients can be held in sediments, mostly in non-bioavailable forms.

During sediment sampling in the nearshore development area, concentrations of nitrogen as nitrite and nitrate (a measure of soluble, oxidised forms of nitrogen) were recorded at very low levels throughout the Harbour (0.28 mg/kg along the pipeline route, and less than 0.1 mg/kg in East Arm and Middle Arm). Soluble nitrogen is therefore considered to form an insignificant portion of the total nitrogen pool (see Appendix 9).

Average total nitrogen concentrations of 581 mg/kg and 356 mg/kg were recorded in the main body of the Harbour (the proposed pipeline route) and in East Arm respectively. Mean total phosphorus levels ranged from 315 mg/kg in the main body of the Harbour to 509 mg/kg in East Arm, which is within the range of that reported by Parry et al. (2002) in a similar study. Total sulfur, another essential plant nutrient, was recorded at concentrations ranging from 0.18% to 0.8% (see Appendix 9). No guideline criteria are available for sediment nutrient levels.

Particle size distribution

Fortune (2006) reported on a sediment grain-size study that included 29 sampling sites extending from the main port area of the Harbour through to the upper reaches of the Elizabeth River. This work was conducted in 1993 prior to the infrastructure development and dredging at the East Arm Wharf facility, with sampling effort concentrated in this area (Fortune 2006). Sediment distribution in the area largely comprised coarse- to fine-grained sand (62–500 µm) with a variable distribution of granules and the finer fractions (silt and clay) among sites. Silt constituted no more than 13% of the samples in those sites in the East Arm section and the finer clay fraction constituted no more than 4.5% by weight for all sites sampled.

Sampling in the East Arm portion of the nearshore development area yielded similar results, with an average clay and silt content of 16.5% across 109 samples. Surface sediments in the main channel area were generally made up of larger-grained sediments such as fine sand, coarse sand and shell fragments. Sediments were finer closer to the shores of Blaydin Point, with higher proportions of silts and fine sands (see Appendix 9).

Surface sediments in the main body of Darwin Harbour (along the pipeline route) were generally fairly coarse, with a silt and clay content of 19.0%. In contrast, surface sediments around the pipeline shore crossing were much finer, with clay and silt accounting for 37.4% of the sample weights and fine sand (<250 µm) contributing a further 51.5%.

Acid sulfate soil potential

Sediments in the nearshore development area were analysed for their potential to oxidise to produce sulfuric acid, as well as for their capacity (in conjunction with sea water) to prevent the formation of acid through neutralisation by carbonaceous sediment or alkaline water. Methods used to assess ASS potential included both the suspension peroxide oxidation combined acidity and sulfate (SPOCAS) and the chromium suites of tests. The ASS risks in the sediments were then screened using texture-based criteria and then a site-specific ASS risk matrix was developed for the nearshore development area. These assessment methods are described in detail in Appendix 9.

Potential ASS risk was identified at a number of sites throughout the nearshore development area, including 54 sample sites in East Arm, eight along the pipeline route and one at the pipeline shore crossing. Oxidisable sulfur contents were recorded at <0.02–1.5% sulfur and acid neutralisation capacities were measured at 0.06–54.4% sulfur equivalent. Sites of potential ASS risk are spread fairly evenly throughout shallow shoreline and deeper channel areas of the survey area (see Appendix 9).

Subsurface sediments

Coffey Geotechnics Pty Ltd (Coffey) conducted geotechnical and geophysical investigations in the nearshore development area in 2008 by drilling a total of 29 boreholes. The major geological units identified in the area are described in Table 3-6.

Table 3-6: Geological units identified in the nearshore development area

Stratigraphic order	Unit	Name	Age	Material description
Recent marine	1a	Channel deposits	Recent/Quaternary	Mainly sands with some silts, clays and gravels.
	1b	Mangrove muds	Recent/Quaternary	Mainly silts and clays with some sands, locally organic and/or calcareous. Marine and intertidal alluvium adjacent to mangrove swamps.
	1c	Channel lag deposits	Recent/Quaternary	Mainly gravels and clayey gravels at base of live and historical channel.
	1d	Coral	Recent/Quaternary	Live coral.
	1e	Lateritic/colluvial soils	Tertiary/Quaternary	Lateritic/colluvial material (clay, sand, silt and gravel).
Burrell Creek Formation	2ai	Phyllites and sandstones (residual soils)	Early Proterozoic	Residual soils derived from sandstones and phyllites of the Burrell Creek Formation (silts and clays with some sands and gravels).
	2aii	Phyllites and sandstones (weak, extremely weathered rock)	Early Proterozoic	Extremely to very low-strength weathered sandstones and phyllite of the Burrell Creek Formation.
	2aiii	Phyllites and sandstones (rock)	Early Proterozoic	Competent phyllites and sandstones (generally low strength or greater) of the Burrell Creek Formation.
	2b	Conglomerate	Early Proterozoic	High-strength conglomerate of the Burrell Creek Formation, possibly an ancient debris flow.
Undifferentiated granite	3	Weathered granodiorite	Early Proterozoic	Weathered granodiorite/granite.

Source: Coffey 2009.

Sediments in East Arm to the north of Blaydin Point generally show several metres' thickness of unconsolidated sediments overlying the phyllites and sandstone of the Burrell Creek Formation (Coffey 2009). The upper 5–15 m of the phyllites are weathered in some areas while unconsolidated recent sediments directly overlie competent phyllite and sandstone rock in other areas.

To the east of Blaydin Point there are several metres of unconsolidated recent muds and channel lag deposits lying over 20–25 m of weathered phyllite and residual soils (Coffey 2009).

The predominant seabed material to the west of Middle Arm Peninsula, near the pipeline shore crossing, is residual soil grading to weathered phyllite and sandstone. There are also pockets and veneers of unconsolidated sands and gravels and harder phyllite (Coffey 2009).

Metals levels recorded in subsurface sediment quality sampling were consistently lower than the guideline screening levels, except for arsenic at a number of sites. Sediment arsenic was found not to be bioavailable to any significant extent and its presence in subsurface sediment indicates that these elevated concentrations are attributable to local geology rather than to anthropogenic contamination (see Appendix 9).

Nickel was also recorded just above the screening level concentration in one subsurface sediment sample in East Arm, but well below the maximum level. This single elevated sample can be considered an anomaly in the context of the overall sampling program, and its origin is unknown.

A number of subsurface sediment samples were classified with potential ASS risk, including six samples in East Arm, one on the pipeline route and three at the pipeline shore crossing. Oxidisable sulfur contents were recorded at <0.02–3.52% sulfur and acid neutralisation capacities were measured at 0.10–18.6% sulfur equivalent. Sites of potential ASS risk were located in both shallow shoreline and deeper channel areas of the survey area (see Appendix 9).

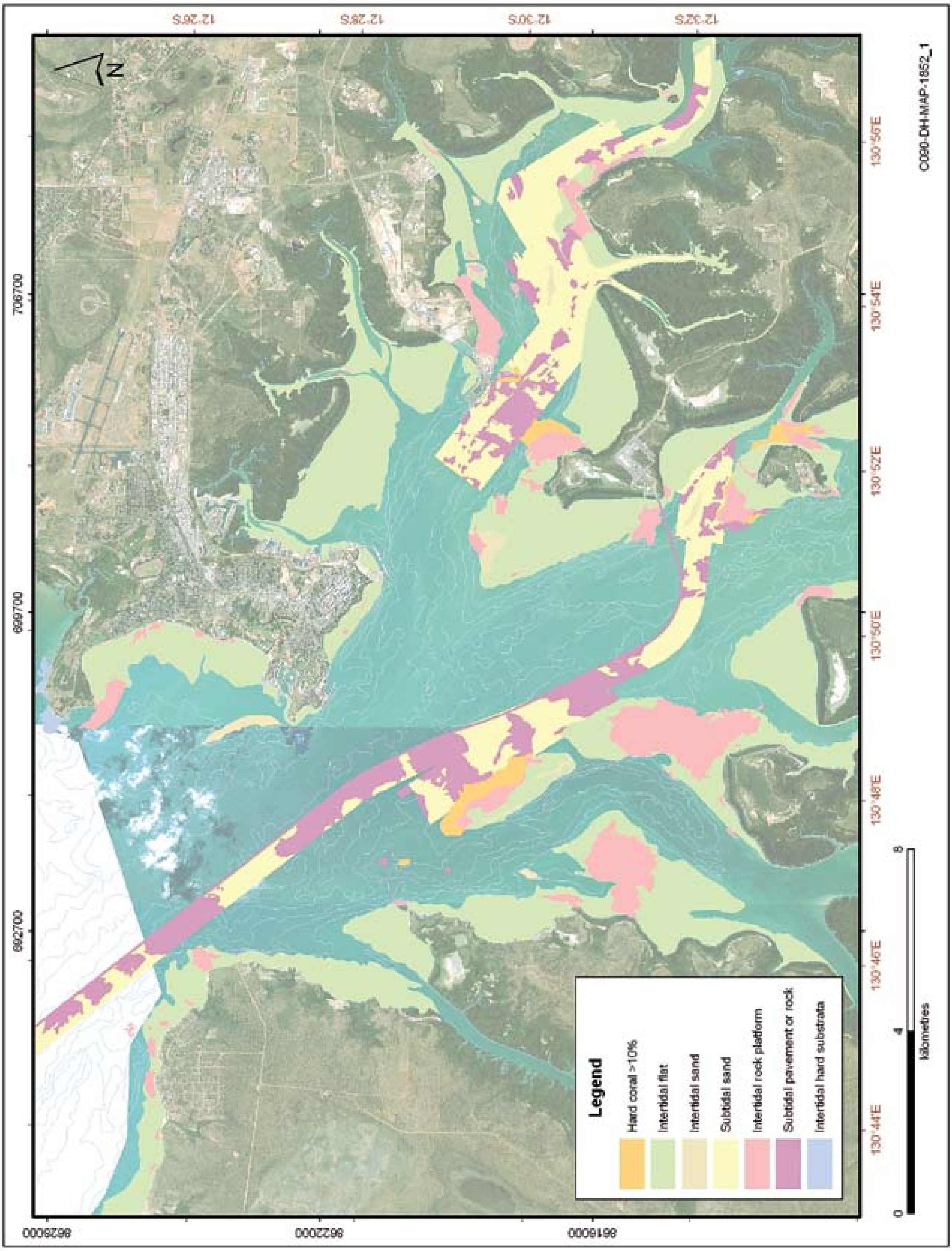


Figure 3-16: Marine habitats in Darwin Harbour

3.3.6 Marine communities

Darwin Harbour has a complex assemblage of marine habitats (Figure 3-16) and there are large differences in the extent, diversity and significance of the biological communities inhabiting them. Rocky intertidal areas are found where headlands protrude into the Harbour. Extensive mangrove communities dominate in the bays and other protected areas throughout the intertidal zone. Seaward of the mangroves, extensive flats occur in the lower intertidal zone. Many of these flats are mud, but some areas are basement rock that may have thin covering layers of sand or mud.

The sides of the main drainage channels are generally rocky, but the bottoms are similar to the intertidal areas in that they vary from exposed pavement, through sand-veneered pavement, to beds of sediment which vary from gravel to fine sands and silt.

The numbers of known species in the major marine taxonomic groups in the Harbour have been presented by McKinnon et al. (2006), as shown in Table 3-7. The major marine communities present in the Harbour are described further in this section. It should be emphasised that the marine environment in the Harbour is complex, and many habitats are present as small units on a single shoreline, with diverse patterns of habitats such as rocky shores, mangroves and mudflats all occurring in a small area.

Table 3-7: Number of marine species per major animal and plant group in the Darwin Harbour region

Taxonomic group	Number of species	Comments
Hard corals	123	–
Soft coral and sea whips	50–65	–
Sponges	56	Only approximately 10% of the sponge fauna has been described.
Algae	110	These numbers represent only macroalgae.
Seagrasses	3	–
Hydroids	63	–
Polychaetes	600+	Highest diversity on subtidal reefs.
Crustaceans	1000+	Estimated number of species.
Molluscs	924	–
Echinoderms	60–117	–
Fish	415	–

Source: McKinnon et al. 2006.

The taxonomic groups and marine communities described in this section are well represented throughout the coastal environments of the Anson–Beagle Bioregion. For example, in the Fog Bay – Bynoe Harbour region, located approximately 35–60 km south-west of Darwin, habitats were identified through satellite and aerial photography and underwater video by NRETAS (2007c). The project revealed a range of different environments including reefs, intertidal flats, subtidal flats, seagrass meadows and associated marine communities. Coral reef assemblages were generally found on fringing and subtidal rocky reefs with low turbidity and relatively good light levels. In high turbidity, algal and sponge communities dominated. More than 200 species of fish were collected; approximately 87 of these did not occur in the embayment of Darwin Harbour. Endangered green sawfish (*Pristis zijsron*) were also found on muddy bottoms in the southern Fog Bay area.

The following sections describe the dominant marine communities in the nearshore marine environment.

Rocky shore communities

Hard substrates in the Harbour consist of coastal cliffs and cliff talus, rocky platforms and rock bars. Weathered and lateritised sandstones and conglomerates form the majority of intertidal rocky platforms (e.g. Weed Reef and Channel Island Reef), intertidal rocky outcrops (e.g. north of Middle Point), subtidal rocky outcrops (e.g. Plater Rock and Stevens Rock) and rock bars in the upper reaches and mouths of Darwin Harbour's tributaries (Smit 2003).

The general zonation of hard substrates in the Harbour has been described by Pope (1967), Ferns (1996), Russell and Hewitt (2000) and some environmental impact assessments for proposed developments. Zonation patterns on the shores can be readily seen, with relatively few species occurring in the upper intertidal zone where organisms are exposed to variable conditions of temperature, sunlight, salinity and other factors that can change suddenly as storms pass through the area during the wet season. Diversity increases further down the shore where conditions are not as extreme (URS 2002).

Intertidal zonation is mostly determined by the period of exposure between high and low tides. In the upper to mid-intertidal zone (above mean sea level), oysters and barnacles are the most abundant faunal groups on the exposed rock, whereas small molluscs (*Nerita* spp. and *Thais* spp.) and isopod crustaceans seek refuge in the more protected areas (e.g. crevices, holes and under rocks). Below the high intertidal zone, approximately at mean sea level, cyanobacteria (blue-green algae) and diatoms form a dark band across the rock bed.

The lower intertidal can be divided into two zones:

- upper zone: mainly bare rock dominated by oysters, limpets, barnacles, chitons, soft corals (*Sinularia* spp., *Sarcophyton* spp. and *Lobophytum* spp.), sponges (*Dysidea* spp.), turf algae and brown algae (*Padina* spp.)
- lower zone: forming the intertidal–subtidal interface, generally represented by those species that are found in subtidal waters. Here, the rock substrate can be covered with hard and soft corals, sponges, crustaceans, anemones and many species of macroalgae (Smit 2003).

Hard-coral communities

Coral-dominated communities in Darwin Harbour are located in lower intertidal to high subtidal areas to depths of 5–10 m below LAT. These areas are characterised by strong currents where the sediment load is kept in suspension and light intensity does not fall below a minimum value for coral and algal survival. Species living in Darwin Harbour are tolerant of conditions—such as variable salinity, high turbidity and sedimentation—that exclude most corals. The corals in the intertidal zone can be exposed to the air during afternoon low-tide periods in the hottest and wettest months of the year (December to February), which renders them vulnerable to desiccation and to freshwater impacts from rainfall, leading to stress, bleaching and mortality. Known localities of coral-dominated communities are Channel Island, Weed Reef, north-east Wickham Point and South Shell Island.

Mass spawning of hard-coral communities in the Harbour is not known to have been observed, although many of the species present are those that reproduce by spawning (i.e. the release of male and female gametes into the water column). Observations in other areas around the world indicate that coral spawning on most reefs extends over a few months during the breeding period, typically between late spring and autumn (Stoddart & Gilmour 2005). Spawning of corals in the Northern Territory Aquarium has been observed around the full-moon period in October and November (TWP 2006). In Northern Queensland, captive corals have been observed to spawn at the same time as those in the adjacent waters.

A comparative assessment of six potential coral sites was undertaken by URS in August 2008: these were Channel Island, South Shell Island, Walker Shoal, Weed Reef, and two sites to the north of Blaydin Point. These assessments were conducted through diving and ROV surveys (URS 2009c, provided as Appendix 8 to this Draft EIS).

A total of 44 species of hard coral was recorded at the six sites. The area covered at each location was approximately 1000 m^2 and only a limited time was available to conduct a full census of the species present. Wolstenholme, Dinesen and Alderslade (1997) reported finding 123 species of hard corals in Darwin Harbour using three divers over ten dives. The results of the survey by URS were broadly consistent with those of the 1997 survey, taking into account the reduced effort.

The Channel Island coral community had the highest percentage cover, species richness (29 species) and diversity of hard corals of all sites. The South Shell Island site and the Weed Reef site had similar cover, diversity and species richness (21 and 22 species respectively), albeit with some differences in species composition. Nine species of hard coral were recorded at the two Blaydin Point sites. No corals were recorded at Walker Shoal.

The rock platform at Channel Island was found to have the most developed hard-coral community of all the sites surveyed. The upper crest and top of the platform (approximately 0 m LAT) was dominated by massive faviid corals, showing clear signs of exposure to air during extreme low tides. These corals were up to 2 m in diameter, with a ring of living tissue approximately 20–30 cm wide around the circumference and dead coral in the middle. Hard-coral cover on the top of the platform was estimated to be approximately 20% of the total area.

The slope at Channel Island (approximately 0.5–1.5 m below LAT) was dominated by *Mycedium elephantotus*, with colonies up to 4 m across. Hard-coral cover in this zone was estimated to be approximately 25–30%. Below the slope (deeper than approximately 1.5 m below LAT), a soft-bottom community of sponges, soft corals, sea whips and sea fans was present. Occasional hard corals were found in this zone, primarily *Goniopora* species. Hard-coral cover in this zone was estimated to be approximately 5%.

South Shell Island was found to have a well-developed hard-coral community on the slope (approximately 0–1.5 m below LAT) with an estimated 15–20% cover of hard corals. Faviids were the dominant corals, although there were numerous *Turbinaria peltata* colonies. Sponges, soft corals and hydroids were numerous on the slope, and were dominant at the base of the slope (deeper than approximately 1.5 m below LAT) along with sea whips, sea fans and feather stars.

The top of Walker Shoal (6 m below LAT) was found to be devoid of hard corals, with biota dominated by gorgonians and sponges (see Appendix 8).

Communities dominated by soft corals and sponges

Previous studies have shown that Darwin Harbour has a relatively low diversity of soft corals and sea whips, with 20–25 species (11 genera) and 30–40 species (18 genera) respectively. Their poor representation can be attributed to the turbidity of the water in the Harbour and to the combination of factors such as sedimentation, light availability, wave and flow exposure and steepness of reefs that control the abundance of soft corals (Fabricius & Alderslade 2001).

Generally, sea whips and sea fans are restricted to current-exposed but wave-protected habitats. Most species require hard substrate for larvae to settle. However, some species have colonised soft-bottom substrates with rootlike structures. These either aggregate gravel with their roots to form a suitable substrate for attachment or dig into the sediment (e.g. sea pens) (Smit 2003).

Sponge-dominated communities occur in areas where hard substrate is available and coral-dominated communities cannot establish. These habitats can occur at any depth in the lower intertidal and subtidal areas. They are patchy by nature and often form a transition zone between hard substrates and the subtidal mud-dominated substrates. Substrates dominated by gravel and/or shell grit or sand–silt are the most favourable to sponge larval settlement. Many species of sponge that do prefer soft substrates are often submersed in the sediment (Smit 2003).

Sponge-dominated communities also contain a wide range of other organisms, including bryozoans, sea squirts, and hydroids (Smit 2003). Very little information is available on these organisms in the Harbour. As with sponges, bryozoans prefer hard substrates and are the most abundant encrusting fauna on wharf pilings. When bryozoans are encountered on soft substrates these substrates tend to be unsorted coarse-grained sediments. This may be because bryozoans are one of the first groups of organisms to colonise gravelly and hard substrates (Smit 2003; Smit, Billyard & Ferns 2000). Hydroids also require a substrate for attachment, even if this is only a small pebble or fragment of shell grit (Smit 2003).

In order to characterise the marine habitats in the nearshore development area, URS conducted drop-camera, ROV and diving surveys on a number of seabed features including wrecks and rocky areas. The results of these surveys (URS 2009c) are summarised here and are presented in full in Appendix 8.

The wrecks of the *Kelat* coal barge and five Catalinas (World War II flying boats) near Blaydin Point and the wreck of the SS *Ellengowan* to the north of Channel Island all supported heavy growths of soft corals, sponges, bryozoans, hydroids and sea squirts, with a sparse occurrence (where present) of solitary hard corals. Pelagic fish life was moderate to abundant at these sites and consisted of *Protonibea diacanthus* (black jewfish), *Platycephalus* spp. (flatheads), *Synanceia verrucosa* (stonefish), and various stingarees (rays of the family Urolophidae), as well as a small number of sharks. Other features investigated were old mooring blocks—either concrete-filled sea containers or plain concrete blocks. These had a sparse cover of plants and animals and low numbers of fish (URS 2009c).

Macroalgae

Macroalga-dominated communities in the Harbour are often located on platform crests and in the intertidal–subtidal interface zone, generally a few metres either side of the low-water mark and often in association with coral- or sponge-dominated communities. Algal composition is highly seasonal and seems to be regulated by the amount of time the community is exposed during spring low tides. During the build-up season (October to December) when the tidal range is at its largest and the extreme spring low tides occur in the middle of the day, the larger macroalgae die back and turf algae dominates. During the dry season, when the tidal range is not so extreme, the larger macroalgae are more prolific. Known localities of these communities are East Point Reef and Weed Reef (Smit 2003).

Marine habitat investigations by URS (see Appendix 8) recorded a sparse though diverse macroalgal community on the rubble-covered pavement at Weed Reef, which included browns (*Sargassum* and *Padina* spp.), foliose reds (*Laurencia* spp.), greens (*Caulerpa*, *Ulva* and *Udotea* spp.) and calcareous greens (*Halimeda* spp.).

Seagrass meadows

Significant seagrass beds are not known to occur in Darwin Harbour and were not recorded in habitat surveys around Blaydin Point. Over the broad areas of sand-veneered pavement at Weed Reef, a very sparse, patchy coverage of a seagrass (*Halophila* sp.) was recorded in baseline surveys for the Project (see Appendix 8). Sparse *Halodule uninervis* and *Halophila decipiens* were also recorded at Wickham Point during baseline surveys for the Darwin LNG Plant (Dames & Moore 1997). Seagrass was not recorded in targeted habitat surveys completed by Whiting (2004) at the reef flat at Channel Island, nor in surveys there by URS.

Immediately outside the Harbour a large seagrass meadow has been described at Casuarina Beach south of Lee Point, extending up to 2.5 km offshore. A variety of seagrass species have been recorded in this area, including *Cymodocea rotundata*, *Halophila ovalis*, *Halophila decipiens* and *Halodule uninervis*. (N. Smit, Marine Biodiversity Group, NRETAS, pers. comm. July 2009).

Soft sediment communities

Even though the spatial extent of marine habitats has not been fully mapped, it is estimated that soft substrates cover approximately 80% of the available substrates in the Darwin Harbour region (McKinnon et al. 2006). Soft substrates consist mainly of muds and fine sand and are found in front of (seaward of) mangroves and in intertidal and subtidal areas between the hard substrates and the main drainage channels.

Intertidal soft substrates mainly consist of muddy to sandy-mud substrates. At first sight they appear to be desert-like, but in fact they support infauna communities dominated by polychaete worms. These substrates generally support communities with low species diversity but high numbers of a particular species. This intertidal substrate is important for feeding by shorebirds during low tides. On the incoming tide many fish migrate with the tide to the higher intertidal areas also to feed on invertebrates living in and on the substrate (Smit 2003).

Subtidal soft-substrate communities are far more diverse than their intertidal counterparts. Marine worms, crustaceans, echinoderms and sponges dominate and they play an important role in the ecological food chain in the Harbour. This substrate consists of varying degrees of mud and sand fractions and ultimately grades into the coarser sediments in the channel (Smit 2003).

There are approximately 600 species of polychaete worms in the Harbour, although only a small percentage has been scientifically described. Polychaetes are found over a wide variety of habitats, but have a preference for fine-grained, sandy and unsorted sediments (Smit, Billyard & Ferns 2000).

The crustacean fauna of Darwin Harbour is typical for northern Australian waters and is dominated by Indo-West Pacific species. The total number of crustacean species throughout the region is thought to be about 1000. It is estimated that there are probably 40–60 species of crabs associated with mangroves in Darwin Harbour. Crustaceans are a diverse group and the many species have different niches in the broad range of marine environments. Consequently, it is difficult to determine which habitats have more species than others (Smit, Billyard & Ferns 2000).

Darwin Harbour is the best-collected locality for marine molluscs in northern Australia. The Museum and Art Gallery of the Northern Territory has compiled a mollusc catalogue for Darwin Harbour which lists 924 species, including 75 associated with mangrove communities. Molluscs are found in a wide range of habitats with many species occupying a specific niche (Smit 2003).

In order to characterise the benthic fauna present in the nearshore development area, sediment samples were analysed by URS in June 2008. The diversity of major taxonomic groups ranged between six and 11 groups at each site, with a total of 17 families of infauna recorded. Amphipods were the most abundant taxon (30% of the total), with polychaetes the second most abundant (27% of the total) (see Appendix 8).

There was a sparse biota in the soft sediments at all sites along the gas export pipeline route within Darwin Harbour, including occasional sea whips, hydroids, sea pens, sponges and sea squirts with low bioturbation (around 10 burrows per square metre) (Figure 3-17).

Source: URS 2009c.

Figure 3-17: Sand, silt and shell fragment substrate with low bioturbation along the gas export pipeline route in Darwin Harbour

Mangrove communities

The intertidal mudflats around Darwin Harbour support extensive tracts of mangroves. This vegetation type is known for species richness, both in terms of the plant species present and the invertebrate fauna that is associated with it. The mangroves around the Harbour and in particular at Blaydin Point are described in Section 3.4.8 *Vegetation communities*, while the invertebrate fauna is discussed in Section 3.4.14 *Blaydin Point invertebrate fauna*.

Fish

Darwin Harbour waters support an abundance of both resident benthic and transient pelagic fish species. The most recent survey of fishes in the Harbour was undertaken by Larson and Williams (1997), which documented a total of 415 species including 31 new records for the Northern Territory. However, very little is known about their basic requirements, such as habitat preference, food habits, places and times of breeding, and lifespan (Larson 2003).

Fish occupy a wide range of habitats in the Harbour catchment. Most species are small, and are difficult to distinguish taxonomically. The most diverse group in the Harbour area is the gobies (approximately 70 species). The next most diverse group is the cardinal fish (20 species) and, unusually for the tropics, the third most species-rich group is the pipefishes (19 species) (Larson 2003).

Mangroves provide habitat for juveniles of most of the fish species commonly harvested by recreational and Aboriginal fishers, such as trevallies (*Caranx* spp.), mackerel (*Scomberomorus semifasciatus*), salmon (*Eleutheronema tetradactylum* and *Polydactylus macrochir*), grunter (*Pomadasys kaakan*) and barramundi (*Lates calcarifer)* (McKinnon et al. 2006). The Darwin Harbour Mangrove Productivity Study found that during high spring tides the mangrove forest is used extensively by a wide range of fish. At low tide, only resident species appear to remain in pools (Martin 2003).

Barramundi is a particularly important commercial and recreational species in the Northern Territory. Commercial fishing of barramundi is not permitted in Darwin Harbour, nor at Shoal Bay to the north of the Harbour (DoR 2009c). Barramundi spawning occurs at river mouths between the months of September and March, when eggs and larval fish are carried by tides into supralittoral swamps at the salt- and freshwater interface, at or near the upper high-water level. The nearest such swamp systems to Darwin Harbour are located in Shoal Bay in the upper reaches of the Howard River. These swamps are vegetated by seasonal plants, including saltwater grasses and various sedges, and provide nursery habitat for the young fish. The swamps are very productive, providing barramundi with conditions for rapid growth and with shelter from predators (Allsop et al. 2003; URS 2001). The Darwin Harbour barramundi stock most likely spawns in Shoal Bay as there is very little suitable nursery habitat in Darwin Harbour (URS 2001).

Towards the end of the wet season, before the swamps dry out, the juvenile fish move out into adjacent rivers or creeks and usually migrate upstream into permanent fresh waters. If they do not have access to fresh water, they may remain in coastal and estuarine areas (Pender & Griffin 1996). After three to five years, most of the freshwater barramundi migrate back to the ocean to spawn at the beginning of the wet season (Allsop et al. 2003).

Jellyfish

Jellyfish have received little attention and are poorly described for the Darwin Harbour area. Several species of jellyfish and two species of box jellyfish appear to be abundant during the wet season (Grey 1978). It is believed that around the end of the wet season the jellyfish migrate into tidal creeks and produce polyps that attach themselves to submerged mangrove roots. When the water temperature begins to increase towards the wet season, the polyps release and grow and are carried out of the creeks by the increased runoff (Smit 2003).

Significant marine communities

The small coral community on the rocky platform at Channel Island has been considered a unique feature in Darwin Harbour, supporting relatively diverse coral, fish and invertebrate assemblages. The Channel Island coral community is listed on the Register of the National Estate (DEWHA 2009c) and is a declared Heritage Place under the *Heritage Conservation Act* (NT). The declaration is based upon the presence of a relatively diverse community, which demonstrates that a coral-based community can survive in an area where most physical conditions are adverse (e.g. high turbidity, strong tidal currents, and seasonally low salinity). The communities also have a high diversity of coral not consistent with their location in an area of deep, fine muds, and very low salinity and high turbidity during the wet season. The high coral diversity, clear reef zonation and the accessibility of the location make the Channel Island coral community important for research and education (DEWHA 2009c).

3.3.7 Marine habitats of the nearshore development area

This section describes the physical and biological features of the marine habitats in areas that are within, or close to, the disturbance footprint of the Ichthys Project at Blaydin Point, Wickham Point, and along the pipeline corridor (near the alignment of the existing Bayu–Undan Gas Pipeline). A full description of Ichthys Project infrastructure is provided in Chapter 4. These marine habitat descriptions were developed by URS during drop-camera, ROV and diving investigations in 2008 (Figure 3-18) (see Appendix 8).

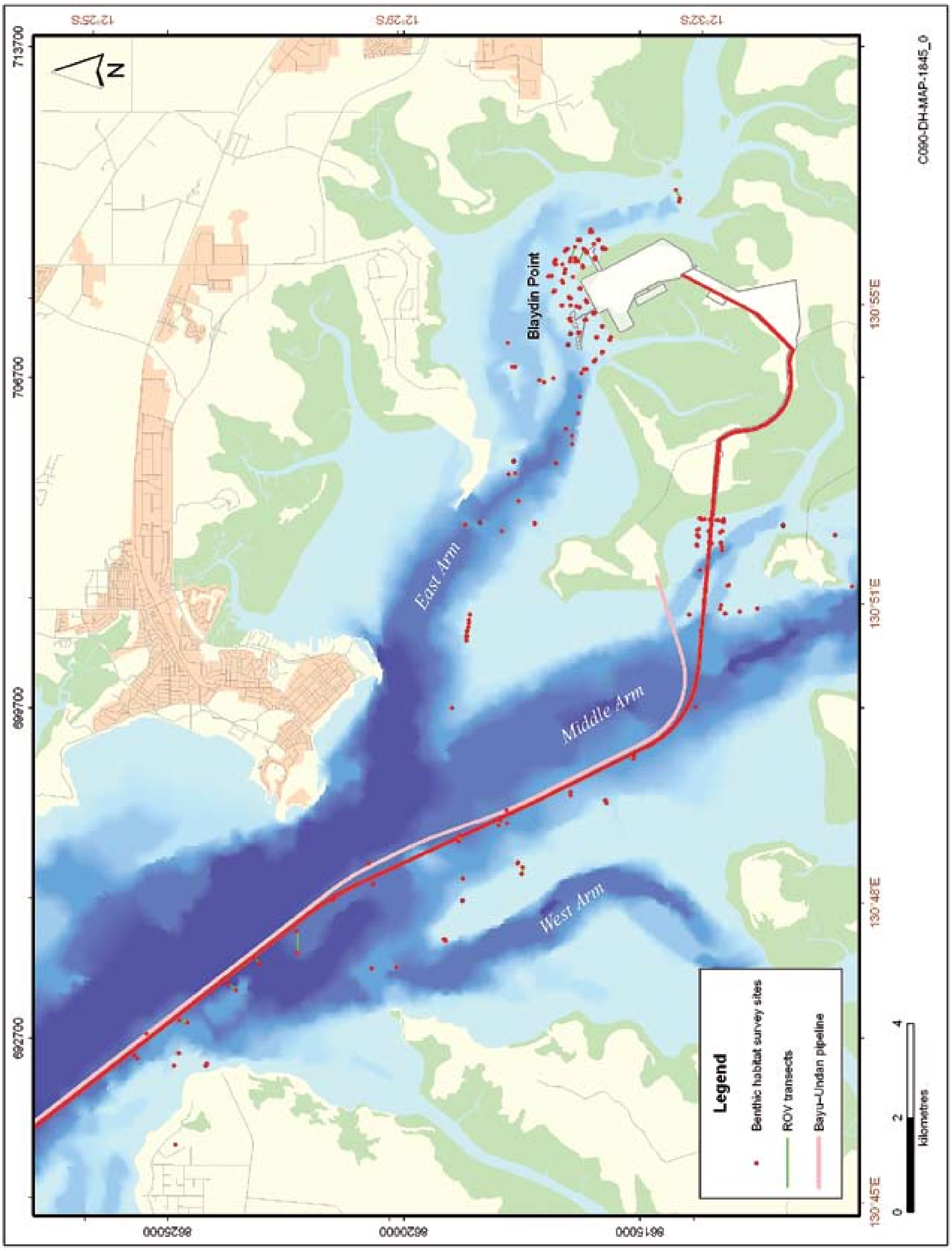


Figure 3-18: Marine benthic habitat survey sites in the nearshore development area

Blaydin Point

Mangroves fringe the greater part of the shoreline of Blaydin Point, becoming less abundant towards the northern point and with a small area at the very north-eastern tip that is devoid of mangroves. In this area sloping rock platforms extend from the shore in northerly and easterly directions. This intertidal platform is an exposed pavement with veneers of coarse sand and silts, gravel, rubble and some larger rocks, with low biota cover present in the northern and western areas (see Appendix 8).

Mangrove mud characterised the greater part of the rest of the mid- to nearshore area surveyed. In general, moderate bioturbation was evident (20 burrows per square metre) with fiddler crabs (*Uca* spp.), alpheid shrimps and mudskippers (*Periophthalmus* spp.) associated with many of the burrows.

In the deeper subtidal area (approximately 1500 m from the shoreline), a low to moderate faunal cover was recorded. This consisted of soft corals (mainly *Sarcophyton* spp. and *Dendronephthya* spp.) where hard substrate was present, together with zoanthids, sponges (laminar, digitate and barrel), bryozoans, hydroids and sea squirts. At deeper sites where hard pavement was not exposed, the faunal community was typically made up of sea fans, sea whips, sea pens and large sponges.

An area of subtidal hard pavement is located approximately 2 km to the north-west of Blaydin Point. The platform, at approximately 0 m LAT, was dominated by green algae with sponges, soft corals, sea whips, sea fans, and limited live coral cover (5%). The slope from 0 m LAT to 1.5 m below LAT supported soft corals, sponges and live hard coral cover (10%) consisting mostly of *Turbinaria peltata*, *Mycedium elephantotus* and several species of faviids. At the base of the slope (deeper than 1.5 m below LAT), a soft bottom with a well-developed community of sponges, soft corals, sea fans and sea whips occurred, with numerous synaptid holothurians (sea cucumbers). This site is considered similar in structure and ecology to other hard-pavement areas in Darwin Harbour and contains benthic species that are widely distributed throughout the Harbour.

Wickham Point

A rock platform extends to the north of Wickham Point (i.e. north of the existing Darwin LNG plant). The eastern edge of this rock platform supports a 10–15% cover of hard coral dominated by laminar *Turbinaria* and *Goniopora* with lower numbers of *Mycedium* spp., faviids and small branching *Acropora* spp., together with soft corals (*Dendronephthya* spp.), sea fans and sea whips. The northern edge of the platform supports a distinctly different assemblage, where the deeper areas consist of coarse sand with sand-wave formations and there are patches of rubble at shallower depths that are dominated by algae and hydroids (see Appendix 8).

Veneers of fine sand and silts were recorded to the east of Wickham Point. All surveyed sites resembled the nearshore sites of Blaydin Point, with low bioturbation (around 10 burrows per square metre) and a low abundance of animals and plants, typically consisting of sea whips and algal turfs.

To the south of Wickham Point, a sparse epibenthic biota and relatively featureless mangrove muds characterised the nearshore intertidal zone. Low to moderate bioturbation was recorded (10–20 burrows per square metre) in a light brown silt veneer overlying a grey fine sand and silt matrix. No epibenthic plants or animals were observed at any of the 12 sites surveyed.

Bayu–Undan Gas Pipeline

The rock armour covering the existing Bayu–Undan Gas Pipeline in Darwin Harbour provides habitat for an abundance of soft corals, sea fans, sea whips, algae and hydroids, with less than 5% hard-coral coverage (Figure 3-19). A moderately rich fish fauna is also found along the pipeline, the most noticeable being members of the family Acanthuridae (surgeon fish). The surrounding sand- and silt-covered seabed supported a sparse coverage of sea whips and sea pens.

Along those parts of the pipeline where mobilised sediments had partially buried the rock armour there was less than 5% coverage, made up of sea fans, sea whips, feather stars, hydroids and algae.

In sections where the pipeline was suspended over troughs in undulations in the seabed, it supported abundant sea fans and sea whips (>90% cover) along with algae, laminar sponges, bryozoans and feather stars. By contrast, the exposed rock-armour positioned where the pipeline passed into the trenched seabed harboured low biotic abundance, dominated by algae with a silt veneer.

Source: URS 2009c.

Figure 3-19: Sea fans, sea whips and sponges on the rock armour covering the existing Bayu–Undan Gas Pipeline

Dredge spoil disposal ground

In order to characterise benthic habitats at the offshore spoil disposal ground (12 km north-west of Lee Point), 100%-coverage sidescan sonar and echo-sounder surveys were conducted by EGS Earth Sciences and Surveying in February 2009. The surveys recorded a flat featureless seabed of silt–sand, at water depths of 15–20 m. This seabed environment is common throughout the Anson–Beagle Bioregion and would likely support sparse benthic communities such as burrowing infauna. The survey was also used to search for any shipwrecks that might have occurred within the spoil disposal ground: none were recorded (EGS 2009).

To further investigate the benthic habitats in the area, a drop-camera survey was completed in September 2009 by Tek Ventures Diving Services (TVDS). The survey covered 21 sites, one per square kilometre of the spoil disposal ground and the surrounding buffer area. Photographs taken during the survey recorded a generally featureless seabed of a sand and/or silt substrate. Very sparse epibenthic fauna was recorded at nine of the sites, typically consisting of occasional bryozoans, sponges and soft corals, with sparse bioturbation (figures 3-20 and 3-21). No seagrasses were recorded in the survey. These results are described further in Appendix 8.

The benthic habitats recorded correlate with mapping of coastal and offshore seabed sediments in the Anson–Beagle Bioregion previously undertaken by NRETAS. Seafloor sampling by Smit, Billyard and Ferns at sites in the vicinity of the offshore spoil disposal ground found the seabed to be primarily composed of carbonate sand. Sparse communities of benthic invertebrates were present, and included bryozoans (which are often associated with coarse-grained sediments), small crabs and shrimps, and worms. Similar sediments and invertebrate communities are widespread across the Anson–Beagle Bioregion (Smit, Billyard & Ferns 2000).

No seagrasses were found by Smit, Billyard and Ferns (2000) in the vicinity of the spoil disposal ground. They considered that extensive seagrass beds would not occur in waters deeper than 5 m, noting that turbid waters were not conducive to seagrass growth. Light levels at water depths of 15–20 m in the region are highly unlikely to be sufficient to support seagrass photosynthesis and growth. The nearest known seagrass meadow is located just off the coast from Casuarina Beach, some 10 km to the south-east (across current) of the spoil disposal ground (N. Smit, Marine Biodiversity Group, NRETAS, pers. comm. July 2009).

3.3.8 Protected species

There are a number of threatened marine species that may be present in the nearshore development area and that are protected under Northern Territory legislation, Commonwealth legislation or international agreements.

Commonwealth and Northern Territory legislation

As described for the offshore marine environment in Section 3.2.8 *Protected species*, the EPBC Act provides a legal framework to protect and manage nationally and internationally threatened plants and animals—defined in the EPBC Act as “matters of national environmental significance”. In addition to locally threatened species, the EPBC Act protects all cetaceans in Australian waters as well as a range of marine and migratory species that are listed under international treaties and conventions (as described below).

Similarly, the Biodiversity Conservation Unit of NRETAS is charged under Section 29 of the TPWC Act with administering the Northern Territory’s Threatened Species List and for assessing and classifying the conservation status of all wildlife species occurring in the Northern Territory.

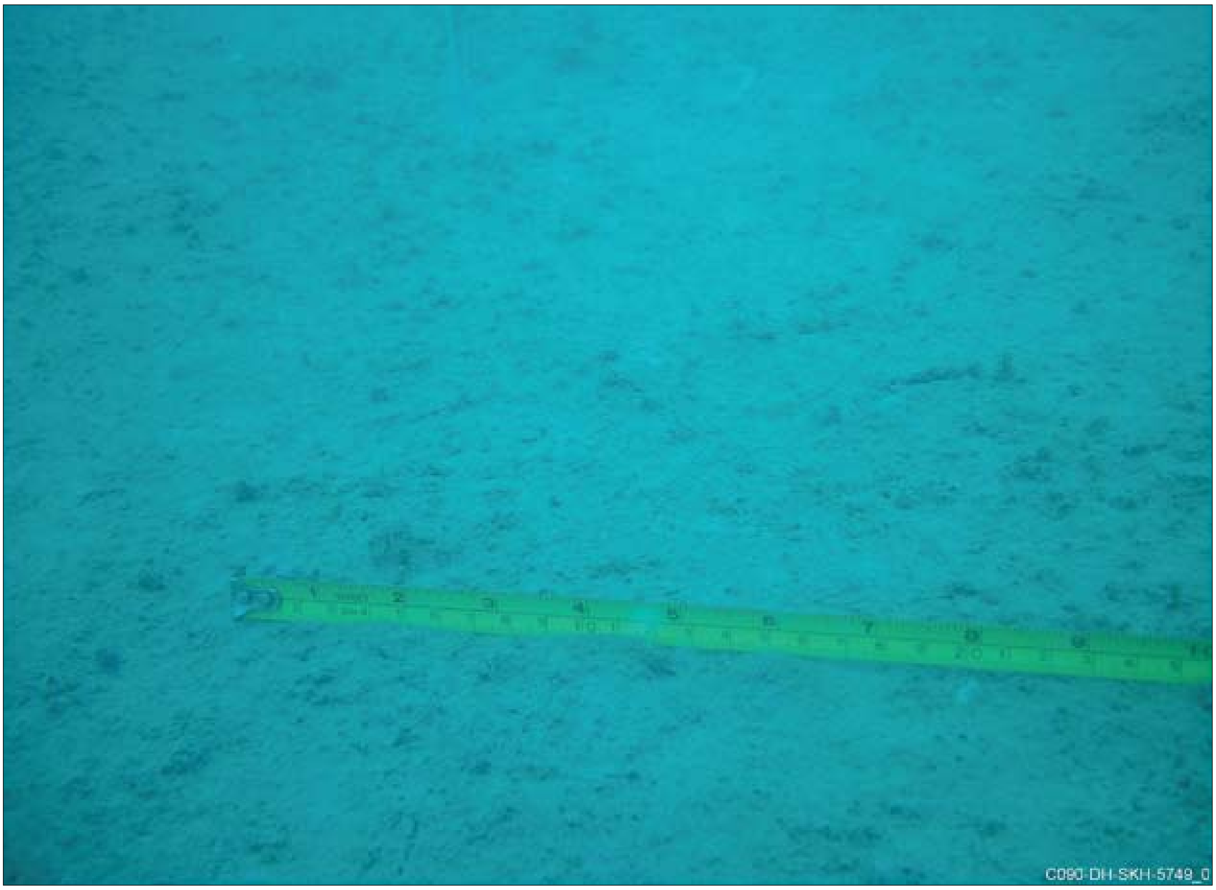


Figure 3-20: Sand and silt substrate recorded at the offshore spoil disposal ground

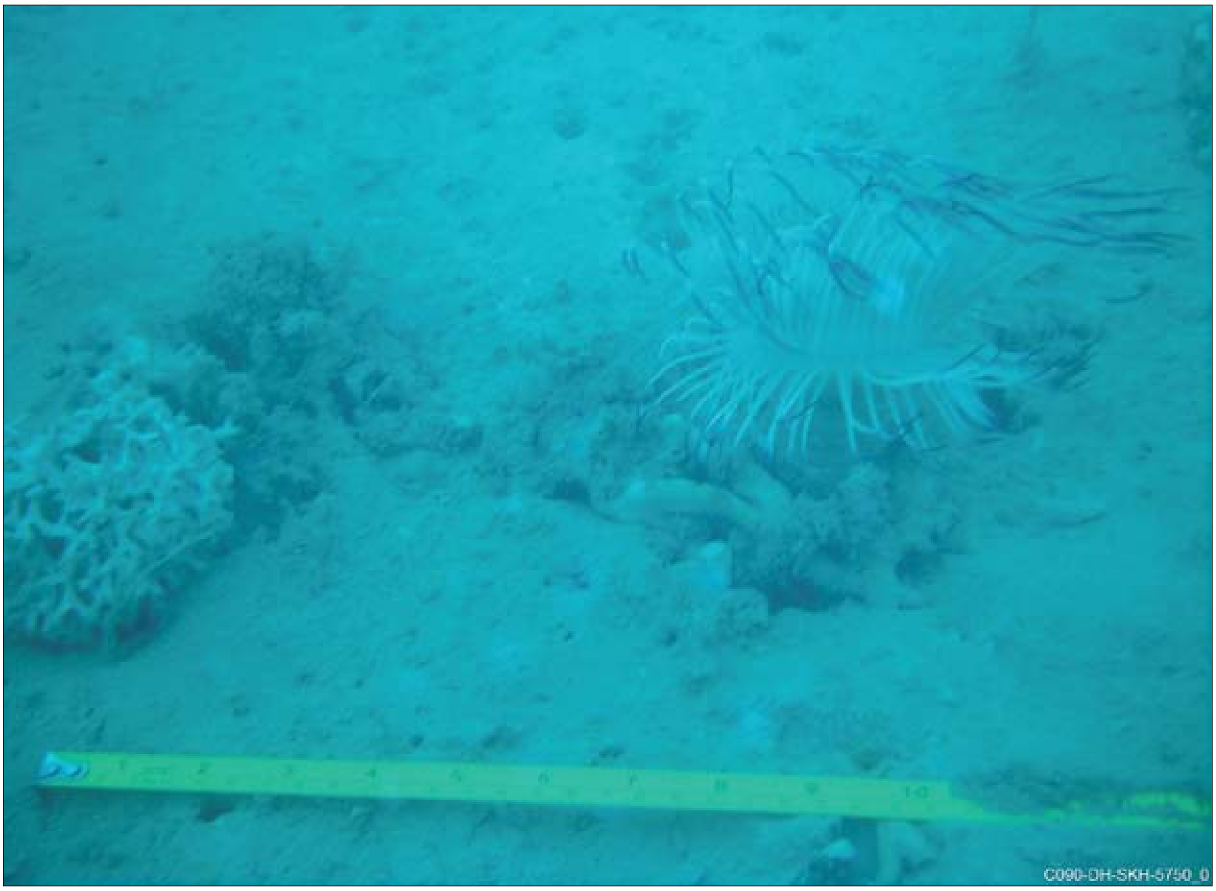


Figure 3-21: A bryozoan and an anemone on the sand and silt substrate at the offshore spoil disposal ground

Marine species categorised as "critically endangered", "endangered" or "vulnerable" under the TPWC Act and EPBC Act and that may be present in or near the proposed nearshore development area are listed in Table 3-8. It is noted that other marine species that fall under less critical conservation categories (such as listed "cetacean" or "migratory" species, or "near threatened" species) also occur in the nearshore development area—key species from these categories are discussed further in this section.

International protection and conservation status

As noted in Section 3.2.8, marine animals that are considered to be under threat of extinction are listed on The IUCN Red List of Threatened Species. They may otherwise be protected by CITES, or by the Bonn Convention. Species that may inhabit the nearshore development area and are protected by such conventions, laws and similar are listed in Table 3-8.

Table 3-8: Protected marine species that may be present in or near the nearshore development area

Scientific name	Common name	Conservation status				
		Commonwealth*	Northern Territory†	IUCN‡	Bonn Convention§	CITES#
Cetaceans: whales						
Balaenoptera musculus	Blue whale	E	–	E	I	I
Megaptera novaeangliae	Humpback whale	V	–	V	I	I
Reptiles						
Caretta caretta	Loggerhead turtle	E	E	E	I, II	I
Chelonia mydas	Green turtle	V	–	E	I, II	I
Dermochelys coriacea	Leatherback turtle	E	V	CR	I, II	I
Eretmochelys imbricata	Hawksbill turtle	V	–	CR	I, II	I
Lepidochelys olivacea	Pacific ridley turtle**	E	–	E	I, II	I
Natator depressus	Flatback turtle	V	–	–	II	I
Cartilaginous fish: sharks						
Pristis microdon	Freshwater sawfish	V	V	CR	–	II
Pristis zijsron	Green sawfish	V	V	CR	–	I
Rhincodon typus	Whale shark	V	–	V	II	II
Ray-finned fishes						
Hippocampus kuda	Spotted seahorse	–	–	V	–	–
Hippocampus planifrons	Flat-faced seahorse	–	–	V	–	–
Hippocampus spinosissimus	Hedgehog seahorse	–	–	V	–	–

Sources: DEWHA 2009a; NRETAS 2007a; IUCN 2009a, 2009b; Bonn Convention 2009a; CITES 2009b.

* Commonwealth Government—*Environment Protection and Biodiversity Conservation Act 1999* (Cwlth).
E = Endangered; V = Vulnerable.

† Northern Territory Government—*Territory Parks and Wildlife Conservation Act* (NT).
E = Endangered; V = Vulnerable.

‡ International—IUCN: The IUCN Red List of Threatened Species.
CR = Critically Endangered; E = Endangered; V = Vulnerable.

§ International—Bonn Convention: Appendices I and II of the Convention on the Conservation of Migratory Species of Wild Animals.
I = Appendix I Endangered Migratory Species; II = Appendix II Migratory Species.

# International—CITES: Convention on International Trade in Endangered Species of Wild Fauna and Flora.
I = Appendix I lists species threatened with extinction; II = Appendix II includes species not necessarily now threatened with extinction, but that may become so unless trade involving them is closely controlled.

** The Pacific ridley turtle is also known as the olive ridley turtle.

Cetaceans

While the blue whale (*Balaenoptera musculus*) is listed as a potential inhabitant according to the public threatened-species database (DEWHA 2009a; see Table 3-8), Darwin Harbour is not blue whale habitat. Likewise, humpback whales (*Megaptera novaeangliae*) are known to migrate to northern Australian waters during June to August, but the species rarely ventures as far north and east as Northern Territory waters.

The most commonly recorded cetacean species in Darwin Harbour are three coastal dolphins—the Australian snubfin (*Orcaella heinsohni*), the Indo-Pacific humpback (*Sousa chinensis*) and the Indo-Pacific bottlenose (*Tursiops aduncus*) (Palmer 2008). An oceanic dolphin, the false killer whale (*Pseudorca crassidens*), has also been recorded in Darwin Harbour (Palmer et al. 2009; Whiting 2003). The current conservation status of each of these species is shown in Table 3-9.

The snubfin dolphin (Figure 3-22) is a recently described species, having previously been considered to be a population of the Irrawaddy dolphin (*O. brevirostris*). Recent morphological and genetic studies on specimens of the genus *Orcaella* have shown that populations in north-eastern Australia are distinct at species level from the South-East Asian populations; this means that the snubfin dolphin is endemic to Australia and is Australia's only endemic cetacean (Beasley, Robertson & Arnold 2005).

The taxonomic revision was based on a range of features and included genetic sampling from South-East Asian and northern Queensland populations, as well as one sample from the Northern Territory. At present, it is believed that the distribution of the snubfin dolphin extends from Broome in Western Australia to Brisbane in Queensland (DEWHA 2009d). Preliminary genetic studies on mitochondrial DNA in snubfin dolphins from Western Australia, the Northern Territory and Queensland indicate that the overall population is genetically similar and does not contain subspecies. Further and more detailed genetic studies are under way to better characterise the extent of gene flow between local dolphin populations (Palmer 2010).

Photograph courtesy of Dr Guido J. Parra, Flinders University.

Figure 3-22: Australian snubfin dolphin (*Orcaella heinsohni*)

Aerial surveys conducted by Freeland and Bayliss in 1984–85 (prior to the taxonomic separation of the Irrawaddy dolphin and the Australian snubfin dolphin) identified large numbers of "Irrawaddy" dolphins in the waters of the Gulf of Carpentaria in the eastern Northern Territory. These dolphins were particularly associated with major shrimp breeding grounds at Blue Mud Bay and inhabited waters between 2.5 m and 18 m deep. By comparison, few "Irrawaddy" dolphins were recorded in the waters of the north-west coast of the Northern Territory (which included Darwin Harbour, the Tiwi Islands and the Cobourg Peninsula). Numbers recorded in that survey were too low to form an estimate of the total population in the area (Freeland & Bayliss 1989). There is currently no overall population estimate available for snubfin dolphins in Australia.

More recently, the Northern Territory Government has commenced a coastal dolphin research project in Darwin Harbour and in the broader Anson–Beagle Bioregion. Preliminary observations since 2008 have identified relatively high numbers of snubfin dolphins at

Table 3-9: Conservation status of dolphins found in Darwin Harbour

Species	Conservation status			
	EPBC Act 1999 (Cwlth)	IUCN Red List*	Bonn Convention†	TPWC Act (NT)
Australian snubfin dolphin *Orcaella heinsohni*	Cetacean‡; Migratory	Near threatened	Migratory	Least concern
Indo-Pacific humpback dolphin *Sousa chinensis*	Cetacean‡; Migratory	Near threatened	Migratory	Least concern
Indo-Pacific bottlenose dolphin *Tursiops aduncus*	Cetacean‡; Migratory	Data deficient	Migratory	Least concern
False killer whale *Pseudorca crassidens*	Cetacean‡	Data deficient	Not listed	Least concern

* IUCN 2009b.

† Bonn Convention 2009a.

‡ All cetaceans are protected in Australian waters under the EPBC Act.

Cobourg Peninsula and in the South and East Alligator rivers (Kakadu National Park). While snubfin dolphins have also been observed in Darwin Harbour and Shoal Bay, the numbers there have been noticeably lower than in these other parts of the Northern Territory coast. The Darwin Harbour and Shoal Bay study has so far surveyed 2347 km of systematic transects and recorded 33 snubfin dolphins in 10 schools (0.01 dolphin per kilometre). Snubfin dolphins have been recorded on the east and west sides of Darwin Harbour, near Lee Point and in Shoal Bay. Population estimates for snubfin dolphins in the Darwin Harbour – Shoal Bay area have not yet been developed, but research is continuing (Palmer 2010).

Indo-Pacific humpback dolphins are widespread and relatively common throughout Australian tropical waters from Shark Bay (Western Australia) north through the Northern Territory, Queensland and northern New South Wales (Mustoe 2008). The species is also believed to extend through the Indo-Pacific region as far as Borneo, the Indian subcontinent, the Gulf of Thailand, the South China Sea and the coast of China to the Changjiang River (Ross 2006). Relatively little is known regarding the ecology and population status of this species throughout most of its range. The exception to this is off the coast of South Africa and in Hong Kong waters, where Indo-Pacific humpback dolphins have been relatively well studied (Parra, Schick & Corkeron 2006).

However, recent genetic studies on Indo-Pacific humpback dolphins indicate that, as with the Australian snubfin dolphin, the Australian Indo-Pacific humpback populations may also be a separate species found only in Australian waters. At this stage, very few DNA samples have been taken in the Northern Territory or north-west Western Australia (Palmer 2008).

Preliminary observations from the Northern Territory coastal dolphin studies indicate that relatively high numbers of Indo-Pacific humpback dolphins occur in Darwin Harbour, as well as at Cobourg Peninsula and the Alligator rivers. The Darwin Harbour surveys have so far recorded 284 humpback dolphins in 88 schools (0.12 dolphin per kilometre) (though a proportion of these will be individuals that are being re-recorded) throughout the areas surveyed in Darwin Harbour and Shoal Bay. Population estimates have not yet been developed (Palmer 2010).

Observations from the Northern Territory coastal dolphins research project indicate that shallow, intertidal areas in Darwin Harbour and Shoal Bay are regularly utilised by Australian snubfin and Indo-Pacific humpback dolphins (Palmer 2010). This correlates with knowledge of these species from elsewhere around northern Australia, where habitat preferences for both species are described as coastal and estuarine waters less than 20 m deep, close to river mouths and creeks, with foraging undertaken in mangrove communities, seagrass beds and sandy-bottom environments through to open coastal waters with rock and/or coral reefs (DEWHA 2010). Darwin Harbour contains only limited areas of seagrass, but river-mouth, mangrove, sandy-bottom, rocky reef and coral habitats do occur throughout the Harbour and Shoal Bay.

Other studies on habitat preferences in Cleveland Bay near the Port of Townsville in northern Queensland indicated that dolphin species utilised areas close to river mouths and modified habitat such as dredged channels and breakwaters. Shallow areas with seagrass ranked high in the habitat preferences of snubfin dolphins, whereas humpback dolphins favoured dredged channels. Both species appeared to be opportunistic generalist feeders, eating a wide variety of fish both on the seabed and within the water column (Parra 2006).

Four snubfin dolphin calves have been recorded in Darwin Harbour during the Northern Territory coastal dolphin study—three near Mandorah and one near East Point—while 34 humpback dolphin calves have been recorded throughout the Darwin Harbour and Shoal Bay survey areas. There appears to be a wet-season peak in observations of calves of both species (Palmer 2010). Little is known of the reproductive biology or population structure of either species (Parra, Schick & Corkeron 2006; Ross 2006).

From the current understanding of the ecology of these two species, it is reasonable to conclude that potential habitat for snubfin and Indo-Pacific humpback dolphins occurs throughout Darwin Harbour, in both soft- and hard-substrate areas near mangroves and rocky reefs.

Research on the snubfin dolphin and the Indo-Pacific humpback dolphin in Cleveland Bay indicated that both species showed site fidelity, returning to the bay as part of a larger home range, with movement patterns following a regular model of annual emigration and re-immigration. Freshwater input from a river system was a feature of the area to which the dolphins regularly returned. Cleveland Bay was not found to be a permanent residence area for the species and the dolphins were expected to be utilising adjacent coastal areas (rather than offshore waters) when outside the bay. Home ranges and territories for the species appeared to be large, as many of the identified individuals spent less than 30 days within the 310-km^2 Cleveland Bay study area (Parra, Corkeron & Marsh 2006).

A similar study on site fidelity has not yet been undertaken for the snubfin and Indo-Pacific humpback dolphins of Darwin Harbour and Shoal Bay, although research is currently under way. Even so, any dolphins that regularly utilise Darwin Harbour and Shoal Bay may do so as part of a wider home range, wherever freshwater input from rivers occurs.

Van Parijs, Parra and Corkeron (2000) investigated the vocalisations of snubfin dolphins and found that they produce broadband clicks, at least three types of pulsed sounds and two low-frequency whistles. The clicks and pulsed sounds, predominantly used during foraging, were of very high frequency at >22 kHz. The whistles produced by the dolphins, however, were much lower in frequency, at 1–8 kHz, were simple in form compared with other delphinid species, and were used during both socialising and foraging.

The Indo-Pacific bottlenose dolphin occurs from South Africa to the Red Sea and eastwards to the Arabian Gulf, India, China and Japan, southwards to Indonesia and New Guinea, and to New Caledonia. The species occurs around the whole Australian coast and frequents a large number of bays and inshore waters in considerable numbers, including parts of the northern coast of Tasmania. It is a coastal species and generally occurs in waters less than 20 m deep. Studies on South African populations of Indo-Pacific bottlenose dolphins suggested that the species rarely migrates and that females stay close to their birthplace throughout their lives (Ross 2006). The ecology of the population in Northern Territory waters has not been researched in detail.

Pods of false killer whales are known to visit the Harbour but little research has been conducted into their utilisation of the area (Palmer 2010; Whiting 2003). Other cetaceans that have been recorded in the Harbour include the sperm whale (*Physeter macrocephalus*), the pygmy sperm whale (*Kogia simus*) and the humpback whale (*Megaptera novaeangliae*). Records of these species are rare, however, and represent sightings of individual vagrants.

Dugongs

Dugongs are known to occur in Darwin Harbour waters, although in relatively low numbers, probably because of the paucity of seagrass habitat (Whiting 2008). As described in Section 3.2.8, dugongs have been recorded in higher densities at Gunn Point and the Vernon Islands, approximately 30–50 km north-east of the mouth of the Harbour. Dugongs have also been observed in relatively high numbers at Bare Sand Island and Dundee Beach in Fog Bay, 60 km south-west of Darwin Harbour (Whiting 1997; S. Whiting, marine biologist, NRETAS, pers. comm. February 2010). The species is known to travel long distances (Whiting 2003, 2008).

In Darwin Harbour, dugongs were observed foraging on the rocky reef flats between Channel Island and the western end of Middle Arm Peninsula in a three-year study conducted by Charles Darwin University and Biomarine International. As no seagrass occurs on the reef flat in this area, the dugongs were likely to have been feeding on macroalgae. Whiting (2008) suggests that this habit of foraging on the algae, sponge and coral communities of macrotidal reefs distinguishes dugongs in the Anson–Beagle Bioregion from conspecifics elsewhere. Dugongs had been observed foraging on algae on similar reefs in Fog Bay (Whiting 2002).

In general, it is considered that dugongs could occur anywhere in the Harbour that could support seagrasses or algae, which corresponds with hard-substrate areas in waters less than 10 m in depth and areas of rocky reef such as Weed Reef and Channel Island (Figure 3-23).

Waterbirds and seabirds

The protected waterbird and seabird species that may inhabit or frequent the nearshore and onshore development areas are described in Section 3.4.12 *Protected species*.

Turtles

As described in Section 3.2.8, six species of marine turtles are known to occur in Northern Territory waters (see Table 3-8). Of these, the green, hawksbill and flatback turtles utilise Darwin Harbour regularly, and the Pacific ridley and loggerhead turtles are suspected to be infrequent users (Whiting 2003). The leatherback turtle is considered to be an oceanic species and is unlikely to occur in Darwin Harbour (Whiting 2001).

The shoreline throughout Darwin Harbour, and particularly in Middle Arm and East Arm, consists largely of mangrove forests and mudflats and does not provide suitable nesting habitat for any species of turtle that may frequent the area (Dr M. Guinea, marine biologist, Charles Darwin University, pers. comm. September 2008). Turtles visiting the Harbour are more likely to be foraging for food.

Green turtles are predominantly herbivorous and feed on seagrasses and algae. Immature and adult green turtles have been observed in a variety of habitats throughout Darwin Harbour feeding on sparse seagrass, algae and mangrove seedlings and fruits (Metcalfe 2007; Whiting 2003). Published records include observations of relatively high numbers of green turtles foraging on the intertidal reef flats between Channel Island and Middle Arm Peninsula, particularly in the dry season when algae are more abundant (Whiting 2001). On the assumption that green turtles could utilise any area where seagrass,

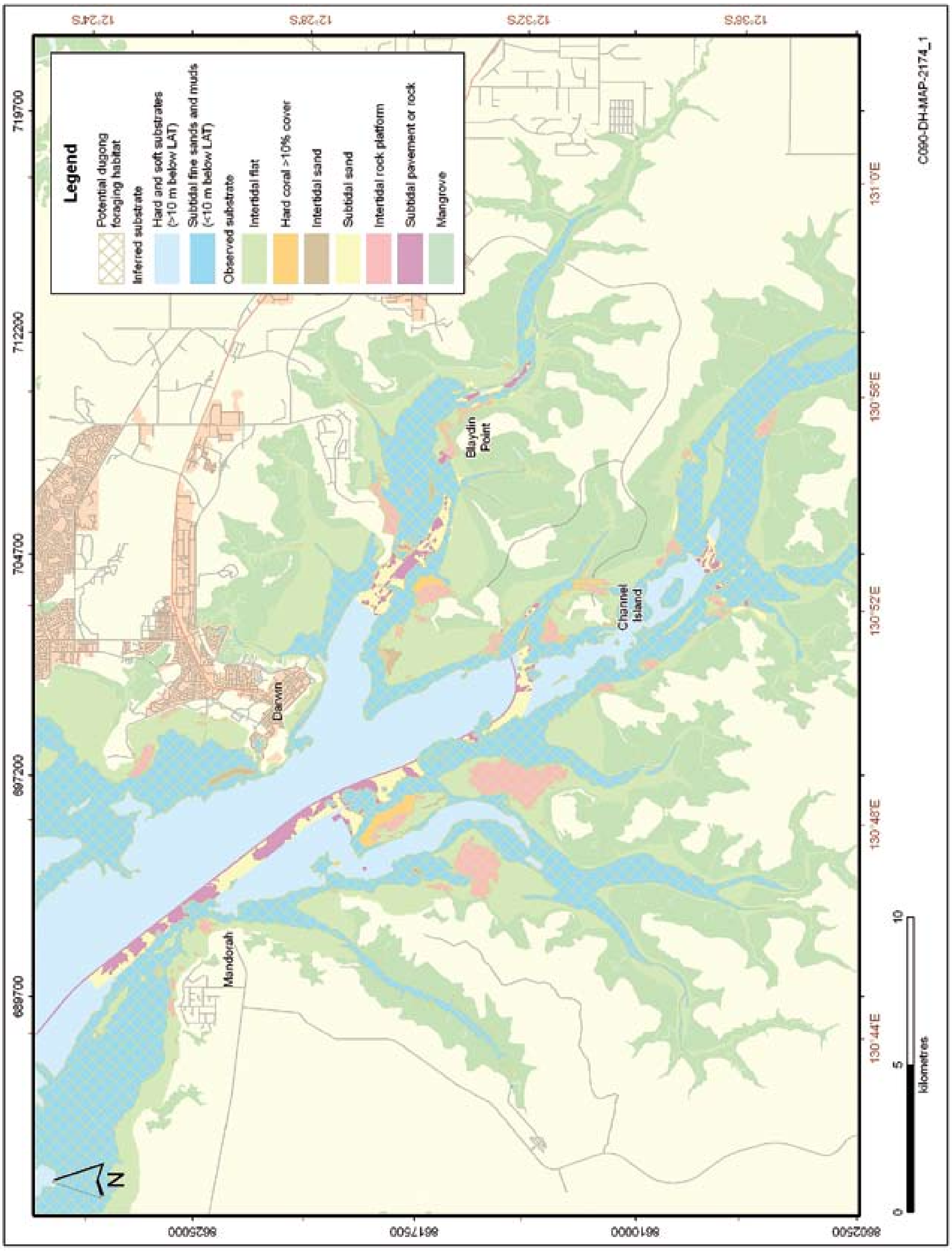


Figure 3-23: Potential dugong habitat in Darwin Harbour

fringing mangrove or macroalgae habitats are available, their potential habitat in Darwin Harbour is presented in Figure 3-24.

Hawksbill turtles are omnivores, feeding particularly on sponges but also on seagrasses, algae, soft corals and shellfish. In Darwin Harbour, immature and adult-sized hawksbill turtles have been reported using rocky reef habitat at Channel Island, but they may also utilise other habitats (Whiting 2001). Hawksbill turtles occur in Darwin Harbour at lower abundances than green turtles, with around four times as many green turtles recorded at the Channel Island foraging area as hawksbill turtles (Whiting 2001). As their preferred foods occur on hard substrates throughout intertidal and subtidal areas of the Harbour, hawksbill turtles could utilise any of the areas indicated in Figure 3-25.

The flatback turtle is carnivorous, feeding mostly on soft-bodied prey such as sea cucumbers, soft corals and jellyfish, which are found mainly in subtidal, soft-bottomed habitats. While flatback turtles are the most commonly encountered nesting species in the Anson–Beagle Bioregion (Chatto & Baker 2008), only limited, low-density nesting has been observed in Darwin Harbour—at Cox Peninsula near Mandorah and at Casuarina Beach. Potential habitat for any flatback turtles foraging in Darwin Harbour is shown in Figure 3-26.

Seasnakes

Although they are only infrequently seen, a diverse range of marine and mangrove-dwelling snakes occur in Darwin Harbour (URS 2002).

The diet of most seasnakes in the Harbour consists of fish, fish eggs and crustaceans that they capture either in the Harbour waters or on the exposed mudbanks. The bockadam (*Cerberus rynchops*) and the white-bellied mangrove snake (*Fordonia leucobalia*) are more commonly encountered than Richardson's mangrove snake (*Myron richardsonii*). The little filesnake (*Acrochordus granulatus*) is the only marine representative of the non-venomous acrochordids that specialise in capturing fish (Whiting 2003). The black-ringed seasnake is the most commonly encountered as it feeds on the mudflats during daylight hours (Guinea, McGrath & Love 1993). Other species such as the yellow-bellied seasnake (*Pelamis platurus*) are rarely encountered because of their pelagic habits, but enter the waters adjacent to Darwin Harbour (Guinea 1992).

The Port Darwin seasnake (*Hydrelaps darwiniensis*) comes ashore on the mudflats during daylight hours to feed on gobies that have retreated to their burrows during low tide (Guinea, McGrath & Love 1993).

Saltwater crocodile

While it is not a threatened species under Northern Territory or Commonwealth legislation, the saltwater crocodile (*Crocodylus porosus*) is listed in CITES under Appendix II. It therefore also appears as a listed marine species under the EPBC Act. This protection is applied to regulate commercial hunting, particularly for the trade in crocodile skins, which historically has resulted in population declines. Today's export-oriented crocodile industry is regulated and wild populations of the species are not considered threatened (PWSNT 2005).

The saltwater crocodile occurs in Darwin Harbour. In the interests of public safety, its abundance here is controlled by a trapping and removal program conducted by the PWSNT. Nesting sites for the saltwater crocodile are limited inside the Harbour, and the area is not considered critical habitat for crocodile survival in the Northern Territory (Whiting 2003).

Ray-finned fish

As is the case for the offshore development area (see Section 3.2.8), there are three seahorse species from the IUCN's Red List that could potentially occur in the Harbour (see Table 3-8); however, the distribution ranges of these are not well known. The flat-faced seahorse has only been recorded in Western Australian waters, the hedgehog seahorse is unrecorded in Australian waters, and the spotted seahorse is found across the Indo-Pacific region (Allen & Swainston 1988; Seahorse Australia 2008). None of these species are listed as threatened under Northern Territory legislation and very little is known of their presence or distribution in Darwin Harbour.

Sharks and other cartilaginous fish

The public threatened-species database (DEWHA 2009a) suggests that the freshwater sawfish, green sawfish and whale shark could occur in the waters of Darwin Harbour, although none have yet been formally recorded in the Harbour.

The freshwater sawfish is a medium-sized sawfish that prefers muddy bottoms of freshwater areas and upper reaches of estuaries. In the Northern Territory, it occurs in the upper reaches of rivers across the Top End from the Keep, Victoria and Daly rivers in the west to the McArthur and Robinson rivers in the east. The species has been reported to spend the first three to four years in fresh water, then to migrate into marine waters after the wet season, and then to return to the estuaries to breed during the following wet season (Larson, Stirrat & Woinarski 2006). It is not known to occur in Darwin Harbour.

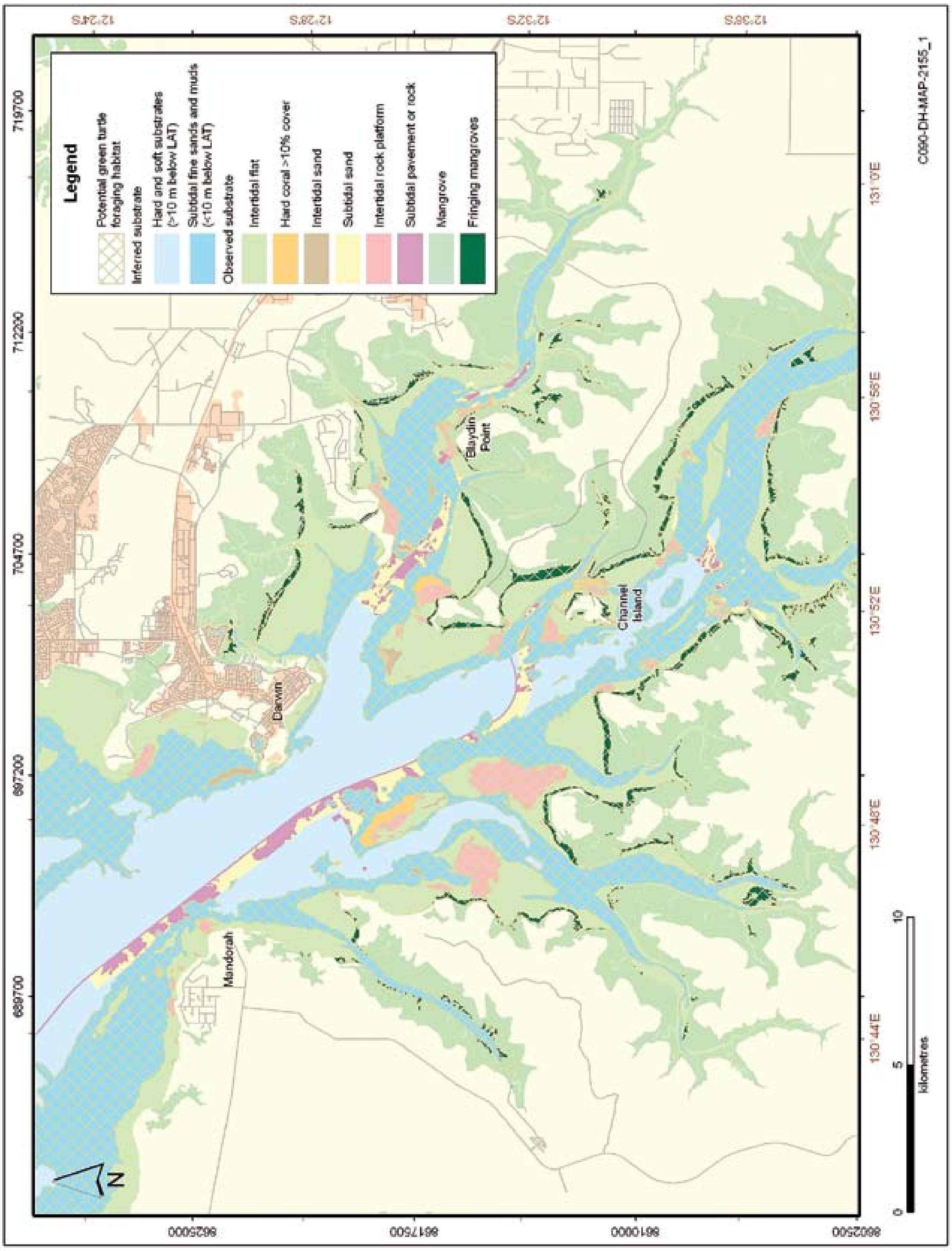


Figure 3-24: Potential green turtle foraging habitat in Darwin Harbour

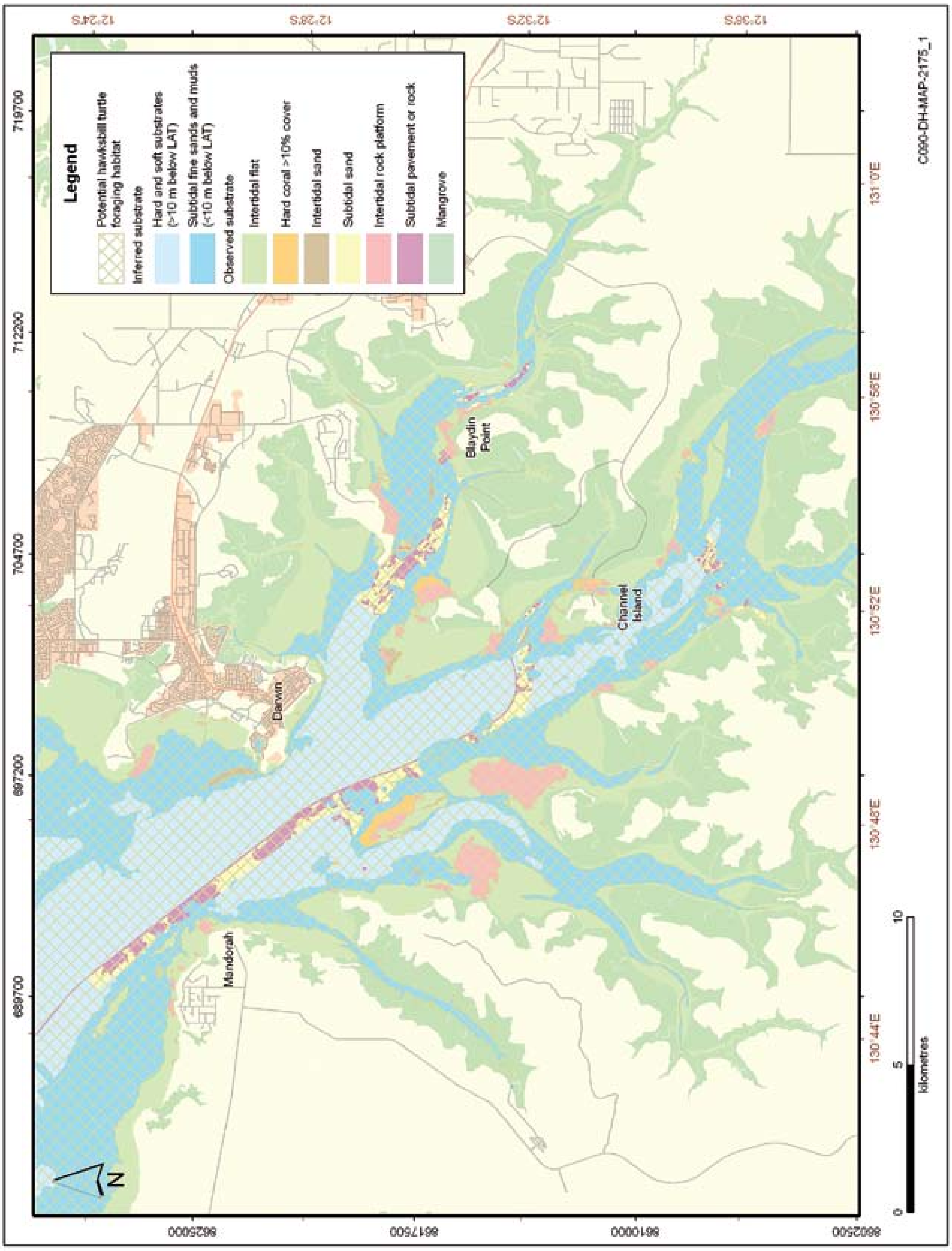


Figure 3-25: Potential hawksbill turtle foraging habitat in Darwin Harbour

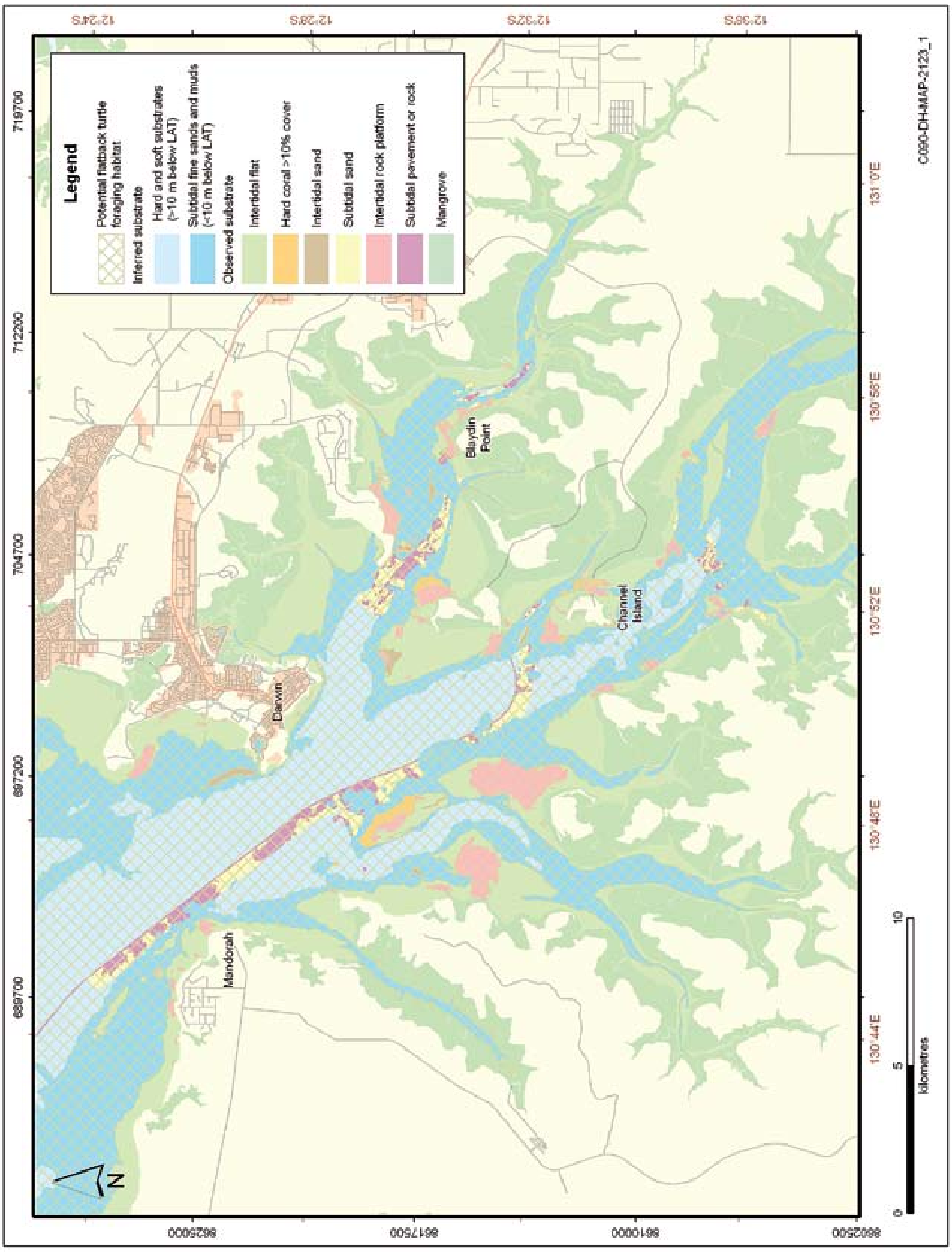


Figure 3-26: Potential flatback turtle foraging habitat in Darwin Harbour

The green sawfish lives on muddy or sandy-mud soft-bottom habitats in inshore areas. It also enters estuaries, where it has been recorded in very shallow water. The green sawfish is widely distributed in the northern Indian Ocean and around Indonesia and Australia. It is the most commonly encountered sawfish species in Australian waters (Last & Stevens 1994) and is more commonly found in Australian tropical waters. In the Northern Territory, specimens have been collected only in Buffalo Creek just outside Darwin Harbour (Stirrat, Larson & Woinarski 2006).

Whale sharks have a broad distribution in tropical and warm temperate seas. In Australian waters, they are known to aggregate at Ningaloo Reef (Western Australia) and in the Coral Sea. The whale shark is a highly migratory fish and only visits Australian waters seasonally, in response to localised seasonal "pulses" of food productivity (DEH 2005b). Its migration path is not known to include Darwin Harbour and only anecdotal records are known from around the Northern Territory coastline (Woinarski et al. 2007).

3.3.9 Marine pests

Marine pests are introduced marine species that have been translocated from their natural environment to an area where they can threaten biodiversity, fisheries and other commercial or recreational values. Native species are threatened by marine pests through competition for food and habitat, or through modification of local ecosystems. Maritime structures and vessels can also be damaged by marine pests that can clog cooling-water intakes and foul the hulls and seawater systems of boats, reducing speed and fuel efficiency (DoR 2009a). Broadly speaking, marine pest risks are highest in shallow water close to land.

The National Introduced Marine Pests Coordination Group has identified 55 marine species that are known to be invasive in Australia, are invasive elsewhere, or are considered to be potentially invasive. The list includes various starfish, bivalves and algae that can be found attached to vessel hulls, as well as dinoflagellates and diatoms that can be transported in vessel ballast water. National monitoring programs at ports throughout Australia target these species, although acknowledging that other species might also be detected and identified as marine pests. None of these 55 target species are known to occur in Darwin Harbour (Wells 2008) and the region is considered to be free of marine pests.

In 1999 a population of the highly invasive black-striped mussel (*Mytilopsis sallei*) was detected in marinas in Darwin Harbour. A multimillion-dollar eradication program was put in place and was successful in eradicating the mussels. This exercise is the only instance of the successful eradication of an alien marine species from Australian waters and the program attracted national publicity. Since then, the Department of Resources (DoR)[6] has applied a rigorous biofouling inspection and control regime to all vessels intending to enter Darwin's marinas.

3.4 Terrestrial environment

As described in Section 3.1.1, the onshore development area includes the terrestrial environment above the low-water mark at Blaydin Point and parts of Middle Arm Peninsula (see Figure 3-3). An access road and pipeline corridor also extend the onshore development area across Middle Arm Peninsula to the pipeline shore crossing at the water's edge south of Wickham Point. An aerial view of Blaydin Point is provided in Figure 3-27.

3.4.1 Bioregional setting

Terrestrial bioregions represent broad landscape patterns resulting from a range of factors, including geology, climate and biota. The Project's onshore development area is located in the Darwin Coastal Bioregion, which is defined by the Australian Natural Resources Atlas (ANRA) as the coastal area from near the mouth of the Victoria River to just west of the Cobourg Peninsula (see Figure 3-28). This bioregion incorporates the floodplains associated with the lower reaches of many large river systems, including the Moyle, Daly, Mary, Finniss, Adelaide, South Alligator and East Alligator rivers (DEWHA 2009e).

The Australian Natural Resources Atlas considers the bioregion to be in reasonably good condition, although degradation has occurred in some areas because of clearing for urban development and horticulture, weed infestations, saltwater intrusion into the floodplains

6 The Northern Territory's Department of Regional Development, Primary Industry, Fisheries and Resources (DRDPIFR) became the Department of Resources (DoR) in December 2009.

Figure 3-27: Blaydin Point, looking north-west towards Darwin

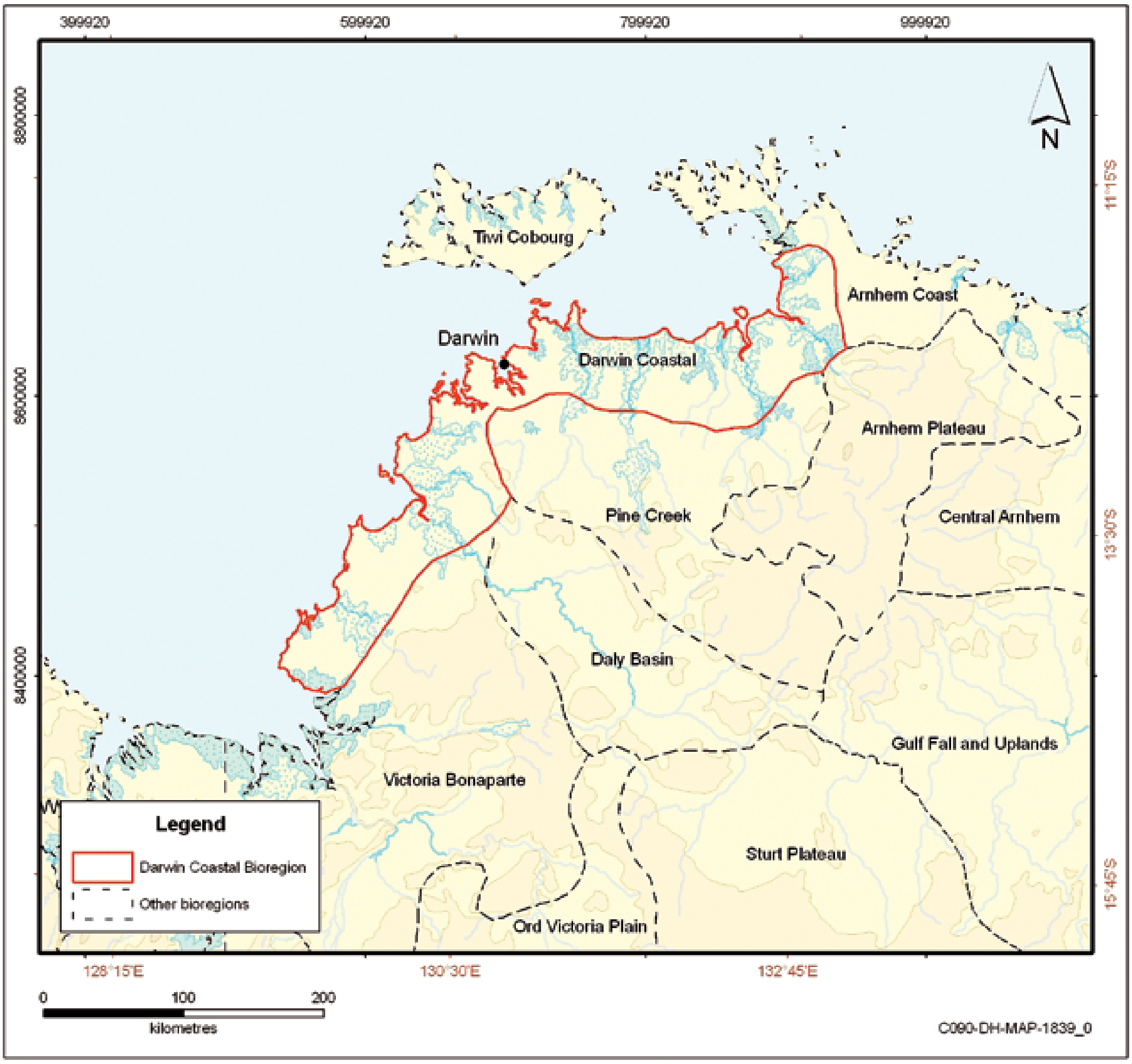


Figure 3-28: The Darwin Coastal Bioregion

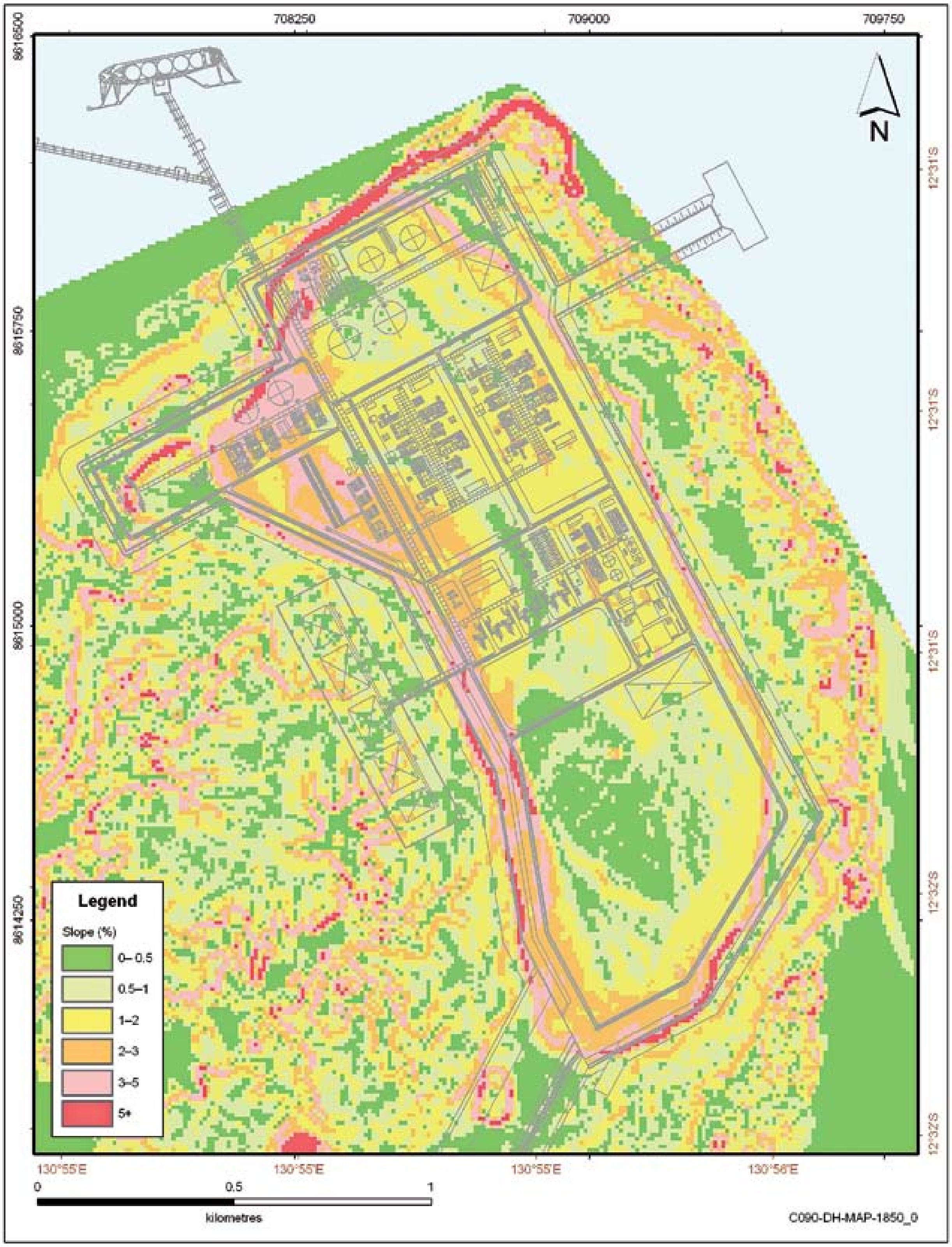
of several major river systems, changed fire regimes and feral animals. Almost 30% of the bioregion is contained in reserves, particularly to the north-east of Darwin (DEWHA 2009e).

3.4.2 Topography and geomorphology

The development of land surfaces in the north of the Northern Territory has traditionally been attributed to successive episodes of uplift, erosion and weathering (Hays 1967). The lower and younger two of the four land surfaces attributed to such development, the Wave Hill and Koolpinyah surfaces, dominate the landscape in the Darwin region (Hays 1967). However, investigations of the relationship between the Cretaceous stratigraphy and the nature of deep weathering in the Darwin region show that these surfaces are structurally controlled and detrital laterite profiles are considered to have formed in situ and are not markers for regional peneplain surfaces (Nott 1994).

Coastal morphology near Darwin is controlled mainly by the gentle warping of a lateritic profile. The lateritic cuirasse (duricrust) forms extensive shore platforms in synclines, but on the anticlines the pallid zone of the weathering profile is eroded by waves, causing the undercut cuirasse to collapse. The dominant modern process on the shore platforms is solutional attack on the laterite, resulting in large depressions (Nott 1994). Many of the platforms are covered by relict layers of cemented laterite cobbles transported by waves of high energy. Carbon-14 dating on carbonate cement between the cobbles shows that one sheet was deposited at about 3700 BP (before present) and the other sheet at about 1700 BP. Waves generated during devastating tropical cyclones last century had little effect on the cobble sheets, and they were probably transported onshore by tsunamis originating in the Indonesian archipelago prior to last century.

Blaydin Point is a low-lying peninsula oriented north–south, which juts out into East Arm. At its highest, the peninsula rises to approximately +10 m Australian Height Datum (AHD). Blaydin Point is separated from the mainland by a mudflat, across which a low causeway has been constructed by INPEX to provide access to Blaydin Point during spring-tide periods. This mudflat is subaerially exposed, except during spring tides. The topography of the onshore development area, presented as "percentage slope", is shown in Figure 3-29.



Source: URS 2009d.

Figure 3-29: Slopes of the land surface at Blaydin Point

Previous changes to the natural landform in the onshore development area include borrow pits on Middle Arm Peninsula. These cover around 25 ha, with maximum depths of about 5 m.

3.4.3 Regional geology

The Darwin region forms part of the Australian Precambrian Shield, which has been comparatively stable since middle Proterozoic times (Stuart-Smith et al. 1980). Metasediments of the Pine Creek geosyncline that overlie the Archaean basement were successively folded and uplifted during the early to middle Proterozoic. Flat-bedded Mesozoic and Cenozoic strata were deposited following erosion of the Proterozoic rocks.

Proterozoic strata in the Darwin region vary according to metamorphic grade. Near Cox Peninsula to the west the unconformable Cretaceous strata overlie upper greenschist to amphibolite facies, quartzofeldspathic and mica schists, gneiss and minor quartzite. To the east, near Gunn Point, lower greenschist facies metasediments occur. The Proterozoic strata underwent one major deformation approximately 1800 million years ago, resulting in tight folds with limbs dipping steeply at more than 50° (Pietsch 1986).

Regional geological mapping for Blaydin Point and its surrounds has been provided by the Northern Territory Geological Survey as part of the Bynoe map sheet compilation (Pietsch 1986) (see Figure 3-31). This information was compiled using aerial photography, traversing, outcrop mapping, stratigraphic drilling, and airborne magnetic and radiometric surveys. In addition, preliminary geotechnical investigations for the onshore development area were undertaken by Arup Pty Ltd in 2008. These involved drilling deep boreholes, excavating test pits and conducting cone penetrometer tests at key locations across Blaydin Point and the onshore pipeline route. The results of these site investigations were generally consistent with the broad-scale geological mapping provided by the government geological survey (Arup Pty Ltd 2008).

The onshore development area is underlain by Early Proterozoic and highly folded rocks of the Finnis River Group's Burrell Creek Formation (see Pfb in Figure 3-31). Some younger Lower Cretaceous rocks of the Darwin Formation (Kld) are exposed at the shoreline of Blaydin Point (Figure 3-30). The Burrell Creek Formation and the Darwin Formation are separated by a major unconformity, or buried erosion

Figure 3-30: Gravel base of the Cretaceous Darwin Formation overlying Proterozoic rocks at Blaydin Point

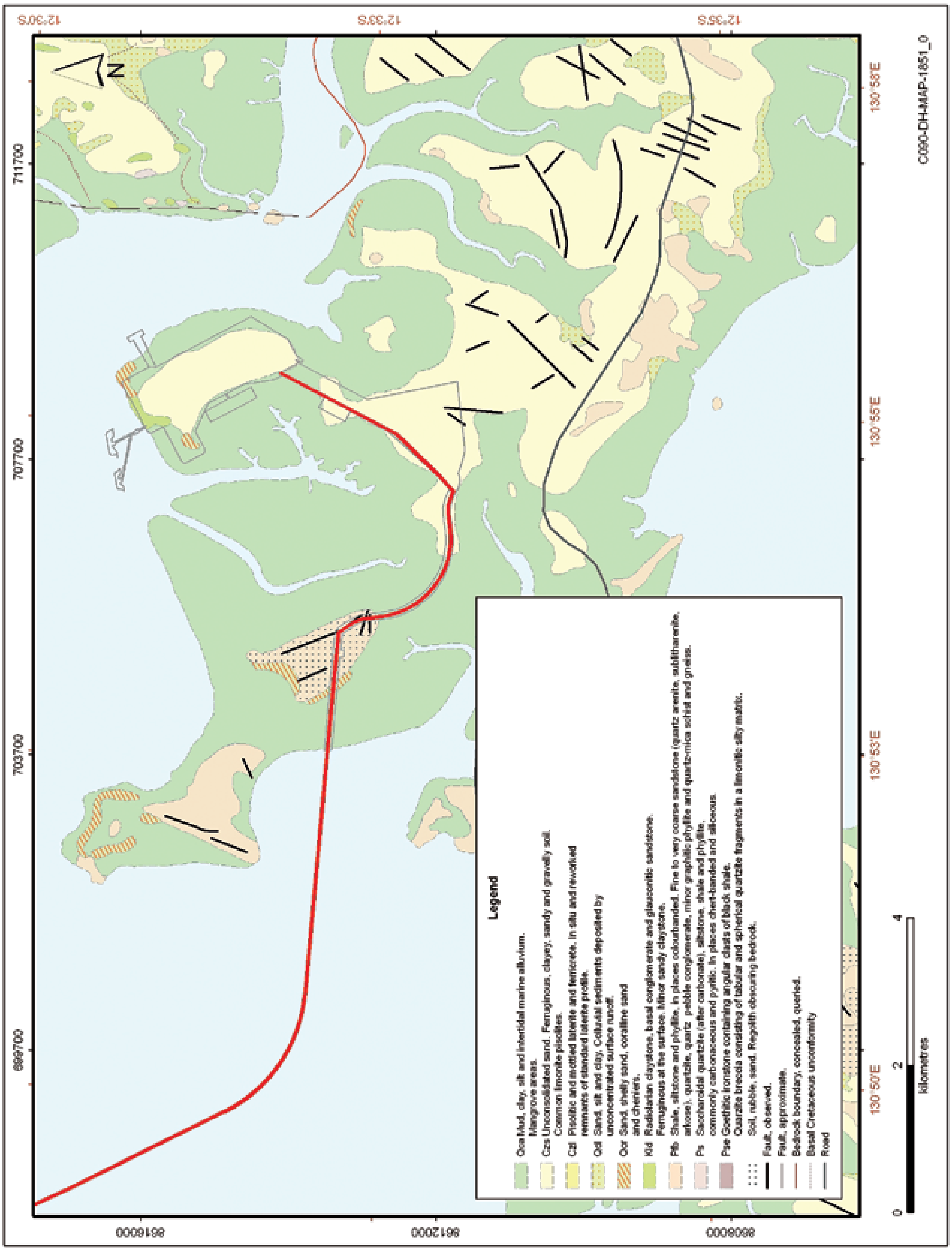
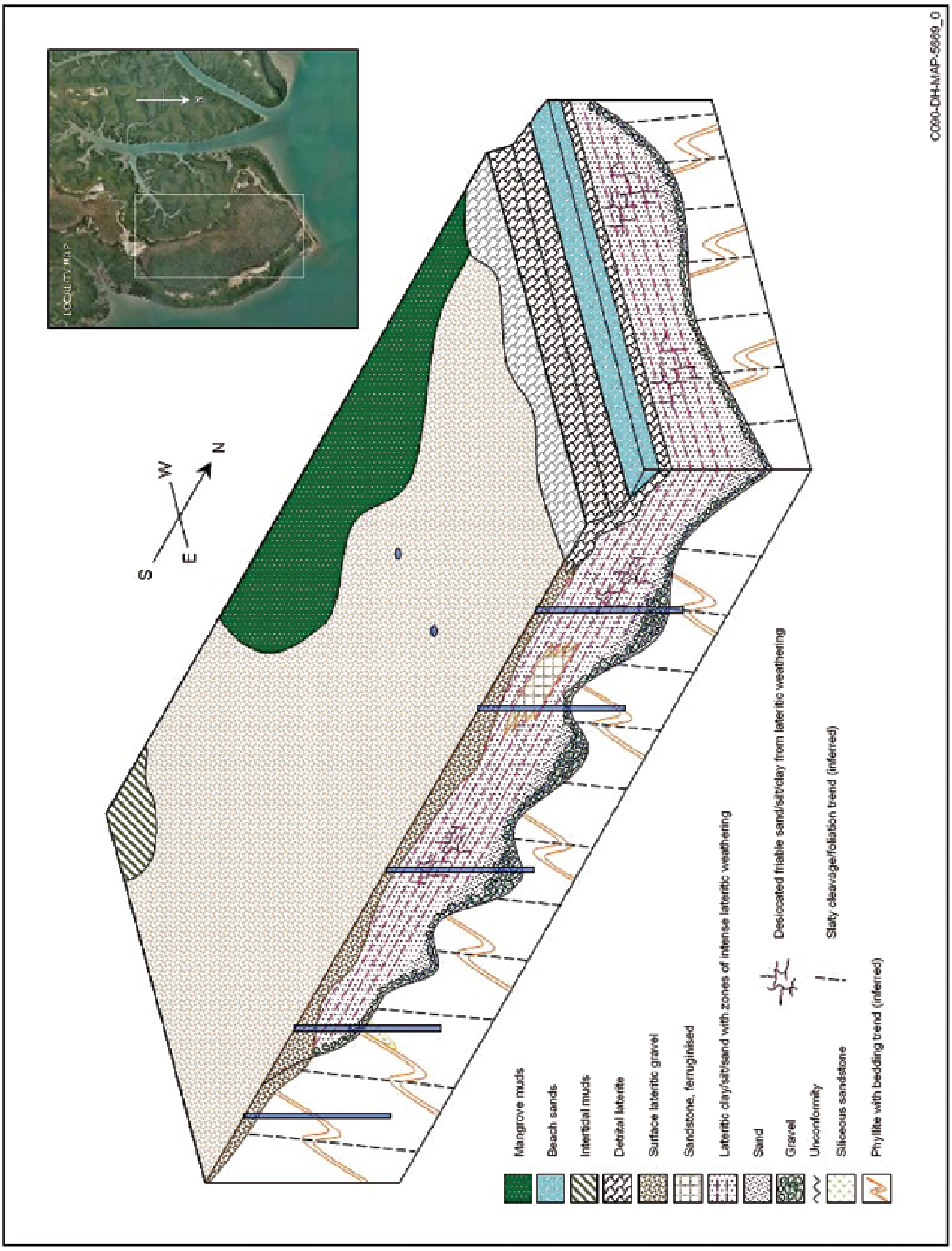


Figure 3-31: Geology of Blaydin Point and its surrounds



Source: Arup 2008.

Figure 3-32: Geological model of Blaydin Point, based on geotechnical investigations

surface, indicating that sediment deposition was not continuous (Arup Pty Ltd 2008).

Recent Quaternary marine alluvium (Qca) overlaps these older rocks. These materials have been subject to weathering and lateritisation for an extended period, possibly since late Cretaceous times (Arup 2008).

At Blaydin Point, the Burrell Creek Formation is dominated by finer-grained lutitic rocks, predominantly claystone and siltstone, which are understood to be steeply dipping and tightly folded. The ground investigation indicated that the Burrell Creek Formation has undergone low-grade regional metamorphism (prehnite–pumpellyite to lower greenschist facies) during the Top End Orogeny, and this metamorphism has altered the parent rocks to phyllites. Slates and possibly mica schist and gneiss are also believed to be present in the Burrell Creek Formation although these were not encountered during the ground investigation (Arup 2008).

Based on the site investigation, Arup (2008) developed a geological model representing the likely geological processes and conditions encountered at Blaydin Point. A three-dimensional graphical representation of the geological model for Blaydin Point is presented in Figure 3-32.

3.4.4 Soils

Soil morphology

Land unit surveys of the Blackmore and Elizabeth river catchments (Fogarty, Lynch & Wood 1984) have described soil morphology at 25 locations near the onshore development area in undulating (1–3% slope) to gently undulating (3–10%) terrain. Underlying rocks outcrop on crests and moderately deep to deep soils occur on deep weathered Cretaceous sediments in this undulating terrain. Estuarine mangrove, tidal flat and dune facies deposited during the Quaternary period fringe the Blaydin Point area.

The dominant soils covering over half the area on the undulating terrain were described as shallow (<0.25 m) to moderately deep (0.25–0.5 m), very gravelly massive earths. Soils in drainage lines and estuarine frontage are very poorly drained (hydrosols) and subject to regular or seasonal inundation and waterlogging. A very high risk of occurrence of ASSs was identified in these areas (Fogarty, Lynch & Wood 1984).

The Tertiary sediments and underlying rocks of the Lower Proterozoic metasedimentary formations (steeply dipping phyllites and schists) are weathered to a depth of approximately 40 m. The residual soils are typically lateritic with ferricrete layers often close to the surface or outcropping. Background levels of heavy metals tend to be elevated on similar land surfaces in this terrain.

Soil families in the onshore development area

In order to categorise the soils and landscape in the onshore development area, a soil-testing program was undertaken by URS in May 2008. The results of this survey are described below, while the full technical report (URS 2009d) is provided in Appendix 17 to this Draft EIS.

The Australian Soil Classification uses soil "orders" to describe soil types at a high level (Isbell 1996). The four soil orders present at the onshore development area are as follows:

- kandosols: massive soils with many fine pores, characterised by gradually increasing clay content and colour intensity with depth
- hydrosols: soils that are saturated for at least 2–3 months in most years and generally experience reducing conditions during the period of saturation
- organosols: deep soils that occur above the range of tidal inundation and where organic materials dominate in the surface 0.4 m
- podosol–tenosol complex: podosols have B horizons (subsurface soil layers) dominated by the accumulation of compounds of organic matter, aluminium and/or iron. These can occur in complex with tenosols, which are sand-dune soils with only weak pedological organisation apart from organic darkening in the A horizon (the surface soil layer).

Within these soil orders, a total of seven soil "families" was identified at Blaydin Point, defined by differences in soil colour, texture, depth and gravel content. These include three kandosols, one organosol, two hydrosols and one podosol–tenosol complex, as described below.

Kandosols

The Blaydin soil family occurs on flat crests and plateau surfaces in the onshore development area. This soil type is characterised by a well-structured A horizon that is very thick and melanic (high in organic matter, >5%) and is described as red, fine sandy clay loam. These soils are deep and support tall monsoon vine forest vegetation. The surface is easily disturbed and prone to dust generation and erosion once the vegetative cover is removed. The soil fertility level is high because of the enhanced organic carbon content.

The Hotham soil family occurs on crests and slopes in the onshore development area. The A horizon is brown in colour and described as massive, fine sandy loam with medium gravel (6–20 mm). These soils are deep and support tall, open eucalypt woodland vegetation.

The Koolpinyah soil family occurs on slopes in the onshore development area. These soils are described as moderately deep, gravelly, imperfectly drained, yellow sandy loam over sandy clay loam. The subsoils are sodic (exchangeable sodium greater than 5%), making these soils pulverulent (powdery or dusty) when subjected to traffic movement and prone to water erosion. These soils support eucalypt woodland vegetation.

Organosols

The Mullalgah soil family was observed on footslopes fringing estuary mangrove swamps in the onshore development area. These deep soils are formed on marine sediments with organic (peaty) A horizons, and acidic groundwater discharge leaves a layer of iron floc on the surface.

Hydrosols

The Euro soil family is found on intertidal flats that experience regular saline tidal inundation under mangrove vegetation. Organic materials from mangrove debris dominate the surface layers to depths of 0.5 m or more. These soils pose a high ASS risk because there can be bacterial reduction of sulfates under anaerobic conditions.

The Maand soil family is found on supratidal flats that are bare of vegetation except for halophytes. Tidal inundation in these areas is infrequent (spring tides) but a saline water table is present at shallow depths. These soils are shallow to moderately deep, non-gravelly, poorly drained marine muds.

Podosol–tenosol complexes

The Rinamatta soil family is found on sandy dunes at the coastal margins of the onshore development area. These soils are described as deep, non-gravelly, well-drained siliceous sands. At the foot of dunes adjacent to tidal swamps, podosols with subsoil organic-aluminium compound accumulation occur. Weakly developed B horizons higher in the dune sequence are typical of tenosols. These soils are prone to wind and wave erosion when surface cover is removed and are sensitive to disturbance by traffic.

The soil families represented in the onshore development area are presented in Figure 3-33, and generally follow similar boundaries to the vegetation communities of the area (described in Section 3.4.8 *Vegetation communities*). A summary of the key factors affecting soil fertility for each soil family is provided in Table 3-10.

Table 3-10: Environmental assessment of soil families

Soil family	PASS	ASS	Pulverulence	Water erosion	Wind erosion	Fertility
Blaydin	No	No	Moderate	Low	Low	High
Hotham	No	No	High	High	Moderate	Low
Koolpinyah	No	No	Very high	High	Moderate	Low
Mullalgah	Low	Moderate	Moderate	Low	Low	Low, waterlogged, saline
Euro	Very high	Low	Low	Low	Moderate	Low, waterlogged, saline
Maand	Low	Low	Low	Low	Low	Low, waterlogged, saline
Rinamatta	Low	Low	Low	Moderate	High	Low, saline

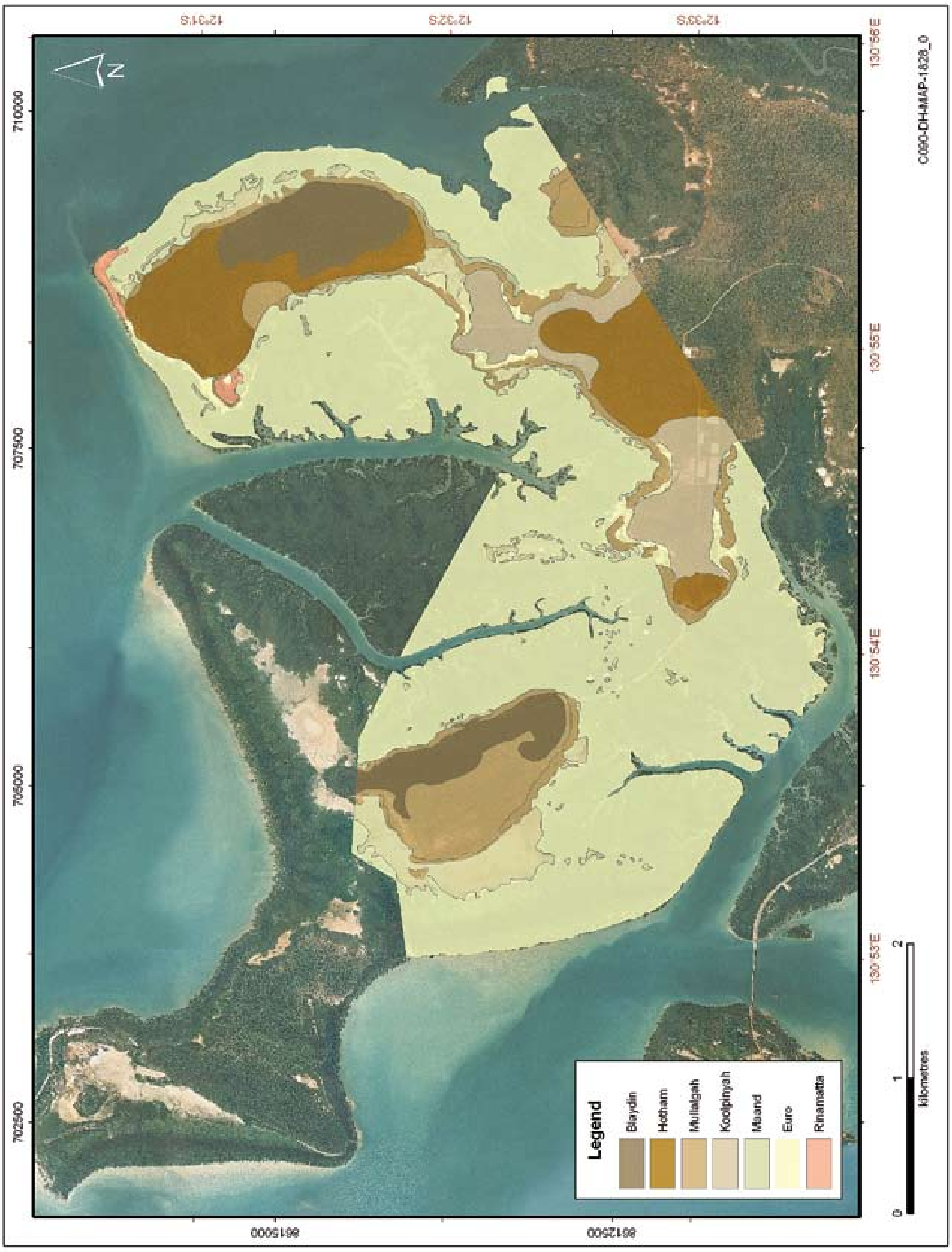


Figure 3-33: Soil families of the onshore development area

Soil chemistry

Previous soil sampling in the Northern Territory has suggested that arsenic in Cretaceous sediments can occur at relatively high levels in the surface 2 m, these levels being above the generic guidelines for contamination risk assessment (DoR 2009b). This situation occurs in deeply weathered lateritic terrain where silicate weathering reduces rock volume over geological time, leading to the residual concentration of heavy metals. However, metals are bound tightly to iron and aluminium sesquioxides in the natural environment and bioavailable fractions tend to be very low (Ng et al. 2003).

Soil-chemistry parameters in the onshore development area, including pH, salinity, extractable metals concentration, organic carbon content, nutrient content and potential ASS risk, were assessed by URS in May 2008 (see Appendix 17). Potential ASS risks were recorded for most of the mangrove and swamp soils throughout the onshore development area and all soils in or near the tidal zone were saline and strongly acid.

The ASS risk was generally an order of magnitude higher in the subsoil than in the surface layers that were commonly characterised by sandy sediment with low organic matter content. Subsurface levels are typically dark-coloured silty clays, with high organic matter accumulation, reducing conditions, and a "rotten egg" odour indicative of hydrogen sulfide (see Appendix 17).

Extractable metal concentrations in the soils throughout the onshore development area were lower than generic environmental criteria (NEPC 1999). High organic carbon and major nutrient levels were recorded in surface soils in the onshore area (above the intertidal zone), suggesting high soil fertility. Copper and zinc trace-metal levels were deficient in soils in the onshore area and all the soils were found to be sodic (see Appendix 17).

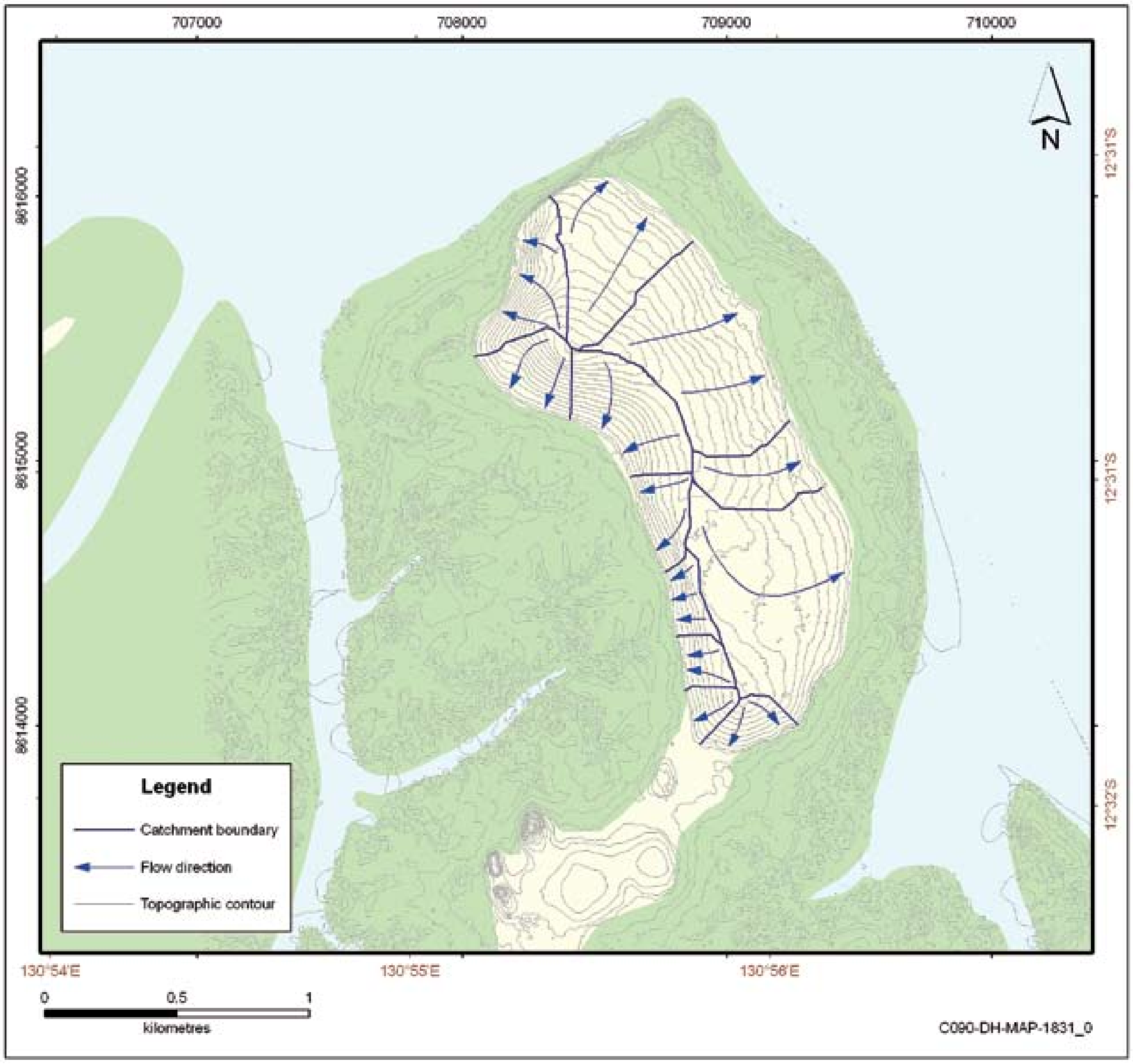


Figure 3-34: Topography and surface-water catchment boundaries of Blaydin Point

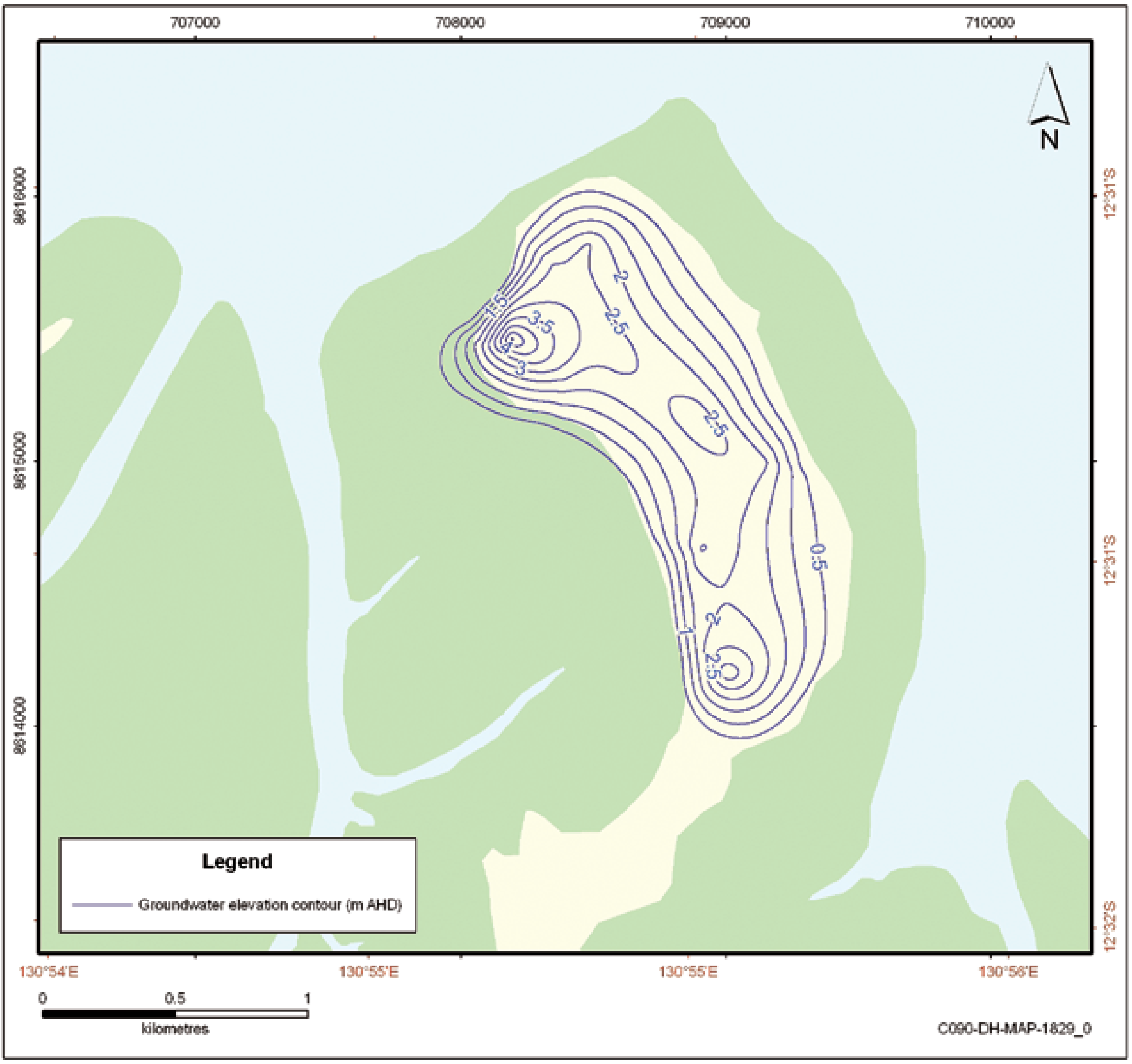


Figure 3-35: Groundwater elevation contours (metres AHD) at Blaydin Point

3.4.5 Seismicity

Distant earthquakes near Indonesia can affect Darwin, although there have been no recorded tsunamis impacting Darwin's shores despite its relative proximity to the convergent margin between the Australian and South-East Asian tectonic plates. Seismically, the northern part of Australia and the Darwin region are comparatively stable and large-magnitude earthquakes are rare. Most of the earthquakes felt in the Darwin region occur approximately 500–600 km to the north along the convergent plate margin near the Banda Sea to the north-east of Timor (Nott 2003).

The greatest earthquake intensity felt in Darwin during historical times was from the M_s 7.3 earthquake that occurred at a depth of 16 km, 530 km north of Darwin on 7 October 1960 (Vanden Broek 1980). Damage to concrete fixtures, toilet fixtures, and walls occurred as a result of this event. An earthquake with a similar intensity in the Darwin area can be expected at least once every 50 years. Buildings most at risk in the immediate Darwin city area are those that are built upon soft alluvial foundations where liquefaction and amplification of seismic waves could occur. The specific geology of an area, therefore, will determine the extent of damage during rare events of this magnitude.

3.4.6 Surface water

The existing surface-water regime at the onshore development area was characterised in field studies conducted by URS in July 2008 (URS 2009e). The results of these are summarised below. (The full URS technical report is provided in Appendix 18.)

The Blaydin Point peninsula is generally flat and varies only 10 m in topography over its area. The site can be divided into approximately 12 surface-water catchments as shown in Figure 3-34.

Throughout the onshore development area the surface soil layer rapidly absorbs water from rainfall when the soil profile is dry, such as at the end of the dry season and into the beginning of the wet season. After regular rainfall the surface layer becomes saturated and overland water flows occur. Because of the low undulating topography, surface flows are most likely to consist of non-turbulent sheet flow over the soil surface. Where water accumulates at the outer edges of Blaydin Point, surface-water flow is likely to become increasingly turbulent and occupy temporary drainage channels. These channels become the ephemeral sections of the tributary creeks that feed into Lightning Creek to the west and East Arm to the east.

The vegetation distribution across the onshore development area also provides insight into the surface-water and groundwater regimes. The central highland portion of the peninsula has mixed species of *Melaleuca* forming low to open woodland with dense sedges and grasslands. Generally, melaleucas can withstand waterlogging (Wong, Wong & Baker 1999) and their presence suggests that the water table is likely to rise close to the ground surface in this part of the onshore development area. Vegetation communities are described in more detail in Section 3.4.8.

3.4.7 Groundwater

The existing groundwater regime at Blaydin Point was characterised in field studies conducted by URS in July 2008. Ten groundwater monitoring bores were developed and cased with polyvinyl chloride (PVC) pipe to enable measurements of groundwater levels. At four sites a confining layer of clay or siltstone was encountered and an extra shallow bore installed to monitor any potential perched aquifers. Pump testing of each bore was undertaken to improve the understanding of hydraulic characteristics of the aquifers across Blaydin Point. The results of the study are summarised below, while the complete technical report is provided in Appendix 18.

Groundwater flows

The most prominent aquifer on Blaydin Point occurs in the sand and gravel horizons of the Bathurst Island Group. A gravel layer is present at the interface between the sediments and bedrock. Sediments overlying the gravel horizon are composed of sand, clay and silt. It is possible that semi-confined conditions may exist in this aquifer.

The underlying bedrock is variably weathered across Blaydin Point and represents the Burrell Creek Formation. It contains minor weathered or fractured rock aquifers. The bedrock elevation is generally below 0 m AHD and is deepest at –15 m AHD.

Groundwater levels across Blaydin Point generally follow the topography and are highest in the north-west area, at 5.06 m AHD, and lowest at the coastal edges (see Figure 3-35).

Seepage pathways beneath the onshore development area include the following:

- transmissive sand aquifers
- weathered bedrock
- fractures and faults in fresh bedrock.

As transmissive aquifers are located below sea level, water flows entering the water table at Blaydin Point could migrate both laterally and vertically, and propagate outward, potentially discharging to Darwin Harbour. The rate of this groundwater movement depends on the hydraulic conductivity and porosity of the media in the flow path and the hydraulic gradient. For the onshore development area, the groundwater velocity is estimated to be 0.08–1.2 m/d, or 29–438 m/a (see Appendix 18).

Groundwater quality

Groundwater under the central, elevated parts of the onshore development area is of low salinity and of a similar quality to rainwater and drinking water. Groundwater salinity increases to brackish or saline towards the edges of the Blaydin Point peninsula, especially under the mangrove vegetation. Groundwater salinity contours, measured as total dissolved solids (TDS) are presented in Figure 3-36.

The pH levels of groundwater in Blaydin Point are neutral to slightly acidic and vary between 4.7 and 6.3. Dissolved salts consist mainly of sodium chloride, although calcium carbonate is also present in high concentrations at some areas around the onshore development area.

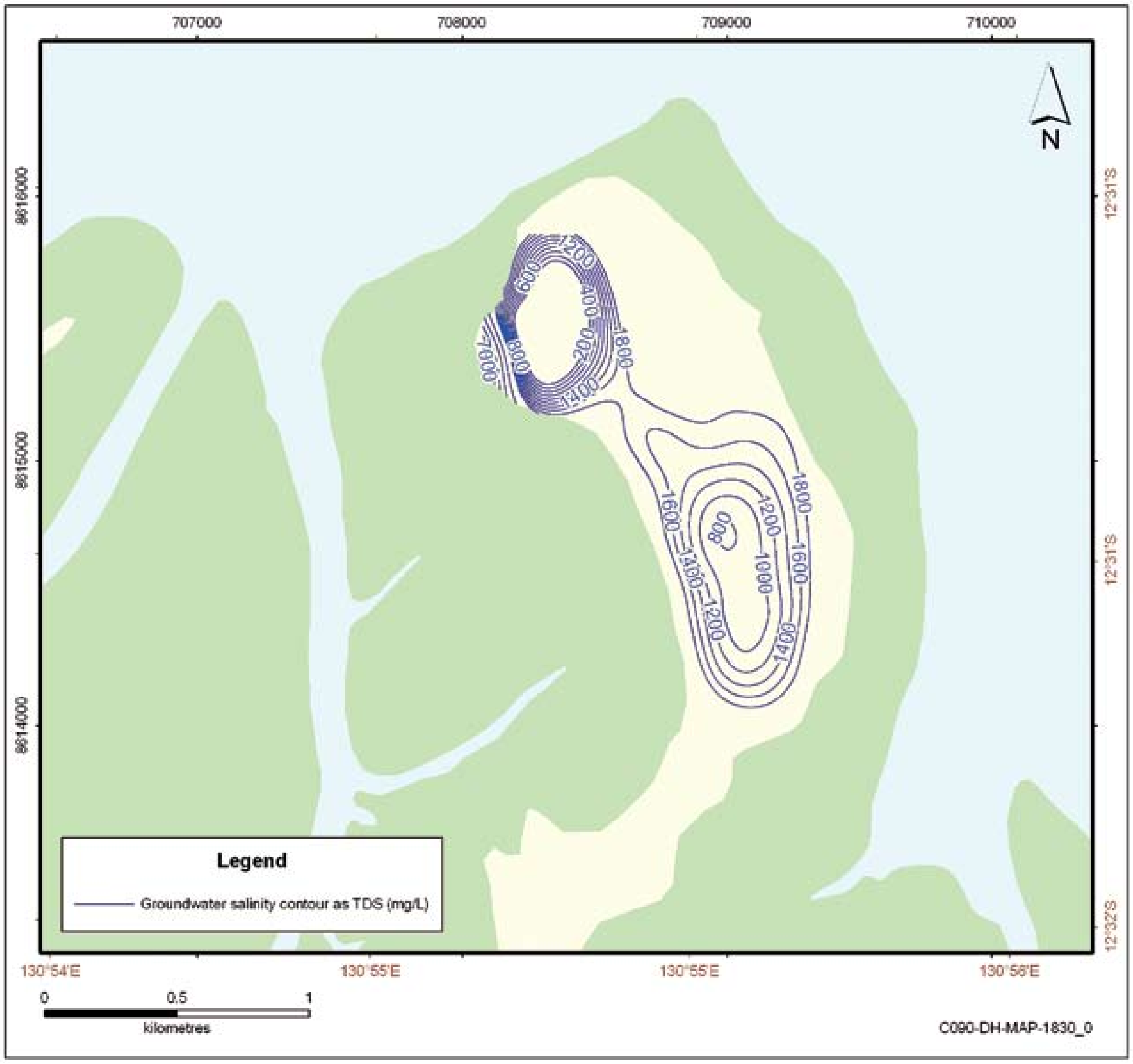


Figure 3-36: Groundwater salinity contours at Blaydin Point

Metals concentrations in groundwater throughout Blaydin Point were compared with the ANZECC and ARMCANZ (2000a) trigger-value guidelines for toxicity for fresh and marine water. Arsenic, chromium, lead, mercury and vanadium levels were all below the trigger values and in some cases were below the laboratory detection limit.

The groundwater presented copper and zinc levels higher than the ANZECC and ARMCANZ marine water trigger values in most of the bores tested. Cadmium, copper, manganese, nickel and zinc were higher than the ANZECC and ARMCANZ (2000a) freshwater trigger values at a number of bores across the onshore development area (see Appendix 18).

3.4.8 Vegetation communities

Darwin Coastal Bioregion

The Darwin Coastal Bioregion contains some of the most extensive and diverse floodplain systems in northern Australia, associated with the lower reaches of many large rivers. There are also substantial tracts of mangroves, patches of monsoon vine forest (also known as “dry rainforest”), and widespread areas of eucalypt tall open forest, typically dominated by Darwin woollybutt (*Eucalyptus miniata*) and Darwin stringybark (*E. tetrodonta*) (DEWHA 2009e). The various vegetation communities found in the bioregion, and their respective areas, are presented in Table 3-11.

Table 3-11: Area of present vegetation communities in the Darwin Coastal Bioregion (*c*.1997)

Vegetation community	Area (ha)	Proportion of total area (%)
Cleared or modified native vegetation	85 368	3.0
Monsoon vine forest	6 964	0.2
Eucalyptus open forest	1 157 372	41.3
Eucalyptus woodlands	4 300	0.2
Melaleuca forest and woodlands	254 548	9.1
Tropical eucalyptus woodland and grasslands	408 476	14.6
Other shrublands	72 064	2.6
Tussock grasslands	6 420	0.2
Other grasslands, herblands, sedgelands and rushlands	621 756	22.2
Chenopod shrub, samphire shrub and forb lands	121 976	4.4
Mangroves, tidal mudflat, samphire and bare areas, claypan, sand, rock, salt lakes, lagoons and lakes	61 620	2.2
TOTAL	2 800 864	100.0

Source: DEWHA 2009e.

The most widespread vegetation community in the region is eucalypt woodland, covering 41% of the land mass. “Woodland” is characterised by fairly sparse foliage cover (less than 30%) with an understorey of perennial and annual grasses (NRETAS 2007d). This vegetation type occurs on the upper slopes and is dominated by stringybark (*Eucalyptus tetrodonta*) and woollybutt (*E. miniata*). Common understorey species include the cycad *Cycas armstrongii*, the sand palm *Livistona humilis* and the pandanus *Pandanus spiralis*, with a perennial grass layer of *Sorghum* species. The annual wet season is characterised by a flush of growth in this understorey layer, while grasses senesce completely in the dry season and support frequent fires. Introduced grass species further enhance the intensity and frequency of this fire regime (DHAC 2003).

Lower in the landscape profile, patches of monsoon vine forest or dry rainforest occur in the bioregion. While this vegetation type represents only a small proportion of the total regional area, it contains a diverse flora and its various flowering and fruiting plant species provide food and habitat for a wide variety of animals. The monsoon vine forest is consequently considered to be of high conservation value (Blanch, Rea & Scott 2005).

Monsoon vine forest is associated with permanent water springs and supports a distinctive community of evergreen trees, with a closed canopy 20–25 m tall. Tree species typically include *Carpentaria acuminata*, *Acacia auriculiformis* and *Calophyllum soulattri* (GHD 2009). The mid-storey has reduced light levels and often comprises juvenile canopy trees and vines.

Many monsoon vine forest species are fire-sensitive, restricting the vegetation type to areas associated with permanent water or fire-protected rocky outcrops (Metcalfe 2002).

Other common lowland vegetation types in the Darwin Coastal Bioregion include paperbark (*Melaleuca* spp.) forest, grasslands and heathlands. The alluvial plains and swamps in the region are regularly inundated during the wet season and are dominated by various sedges and rushes, particularly of the genera *Eleocharis*, *Fimbristylis* and *Cyperus*, and the grasses *Pseudoraphis spinescens*, *Hymenachne acutigluma* and *Oryza meridionalis.* During the dry season these areas dry out and much of this dense vegetation dies or exists as underground tubers (DHAC 2003).

The intertidal mudflats of the greater Darwin Harbour area between Charles Point and Gunn Point carry extensive tracts of mangroves covering 27 350 ha, which constitutes 44% of the mangrove community in the bioregion, and about 5% of the total mangrove area of the Northern Territory. About 80% of this area (20 450 ha) occurs in the “inner” Harbour, between Sadgroves Creek (near Darwin’s CBD) and Mandorah. As of 2004, around 400 ha (2%) of these inner-Harbour mangroves had been cleared for residential, industrial and infrastructure developments, such as East Arm Wharf (WMB 2005).

This mangrove vegetation community is known for its species richness, containing 36 of the 50 mangrove species known worldwide. The most common mangrove species in Darwin Harbour are *Rhizophora stylosa*, *Ceriops tagal*, *Sonneratia alba*, *Bruguiera exaristata*, *Avicennia marina* and *Camptostemon schultzii.* The mangrove species occur in distinctive vegetation "assemblages", of which 11 have been identified in Darwin Harbour (Figure 3-37) (Brocklehurst & Edmeades 1996; WMB 2005).

The structure and composition of mangrove assemblages vary according to tidal conditions and geomorphology. As shown in Figure 3-37, in some areas the mangrove zone exists in a narrow band, while other areas support dense forests up to 20 m in height across a wide intertidal zone, with defined strips of different mangrove assemblages reflecting the length of tidal inundation and salinity (DHAC 2003).

Mangroves form a valuable part of the marine ecosystem by producing large amounts of organic matter and nutrients, utilised by animals such as crustaceans and fish. Many fish and prawn species, including species significant to recreational and commercial fisheries, utilise the mangroves as spawning grounds and nursery habitat (WMB 2005). Most of the mangrove tracts surrounding Darwin Harbour are zoned for "conservation" under the Northern Territory Planning Scheme (DPI 2008), recognising the biodiversity value of this vegetation community.

Onshore development area vegetation communities

Vegetation communities were identified in the onshore development area using publicly available vegetation mapping (Brock 1995; Brocklehurst & Edmeades 1996) and aerial photography. Verification of this preliminary mapping was undertaken through field surveys conducted by GHD in October 2007 and May 2008. A total of 17 quadrats, each 50 m × 50 m, were surveyed throughout the onshore development area to record plant species and vegetation community structure (e.g. landscape position, canopy cover, ground cover, and stand basal area).

The resulting vegetation distribution is presented in Figure 3-38 and the identified vegetation communities are broadly described in Table 3-12. Photographs of some of the major vegetation communities surveyed are shown in figures 3-33 to 3-35. The full technical report for the flora study (GHD 2009) is provided in Appendix 16 to this Draft EIS.

Significant ecological communities

No ecological community found at the onshore development area is a listed threatened ecological community under the EPBC Act.

However, both the monsoon vine forest and the intertidal mangrove communities are considered to have conservation significance in the context of the Darwin Harbour region and the Northern Territory. Both of these communities are utilised as feeding or breeding areas by a wide range of vertebrate and invertebrate animals.

3.4.9 Plants in the onshore development area

As described in Section 3.4.8, plant surveys were conducted in the onshore development area by GHD in October 2007 and May 2008, representing dry-season and wet-season vegetation conditions respectively (see Appendix 16). Seventeen quadrats of 50 m × 50 m were included in the survey, which recorded all plant species and their distribution within each quadrat.

Not all plant samples could be identified to species level in the field because of a lack of sufficient diagnostic material (e.g. flowers and seeds). Where possible, samples were analysed and identified by the Northern Territory Herbarium, but in some cases identification to species level was not possible.

The following numbers of species were recorded in the field survey:

- 196 species positively identified to species level
- 28 species positively identified to genus level (species unclear)
- 21 species positively identified to family level (genus and species unclear)
- 5 species where no positive identification was possible.

Of the species that were positively identified, 109 represent new records for Middle Arm Peninsula and its surrounds. This is a reflection of the relative lack of botanical studies undertaken in the area. A total of 177 species was recorded in wet-season surveys, including 23 from the family Poaceae, 11 from the family Myrtaceae and 9 from the family Fabaceae. Fewer species were recorded in the dry season survey (89 in total), with the Myrtaceae, Sterculiaceae and Euphorbiaceae being the most commonly recorded families (with 9, 6 and 5 species respectively) (see Appendix 16).

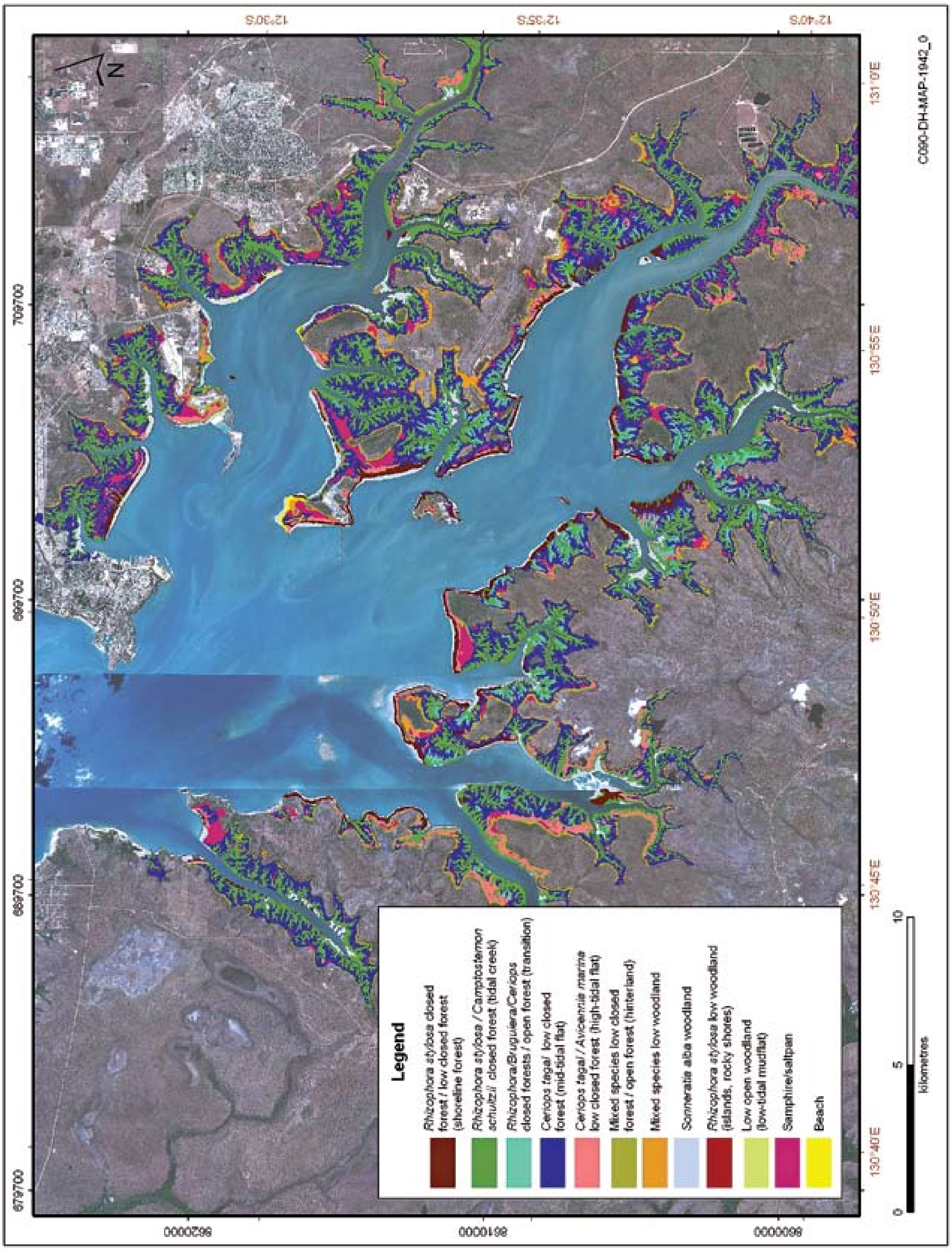


Figure 3-37: Mangrove distribution and zonation around Darwin Harbour

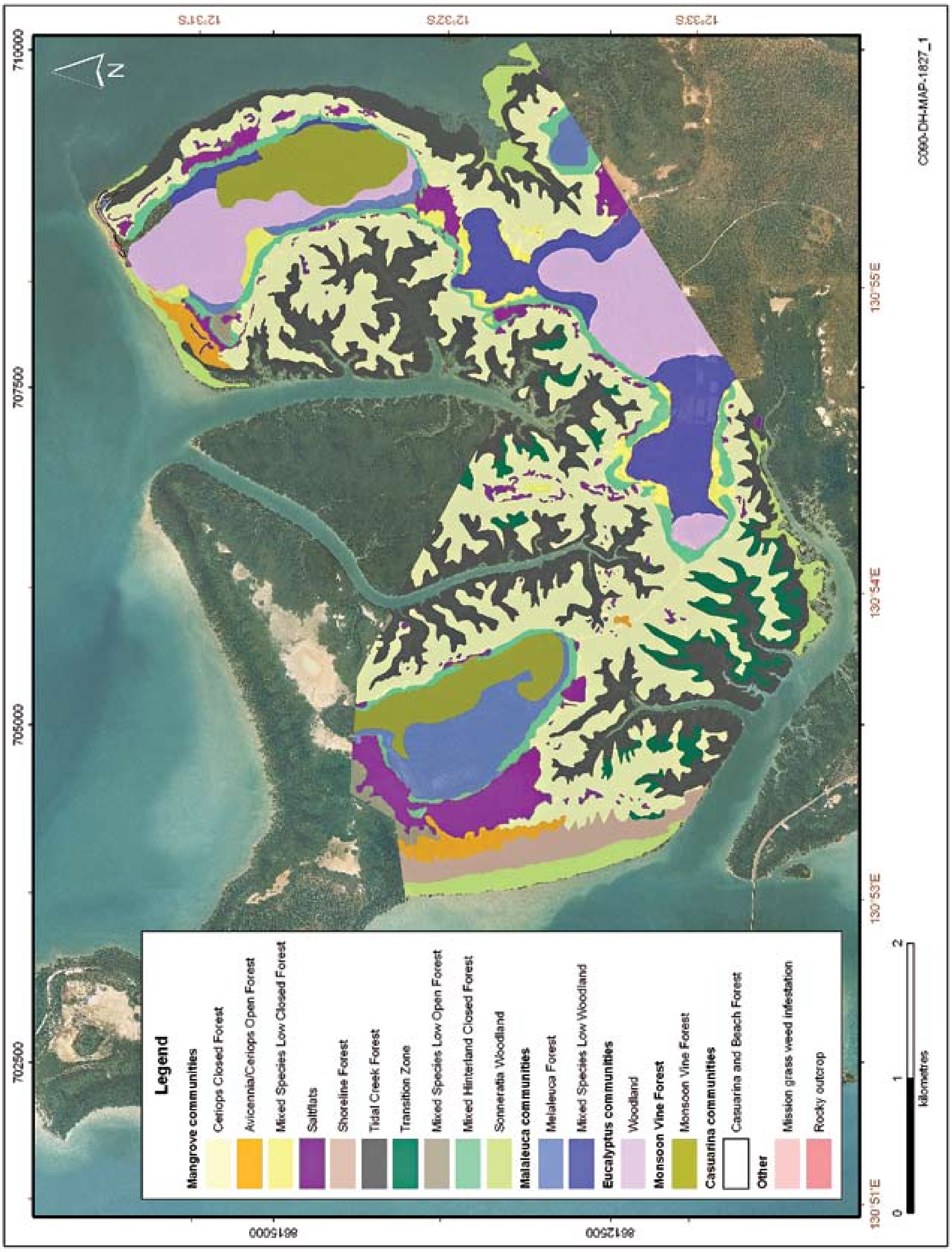


Figure 3-38: Vegetation communities of the onshore development area

Table 3-12: Descriptions of vegetation communities in the onshore development area

Vegetation community	Description
Mangrove communities	
Ceriops closed forest	*Ceriops australis* low closed forest.
Avicennia–Ceriops closed forest	*Avicennia marina – Ceriops australis* closed forest (see Figure 3-41).
Mixed species low open forest	*Melaleuca leucadendra – Acacia auriculiformis* open forest with a dense mid-storey characteristic of coastal monsoon vine forest such as *Canarium australianum* and *Strychnos lucida.*
Sparse samphire shrubland	Salt flats with sparse samphires such as *Tecticornia* (formerly *Halosarcia*) *halocnemoides* with low, very sparse mangrove species.
Rhizophora closed forest	*Rhizophora stylosa* closed forest.
Rhizophora–Sonneratia closed forest	*Sonneratia alba – Rhizophora stylosa – Camptostemon schultzii* closed forests in tidal creeks.
Transition zone	Preliminarily mapped as a transition zone between seaward mangrove elements (*Rhizophora–Sonneratia*) and mangroves in the higher end of the tidal level (*Ceriops australis*).
Corymbia bella – Melaleuca leucadendra transitional open forest	Transitional open forest between terrestrial vegetation communities and mangrove communities. Dominated by *C. bella* and *M. leucadendra* and contains elements of woodland and terrestrial forest communities.
Sonneratia closed forest	*Sonneratia alba* closed forest at the seaward margin of mangrove communities.
Melaleuca communities	
Mixed species low open woodland	*Melaleuca nervosa*, *M. viridiflora*, *Grevillea pteridifolia* and *Lophostemon lactifluus* mixed species low woodland to low open woodland. Dense to mid-dense sedgeland–grassland which includes *Leptocarpus spathaceus*, *Eriachne burkittii*, *E. triseta* and *Pseudopogonatherum* spp.
Melaleuca open woodland	*Melaleuca leucadendra*, *M. viridiflora* open woodland with *Acacia auriculiformis* and elements of monsoon vine forest such as *Flagellaria indica*.
Eucalyptus community	
Eucalyptus miniata – E. tetrodonta woodland	*Eucalyptus miniata – E. tetrodonta* woodland to low woodland, with a mixed-species mid-stratum including *Cycas armstrongii* and a grassland understorey (see Figure 3-39).
Monsoon vine forest	
Closed monsoon vine forest	Mixed species closed monsoon vine forest associated with permanent moisture. Closed canopy 20–25 m tall dominated by evergreen species, including *Acacia auriculiformis*, *Calophyllum soulattri*, *Carpentaria acuminata*, *Horsfieldia australiana* and *Syzygium nervosum* (see Figure 3-40).
Casuarina community	
Casuarina and beach open woodland	Beach vegetation on areas of sand including some mangrove species such as *Bruguiera exaristata* and *Ceriops australis*, also with *Ipomoea pes-caprae*, *Thespesia populneoides* and *Sesuvium portulacastrum*.

Figure 3-39: Eucalypt woodland at Blaydin Point

Figure 3-40: Monsoon vine forest at Blaydin Point

Figure 3-41: Mangroves and mudflat at the edges of Blaydin Point

Flora species of conservation significance

The cycad *Cycas armstrongii* is listed as vulnerable under the TPWC Act, and was recorded in the field survey of the onshore development area. This species is endemic to the Northern Territory and is locally abundant across the western Top End region, the Cobourg Peninsula and the Tiwi Islands. It is considered vulnerable in conservation terms as only a very small proportion of its distribution range occurs in conservation reserves (approximately 1%), and because its preferred habitat of deep loamy soils is also favoured by agriculture, horticulture and forestry and is therefore at risk of land clearing.

After land clearing, the most significant threat to *C. armstrongii* is fire. Adult stems suffer mortality in fires with higher-than-average temperatures, such as those fuelled by the high litter loads produced by introduced grass species such as gamba grass (*Andropogon gayanus*) and mission grass (*Pennisetum polystachion*) (GHD 2009). Fire also reduces seed viability.

Cycas armstrongii was observed in the study area throughout the *Eucalyptus miniata – E. tetrodonta* woodland community.

No plant species listed under the EPBC Act were recorded in field surveys of the onshore development area, and none appear on the public database of threatened species for the Blaydin Point area (see Appendix 16).

3.4.10 Weeds

A survey of existing weeds (introduced plant species with the potential to become invasive) was undertaken in the onshore development area by GHD during July 2008 (dry season). The survey concentrated on roads, tracks and areas of historical and present-day soil disturbance on Blaydin Point and Middle Arm Peninsula. Weeds were identified and mapped, and assessed for the extent of their infestations and their potential to spread further. The full results of this survey are provided in Appendix 16.

A total of 12 weed species were recorded during the survey, listed in Table 3-13. Four of these—hyptis, lantana, gamba grass and mission grass—are listed as declared weeds under the *Weeds Management Act 2001* (NT), and three are also weeds of significance according to the Commonwealth list of "weeds of national significance".

Table 3-13: Weeds recorded in the onshore development area

Species name	Family	Common name	Northern Territory status*	Commonwealth status
Andropogon gayanus	Poaceae	Gamba grass	Class B/C	–
Chloris inflata	Poaceae	Purpletop chloris	–	–
Crotalaria goreensis	Fabaceae	Gambia pea	–	–
Hibiscus sabdariffa	Malvaceae	Rosella	–	–
Hyptis suaveolens†	Lamiaceae	Hyptis, horehound	Class B/C	–
Lantana camara	Verbenaceae	Lantana	Class B/C	Weed of national significance
Melinis repens	Poaceae	Red Natal grass	–	–
Passiflora foetida	Passifloraceae	Stinking passion flower	–	–
Pennisetum pedicellatum	Poaceae	(none)	–	–
Pennisetum polystachion†	Poaceae	Mission grass	Class B/C	–
Scoparia dulcis	Scrophulariaceae	Scoparia	–	–
Stylosanthes viscosa	Fabaceae	Shrubby stylo, seca	–	–

Source: GHD 2009.

* Refers to the listing of declared weeds under the *Weeds Management Act 2001* (NT): Class A—to be eradicated; Class B—growth and spread to be controlled; Class C—not to be introduced to the Northern Territory.

† *Hyptis suaveolens* and *Pennisetum polystachion* were ranked 22nd and 46th respectively out of 71 weeds assessed as potential "weeds of national significance". The inaugural list of weeds of national significance contains the top 20 ranked weed species (Thorp & Lynch 2000).

Overall, weeds in the onshore development area are not abundant and are mainly found along roads and tracks, as vehicles are important vectors for weed spread. There are a number of informal tracks leading from Wickham Point Road and Channel Island Road north through the natural vegetation to the coast at Blaydin Point—these may have been created as access roads for recreational camping and fishing. Weed species such as mission grass and red Natal grass were common along the roadsides but were not observed extending far into the vegetation away from the road, nor forming dense thickets in areas of abundant bare ground. These species were not colonising areas of bare ground away from the roadsides and none were observed growing on the salt flats and mangrove tidal areas along Wickham Point Road (GHD 2008a).

Other key weed infestations are in areas of previous land clearing and soil disturbance. One such area of around 11.5 ha is located on Middle Arm Peninsula south of Blaydin Point, where borrow pits were created during the construction of the Darwin LNG plant and associated roads and service corridors around five years ago. This area now contains a mixture of native and introduced plant species, bare ground and depressions that hold water during the wet season. Introduced vegetation in this clearing is dominated by mission grass, which forms dense thickets up to 3 m tall, excluding almost all other vegetation. Hyptis is also scattered throughout this clearing.

A second cleared area of around 1.9 ha is located at the intersection of Wickham Point Road and the access track to the borrow pits. This area has been affected by mounding and excavation earthworks and now supports dense thickets of mission grass, as well as hyptis and stinking passion flower (GHD 2008a).

No weed species identified at the onshore development area is unique to Middle Arm Peninsula, and most are widespread throughout the Darwin Coastal Bioregion. The weed species of most concern to the local vegetation communities are mission grass, gamba grass and hyptis because of their potential to spread rapidly and to alter the ecology of the natural vegetation.

Mission grass and gamba grass form dense thickets that can support excessive fire frequencies and intensities that alter the vegetation structure of the northern savannahs, including the tree layer (NTPFES 2003). They are also prolific seeders—large quantities of seed were observed in dense mats underneath mission grass in the onshore development area (GHD 2009).

Hyptis is known to be an aggressive invader of native vegetation and is a well-established weed of the roadsides of the Top End. Individual hyptis plants were observed across the onshore development area, suggesting that there is potential for spread from roadsides outwards, through the lower storey of the woodlands. Hyptis is easily spread as the persistent spiny calyx enclosing the seeds adheres readily to human clothing and to the fur of animals and can also become embedded in the dust and mud coatings of vehicles (GHD 2009).

3.4.11 Terrestrial animals

Darwin Coastal Bioregion

The broader Top End of the Northern Territory supports a wide variety of vertebrate and invertebrate animals, with species richness increasing in the northern high rainfall areas. In comparison with high-endemism areas in the Northern Territory such as the Arnhem Plateau and MacDonnell Ranges bioregions, the fauna of the Darwin Coastal Bioregion has a relatively low level of endemism.

Most mammal species in the Darwin Coastal Bioregion are nocturnal and relatively inconspicuous. Mammals known to inhabit the bioregion include the northern quoll (*Dasyurus hallucatus*), the northern brown bandicoot (*Isoodon macrourus*), the northern brushtail possum (*Trichosurus vulpecula arnhemensis*) and the agile wallaby (*Macropus agilis*) (GHD 2009; URS 2002).

There is a rich diversity of bird species in the bioregion, although few of these species are endemic. Birds local to the area include a variety of raptors (kites, goshawks, falcons and eagles), kingfishers, doves, lorikeets, cockatoos, honeyeaters and terns (GHD 2009).

Migratory birds are common in the Darwin Coastal Bioregion, where the coastline and wetlands support large numbers of various species of waders or shorebirds. These birds migrate to the northern hemisphere to breed during the northern summer, and may also travel through the Northern Territory to southern Australia for the southern summer period. Other birds such as the koel (*Eudynamys scolopacea*), dollarbird (*Eurystomus orientalis*) and rainbow bee-eater (*Merops ornatus*) make annual migrations to Indonesia and other parts of south-eastern Asia (NRETAS 2007e).

Lizards, particularly skinks, dominate the reptile fauna of the Northern Territory. The saltwater crocodile (*Crocodylus porosus*) is found in the bioregion, along with a wide variety of snakes including the olive python (*Liasis olivaceus*) and brown tree snake (*Boiga irregularis*).

Amphibians occur throughout freshwater environments—the green tree frog (*Litoria caerulea*), the brown tree frog (*L. rothii*) and the dwarf tree frog (*L. bicolor*) are examples of local species (URS 2002).

Fauna conservation and species richness in the Darwin Coastal Bioregion is influenced by several alien "pest" animal species, including the cane toad (*Bufo marinus*), feral cat (*Felis catus*) and feral pig (*Sus scrofa*). These threaten native animal populations through predation and competition for food and habitat (NRETAS 2007e).

Habitats of the onshore development area

Previous fauna surveys on Middle Arm Peninsula have identified a total of 289 vertebrate species in the area, according to the NRETAS survey database. These include 26 mammal, 224 bird, 33 reptile and 6 amphibian species.

A survey of terrestrial vertebrate fauna was carried out at the onshore development area by GHD to characterise the existing features of the area. The survey effort included sampling during both late dry season (late October 2005) and late wet season (early May 2008) conditions. The survey sites utilised for the fauna survey were a subset of the sites developed for the vegetation survey (discussed in Section 3.4.8) and included a total of 13 quadrats of 50 m x 50 m. Systematic trapping was undertaken at each site over a period of three nights during each season, using pit traps, funnel traps, cage traps, Elliott traps and hair tubes. Bat surveys were conducted using echolocation calls for insectivorous bats (GHD 2009).

In total, 148 vertebrate species were recorded in the fauna survey, including 9 species of mammal (of which 4 were bats), 106 birds, 22 reptiles and 11 frogs. The results are summarised as follows, while the full technical report is provided in Appendix 16 to this Draft EIS (GHD 2009).

Results of the trapping program indicated that the major habitat types important to animal groups at the onshore development area are closely related to the vegetation communities presented in Section 3.4.8. The eucalypt communities and savannah woodlands are the more species-rich communities for animals, particularly birds.
The eucalypt savannahs occupy the largest proportion of the onshore development area, as they do of the Northern Territory. However, the significance of the observation of more species occurring in the savannahs is diminished as most vertebrate species have a diverse habitat requirement and would realistically exploit seasonal abundances of resources in particular habitats at particular times of year.

The probable dependence of species on multiple habitat types may be more important than an apparent bias towards the eucalypt savannah community (GHD 2009).

The monsoon vine forest habitat is structurally complex and provides habitat for a distinctive bird fauna, and theoretically for mammals. However, no small or mid-sized ground mammals (with the exception of the alien black rat) were recorded in the surveys (GHD 2009), and secondary traces (e.g. diggings and scats) were rarely observed. Unburnt monsoon vine forest patches with abundant leaf litter were present in the onshore development area despite recent fires, and still did not contribute any recordings of small mammals. This suggests that other factors may be influencing the presence of small ground mammals at the onshore development area (GHD 2009).

Across the onshore development area, areas of savannah woodland had high ground-level complexity and therefore tended to support a higher abundance and species richness of reptiles and birds. Mammals could also be expected to inhabit this community but, as described above, few were recorded in surveys of the onshore development area (GHD 2009).

The mangrove vegetation community provides habitat for mangrove-specialist bird species like honeyeaters, as well as for raptors. The intertidal areas around the onshore development area have low levels of understorey and ground-level vegetation and are therefore likely to offer only a low level of resources for vertebrate animals such as birds. However, it should be recognised that conditions and resources in this habitat type are more dynamic than in other vegetation types, fluctuating with tidal conditions. The tidal flats will periodically represent high-value foraging habitat for migratory wetland birds. The intertidal area can support few amphibians because of the lack of grass cover and the high salinity levels (GHD 2009).

A borrow pit in the onshore development area provides a seasonal waterbody that supported the majority of amphibians recorded during surveys, as well as some species of wetland and grassland birds (GHD 2009).

3.4.12 Protected species

As described in Section 3.2.8, the Commonwealth's EPBC Act provides a legal framework to protect and manage nationally and internationally threatened plants and animals. Threatened species may be listed under the EPBC Act in one of several categories depending on their population status (e.g. "critically endangered", "endangered", "vulnerable", and "conservation dependent"). In addition, a range of migratory terrestrial species are protected under the

EPBC Act as they are listed in international treaties and conventions for the protection of wildlife.

Threatened species in the Northern Territory are protected under the TPWC Act, and may also be classified in a range of categories (e.g. "critically endangered", "endangered", "vulnerable", "near threatened", "data deficient" and "not threatened in the Northern Territory").

None of the animal species recorded in field surveys of the onshore development area are listed as threatened under the TPWC Act or EPBC Act (GHD 2009). However, publicly available databases suggest that there are a number of threatened animal species that could potentially occur in and around the onshore development area. Those that are listed as "critically endangered", "endangered" or "vulnerable" are presented in Table 3-14. It is noted that other species with less critical conservation status may also occur in the onshore development area (see the full list provided in Appendix 16 to this Draft EIS).

In addition to Northern Territory and Commonwealth legislation, terrestrial animals that are considered to be under a global threat of extinction are listed on The IUCN Red List of Threatened Species, or may be protected by international treaties such as CITES or the Bonn Convention. Species protected by such conventions and laws and that may occur in the onshore development area are also noted in Table 3-14.

Some of the threatened species that may inhabit the onshore development area are described in more detail below.

Mammals

Northern quoll

The northern quoll (*Dasyurus hallucatus*) has been recorded across the Top End of the Northern Territory and as far south as Alexandria Station on the Barkly Tableland (central-eastern Northern Territory). In recent times the species has experienced a marked contraction in range that has been attributed to numerous potential causal factors including changes in fire regime, vegetation structure, disease and competition with feral cats. The decline of the northern quoll has been exacerbated by the recent arrival in the Northern Territory of the invasive cane toad *Bufo marinus*. Quolls that prey on the toads are killed by the poisons contained in the skin glands of the toads (GHD 2009).

Table 3-14: Protected terrestrial animal species that may be present in or near the onshore development area

Scientific name	Common name	Conservation status				
		Commonwealth*	Northern Territory†	IUCN‡	Bonn Convention	CITES#
Mammals						
Dasyurus hallucatus	Northern quoll	E	CE	LR (NT)	n.a.	–
Xeromys myoides	Water mouse (or false water-rat)	V	DD	V	n.a.	I
Birds						
Erythrotriorchis radiatus	Red goshawk	V	V	V	n.a.	II
Geophaps smithii smithii	Partridge pigeon (eastern)	V	V	(NT)	n.a.	–
Calyptorhynchus banksii	Red-tailed black-cockatoo	E	NT	(LC)	n.a.	–
Erythrura gouldiae	Gouldian finch	E	E	E	n.a.	–
Reptiles						
Varanus panoptes	Floodplain monitor	–	V	–	n.a.	II

Sources: DEWHA 2009a; NRETAS 2007a; IUCN 2009a, 2009b; Bonn Convention 2009a; CITES 2009b.

* Commonwealth Government—*Environment Protection and Biodiversity Conservation Act 1999* (Cwlth).
E = Endangered; V = Vulnerable.

† Northern Territory Government—*Territory Parks and Wildlife Conservation Act* (NT).
CE = Critically Endangered; E = Endangered; V = Vulnerable; DD = Data Deficient; NT = Near Threatened.

‡ International—IUCN: The IUCN Red List of Threatened Species.
E = Endangered; V = Vulnerable; LR = Lower Risk; (NT) = Near Threatened; (LC) = Least Concern.

\# International—CITES: Convention on International Trade in Endangered Species of Wild Fauna and Flora.
I = Appendix I lists species threatened with extinction; II = Appendix II includes species not necessarily now threatened with extinction, but that may become so unless trade involving them is closely controlled.

n.a. = not applicable.

The northern quoll was previously recorded from savannah woodland and mangrove fringes at Middle Arm Peninsula. There are also 14 records of northern quolls at the onshore development area between 1990 and 2001. Despite the presence of suitable quoll habitat at Blaydin Point, no traces of the northern quoll were detected in recent dry- or wet-season surveys of the area. The cane toad is currently well established and occurs in most habitats at Blaydin Point. It is possible, therefore, that the quoll has experienced localised declines following the arrival of the toads. However, quolls are relatively secretive and can go undetected in trapping surveys, so the survey result should be considered inconclusive (GHD 2009).

Water mouse

The water mouse or false water-rat (*Xeromys myoides*) has not been recorded previously at the onshore development area and signs of its presence were not observed during recent surveys. If the species does utilise the area, the proposed removal of mangroves by the Project will have a relatively minor impact on its habitat availability, as similar habitat is available throughout Darwin Harbour and the Darwin Coastal Bioregion (GHD 2009).

Birds

Red goshawk

The red goshawk (*Erythrotriorchis radiatus*) occurs across much of northern Australia. It generally occurs in taller forests in high rainfall areas and preys mainly on medium-sized birds. The onshore development area does not appear to provide habitat characteristics ideal for red goshawk foraging or breeding. There are no historical records of the red goshawk in the onshore development area and the species was not recorded in recent surveys (GHD 2009).

Partridge pigeon

The partridge pigeon (*Geophaps smithii smithii*) is a medium-sized ground-dwelling pigeon that occurs across the top of the Northern Territory and the Kimberley. It is grey-brown in colour, with a red face and a white leading edge to the wing. The partridge pigeon may occur in large groups around water sources in the late dry season.

The species is listed as "vulnerable" under the TPWC Act and the EPBC Act. It occurs mainly in lowland eucalypt forests and woodlands with grassy understoreys. This species has not been recorded in the onshore development area and there is a lack of suitable habitat to support the species (GHD 2009).

Red-tailed black-cockatoo

The red-tailed black-cockatoo (*Calyptorhynchus banksii*) is endangered in some parts of Australia, mainly because of threats to its habitat by land clearing. However, the species is relatively common in low savannah woodland in the Darwin Coastal Bioregion and it was recorded 13 times in surveys of the onshore development area (GHD 2009). As woodland habitat is available throughout Middle Arm Peninsula and the broader region, the Project is unlikely to pose a threat to the distribution of this species.

Gouldian finch

The Gouldian finch (*Erythrura gouldiae*) is restricted to isolated areas mostly in the Northern Territory and the Kimberley. It is found in wooded eucalypt hills from February to October and in lowland drainages in the wet season. The onshore development area does not provide suitable habitat to support this species and it has not been recorded in the area (GHD 2009).

Migratory birds

Five raptor species were recorded in the onshore development area, including the brahminy kite (*Haliastur indus*), black kite (*Milvus migrans*), whistling kite (*Haliastur sphenurus*), brown goshawk (*Accipiter fasciatus*) and white-bellied sea-eagle (*Haliaeetus leucogaster*) (GHD 2009). All are listed migratory and/or marine species and are protected under the EPBC Act. All historical records from the area indicate that raptors are common in appropriate habitat across the Northern Territory and are generally classed as species of "least concern" under the TPWC Act.

Five species of migrant shorebirds were recorded during the surveys—the lesser sand plover (*Charadrius mongolus*), Pacific golden plover (*Pluvialis fulva*), eastern curlew (*Numenius madagascariensis*), whimbrel (*Numenius phaeopus*) and marsh sandpiper (*Tringa stagnatilis*). All are listed as protected marine and migratory species under the EPBC Act; however the onshore development area does not provide critical breeding or foraging habitat for these species. Shorebirds could be expected to pass through the onshore development area occasionally (GHD 2009). There are a large number of bird species that are listed as "migratory" or "marine" protected species under the EPBC Act and which have previously been recorded in the vicinity of the onshore development area. These include the little tern (*Sterna albifrons*), fork-tailed swift (*Apus pacificus*), grey-tailed tattler (*Tringa brevipes*) and ruddy turnstone (*Arenaria interpres*) (see Appendix 16 for a full list). The majority of these species are either unlisted or categorised as "data deficient" under the TPWC Act, and migrate internationally over very large ranges.

Chatto's (2000) investigation of major congregations of seabirds along the Northern Territory coast did not identify Darwin Harbour as a significant site for seabirds. Although a number of these species will occur from time to time in the vicinity of Blaydin Point and Middle Arm Peninsula, the area cannot be defined as "important habitat" for seabirds (GHD 2009).

Reptiles

Two monitors have been recorded at Blaydin Point in previous surveys—the sand goanna (*Varanus gouldii*) and the yellow-spotted monitor (*Varanus panoptes*). Neither species was recorded in recent surveys of the onshore development area. The yellow-spotted monitor is listed as "threatened" under the TPWC Act because its prey includes cane toads and it dies after ingesting the toad's toxins. Sand goannas may also be affected by the cane toad (GHD 2009).

3.4.13 Introduced animal species

The most widely occurring pest animal species recorded in surveys of the onshore development area was the cane toad (*Bufo marinus*). Cane toads were observed in savannah woodland, monsoon vine forest, mangrove fringes and in the vicinity of water-filled borrow pits, as well as on the road access tracks throughout the onshore development area (GHD 2009).

In addition, the black rat (*Rattus rattus*) was recorded in monsoon vine forest at Blaydin Point and the feral pig (*Sus scrofa*) was observed in mangroves; pig wallows and diggings were observed at the interface between mangroves and monsoon vine forest (GHD 2009).

3.4.14 Blaydin Point invertebrate fauna

Mangroves occupy most of the coastal margins of Darwin Harbour, as described in Section 3.4.8, and provide habitat for a range of invertebrate animals such as fiddler crabs, sesarmid crabs and polychaete worms.

To characterise the invertebrate fauna in the mangrove communities of the onshore development area, GHD conducted a field survey in December 2007. Nine transects were established in the intertidal zone around Blaydin Point and south of Wickham Point. Quadrats of 1 m^2 were developed every 20 m along each transect, and invertebrate animals (identified to species or species-group level), plants, burrows and pneumatophores were recorded in each quadrat. A total of 1231 individual animals from 13 species or species groups were recorded in the transect surveys, including fiddler crabs, sesarmid crabs, molluscs (*Telescopium telescopium* and *Terebralia semistriata*) and mudskippers (family Gobiidae) (GHD 2008b).

In addition, marine worms were assessed by digging up the top 0.1 m of mud from quadrats measuring 0.5 m x 0.5 m, and washing this through a sieve. All worms were removed and identified to the highest possible taxonomic level by the Museum and Art Gallery of the Northern Territory. A total of 39 animals belonging to 20 species were collected from the mud samples, including 17 from the class Polychaeta (GHD 2008b).

Previous studies of the distribution of invertebrate fauna in mangroves show that their zonation patterns can parallel the zonation of the mangrove plant species (Dames & Moore 1997). The patterns of distribution recorded in this survey conform to the general patterns previously reported for Darwin Harbour (GHD 2008b).

The invertebrate fauna at Blaydin Point was fairly uniform in animal abundance across all mangrove zones. Individual mangrove invertebrate species have unique patterns of habitat association, with all mangrove zones contributing significantly to the abundances of some species (GHD 2008b).

Surface fauna

Fiddler crabs exhibited a peak in abundance in the more seaward *Sonneratia*, *Sonneratia–Rhizophora*, and *Rhizophora* zones and were more abundant in areas with larger numbers of pneumatophores (GHD 2008b).

The abundance of sesarmid crabs was lower in the more landward areas such as salt flats. Among the mangrove zones sesarmid crab abundance did not vary greatly and was not influenced by the numbers of pneumatophores (GHD 2008b).

The mollusc *Telescopium telescopium* exhibited a peak in abundance in the *Rhizophora–Ceriops* and *Ceriops* zones. *Terebralia semistriata* showed a similar distribution and was also abundant in the *Ceriops* and *Avicennia* zones (GHD 2008b). Irrespective of mangrove zone, *Telescopium telescopium* and *Terebralia semistriata* were more abundant in areas with more species-rich vegetation (i.e. transition zones).

Mudskippers were more abundant in the *Sonneratia*, *Sonneratia–Rhizophora*, and *Rhizophora* zones, and preferred areas with large numbers of pneumatophores.

Polychaete worms

Species richness and abundance in polychaete worms increased towards the seaward margins around Blaydin Point. The mudflat–*Sonneratia* zone at Blaydin Point had the greater species richness and abundance of polychaete worms and the more equitable distribution of individuals among species. The composition of the fauna of the *Rhizophora–Ceriops* zone was slightly different from that of the mudflat–*Sonneratia* zone (GHD 2008b).

3.4.15 Biting insects

Two groups of biting insects are common in the area around Darwin. These are the biting midges of the family Ceratopogonidae and the mosquitoes of the family Culicidae.

Ceratopogonid biting midges can be considerable pests within a few kilometres of the coast in the Northern Territory, with the highest numbers occurring within 1.5 km of mangrove communities (Shivas & Whelan 2001). These insects can cause painful bites, while some people experience secondary effects such as intense itching, infection and scarring from scratching.

Mosquitoes are notable, of course, for their nuisance value to humans but they are also a potential public health problem in the Northern Territory because of their role as vectors of a number of viruses causing human diseases. These include the Murray Valley encephalitis virus, the Kunjin virus, the Ross River virus and the Barmah Forest virus (Medical Entomology Section 2009).

In order to characterise the existing populations of biting insects in the onshore development area, staff of the Medical Entomology Section (from the Northern Territory Government's Centre for Disease Control) conducted surveys in October and December 2007. Sampling was conducted using encephalitis virus surveillance traps baited with carbon dioxide, set overnight in six locations in the onshore development area. All survey sites were located above the high-water mark, inland of the intertidal mangrove zone. Trapped mosquitoes and biting midges were identified to species level by specialists at the Medical Entomology Section. The results of these surveys are summarised below, while the complete technical report is provided in Appendix 21.

Biting midges

Of the biting midges recorded in the trapping surveys, the mangrove biting midge (*Culicoides ornatus*) is the species most likely to be the cause of problems to personnel working in the onshore development area. However, there are other species of biting midges not yet recorded in the trapping program that can be significant pests and are likely to be found in the onshore development area. These include *Culicoides flumineus*, a species normally only found inside mangrove communities and therefore not recorded during the trapping survey (Medical Entomology Section 2009).

The mangrove biting midge will be present in its highest seasonal numbers throughout the onshore development area during the late dry season from August to November. Mass movement of adults can occur from 0.5 to 1.5 km from the mangrove margin of their major breeding sites, with smaller numbers up to 3 km from the nearest mangrove margin. The entire onshore development area is located within 300 to 400 m of mangrove areas, suggesting that *C. ornatus* will be present throughout. Trapping showed a marked peak in numbers on the western edge of Blaydin Point because of the proximity of the upper tidal mangrove tributaries of Lightning Creek. This creek and the small creeks at the south-eastern edge of Blaydin Point contain substantial upper tidal mangrove communities, which will be the most important breeding sites for biting midges affecting the onshore development area (Medical Entomology Section 2009).

Mosquitoes

Mosquito populations at the onshore development area are not expected to be as high as in other parts of Darwin because of the lack of extensive areas of potential breeding sites such as are offered by coastal plains, creeks and rivers. The most productive mosquito breeding sites at Blaydin Point are localised depressions in upper tidal areas, depressions in seepage areas, and the monsoon vine forest near the landward mangrove margin. On Middle Arm Peninsula, borrow pits and depressions in upper tidal areas could provide potential breeding sites for mosquitoes (Medical Entomology Section 2009).

The mosquitoes *Aedes vigilax*, *A. notoscriptus*, *Culex annulirostris*, *C. sitiens* and *Verrallina funerea* were recorded in the onshore development area; these are all pest and potentially disease-carrying mosquito species (Medical Entomology Section 2009).

3.5 Regional climate

3.5.1 Meteorology

Browse Basin

The climate in the Browse Basin region surrounding the Ichthys Field is monsoonal and seasonally controlled by the meridional position of large high-pressure cells, which pass from west to east across the Australian continent (Osborne et al. 2000). These pressure systems, with their anticlockwise wind circulation, migrate from latitudes of 25–30°S in winter to 35–40°S in summer (Pearce et al. 2003). Owing to this pattern, summer (October to February) prevailing winds are warm and come from the north-west and south-west. During winter (May and June), the prevailing winds are cooler south-easterlies.

These winds also result in higher relative humidity in the summer (about 50%) compared with the winter (30–40%). Two shorter transitional periods with more variable wind directions occur between these seasons, usually from March to April and August to September (see Appendix 4).

This area is also prone to tropical cyclones, mostly during the tropical wet season from December to March. It is expected that cyclones could have an impact on the Ichthys Field at least once every two years. Under extreme cyclone conditions winds can reach 300 km/h. The El Niño Southern Oscillation (ENSO) cycle can lead to a lower incidence of cyclones in this region, with cyclones instead forming further east under the influence of El Niño (BOM 2009a).

Darwin

The onshore development area lies in the monsoonal tropics of northern Australia and experiences two distinct seasons—a hot wet season from November to March and a warm dry season from May to September. April and October are transitional months between the wet and dry seasons. Maximum temperatures are defined as hot all year round, but November is the hottest month with a range of 25 °C minimum to 33 °C maximum, while June and July normally experience the lowest average daily temperatures with a range of 20 °C minimum to 30 °C maximum (BOM 2009b). Monthly temperature averages from Darwin International Airport are provided in Figure 3-42.

Darwin has a mean annual rainfall of 1711 mm, with rain falling on an average of 111 days, mainly in the wet season. A range of monthly rainfall averages received at Darwin International Airport (highest, mean and lowest monthly rainfall) is provided in Figure 3-43. Monthly mean evaporation ranges from 167 mm in February to 259 mm in October. The mean annual evaporation rate is 2630 mm (BOM 2009b).

The mean relative humidity experienced at 0900 hours and 1500 hours in Darwin is illustrated in Figure 3-44. The humidity is higher during the wet season than in the dry season, mirroring rainfall patterns.

The wet and dry season wind roses for Darwin are presented in Figure 3-45. As shown, during the wet season Darwin is dominated by westerly and west-north-west winds. Dry-season winds vary from the south-east through to the north.

The monsoonal tropics also experience cyclone activity. The strongest winds and heaviest rainfall are associated with the passage of tropical cyclones, which can occur in the region at any time during the period November to April. Tropical cyclones cause most damage within a distance of 50 km from the coast. Aside from the impacts of strong winds, storm surges can be of concern to coastal developments and flood damage can also result from associated squally rains.

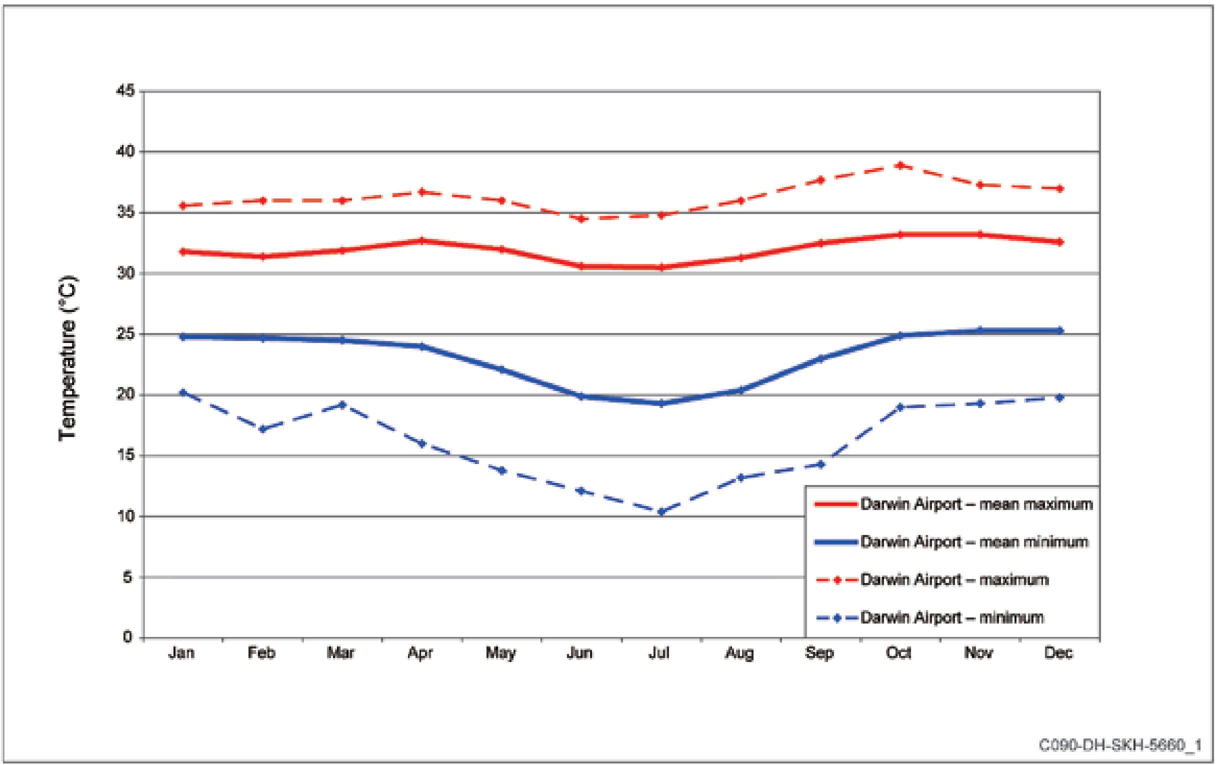


Figure 3-42: Maximum and minimum monthly temperatures for Darwin (°C)

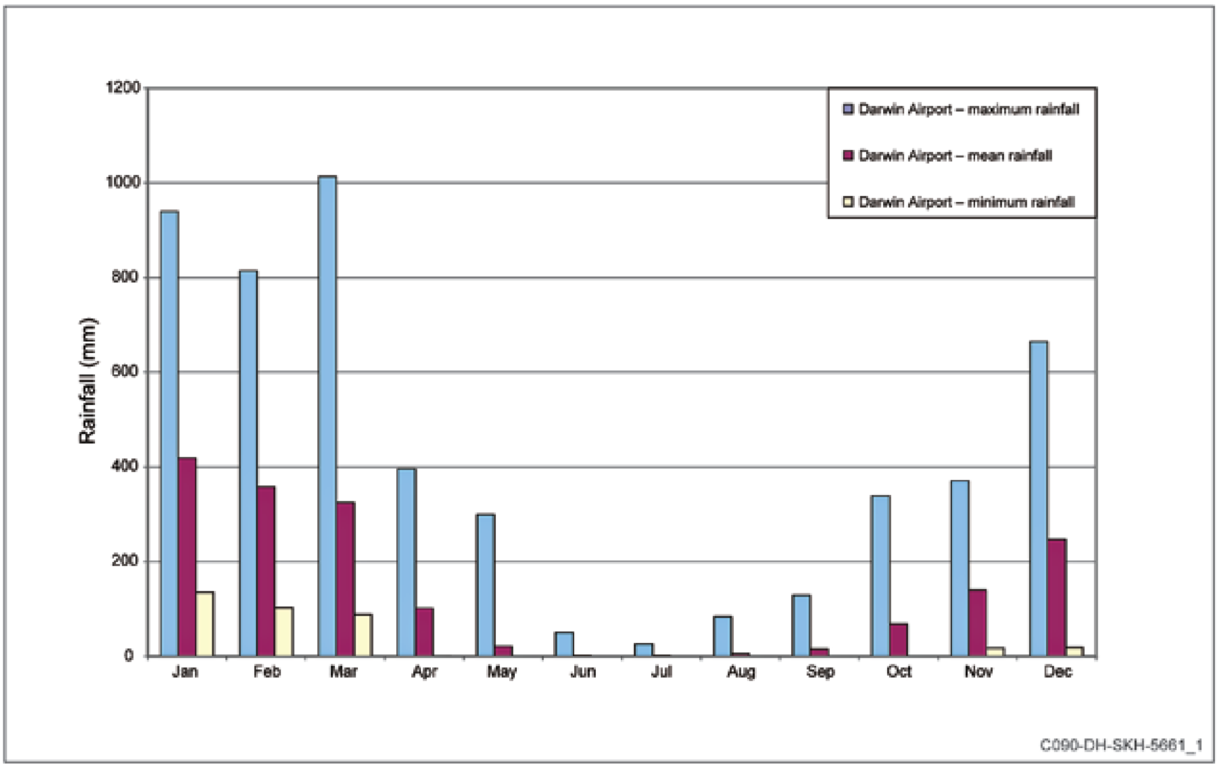


Figure 3-43: Average monthly rainfall for Darwin (mm)

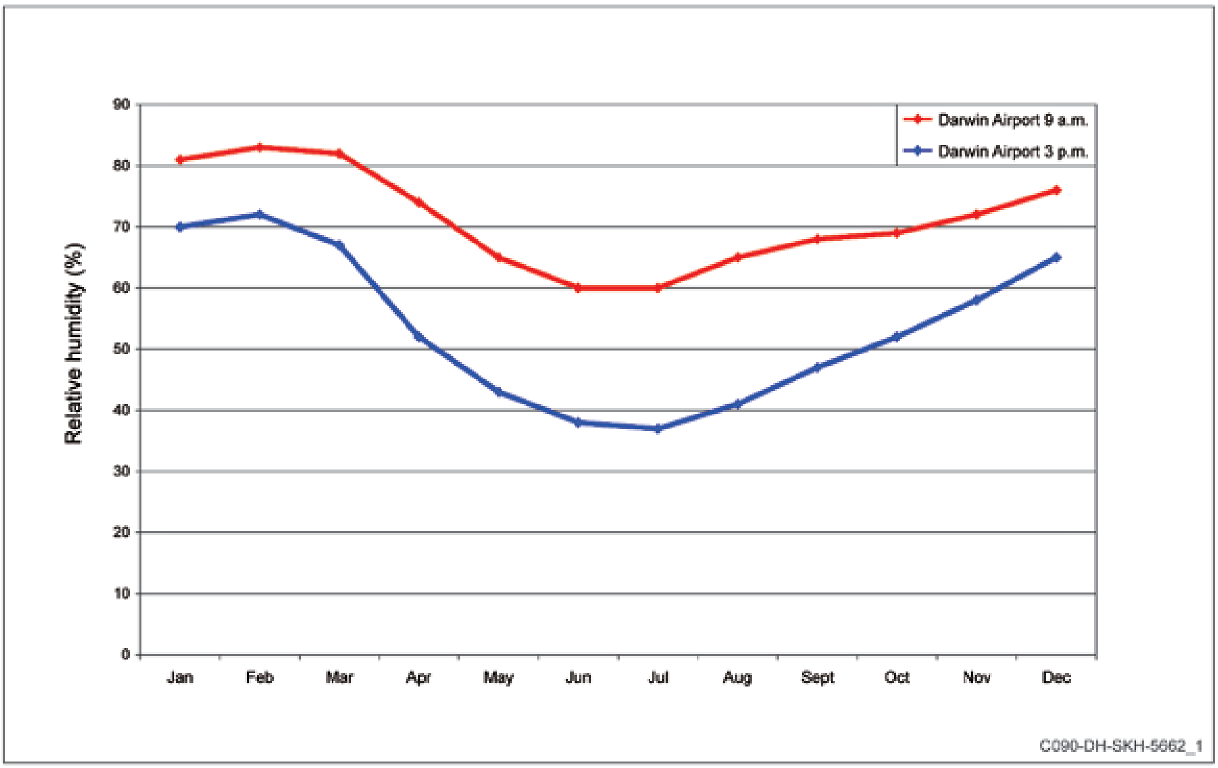
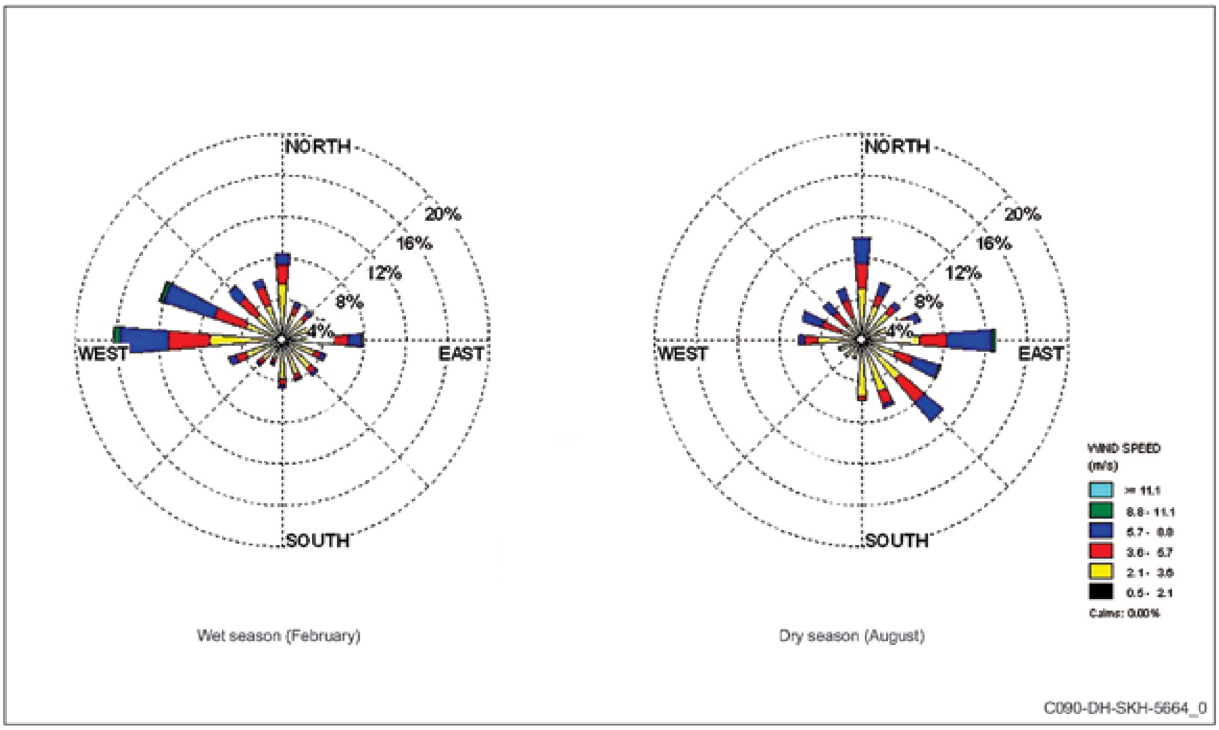


Figure 3-44: Relative humidity for Darwin (%)



Source: SKM 2009.

Figure 3-45: Wind rose for Darwin during wet and dry seasons, 2000–2007

3.5.2 Air quality

Ambient air quality in the Darwin region is influenced by a number of sources including biogenic emissions (from vegetation and soil), smoke from bushfires, and anthropogenic emissions from vehicles and industrial facilities.

Pollutants that could affect public or environmental health, and are relevant in the context of the Project, include particulates less than 10 µm in diameter (PM_{10}), oxides of nitrogen (NO_x, especially nitrogen dioxide NO_2), sulfur dioxide (SO_2), ozone (O_3) and volatile organic compounds (VOCs).

Currently, the major sources of emissions of these compounds in the Darwin region are as follows:

- natural or agricultural vegetation (particularly for VOCs, and particulates during bushfires or prescribed burning)
- soil and bodies of water (particularly for NO_x)
- motor vehicles (particularly for VOCs, NO_x and SO_2)
- ConocoPhillips' Darwin LNG plant
- Channel Island Power Station
- emissions from commercial shipping (SKM 2009).

The National Environment Protection Council (NEPC) provides ambient air-quality criteria as benchmarks for levels of pollutants that could affect public health; these criteria are known as National Environment Protection Measures (NEPMs). Research into the current ambient air quality in the Darwin region was conducted by Sinclair Knight Merz (SKM) in 2008.

A three-dimensional computer-based modelling program (The Air Pollution Model (TAPM), developed by the CSIRO) was used to estimate ambient air quality. Emissions from existing sources in the Darwin region were quantified using publicly available data and the scientific literature. The model accounts for dispersion processes such as convection, sea breezes and terrain-induced flows and it can be used to predict photochemical processes. The results of the ambient air-quality modelling are summarised as follows, with the full technical report (SKM 2009) provided in Appendix 19 to this Draft EIS.

The ambient air quality study found that concentrations of NO_2, SO_2 and O_3 in the Darwin airshed are relatively low, and well below the NEPM criteria as shown in Table 3-15. The highest levels of NO_2 and SO_2 currently occur in the vicinity of the Darwin LNG plant, while the maximum ground-level concentrations of O_3 occur over the ocean approximately 12 km north-west of Darwin (SKM 2009).

Ozone is produced through the photochemical reaction of oxides of nitrogen (NO_x) and volatile organic compounds (VOCs). While NO_x emissions can originate from anthropogenic sources (e.g. motor vehicles), VOCs can be emitted in significant amounts by biogenic sources (e.g. tropical vegetation).

Table 3-15: Maximum predicted ground-level concentration on modelled grid

Pollutant	Averaging period	Maximum (ppm)	NEPM criterion (ppm)	Percentage of criterion
NO_2	1 hour	0.03	0.12	23
	Annual	0.002	0.03	8
SO_2	1 hour	0.01	0.20	7
	24 hours	0.006	0.08	7
	Annual	0.002	0.02	10
O_3	1 hour	0.06	0.10	59
	4 hour	0.06	0.08	68

Source: SKM 2009.

However, the emission rates of biogenic VOCs, particularly in Australia, are poorly understood. In addition, few previous measurements of O_3 have been undertaken in the Darwin airshed. In order to increase the accuracy of the VOC input data used in the ambient air quality model, passive sampling programs were conducted by SKM at key sites in the Darwin airshed in the wet season of early 2009 and the dry season later in the year (see Appendix 19).

Estimates of particulate levels in the Darwin airshed were drawn from a pilot study of air quality by the CSIRO in 2000, which suggested that dry-season PM_{10} levels over a 24-hour period were up to 20 µg/m^3, mainly corresponding with smoke generated by bushfires. Wet-season PM_{10} concentrations were lower, at around 10 µg/m^3. The NEPM criterion for PM_{10} is a maximum concentration of 50 µg/m^3 over a 24-hour period, indicating that airborne particulate levels in Darwin are relatively low (SKM 2009).

More recent combined NRETAS and CSIRO air-quality data sets indicate that there were four excursions above the NEPM criterion attributable to smoke from bushfires between 2004 and 2008.

3.6 Social and cultural environment

This section describes the existing social and cultural environment in the Project area, at the local community, territory and national scales.

3.6.1 Description of baseline

A profile of the existing socio-economic conditions in the Project area was developed using publicly available data and published studies. Background socio-economic information relevant to the Project includes a geographical and development context, population demographics, community networks and culture, values and attitudes, and key economic activities.

Data sources and limitations

Baseline study data were collected from government agencies and other sources. The most up-to-date data are used wherever possible; however, for most statistics there is a time lag of several years between collection and publication. This is particularly the case with data relating to composite industries such as tourism (which is made up of the accommodation, transport, recreation, and travel services industries). The basic population data sets used are sourced from the Australian Bureau of Statistics (ABS) *Census of Population and Housing 2006* (ABS 2007a) at the statistical subdivision (SSD) or Territory level unless otherwise stated. As the Census is conducted every five years, the 2006 Census represents the most up-to-date collection of population statistics for the Project area.

Unless otherwise stated, census data are based on location on census night (the place of enumeration). This is the mode most readily available for collecting data as a time series from the 1996, 2001 and 2006 censuses.

The Census rather than the ABS's monthly Labour Force Survey was used in preparing the basic labour force estimates for this study, as data for the Labour Force Survey are collected at an aggregated labour force region level rather than at the SSD level. For the Northern Territory, data are only released for the Territory as a whole. In addition, using the Labour Force Survey does not accurately represent the employment situation in the study area, as members of the Australian Defence Force (ADF) are excluded from participating. Given the large numbers of ADF personnel present in the Northern Territory, this means that employment figures can be an underestimate.

The study area

For the purposes of the socio-economic baseline, the area relevant to the Project has been defined by the statistical divisions (SDs) and statistical subdivisions (SSDs) of the ABS. The Darwin region is represented by the Darwin SD, and comprises the cities of Darwin and Palmerston and the semi-rural Litchfield Municipality. The "Darwin City" and "Palmerston – East Arm" SSDs (Figure 3-46) contain the two major population centres of the region and are the SSDs most likely to be affected by the Project. Therefore population demographics presented in this assessment focus mainly on these two subdivisions.

3.6.2 Government policies and plans

The Project will be regulated through three separate but overlapping levels of government:

- the Commonwealth Government
- the Northern Territory Government
- local government, including Darwin City Council, Palmerston City Council and Litchfield Council.

Direct regulatory control of the Project will be through legislation administered by the Northern Territory and Commonwealth governments. At the policy level, most of the activity occurs at Territory government level and is targeted primarily at the Territory's strategic development plans. Commonwealth policy focuses on broader economic development, although there have been recent developments in relation to marine planning.

There are a number of policies and strategies that are potentially relevant to the Project; these are summarised in Table 3-16.

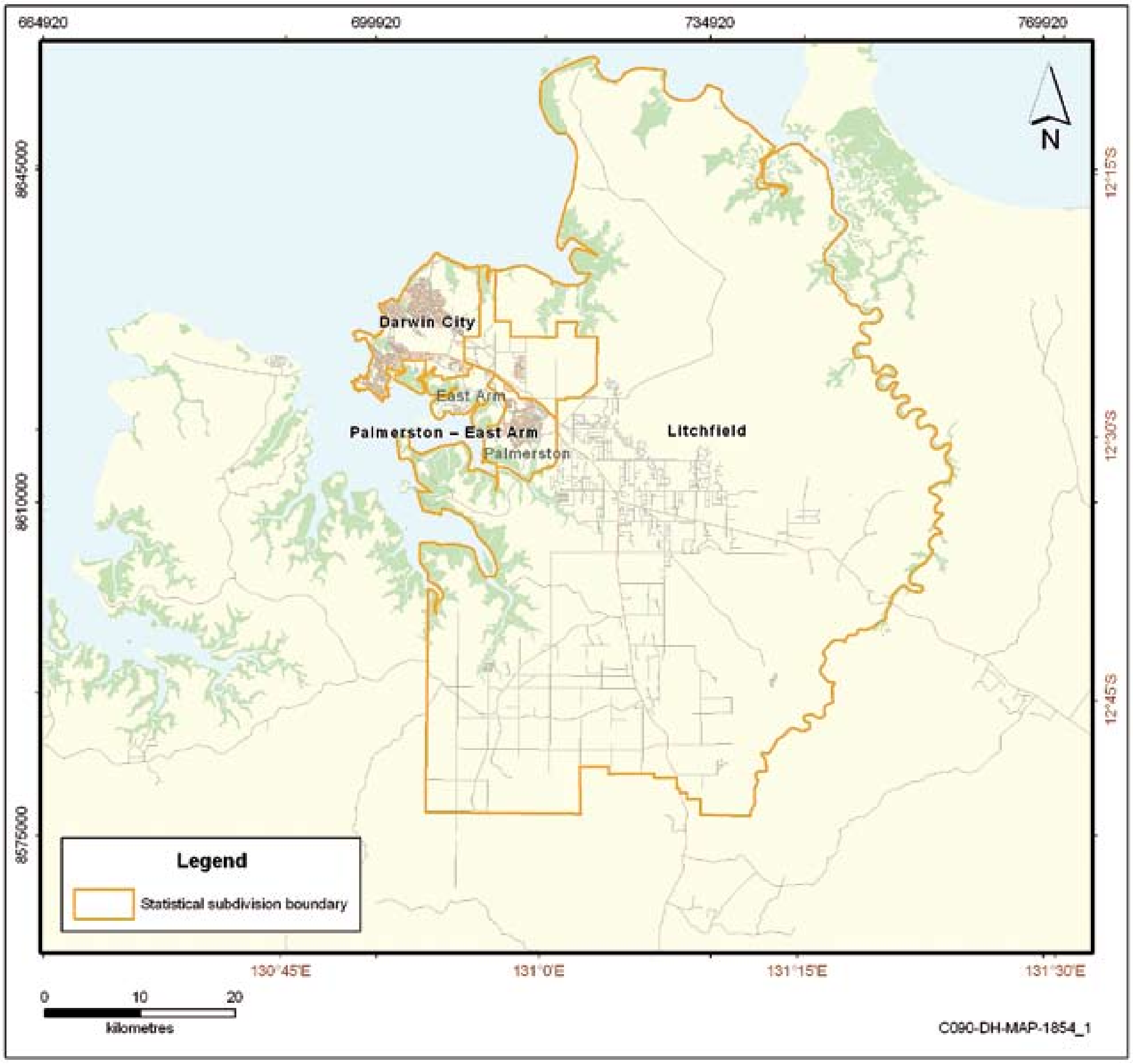


Figure 3-46: Study area statistical subdivisions

Table 3-16: Policies and plans that are potentially relevant to the Ichthys Project

Policies and plans	Description
Commonwealth Government	
Industry statement: global integration—changing markets, new opportunities (Department of Industry, Tourism and Resources, now the Department of Innovation, Industry, Science and Research) (DITR 2007)	This statement delivers three major initiatives to assist Australian firms to succeed as global businesses—"Australian Industry Productivity Centres", the "Global Opportunities program" and changes to the Australian Taxation Office's research & development tax concession.
Marine bioregional planning: a new focus for Australia's marine planning (Department of the Environment and Heritage, now the Department of the Environment, Water, Heritage and the Arts) (DEH 2006b)	This program is intended to assist in assessing the impacts of actions on the Commonwealth marine environment and determining the circumstances under which actions can take place.
Oceans policy: principles and processes (National Oceans Office 2003)	This policy sets out the Commonwealth Government's approach to implementing Australia's oceans policy. It aims to help marine managers and users deliver more sustainable and efficient outcomes. Components include the following: • setting out an approach for implementing Australia's oceans policy • focusing on sustainable outcomes.
Stronger regions, a stronger Australia (Department of Transport and Regional Services, now the Department of Infrastructure, Transport, Regional Development and Local Government) (DOTARS 2001)	The goals of this development framework are to strengthen regional economic and social opportunities; sustain productive natural resources and the environment; deliver better regional services; and adjust to economic, technological and government-induced change. Components include the following: • fostering federal, state and local government cooperation to achieve economic and social objectives for regional communities • improving regional services • helping regional communities to manage change • analysing regional needs and impediments to growth.
Summary of Australia's foreign investment policy (The Treasury 2008)	The foreign-investment policy aims to encourage foreign investment consistent with community interests.
Northern Territory Government	
Building Northern Territory industry participation (Northern Territory Government 2006)	This framework consists of a nationally agreed set of objectives, principles and strategies that will strengthen industry participation and build on existing arrangements. Large projects with expected values of more than $5 million are strongly required (if assisted by the Northern Territory Government) or strongly encouraged (if not assisted by the Northern Territory Government) to develop industry participation plans for engaging local businesses. Components include the following: • increasing local industry participation in projects • supporting sustainable economic development • facilitating education and training opportunities to maximise local jobs • identifying and creating opportunities for Aboriginal economic development.
Economic development framework (Northern Territory Government 2005)	This is a 10-year economic development plan for the Northern Territory. It commenced in 2005 and has five main objectives: encouraging regional growth, promoting investment, developing the local workforce, improving productivity and integrating development with good environmental management. Components include the following: • maintaining a competitive business environment • encouraging greater local content in business and industry • developing workforce skills • using major projects to improve workforce capability • streamlining business regulations.

Table 3-16: Policies and plans that are potentially relevant to the Ichthys Project (continued)

Policies and plans	Description
Palmerston partnership agreement (Northern Territory Government and Palmerston City Council) (Northern Territory Government 2007)	This is an agreement between the Northern Territory Government and the Palmerston City Council to enable cooperative management and planning for the strategic development of the Palmerston area.
Northern Territory planning scheme (Department of Planning and Infrastructure*, Northern Territory Government) (DPI 2008)	This scheme sets out the policy and provisions for the use and development of land throughout the Northern Territory, and provides specific land-zone maps for particular areas. Components include the following: • promoting community, environment and industry through effective land-use planning frameworks • facilitating the supply of land for industry and all other uses so that land subdivision is cost-effective, equitable and maximises the value of public and private investment in infrastructure • contributing to the sustainable use and development of land • valuing land for the ecosystem services it provides.
Darwin Harbour regional plan of management (Northern Territory Government 2003) (NRETAS 2007f)	This plan laid out the goal of protecting the environment of Darwin Harbour through key outcomes such as improving water quality, managing development appropriately, protecting biodiversity, supporting recreational use of the Harbour, and fostering community involvement in Harbour management. Components include the following: • promoting a healthy environment in Darwin Harbour and its catchment • supporting recreational use of the Harbour • encouraging ecologically sustainable development • protecting the cultural values of the Harbour.
Local government	
TOPROC Greater Darwin regional development strategy	TOPROC (Top End Regional Organisation of Councils) is made up of the Darwin, Palmerston, Litchfield, Coomalie, Cox Peninsula and Belyuen local councils. Their collaborative development strategy emphasises key actions such as encouraging appropriate urban development, improving Aboriginal employment levels, and developing a social plan for the area.
Palmerston – a place for people (Palmerston City Council 2007)	Palmerston City Council, supported by the Northern Territory Government, developed this community plan for the future development of Palmerston in 2003. In 2007 the council adopted the Palmerston City Plan for 2007/08 – 2009/10 as the implementation strategy for the plan. It provides for Palmerston's development in a socially, environmentally and economically sustainable manner. Components include the following: • increasing job readiness through partnership with industry and training providers, with particular emphasis on youth and Aboriginal employment • encouraging major projects that meet environmental and social sustainability objectives • promoting Palmerston as a regional supply and service centre.
Evolving Darwin: strategic directions—towards 2020 and beyond (Darwin City Council 2008)	In 2008 Darwin City Council released a discussion paper outlining future directions for Darwin City. These directions will be built around issues of improving lifestyles, connectivity, governance, environmental sustainability and a cohesive community. Components include the following: • developing collaborative relationships with all stakeholders • improving the active, positive lifestyle enjoyed by Darwin residents • maintaining environmental sustainability • facilitating the development of a cohesive community.

* The Department of Planning and Infrastructure became the Department of Lands and Planning in December 2009.

3.6.3 Land tenure and sea use

Middle Arm Peninsula was identified as a site for future industrial development by the Northern Territory Government and is classified as such under the Northern Territory Planning Scheme (DPI 2008). The onshore development area on Middle Arm Peninsula is currently undeveloped vacant Crown land falling within the jurisdiction of the Litchfield Council. Previous sites of disturbance in the area include around 25 ha of borrow pits, and a number of access tracks left by previous development projects.

Current use of the land and marine environment on Middle Arm Peninsula includes a power station on Channel Island and ConocoPhillips' Darwin LNG plant and offloading facility at Wickham Point. A number of aquaculture ventures also exist around the peninsula, and the area is regularly used for recreational fishing. Lightning Creek, west of Blaydin Point, currently contains a pearling lease and is utilised as a cyclone mooring for vessels—whether these facilities will remain in future years is unknown. Blaydin Point itself is accessible by four-wheel-drive vehicles using informal tracks and there is also evidence of camping.

In Darwin Harbour, the most intensive use of the marine area is for commercial shipping, recreational boating and military activities. Underwater power and communication cables extend across the Harbour on the seafloor between Mandorah and Myilly Point, and the Bayu–Undan Gas Pipeline to the Darwin LNG plant runs down the middle of the Harbour.

The Charles Darwin National Park is located in Frances Bay between the Darwin CBD and East Arm Wharf. Marine areas in this park include the western bank of Sadgroves Creek, Reichardt Creek and part of Blessers Creek, and a large portion of intertidal mudflat. Other conservation areas in the Harbour include the Channel Island Reef, which contains a coral community and is a listed heritage place on the Register of the National Estate (see Section 3.3.6 *Marine communities*). Fisheries management areas have been designated at Doctor's Gully Aquatic Life Reserve (near Darwin's CBD) and at the East Point Aquatic Life Reserve (near the mouth of Darwin Harbour), to reduce commercial and recreational fishing activity, under the *Fisheries Act* (NT).

Tourism activities such as charter fishing, scuba-diving, sailing and general boating are undertaken throughout the Harbour. Very little commercial fishing is undertaken in the Harbour; the commercial fisheries in the nearshore and offshore development area are described in detail in Section 3.7.4 *Commercial fishing and aquaculture*.

Aboriginal people living in the Darwin area frequently fish and forage for food and other resources in intertidal areas at low tide. These activities are common in the Harbour around Nightcliff, Coconut Grove, Kululuk, Sadgroves Creek and Lee Point. There are currently seven Aboriginal fisheries consultative committees in the Northern Territory. The Beagle Gulf Fisheries Committee was formally established in April 1999 and covers the Darwin Harbour region. Key issues discussed at these meetings include the involvement of Aboriginal people in the enforcement of fisheries regulations and the wasted bycatch from commercial barramundi fishers.

The Royal Australian Navy's Northern Australia Exercise Area (NAXA) extends west of Darwin into the Bonaparte Gulf. This marine area is used to conduct realistic at-sea exercises with naval and shore-based weapon-firing training (RAN 2006).

3.6.4 Demographics and population trends

The ABS population statistics in this section are based on place of usual residence. This means that the people counted actually live in the locality presented for at least six months of the year. The data were collected by the five-yearly ABS *Census of Population and Housing*, conducted in 1996, 2001 and 2006.

Population

The population of the Northern Territory in 2006 was 192 898 people, representing approximately 1% of Australia's total population. Around half of this population resided in the Darwin region. Population statistics for Darwin City, Palmerston – East Arm and the Northern Territory are presented in Table 3-17.

The Darwin regional population grew by 5.7% between 2001 and 2006, which is comparable to the increase in Australia's population over the same period (5.8%). Much of this growth was concentrated in the Palmerston – East Arm locality, where the rate of growth was 13.9% (ABS 2002, 2007a).

Table 3-17: Population statistics for the Darwin region, 2001 and 2006

Locality	2001	2006	Percentage change
Darwin City	64 341	66 290	+3.0
Palmerston – East Arm	21 192	24 145	+13.9
Darwin region	100 255	105 990	+5.7
Northern Territory	188 075	192 898	+2.6

Sources: ABS 2002, 2007a.

In 2006, Aboriginal people made up approximately 28% of the Northern Territory population, compared with 2.3% nationally. Most (83%) lived outside the Darwin region. Although relatively small, the Darwin regional population of Aboriginal people increased significantly (by 12%, or around 1000 people) from 2001 to 2006. This is comparable to the growth rate of the national Aboriginal population (ABS 2002, 2007a).

Population projections

Based on 2004 population estimates, by 2021 the Northern Territory's population is expected to grow to between 215 300 and 279 200 people. The greater part of this growth is likely to occur in the Darwin region. Upper growth rates estimate that Darwin's population will increase by 51%, showing a rate of increase nearly double that of Australia as a whole (24%) (ABS 2008a). Population projections for the Darwin region in 2021 and 2051 are provided in Table 3-18.

Ethnic diversity

Perhaps because of its geographical proximity to South-East Asia, Darwin is relatively ethnically diverse. ABS statistics indicate that 34% of the Northern Territory population speak a language other than English at home, including Aboriginal languages, Chinese, Greek and Indonesian. The 2006 Census shows that 30.6% of Darwin's population was born overseas, an increase from 28.6% in 1996 (ABS 2007a).

Age and sex ratio

The age structure of Darwin's population is much younger than that of the general Australian population (Figure 3-47), mainly because of the high turnover of the working-age population and the younger age structure of the Aboriginal segment of the population. There is a particularly high proportion of adults in the age 25–34 and age 35–44 categories in the Darwin region, and much lower proportions of senior and elderly people (age 55 and over) than the Australian averages. The median age of both males and females in the Northern Territory is 30 years, compared with the national median ages of 35 and 37 years for males and females respectively.

On the community level, there are proportionally more children (0–14 years old) and young adults (25–44) in the Palmerston – East Arm area than in Darwin City. The proportion of older people (age 45 and over) in the population is much higher in Darwin City (ABS 2007a).

There are generally more men than women throughout the Northern Territory, unlike the rest of Australia where women are slightly more numerous. In Darwin City, there are 106.6 males per 100 females, while there are 104.4 males per 100 females in Palmerston – East Arm (ABS 2007a).

Family structure

As suggested by the population age structures, there are more young families living in Palmerston – East Arm than in Darwin City, and both communities have more young families than the general Australian population. Some 56% of families in Palmerston – East Arm have children under 15 years old, compared with 43% for Darwin City and 40% for the whole of Australia.

3.6.5 Income support payments

A relatively small proportion of residents in Darwin City and Palmerston – East Arm receive income support from the government: 16% and 14% respectively, compared with the national average of approximately 23%. The proportion receiving the age pension is much lower, as would be expected considering the younger age structure in the Darwin region and Northern Territory.

The Newstart Allowance, which is available to those seeking employment, is received by a high number of people in the Northern Territory: 7.2% compared with 2.8% nationally. However, Newstart Allowance is only claimed by 3.8% of people in Darwin City and by

Table 3-18: Population estimates for the Darwin region for 2021 and 2051

	2004	2021		2051	
	Current population (thousands)	Lower growth estimate (thousands)	Upper growth estimate (thousands)	Lower growth estimate (thousands)	Upper growth estimate (thousands)
Darwin region	109.4	127.5 (16.5%)	164.8 (50.6%)	153 (39.9%)	295.5 (170.1%)
Northern Territory	199.8	215.3 (7.8%)	279.2 (39.7%)	224.3 (12.3%)	470.5 (135.5%)
Australia	20 091.5	22 988.4 (14.4%)	24 878.4 (23.8%)	24 864.5 (23.8%)	33 389.8 (66.2%)

Source: ABS 2008a.

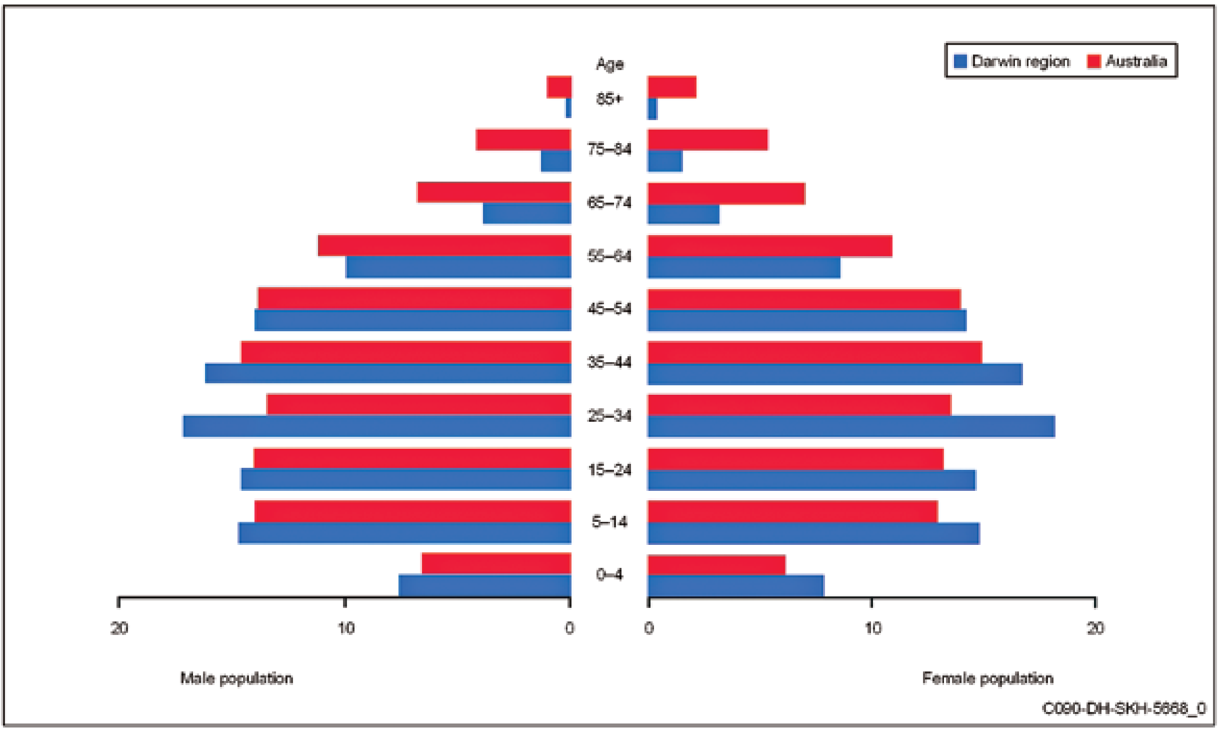


Figure 3-47: Population distribution by age in the Darwin region and Australia in 2006

2.8% in Palmerston – East Arm. This apparent high unemployment level is therefore likely to be affecting people in more remote areas of the Northern Territory.

3.6.6 Education and training profile

The Darwin City population shows a level of schooling similar to that of the overall Australian population, with 44% of people having completed Year 12 compared with the national average of 42%. Far fewer have completed senior school in Palmerston – East Arm (33%). The Northern Territory average is also low (33%) (ABS 2008b).

The Charles Darwin University (CDU) was formed in 2003 by a merger of the Northern Territory University, the Alice Springs-based Centralian College, the Northern Territory Rural College in Katherine, and the Menzies School of Health Research. The Menzies School of Health Research is a joint venture between the CDU, the Menzies Foundation and the University of Sydney and is located at the Royal Darwin Hospital, close to the university.

The CDU is a "dual-sector" university, which means that it offers courses from vocational education and training (VET) through to higher education undergraduate and postgraduate courses over a wide range of subjects and disciplines. There are campuses in both Casuarina and Palmerston, and courses are offered in business, the arts, education, health, science and technology.

3.6.7 Training

One of the aims of the Northern Territory's Department of Education and Training (DET)[7] is to build and expand the skills of the Northern Territory workforce, and it works with industry to improve the access of Territorians to the opportunities arising out of a growing economy. The DET provides a choice of over 390 industry apprenticeships and traineeships in the Territory and aims to achieve 10 000 apprentice and trainee commencements over four years. The Northern Territory's Employer Incentive Scheme, included in a range of strategies in the Northern Territory's Jobs Plan, provides eligible Territory employers with financial incentives aimed at promoting the uptake of additional apprentices and trainees.

The Department's 2007–2008 annual report highlights an increased uptake and completion of apprenticeships and traineeships following the implementation of a range of strategies to increase commencements, completions, and retention rates of apprentices and trainees. The number of apprentices and trainees in training increased from 2500 in 2002–03 to 3300 in 2007–08, with at least 2800 new commencements in 2007–08. A total of 317 Occupational Shortage Employer Incentives, valued at $4000 each, was allocated in 2007–08 to encourage employers to take on an apprentice in areas of occupational shortage (DEET 2008).

7 The Department of Employment, Education and Training became the Department of Education and Training in August 2008.

Training for Aboriginal and Torres Strait Islander people

The DET provides funding for training programs for Aboriginal and Torres Strait Islander people and provides opportunities for them to access VET. The programs include the following:

- The "flexible response funding" program, which delivers short training programs on site in the community, with content tailored to community projects or local enterprise development (DET 2009a)
- The "training for remote youth" program, which is aimed at bringing together youth that are disengaged from school and training organisations, to prepare them for employment in the community or re-engage them in further learning (DET 2009b)
- The "Indigenous training for employment program", which supports practical projects that ensure that adults in regional and remote areas can take up VET (DBE 2009).

The Indigenous Economic Development Taskforce, whose membership is drawn from national and Northern Territory Indigenous organisations, from industry, and from Northern Territory and Commonwealth government agencies, identifies opportunities for Aboriginal and Torres Strait Islander economic development in Northern Territory communities in 13 targeted industry sectors (Northern Territory Government undated).

3.6.8 Housing

Household size and status

The average household sizes in Darwin City and Palmerston – East Arm are 2.6 and 2.7 respectively for family and non-family households; this is very similar to the national average household size (ABS 2007a).

In 2006, most of the housing in Palmerston – East Arm consisted of separate dwellings (76.5%, compared with 12.3% semi-detached, terrace or townhouses and 10.1% units) (ABS 2007a). Townhouses and units are much more common in Darwin City, where a large number of high-rise residential apartment buildings have been constructed in recent years.

Housing availability

Demand for inner-city housing in Darwin has been continually increasing, driven by the migration of new workers in the mining, tourism and defence industries from interstate and overseas (Propell National Valuers 2008). Population growth as well as strong wages growth have caused house and rent prices to continue rising. In the June quarter of 2008 house prices grew at 3.51%, the highest rate in the country.

Demand for rental properties is extremely high, with rental vacancy rates at 1.3%. Median rents in inner Darwin increased by 14.2% to $480 per week for a three-bedroom house over the year to June 2008. Demand for rental properties in Palmerston is also high, with the median rent increasing by 18.3% to $360 over the same period (Propell National Valuers 2008).

Future housing developments

In 2008, it was noted that the Northern Territory's Department of Planning and Infrastructure (DPI)[8] was releasing approximately 300 new lots of land in the Darwin region every year and that this number might increase significantly in response to future population growth (Calacouras 2008).

New suburbs planned for development in the City of Palmerston from 2009 include Johnston, Mitchell, Bellamack and Zuccoli (Calacouras 2008; Northern Territory Lands Group 2009). The Berrimah Farm subdivision, located between Palmerston and Darwin was also intended to provide new lots of land for residential development (Northern Territory Government 2008a) but is currently being reconsidered along with other areas (Calacouras 2009).

3.6.9 Road traffic

Darwin and Palmerston

To characterise the existing traffic conditions and volumes on major roads in Darwin and Palmerston, and on Middle Arm Peninsula, URS conducted a traffic assessment in September 2008. Information on traffic volumes and vehicles was provided by the DPI, and data on turning movements at major intersections were collected through live traffic surveys conducted by Territory Asset Management Services. The main results of the study are summarised below, while the complete technical report (URS 2009f) is provided in Appendix 22 to this Draft EIS.

The road networks through the cities of Darwin and Palmerston are broadly structured around the Stuart Highway, a dual carriageway that runs approximately east–west. Tiger Brennan Drive is a major road which runs parallel to the Stuart Highway between Darwin and the suburb of Berrimah and then links with Wishart Road to continue as an alternative route to Palmerston. A number of north–south arterial roads connect Stuart Highway and Tiger Brennan Drive and then extend further into the suburban areas of Darwin and Palmerston (URS 2009f).

8 The Department of Planning and Infrastructure became the Department of Lands and Planning in December 2009.

Along the Stuart Highway, traffic volumes are heaviest near the Darwin CBD, with an average of 26 591 vehicles per day in 2007. Traffic volumes on the Stuart Highway decrease to around 17 000 vehicles per day in the vicinity of Palmerston. Speed limits vary on the highway between 60 km/h and 100 km/h (URS 2009f).

The city of Palmerston is based on a network of curvilinear collector and local roads, with intersections with Stuart Highway to the east. Chung Wah Terrace is the main collector road running through Palmerston. It connects to Channel Island Road and is a single carriageway with very few private access driveways and speed limits of 60–80 km/h. Average traffic volumes on the main collector roads in Palmerston were around 5000–7000 vehicles per day in 2007 (URS 2009f).

Berrimah Road provides a key link between East Arm Wharf and the Stuart Highway and also intersects Tiger Brennan Drive and Wishart Road. It is a single carriageway with speed limits of 60–80 km/h. The road condition is poor in some parts, although Berrimah Road is currently undergoing major redevelopment. A relatively high proportion of commercial vehicles (28%) utilise this road at its southern end near East Arm Wharf (URS 2009f).

Channel Island Road is the main access road along Middle Arm Peninsula and is a rural single-carriageway road with speed limits of 80–100 km/h. It links with Wickham Point Road, which provides access to Blaydin Point and the Project's onshore development area. Channel Island Road is connected to Palmerston by the single-carriageway Elizabeth River Bridge (URS 2009f).

Quarry traffic

Sources of hard rock (e.g. for rock armouring) in the region include quarries at Mount Bundy, 100 km east of Darwin along the Arnhem Highway, and Katherine, 300 km south of Darwin on the Stuart Highway.

The Arnhem Highway is a Northern Territory arterial road which connects Darwin to Kakadu National Park. The route from Darwin to Mount Bundy passes through freehold land, Djukbinj National Park and Defence land (Mount Bundy Training Area), as well as the towns of Corroboree Park and Humpty Doo. The Arnhem Highway carries mainly light-vehicle traffic from locals, tourists and Defence personnel. Heavy-vehicle traffic includes freight trucks and vehicles servicing the Ranger Uranium Mine near Jabiru. The highway is subject to flooding at some points during the wet season and can be closed for a few days at a time.

The Stuart Highway is a National Highway. The route from Katherine to Darwin passes through freehold land, towns (Pine Creek, Hayes Creek, Adelaide River, Acacia and Noonamah), the Manton Dam Recreation Area, and the Aboriginal lands of Jawoyn, Barnjarn, Wagiman and Larrakia. The Stuart Highway carries heavy commercial vehicles (e.g. road trains), light commercial vehicles (e.g. courier vans), tourist vehicles (e.g. coaches and caravans), and local light-vehicle traffic. It is a high-use road, especially in the dry season, as it connects Darwin to other major cities and regional centres.

From Humpty Doo into Darwin, both quarry routes use the Stuart Highway, through rural-residential land to the outskirts of Palmerston, and through medium commercial and residential areas from Palmerston through to Berrimah Road. The route to East Arm Wharf passes a school (Kormilda College), many commercial premises and the Darwin Railway Station. The route to Blaydin Point passes through some residential areas in Palmerston (via Lambrick Avenue and Chung Wah Terrace) and leads on to Channel Island Road, which carries mainly commercial traffic to the Channel Island Power Station, aquaculture areas and the Darwin LNG plant.

3.6.10 Maritime traffic

The Port of Darwin contains well-established trading and recreational facilities that receive a wide variety of vessels ranging from small pleasure boats to commercial tankers. The port boundaries encompass all parts of Darwin Harbour (including East Arm, Middle Arm and West Arm) and extend into Beagle Gulf. Facilities and trade at the Port of Darwin are described in more detail in Section 3.7.5 *Industrial infrastructure and services*.

Vessel traffic in the port has been increasing since 2004, as shown in Figure 3-48. Most maritime traffic is made up of non-trading vessels such as naval vessels, research and recreational craft, fishing and fishing supply vessels, and pearling industry support vessels. Trading vessels are commercial ships carrying cargo or passengers, and include rig tenders, tankers, livestock carriers, bulk-cargo vessels, barges and cruise vessels (Darwin Port Corporation 2009).

In 2008–09, the main types of non-trading vessels utilising the port were fishing and prawning boats (92%) followed by other small vessels such as patrol boats (3.6%). Trading vessels mainly consisted of barges and stone-dumping vessels (36%) and rig tenders (32%), while bulk-liquid tankers (e.g. petroleum tankers) represented 7% of all vessels (Darwin Port Corporation 2009).

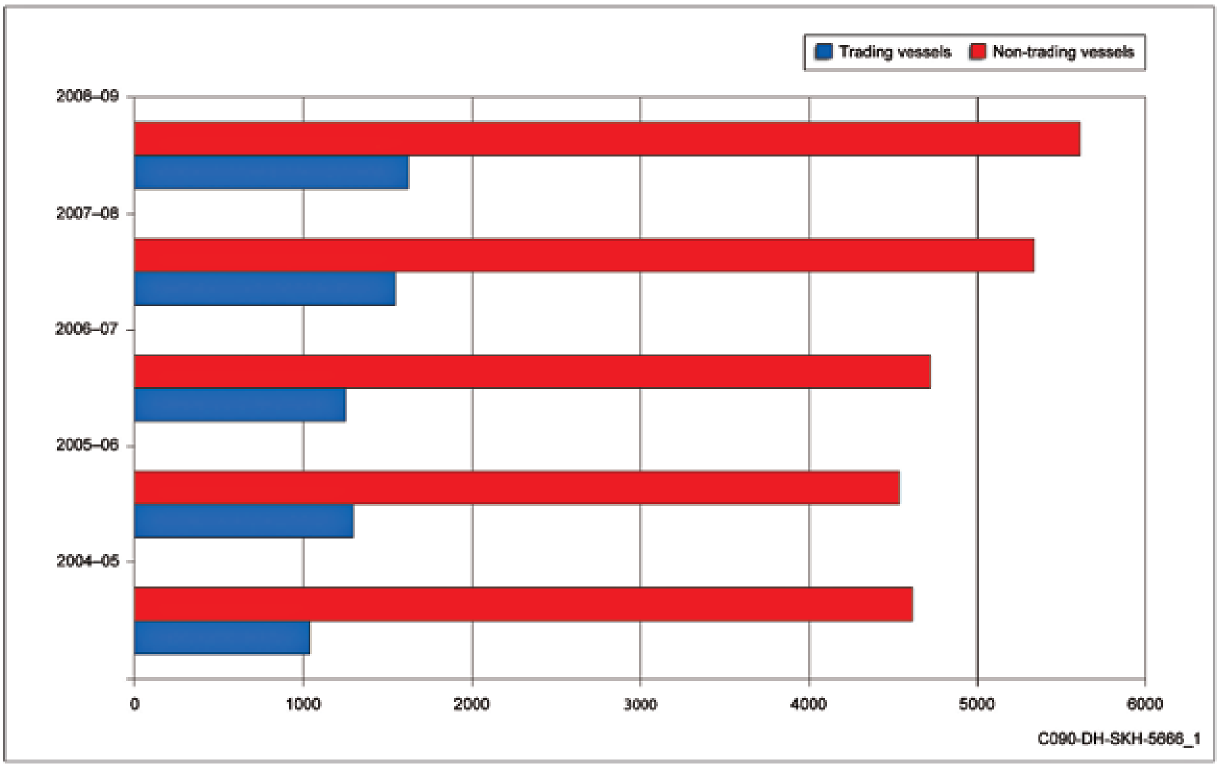
3.6.11 Social infrastructure and services

The major community facilities and services available in Darwin and Palmerston are as follows:

- two hospitals—the Royal Darwin Hospital (350 beds) and Darwin Private Hospital (87 beds)
- specialist health services including mental health programs, aged and disability programs, alcohol and other drug programs, oral health services, audiology and hearing health services, women's health programs, cancer screening, child protection and family support programs
- two privately run nursing homes and a palliative-care centre
- a mixture of 37 government- and privately operated childcare centres, which had 3631 places in 2006–07 (DHCS 2007)
- four police stations and four fire stations, serviced by the Joint Emergency Services Communications Centre
- sewage treatment and disposal services, administered by the Power and Water Corporation
- land-based transport infrastructure including the Stuart Highway and AustralAsia Railway
- shipping transport infrastructure at Darwin
- airport infrastructure at the Darwin International Airport, out of which several airlines operate (including Qantas, Jetstar, Garuda, Airnorth, Virgin Blue and Skywest)
- public bus transport services, including special services for schools, people with disabilities and the elderly
- entertainment and cultural facilities including the Darwin Entertainment Centre, Darwin Convention Centre, Northern Territory Museum and Art Gallery and the Darwin Botanic Gardens
- sports and racing facilities including the Marrara Sports Complex, TIO Stadium, Darwin Turf Club and the Hidden Valley Motorsports Complex
- telecommunications services including landline, mobile phone and satellite phone services, and broadband internet. Service providers include Telstra, Optus and Vodafone
- a number of television networks, including ABC, SBS, Channel Nine, Southern Cross Television (SCTV—formerly Channel Seven), and AUSTAR pay television
- a number of radio stations, including ABC, commercial and community-based stations.

3.6.12 Recreation

Lifestyles in the Northern Territory are often described as "laid-back" or "relaxed", and are characterised by outdoor-based activities. Popular recreational activities in the Darwin region include fishing, sailing, waterskiing, swimming, camping and off-road driving.



Source: Darwin Port Corporation 2009.

Figure 3-48: Annual number of vessels visiting the Port of Darwin

Darwin Harbour is a prime recreational and tourism resource for the region. The qualities and resources of the Harbour make it an aesthetically beautiful place with high recreation values. Fishing, boating, scuba-diving, sailing, waterskiing and beach use are popular activities. A 1997 survey on Darwin Harbour visitation found that 50% of respondents (out of 700) visited the Harbour once a week or more (Brown & Reynolds 1997).

The Northern Territory has the highest rate of fishing-club membership in Australia. The National Recreational Fishing Survey conducted in 2000 suggested that over of 540 000 hours were spent fishing in the Darwin region during the survey year, half of these by Darwin residents and half by visitors to the region. Around one-third of all fishing effort occurs in Darwin Harbour (Coleman 2004). The amount spent by tourists and locals on recreational fishing in the Northern Territory is estimated to be nearly $35 million per year. This does not include the many fishing-tour operators, most of whom operate out of Darwin. Because of the risks from saltwater crocodiles and tidal surges, most fishing is conducted by boat.

Species commonly fished in Darwin Harbour include snapper, mud crab and small baitfish, as well as barramundi and some game fish. There are four marinas for private boats in Darwin Harbour: these are Cullen Bay Marina, Tipperary Waters Marina, Bayview Marina and the Frances Bay Mooring Basin.

3.6.13 Aboriginal cultural heritage

Archaeology

Archaeological surveys were undertaken throughout Middle Arm Peninsula by Earth Sea Heritage Surveys in October 2007 (Bourke & Guse 2007). The majority of the archaeological sites and objects recorded in the area are associated with past Aboriginal use of marine resources and are located within 300 m of the shoreline.

Middle Arm Peninsula is within the traditional country of the Larrakia people. Subsistence activity for this group of Aboriginal people was concentrated in areas close to sources of water and raw materials suitable for stone artefact manufacture, such as creeks, waterholes, ridges and hills. The meeting points between tidal areas or the mangrove zone and the adjacent higher ground regularly yield archaeological artefacts from Aboriginal activities.

There are approximately 117 previously recorded archaeological sites located on Middle Arm Peninsula west of the Elizabeth River Bridge (Bourke 2005; Bourke & Guse 2007; Crassweller 2006). The majority contain shells of the mollusc *Anadara granosa* either as a midden (mound of debris) or a scatter. The gastropod *Telescopium telescopium* is often the dominant shell present in the shell scatters. Around one-third of the sites also have stone artefacts present on the surface. Eight sites and one isolated artefact are located close to, or within, the boundary of the onshore development area (Figure 3-49).

Places of cross-cultural engagement are generally referred to by archaeologists as “contact period” sites. Very few of these types of sites have been documented for the Darwin region, and two have been recorded on Middle Arm Peninsula. One of these is located close to the proposed access road to Blaydin Point (labelled “Shell and glass scatter” in Figure 3-49), and contains dark green bottle glass that has been modified for use by Aboriginal people. Research at this site could provide information on continuity and change in Aboriginal occupation in the region over many hundreds of years, and on the incorporation of new technological products, such as European glass, into existing Aboriginal systems (Bourke & Guse 2007).

There are no archaeological or historical sites recorded on either the Register of the National Estate or the National Heritage List located in the vicinity of the onshore development area, nor any heritage places and objects recorded on the Northern Territory Heritage Register.

Sacred sites

The Aboriginal Areas Protection Authority (AAPA) identified six sacred sites in the vicinity of the nearshore development area (Figure 3-50). Sacred sites are surrounded by “restricted works” areas in which, under the provisions of the *Northern Territory Aboriginal Sacred Sites Act* (NT), no land or maritime development works of any kind are allowed.

One of the identified sacred sites is located approximately 2.4 km north-west of Blaydin Point in the waters of Darwin Harbour (Figure 3-50). This site is known as “Yirra” and features in a Dreamtime story about the Kangaroo. Yirra was described as part of the EIS developed by the Phillips Oil Company Australia for the Darwin LNG plant (Dames & Moore 1998), as follows:

> This story involves the Dreaming Kangaroo, who was travelling north fleeing people who did not speak his language. As the Kangaroo travelled northwards he hopped across from the land south of what is now known as Middle Arm, landing on the dry land on Wickham Point. By this stage the Kangaroo was exhausted from being chased for so long but knew he had to get to the East Arm side of the mainland to be safe. His only choice was to jump to the other side, and in doing so he realised he would never make it. Just as he was going to go down into the water, Yirra Island came up for him to rest his foot on.

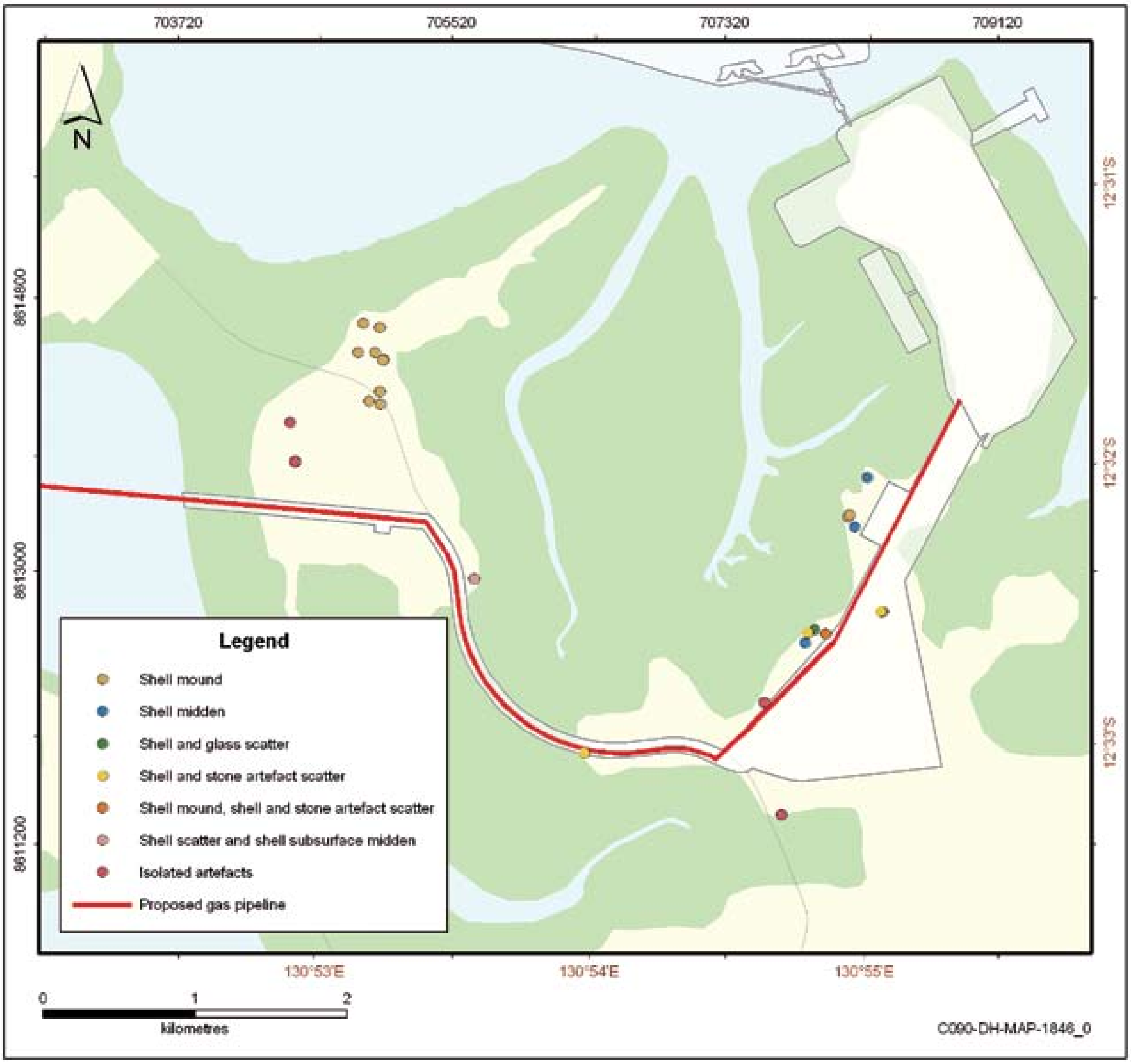


Figure 3-49: Aboriginal heritage sites in the vicinity of the onshore development area

The area of water around the island is believed to be dangerous; people approaching should do so in a certain way so that the Kangaroo does not thrash its tail and swamp their boats. The sand bars extending from the island represent the tail of the Kangaroo. Aboriginal families utilise the area for fishing and foraging and to pass their knowledge of this Dreamtime story on to their children (Dames & Moore 1997).

Other sacred sites in the vicinity of the subsea pipeline route include three rocky areas or shoals on the western side of the Harbour, and an underwater sand and rock bar outside the mouth of the Harbour north of Cox Peninsula.

3.6.14 Non-Aboriginal cultural heritage

Terrestrial heritage sites

There are several non-Aboriginal historical sites on Middle Arm Peninsula. These are related to World War II activities in the area and consist of five anti-aircraft searchlight batteries, one heavy anti-aircraft battery and the remains of the Z Force commando training camp that was mostly removed during the construction of ConocoPhillips' Darwin LNG plant (Bourke & Guse 2007; Crassweller 2001a, 2001b, 2002).

Three sites have been identified as non-Aboriginal historical sites within the onshore development area. The first site is located on the north headland of Blaydin Point and consists of a number of features relating to World War II occupation (Figure 3-51).

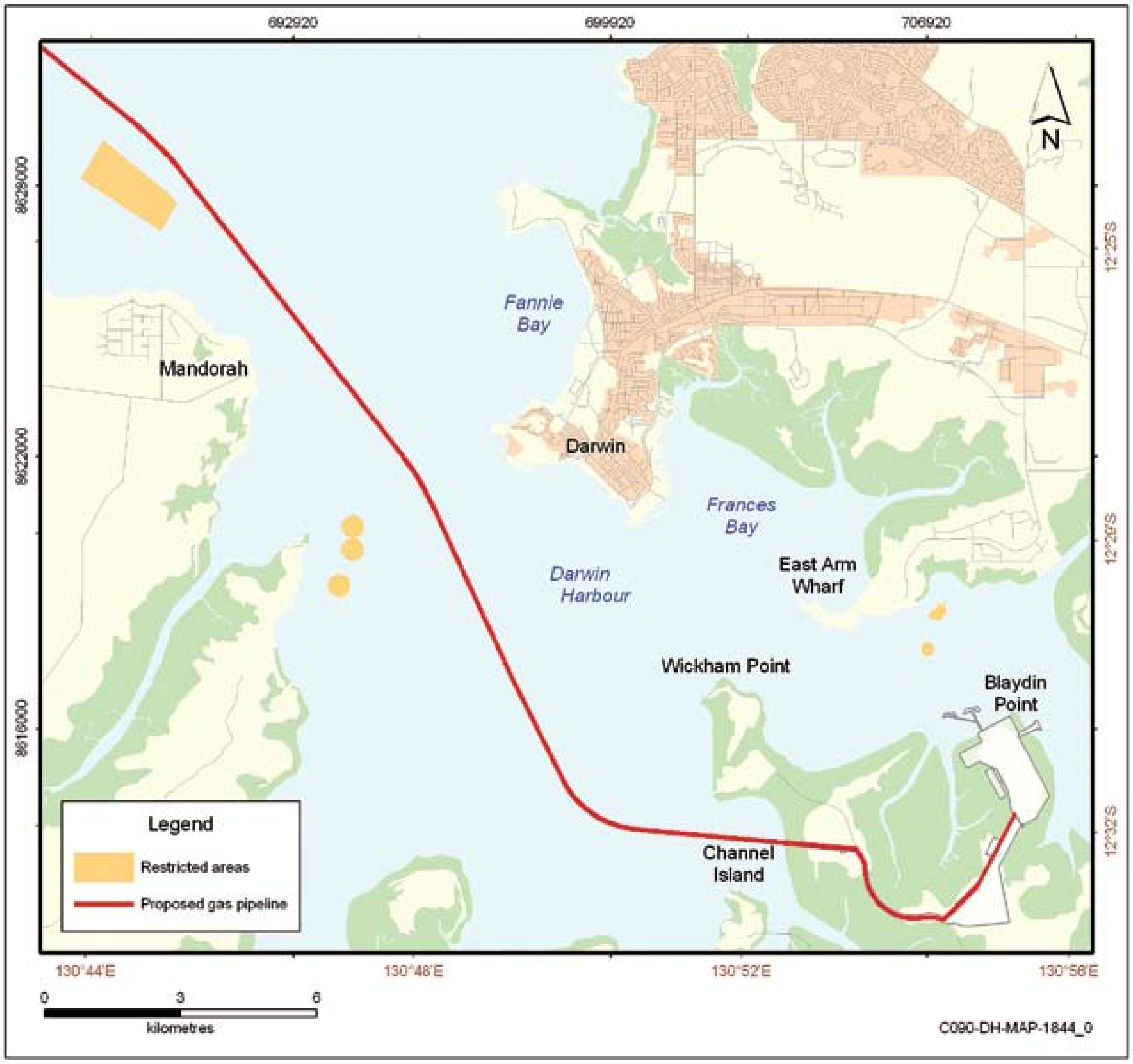


Figure 3-50: Aboriginal sacred sites in the nearshore development area

These include several concrete slabs, a possible searchlight foundation, a bomb-shelter trench and buried refuse pits containing postwar and World War II materials. In addition, two communication insulators and wire were found in trees south of the main site (Bourke & Guse 2007).

Maritime heritage sites

Maritime heritage sites in the vicinity of the nearshore development area are presented in Figure 3-51, and were located through literature review, geophysical surveys and follow-up diving surveys.

In February and March 2008, Fugro conducted geophysical surveys of the seabed in the nearshore development area (including the pipeline route through Darwin Harbour) to characterise seabed types and bathymetry for nearshore engineering purposes. The survey utilised a differential global positioning system (accuracy to 0.5 m or better), a Geoswath multibeam echo sounder and sidescan sonar system, a single-beam echo sounder and a boomer sub-bottom profiler. In addition to natural seabed features, the survey identified debris and wrecks on the seabed on 1:5000 scale drawings. Data were collected throughout the proposed disturbance area for the Project, up to the edge of mangroves and into minimum depths of 4.3 m above LAT. Small gaps of incomplete coverage occurred on very shallow sections of the intertidal flats and at a rocky shoal to the west of South Shell Island (Fugro 2008).

Where suspected wrecks or debris were identified by the geophysical survey, follow-up diving surveys were undertaken by TVDS to investigate the seabed feature. While some of these locations were natural features (rock ledges or sinkholes), others were confirmed as wreck sites (TVDS 2008). One such site, on closer

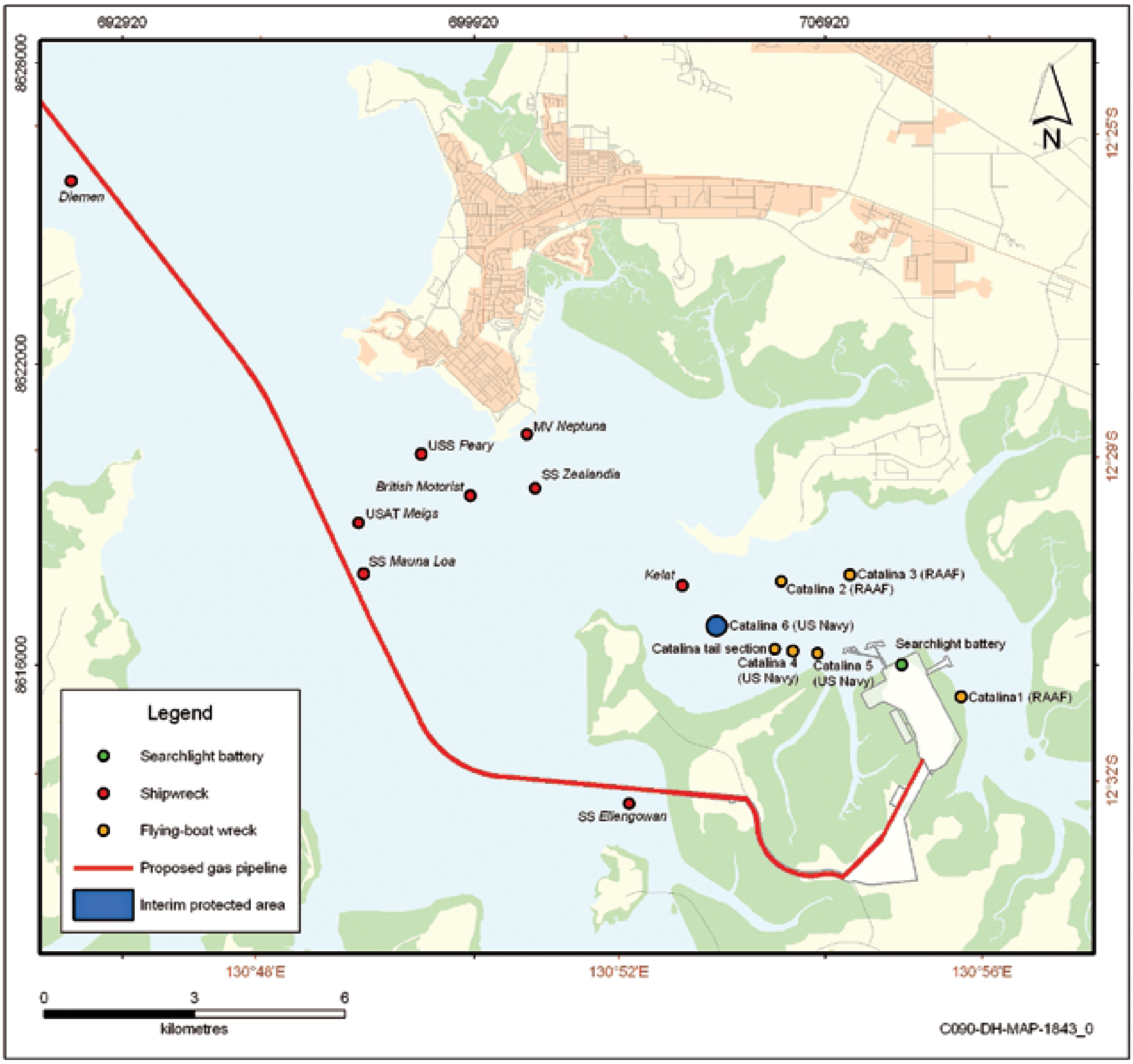


Figure 3-51: Non-Aboriginal heritage sites in the vicinity of the nearshore development area

inspection, was believed to be the wreck of a World War II Catalina flying boat from the United States Navy, and represented the first discovery of this particular heritage site (Catalina 6 in Figure 3-51). The discovery was reported to the Heritage Branch of NRETAS in May 2008.

In total, six Catalina flying-boat wrecks are located in the vicinity of the nearshore and onshore development areas. Three of the Catalinas were brought to Darwin by the United States Navy during World War II and were sunk during the Japanese air raids in February 1942. These wrecks (two PBY-4 Catalinas and one PBY-5) are protected by the United States *Sunken Military Craft Act* 2005 as well as by customary international law.

The other Catalinas (of the PBY-5 series) were owned and operated by the Royal Australian Air Force (RAAF) and were sunk in accidents. One of these ("Catalina 1") crashed on take-off in 1945, and is located in the mangroves on the east side of Blaydin Point.

The Heritage Branch of NRETAS has indicated that there may be heritage values associated with all the Catalina wrecks, and these are currently under assessment. An "interim conservation order" was placed on the newly discovered wreck of Catalina 6, under the *Heritage Conservation Act* (NT), in February 2009.

A number of other World War II shipwrecks are located near the pipeline corridor through Darwin Harbour, including the SS *Mauna Loa*, the tanker *British Motorist*, the USAT *Meigs*, the MV *Neptuna*, the SS *Zealandia* and the USS *Peary*. These were sunk as a result of a raid by Japanese forces on Darwin Harbour in February 1942.

The prawn trawler *Diemen* is also located in this area; it was sunk during Cyclone Tracy in 1974.

The SS *Ellengowan* is the oldest known shipwreck in Darwin Harbour and is one of the earliest examples of shipping associated with European settlement in the area. It is a unique example of nineteenth-century maritime history in the Northern Territory and its conservation values are rated highly because of its age and construction. It is one of only two known examples of transitional sail–steam iron-hull schooners (NRETA 2007b). As it is more than 75 years since the date of its loss (in 1888), the SS *Ellengowan* is protected under the *Historic Shipwrecks Act 1976* (Cwlth) and the *Heritage Conservation Act* (NT). It was placed on the Northern Territory Heritage Register in 1995. The wreck is located south of the proposed pipeline shore crossing for the onshore processing plant.

The wreck of the coal barge *Kelat*, built in 1881, is also located near the nearshore development area. It was damaged during the Japanese air raid on Darwin in 1942 and sank five days later.

3.6.15 Noise

Noise emissions in the Darwin and Palmerston areas are typical of urban areas with moderate to high levels of development. Major noise sources that commonly affect the community include traffic, noise from industrial or construction sites, and occasional aeroplane traffic from Darwin International Airport and RAAF jets flying through the area.

As part of the environmental impact assessment for the Project, ambient noise levels were measured by SVT Engineering Consultants in May 2008 at two locations selected in consultation with NRETAS (SVT 2009b) (see Appendix 20 for the full report). These sites are considered representative of residential areas in Darwin and Palmerston:

- O'Ferrals Road, Bayview Haven—approximately 2.5 km to the north-east of the Darwin CBD and 10 km to the north-west of the onshore development area
- Constance Court, Palmerston—approximately 5.5 km to the north-east of the onshore development area.

The $L_{A\,90}$, the noise level exceeded for 90% of the time, recorded at O'Ferrals Road was 37.3 dB(A), while the $L_{A\,10}$, the noise levels exceeded for 10% of the time, could rise to 43.5 dB(A) on occasion. At Constance Court the $L_{A\,90}$ was 39.9 dB(A), rising to an $L_{A\,10}$ of 48.9 dB(A).

The noise-logging data at both locations were very consistent throughout the fortnight monitoring period, indicating stable weather conditions. The results also showed a daily cycle of higher noise levels during the day and lower levels at night, typical of human activity patterns in urban environments (SVT 2009b). For reference, noise levels of 60 dB can be generated by normal conversation between people, 80 dB would be generated by heavy traffic and 90 dB would be emitted from a lawn mower.

3.6.16 Aesthetics and light

The visual amenity of Darwin Harbour is an important community value, which is closely linked with the recreation, tourism and residential values of the area. The shoreline around the Harbour contains relatively large tracts of undeveloped land, mainly comprising tidal flats vegetated by mangrove stands. The shoreline of Middle Arm is almost completely undeveloped, while some residential, industrial and infrastructure development has been undertaken along the shores of East Arm.

Major man-made features of the shoreline in the Harbour include the following:

- ConocoPhillips' Darwin LNG plant on Wickham Point approximately 5 km to the west of Blaydin Point
- East Arm Wharf on the northern shoreline, approximately 3 km away from Blaydin Point across the waters of East Arm
- Darwin's CBD on the eastern side of the mouth of the Harbour
- suburban developments from Darwin in the north to Palmerston in the east of the Harbour shoreline. A small residential area also exists in Mandorah, on the western side of the mouth of the Harbour.

These man-made features also represent the major sources of artificial light around the Harbour, along with beacons throughout the Harbour that are used for shipping navigation. These light sources contribute to an overall light "glow" from the city area which is visible (if very faintly) from up to 40 km away.

3.7 Economic environment

This section describes the current economic conditions in the Northern Territory, particularly the Darwin region, with reference to the national Australian economy.

3.7.1 National oil and gas industry

Australia has in recent years experienced growth in oil and gas exploration and production in order to meet increasing demand for energy, particularly from overseas markets. Australia is the world's fifth-largest LNG exporter after Qatar, Malaysia, Indonesia and Algeria. According to EnergyQuest, Woodside expects LNG demand to double over the next 10 years while forecast supply has been lowered (AER 2007). Energy export projects are being developed at a rapid pace in north-west Western Australia and the Northern Territory.

The majority of the known natural gas reserves in Australia are found offshore from central and north-west Western Australia in the Carnarvon, Browse and Bonaparte basins. Existing exploration and production in these three areas may be summarised as follows:

- Carnarvon Basin: located in the Indian Ocean, this area holds about 60% of Australia's known conventional natural gas reserves and currently accounts for about 34% of gas produced for the Australian domestic market. The North West Shelf Joint Venture converts some gas produced from the Carnarvon Basin to LNG gas for export (646 PJ in 2005–06).
- Browse Basin: located in the Indian Ocean, this area contains significant contingent gas resources (i.e. resources that are potentially recoverable but only if a number of contingent hurdles are overcome) estimated at 31 000 PJ. INPEX's Ichthys Field lies in the Browse Basin.
- Bonaparte Basin: located in the Timor Sea, this area is estimated to contain a contingent resource of about 19 500 PJ, which is shared between Australia and East Timor. The Bayu–Undan gas and condensate field was the first field in the basin to produce gas, which is processed for export at ConocoPhillips' Darwin LNG plant. In September 2009 the Blacktip Field, operated by Eni Australia B.V., commenced production and Eni's gas-processing plant at Wadeye is now supplying domestic gas to the Northern Territory.

Smaller gas-producing areas around Australia include the Gippsland Basin in Victoria, the Cooper–Eromanga Basin in South Australia and Queensland, the Perth Basin in Western Australia, and the Bowen–Surat Basin in Queensland (ABARE 2008).

Production of natural gas in Australia is predicted to increase by 217% between 2004 and 2030 to meet growth in both domestic and international demand. Demand for gas is expected to be strong in the electricity generation, manufacturing and mining sectors, partly as a result of government climate change policy initiatives that favour natural gas use over coal. Projections of Australian natural gas production suggest that by 2029–30 total production will reach 5343 PJ, with 3650 PJ exported as LNG (Table 3-19) (Cuevas-Cubria & Riwoe 2006). This would make natural gas the fastest growing of all Australia's energy exports.

Table 3-19: Australian gas production projections

	2004–05	2029–30
Natural gas production	1685 PJ	5343 PJ
Net exports of LNG	576 PJ	3650 PJ

Source: Cuevas-Cubria and Riwoe 2006.

The majority of large importers of LNG are in the Asia-Pacific region, giving Australia a natural advantage in terms of short distance to key markets. In 2007, Australia exported LNG mainly to Japan and China, with smaller volumes exported to South Korea and Taiwan (BP 2008).

3.7.2 Darwin regional context

As described in Section 3.6.1 *Description of baseline*, the socio-economic baseline for this study has been defined by the ABS statistical subdivisions of Darwin City and Palmerston – East Arm (see Figure 3-46), which are the two major population centres in the Darwin region. Background data on the economic environment in these areas are provided in the following section.

Labour force

In 2006, the labour force in Darwin City totalled 38 998 people, with a labour force participation rate of 65.6% (ABS 2007a). This is higher than both the Northern Territory and Australian participation rates of 64.2% and 60.4% respectively, and indicates a strong working population. Over the ten years to 2006, the labour force of Darwin has grown by only 800 persons, or 2.1%, while employment has increased by 2277 jobs and unemployment has more than halved. This indicates that many people in the labour force have benefited from an increase in jobs available, with almost 1500 people moving out of unemployment. As of 2006, the unemployment rate in Darwin stood at 3.6%, below the rate of 5.2% experienced overall in Australia. In fact, over time Darwin has tended to have lower unemployment than other areas of Australia—this has been the case in all three population censuses since 1996 (ABS 2007a).

The labour force statistics for Palmerston – East Arm are indicative of an area undergoing rapid expansion. Palmerston began to be developed in the 1980s as the supply of residential land in Darwin started to diminish, and it is now the primary urban development area of the Darwin region. The total population of Palmerston – East Arm almost doubled between 1996 and 2006 (ABS 2007a). In 2006, there were 11 406 people in Palmerston – East Arm participating in the labour force, with a participation rate of 66.2%—even higher than the participation rate in Darwin. Between 1996 and 2006, the Palmerston – East Arm labour force grew by 90.4% and the number of people employed effectively doubled. Over the same period, unemployment fell from 8.7% to 4.1%, below the Australian average of 5.2% but still slightly above Darwin's rate of 3.6% (ABS 2007a).

Employment by industry

City of Darwin

Employment in the City of Darwin is spread across a range of areas, with a particular focus on the service industries (such as finance, hospitality, real estate, and administration). The largest industry employer in 2006 was in the area of public administration and safety, which employed 7172 people (ABS 2007a) (see Figure 3-52). There is a large ADF presence in Darwin, and it is likely that many of those people employed in public administration and safety are associated with the ADF. As Darwin is the seat of government for the Northern Territory, there are also many government officials located in the city.

For many Territorians, Darwin is a regional hub where people come to shop, to access specialised health services, or to study at the senior schools or university. For this reason there are high levels of employment in the retail trade (3563 people), health care and social assistance (3519 people), and education and training (3268 people). Given Darwin's attraction as a tourist destination, the employment of 2560 people in the accommodation and food services industry is not surprising. There is also a strong construction industry (2665 people) (ABS 2007a).

Over the past decade in Darwin City, only the public administration and safety sector has shown a significant change in employment, with an increase of nearly 22% between 2001 and 2006 (ABS 2007a). Some growth has also occurred in education and training, transport, postal and warehousing, and retail trade. The construction sector has experienced some employment volatility since 1996, with employment falling sharply by 30.4% between 1996 and 2001, but rebounding by 41.2% by 2006 (ABS 2007a). This is consistent with the cyclical impacts when major projects end and new ones begin.

Palmerston – East Arm

Like Darwin, the largest industry employer in Palmerston – East Arm is public administration and safety—in 2006, nearly 1 in 4 people were employed in this industry (2593 people). As with Darwin, much of this employment can be attributed to the defence

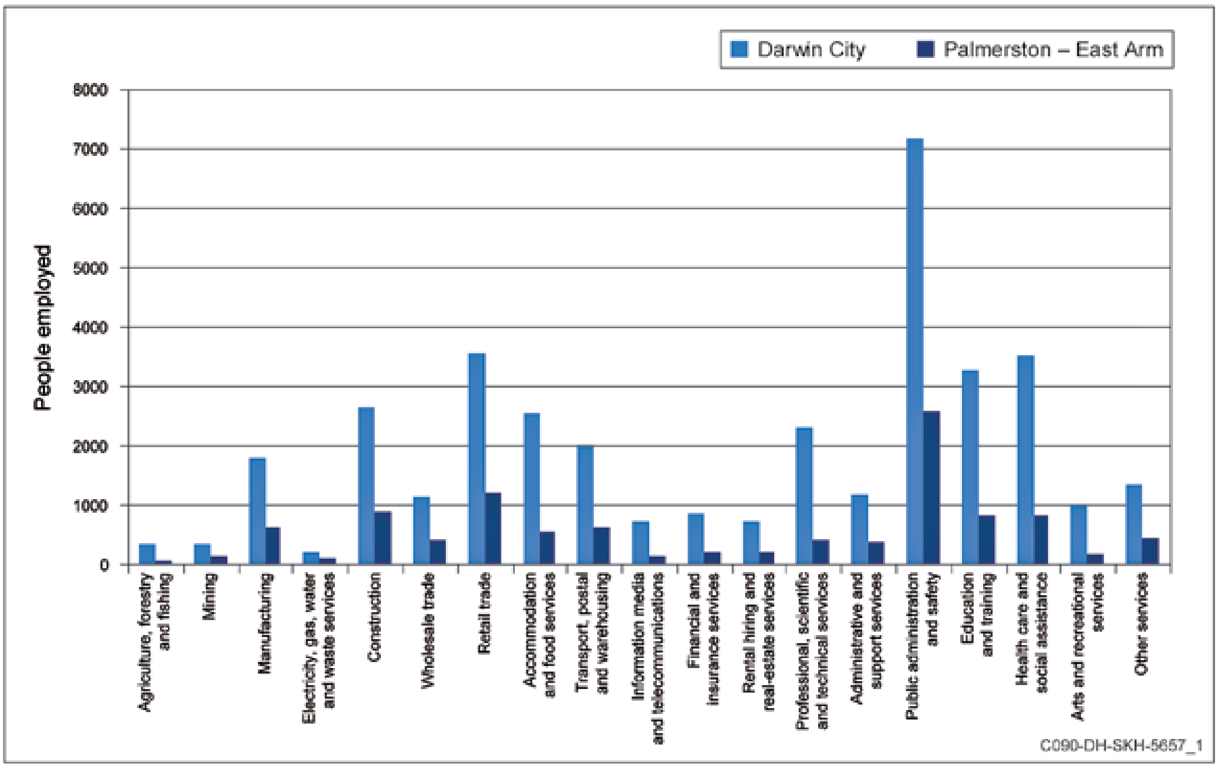


Figure 3-52: Employment by industry in 2006 in Darwin City and Palmerston – East Arm

sector, in particular to the Robertson Barracks situated near Palmerston. Other important industries in Palmerston – East Arm include the retail trade (1193 people), construction (881 people), health care and social assistance (832 people) and education and training (829 people) (see Figure 3-52) (ABS 2007a).

Over the past decade, all industry sectors in Palmerston – East Arm experienced an increase in the total number of people employed, although rates of growth varied. Public administration and safety experienced the largest rate of employment growth (ABS 2007a).

Employment by occupation

The spread of occupation types in Darwin City is very similar to the Australian average. In 2006, professionals were the largest employment category, followed by clerical and administrative workers, technicians and trades workers, managers, and community and personal service workers, among others (see Figure 3-53) (ABS 2007a).

In the ten years to 2006, the proportions of people in each occupation category has changed very little. There was a drop in the number of technicians and trades workers, and machinery operators and drivers, in line with the general downward trend around the Northern Territory and Australia (ABS 2007a).

Palmerston – East Arm is characterised by lower proportions of professionals and managers than Darwin, the Northern Territory and Australia. In 2006, clerical and administrative workers made up the largest employment category by occupation, followed by technicians and trades workers, and community and personal service workers (Figure 3-53) (ABS 2007a).

Over the ten years between 1996 and 2006, the number of community and personal service workers in Palmerston – East Arm has more than doubled. This increase is likely to be partly attributable to the inflow of defence personnel between 1996 and 2001 when the Army Presence in the North (APIN) program was very active and personnel were being transferred to the area from elsewhere in Australia.

Wealth and incomes

In 2005–06, the mean household income per week in the Darwin region was $1675, which is higher than the Australian average of $1410 per week (ABS 2007b). Disposable household income was also higher at $730 per week, compared with $678. These results are likely to be in part attributable to the younger population and larger working population in the area. The proportion of households in the area receiving government pensions or allowances as their main source of income was the lowest in the country, at 8.5% of total households. This estimate has a large standard error of 25–50% and should not be considered reliable. However even if the proportion of households receiving government pensions was doubled, Darwin would still have the second-lowest proportion of such households in the country, behind Canberra (ABS 2007b).

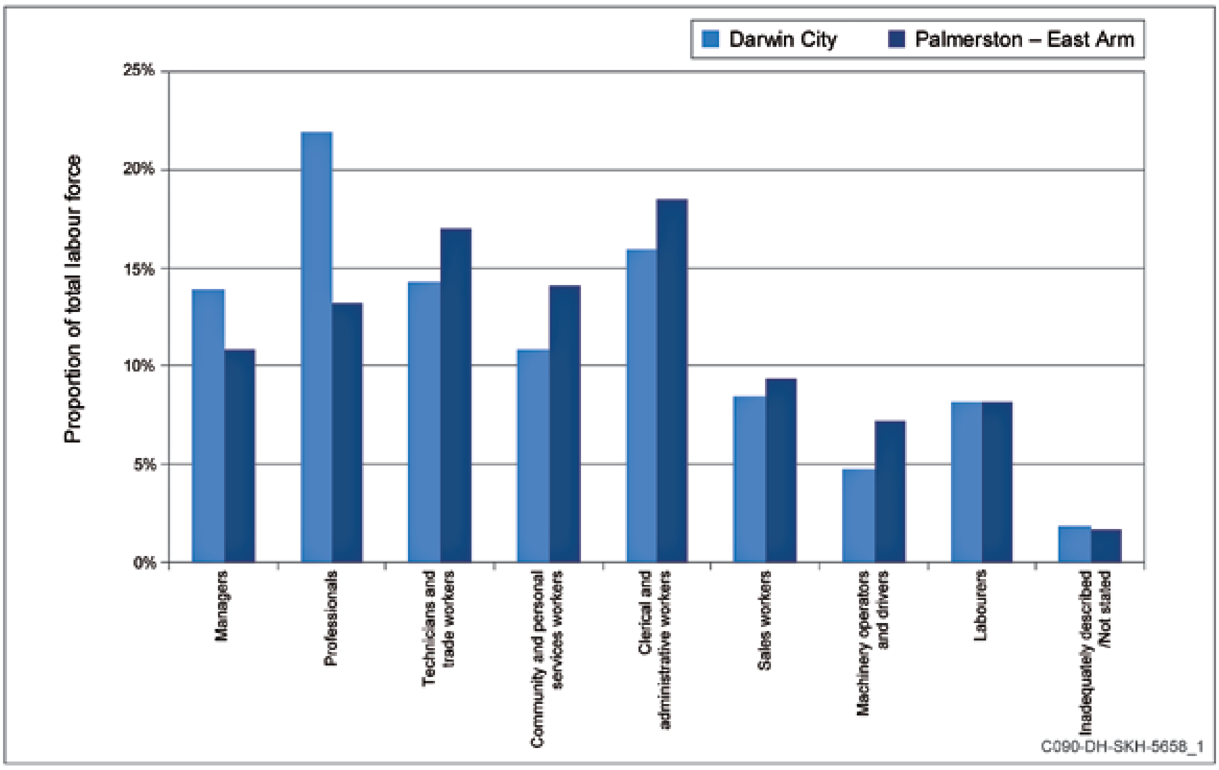


Figure 3-53: Employment by occupation type in Darwin City and Palmerston – East Arm, 2006

Despite these relatively high levels of income, the population of the Darwin region is not necessarily "wealthy". Mean household net worth, an estimate of a household's assets such as property and investments, was the lowest in the country, at $411 569. This finding would be related to Darwin having the highest proportion of renters in the country (38.6% of total households) (ABS 2007b). In addition, the number of Darwin households in 2006 experiencing one or more cash-flow problems is higher than the national average, at 22.7% compared with 17.6% nationally (ABS 2007c). Cash-flow problems include being unable to pay telephone bills on time or having to borrow money from friends or family.

3.7.3 Regional industry

The Northern Territory has a relatively diverse economy, with a strong reliance on the mining industry. "Value added" is a measure of output, and refers to the additional value of a commodity over the cost of commodities used to produce it from the previous stage of production. In the Northern Territory economy, over a quarter of value added comes from mining; however the service industries (e.g. finance, hospitality, real estate, administration) also play a major role in the economy. Other industries of importance include construction, government administration and defence, and manufacturing (Table 3-20) (ABS 2007d).

Further discussion on key industries from the Darwin region is provided below. These industries are particularly relevant to the Project as they utilise Darwin Harbour and include Defence, tourism, fishing, construction, manufacturing, and transport.

Table 3-20: Northern Territory value added by industry, 2006–2007

Industry sector	Value added 2006–2007 ($ million)	Percentage of total industry value added
Agriculture, forestry and fishing	301	2.4
Mining	3 284	25.8
Manufacturing	719	5.7
Electricity, gas and water	167	1.3
Construction	985	7.7
Wholesale trade	265	2.1
Retail trade	551	4.3
Accommodation, cafes and restaurants	329	2.6
Transport and storage	554	4.4
Communication services	273	2.1
Finance and insurance	297	2.3
Property and business services	964	7.6
Government administration and Defence	1 039	8.2
Education	541	4.3
Health and community services	706	5.5
Cultural and recreational services	203	1.6
Personal and other services	278	2.2
Rental property (residential)	1 268	10.0
Total industry gross value added	**12 724**	**100.0**

Source: ABS 2007d.

Defence

The Australian Defence Force has a key presence in the Northern Territory, with around 5600 personnel stationed there in 2006. This represents approximately 10% of the total operational personnel of the ADF. When the families of personnel are included, the total number of people associated with the ADF in the Northern Territory is over 13 000, or 6.5% of the Northern Territory population. All ADF operations in northern Australia, including north Queensland and northern Western Australia, are controlled by Headquarters Northern Command in Darwin. Robertson Barracks in Palmerston is the largest armoured fighting vehicle base for the ADF. Other key defence facilities in and around Darwin include Larrakeyah Barracks, the naval base HMAS *Coonawarra*, Defence Establishment Berrimah and RAAF Base Darwin (DBERD 2006).

The APIN program resulted in the transfer of many serving ADF personnel from Holsworthy Barracks in New South Wales and Puckapunyal in Victoria to the Northern Territory during the 1990s. Between 1992 and 2006, the number of personnel stationed in the Territory more than doubled. This placed pressure on housing stocks and was a factor influencing the Northern Territory's housing boom in the mid- to late 1990s. In 2005, Defence Housing Australia (DHA) held approximately 1750 properties in the Darwin area and it is currently investing in residential developments in the suburbs of Lyons and Muirhead to boost these stocks (DBERD 2006).

The amount of money spent by the ADF in the Northern Territory totalled $1.08 billion in 2006–07. This is direct expenditure only, and the actual value of the defence industry to the Northern Territory is larger than this. The territory is host to national and international defence exercises such as Exercise Pitch Black, a joint operation between the Australian, French, Thai, Singaporean, UK and US air forces. In addition, overseas naval vessels regularly visit the Port of Darwin; in 2007, 47 major naval vessels visited Darwin, contributing to the Northern Territory economy through sailors' shore leave and ship servicing expenditure. The local defence support industry in the Northern Territory was estimated to have obtained approximately $200 million worth of defence contracts in 2006–07, and provides support in the areas of logistics, vehicle maintenance, communications, radar monitoring, ship maintenance, infrastructure construction and electronic systems design (Northern Territory Government 2008b).

Tourism and recreation

The Northern Territory is divided into nine tourism regions. Darwin Harbour, the cities of Darwin and Palmerston and the outer rural area around the cities are all contained in the "Darwin" tourism region. This region, although relatively small in size, holds a large share of tourism in the territory. Between 2005 and 2007, the Darwin tourism region received an average of 720 000 visitors per year, which represents 51% of total visitors to the Northern Territory (Tourism NT undated).

In total, there were 1 398 000 visitors to the Northern Territory during the year ending March 2009. The average length of stay was 6.9 nights and visitor expenditure was estimated at $1660 million. Almost half of the visitors to the Northern Territory come from interstate, while intra-Territory and international visitors made up nearly one-third and one-quarter of the total respectively. Most interstate and international visitors travel to the Northern Territory for a holiday, while Territorians are more likely to travel to visit friends and family or for business purposes (Tourism NT 2009).

Tourism is a composite industry made up of a variety of service industries such as accommodation and transport. It is a key contributor to the economy of the Northern Territory and in 2003–04 tourism contributed $615.7 million to Northern Territory gross value added (GVA). This equates to 6.7% of total economic activity and is almost twice the level contributed by the national tourism industry to the Australian economy (Spurr et al. 2007).

Some sectors in the Northern Territory are more dependent on tourism than others—accommodation, cafes and restaurants are particularly exposed (Tourism NT undated). In the Northern Territory in December 2007 there were 178 accommodation providers, employing 3591 persons.[9] Takings from accommodation for the quarter ending December 2007 were estimated at $61.1 million (ABS 2008c).

Construction

The construction industry in the Northern Territory has undergone a rapid expansion in recent years, with spikes of intense activity in some years (see Figure 3-54). The value of engineering construction activity increased from $59 million to almost $290 million between 2000 and 2008 (ABS 2008d). The large spike between 2001 and 2002 was largely because of the construction of the Adelaide–Darwin railway line, while other major projects such as the construction of the ConocoPhillips Darwin LNG plant and the expansion of Alcan Gove's refinery have also contributed to strong demand for construction activity.

Since the completion of these major projects, the construction industry has started to decline. The Darwin LNG plant was completed in 2005 and Alcan's expansion of the Gove refinery was completed in 2007. As shown in Figure 3-54, the value of engineering construction work done began to decline from around mid-2006. This trend is projected to continue unless another major project commences (Northern Territory Government 2008c).

Major projects such as those mentioned above are important contributors to the growth of the construction industry in the Northern Territory, but they are not the only factor involved. Between 2000 and 2008, residential building activity has approximately doubled, with construction work on residential buildings worth $51.1 million in 2000 and $102.3 million in 2008 (ABS 2008e).

A significant proportion of the rise in residential building activity can be attributed to the involvement of the DHA in the development of new residential subdivisions in Darwin. The $280-million DHA-funded development of the suburb of Lyons, for instance, commenced in 2006 and was formally opened in June 2008; construction of houses in that suburb will be completed in 2011 (DHA 2008; Northern Territory Government 2008b). The development of the neighbouring suburb of Muirhead, beginning in 2010, will provide continued opportunity for growth in the residential building industry.

9 These figures should be used with caution, as some data were not publicly released in order to protect business confidentiality.

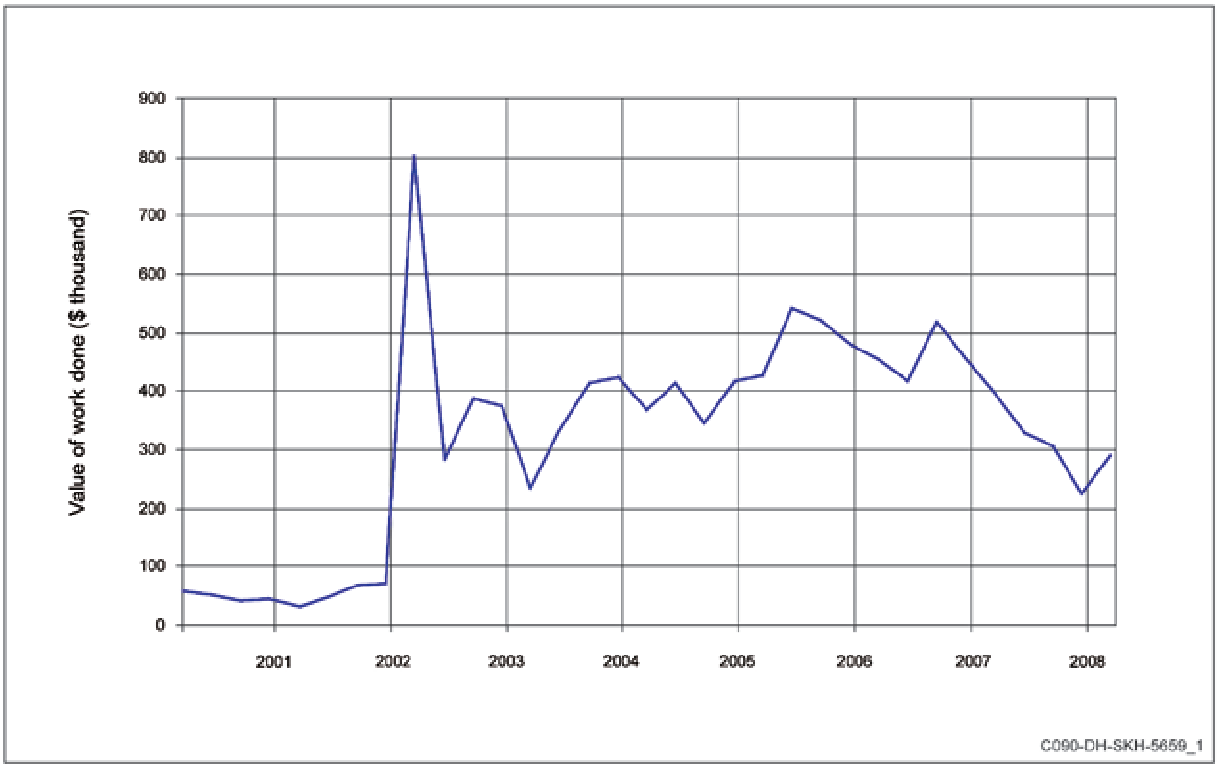


Figure 3-54: Engineering construction activity in the Northern Territory, 2000–2008

Manufacturing

The manufacturing industry in the Northern Territory is relatively small. In 2006–07 it accounted for only 5.4% of gross state product and employed 4600 people (Northern Territory Government 2009d). The sector is dominated by the manufacture of metal products, and the manufacture of petroleum, coal, chemical and associated products. These categories together account for over half of the gross value added of the manufacturing sector.

The two major projects that have contributed to the dominance of the metal product and petroleum manufacturing sectors are the Alcan Gove alumina refinery on the Gove Peninsula in east Arnhem Land and the Darwin LNG plant at Wickham Point in Darwin Harbour. With the completion of its expansion project in 2007, the refinery was expected to produce 3.0 Mt/a of alumina for export in 2007–2008, increasing to 3.5 Mt/a in 2008–2009 (Northern Territory Government 2008d). The Darwin LNG plant began operations in February 2006 and has a production capacity of 3.7 Mt of LNG per annum. Japanese buyers are contracted to buy up to 3.3 Mt/a of the LNG, providing an export income of approximately $500 million every year (Wilson 2007).

3.7.4 Commercial fishing and aquaculture

Fisheries

The offshore and nearshore development areas are located within the boundaries of a number of commercial fisheries managed by the Commonwealth, Western Australia and the Northern Territory. Commercial fisheries cover very large areas of the offshore and nearshore environment, but the actual fishing effort applied in each fishery is often concentrated on particular sites. In addition, the number of licences issued for each fishery varies, and in some cases can be fewer than 10. This has the effect of reducing the likelihood that Project activities would impact these commercial operations.

The following commercial fisheries overlap the offshore development area at the Ichthys Field:

- North West Slope Trawl Fishery (Commonwealth): This is located in deep water off north-west Western Australia, extending seaward from the 200-m isobath to the edge of the Australian Fishing Zone. The Ichthys Field is located close to the north-east boundary of this fishery. Seven fishing permits are issued for the fishery. Fishing is conducted using demersal crustacean trawling, which involves towing a net close to the seabed just above the benthic zone (Granherne Pty Ltd 2007).

- Northern Demersal Scalefish Fishery (offshore zone only; Western Australia): This is located off the north coast of Western Australia. As of 2008, 11 offshore permits had been issued for the fishery, which utilises traps or handlines and droplines (Fletcher & Santoro 2008).
- Western Tuna and Billfish Fishery (Commonwealth): This fishery extends throughout the coastline of the Northern Territory, Western Australia and South Australia. Fishing effort data from 2001 for both domestic and Japanese operators in this fishery indicated that the Project's offshore development area is well outside the areas of fishing activity, which mainly occur to the west in deep offshore waters. Fishing is conducted by pelagic longlining in waters beyond the continental shelf break (Granherne Pty Ltd 2007).
- Southern Blue Fin Tuna Fishery (Commonwealth): This extends around the entire Australian coast to the boundary of the Australian Fishing Zone (approximately 370 km offshore). Longline fishing for southern bluefin tuna occurs primarily off southern New South Wales and to a lesser extent off southern Western Australia, distant from the onshore development area (AFMA 2009a).
- Mackerel Managed Fishery (Western Australia): This is located throughout the nearshore and offshore waters of the Kimberley coast usually around reefs, shoals and headlands. There were 22 fishing permits active in 2008, and fishing is mainly by surface trolling or by hand line in coastal waters (Fletcher & Santoro 2008).

All of these fisheries also coincide with the gas export pipeline route at its western end. In its eastern sections approaching the Northern Territory, the pipeline also crosses other commercial fisheries. These are as follows:

- Kimberley Prawn Managed Fishery (Western Australia): This is located off the Kimberley coast of Western Australia and extends into offshore waters. As of 2008, there were 137 licences but only 20 boats active in the fishery. The main fishing method is otter trawling, which involves towing a net along the seabed (Fletcher & Santoro 2008).
- Northern Prawn Fishery (Commonwealth): This extends from the coast to the boundary of the Australian Fishing Zone, from the northern Kimberley coast into the Northern Territory. In 2008–09 there were 25 "statutory fishing right" holders in the fishery. The main fishing method is otter trawling, which involves towing a net along the seabed (AFMA 2009b).
- Northern Shark Fisheries (Western Australia, Joint Authority): These fisheries comprise the state-managed Western Australian North Coast Shark Fishery, located off the Pilbara and western Kimberley coast, and the Joint Authority Northern Shark Fishery in the eastern Kimberley. Nine licences (shared by 11 boats) have been issued for the fishery and the primary fishing method is demersal longlining (Granherne Pty Ltd 2007).
- Coastal Line Fishery (Northern Territory): This fishery lies within 15 nautical miles of the coast. In 2007 there were 24 active licences and fishing effort, which was highest in the early 1990s, has been decreasing for the last four years (DRDPIFR 2008).
- Coastal Net Fishery (Northern Territory): This fishery occurs within three nautical miles of the coast. Commercial fishing effort is low, with only five licences at the end of 2007 because of a voluntary licence buy-back scheme. Licensed fishing gear includes coastal nets, cast nets and a limited number of gill nets (DRDPIFR 2008).
- Offshore Net and Line Fishery (formerly Shark Fishery) (Northern Territory): This extends from the coast to the Australian Fishing Zone boundary, but with most fishing effort within 12 nautical miles of land. Fishing methods include longlines or pelagic nets, but no bottom-set gill nets. There are 17 licences permitted to operate of which 11 were active in 2007. Fishing effort is dependent on operational and market conditions and has been decreasing since 2003 (DRDPIFR 2008).
- Spanish Mackerel Fishery (Northern Territory): This extends from the coast to the Australian Fishing Zone boundary. Most fishing effort occurs near the coast, around reefs, headlands and shoals, using heavy troll lines. In 2007 there were 19 licences of which 16 were actively operating (DRDPIFR 2008).

Very little commercial fishing activity takes place in the Project's nearshore development area (inside Darwin Harbour), mainly because of the high levels of recreational fishing that occur in the area. Operators in the Coastal Line Fishery, which is managed by the Northern Territory, are permitted to fish in Darwin Harbour but rarely do so. Similarly, the Aquarium Fishery includes Darwin Harbour but only two operators actually fish in the area. Darwin Harbour provides a base for vessels operating in fisheries throughout the Northern Territory and northern Western Australian waters (K Sarneckis, Northern Territory Seafood Council, pers. comm. March 2009).

The DoR manages wild-harvest fisheries in the Northern Territory, which in 2007 had a gross value of production of $30.1 million at point of first sale. The three highest catch value wild-harvest fisheries in the Northern Territory in 2007 were mud crab, barramundi and the Timor Reef fishery (DRDPIFR 2008), none of which occur to any significant extent in the offshore or nearshore development areas.

Aquaculture

The aquaculture industry in the Northern Territory in 2008 was worth $21 million at point of first sale. The industry is dominated by the pearling industry, which had a gross value of production of $16.3 million and employed 114 people in 2008. The majority of pearl oysters are now reared in hatcheries, with very few taken from the wild (DoR 2009c).

Barramundi farming is the second-largest aquaculture fishery by value, with a gross value of production of $4.3 million. In 2008, all four barramundi-farming operations in the Northern Territory were pond-based, with no sea-cage operations. Mud crabs were farmed on a small scale, including in one pond-based farm located near Darwin Harbour, but these ceased operations in 2008 (DoR 2009c).

Two commercial pearl culture leases exist near Middle Arm, although these are not currently in operation. Another pearling lease currently exists in Lightning Creek on the west side of Blaydin Point; it is not known whether this lease will continue to be used.

The Darwin Aquaculture Centre is situated on Channel Island, west of Middle Arm Peninsula. The centre was established in 1998 and provides for commercial barramundi fingerling production, as well as aquaculture research. In 2008 it accommodated 16 staff and 2 postgraduate students (DoR 2010).

3.7.5 Industrial infrastructure and services

Utilities

Power and water services to the Darwin area are primarily provided by the Power and Water Corporation. The corporation operates the 254-MW Channel Island gas turbine generator and has allocated over $126 million to build a new power station at Weddell. The new power station is being built to service the growing energy demands of Darwin and Palmerston.

Ninety per cent of Darwin's water supply is obtained from the Darwin River Dam, which has a capacity of 265 000 ML. Additional water supplies are obtained from groundwater. In 2006 licensed extraction from these sources provided 46 420 ML/a and demand was 40 000 ML/a. To provide for future population growth in the Darwin area, new water supplies will need to be found or water usage reduced. Darwin residents currently have the highest water consumption per capita in Australia, and reducing their use to the national average will delay the need for alternative water supplies for potentially another 50 years (Power and Water Corporation 2006b).

There are currently no electricity or water facilities at Blaydin Point. The nearest distribution lines are along Wickham Point Road and new lines would have to be constructed to connect these to the onshore development area.

Rail transport

The construction of the railway from Adelaide to Darwin has created a new link in the transport network, allowing goods to be transported easily to Darwin for export overseas. The first train between the two cities ran in 2004, taking just two days to cross the continent. Previously there were two options for the transport of goods: from Adelaide to Alice Springs by rail and then from Alice Springs to Darwin by road, or using sea freight to Darwin. But the rail-and-road option was not economically feasible for bulk commodities such as minerals, while transport by sea was relatively slow.

The new rail link is operated by FreightLink. It carries around 800 000 t of intermodal freight, 70 000 t of bulk liquids and more than 3 Mt of bulk freight per year. The company operates six services a week between Darwin and Adelaide (FreightLink 2009).

The advantages of the new rail service include cheaper and more competitive bulk freight options for exporting industries such as mining and agriculture (e.g. live cattle), and logistical support for the ADF with the movement of troops and matériel.

FreightLink has already entered into freight contracts with several mining companies to transport manganese and iron ore to the Port of Darwin from remote sites in central Australia. A report by Access Economics in 1999 suggested that the economic benefits of the railway would be significant, with Northern Territory gross state product increasing by $3 billion (AustralAsia Railway Corporation 2003).

Port and shipping

The Port of Darwin is Australia's gateway to the markets of South-East Asia. Geographically it is closer to South-East Asia than any other port in Australia. The port is managed by the Darwin Port Corporation as a Government Business Division of the Northern Territory Government, and answers to the Minister for Infrastructure and Transport (Darwin Port Corporation 2009).

It is Australia's primary port for live cattle exports and also has facilities for container and general cargo, and bulk commodities such as iron ore and manganese. It is Australia's second-largest LNG exporting facility and received 115 tanker vessel calls in 2008–09 (Darwin Port Corporation 2009). In addition to international trade services, the port also includes a mooring basin for the Darwin-based fishing fleet and smaller vessels, the Darwin Wharf Precinct (a retail, restaurant and tourism complex), and a naval and cruise ship berth (Darwin Port Corporation 2008).

As shown in Figure 3-55, trade at the Port of Darwin has been increasing markedly since 2001. In 2007, $24 million was spent on a new bulk minerals export facility at East Arm Wharf, which is utilised by mining projects (Northern Territory Government 2008e).

Trade from the Port of Darwin is also increasing as a result of the new rail link from Adelaide to Darwin, which connects East Arm Wharf to the national rail network.

In 2008–09, total trade through the port was approximately 3.8 Mt, an increase of 38% on the previous year. During 2007–08 and 2008–09 exports outweighed imports, mainly because of large increases in the trade of dry bulk goods. This cargo segment represented 87% of the exports shipped from the port and consisted mainly of iron ore and manganese. Livestock exports represented 5.7% of the export total volume and petroleum represented 2.6% (Darwin Port Corporation 2009). It is noted that exports from the Darwin LNG plant, which has its own port facilities, are not included in these summary values.

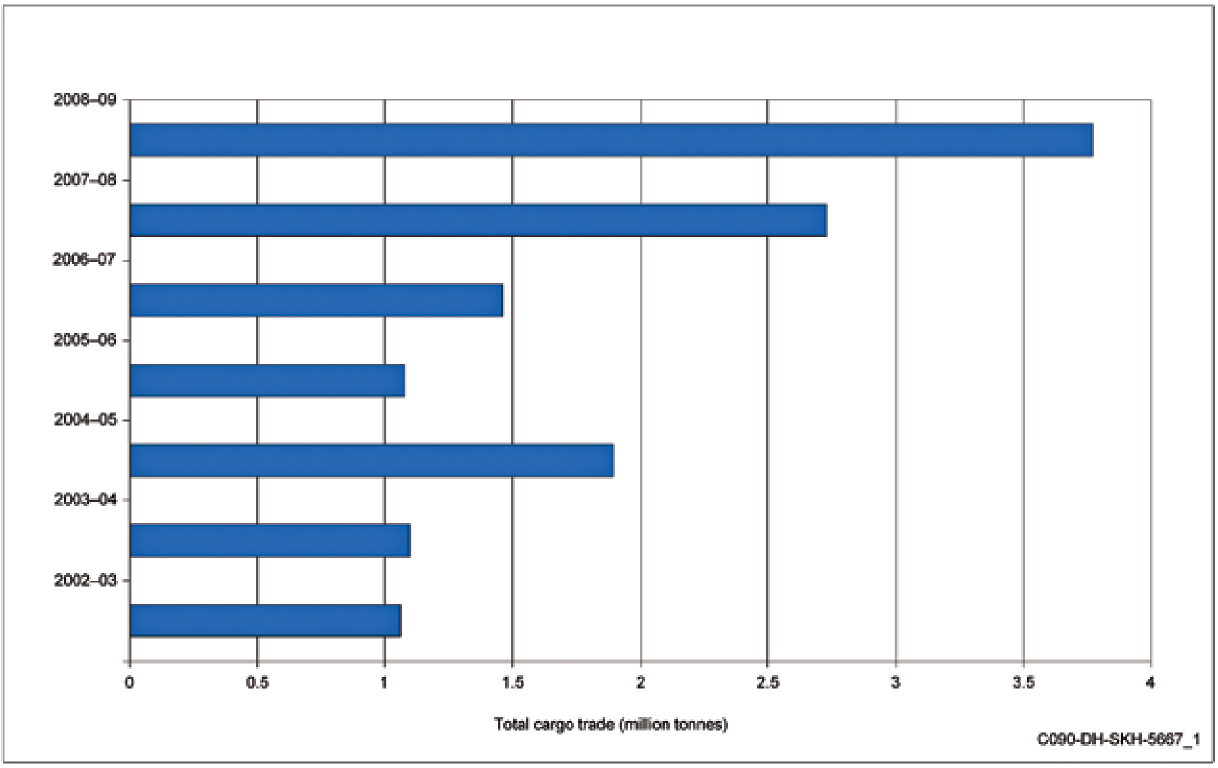


Figure 3-55: Total annual cargo trade at the Port of Darwin, 2001–2009

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ABS—*see* Australian Bureau of Statistics.

AER—*see* Australian Energy Regulator.

AFMA—*see* Australian Fisheries Management Authority.

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4 Project Description

4 PROJECT DESCRIPTION

4.1 Introduction

This chapter of the draft environmental impact statement (Draft EIS) for the Ichthys Gas Field Development Project (the Project) describes the major infrastructure components and supporting facilities required to take the Ichthys Field to commercial production. These include the installation of subsea and processing facilities offshore, the installation of a subsea gas export pipeline, and the construction of an onshore gas-processing plant and export facilities. The construction and installation of these components are described sequentially from the Ichthys Field through to Darwin Harbour, and from the Harbour to the onshore processing plant at Blaydin Point.

Environmental, social, economic and safety criteria have been considered in the selection of technically viable design alternatives. Where applicable, these criteria are included in the descriptions of Project components in this chapter.

Many of the terms used in this chapter for equipment, processes and practices are defined in the glossary to this Draft EIS.

4.1.1 Major infrastructure

The infrastructure required for the Project will consist of offshore gas and condensate extraction, processing, storage and transportation facilities; a subsea pipeline; and onshore gas-processing and export facilities at Blaydin Point. Key considerations in the design of the offshore and onshore facilities include the following:

- ensuring the health, safety and welfare of personnel working on the Project
- minimising any negative impacts the Project might have on the environment and the Northern Territory community
- fulfilling all relevant territory and Commonwealth legislative obligations
- incorporating projected climate-change scenarios into the design, for example potential rises in sea level and/or temperature change
- developing and maintaining a culture of corporate social responsibility in respect of the community and a wide range of stakeholders
- providing a reliable long-term supply of LNG, LPGs (propane and butane) and condensate to customers.

The following represents the "base case" infrastructure proposed as part of this Draft EIS as developed in the front-end engineering design (FEED) phase. As FEED progresses and the Project moves into the detailed-design phase, the design of this infrastructure will be refined.

Subsea infrastructure at the offshore development area will consist of the following:

- approximately 50 subsea wells drilled from between 12 and 15 drill centres, developed over a period of 40 years
- control umbilicals, service lines and wet-gas, corrosion-resistant infield flowlines.

The subsea infrastructure will be tied back to a floating central processing facility (CPF) by a series of flexible risers, flowlines and umbilicals. The CPF in turn will be connected to a floating production, storage and offtake (FPSO) facility by a transfer system consisting of flexible risers and flowlines as well as by a communications umbilical. Both the CPF and FPSO, as presented in Figure 4-1, will be moored in position for the expected 40-year life of the Project.

These facilities will provide the following services:

- The CPF will be used for gas–liquid separation; gas dehydration; gas export; future inlet compression; and export of a commingled stream of condensate, monoethylene glycol (MEG) and water to the FPSO. (The MEG is used to prevent the formation of hydrates, primarily between methane and water.)
- The FPSO will be used for condensate dewatering and stabilisation, condensate storage and export, MEG regeneration, and produced-water treatment.

A subsea gas export pipeline with an outside diameter of approximately 42 inches (*c*.1.07 m) and approximate length of 852 km will be installed between the offshore development area and the entrance to Darwin Harbour. (The total length of the pipeline from the CPF to the receiving facilities at the gas-processing plant at Blaydin Point will be approximately 885 km.) The pipeline will be weight-coated with concrete for stabilisation on the seabed, but sections will also be afforded additional protection, where required, by trenching and "rock dumping" depending on depth and location.

Nearshore infrastructure will consist of the following:

- an approximately 27-km length of the subsea gas export pipeline from the mouth of Darwin Harbour parallel to the existing Bayu–Undan Gas Pipeline to the western side of Middle Arm Peninsula
- a pipeline shore crossing on the western side of Middle Arm Peninsula
- a module offloading facility on Blaydin Point for receiving prefabricated gas-processing modules and some construction materials
- a product loading jetty on the north-western end of Blaydin Point with one berth for LNG export and one for LPG and condensate export

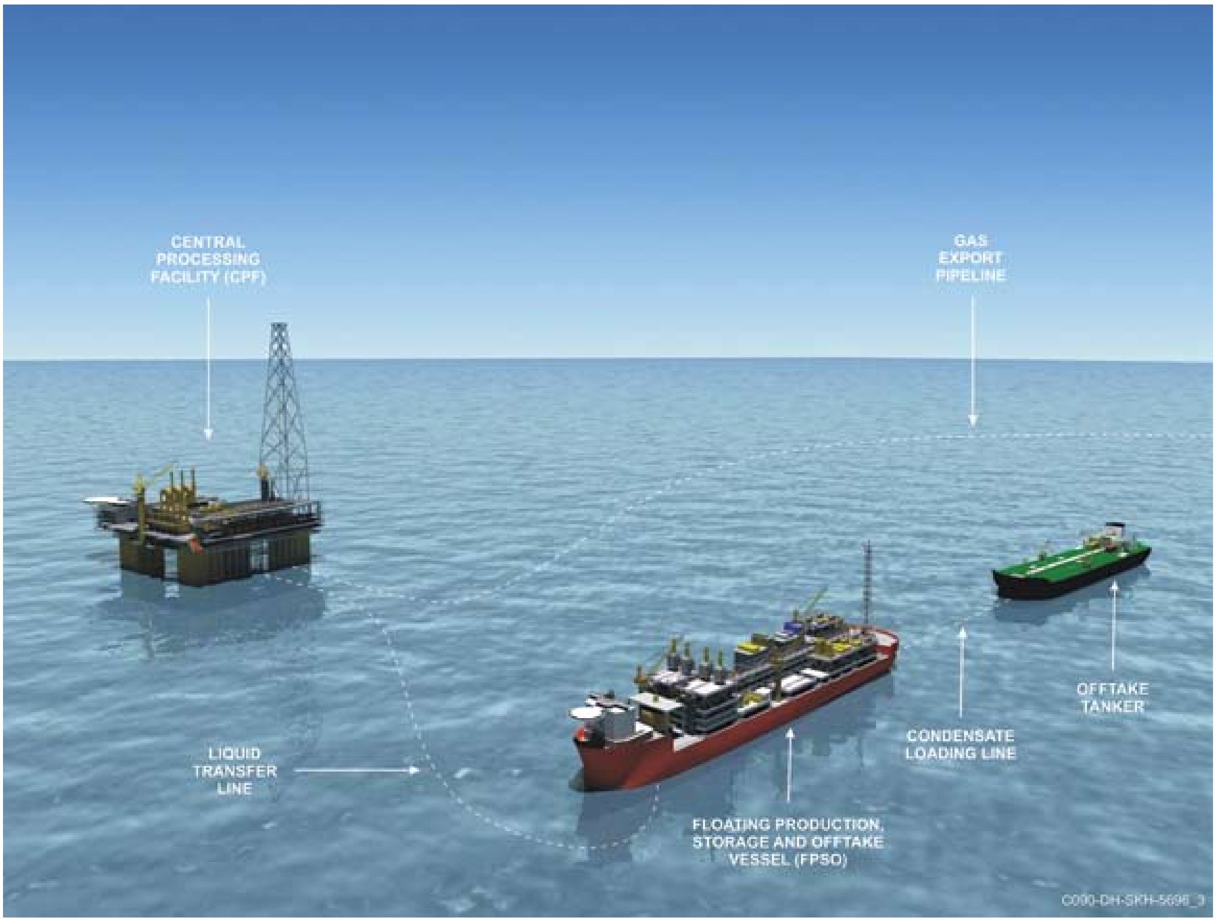

Figure 4-1: Indicative schematic of the offshore floating facilities

- a shipping channel, approach area, turning basin and berthing area for the product tankers
- a dredge spoil disposal ground outside Darwin Harbour, 12 km north-west of Lee Point.

Onshore infrastructure will consist of the following:

- a 6-km-long onshore pipeline corridor from the shore-crossing area to the Blaydin Point gas-processing plant site
- a gas reception area with a pig receiver and a slug catcher
- two gas liquefaction trains (each producing approximately 4.2 Mt/a of LNG)
- gas treatment facilities (for acid gas removal, dehydration, and mercury removal)
- a propane and butane fractionation plant
- a condensate stabilisation plant
- utilities distribution and storage (power generation, fuel, water, nitrogen, compressed air)
- storage tanks (two tanks for LNG; two large and one small tank for condensate; and one tank each for propane and butane) and LNG and LPG recovery units for boil-off gas
- an emergency gas flare system consisting of a ground flare and enclosed tankage flares
- a wastewater drainage and treatment system
- various other installations, including a warehouse, workshops, a fuel storage area, firefighting facilities, a guard room and security buildings, and a control room.

Onshore permanent supporting facilities such as communications, security and administration buildings will be located in a site administration area south of Blaydin Point in the central part of Middle Arm Peninsula.

An indicative schematic of the onshore and nearshore infrastructure is presented in Figure 4-2.

Other facilities required to support the Project that are not directly assessed in this Draft EIS include the following:

- an accommodation village for the workforce during the construction period
- quarries for the supply of fill, rock and aggregate
- a rock load-out facility and stockpile area for transferring rock for subsea pipeline stabilisation
- a maritime supply base for onshore and offshore operations
- a tug harbour
- waste disposal resources
- utility corridors (e.g. for power and water).

These facilities will either be supplied by third parties or will be subject to separate approval processes.

Figure 4-2: Indicative schematic of the onshore and nearshore infrastructure at Blaydin Point

4.1.2 Site selection

Following the appraisal of the Ichthys Field's gas and condensate reserves, INPEX investigated the options to bring the hydrocarbon products to market. Currently available technology for the processing of LNG for export involves the development of large onshore gas-processing trains with deepwater anchorages for LNG tankers. A decision was made by INPEX to pursue this proven technology for the Project.

The selection of a site for the onshore gas-processing component of the Ichthys Project commenced with studies conducted in 2002 that assessed a number of possible locations. These studies indicated that the Maret Islands in the Kimberley region of Western Australia were the most appropriate location for the onshore facility; this was based on what was understood at that time of the environmental, political, engineering and commercial constraints.

INPEX initiated an approvals process with the Commonwealth Government in May 2006 in order to pursue the Maret Islands option, referring its proposal to develop the Ichthys Field to the Commonwealth's Department of the Environment and Water Resources (DEW)[1] and Western Australia's Environmental Protection Authority (EPA). These agencies determined that the Project should be formally assessed at the EIS and the ERMP (environmental review and management program) levels respectively.

Work accordingly began on the preparation of a draft EIS/ERMP for the Maret Islands location.

By 2007, significant uncertainty relating to INPEX's ability to develop the LNG facility at the Maret Islands location in the Kimberley region became apparent. Consequently, INPEX revisited sites that were considered in earlier stages of the Project's site-selection phase and determined that it would be technologically feasible to export Ichthys gas to an onshore gas-processing location in the Darwin region, despite the considerably greater length of subsea pipeline that would have to be constructed to transport the gas. During this period, the Northern Territory Government offered INPEX the Blaydin Point site for the onshore components of the Project.

1 The Commonwealth's Department of the Environment and Water Resources became the Department of the Environment, Water, Heritage and the Arts (DEWHA) in December 2007.

It is the Northern Territory Government's preferred site for an LNG facility and is primarily zoned for industrial development under the Northern Territory Planning Scheme[2].

In order to facilitate the acquisition of land tenure, INPEX initiated discussions with the Northern Territory Government which led to the signing of a Project Development Agreement (PDA) on 18 July 2008 by INPEX Browse, Ltd., Total E&P Australia, and the Northern Territory Government. The PDA outlined the approximate plan for the onshore area of the Project as well as conditions that are required to be fulfilled in order to gain land tenure. The ongoing discussion regarding land tenure of the onshore development area will be based on the adjusted development area boundaries as presented in this Draft EIS.

4.1.3 Design alternatives

Consideration of environmental, social, economic and safety criteria has been included in the concepts and designs selected for the Project. Technically feasible design concepts that have been particularly influenced by these criteria include the following:

- alternative subsea pipeline routes, shore-crossing locations and onshore pipeline routes
- alternative locations for offloading the modules for the onshore gas-processing plant, that is, whether to build a new module offloading facility at Blaydin Point or to use the existing facilities at East Arm Wharf and transport the modules to site by road
- alternative concepts for the product loading jetty and navigation channels at Blaydin Point
- alternative locations for a dredge spoil disposal ground
- alternative onshore gas-processing plant layouts.

INPEX also considered a number of alternative offshore processing concepts and selected the one considered most appropriate for the scale of the Project and the location of the Ichthys Field.

Alternative locations and designs of the accommodation village for the construction workforce are subject to a series of separate approvals from the regulatory authorities that are not within the scope of this Draft EIS.

4.1.4 Consequences of adopting the "no development" option

As the permit holder and Operator of the Ichthys Project, INPEX has an obligation to undertake exploration of its permit area, to verify the nature and extent of the hydrocarbon reserves which it contains and to investigate the manner in which these reserves can be commercialised. Should the Project be commercially viable and not proceed, INPEX would not be fulfilling its obligations.

In addition, significant social and economic advantages resulting from the Project would be lost to northern Australia in general and to the Darwin region in particular. The Project has the potential to generate substantial new export income, to create numerous employment opportunities and to strengthen the Northern Territory's economic development. It would be the largest private-sector investment in the history of the Darwin region and would provide opportunities for business and employment for over four decades.

Predictions from economic modelling indicate that the gross state product (GSP) of the Northern Territory would be on average almost 18% higher each year as a result of the Project. It is also predicted that the Project will contribute A$3.5 billion (an additional 0.2%) to Australia's gross domestic product (GDP).

The economic model and other potential positive impacts are assessed in detail in Chapter 10 *Socio-economic impacts and management*.

4.1.5 Development schedule

The construction phase of the Project will cover a period of 5 to 6 years from the final investment decision (FID) to the production of first LNG cargo. Figure 4-3 presents the indicative construction schedule. As presented, construction and commissioning of the second LNG train will continue as gas is being produced from the first LNG train. From the commencement of commissioning, the aim is to run both the offshore and onshore facilities continuously for the duration of the anticipated 40-year life of the Project.

2 Department of Planning and Infrastructure. 2008. *Northern Territory planning scheme*. Department of Planning and Infrastructure, Darwin, Northern Territory.

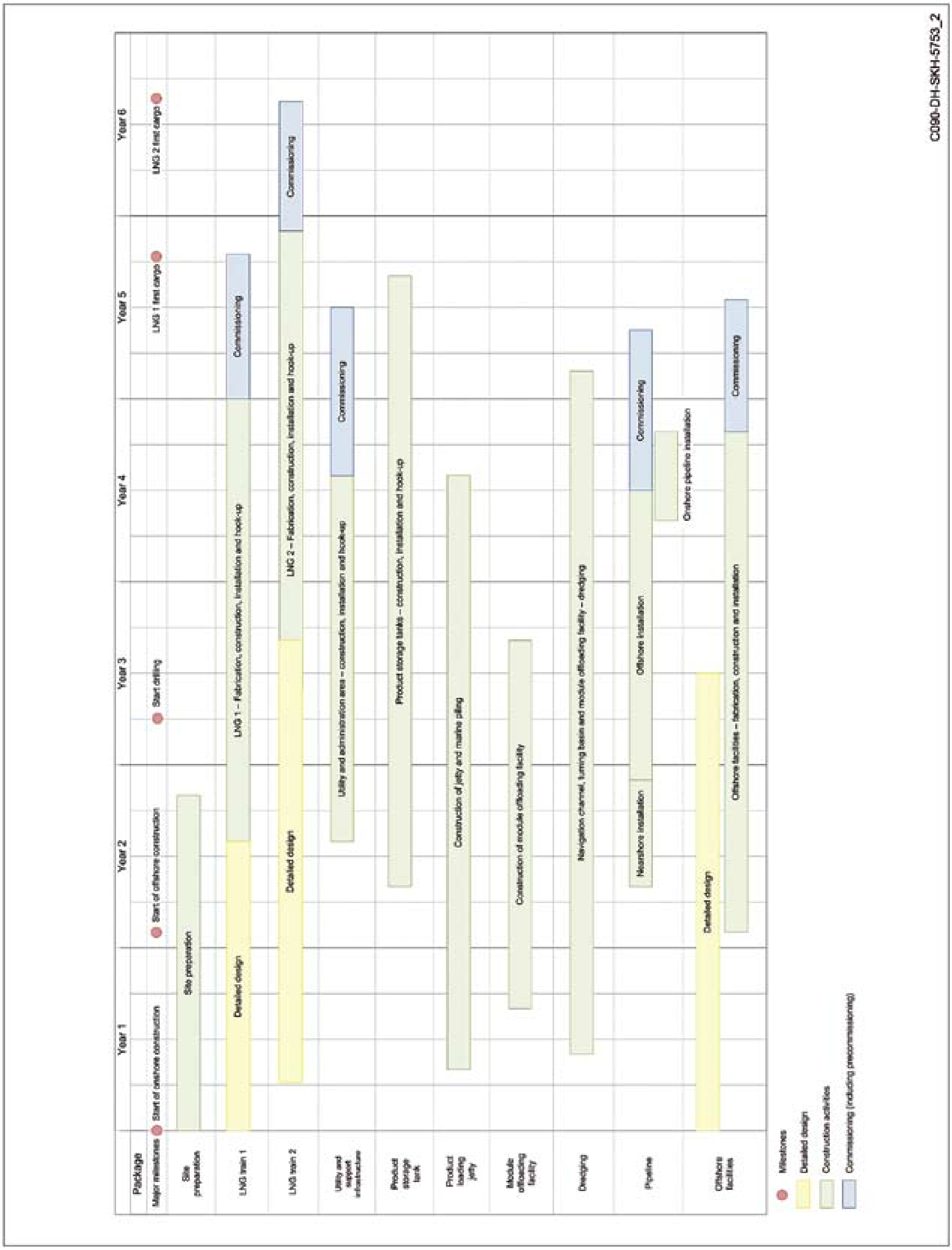

Figure 4-3: Indicative development schedule

Key steps in the development process include the following:

- *Pre-front-end engineering design (pre-FEED):* Oil and gas reserves, market opportunities, possible offshore and onshore locations, technology options and preliminary design options are evaluated. The objective is to determine if the Project is likely to be viable.
- *Front-end engineering design (FEED):* The design of the facilities is defined in more detail. No significant investments in equipment or technologies are made during this phase. The objective is to progress designs, cost estimates, schedules and approvals to a high enough level of certainty to allow for a final investment decision to be made.
- *Final investment decision (FID):* By this point, technical viability, schedule, budget, environmental approvals, land tenure and community relations have been progressed to a high enough level of accuracy and certainty to allow for a decision on whether or not to proceed with funding the Project as designed by the FEED process.
- *Detailed design:* The major engineering contractors design offshore and onshore facilities in enough detail to allow construction. Orders are placed and commitments are made for expensive equipment and off-site construction and assembly facilities (e.g. drilling-rig operators, shipyards, module yards, and the pipe mills to make 42-inch steel pipe for the gas export pipeline).
- *Construction and precommissioning:* INPEX and the major engineering contractors work to construct and install the Project infrastructure and supporting facilities (e.g. wells are drilled, the CPF and FPSO are sailed into place; LNG plant modules are brought from offshore yards; pipelay barges lay the gas export pipeline; and dredging takes place). Construction includes precommissioning activities such as hydrotesting of vessels, pipework and equipment.
- *Commissioning:* Systems are function-tested before the first hydrocarbons are introduced into the CPF from the reservoir and are directed to the onshore facilities to begin production of saleable products. Commissioning teams work to achieve steady-state operations, resolve issues, and make sure that facilities operate and perform as intended.
- *Operations:* Start-up issues have been resolved and a smaller operations team takes over operation of all facilities for the long term.
- *Decommissioning:* At the end of the useful life of the field, the wells are plugged and abandoned and the onshore and offshore facilities are decommissioned.

4.1.6 Ichthys Field reservoir characteristics

The Ichthys Field encompasses an area of approximately 800 km^2, with water depths ranging from 235 to 275 m (Figure 4-4). The field consists of two reservoirs: an upper reservoir in the Brewster Member and a lower reservoir in the Plover Formation. Notable physical characteristics of the Ichthys Field that will influence the location, design and the resulting environmental management of the proposed Project facilities include the following:

- its remote location
- the depth, pressure and temperature of the gas and liquids in the reservoirs
- the porosity and permeability of the reservoirs
- the water depth and seabed characteristics.

The percentage gas compositions for the major gas constituents in the Brewster Member and Plover Formation are presented in figures 4-5 and 4-6. In addition, traces of impurities such as hydrogen sulfide (H_2S) and mercury (Hg) also exist in the gas and liquid streams. Extraction of these impurities is expected and disposal mechanisms will be designed to suit the quantities recovered.

Produced formation water is saline water found as a liquid in a natural-gas formation along with the gas. Condensed water is produced from the processing of the gas when water vapour (evaporated into the gas) cools and condenses to a liquid. This condensed water is typically non-saline. Produced water is the combination of produced formation water and condensed water.

The peak production of produced water is expected to be approximately 3250 m^3/d in Year 23 of the Project as indicated in Figure 4-7.

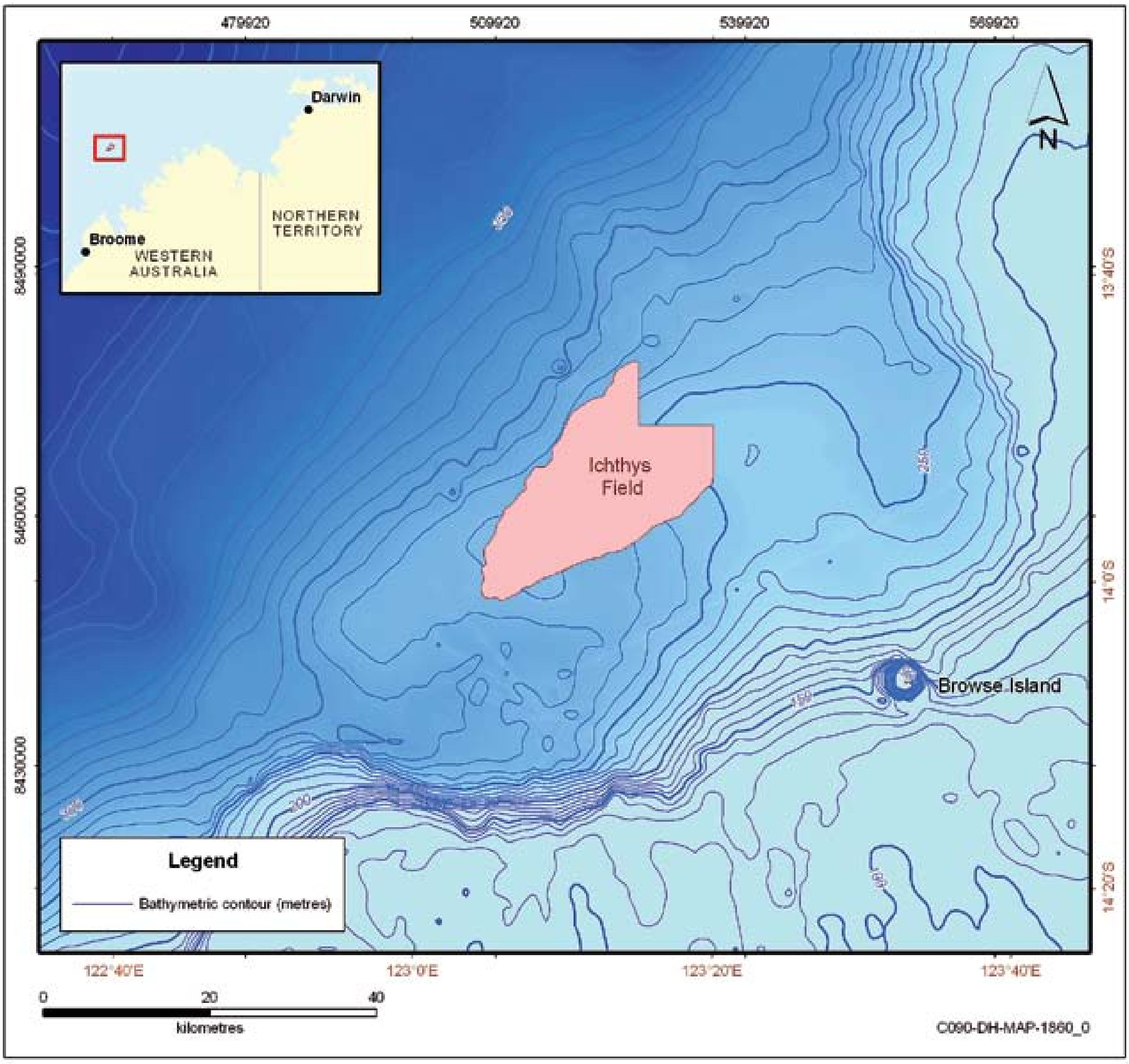

Figure 4-4: Location of the Ichthys Field

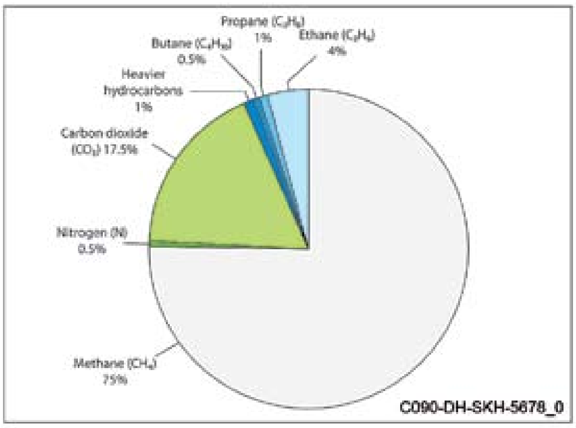

Figure 4-5: Plover Formation gas composition (mol %, excluding condensed water)

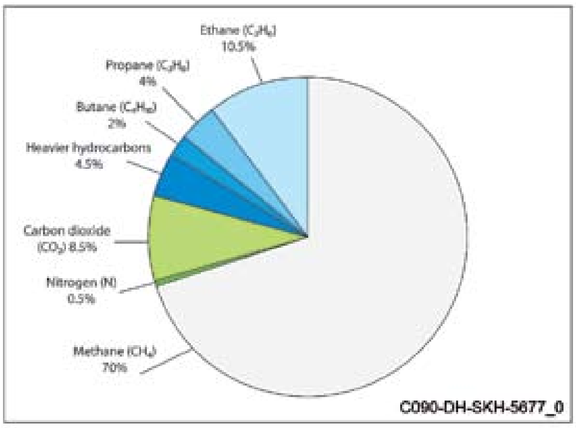

Figure 4-6: Brewster Member gas composition (mol %, excluding condensed water)

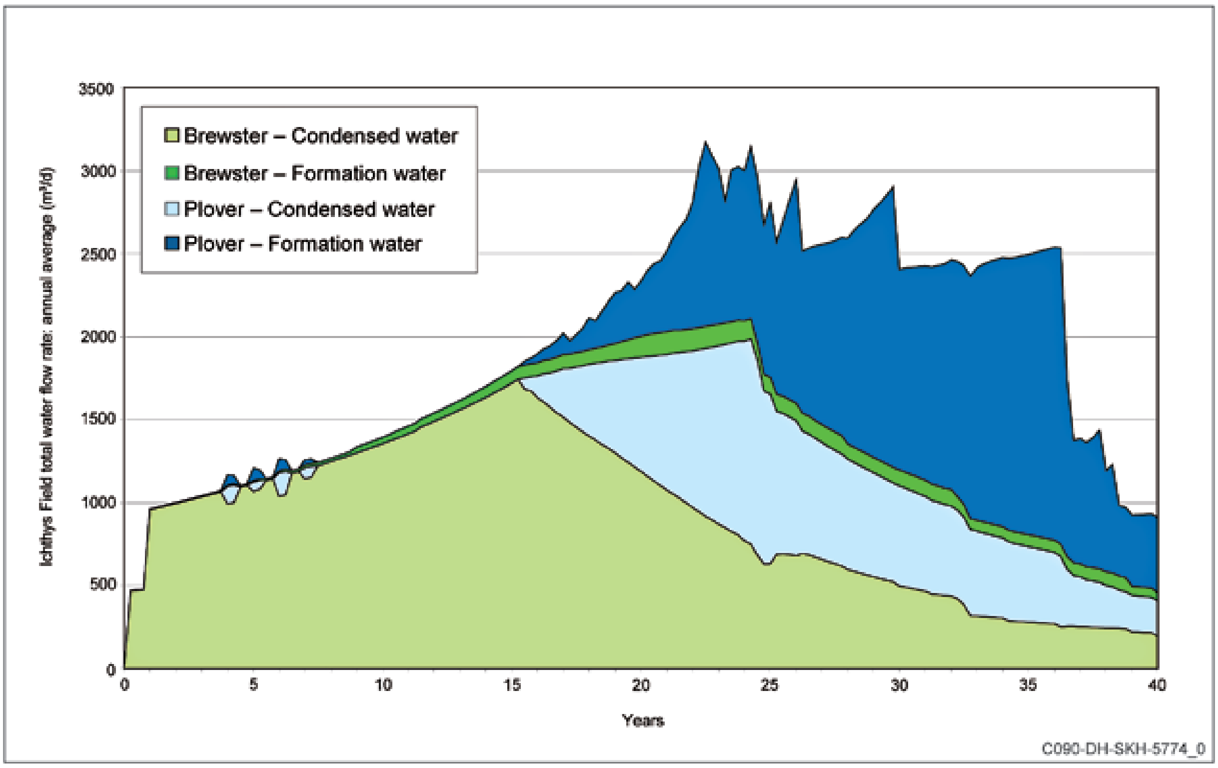

Figure 4-7: Average volumes of produced water discharged from the offshore facilities over the 40-year life of the Project

4.1.7 Products

The operating life of the Project is expected to be approximately 40 years. Over this period, hydrocarbon gas and liquids will be extracted from the Ichthys Field, processed both at the field and at Blaydin Point and then exported as the following products:

- *Liquefied natural gas:* LNG consists primarily of methane (CH_4), with some ethane (C_2H_6), that has been treated to remove almost all impurities in order to meet the buyers' gas-quality specifications. Following treatment, the natural gas is cooled by refrigeration to its liquefaction temperature of around –160 °C. LNG is approximately one six-hundredth the volume of natural gas at standard temperature and pressure, making it cost-efficient to transport over long distances. It is stored in cryogenic storage tanks at around –160 °C and is transported in custom-designed cryogenic ships to LNG reception and regasification terminals. INPEX plans to export approximately 8.4 Mt of LNG from the Blaydin Point facility each year.
- *Liquefied petroleum gas:* LPG is the general term for liquefied propane (C_3H_8) and butane (C_4H_{10}). These can be sold either as separate products or as a mixture. The Blaydin Point facility will produce and export these as separate products. Both propane and butane are gases under standard temperature and pressure and have to be refrigerated or compressed in order to be stored as liquids. INPEX plans to produce propane and butane at a rate of approximately 1.6 Mt/a.
- *Condensate:* This is essentially light oil that consists of a mixture of hydrocarbons, normally in the carbon-chain range of C_4 and above, which are liquid at standard temperature and pressure. Condensate does not require refrigeration for storage or transport. The bulk of the Project's condensate will be exported directly from the Ichthys Field at an average rate of 85 000 barrels per day (at the start of LNG production) after processing on the FPSO, with an additional 15 000 barrels per day being produced and exported by sea from the onshore processing plant at Blaydin Point.

4.2 Offshore infrastructure

The infrastructure and associated activities required in the offshore development area to manage the extraction, processing and export of hydrocarbons from the Ichthys Field are listed in Section 4.1.1 *Major infrastructure*. These are described in more detail in the following sections.

4.2.1 Drilling of subsea wells

Development of the Ichthys Field will require the drilling of approximately 50 wells over the Project's lifetime. A number of these will be drilled in the initial construction period, with remaining wells and drill centres being added to maintain gas production as the two reservoirs are depleted over time. Wells will be drilled in groups to optimise the efficiency of rig operations and to minimise the Project's footprint on the ocean floor.

Wells will be drilled using directional-drilling technology as this allows for clustering of wells and subsea facilities. Drilling will be undertaken using a semi-submersible mobile offshore drilling unit (MODU) kept in position by 8 to 12 anchors (see Figure 4-8). Drilling activities involve the boring of a sequence of holes of decreasing diameter (typically starting at 1 m) at increasing depths until the target reservoir is reached. Steel casing is then inserted into the holes and cemented into place.

In the process of drilling, the crushed and ground rock generated by the drill bit (the "drill cuttings") are continuously removed from the hole using drilling fluids. The type of drilling fluid used depends on the type of rock being drilled, with synthetic-based muds generally being used deeper in the boreholes. Drilling fluids are also important in well control.

Table 4-1 presents the types of drilling fluid used for different diameters of drill bits and hole sections. The final choice of fluids will be determined during the drilling programs.

Figure 4-8: Indicative schematic of a semi-submersible drilling rig

Table 4-1: Drilling fluid types

Drill-bit diameter (inches)*	Drilling-fluid type
42 to 26	Water-based muds (sea water and high-viscosity gel sweeps)
17½ and 16 to 17½	Water-based mud (polymer gel)
12¼	Synthetic-based muds
8½	Synthetic-based muds (with calcium carbonate ($CaCO_3$))

* 1 inch = 25.4 mm.

4.2.2 Subsea system

The subsea system will consist of wellheads, “subsea trees” and associated manifolds and flowlines, together with umbilicals to communicate with the seabed structures from the CPF. The completion of permanent production wells will enable the production of reservoir fluids. The wells will be drilled in the Brewster and Plover reservoirs over the life of the Project in cluster formations, tying back to subsea manifolds.

Indicative locations of the subsea wells and the drill centres are presented in Figure 4-9.

A subsea wellhead is installed at the top of each well and is used to support the inner casing of the well. Each subsea tree consists of a series of valves and other instruments which are connected to the CPF through umbilicals to allow control and monitoring of the production from each well. An example of a subsea system is shown in Figure 4-10.

The clusters of subsea trees will be connected to manifolds which are required to gather and commingle the produced fluids into flowlines for transport to the CPF. The control valves on the subsea system will use either an open or a closed-loop hydraulic system. The open-loop system releases a small amount of

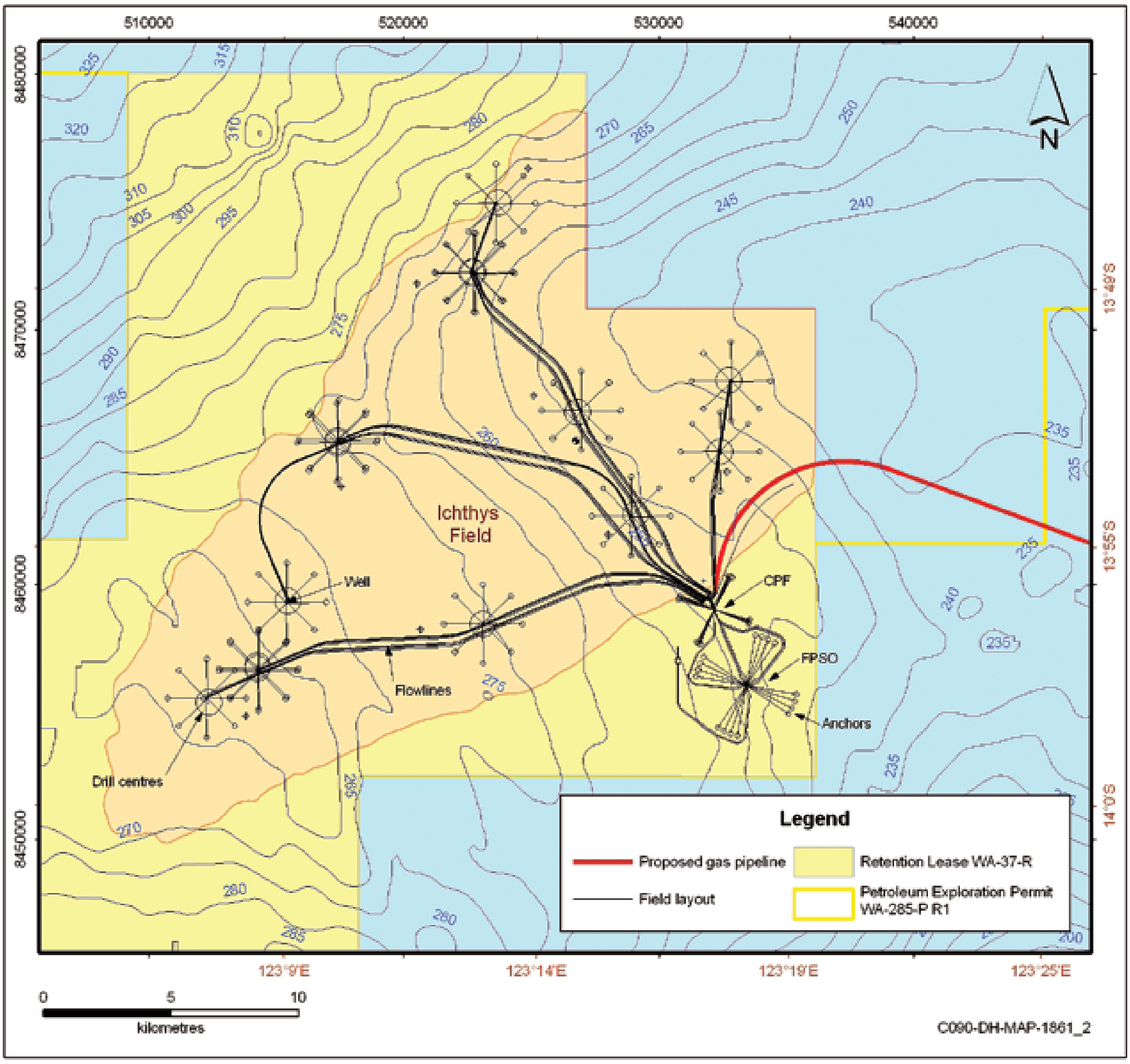

Figure 4-9: Indicative field layout showing subsea facilities

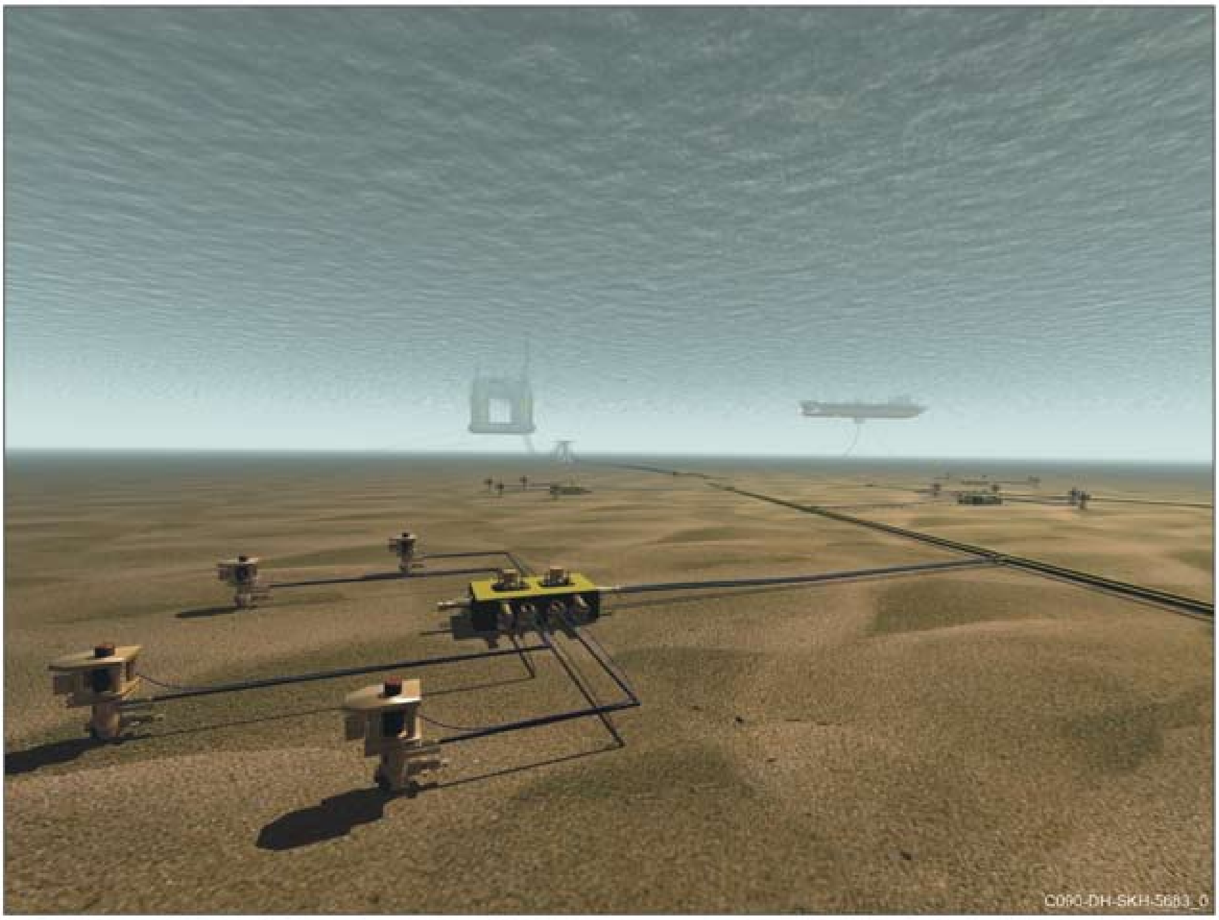

Figure 4-10: A typical layout for a subsea system

hydraulic fluid to the sea each time a valve is opened and closed, while the closed-loop system contains the fluid but has a detrimental effect on valve closure time. The final choice of system is likely to be open-loop; however, performance evaluation of these two systems will be undertaken during detailed design.

From the production manifolds, the reservoir fluids will flow towards the CPF through flowlines. The flowlines terminate at the subsea safety isolation valves. Flexible risers connected to the subsea safety isolation valves provide a conduit for reservoir fluids to reach the CPF. Umbilicals will also run from the CPF to individual wells and subsea trees to provide services, chemicals and controls. These umbilicals consist of an array of small tubes and electrical cables within a single large-diameter pipe.

The production system, infield flowlines and risers are internally corrosion-resistant and protected from produced fluids and sand particles. Production flowlines will also be insulated to maintain fluid temperature within acceptable levels and sacrificial anodes and anticorrosion paints will be used to protect each flowline against external corrosion.

Construction and installation of subsea system

The subsea trees and manifolds will be installed by the MODU or another installation vessel after the drilling process has been completed. Once the subsea trees and manifolds are in place, flowlines will be laid by pipelay vessels, flexible risers will be connected, and these risers and umbilicals will be connected to the CPF after it has been installed.

4.2.3 Offshore processing facilities

INPEX has selected a semi-submersible processing platform concept for receiving, processing, storing and exporting hydrocarbon gas and fluids from the Ichthys Field.

Hydrocarbon gas will be exported from the CPF through a subsea pipeline to the onshore facilities at Blaydin Point, Darwin. Most of the condensate will be exported from the FPSO to tandem-moored offtake tankers. A safety exclusion zone with a radius of 500 m will be put in place around surface equipment in the offshore development area. A cautionary zone will also be established, in consultation with the appropriate authorities, to protect it from potential damage from anchors, trawl nets, etc.

An indicative offshore process is presented in Figure 4-11.

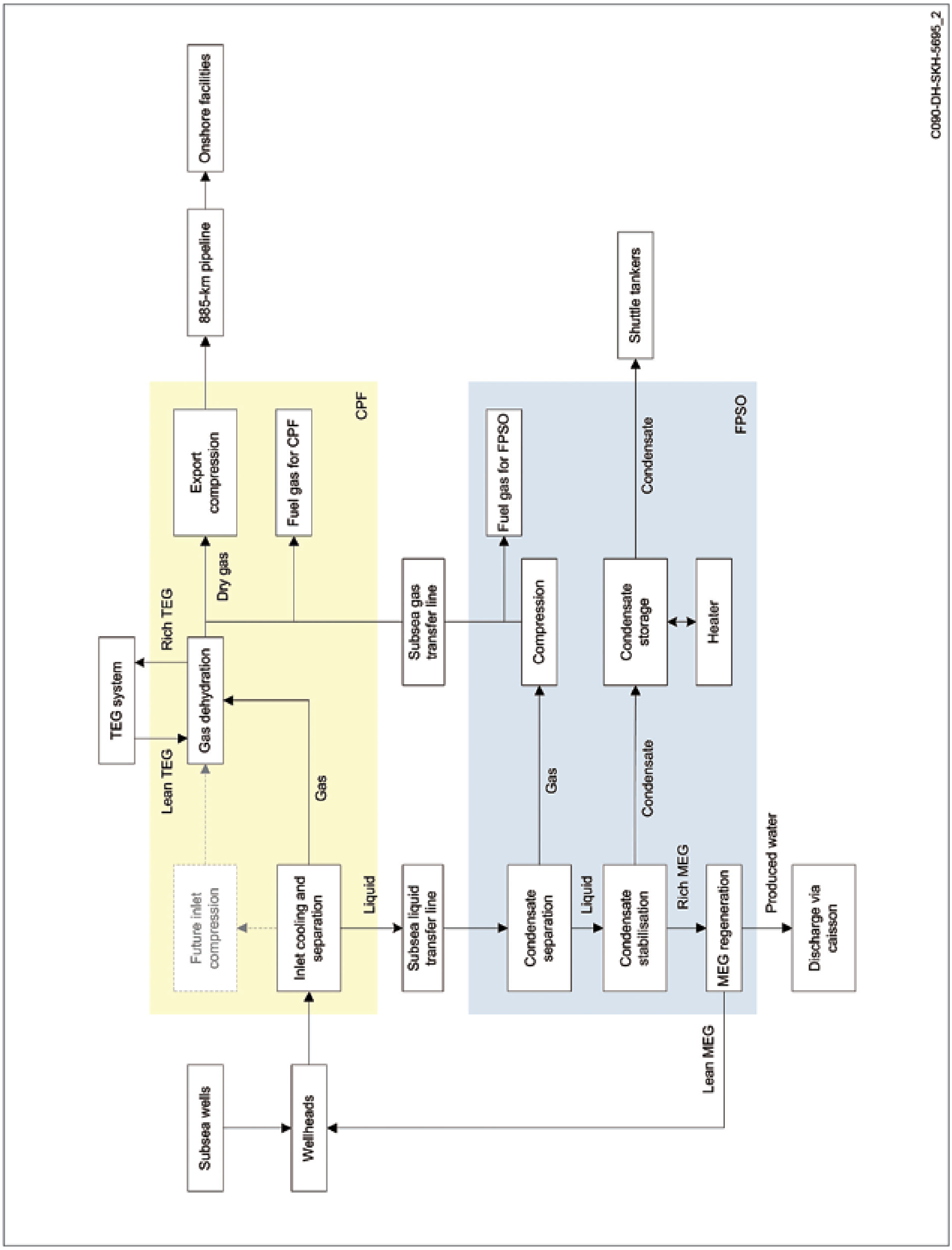

Figure 4-11: Offshore process flow diagram

Central processing facility

The CPF will be moored in a water depth of approximately 250 m and will be based on a semi-submersible floating production design that will remain at the Ichthys Field for the duration of the Project. The CPF will likely be oriented in a north-west – south-east direction to maximise ventilation from prevailing winds. This orientation provides good ventilation across the facility and supports maritime logistics operations at the facility.

The CPF will be moored in place using between 24 and 32 chain-mooring systems and suction piles. Figure 4-12 shows an example of a similar facility, the floating production unit *Asgard B*, operating in the Norwegian Sea in the North Atlantic.

Figure 4-12: Example of a semi-submersible processing platform, the *Asgard B*

The well-stream fluids will be directed to the CPF where reception facilities will separate the gas from the liquids. The gas will be dehydrated using triethylene glycol (TEG) to meet the export water dewpoint specification to prevent condensation of water and potential hydrate formation and corrosion in the gas export pipeline. A circulating TEG system will be used (along with compression and cooling). The dehydrated gas will be compressed and exported to the onshore facilities at Blaydin Point.

The liquid stream from the reception facilities, consisting of a commingled stream of condensate, water and MEG, will be routed to the FPSO for further treatment.

Gas inlet compression will be required to maintain sufficient suction pressure to the export gas compression after approximately Year 11 when the well-stream fluid's arrival pressure will decline.

The emergency flare system will be designed for blowdown of the facilities in the event of an emergency, in line with industry codes and standards. It will comprise a high-pressure flare and a low-pressure flare on a common stack with a pilot and ignition system.

Services and utilities on the CPF will include the following:

- a power generation and distribution system
- a fuel-gas supply system which will provide fuel to the power generation gas turbines
- an instrument air system to provide clean dry air and nitrogen to process units
- a chemical injection package to provide dosing chemicals such as MEG, scale inhibitors, wax inhibitors and hydraulic fluids
- a subsea control support system
- a fuel storage facility (diesel fuel will be bunkered in storage tanks within the hull of the CPF)
- open and closed drainage systems to separate deck drainage from hazardous and non-hazardous areas
- a bilge system to drain watertight compartments
- a ballast system to manage the draught of the CPF.

All non-process services and living quarters will be located in non-hazardous areas.

The CPF will have accommodation for up to 150 people on board. Its facilities will include galley units; a helicopter deck; firefighting systems; material, waste and chemical storage areas; a reverse-osmosis (RO) plant to provide potable water; and a sewage discharge system. In addition, a diesel emergency generator will provide a backup power supply for essential services and power when main power generation is unavailable. Cathodic protection of the external hull of the CPF will be provided.

Discharges from the CPF are discussed in Chapter 5 *Emissions, discharges and wastes*.

Floating, production, storage and offtake facility

The FPSO will be ship-shaped, similar to an oil trading tanker, but without propulsion, steering and navigation systems. It will be permanently moored at the designated field location for the life of the field. The facility will be equipped with hydrocarbon processing and MEG regeneration facilities. The FPSO will have a condensate storage capacity of more than 1 000 000 barrels.

The FPSO will be turret-moored, permitting 360° weathervaning. To assist in heading control and to mitigate roll movements while weathervaning, it may be fitted with ancillary thrusters. The turret connecting the FPSO to the seabed will have mooring legs with suction piles located in such a way that the distance from its stern to the CPF will be approximately 2–3 km with consideration of the prevailing winds and currents.

Figure 4-13 shows an example of an existing FPSO vessel.

Figure 4-13: Example of an FPSO

The FPSO topsides will receive liquids from the CPF. Processing of the liquids on the FPSO will include condensate stabilisation, mercury removal from the condensate, MEG regeneration and reclamation and produced-water treatment facilities.

The stabilised condensate will be stored within the hull of the FPSO prior to export to offtake tankers. Gas that comes off the liquid stream will be cooled, compressed and used for FPSO fuel gas, with any excess being sent back to the CPF where it will be commingled with the untreated gas arriving from the wells.

Waste-heat recovery systems will be installed on gas turbines to provide heat to the condensate stabilisation and MEG regeneration facilities.

The MEG regeneration facilities will remove most of the water and salt from the "rich MEG" so that "lean MEG" can be pumped back to the wellheads for reuse.

Produced water from the MEG regeneration plant will be further treated in produced-water treatment facilities to meet the required discharge standards prior to discharge to sea.

Some types of services and utilities found on the CPF will also be required on the FPSO, including accommodation quarters for up to 150 personnel, communication systems, a power generation plant, cooling and heating media, ballast and bilge systems, and flare systems. Cathodic protection of the external hull of the FPSO will be provided.

4.2.4 Construction and installation of offshore processing facilities

Both the CPF and the FPSO will be constructed at off-site fabrication yards and will be towed to the field as single units. The hull of the CPF will include pontoons, columns, the deck, hull ballast and support systems, living quarters, process and utility equipment, and the flare boom. Integrated deck modules will also be constructed in overseas fabrication yards and will most likely be installed on the CPF at the fabrication yard. As far as is practicable, all components of the CPF and FPSO will be comprehensively tested and commissioned at the fabrication yards before being transported to the Ichthys Field.

During towing to site, the CPF and FPSO will be manned and have fully functional living quarters and support systems. Once the CPF and FPSO are on location in the field they will be detached from their respective towing vessels and held in position by tugs while the permanent mooring systems are attached. Following detachment from the towing vessels, they will be de-ballasted for operation. The power generators will be started on diesel fuel.

The subsea pipeline and flowline risers will be installed between the seabed and the CPF and all the recently connected joints will be pressure-leak-tested with treated sea water. All leak- and pressure-testing of pipework offshore, similar to the process used for testing all hydrocarbon pipework, vessels and valves on the CPF and FPSO at the fabrication yards, will be undertaken using hydrotest water and/or high-pressure nitrogen containing trace quantities of helium for detection.

4.2.5 Offshore commissioning, operations and maintenance

The completion of the CPF and FPSO will coincide with the completion of the onshore plant. When all facilities are certified as ready for start-up, the first reservoir fluids will be introduced into the system. The first well will be opened on a reduced opening to permit safe pressurisation and the well-stream product will begin to flow to the CPF in the following sequence of events:

- The flare pilot and purge system will be commissioned.
- The flare pilots will be ignited and lit using bottled propane. These bottles will remain available throughout the life of the field as flare ignition backup.
- The topsides process will be pressured up and flow directed to the fuel-gas distribution system.

- The well-stream product will be introduced into the primary separation package where the liquid stream will be directed to the FPSO for treatment; as a temporary measure all the gas will be diverted to the flare on the CPF.
- A portion of the gas will be used for fuel gas to run the main power generation turbines and also to help boost the heating medium required for the gas-drying process.
- The main gas stream will be sent to the gas-treatment trains for drying using TEG. The water will then be boiled off and the TEG recycled. Once dry and to specification, the gas will be sent to the gas export pipeline to be exported to the onshore plant.

As the various systems are tuned and begin to operate at stable conditions, the flow rates will be increased up to full operational levels for proving and testing. When the systems are in steady-state operation, INPEX's operations division will be responsible for maintaining the facilities. A maintenance function will be part of the operations division's role, with prime responsibilities in the following order of importance:

- to safeguard the technical integrity of the facility and ensure a safe working environment
- to ensure that equipment and systems are maintained to a standard where they are able to satisfy environmental and regulatory-authority requirements
- to maximise the amount of time the facilities are running.

A risk-based approach will be taken to develop maintenance strategies that will be applied to different types of equipment and facilities. Preventive, predictive and corrective maintenance strategies will be developed using experience and good practice, supported when appropriate by techniques such as risk-based inspection and reliability-centred maintenance.

As personnel competence is considered key to the effectiveness of the maintenance function, appropriate selection procedures will be put in place and, where necessary, training of in-house and specialist personnel will be undertaken.

4.3 Gas export pipeline

Hydrocarbon gas will be exported from the CPF through flexible risers and a subsea manifold to the gas export pipeline and then on to the onshore processing plant at Blaydin Point. This section describes the pipeline route and associated activities through different phases of the Project.

4.3.1 Pipeline route

The gas export pipeline will run from the export pipeline manifold adjacent to the CPF to the Blaydin Point onshore processing plant. The pipeline route follows an approximately direct line from the CPF to the mouth of Darwin Harbour through the existing Northern Australia Exercise Area (administered by the Department of Defence), and then through the Harbour to Blaydin Point. The total length of the pipeline from the CPF to the gas-receiving facilities at Blaydin Point will be approximately 885 km. The pipeline route is illustrated in figures 4-14 and 4-15.

Key criteria used in determining the offshore and onshore pipeline route were:

- to achieve as direct a route as possible
- to avoid significant seabed features and obstructions such as scarps, reefs, and rough seafloor
- to minimise disturbance to potentially environmentally sensitive areas
- to avoid sensitive heritage areas such as World War II wrecks and Aboriginal sacred sites in Darwin Harbour
- to avoid existing infrastructure such as the Bayu–Undan Gas Pipeline
- to minimise any disturbance of potential acid sulfate soils which would result in the generation and release of sulfuric acid
- to minimise any disturbance to the hydrology of creek systems.

During the laying of the offshore pipeline, a detailed seabed route survey will be undertaken to ensure that the route avoids subsea obstructions and sensitive habitats.

Within Darwin Harbour, it is proposed that the pipeline will follow a similar route to, but to the west of, ConocoPhillips' existing Bayu–Undan Gas Pipeline to Wickham Point. Once onshore, the pipeline will be buried adjacent to the existing road alignment of Wickham Point Road for approximately 2.5 km, then proceed north-east to the onshore processing plant site at Blaydin Point, for a total distance of approximately 6 km (see Figure 4-16).

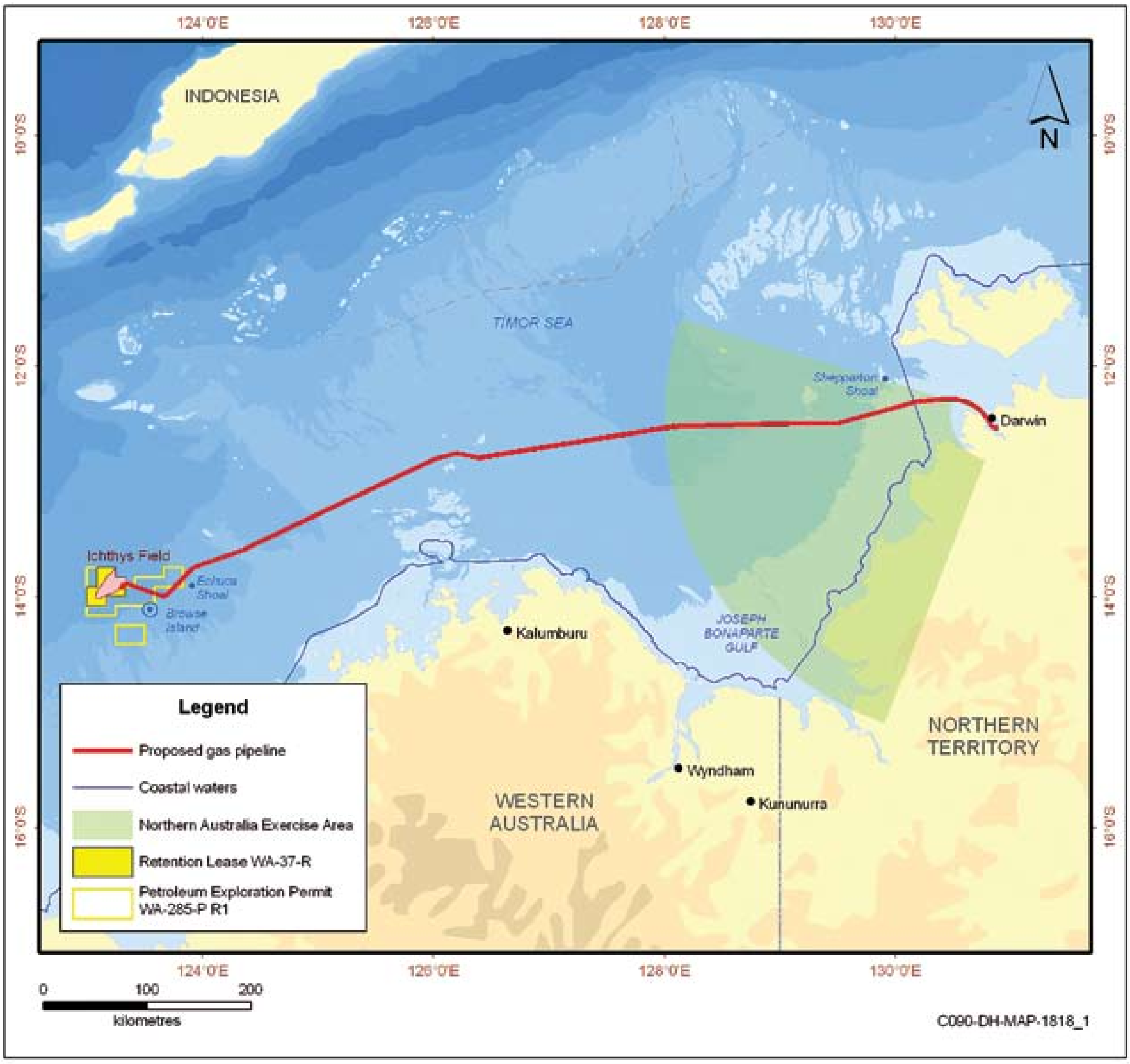

Figure 4-14: Proposed gas export pipeline route from the Ichthys Field to Darwin Harbour

4.3.2 Pipeline construction

Offshore pipeline construction

The pipeline will be constructed using conventional offshore pipeline construction methods which involve the use of many high-specification vessels sourced from around the world. The carbon-steel pipeline will be treated externally with an anticorrosion coating. In addition, sacrificial bracelet anodes will be attached at regular intervals along the pipeline for cathodic protection. A concrete coating will also be applied along the entire submerged pipeline length to provide on-bottom stability and mechanical protection.

The primary vessel used to install the pipeline will be a deepwater pipelay vessel. These vessels maintain position using either a dynamic positioning system (which controls thrusters) or an anchor system.

Vessels used to support the pipelay vessel may include pipe-supply vessels, a trailing suction hopper dredger, rock dumpers, anchor handlers, diving support vessels, hopper barges, supply vessels, ploughing support vessels and survey vessels.

Anchored barges typically have between 8 and 12 anchors. The anchors provide the reaction force to the lay tension as well as station-keeping against prevailing ocean conditions.

On the pipelay vessel, the coated segments of pipe approximately 12 m in length will be welded together in a continuous process known as “S-lay”. Once welded, the joints will be inspected for any welding defects before being “overboarded” at the back of the pipelay vessel.

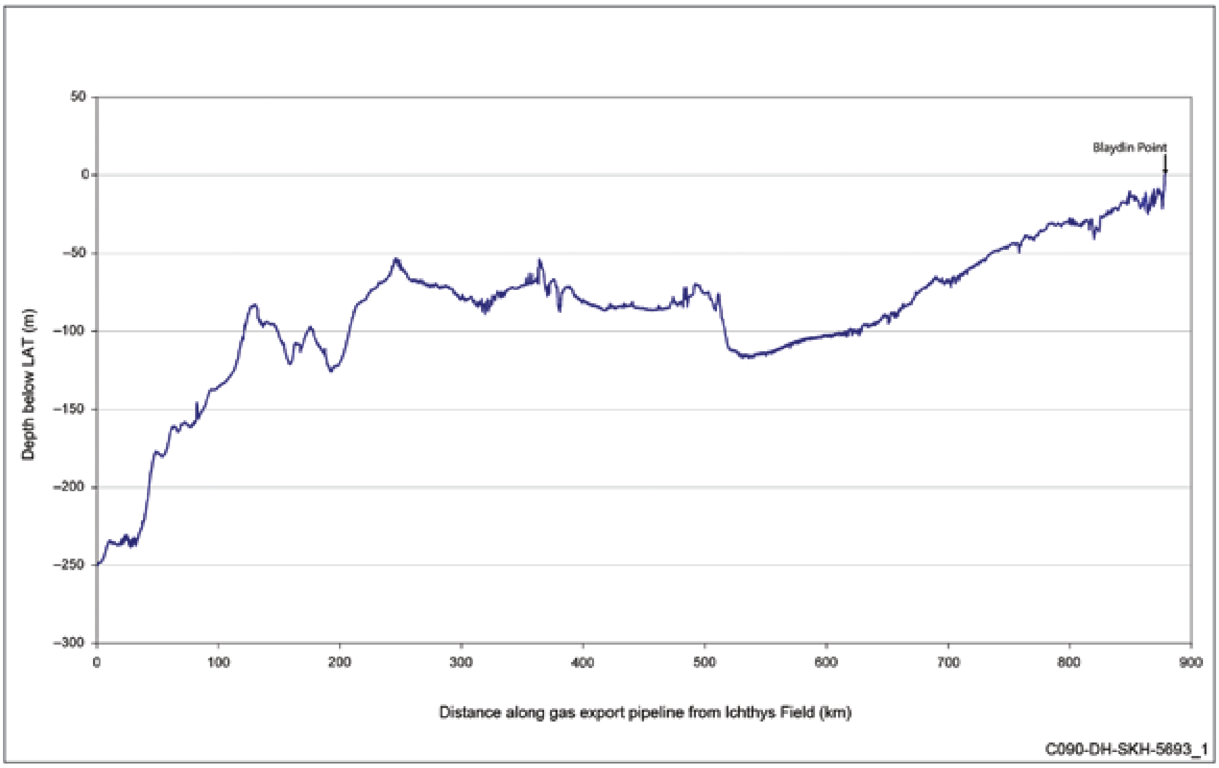

Figure 4-15: Gas export pipeline route depths in longitudinal cross-section

During construction, the pipelay vessel and support vessels will manoeuvre in a construction corridor which will be approximately 1000 m wide in Darwin Harbour and 2000 m wide offshore. The construction corridor allows room for the pipelay barge anchors and support vessel movements while also allowing for flexibility to modify the pipeline route around any local seabed obstruction.

The primary means of maintaining pipeline stability on the seabed will be through concrete weight-coating. Where stability cannot be obtained by this means alone, the pipeline may be trenched. The proposed trenching method may involve the use of underwater ploughs and/or underwater mechanical trenchers depending on the hardness of the seabed.

Where trenching is insufficient to achieve pipeline stability, rock dumping will be carried out by specialised construction vessels. Rock will most likely be sourced from an onshore quarry in the Northern Territory, such as Mount Bundy, and stored in a transfer area at East Arm Wharf prior to load-out to the pipelay operation. Typically the rock dump or berm over the pipe would be approximately 10 m wide at the base (as shown in Figure 4-17).

Nearshore pipeline and shore-crossing construction

It is anticipated that in Darwin Harbour the pipeline will be installed adjacent to the Bayu–Undan Gas Pipeline. A smaller shallow-water lay barge will be required in the Harbour for this purpose. Typical shallow-water lay barges maintain position by utilising anchors only. There are typically between 8 and 12 anchors, which are spread out from each corner of the lay barge to keep it stable.

The pipeline inside the Harbour will likely require partial burial and rock-armouring to minimise any risk of damage. Potential threats to the pipeline include damage from anchors or from ship groundings by the large vessels which use the Harbour.

The pipeline route through Darwin Harbour will be excavated using a backhoe dredger. The trench will be relatively shallow (to a depth of 3 m) and will form a gutter that will provide stability to the pipeline. The volume of dredge material generated by pipeline construction in Darwin Harbour is estimated to be approximately 600 000 m^3. The dredged material will be removed and disposed of at an approved location as discussed in Section 4.4.3 *Dredging and dredge spoil disposal.*

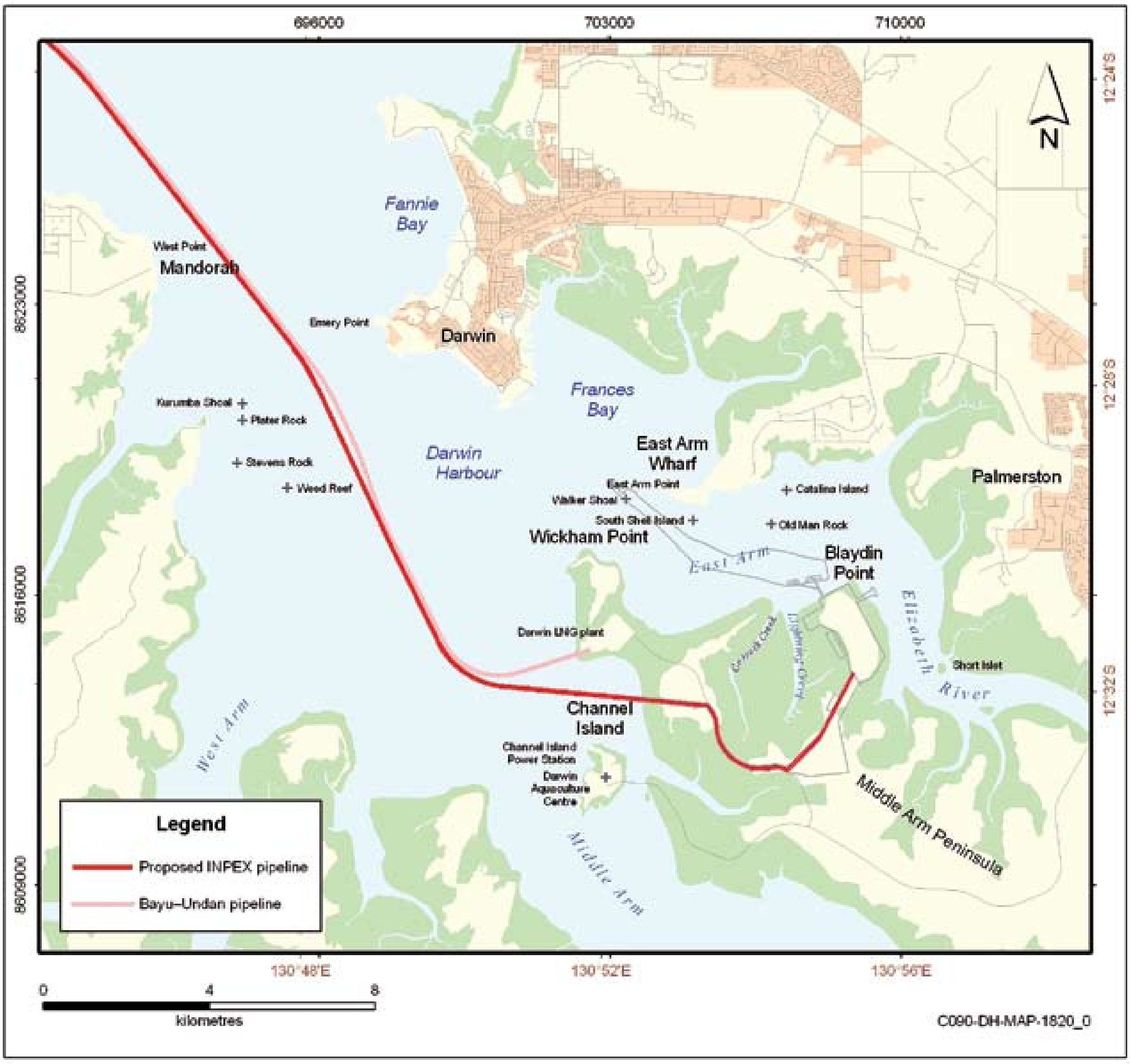

Figure 4-16: The gas export pipeline route through Darwin Harbour

Rock-armouring will be put in place over the top of the pipeline once it has been constructed on the seabed. Approximately 850 000 t of rock, which will likely be sourced from existing quarries, will be transported by road to East Arm Wharf where specialised rock-dumping vessels will take it offshore for dumping directly over the pipeline.

Pipeline shore crossing

The primary criteria used to determine a suitable location for the pipeline shore crossing were the following:

- to avoid historical sites in the Harbour, such as the wreck of the SS *Ellengowan*
- to minimise the dredging required to manoeuvre the lay barge close to shore
- to minimise the environmental footprint and disturbance by aligning the pipeline adjacent to the Bayu–Undan Gas Pipeline
- to avoid crossing over the Bayu–Undan Gas Pipeline.

The construction techniques considered for the pipeline shore crossing included open-trench excavation, micro-tunnelling and horizontal directional drilling.

The open-trench excavation method requires the construction of a trench using sea-based dredging equipment and land-based hydraulic excavators. Upon completion of the trench excavation across the shore, the pipeline would be pulled through the trench from the lay barge using an onshore winch spread. Alternatively, pipeline strings may be prefabricated onshore behind the trench and pulled through the trench with the equivalent winch spread on the pipelay vessel. This would be a robust construction technique and it was the one used in the construction of the Bayu–Undan Gas Pipeline.

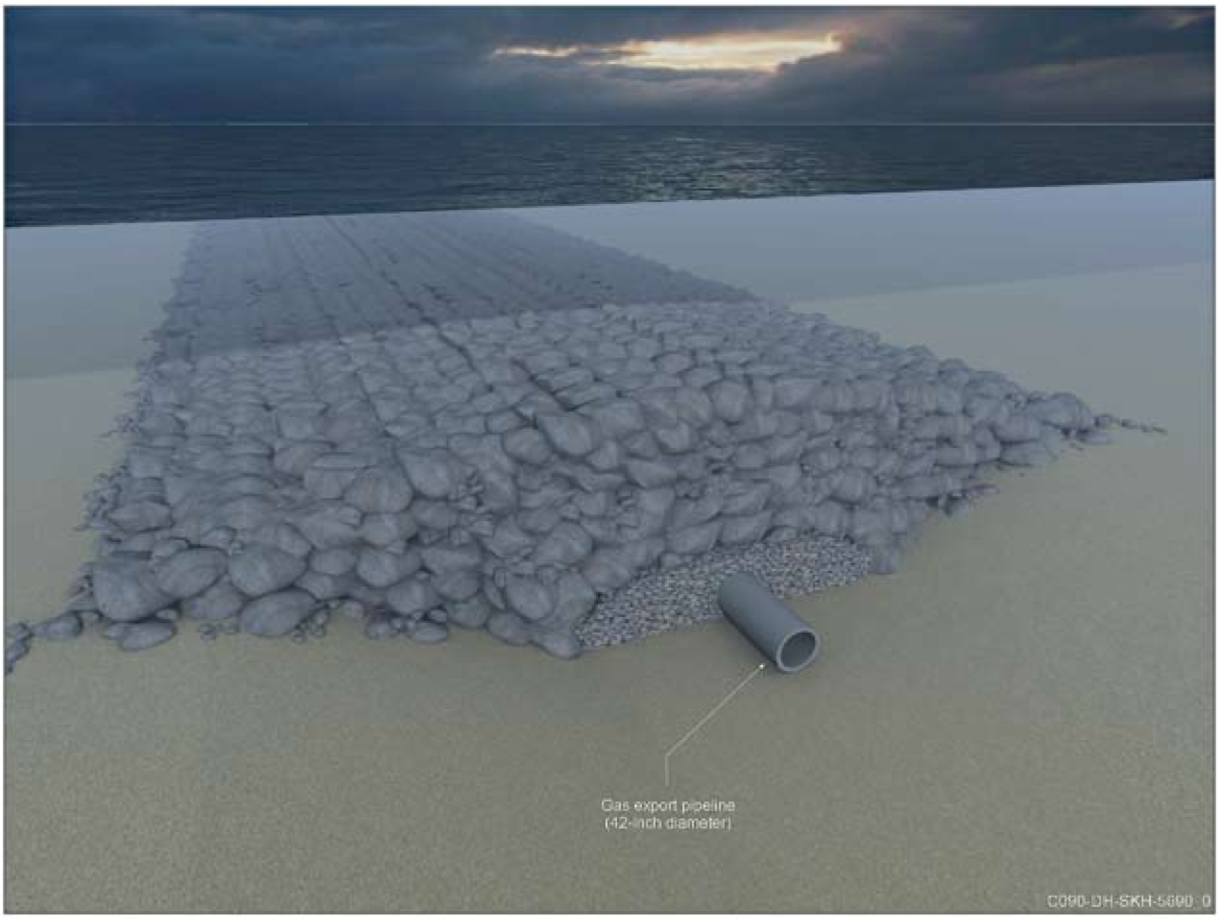

Figure 4-17: Indicative schematic of pipeline and rock-armouring

Micro-tunnelling is also considered for large-diameter pipelines when the shoreline has high steep cliffs which may preclude the application of a conventional open-trench excavation method. Micro-tunnelling to produce a shaft and tunnel uses a form of steerable pipe-jacking in which a tunnel-boring machine (TBM) is thrust forward by hydraulic rams. Steel or concrete pipe segments approximately 2 m in diameter are placed behind the TBM and are used to transfer thrust to the face of the tunnel. They are continuously added as the TBM progresses along the chosen alignment. The concept requires an onshore vertical shaft from which the TBM would be launched. The TBM bores to a location offshore where it can be recovered, and the pipeline is then installed in the tunnel.

Horizontal directional drilling is based on drilling a small pilot hole with a diameter of 10–16 inches (*c*.25–40 cm), which is subsequently opened up to a size typically 35–50% larger in diameter (depending on ground conditions) than the pipeline to be installed. The horizontally drilled boreholes are typically opened up by forward reaming as it is unlikely that continuous offshore support can be provided during back reaming. Forward reaming in soft soils places large compressive loads on the drill pipe and will consequently limit achievable reaming lengths. Upon completion of the reaming, the pipeline is pulled or pushed through the drilled hole.

The geology of the proposed shore-crossing location at Middle Arm Peninsula and the proposed diameter of the pipeline make open-trench excavation the most suitable and robust method. Neither micro-tunnelling nor horizontal directional drilling are suitable techniques for a 42-inch pipeline.

The pipeline right of way through the mangrove area to the south of Wickham Point Road will be approximately 20–25 m wide and will be dependent upon the results of geotechnical investigations. A berm (causeway) will be constructed along and within the pipeline right of way to facilitate the pipeline stringing, welding, trenching and lowering operations. The finished height of the berm will be approximately the same height as the existing road structure which it parallels. The pipeline will be laid in an open trench at the side of the berm. The excavated trench will be approximately 1.5 m deep and 2–3 m wide, depending on existing ground conditions. Once the pipeline has been laid, the trench will be backfilled with clean fill. Additional fill will be placed over the pipeline trench to a level equal to the finished height of the berm. A minimum pipeline cover depth of 1.2 m will be maintained. Drainage culverts will be installed across the width of the berm at regular intervals to ensure that drainage is maintained to the mangroves retained between the berm and Wickham Point Road.

Depending on the construction option chosen, an estimated volume of 35 000 m^3 of material in the intertidal zone may need to be excavated. One of the key considerations in undertaking the open-trenching method is to avoid the generation of sulfuric acid by disturbing potential acid sulfate soils. Management controls for this are discussed in further detail in Chapter 8 *Terrestrial impacts and management.*

Following the installation of the pipeline through the shore crossing, approximately 30 000 t of rock will likely be required for rock-armouring in the intertidal area. Reinstatement and rehabilitation of the temporarily disturbed shore-crossing location area seaward from the beach valve will be undertaken when the construction of the pipeline shore crossing is complete.

4.3.3 Pipeline precommissioning

When the pipeline has been installed, the construction process will be completed through a number of stages of precommissioning. These will typically involve the following:

- flooding, cleaning and gauging of the pipeline with treated sea water, driving a pig train from the shore with a flooding spread set up at the shore-crossing location
- hydrotesting of the pipeline with treated sea water using a pressure-testing spread set up at the shore-pull location
- dewatering of the pipeline from onshore to offshore using a dewatering spread set up at the shore-pull location
- conditioning of the pipeline in readiness for the introduction of hydrocarbons. Options under evaluation include a combination of glycol swabbing (during dewatering), purging with nitrogen, pipeline evacuation (air removal), vacuum-drying, and air-drying.

The equipment required at the shore-pull area during precommissioning will typically include water-winning pumps, pressurisation pumps, chemical injection equipment, compressors, filters, driers, coolers, generators, and storage tanks for chemicals and diesel. A typical layout of a shore-pull area is shown in Figure 4-18.

Figure 4-18: Indicative schematic of the shore-pull area

4.3.4 Pipeline commissioning, operation and maintenance

Once precommissioning has been completed, the pipeline will be ready for start-up and the introduction of hydrocarbons. The equipment at the shore-pull area will be demobilised and the pipeline will be ready to enter its operating phase.

Following commissioning, the pipeline will be continuously operated to provide gas to the onshore plant for the duration of the 40-year life of the Project. Ordinarily, maintenance will include regular internal and external inspections and monitoring with repairs as necessary to ensure the integrity of the pipeline.

4.4 Nearshore infrastructure

Infrastructure and activities in the nearshore development area that will support the construction and operations phases of the Project are listed in Section 4.1.1 *Major infrastructure*. These are described in more detail in the following sections.

4.4.1 Module offloading facility

Facilities necessary for the importation of materials, equipment and process modules are required from the outset of construction of the onshore facility.

Ports in the Darwin area have been assessed for their capacity to fulfil the requirements of the Project. The primary factor was the ability and capacity of ports to accept large prefabricated modules from ocean-going vessels. While the facilities at East Arm Wharf are capable of taking general cargo and equipment and some of the modules, it was found that most of the modules could not be accommodated.

It will therefore be necessary to design and construct a module offloading facility at Blaydin Point, the primary purpose of which will be to unload modules for the LNG plant. After completion of the construction phase, the module offloading facility will be fenced off and retained for future use, such as for major maintenance operations.

The module offloading facility will be linked with the main LNG plant area by a gently sloping embankment around 60 m wide (Figure 4-19).

Construction of the module offloading facility

The module offloading facility will be constructed with steel sheet piles, or with a concrete deck on steel piles, or using a combination of these two methods. Various design techniques are being considered for a causeway to the facility. The techniques may include use of granular fill compacted in layers sourced from the site or from a local quarry, or by a combination of these two, together with the installation of rock-armouring along the causeway for support and protection from wave action. The final construction technique will be evaluated based both on its engineering feasibility and on its associated costs.

The generation of dredge spoil and its disposal is discussed in Section 4.4.3 *Dredging and dredge spoil disposal*.

Figure 4-19: Indicative schematic of the module offloading facility

4.4.2 Product loading jetty

The ability to efficiently and safely berth tankers and load product at the product loading jetty is critical to the Project. Jetty design is based on a series of complex loading and navigation studies, geotechnical and environmental surveys, and safety quantitative risk assessments (QRAs).

Key technical criteria influencing jetty design include the following:

- The water depth and channel width in the approaches to the jetty must be sufficient for safe navigation.
- The turning basin width must be sufficient to allow tugs to safely turn and manoeuvre product tankers to the jetty head.
- The jetty alignment must take into account prevailing winds and tidal currents to facilitate safe manoeuvring for product tanker turning, berthing and departing.
- The separation distances for berthing vessels at East Arm Wharf and the product loading jetty at Blaydin Point need to be maximised for safety reasons.

In addition, during consultation with community stakeholders, a particular concern raised was that recreational fishing access should be maintained to Lightning and Cossack creeks adjacent to Blaydin Point. As a result, INPEX committed to investigating jetty design concepts which would maintain safe public access to these creeks.

Alternative jetty concepts

Based on assessment against technical criteria and in consideration of community concerns, several alternative jetty concepts were investigated. The resulting technically viable concepts fell into two categories:

- a short-jetty concept—a short jetty length, with a position and orientation as shown in Figure 4-2
- a long-jetty concept—a long jetty (approximately 3 km) with an orientation running directly across the entrance to Lightning and Cossack creeks as shown in Figure 4-20.

In addition, INPEX also explored the possibility of sharing the loading jetty at ConocoPhillips' Darwin LNG plant at Wickham Point. This option was not pursued, however, for the following reasons:

- INPEX requires export facilities for LPGs and condensate which are not available at the ConocoPhillips jetty.
- The 26 km of cryogenic-rated loading line from the Blaydin Point LNG tanks to the Wickham Point export jetty and back to Blaydin Point would be commercially unviable.
- The efficiency of INPEX's LNG plant would be reduced, as a significant proportion of the LNG would be regasified during the approximately 26-km round trip to the end of the ConocoPhillips jetty head. (The LNG is maintained in continuous circulation to keep the export pipeline in a cryogenic state.)
- There would be significant commercial and legal complications to any joint operations by the two companies at Wickham Point. Examples of possible complications would include the following:
  - questions over which company's vessels would be given preference for loading
  - the assignment of liability should damage be caused to the jetty by one party which would prevent product loading by the other party
  - the assignment of responsibility for recovery or flaring of boil-off gas at the loading berths.
- Joint use of the jetty facilities by the two companies would increase the safety risk.

Recognising that there were complex and competing environmental, social and technical issues associated with the selection of a short or long jetty, INPEX undertook a detailed evaluation of the long-jetty vs short-jetty concepts. The short-jetty option was found to be the better option.

The key advantages of the short-jetty concept include the following:

- a reduction in the risk of recreational vessels travelling into jetty safety exclusion zones and taking potentially unsafe short cuts under the jetty trestle
- a reduction in safety risks from the Project's product loading jetty because of the increased separation distances for vessels berthing at East Arm Wharf
- a reduction in the long-term impact on visual amenity from Darwin's central business district and other vantage points around Darwin Harbour
- the elimination of the need for jetty piling and jetty construction works in close proximity to the World War II Catalina flying-boat wrecks
- a reduction in leak paths for products (LNG, LPGs and condensate) from the jetty loading lines.

The disadvantage of the short-jetty concept is that larger dredge volumes are required to be removed in the shallower water closer to Blaydin Point. Overall, however, the temporary environmental and social disadvantages caused by an increased dredge volume are mitigated by improved safety outcomes, a reduction in long-term visual amenity impact, and a reduction in the extent of the area excluded by safety requirements for recreational users in East Arm.

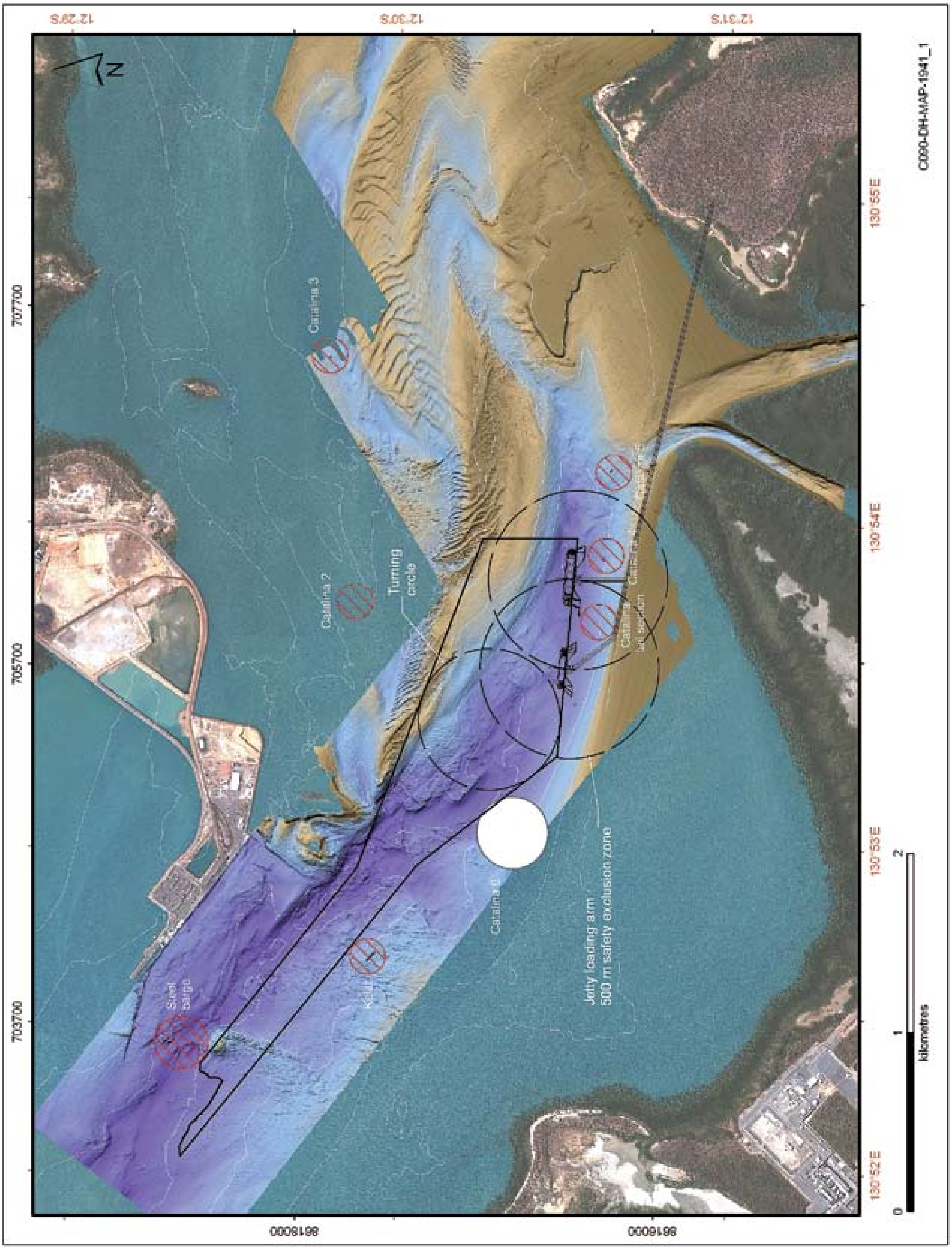

Figure 4-20: The "long-jetty" concept

INPEX has presented a comprehensive assessment of the potential marine impacts associated with the short-jetty concept in Chapter 7 *Marine impacts and management*, while the potential social impacts are presented in Chapter 10.

Design of the product loading jetty

The deck level of the product loading jetty will be approximately 16 m above Lowest Astronomical Tide (LAT). The berths will be designed to minimise the effect of wind and currents on navigation. There will be two berths along the jetty, one solely for LNG loading and the other for propane, butane and condensate loading. Based on safety assessments there will be a separation distance of 500 m between the berths.

Each berth will consist of a loading platform and berthing and mooring dolphins. A mooring dolphin is a maritime structure fixed to the seabed (and not connected to the shore or to the jetty) which extends above water level as a platform to provide a mooring point for ships.

The product flowlines from the gas-processing plant will run the length of the jetty to the loading arms and will be equipped with a leak-detection system. A wastewater discharge outfall will also be located at the end of the jetty. The outfall will be designed to maximise the dispersion of treated wastewater.

The deck of the jetty will accommodate a 4-m-wide road to allow standard truck and mobile crane access.

A security gate and access road may also be located between the berths and the product storage tank area.

Construction methods for the product loading jetty

Jetty construction methods are being investigated and will be further defined in the detailed-design phase of the Project. The most likely construction method would involve piledriving and installation of concrete prefabricated deck sections using cranes on jack-up barges. The pipe racks for the jetty trestle would be transported by self-propelled module transporters by land.

The process would continue, working out from the shore abutment until the required jetty length is reached. The piles, precast deck beams and other materials would be brought to the jack-up barge by a support barge. Rock anchors to stabilise the piles might also be required. These would be installed after the deck sections are installed.

The choice of jetty construction method will depend on the results of detailed nearshore geotechnical investigations.

4.4.3 Dredging and dredge spoil disposal

A significant amount of dredging needs to be carried out in Darwin Harbour to support the Project. The purpose of the dredging program is as follows:

- to extend the existing safe shipping access from the vicinity of East Arm Wharf to the proposed product loading jetty at Blaydin Point
- to provide a turning basin large enough to permit the safe manoeuvring of ships that are more than 350 m in length overall
- to provide a safe approach and departure area to and from the product loading jetty
- to provide two berthing pockets at the product loading jetty to accommodate two product export tankers
- to provide an approach apron with a berthing pocket capable of accommodating up to four barges at any one time at the module offloading facility area
- to provide a trench to accommodate the subsea gas export pipeline to Middle Arm Peninsula.

The primary consideration in the design of the preliminary dredging program has been the need to ensure that the environmental impact of the dredging operations in Darwin Harbour will be kept to as low a level as is reasonably practicable.

To facilitate assessment in the time frame required by the environmental approval process, a preliminary dredging program was developed by INPEX using the services of specialist dredging engineers and data obtained from environmental, geotechnical and geophysical studies. These studies provided information on the volume and nature of the material within the dredge footprint and allowed the identification of the types of dredging equipment that would be necessary, the development of a sequence and schedule of dredging activities, and the development of a cost estimate. A number of potential dredging methodologies which could have significantly reduced the dredging program costs were rejected by INPEX on the grounds that they might have resulted in significantly greater environmental impact.

Dredging depths will be determined by allowing safe under-keel clearance (based on Project-specific navigation studies and internationally recognised navigation standards) at all stages of the tide for all types of product tankers. The largest tankers will have a fully laden draught of approximately 14 m.

The dredging program will be carried out by a dredging contractor who will be engaged at a later stage. Only a limited number of specialised dredging companies having the capacity to undertake the scale of dredging required for the Project are available worldwide. Therefore, until the dredging contractor has been engaged, dredging methods can only be planned conceptually and INPEX's dredging program will only be finalised once the contractor has been appointed.

The final dredging program will be designed so that any changes in methodology do not result in any significant increases to the predicted environmental and social impacts outlined in chapters 7 and 10 of this Draft EIS. Confirmatory modelling will be undertaken if required and, if so, will be included in subsequent dredging applications made to the Northern Territory Government. These will include a detailed dredging environmental management plan required as part of a construction environmental management plan under the *Waste Management and Pollution Control Act* (NT) and an application for a waste discharge licence under the *Water Act* (NT).

A detailed description of the preliminary dredging program is provided in the following sections.

4.4.4 Preliminary dredging program

Dredge volumes, dredged materials, and footprint

Based on preliminary estimates it is expected that a total of 16.9 Mm^3 of spoil will be generated during the dredging program. This will be made up of 15.1 Mm^3 from the shipping channel, turning basin and berthing area, 1.2 Mm^3 from the module offloading facility (see Figure 4-21), and 0.6 Mm^3 from the subsea section of the gas export pipeline from the mouth of Darwin Harbour to Middle Arm Peninsula.

Dredging calculations for the shipping channel are based on the need to provide clearance for all product tankers, with appropriate allowances being made for the large tidal range experienced in the Harbour. The dredge footprint has also been designed to

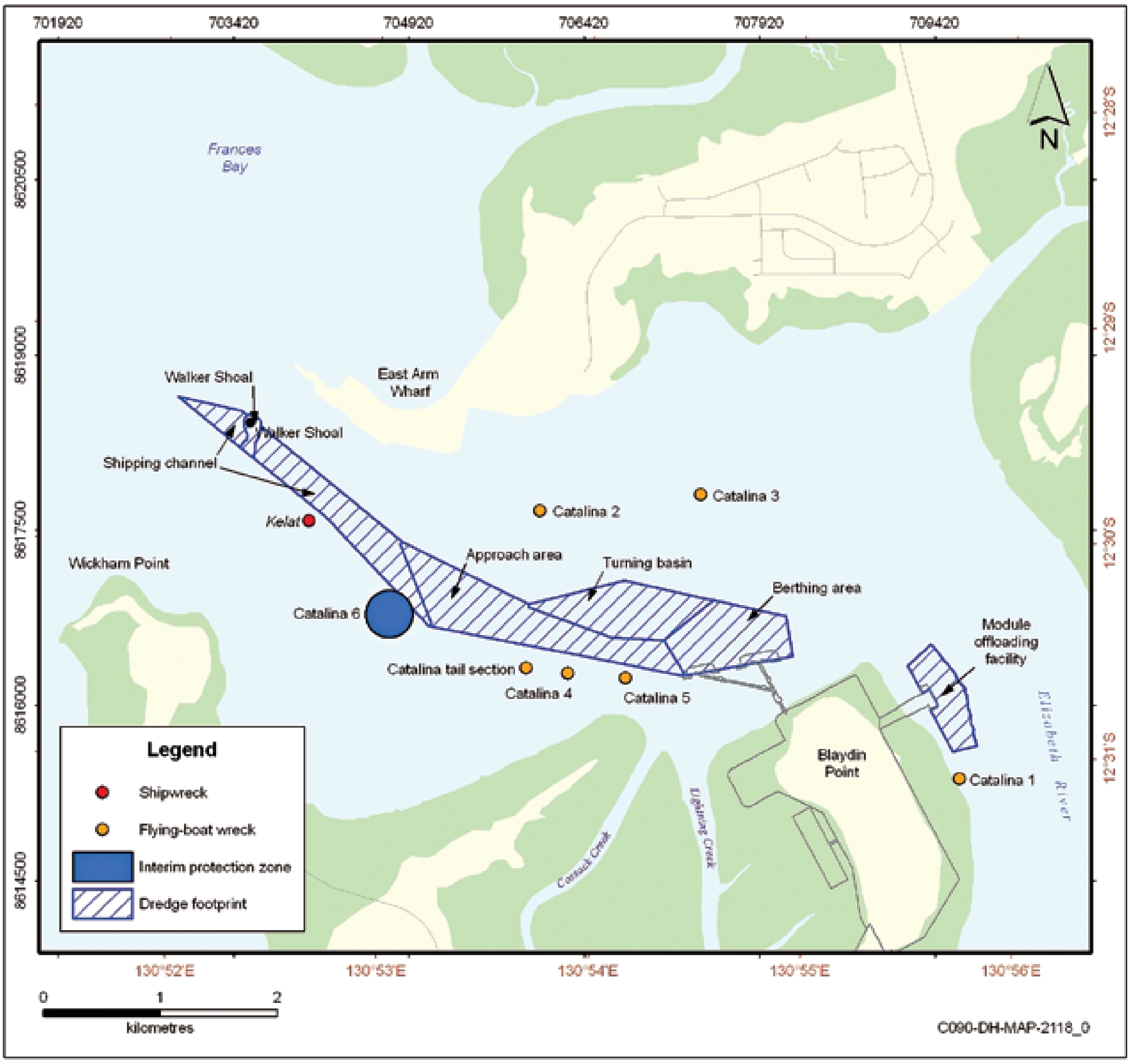

Figure 4-21: Indicative dredging footprint for the shipping channel, turning basin and module offloading facility in Darwin Harbour

avoid maritime heritage sites, while at the same time maintaining the safety buffer necessary to protect the operations of the East Arm Wharf port facilities. The largest fully laden tanker will require a 14-m-deep channel for safe navigation.

As specified in the previous section on pipeline construction, a dredged trench will be necessary to protect the pipeline, especially in the shallower areas of the Harbour where it would be vulnerable to damage by vessels and their anchors. In addition, however, the position of the pipeline in Darwin Harbour will be indicated on navigational charts as a prohibited area for anchoring. The buried pipeline will be covered by backfilled material which will provide additional safety to the ships passing in the area.

The spoil generated will be composed of different types of material depending on the location of the dredging activities. The material has been categorised as follows:

- sediments: high-moisture-content clays, silty sands, and gravels (estimated to be 50–70%)
- soft rock or rocklike material: fractured soft rock known as phyllite with lenses or dykes of quartz (estimated to be 30–50%)
- hard rock: metamorphic conglomerate intrusions such as those of Walker Shoal (estimated to be 1–2%).

Dredging method

The methods envisaged to be adopted for the dredging program depend on the types of material to be dredged, the water depths in which they lie and the potential impacts on the environment. The dredged spoil will be transported to the offshore spoil disposal ground outside Darwin Harbour. A number of dredging vessels will be required and these will operate for 24 hours a day and 7 days a week during specified periods. However, the final selection of equipment and sequence of operation will only be finalised after a dredging company has been selected.

Drilling and blasting will also be necessary to fracture hard rock intrusions which exist within the dredge footprint and which cannot be removed by conventional dredging methods.

Walker Shoal, which lies at the entrance to the proposed shipping channel, is the most significant of these intrusions. As the top of the shoal rises to 6 m below LAT it must be removed to allow for safe navigation. INPEX explored options to realign the shipping channel in order to avoid the shoal, but the constraints posed by the heritage-listed wreck of the coal hulk *Kelat* and the proximity of the East Arm Wharf facilities (see Figure 4-21) prevented any realignment.

The preliminary dredging program will require the following vessel types:

- a trailing suction hopper dredger (TSHD)
- a cutter-suction dredger (CSD)
- a backhoe dredger (BHD) or a grab dredger (GD)
- self-elevating drilling platforms (SDPs) for the drill-and-blast operations
- hopper barges (HBs).

A typical TSHD is shown in Figure 4-22. It is used to remove unconsolidated marine sediments using suction pipes or “drag arms” that are lowered from the vessel to the seabed. The sediments are pumped to hoppers where solids separate out; the unwanted water may be discharged at keel level. When the hoppers are full, the vessel can travel to the offshore spoil disposal ground and discharge the material to the seabed. For the preliminary dredging program, it is proposed that the TSHD be operated without overflow of excess water into the harbour. While this reduces the discharge of suspended fine material into the harbour and consequently reduces the impact on the environment, it significantly reduces the efficiency of the dredging operation and extends the duration of the dredging program.

A typical CSD is shown in Figure 4-23. This type of dredger is used primarily on consolidated sediment and weak-to-medium-strength rock which needs to be broken up before it can be recovered. To achieve this, the dredger is equipped with a cutter head which excavates the substrate before it is sucked up by the dredge pump(s). During its operations, the dredger moves around a spud pole by pulling and slacking on the two fore sideline wires. As is typical in such dredging programs, the dredged material will be redeposited on the seabed for subsequent recovery by the TSHD.

A typical BHD is shown in Figure 4-24. Such dredgers are used in substrates consisting of firm clay, soft rock and blasted rock, and when large stones can be expected. A BHD is also used where shallower waters prevent access for the larger and more efficient TSHD. The length of the boom of a BHD determines the dredging depth. These stationary dredgers are anchored by three spud poles.

The GDs (see Figure 4-25) are mechanical dredgers which use a crane with a clamshell grab. Similar to backhoes, they have the crane mounted on a floating stationary platform which is anchored by three spud poles. They are typically used to dredge sediment types such as gravels, silty sands and soft clays, but they are also useful for picking up large rocks and stones.

The environmental performance of a GD is similar to that of a BHD.

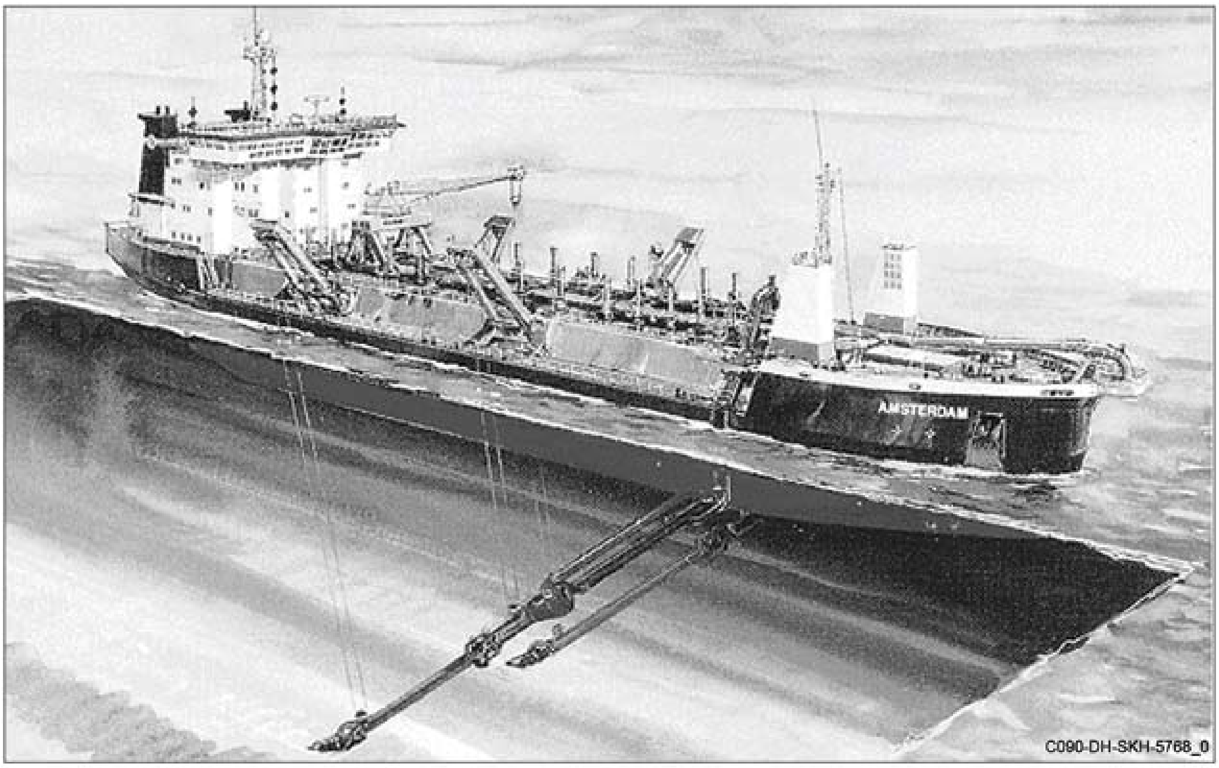

Figure 4-22: Example of a trailing suction hopper dredger

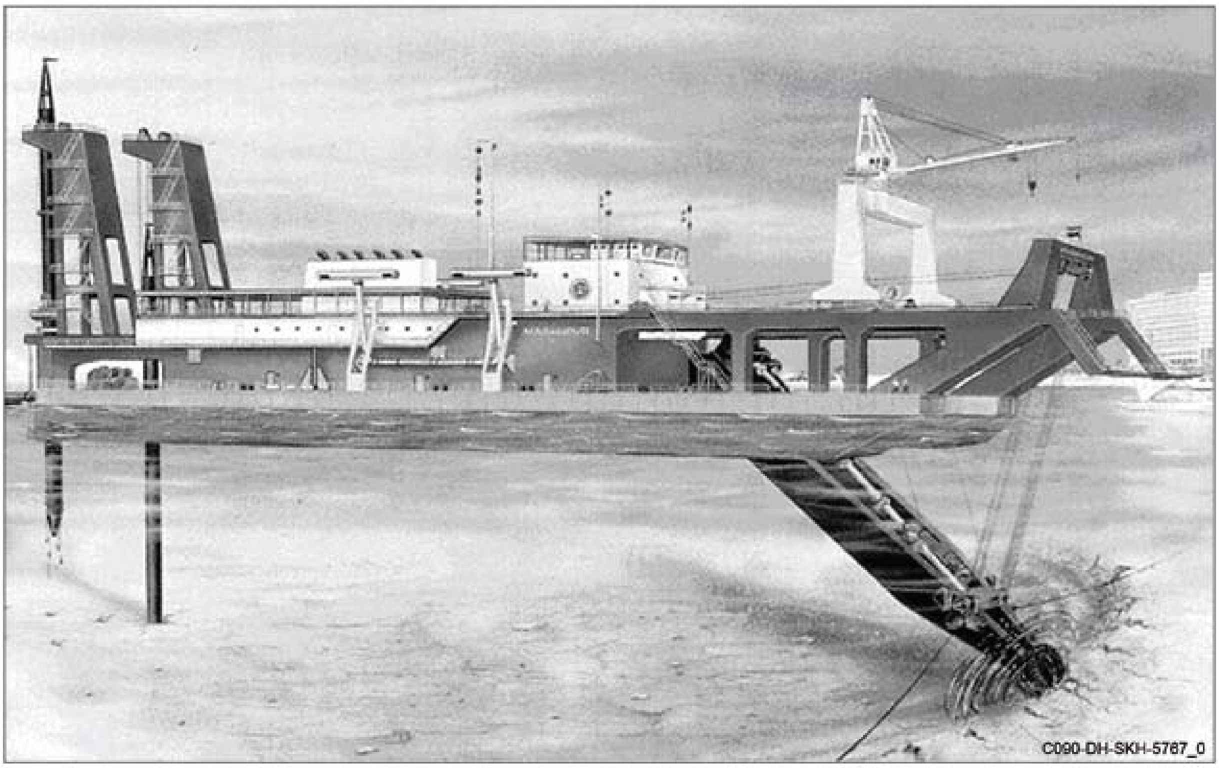

Figure 4-23: Example of a cutter-suction dredger

Figure 4-24: Example of a backhoe dredger

The BHD will excavate material of lower strengths, the CSD will excavate material of medium strengths, and the drill-and-blast operations will fragment hard rock material.

The HBs are purpose-built vessels for transporting dredge spoil to designated disposal sites. They may be self-propelled or pushed or towed by a tug. Once at the disposal site, the spoil is discharged through the keel either by hydraulically opening the hopper or by opening bottom doors. They vary in capacity from a few hundred cubic metres to several thousand cubic metres.

As noted above, the harder material, such as that on Walker Shoal, that cannot be dredged by more conventional methods, will be fragmented during a drill-and-blast program undertaken using one or more SDPs. The fragmented material will be removed by a BHD or a GD and loaded on to HBs for dumping at the offshore spoil disposal ground.

Alternative techniques to drilling and blasting are being investigated to remove the hard rock material within the shipping channel. At this stage, however, it is not possible to confirm whether there are any viable alternatives.

Dredging program

The section which follows describes the dredging methodologies, the dredging schedule and the volumes and nature of the material to be dredged under the preliminary dredging program.
This information has been used to inform the dredge modelling provided in Chapter 7.

The key features incorporated into the preliminary dredging program to reduce environmental and social impacts are as follows:

- using the BHD and/or GD in preference to the CSD wherever practicable, as the BHD and GD release significantly lower amounts of fine material than the CSD
- using the TSHD in a "no-overflow" mode which avoids the discharge of water laden with fine sediments back into Darwin Harbour. While this operating mode will reduce the release of fine sediments into the Harbour, it will result in reduced dredging efficiency and will extend the duration of the dredging program
- designing the jetty and dredge footprint in such a way that the offset distances from maritime heritage sites are maximised as far as practicable

Figure 4-25: Example of a grab dredger

- ensuring that there is an adequate buffer for the pipeline route through the Harbour in the vicinity of Aboriginal sacred sites and maritime heritage sites.

As noted previously, the final dredging program may differ from the preliminary dredging program provided that it can be demonstrated that there are no significant increases to the predicted environmental and social impacts outlined in chapters 7 and 10.

One such change, for example, could be operating the TSHD in a "minimal overflow" mode rather than a "no overflow" mode.

Table 4-2 summarises the indicative volumes of the different materials to be dredged within the dredge footprint and the methods which are proposed for their removal.

Table 4-2: Summary of dredging equipment, the type and indicative volumes of dredge material, and the sequence of operations proposed in the preliminary dredging program

Equipment	Dredge material	Volume (Mm^3)	Dredge localities
TSHD	Weak	8.96	Shipping channel, approach area, turning basin, and tanker berthing area
BHD	Weak	6.60	Shipping channel, approach area, turning basin, tanker berthing area, and module offloading facility
CSD	Medium	0.57	Shipping channel, turning basin and tanker berthing area
Blasting	Strong	0.17	Shipping channel (primarily Walker Shoal)
Subtotal		**16.3**	
BHD	Weak	0.6	Gas export pipeline to shore crossing
Total		**16.9**	

In order to optimise the use of available equipment and minimise any adverse impact on the environment, it is planned to undertake the dredging program in stages. It is anticipated that dredging may start either at the area of the module offloading facility or at the pipeline trench. Alternatively the dredging at the module offloading facility and pipeline may start simultaneously provided that adequate dredging equipment is available for mobilisation. The dredging program will end in the Walker Shoal area.

At the outset of the dredging program, it is planned that only the BHD (and/or the GD) will be operating. It (or they) will be joined by the TSHD as the dredging progresses. At the peak of dredging activity it is envisaged that the TSHD, BHD (and/or the GD) and CSD will be operating simultaneously. An indicative dredging schedule is shown in Figure 4-26 and a description of the dredging operations identified for the preliminary dredge program is provided in the following sections. As mentioned above, the dredging methods to be used and the dredging schedule will be decided upon after negotiations with the selected dredging contractor.

Module offloading facility

Dredging operations for the module offloading facility will include the facility's apron and berthing area. The initial geotechnical studies and surveys indicate that the material to be dredged will consist mainly of unconsolidated sands, silts and gravels along with some clay. The operations will commence with the mobilisation of a large BHD and three HBs. All of the dredged material will be loaded into the HBs for transport to the offshore spoil disposal ground.

At the time of preparing this schedule it was believed that the selected dredging contractor would be able to provide the three HBs for this operation. These would operate simultaneously. Following the completion of dredging, the area will be handed over to an appropriate civil contractor for further work. It is expected that dredging for the module offloading facility will be completed within five months of the start of the works.

Berthing area at the product loading jetty

When dredging for the module offloading facility has been completed, the dredging equipment will be moved to the vicinity of the proposed product loading jetty where the export tankers will berth. The berthing area will consist of two berths, one for LNG tankers and the other for LPG and condensate tankers. It will be located close to the northern tip of Blaydin Point. Most of the area to be dredged in and around the product loading jetty is shallow and, based on geotechnical surveys, is expected to consist of loose sands and silts underlain by weak rock material and below that by some medium-to-hard material. The dredging around the product loading jetty is expected to last for just over two years. The sequence expected to be followed at the berthing area is as follows:

- The BHD will be transferred from the module offloading facility area to the berthing area and will dredge most of the loose material present in the shallower areas. The material dredged using the BHD will be loaded into an HB for transport to the offshore spoil disposal ground.
- Once the BHD has finished in this area it will be followed by the TSHD to remove the remaining unconsolidated material in the deeper areas. All the material dredged by the TSHD will be transported to the offshore spoil disposal ground.
- Any base material of medium strength will be dredged using the CSD. The dredged material produced by the CSD will be deposited continuously on the seabed, as is common practice, to be recovered at a later stage by the BHD.

Following dredging of the berthing area by the BHD and the TSHD, it will be handed over to the piling contractor to carry out the installation of the jetty.

Turning basin

The turning basin will be used by the incoming unladen product tankers or carriers to turn through 180° before berthing. This will allow direct seaward departure for the fully laden vessel from the product loading jetty. Geotechnical surveys indicate that the geology of the basin is similar to that of the berthing area. The sequence of operations in the basin will be similar to that followed during the dredging of the berthing area, that is, initial dredging by the BHD of the shallower areas followed by the TSHD until medium-strength material is encountered. The CSD will then be brought in to remove this. The medium-strength material will be collected in due course by the TSHD and the BHD.

The finished depth in the turning circle will be around 14 m below LAT. Dredging in the turning basin is expected to take approximately two years.

Approach area

The approach area connects the turning basin and the berthing area at the product loading jetty with the shipping channel. Geotechnical surveys indicate that its geology is similar to that of the turning basin but with a few pockets of medium-strength material located on the northern corner close to the shipping channel.

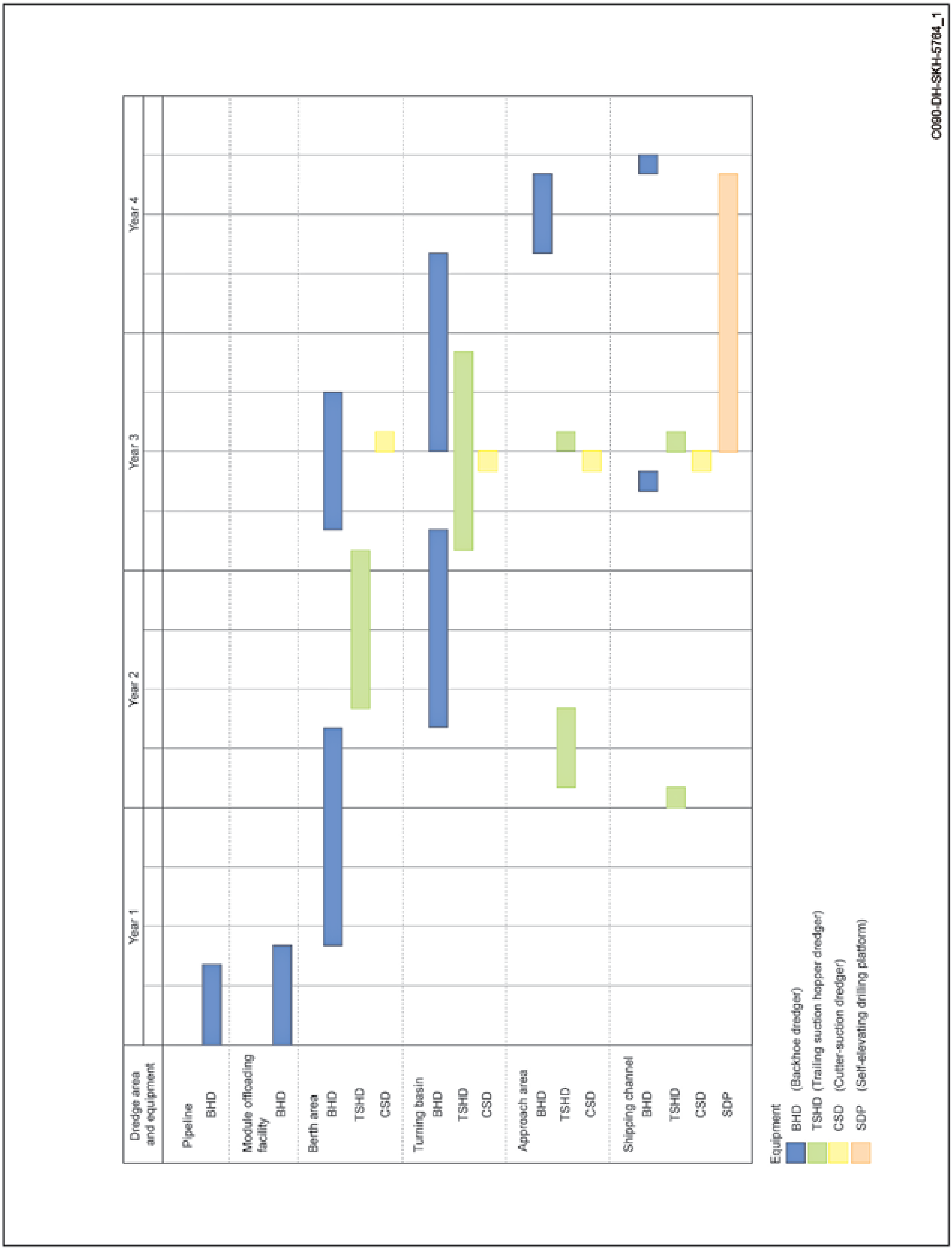

Figure 4-26: An indicative dredging schedule for Darwin Harbour

The dredging of the approach area is expected to start with the TSHD, which will recover the naturally occurring unconsolidated material on the seabed. When this material has been removed and disposed of at the offshore spoil disposal ground a CSD will dredge the medium-strength material. The TSHD and the BHD, supported by an HB, will then recover the material left on the seabed by the CSD.

Dredging in this section is likely to continue for almost a year.

Shipping channel

The shipping channel connects the approach area to the naturally deep parts of Darwin Harbour which will not require dredging. Geotechnical surveys indicate that the seabed in the shipping channel area is composed of weak through to strong material. Weak-to-medium material has been found throughout the shipping channel footprint. The strong material is found predominantly at Walker Shoal.

Dredging operations for the shipping channel are likely to occur in the following order:

- A TSHD and BHD, supported by an HB, will be used to dredge unconsolidated material in the deeper areas.
- A CSD will be used to cut potentially medium material present within the shipping channel. This material will be recovered later by a TSHD for transport to the offshore spoil disposal ground. This operation is expected to take approximately one to two months.
- Drilling and blasting will be required in the Walker Shoal area of the shipping channel where very hard rock has been found. It is planned to station one or more SDPs on Walker Shoal for the duration of the drill-and-blast program. Blasting will be limited to the daytime.
- A BHD will be used following the drill-and-blast activities to remove the fragmented hard material for transportation by HB to the offshore spoil disposal ground.

The duration of the drill-and-blast program in the shipping channel is anticipated to be up to 14 months. Details of the control measures to prevent impacts to people and infrastructure and to minimise environmental and social impacts are provided in chapters 7 and 10.

Pipeline dredging

Dredging for the pipeline in Darwin Harbour is likely to be undertaken using conventional dredging techniques that may include the following:

- excavation of soft seabed material by “mass flow excavation”. This technique uses a T-shaped tool hanging just above the seabed to draw in water laterally and direct a high-volume, low-pressure stream directly down into the seabed sediments. This effectively creates a trench into which to lay the pipeline. Mass flow excavation can be used with or without high-pressure jets to remove the material and may be required for pipelay near the entrance to the Harbour.
- excavation of soft-to-medium material by BHD. This will be required to complete a trench through the intertidal area at the shore crossing for pipeline stability and protection, and to provide sufficient access for the pipelay barge

It is expected that most of the work for preparing the pipeline trench will be carried out by the BHD. However, use of the CSD and/or the TSHD is not ruled out. It is likely that the pipeline dredging will take approximately three to four months.

Alternative dredging methodology

An increase in the amount of dredging equipment mobilised could reduce the overall duration of the program. This option remains under consideration by INPEX, but advice from dredging companies is that the availability of dredging equipment and the sourcing of Australian crews to run them are likely to be limiting factors. If the logistic and commercial constraints of engaging additional dredging equipment can be overcome, then INPEX may opt to utilise additional equipment and reduce the duration of the dredging program. The environmental and social impact assessment of the dredging program is, however, based on the base case of INPEX’s not having access to additional equipment. This provides the most conservative case for modelling and for social and environmental impact assessment.

Clean-up dredging

It is possible that some sediment may be deposited in the main shipping channel of the Harbour adjacent to East Arm Wharf. INPEX therefore proposes that, prior to the decommissioning of the dredging equipment from the Harbour, it will carry out a survey to determine the extent of such sediment deposition, if any. In the event that significant sediment deposits are recorded during the survey, INPEX will commission a clean-up dredging program.

4.4.5 Maintenance dredging

Sediment transport modelling was undertaken in 2009 by INPEX's FEED design contractor, the JKC consortium, in order to assess the amount of maintenance dredging that may be necessary during the operations phase of the Project. JKC's model focused on the area from East Arm Wharf to Blaydin Point and was calibrated by comparing the modelled bed changes with the surveyed bed changes over the 11-year period between 1997 and 2008. The calibrated model achieved a credible representation of the primary measured erosion and accretion areas at East Arm Wharf and in the area of sand waves to the north of Blaydin Point.

The calibrated model was further modified to include the post-dredging bathymetry, the plant site reclamation works and the new module offloading facility causeway. Modelling was then carried out for ambient tide conditions, over 10- and 20-year periods, for a 100-year-ARI (average return interval) flood event in the Elizabeth River, and for a Category 3 cyclonic event consisting of a 100-year-ARI storm surge level combined with the inclusion of waves generated by cyclonic winds across critical fetches. The impacts from the flood and cyclonic events were found to be minor in comparison with the longer-term impacts from the 10- and 20-year ambient-tide modelling runs.

The modelling results were examined by INPEX engineers to determine if a product tanker approaching the product loading jetty could sail through the dredged channel without any difficulty. Based on the preliminary results of the modelling it was estimated that approximately 200 000 m^3 of sandy material might be deposited within the proposed dredge footprint after 10 years, in which case maintenance dredging might be necessary. This siltation, however, will be most intense close to the dredge batters on the northern edge of the turning basin and berthing area and is unlikely to have a major impact on ship navigation as this area will only be utilised by tankers during arrival manoeuvres, when they are unladen and have a shallower draught. These deposits were forecast to build up to a typical depth of 1.5 m, but most of it will be limited to within 100 m of the toe of the batter slope. It is therefore suggested that maintenance dredging may be necessary after approximately 10 years. Extraordinary events such as cyclones may necessitate more frequent maintenance dredging. The actual volumes of sediment to be removed will be determined through annual surveys of the shipping channel by INPEX.

4.4.6 Dredge spoil disposal ground

An appropriate disposal location for the spoil generated by the dredging program is required. Options considered include offshore disposal of acceptable material to a subsea spoil ground, and onshore disposal to settlement ponds either on Blaydin Point or on land managed by the Darwin Port Corporation (DPC), for land reclamation. It was initially considered that the existing settlement pond capacity at East Arm Wharf and the area for its proposed future expansion might provide opportunities for onshore disposal. INPEX's geotechnical and geophysical investigations have, however, demonstrated that the dredge source material is very fine and therefore unsuitable for infill and construction purposes. The results of the INPEX investigations have been made available to the Northern Territory Government. The use of dredge material for fill purposes on Blaydin Point had been previously ruled out because there is insufficient space to accommodate the necessary settlement ponds.

Therefore, for the purposes of the Draft EIS, it is assumed that all dredge spoil material will be disposed of offshore. Should the opportunity for some onshore disposal arise closer to the start of the dredging program, INPEX would explore the option in conjunction with the DPC.

In order to identify a suitable location for offshore dredge spoil disposal, key stakeholders were consulted. These included NRETAS, the Department of Planning and Infrastructure (DPI)[3], the DPC, the Amateur Fishermen's Association of the Northern Territory (AFANT) and local shipping companies. Key concerns raised during this consultation included the following:

- the possibility of impacts from sediment remobilisation on to Darwin's northern beaches, for example at Fannie Bay, and on to sensitive seagrass beds adjoining these beaches
- the possibility of creating navigation hazards for vessels entering and leaving Darwin Harbour
- the possibility of sediment remobilising back into Darwin Harbour or into the DPC-proposed Charles Point Patches navigation channel and thus interfering with safe navigation
- the possibility of sediment remobilisation adversely affecting fishing grounds in the inner Charles Point Patches and Charles Point area as well as disrupting recreational fishing boat movements between these areas and the outer fishing grounds of South Gutter and Fenton Patches

3 The Northern Territory's Department of Planning and Infrastructure was restructured in December 2009 and its functions were transferred to two new departments, the Department of Lands and Planning and the Department of Construction and Infrastructure.

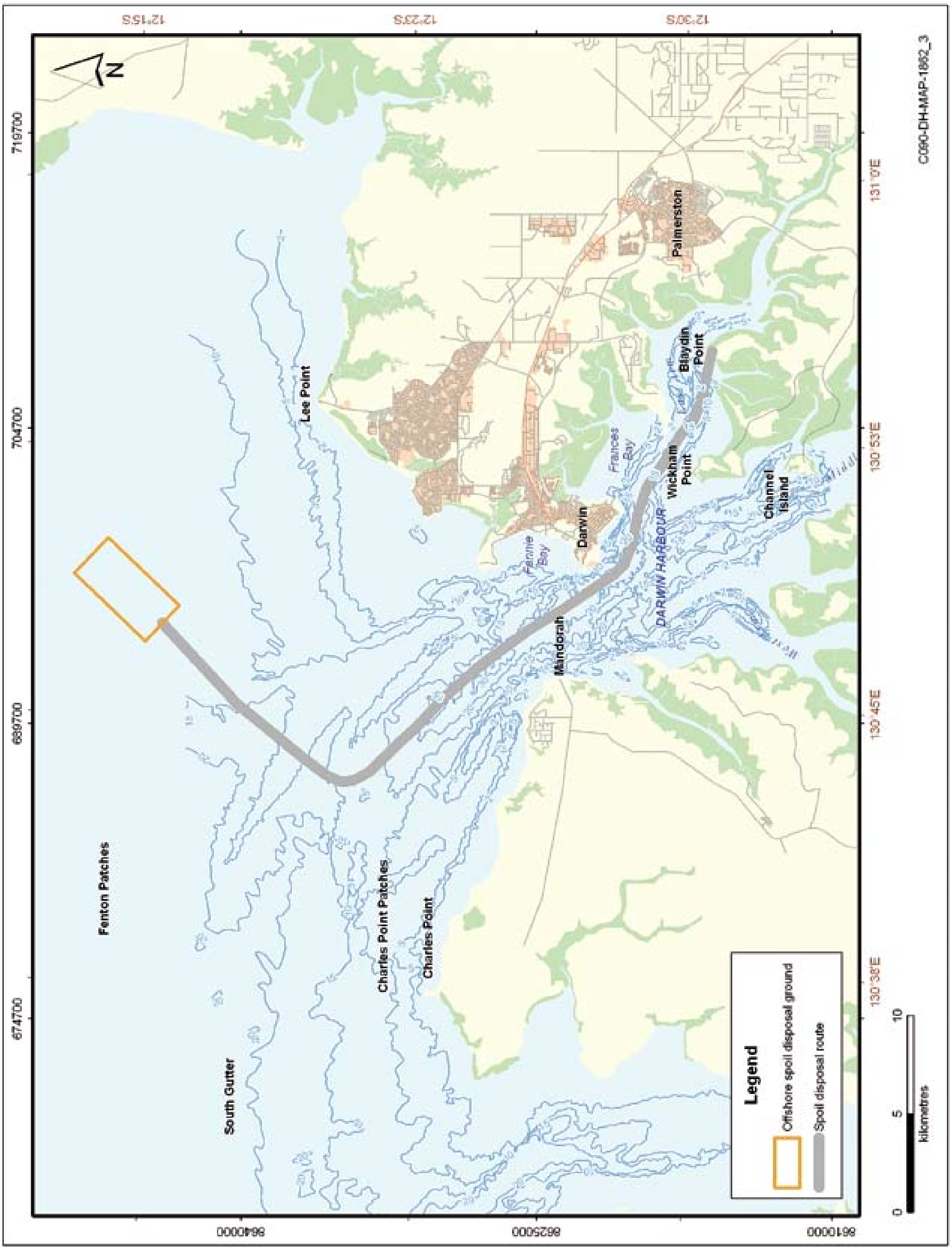

Figure 4-27: Dredge spoil disposal ground

- the possibility of sediment remobilisation adversely affecting recreational fishing activities at the series of artificial reefs off Lee Point.

In addition, the shortest possible distance to the spoil disposal ground was preferred, to minimise vessel travel times and to avoid extending the overall duration of the dredging program in Darwin Harbour.

A suitable offshore disposal ground was selected by using predictive modelling to determine the movement of dredged sediments and turbid plumes from the disposal site in ocean currents (see Appendix 14 for details). Nine sites were considered. The selected spoil disposal site is located around 12 km north-west of Lee Point (Figure 4-27).

4.4.7 Maritime traffic in Darwin Harbour

Construction maritime traffic

A number of maritime vessels will be present in the nearshore area around Blaydin Point from the commencement of construction activities. Ships carrying process modules, heavy equipment and bulk materials from the overseas fabrication yards will be unloaded at the module offloading facility. Based on an estimate that there will be more than 200 modules, it is expected that five modules will be offloaded per month at the module offloading facility. This will vary depending on the stage of the Project. Other construction vessels supplying cargo and heavy equipment for the Project will be unloaded at East Arm Wharf. Where cargoes cannot be transported by road from East Arm Wharf, they will be transferred by sea across East Arm directly to the module offloading facility.

Based on preliminary shipping studies, there will be approximately 80 maritime shipments to East Arm Wharf and around 40 maritime shipments to the module offloading facility.

Other construction-related traffic will involve movement of the following vessel types in the Harbour:

- pipelay barges
- anchor-handling vessels, supply vessels, crew-transfer vessels, and security and escort vessels
- rock-dumping barges
- dredging and support vessels including:
  - a cutter-suction dredger
  - a trailing suction hopper dredger
  - a backhoe dredger and/or grab dredger
  - hopper barges
- self-elevating drilling platforms
- jetty construction support vessels
- jack-up barges
- tug support vessels
- storage barges
- survey vessels.

A detailed discussion of the impact of increased maritime traffic in Darwin Harbour can be found in Chapter 10.

Operational traffic

Operational maritime traffic will consist of product tankers and their associated tug and support vessels. Other vessels associated with Project activities may include maintenance dredging vessels.

Product tankers range in size according to the type and volumes of product being loaded. Typically, a fleet of LNG and LPG tankers is dedicated to a particular facility, whereas condensate tankers can come from the open market. Figure 4-28 shows a typical LNG tanker.

Figure 4-28: Example of an LNG tanker in transit

Approximately 200 tankers per year (up to four tankers per week) will berth at the jetty at Blaydin Point. Table 4-3 gives the estimated frequency of shipping movements by product type.

Table 4-3: Frequency of tanker movements

Product tanker	Size of ships	Frequency of movements (average per week)
LNG	125 000 to 265 000 m^3	3
LPG (propane or butane)	35 000 to 85 000 m^3	1
Condensate	21 000 to 130 000 m^3	<1

Both the LNG and LPG–condensate berths may be occupied at the same time. The berths will be designed to be capable of berthing and loading tankers safely in most non-cyclonic weather conditions. Each loading facility will have liquid loading arms and vapour recovery arms designed for the high local tidal range. They will have proven automatic systems which will release the arms safely from the ships if wave conditions exceed design levels.

A fleet of four tugs will be required to manoeuvre the LNG, LPG and condensate tankers in and out of the Harbour. While a vessel is alongside, one of the tugs will maintain a standby role as part of the emergency response and security procedures. Currently, because of the relatively low number of shipping movements in the port, the tugs located in Darwin have surplus capacity and investigations into potential operational synergies will be undertaken with the DPC and other port users to optimise the available tug power and numbers. A secure mooring for tugs will be required, particularly with regard to cyclone management, and discussions will be undertaken with the DPC regarding options for these facilities.

Marine exclusion zones

The establishment of exclusion zones is essential to ensure that the safety of workers and Harbour users is not compromised. Their boundaries will be determined through a series of safety assessments in consultation with the DPC and the Commonwealth's Department of Infrastructure, Transport, Regional Development and Local Government (formerly the Department of Transport and Regional Services). Table 4-4 provides a preliminary assessment of the exclusion zones deemed necessary for different components of the nearshore infrastructure and activities. These zones are subject to safety confirmation through the quantitative risk assessment process (see Chapter 10).

Table 4-4: Preliminary exclusion zones around Project infrastructure and vessels in Darwin Harbour

Infrastructure or vessel type	Size of exclusion zone
General construction vessels and jack-up barges	Various, depending on vessels.
Operating dredge vessels	Various, depending on vessels.
Pipelay operation (outside and inside Darwin Harbour)	500-m radius from lay barge.
Loading arms on product loading jetty and trestles	500-m radius from loading arms when a ship is berthed.
LNG, LPG and condensate product tankers in transit	1000 m astern and 500 m around the sides of the tankers.
General security zone around Blaydin Point	Subject to safety confirmation through the quantitative risk assessment process.

Navigation aids and moorings

The Project will require new navigation aids and channel markers and the relocation of some existing navigation aids in the Harbour. Location of the navigation aids will be decided in consultation with the DPC. Temporary mooring buoys and navigation aids may also be required. Areas for the mooring of construction vessels will be allocated and will be positioned away from sensitive environmental receptors such as heritage wrecks and coral communities. Spar buoys or piled beacons are proposed for all permanent navigation aids.

4.5 Onshore infrastructure

Infrastructure and activities in the onshore development area that will support the construction and operations phases of the Project are listed in Section 4.1.1.

The Project's onshore processing plant will be located on Blaydin Point in Darwin Harbour. The onshore development area, consisting of the LNG, LPG and condensate processing plant area, the flare pad, the administration area, the construction laydown areas, borrow area and the onshore pipeline route and easement, will require approximately 406 ha of land (Figure 4-29).

Gas will be brought to the onshore processing plant from the Ichthys Field through the gas export pipeline. The gas will be processed and products recovered, stored and then exported by tanker from the product loading jetty. The gas-processing plant will be designed to produce approximately 8.4 Mt/a of LNG from two 4.2-Mt/a LNG trains which will be started up approximately 9–12 months apart. The processing plant is intended to operate for 40 years.

The design of the processing plant layout has taken the following criteria into consideration:

- The plant layout should be designed to minimise impacts on ecologically significant areas (such as the mangrove communities), to limit the environmental footprint, and to provide protection from long-term shore movement and extreme weather events.
- The plant should be established above the predicted peak combined sea levels (tides together with storm surge) for East Arm Wharf, which is the closest location to Blaydin Point with available data (a 6-m AHD (Australian Height Datum) storm surge for a 1-in-1000-year event). Adequate protection should be provided to areas exposed to tidal and storm-surge events (e.g. using rock-armouring or similar).

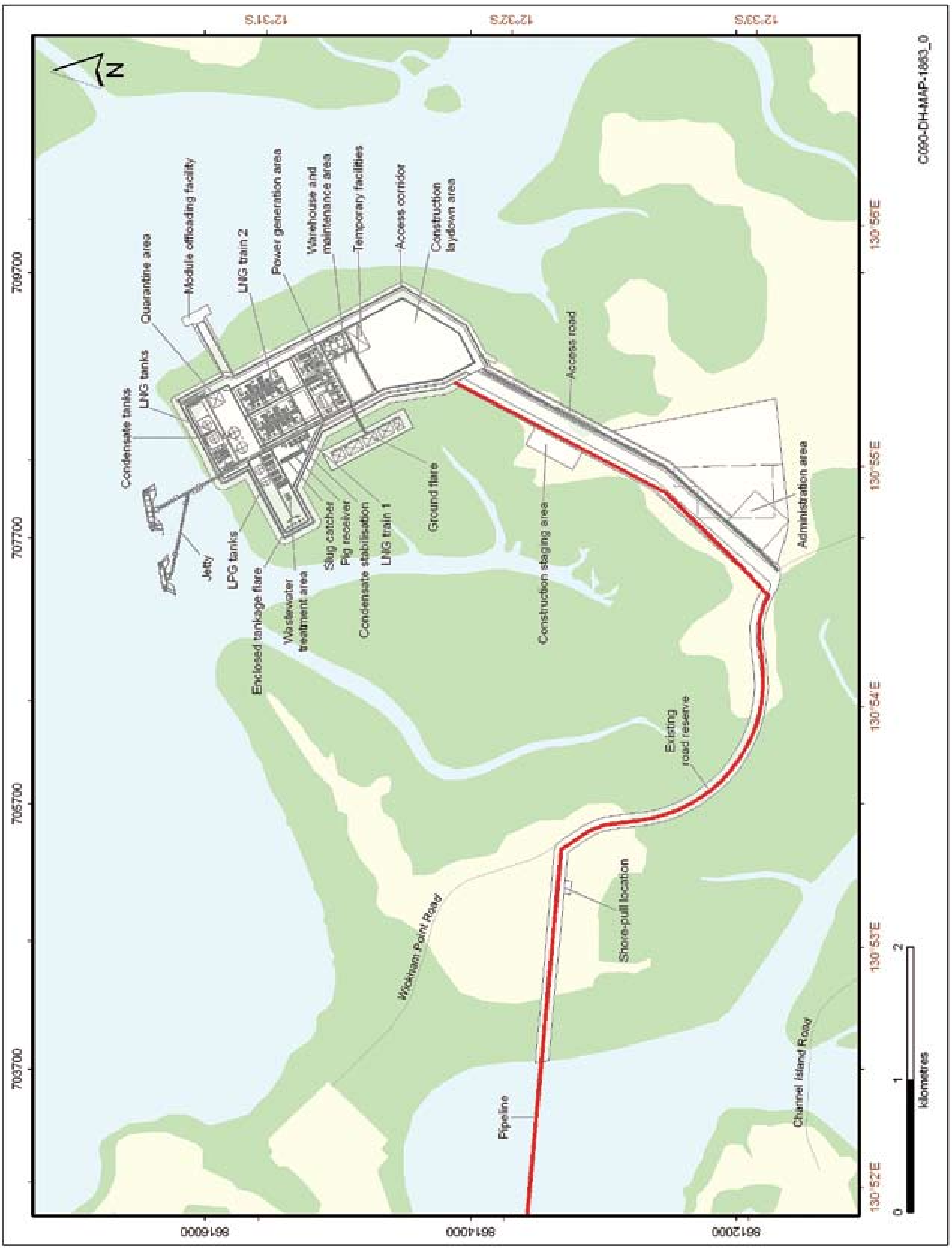

Figure 4-29: Onshore development area infrastructure

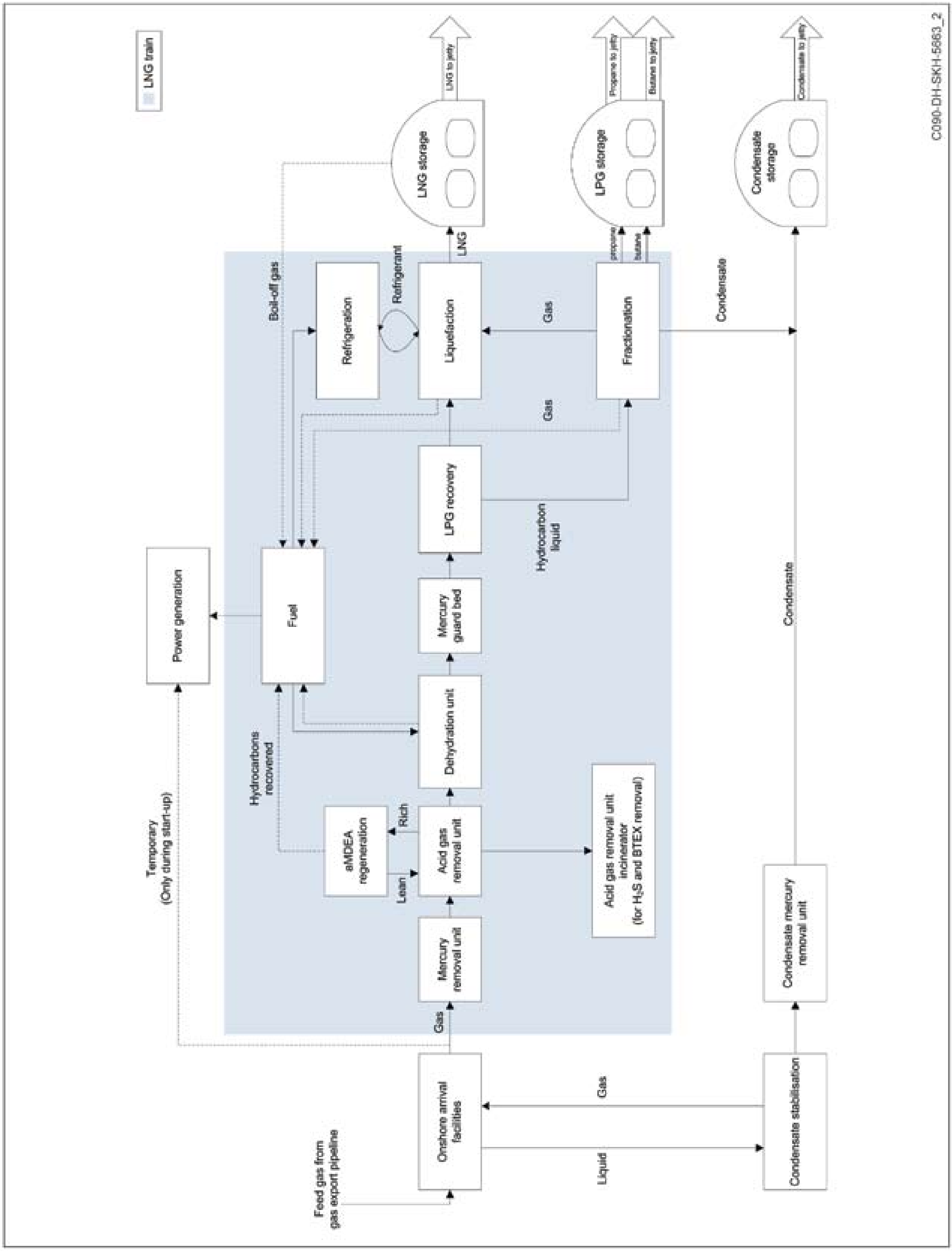

Figure 4-30: Onshore processing plant process flow diagram

- The plant should be constructed above a potential rise in sea level of 0.2 m as predicted by future climate-change scenarios for the Project's lifetime.
- Sufficient separation distances between process areas and non-process areas will be maintained, for example between the process areas and the administration building, warehouse and training centre, to minimise on-site risk.
- The road network should allow for safe emergency response and access to the process areas and the jetty.
- The plant design should take into account the prevailing wind direction to maximise natural air circulation for greater efficiency.
- The design of plant layout should position equipment to reduce off-site public risk by providing adequate separation distances.
- There should be sufficient separation between the different process areas to ensure that upset conditions in one area of the plant will not affect other areas.
- Plant layout should allow for space for future facilities, especially pipeline alignments, tanks and processing trains.

4.5.1 Onshore gas-processing facilities

Both gas-processing trains will use the same equipment and process for the cooling of the natural gas to below its liquefaction temperature of around –160 °C and for the separation of propane and butane and the stabilisation of condensate. The facility is called a "train" because the gas flows sequentially through a series of vessels that on an engineeer's process flow diagram fancifully resemble a series of railway carriages. This is shown in Figure 4-30, which presents an overview of the process.

Onshore arrival facility

The purpose of the onshore arrival facility is to separate the feed received from the offshore facilities into gas and liquid streams and to deliver these streams at a constant pressure to the LNG trains and the condensate stabilisation system respectively.

The arrival facilities will consist of pig-receiving facilities (for subsea pipeline inspection and cleaning) and a slug catcher. Pigging in the maintenance of pipelines refers to the practice of using pipeline inspection gauges or "pigs" to perform various operations on a pipeline without stopping the flow of the product in the pipeline. These operations include cleaning and inspection of the pipeline. This is accomplished by inserting the pig into a "pig launcher". The launcher is then closed and the pressure of the fluids in the pipeline is used to push the pig along the pipe until it reaches the receiving trap, the "pig receiver".

The slug catcher will be of a "finger" type and its capacity will be optimised during FEED and detailed design. It will consist of two halves to allow the isolation of one half to enable the slug catcher to be cleaned and inspected as required. The slug catcher will be followed by a pressure reducing station, which will regulate gas flow to the LNG plant.

The liquid fraction recovered in the slug catcher will be reduced in pressure and directed to the condensate treatment facilities while the gases recovered will be directed to the LNG trains.

The reception facilities are also designed to provide a supply of fuel gas for at least one power generator for start-up activities.

Condensate treatment

The condensate treatment facilities include the condensate stabilisation unit and the condensate mercury removal unit. After treatment, the mercury-free condensate is directed to the storage tanks.

Condensate stabilisation

Liquids from the slug catcher are fed into a separator to separate gases and liquid. The hydrocarbon liquids will be directed to the condensate stabiliser unit where they will be heated using a hot-oil system. The purpose of heating the liquids is to drive off any hydrocarbon vapours such as ethane, propane and butane in order to stabilise the vapour pressure of the condensate. The stabilised condensate will be fed to the condensate mercury removal unit.

Gases from the tops of the stabiliser units will be compressed and mixed with the feed gas to the gas treatment system.

Mercury removal unit

Based on analyses of initial samples, the condensate could contain traces of mercury compounds, which will be removed to conform with the buyers' quality requirements for the condensate.

The mercury removal unit will be designed to keep the mercury content in the product below 30 ppb by weight. When the adsorbent beds in the unit are saturated with mercury, a specialist contractor will be engaged to remove the packaging and to transport the beds to an approved disposal facility.

Storage tanks

Following treatment, the condensate will be transferred from the mercury removal unit to the condensate storage tanks after being combined with condensate from the de-isopentaniser. The recovered condensate will be stored in two large tanks and one small tank, each fitted with a floating roof. They will be bunded to contain their full volume in case of accidental release.

LNG train

Mercury removal unit

Gas from the top of the slug catcher will be directed to the mercury removal unit. The purpose of this unit is to prevent the release of mercury to the atmosphere in the acid gas stream from the acid gas removal system and to prevent corrosion of the aluminium alloy equipment in the downstream cryogenic systems.

The maximum mercury content of the gas leaving the mercury removal unit will be 0.01 µg/Nm^3.

The mercury adsorber removes any mercury present in the feed gas using a non-regenerable adsorption bed. As the gas passes through the vessel, trace mercury reacts with the sulfur and remains chemically trapped on the adsorbent.

The bed material acts as a filter and will be replaced periodically for recycling or disposal when it becomes inactive. Specialised contractors capable of safely removing the packaging and transporting the mercury-contaminated adsorbent bed will be employed for this purpose.

The treated feed gas continues to the acid gas removal unit (AGRU).

Acid gas removal unit

The feed gas stream will enter the bottom of the absorber column and flow upwards, coming into contact with a stream of fresh (or "lean") activated methyldiethanolamine (aMDEA) solvent flowing in the counter-current direction. The packed bed will be designed to selectively remove the "acid gases"—carbon dioxide (CO_2) and sulfur compounds such as hydrogen sulfide (H_2S). During this process these gases will be chemically adsorbed from the hydrocarbon gas stream along with small amounts of hydrocarbons. The treated feed gas will then be directed to the dehydration unit.

The CO_2 has to be removed from the gas in order to prevent it from freezing in the liquefaction process and blocking the main cryogenic heat exchanger and other equipment. The sulfur compounds have to be removed from the gas stream to meet buyers' specifications for the gas products.

The aMDEA solvent will generally absorb the acid gases until it is saturated. The saturated or "rich" aMDEA will then flow from the bottom of the absorber column to a high-pressure "flash drum" where most of the co-absorbed hydrocarbons will be flashed off and sent to the low-pressure fuel-gas system. The solution from the bottom of the high-pressure flash drum will be sent to the low-pressure flash drum, heated by the lean–rich exchanger and then sent to the top of the regeneration column. The acid gas will first be flashed off in the low-pressure flash drum and then the remainder of the acid gas will be stripped from the rich solvent in the regenerator using a heating medium. The regenerated aMDEA will then be cooled and pumped back to the absorber. The vapour stream from the regenerator will be sent back to the low-pressure flash drum.

The vapour stream from the low-pressure flash drum will be directed to the condenser to recover water, and will then be introduced to the acid gas incinerator unit.

In the acid gas incinerator unit, the waste vapour stream will be preheated and then oxidised to destroy H_2S and aromatic hydrocarbons. The H_2S will be converted to sulfur dioxide (SO_2) and the aromatic hydrocarbons will be burned, creating CO_2 and water vapour. In the unlikely event that the AGRU incinerators are shut down, these exhaust gases will be hot-vented through gas turbine exhaust stacks.

Dehydration unit

The treated feed gas from the AGRU is now free of acid gases, but it is still saturated with water which has to be removed in the dehydration unit. Gas will enter the dehydration inlet separator where it will be cooled with propane but maintained above the hydrate formation temperature. The cooling process will condense water and some hydration liquid from the gas stream before it enters the main part of the dehydration unit. The water will be removed to prevent it from freezing and causing process vessels and pipes to be blocked by hydrate crystals in the cryogenic liquefaction unit.

Gas from the dehydration inlet separator will be passed through a molecular sieve system which will adsorb the remaining water to a level below 1 ppm by volume.

It is planned that three vessels containing molecular sieve beds will be installed. Two of the vessels will be in adsorption mode at any given time while the third vessel is being regenerated. The rich molecular sieve beds will be regenerated by waste heat recovered from the gas turbine in the refrigerant system. The heated gas will be passed through the molecular sieves to remove adsorbed water. The regeneration stream will then be air-cooled to condense water, which will be separated from the regeneration gas in the regeneration gas drum and directed to the high-pressure flash drum of the acid gas removal unit as water wash for limiting aMDEA carry-over.

The dehydrated gas will be directed to the final mercury guard bed and the cooled regeneration gas will be sent back to the fuel-gas unit.

Mercury guard bed

The mercury guard bed provides an online backup to the mercury removal unit in case of upset conditions when the mercury removal unit is unable to reduce the mercury content of the gas to below 0.01 μg/Nm^3.

The bed material will be replaced periodically for recycling or disposal during major shutdowns of the LNG train every eight years. Specialist contractors who are capable of safely removing the packaging and transporting the mercury-contaminated adsorbent bed will be employed for this purpose. During FEED, the design team will investigate if this system will be required should the efficiency of the upstream mercury removal unit be improved.

Liquefied petroleum gas recovery

The purpose of the LPG recovery system is to maximise the removal of heavy components from the gas stream in order to provide gas that meets the LNG product specification.

The LPGs (propane and butane) will be recovered from the natural gas feed through the demethaniser column and associated equipment such as a turboexpander. The demethaniser column will be designed to remove hydrocarbons by distillation through a number of trays.

The product gas stream will then be compressed by the feed recompressor of the main cryogenic heat exchanger and sent to the liquefaction unit. The heavy components will be directed to the fractionation unit.

Liquefaction and refrigeration

The gas stream from the LPG recovery unit will be compressed in the inlet gas compressor of the main cryogenic heat exchanger, cooled against air and four levels of propane chilling, then directed to the main cryogenic heat exchanger and associated refrigeration where the gas will be liquefied to create LNG.

The refrigerant compressor will provide the power for the cooling process. The configuration of the required compressor driver turbines is the subject of ongoing investigation. It is likely that two compressor driver turbines will be used per train, four in total at *c.*85 MW each. INPEX aims to optimise the use of waste-heat recovery on these systems.

The main cryogenic heat exchanger will be a large vertical vessel containing internal tubing which will provide a large surface area for the efficient transfer of heat from the main gas stream. The product stream will leave the vessel at approximately –150 °C prior to entering the end-flash-process section.

The end flash process will drop the pressure of the LNG from the cryogenic heat exchanger to near atmospheric pressure through a liquid expander, thus reducing the temperature to around –160 °C. At this temperature, and near to atmospheric pressure, the mostly methane stream will be converted to liquid form (the LNG product) and will be directed to the cryogenic storage tanks. Details of the storage tanks are provided in Section 4.5.4 *Product storage and loading facilities*.

Fractionation

The purpose of the fractionation system is to separate out the heavy hydrocarbon components from the light gas—methane with some ethane—which is destined to become LNG. The fractionation system produces ethane, propane, butane, isopentane and condensate streams.

The ethane will be used as a refrigerant. Excess ethane will be sent to the high-pressure fuel-gas system. A portion of the propane will be used as refrigerant and the greater part will be sent to the export facilities as product. Butane and condensate will be sent to the export facilities as separate products. Isopentane that does not remain in the condensate will be sent to the fuel-gas system and used as fuel gas.

The propane, butane and condensate products will be sent to storage tanks where they will be held before loading on to ships for export.

4.5.2 Utilities

Refrigerant storage

Supplies of propane refrigerant will need to be imported to start up the liquefaction process, but after a period of time the process will be self-sufficient. Once the operations stabilise following commissioning, propane produced at the plant will be used as refrigerant. The propane will be stored in a spherical storage tank.

Fuel

Fuel gas

The fuel-gas system will supply clean superheated gas at high pressure to all the compression and power generation gas turbines. A backup fuel supply will be provided to supplement the normal supply in the event of a plant upset or fuel-gas system failure. The fuel-gas system will also supply gas at low pressure for fired furnaces and incinerators as well as for pilot-light and purge purposes on flares and generators.

Diesel

Fuel storage tanks will be required at the site for the supply of diesel fuel for dual-fuel power generation turbines, vehicles and equipment during operations. These will be located on hardstands on site in the administration and processing-plant areas. During construction, a temporary fuel system with pumps, storage tanks and pipework will be required to service light vehicles, construction equipment and temporary diesel power generator sets.

Heating medium

Many of the process units in the LNG trains require heat. This heat will be provided by a hot-oil-based system, which will aim to maximise the use of waste heat from the exhaust of the main compressor's gas turbine driver on each gas-processing train. Once the heating medium has been heated, it will be circulated through the system in a closed loop.

Compressed air

Compressed air is required for three main purposes: plant air for general use, instrument air for control systems, and feed for the nitrogen plant air-separation unit. In the event that instrument air supply pressure begins to drop, the plant air system will be shed to ensure the availability of instrument air.

Plant lighting

Lighting will be required throughout the process and non-process areas to provide light for operability and plant safety. This is part of INPEX's duty-of-care obligation to its employees and contractors. A lighting system will be adopted for the gas-processing plant site with a range of lighting options dependent on the area in question and the type of operation.

Power generation and distribution

A total of nine open-cycle power generation turbines (*c.*40 MW each) will be required to service the operation of both LNG trains. However, INPEX is also investigating a combined-cycle gas turbine configuration which will reduce the required number of gas turbines and improve the efficiency of the onshore plant.

Power generation from diesel generators will also be employed for emergency power and during the initial commissioning of the facilities. These diesel generators are additional to, and independent of, the main power generation system and will be provided to supply power for those services required to ensure the safety of the installation and personnel in the event of a major incident. During the construction phase, temporary diesel power generators will be used, and power may also be imported from the Northern Territory Government's power distribution system (operated by the Power and Water Corporation (PWC)) at a point on Wickham Point Road. Distribution infrastructure, facilities and transformers may also be required.

To reduce diesel use further and to aid commissioning activities it is planned to import gas from the PWC gas transmission line. Once permanent feed gas is established from the gas export pipeline this connection to the PWC supply will be isolated (as it may be required again in the future during unforeseen events and/or emergencies).

Control of nitrogen oxides

The compressor and power generation gas turbines will be designed to achieve a low nitrogen oxides (low-NO_x) outcome. Options specific to the design of the facility are being investigated. The final selection will be determined in the detailed-design phase. Further discussion on NO_x emissions is provided in chapters 5 and 8.

Water demand and supply

Potential water demand and sources have been investigated to determine how water will be provided for the Project. These investigations have considered the requirements for the various stages of the Project's life, from the site preparation and construction phases up to and including the operations phase.

The levels of water demand can be separated by Project phase:

- *Construction:* During the construction phase, potable-water demand will gradually increase from the start of site preparation (as personnel numbers and construction activities increase) to approximately 1200 m^3/d. This includes service water and water required for concrete batching and dust suppression. It should be noted that water use is likely to be mainly during the daytime period and construction water usage will vary depending on the season (e.g. there will be reduced water demand for dust suppression in the wet season).
- *Precommissioning:* The peak water demand for the Project will be during the tank hydrotesting phase. During this period of approximately 16 months, large volumes of water will be required for the hydrotesting of storage tanks. It is anticipated that water demand could peak at approximately 7800 m^3/d, which would be required 24 hours a day intermittently for a few weeks. Where technically feasible, water demand will be minimised through reuse of tank hydrotest water.

- *Operations:* During the operations phase, water demand will be required at a consistent level over the plant's projected lifetime of approximately 40 years. Potable water required for the operation of the gas-processing facility and the site administration area would amount to approximately 2000 m^3/d. This would supply service water and water for the gas-production process.

In addition, major shutdowns are expected to occur periodically (once every 6–8 years), with each shutdown expected to last between 5 and 35 days. When one LNG train is shut down, the process-water demand will reduce; however the manning level is expected to increase to 500–600 people on site during this time and the net water demand may therefore not differ significantly from that of normal operations.

The supply of water is likely to come from the existing water main located in the road reserve of Wickham Point Road, which connects into the Darwin water supply scheme through the McMinns Water Treatment Storage Facility. Recent advice from the PWC has indicated that there will be sufficient capacity to accommodate the water demands of the Project.

Infrastructure that may be required to provide PWC water to the onshore development area includes a potential booster station near Elizabeth River Bridge and upgrading pumping capacity at the McMinns storage facility. Alternatives to using PWC water and incorporating water efficiency measures into the design of the onshore gas-processing facility are being investigated.

Sewage and grey-water treatment

Sewage and grey-water treatment will be required from the commencement of activities at Blaydin Point. As with water demand, sewage treatment capacity will be increased progressively as the Project workforce expands. The sewage management requirements for the different stages of the Project are likely to be met by packaged sewage treatment plants, self-contained septic-tank systems and ablution blocks. During construction, sewage will either be stored at site followed by disposal to existing sewage treatment facilities in the Darwin area or it will be treated and discharged to the marine environment through a temporary outfall. Ground infiltration of treated wastewater is also an option being considered; this, however, will be subject to assessment for its environmental acceptability.

A permanent sewage treatment facility will be installed to provide for operational and maintenance requirements. Separate sewage treatment and discharge facilities will be required at the process and administration areas during operations. Treated sewage from these facilities will either be used for irrigation or infiltration within a designated area or be directed to the jetty outfall.

INPEX or its subcontractors will be responsible for the operation and maintenance of the sewage and grey-water treatment facilities.

Firewater system

A firewater system will be designed with deluge and fire-monitoring systems for use in emergencies. The fire pumps will meet all statutory requirements for safety systems. During normal operations, the maintained pressure in the firewater ring main will be supplied from a freshwater tank, which can be used for testing purposes. The fire system will normally be maintained in a freshwater environment. Provision for a backup seawater supply to the firewater system is also included in the design.

Chemicals

A range of chemicals will be required for the operation of the gas-processing facilities. To ensure that chemicals are contained securely to protect underlying groundwater from accidental spills and leaks, adequate storage for all hazardous and non-hazardous liquids and chemicals will be provided at the appropriate facilities. Permanent storage areas will have the following features:

- bunded areas with drainage and adequately sized sumps
- laydown areas provided with adequate protection and lashing points
- custom-built skids with provision for spare portable tanks
- custom-built skids for transfer from portable tanks into a facility storage tank.

Temporary bunding will also be required for liquid and chemical storage in the construction phase.

Bunding and storage facilities for hazardous liquids and chemicals, including fuels, will be constructed in accordance with the relevant Australian standards and any Northern Territory requirements for dangerous goods storage.

The provision of adequate storage areas for liquids and chemicals will be critical to the effective implementation of the spill prevention and waste management plans as described in Chapter 8 *Terrestrial impacts and management* and Chapter 11 *Environmental management program*.

4.5.3 Ground flare

A flare system is required at the onshore facilities to ensure the reliable and safe collection and disposal of hydrocarbon vapour and liquid streams resulting from emergencies, process upsets, plant start-ups and shutdowns, and commissioning and maintenance activities. The flare system is the primary safety device for the facility and needs to be continuously available during commissioning and operations. The flare system must be designed to achieve the following:

- to collect vented hydrocarbon gas from the process systems and burn the gas safely at the flare tips
- to enable controlled depressurisation of systems containing hydrocarbons
- to enable safe emergency blowdown as a result of system upsets or emergencies (commonly known as "trips").

Flare designs vary in size and complexity depending on the requirements of the facility and the environmental requirements in the Project area.

The design of the flare system will be sized to accommodate all commissioning and normal operational flaring through separate cold–dry and warm–wet systems. It will be designed to minimise smoke production and will be surrounded by noise and radiation shielding. Although the base case is for a rectangular design, the configuration of the flare pad will be finalised during detailed design. Alternatives to the configuration presented in Figure 4-31 include a square design with a similar footprint.

The flare pad will be located around 150 m west of the plant site and will cover an area of approximately 12 ha. Criteria used in determining the location of the ground flare included safety and noise impacts on the site as well as the potential visual impact and impacts on aircraft flight pathways. Safety factors include the calculation of thermal radiation zones to isolate the flare from the plant facilities and to limit the thermal radiation at the boundary of the flare area.

A causeway will connect the flare area to the main site. This will grade from 6.5 m AHD to 12 m AHD at the flare and will be designed to accommodate a 10-m-wide pipe rack, a one-way road and shoulders. Decreasing the height of the flare pad is part of ongoing investigation. The edges of the causeway will be protected by rock-armouring.

Figure 4-31: Indicative schematic of flare design

4.5.4 Product storage and loading facilities

Products from both gas-processing trains will be directed to the storage and loading facilities. The purpose of these facilities is to store products safely and to pump the stored products to their respective berths and product tankers.

Separate storage tanks are required for each of the products from the gas-processing plant, namely LNG, propane, butane and condensate.

The size and number of the LNG, LPG and condensate storage tanks are influenced by production rates, the frequency of tanker arrival, and the offtake volumes. This cycle is in turn influenced by the speed and size of the vessels; the berthing and unberthing time and the loading rates; and the state of the sea, the tide, and the weather. Storage requirements are determined based on the input of these factors into probabilistic shipping simulations. Preliminary simulations have determined that the numbers and sizes of storage tanks are as presented in Table 4-5.

The primary factor in the location of product storage tanks is distance from the loading facilities. The further away the product tanks are from the loading facility, the greater the requirement for insulated pipelines and a potential requirement for recompression and reliquefaction. These requirements would decrease the efficiency of the process, thereby increasing the volumes of emitted greenhouse gases and the cost of generating the product. The location of the tanks on Blaydin Point has therefore been designed to be as close to the product loading facilities as possible.

The storage and loading facilities are also required to manage vapours from the product tankers and storage tanks. These vapours, which are displaced when tanks and vessels are loaded, are commonly referred to as "boil-off gas" (BOG).

The BOG from LNG storage tanks and shiploading operations (ship cargo tanks) will normally be recompressed in BOG compressors and directed to the fuel-gas supply or reprocessed. BOG from propane and butane storage tanks will normally be recovered, processed and returned to the product storage tanks. LPG export tankers are fitted with their own vapour recovery systems where gases are reliquefied back to the cargo tanks. The condensate storage tanks onshore will also be fitted with floating roofs to minimise hydrocarbon vapour release.

In addition, an enclosed tankage flare will be used during loading to accommodate the BOG from storage tanks and ships that cannot be recovered. Flaring from the enclosed tankage flares may occur under the following circumstances:

- If one or more of the BOG compressors are inoperative, some or all of BOG produced may have to be sent to the enclosed tankage flare.
- If a compressor reaches capacity, excess gases will have to be flared. This can occur, for example, when large volumes of BOG are produced from tankers which have been heating up beyond normal expectation during the journey to Darwin. These ships (referred to as "hot ships") require a period of prolonged operation or flaring before bulk loading can commence, during which time a proportion of their BOG has to be flared.
- If tankers have been in dry dock for maintenance, upgrades or repairs, they will contain inert gases such as nitrogen which cannot be recompressed for reuse as fuel gas and/or reprocessed; boil-off gases from such sources will need to be flared.

4.5.5 Drainage and wastewater treatment system

The drainage and wastewater treatment systems for the onshore facility have been designed to achieve the following ends:

- to collect and treat wastewater streams
- to distribute surface water to multiple points around the onshore development area
- to minimise the erosion of landforms and the transportation of sediments
- to minimise the creation of breeding habitat for mosquitoes and other biting insects
- to minimise the impact on downstream water quality, specifically that of Darwin Harbour.

Table 4-5: Indicative product storage requirements

Product and storage type	Number of tanks	Total stored volume (m^3)	Outer dimensions of tanks	
			Width (m)	Height (m)
LNG (cryogenic)	2	330 000 m^3	85	50
Propane (refrigerated)	1	90 000 m^3	70	35
Butane (refrigerated)	1	90 000 m^3	70	35
Condensate (ambient temperature)	2	120 000 m^3	55	25
Condensate (ambient temperature)	1	*c.*7500 m^3	22	20

Plant drainage will be designed to separate contaminated from non-contaminated areas. Wastewater from potentially contaminated areas will be isolated and treated by separate drainage systems. Where wastewater is potentially contaminated by hydrocarbons, it will be routed to the oily-water treatment plant or collected locally and disposed of off site. The drainage system will also be designed to accommodate firewater in the event of an emergency. Treated wastewater streams will be commingled and directed to the jetty outfall.

Non-contaminated drainage will be directed to multiple discharge points around the perimeter of the site through open channels designed to minimise erosion. In locations where drainage cannot be captured by the main drainage system, the non-contaminated water will be discharged directly to the Harbour (e.g. the runoff from the module offloading facility access ramps).

Discussion on wastewater sources, treatment, volumes and characteristics is provided in Chapter 5. A description of the dispersion of wastewater from the combined outfall is discussed in Chapter 7.

4.5.6 Supporting facilities

Facilities that will be installed to support the production process and the logistic and administrative requirements for the workforce for the construction and operations phases are outlined in this section.

Administration area

The administration area is required to support the operation of the plant and supporting facilities. This area is 2.5 km south of the processing facility on the site access road leading to Blaydin Point. Like the plant pad, the administration area will be designed to be above storm-surge height. It is likely that the administration area pad will not require rock-armouring as it is above the Highest Astronomical Tide (HAT) datum and will not be subject to tidal inundation or wave action. During construction, the area may be used as a temporary laydown area and may house temporary buildings, utilities and facilities not required in the processing plant area.

Roads

A sealed access road will be built from Wickham Point Road past the administration area to the gas-processing plant on Blaydin Point. It will be an 11-m-wide road with two 3.5-m-wide trafficable lanes, a 1-m-wide sealed shoulder on each side and a 1-m-wide unsealed shoulder on each side. The trafficable road surface will be sealed.

Culverts will be constructed below the access road in order to allow the tide to maintain its flow through to the mangrove areas. The exact location of the culverts will be determined through detailed drainage investigations along the road. The road will be drained and drainage trenches placed alongside. The drainage trenches will remain unsealed to allow natural infiltration to occur.

A minor road from the access road to the administration area will also be required.

Communications

Internal and external communications will be required on the site. Internal communications will be supplied by a fibre-optic cable between Wickham Point Road, the administration area and the processing-plant facilities. The administration area will be connected to external communications systems through a communications tower, satellite dishes and other communications equipment. Temporary communications will also be required from the start of the construction phase, including hand-held radios and temporary communications landlines.

4.5.7 Construction of onshore infrastructure

The construction of the gas-processing facilities and supporting infrastructure in the onshore development area will take place over a period of five to six years. Onshore and nearshore construction activities will run in parallel with off-site fabrication of process modules and equipment, as well as with the installation of the offshore facilities.

The construction approach for the onshore infrastructure will be to install a combination of prefabricated gas-processing modules and facilities constructed on site, for example the product storage tanks and supporting facilities. This approach will optimise the time and resources required at the site through the concurrent construction of the process modules at overseas module yards and the preparation of the site and purpose-built facilities. Prior to installation and hook-up of the modules, significant site preparation and civil works will need to be undertaken.

Site preparation

Site preparation is required to ensure that ground conditions are appropriate for construction. Activities will primarily consist of the following:

- establishing all-weather access roads, fencing, ablution facilities and amenities
- pegging-out the areas to be cleared and those to be protected
- mobilising clearing and earthmoving plant, temporary facilities and other equipment to site
- site-clearing and disposing of and/or storing of cleared vegetation

- engaging in major site earthworks on site and at the on-site borrow area
- installing drainage for the civil construction phase, including temporary sedimentation ponds for drainage and erosion control
- suppressing dust using potable water.

Earthworks machinery is likely to consist of drilling rigs; excavators; bulldozers; scrapers; pick-ups or light-duty vehicles; water trucks; cranes; minibuses; transit mixers; forklifts; truck-mounted concrete pumps, compressors and generators; compactors; tipper trucks and trailers; fuel and lube trucks; flat-bed trucks; and pumps.

Drainage will be put in place during site preparation for the following reasons:

- to minimise the amount of disturbed soil at any one time
- to prevent runoff from off-site areas flowing across disturbed areas
- to slow down runoff flowing across the site
- to remove sediments from on-site runoff before it is discharged to the Harbour (either by employing temporary sedimentation ponds or by building treatment structures).

The extent of the earthworks required for the site is dependent on the results of detailed geotechnical investigations and the characteristics of the soils from the borrow-pit areas. Table 4-6 presents the preliminary volumes of cut and fill required for the Project. Earthworks will involve relocating material cut from around the borrow pit at Blaydin Point to bring the site up to the required level. Use of the existing borrow pit will be maximised and additional fill will be sought from a borrow area adjacent to the administration area, which roughly follows the 7-m AHD contour, in order to allow for potential future development needs. Alternatives to using this area for borrow material are being investigated in the vicinity of Middle Arm Peninsula.

Measures will be put in place to control the flow of water across the site and in drainage channels. These measures will serve to encourage the settling of suspended solids that may be produced from stormwater drainage. Cut-off drains will intercept off-site runoff from higher ground and prevent it from flowing across the site.

During the site preparation stage, some topsoil will be stockpiled for later use in site reinstatement. Following commissioning, stable landforms will be established in the construction laydown areas and borrow pits for potential future use. Temporarily disturbed areas such as those in the vicinity of the pipeline shore crossing and onshore pipeline route will be reinstated and rehabilitated, as will any areas around the plant that do not need to remain cleared.

Temporary facilities and construction laydown

From the commencement of site preparation and throughout the construction phase, large areas will be needed for laydown to cater for a range of temporary facilities, construction materials and equipment. These will potentially include the areas and facilities listed below:

- storage areas for process modules
- storage areas for equipment and materials such as steel, piping materials, tank plates and cables
- vehicle checking and washdown areas
- temporary office and crib facilities
- ablution facilities
- parking areas and roadways for construction equipment and personnel vehicles
- fuel storage, bunded areas and distribution facilities
- water storage and distribution facilities
- a temporary sewage treatment plant
- a temporary warehouse and workshops
- liquid, chemical and waste storage and transfer areas
- evaporation and settling ponds

Table 4-6: Indicative earthworks estimates for Blaydin Point and the borrow area

Area	Cut (m^3)	Fill (m^3)	Balance (m^3)
Onshore processing plant	–1 060 000	1 350 000	290 000
Ground flare pad	n.a.	900 000	900 000
Module offloading facility	n.a.	150 000	150 000
Access road	–10 000	70 000	60 000
Administration area	–120 000	30 000	–90 000
Borrow area	–1 160 000	n.a.	–1 160 000
Total	–2 350 000	2 500 000	150 000

n.a. = not applicable.

- welding, grinding, cutting and other hot-work fabrication facilities
- industrial-cleaning, abrasive-blasting and spray-painting areas
- rock-crushing and screening plant or plants
- storage areas for soil and rock
- an acid sulfate soils neutralisation area
- a lime stockpile area for acid sulfate soil neutralisation
- a bitumen plant
- a concrete batching plant
- scaffolding and lifting-equipment storage and maintenance areas.

Construction laydown areas are required to be as close to the construction site as possible. Temporary facilities may also be located on areas which will be used later for permanent facilities.

Construction of onshore gas-processing plant

Once the site has been levelled and all access roads and drainage put in place, construction of the foundations for the processing plant will start.

The construction plan for the two LNG trains at Blaydin Point is based on a modularisation approach with a minimum of "stick-built" facilities (i.e. facilities that are constructed entirely on site with no pre-assembling of parts). A modularised construction approach is defined as a process where the plant facilities are packaged on a systems basis so that they can be fabricated off site and efficiently installed, connected and commissioned on site with as few interconnections as possible. It is planned that the process units and vessels will be built in fabrication yards overseas and transported by sea in defined modules to Blaydin Point.

The construction of any non-modularised supporting facilities, site drainage, foundations and bunded areas will run concurrently with the overseas fabrication of the processing-plant modules.

Plant foundations

The greater part of the LNG trains area will be completed with a concrete slab layer set on top of a rock-and-fill pavement layer. Where concrete is installed in areas with a potential for acid sulfate soils, a liner will be required to protect the concrete from degradation.

The process plant and equipment items are likely to be installed directly on concrete spread foundations. However, depending on the ground and load conditions of different parts of the facility, piled foundations may be adopted. Final foundation design will be determined through more detailed geotechnical investigations.

Perimeter drains and rock-armouring will be installed around the site perimeter for erosion control. Rock-armouring, crushed rock paving, and hardstand material for the construction of the bases of foundations and construction laydown areas will be sourced from the borrow area on site and from a local quarry site operated by a third party. Trucks will be required to transport the rock-armour and other materials from the quarry to the site for stockpiling prior to use.

Ground flare pad and causeway

Construction of the flare pad will require the reclamation of an area in the mangroves to provide an approach and an elevated platform made of earth fill. The fill will be obtained from the borrow pit area. Alternatives to this option, such as constructing a piling and deck structure or inserting stone or concrete columns, are being investigated.

Module offloading and installation

The installation of modules at Blaydin Point will occur sequentially so that the two LNG trains will be commissioned 9 to 12 months apart. This period is to allow module fabrication and construction activities to be scheduled without excessive overlap.

The number of modules has been minimised by making module sizes as large as possible within transportation constraints. Approximately 200 modules of varying shapes, sizes and weights will be imported through the module offloading facility. There are likely to be up to 50 modules for the main process trains and a number of smaller modules with interconnecting pipework and utilities. Offloading of the modules will be effected using hydraulic, self-propelled, multi-wheeled trailers from the delivery vessel.

Construction of LNG, propane, butane and condensate storage tanks

The onshore product storage tanks will be built on site by specialist contractors. The product storage tanks are likely to be constructed of reinforced concrete, insulation material and steel sections. The roofs of the storage tanks will either be lifted into place by a crane or by compressors that gradually lift the roofs into their required positions.

Ground improvement will be necessary prior to construction of the concrete tank foundations. The requirements for piling to support the concrete slab will be established after detailed geotechnical surveys have been conducted.

Construction and installation of supporting facilities

Construction activities associated with supporting facilities include site clearance, bulk earthworks, the construction of foundations, the erection of perimeter fencing and the provision of services such as power and water to designated interface points within each area.

The construction of the roads will be phased, with different road-surface standards being applicable at different stages. During the initial site preparation phase, the roads will take the form of earthen haul roads or access tracks and there will be a minimum of embankment earthworks prior to bituminising. The construction of the roads will require cut-and-fill activities with borrow material being used for pavement and embankment construction.

Accommodation village

The construction workforce is estimated to be between 2000 and 3000 at the peak of the five- to six-year construction period. It is proposed that an accommodation village will be constructed to house most of these people. Normal operations and periodic maintenance-campaign accommodation for personnel will also be required during the operations phase. An accommodation strategy is being developed to identify and investigate accommodation requirements and options during the operations phase. In addition, part of the accommodation village may be required during the operations phase to support accommodation requirements during maintenance shutdowns when personnel requirements increase.

A number of potential locations for the accommodation village were presented to INPEX by both the private sector and the government. The preferred location was chosen from a short list of sites with consideration of stakeholder input and the criteria listed below:

- There should be land potentially available for development.

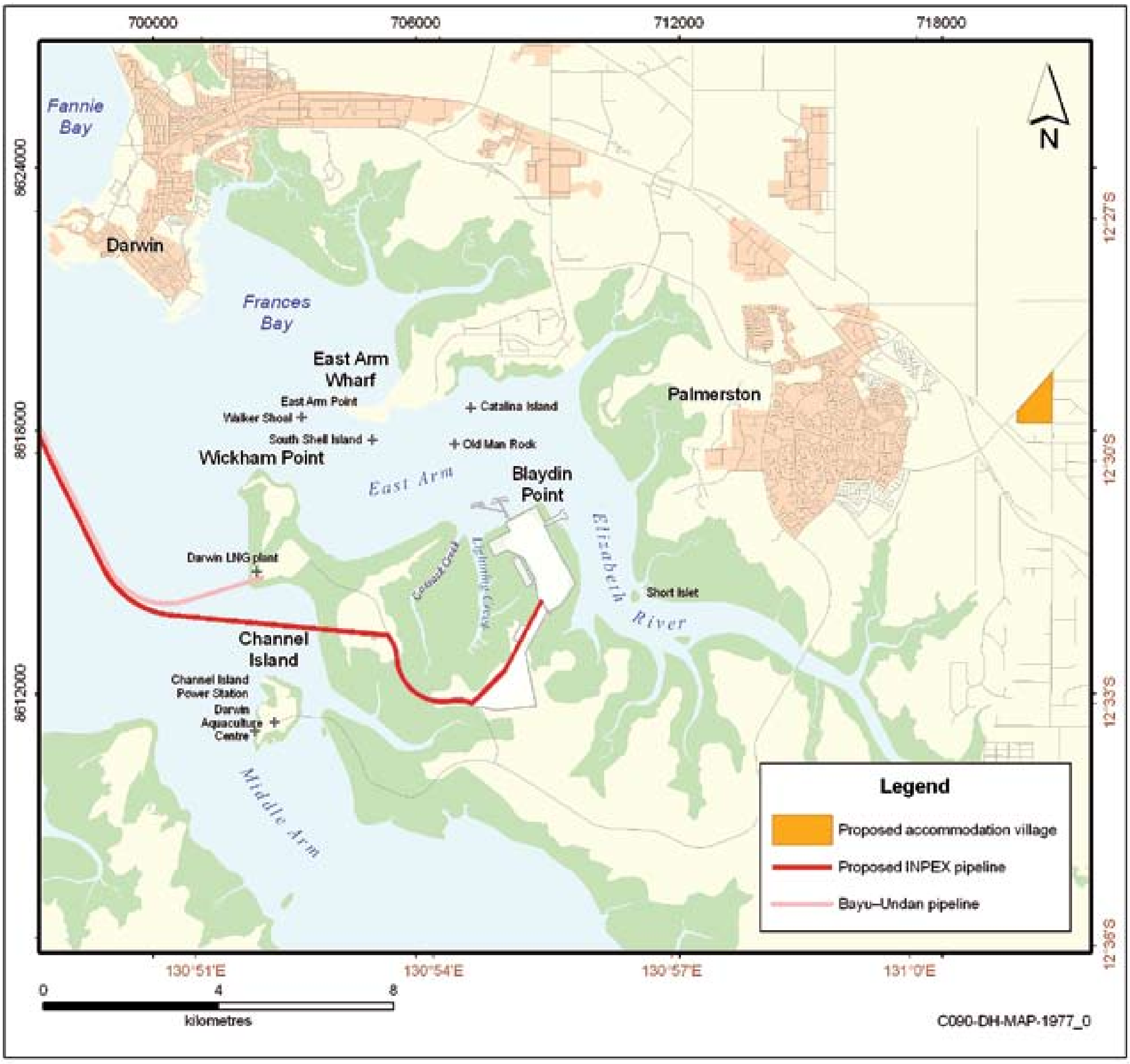

Figure 4-32: Preferred accommodation village location

- The area of available land should be sufficient to accommodate a workforce of 2000–3000 people.
- There should be access to adequate transport infrastructure.
- The location should have access to and be in close proximity to domestic utilities such as power, water and sewerage.
- The location should be in proximity to the onshore development area at Blaydin Point.

The preferred location for the accommodation village is a site on Howard Springs Road, encompassing contiguous land sections 2818, 2819 and 273 (see Figure 4-32).

As the accommodation village must be completed and available prior to the start of construction of the onshore component of the Project, a series of approvals separate from this Draft EIS are being sought. These approvals require assessment of environmental factors such as the direct impacts of vegetation clearing and sediment control on the site.

The social impacts associated with the operation of the accommodation village have been included in this Draft EIS and are detailed in Chapter 10. The issues which have been addressed include increased pressure on local infrastructure, increased traffic, and social interactions between the local community and the new workforce.

Road traffic

During the five-year construction phase, large quantities of bulk materials, other supplies, heavy equipment and plant will be brought to site. Where possible, these will be sourced from Darwin or imported by road from East Arm Wharf or directly to site across East Arm through the module offloading facility. The Project's aim is to optimise the use of the module offloading facility in order to limit the impacts on existing infrastructure. As the larger modules will be offloaded from vessels at the module offloading facility, the need for road-widening to accommodate very large vehicles is not considered necessary. Construction traffic will also include personnel commuting between the onshore development area and the accommodation village, Palmerston and Darwin.

Road traffic for the construction phase of the Project is summarised in Table 4-7 and has been the subject of a detailed traffic impact study, as described in Chapter 10.

Once the Project is fully into the operations phase, the volume of road traffic will decrease substantially. Operations road traffic will consist of light vehicles and buses carrying personnel and a range of supply and waste-transport vehicles. Volumes of personnel traffic will increase during temporary maintenance shutdowns.

Table 4-7: Assumed average peak daily road traffic generated by construction activities

Origin	Destination	Approximate number of round trips per day	Cargo
Blaydin Point	Shoal Bay landfill	30	Construction waste; domestic waste and recyclables; green waste; hazardous materials.
Blaydin Point	Shoal Bay landfill	80*	Acid sulfate soils for disposal.
Darwin	Blaydin Point	170†	Raw materials; aggregate; sand; cement; asphalt; scaffolding; tools; equipment; personnel.
East Arm Wharf	Blaydin Point	74	Fuel and cargo from maritime vessels.
East Arm Wharf	Darwin	2	Cargo from maritime vessels.
Mount Bundy quarry	Blaydin Point	60	Rock-armouring and aggregate for site construction.
Mount Bundy quarry	East Arm	102	Rock-armouring for pipeline stabilisation.
Mount Bundy quarry	Shore-crossing location	3	Rock-armouring for stabilisation of the pipeline shore-crossing location.
Accommodation village	Blaydin Point	100	Personnel from the village (bus movements).
Accommodation village	Blaydin Point	125	Personnel from the village (light-vehicle movements).
Accommodation village	Shoal Bay landfill	2	Waste and recyclables.

* Note that several methods for treatment and disposal of acid sulfate soils are being considered, including treatment in situ and disposal offshore. Depending on the final option chosen, the indicative vehicle movements shown here may not be required.

† This figure includes 100 car trips.

Mainland supply base

Logistic and supporting facilities from the mainland will be required for the offshore component of the Project. The mainland supply base will allow for the loading and refuelling of supply vessels, the storage of construction materials, the offloading of deliveries requiring transport and packaging, and the storage of fuel, chemicals and waste. The supply base will include warehouse, administrative, security and related facilities.

As INPEX has yet to decide on the location of the mainland supply base, it cannot be described in detail in this Draft EIS. Existing facilities are being investigated but a new mainland supply base may be required which would be subject to a separate governmental assessment process. Locations being investigated include Darwin, Broome, Point Torment near Derby, and Derby. The mainland supply-base location will be determined during the detailed-design phase of the Project.

4.5.8 Onshore infrastructure precommissioning

A number of steps will be involved in the precommissioning of the onshore processing plant and supporting facilities prior to the introduction of hydrocarbons during commissioning.

The option for the precommissioning of process modules at the fabrication yards prior to shipping to site is being investigated. If this can be done, it will reduce the volume of hydrotest wastewater discharged into Darwin Harbour and reduce the number of personnel required for the precommissioning process.

Three aspects that will require particular attention are as follows:

- the disposal of flushing fluids
- the dewatering of pipelines
- the dewatering of product storage tanks.

Once equipment has been installed, the major activities in the precommissioning process will be as follows:

- the pressure-testing of systems with air and/or hydrotest water
- the chemical cleaning of some systems
- the commissioning of rotating equipment (turbines and pumps)
- the loading of chemicals such as aMDEA solvent, absorbents required in the molecular sieve for dehydration, and activated carbon for the mercury removal unit
- (potentially) the carrying out of the first fill of refrigerants.

The common utilities and power generation facilities will be installed and precommissioned as a priority. This will be followed by the installation and precommissioning of the inlet facilities and condensate treatment facilities. The product loading jetty will be precommissioned in advance of the hydrotesting of the product storage tanks.

The discharges associated with hydrotesting are described in chapters 5 and 7.

4.5.9 Onshore commissioning, operations and maintenance

The gas-processing trains are likely to be commissioned nine to twelve months apart. The first three months of commissioning may be undertaken with third-party gas followed by the introduction of gas from the offshore facilities. The initial introduction of gas into the onshore facility will be undertaken in stages. These stages include the following:

- the introduction of gas into process vessels and piping
- the checking and rechecking of piping, vessels, valves and flanges
- the testing of systems
- the commissioning of the main compression and LNG process units.

Once the system has been confirmed as having no leaks and has been defrosted, it will be ready to commence cooling the equipment to the normal operating temperatures for an LNG plant. While it is cooling down, the system will initially be too warm to create LNG and the gas will be directed to the flare in line with normal practice. The system will gradually come down to normal operating temperatures and start producing LNG. Throughput can then be slowly increased until steady-state operation is achieved for the first time.

Once the plant is in steady-state operation, INPEX's operations division will be responsible for maintaining the facilities. A maintenance function will be part of the operations division's role, with prime responsibilities in the following order of importance:

- to safeguard the technical integrity of the facilities
- to ensure that equipment and systems are maintained to a standard where they are able to satisfy environmental and regulatory-authority requirements
- to maximise the amount of time the facilities are running.

A risk-based approach will be taken to develop maintenance strategies that will be applied to different types of equipment and facilities. Preventive, predictive and corrective maintenance strategies will be developed using experience and good practice, supported where appropriate by techniques such as risk-based inspection and reliability-centred maintenance.

As personnel competence is considered key to the effectiveness of the maintenance function, appropriate selection procedures will be put in place and, where necessary, training of in-house and specialist personnel will be undertaken.

4.6 Decommissioning

The estimated life of the Project is 40 years. The Project will be decommissioned at the end of its operating life when production from the gas reservoirs is predicted to reach the limit of economic viability. The final state of the site after the 40-year lifespan of the Project will be dependent on the final land use to be determined by the Northern Territory Government.

An environmental impact assessment and approval may be required to confirm that the planned decommissioning activities are the most appropriate to the prevailing circumstances. This assessment would outline management controls and aim to demonstrate that the decommissioning activities would not cause unacceptable environmental impacts.

4.6.1 Offshore decommissioning

Once the field has reached the end of its useful life, the CPF and FPSO will be decoupled from their moorings and towed from the infield location, the reservoir will be permanently isolated, necessary well equipment will be removed, and the wells will be plugged and abandoned.

The process of decommissioning the offshore facilities will necessitate the assessment of a range of options, including finding alternative uses (including recycling or onshore disposal) for the CPF and the FPSO or their component parts. The options include leaving certain subsea structures in place, such as the mooring suction piles and infield flowlines. The assessment of options will be based on a range of physical factors (e.g. water depth, ocean processes, and the physical state of the facilities) and other considerations (e.g. proximity to sensitive habitats and interference with fishing-industry activities).

The gas export pipeline will be left in place following decommissioning.

Offshore decommissioning will also be subject to assessment under the relevant legislation and international conventions and treaties. While the requirements for decommissioning will depend on the regulations prevailing nationally and internationally at the end of the useful field life of the Project, consideration of the feasibility of different decommissioning options will be incorporated into the design of the offshore facilities.

4.6.2 Onshore and nearshore decommissioning activities

The extent of onshore and nearshore decommissioning and site rehabilitation will be agreed with the Northern Territory Government prior to the commencement of decommissioning. Options for decommissioning will depend upon the anticipated future land use and the requirements of the government.

If the land is to be used for future industrial activities, it may be desirable that the module offloading facility should be left in situ along with other valuable infrastructure such as the major access road and drainage control structures. Under this scenario, non-essential aboveground infrastructure would be removed and landforms made stable to prevent erosion. If, however, it were to be decided that the onshore development area should be returned to natural habitat, all aboveground infrastructure would be removed and an active revegetation program would be initiated; the effectiveness of such a rehabilitation program would be assessed against agreed completion criteria.

Removal of onshore infrastructure

As with the offshore facility, consideration of decommissioning feasibility will be incorporated into the design of the onshore facility. The exact designs and methods for decommissioning will need to take into account the possibility of advances in technology and knowledge over the 40-year life of the Project. Limiting decommissioning options to those available during the design phase risks the Project falling well short of best practice at the time of decommissioning.

An indicative outline of the activities that may be required to remove infrastructure from the onshore site has been provided below. The exact sequence of demolition would be laid down in a detailed decommissioning management plan to be provided to, and agreed by, the Northern Territory Government before decommissioning commences.

Gas-processing plant

As most of the components of the gas-processing plant on Blaydin Point will be installed in large prefabricated modules, it may be possible to remove the same modules in the reverse sequence of the installation process.

Such a sequence for removal could involve the following steps. The pipes and cables that interconnect the common facilities and LNG processing modules could first be disconnected at the individual module and pipe-rack boundaries. The individual modules and pipe-rack sections could then in turn be disconnected from their foundations and lifted off their supports using the same type of self-propelled module transporters used during their original installation. The individual modules and pipe-rack sections could then be transported down to the module offloading facility for loading on to a transportation barge. Once on the transportation barge they could be sea-fastened and then towed to an approved location for dismantling or reuse.

Prefabricated structures of all sizes could be removed using this approach. However, while the plant will be sound for operational purposes, it may not have the structural integrity for removal in large portions.

Once the processing facilities are removed, shallow-spread foundations could be excavated and demolished. The debris and foreign materials would be loaded on to trucks for removal and disposal.

If piled foundations are utilised in construction, the support plinths and pile caps would be excavated and demolished to a depth of 1 m below existing ground level. The piles themselves would have to remain in situ as the ground disturbance involved would be significant.

All excavations resulting from the removal of foundations could be backfilled with locally sourced materials.

Product storage tanks

Onshore decommissioning of the product tanks would be likely to be undertaken by a specialist demolition subcontractor.

It is envisaged that for onshore infrastructure, controlled use of explosives could be needed during some phases of the demolition of the redundant LNG and LPG storage tanks. The storage tanks and any shallow ground-bearing spread foundations could be removed completely. All excavations resulting from the removal of foundations could be backfilled. Deep (piled) foundations that could not be removed may be managed as described above for the gas-processing facilities.

4.6.3 Decommissioning management

Notice will be given by INPEX to the Northern Territory Government at least 10 years before the end date of production, to allow discussions regarding the decommissioning management plan to begin.

It is envisaged that the process of developing detailed decommissioning management plans will be staged, initially outlining potential options and studies required for discussion with the regulatory authorities, and finally leading to agreed plans prior to the commencement of decommissioning. The content of the final plans will be dependent, for example, on the anticipated future land use determined by the Northern Territory Government for the onshore site on Middle Arm Peninsula. The plans will include methods and activities associated with the decommissioning of the offshore and onshore infrastructure, including the transportation and final disposal or reuse strategy for Project components and wastes. Completion criteria will be detailed in the management plans and will include, for example, criteria for the composition of rehabilitated vegetation communities, for erosion control measures, and for the visual amenity of the site. These completion criteria will be determined in consultation with the government.

A Provisional Decommissioning Management Plan has been outlined in this Draft EIS and is provided as Annexe 5 to Chapter 11.

5 Emissions, discharges and wastes

5 EMISSIONS, DISCHARGES AND WASTES

5.1 Introduction

Over the lifetime of the Ichthys Gas Field Development Project (the Project) a range of emissions, discharges and wastes will be produced that will have the potential to effect the environment.

This chapter describes the air, light and noise emissions, the liquid discharges to the marine environment, and the non-discharged liquid and solid wastes that will be produced through the different phases of the Project.

The data in this chapter have been used as the basis for a number of technical studies, including air-quality modelling, noise modelling and water-dispersion modelling. These studies are discussed in subsequent chapters of this draft environmental impact statement (Draft EIS) and are provided in full as separate technical reports in the appendices.

5.2 Greenhouse gas emissions

Development of the Ichthys Field will result in greenhouse gas (GHG) emissions over the life of the Project. These emissions and their management are discussed in Chapter 9 *Greenhouse gas management*.

5.3 Air emissions

Combustion emissions will be generated from the offshore and onshore facilities over the 40-year life of the Project. Other air emissions of lower volume or magnitude will be non-combustion hydrocarbons released from vented and fugitive sources and nuisance emissions such as dust, smoke and odour.

An air-quality assessment has been conducted to determine predicted ground-level concentrations of key air pollutants produced by the Project. This is discussed in detail in Chapter 8 *Terrestrial impacts and management*.

5.3.1 Combustion emissions

Significant gaseous emissions from the production of gas and condensate will be generated by the combustion of fuel gas in the compressor turbines and power generation turbines at the offshore and onshore facilities. Other combustion sources include the flares, acid gas removal unit (AGRU) incinerators, hot-oil furnaces and supplementary steam boilers.

The most significant non-GHG pollutants from combustion emissions, in terms of volumes produced, are nitric oxide (NO) and nitrogen dioxide (NO_2) (together known as "NO_x") and carbon monoxide (CO). Small quantities (trace amounts) of methane (CH_4) and sulfur dioxide (SO_2) will also be present in the emission streams.

Emissions data for the priority pollutants NO_2, ozone (O_3), SO_2 and particulates (PM_{10}) have been modelled at the onshore location to predict ground-level concentrations in the Darwin region. Model outputs are provided and discussed in Chapter 8 and have been compared with Australian ambient air quality standards.

5.3.2 Non-combusted emissions

Non-combusted emissions, consisting primarily of volatile organic compounds (VOCs), will be produced from the onshore and offshore facilities. The main sources include vented emissions released from storage and loading facilities and fugitive emissions from compressor seals, valves, flanges and pumps.

VOCs are organic chemical compounds with a high enough vapour pressure under normal conditions to vaporise and enter the atmosphere. Benzene, toluene, ethylbenzene and xylenes (known collectively as BTEX) are examples of VOCs.

5.3.3 Ozone

Gas processing can generate the precursors required to initiate the generation of O_3, a colourless gas naturally found in the upper atmosphere. It is produced photochemically by the reaction of NO_x and VOCs in sunlight.

The generation of O_3 from photochemical smog is a localised phenomenon; it is produced relatively slowly, over several hours, after exposure to sunlight has been sufficient for a series of chemical reactions to be completed.

5.3.4 Particulates

Particulates will be generated during onshore construction and decommissioning in the form of dust, and during the operation of the onshore and offshore facilities in the form of smoke. Particulates of interest are those less than 10 μm in diameter (known as PM_{10} for particulate matter <10 μm) as these can remain airborne and can be spread by winds over wide areas and long distances.

Emissions of PM_{10} from the operation of the onshore processing plant have been quantified and included in the air quality modelling.

Dust

Dust emissions during the construction phase will result from the following:

- vegetation clearing and site preparation
- earthworks (e.g. site levelling and excavation)
- cut-and-fill activities
- wind erosion of stockpiled materials
- traffic movements on unsealed roads
- loading and transport of loose soil, aggregate and/or other dust-generating material
- the operations of crushing and screening plant
- the operations of concrete batching plant.

The quantification of dust emissions is problematic as they can vary substantially according to the effectiveness of the dust-control measures employed, the physical characteristics of the soil, the prevailing weather conditions and the level of construction activity being undertaken.

Dust emissions during the operations phase of the Project will be minimal as most earth movement will have been completed and all roads and permanent work areas will have been sealed. Activities similar to those of the construction phase will be undertaken during the decommissioning phase, but this is expected to generate lower volumes of dust.

Smoke

The main potential source of PM_{10} from the operation of the onshore processing plant will be from the shielded ground flare and the enclosed tankage flare. Particulates can be released during the incomplete combustion of hydrocarbons, which can occur when the flares are too cold or there is insufficient oxygen in the flames. These particulates are often visible as smoke and contain PM_{10}.

The flares will be designed to burn efficiently, thereby minimising smoke production. Flaring of gases will be significant in the few months of commissioning and during the subsequent and occasional 1-hour to 5-day events when:

- warm or inert liquefied natural gas (LNG) tankers are being loaded
- shutdowns and start-ups are taking place
- process upset conditions occur
- there is a real threat or perceived danger to personnel or the facility.

During these events, high-pressure gas sent to the flares will periodically produce smoke. The likelihood of smoke production will be increased when propane and butane are sent to the flares. This is because propane and butane are longer-chain hydrocarbons than methane and require more oxygen to burn; they are therefore more likely to produce particulate matter.

5.3.5 Odour

Potential odours associated with offshore and onshore gas processing during the Project may originate from sulfurous compounds such as hydrogen sulfide (H_2S) in the reservoir gas. The H_2S content in the Brewster and Plover reservoirs is predicted to be around 25 ppm (parts per million) by volume.

The H_2S needs to be removed from the natural gas to ensure that the LNG and other products meet buyers' specifications. Its removal is achieved by treating the gas in the AGRUs (which also remove carbon dioxide (CO_2)). The emissions from the AGRUs are directed to incinerators where residual H_2S is converted to the non-odorous sulfur oxides (SO_x) prior to release to atmosphere.

In the unlikely event that the AGRU incinerators are shut down, exhaust gases will be hot-vented through gas turbine exhaust stacks to facilitate safe dispersion. Potential odour impacts are discussed in Chapter 8.

5.3.6 Summary of air emissions

The following assumptions were made in estimating annual emissions from Project operations:

- The emissions are based on 365 days of production per year.
- The central processing facility (CPF) at the Ichthys Field will use gas turbines for export gas compression and power generation from the start of the Project, with additional turbines being employed for inlet compression from Year 11.
- The floating production, storage and offtake (FPSO) facility at the Ichthys Field will also use gas turbines to provide electrical power. Supplemental fired heating will be required for monoethylene glycol (MEG) regeneration when waste heat from the gas turbine stacks is not sufficient to fully regenerate all of the MEG.
- The onshore process will use nine open-cycle industrial gas turbines for power generation, with an operating philosophy of eight running and the ninth available from cold start.
- The onshore process will use gas turbine drivers for refrigerant compression loops, which will be operating continuously at 100% design load.
- The onshore process will include one incinerator and one hot-oil furnace on each LNG train.
- Waste-heat recovery systems will be installed on gas turbines on the FPSO and at the onshore facilities.

Table 5-1 provides estimates of the Project's key combustion emissions for the offshore and onshore facilities in tonnes per annum.

Table 5-1: Estimated annual combustion emissions from routine operations of the Ichthys Project

Ichthys Project emissions* (t/a)		
Air emission	Offshore facilities	Onshore processing plant
NO_x (as NO_2)	5000	2700
CO	5800	Not calculated
SO_x (as SO_2)	16	950
CH_4	8500	10 500
PM_{10}†	Not calculated	150
VOCs	1100	500

* Values are based on normal operating conditions and do not include fugitive or vented emissions.

† PM_{10} from dust is not included in this calculation because quantification of a non-point-source emission is difficult.

5.4 Light

The generation of artificial light from the construction and operation of the offshore facilities, the onshore processing plant and other Darwin Harbour infrastructure has the potential to result in light spill to the environment.

5.4.1 Offshore lighting

To provide safe working conditions, lighting will be required from the commencement of drilling and through the installation of the CPF and FPSO facilities to production. Lighting will be designed in accordance with the relevant Australian and international standards to ensure that worker safety is not compromised. For this purpose, lighting levels are required to be 150 lx at 1 m above the decks of the CPF and FPSO (note that 1 lx is equal to 1 lm/m^2).

Additional lighting will be required periodically on cranes and on portions of the CPF, the FPSO and the mobile offshore drilling unit (MODU) to allow safe loading and unloading of support vessels and export tankers. The purpose of these additional lights will be to minimise the potential for safety and environmental hazards and they will not be intentionally focused into the water. Light spill from these sources is expected to be of low intensity.

5.4.2 Onshore and nearshore lighting

Construction of the onshore facilities at Blaydin Point will primarily be conducted during daylight hours. Where night-time activities are required, lighting will be generated by white metal halide, halogen and fluorescent bulbs directed on to working areas to allow the safe movement of personnel.

General vessel movement around Blaydin Point and the construction of the module offloading facility and the product loading jetty will also primarily occur during daylight hours. Again, situations may arise where work is required at night. For example, modules may be transported from the module offloading facility at night to prevent delays and allow for the correct sequencing of deliveries to site. Vessels moored during construction, dredging and pipe-laying operations in the vicinity of Blaydin Point will also require lighting for safe operation at night.

From the commencement of commissioning, work will be conducted on a 24-hour-a-day basis on the site for the entire 40-year life of the Project. Lighting will be designed to ensure that worker safety is not compromised and will be in accordance with the relevant Australian and international standards. Typical lighting will consist of white metal halide, halogen and fluorescent bulbs and tubes. Lighting will also be designed in consultation with the Darwin Port Corporation (DPC) and will aim to minimise navigational hazards. Product tanker lighting will also be subject to consultation with the DPC.

During the commissioning of the two LNG trains, flaring will be continuous for extended periods. However, as described in Chapter 4 *Project description*, the ground flare will be shielded and will be designed to accommodate all the flaring emissions, thereby avoiding direct light emissions from this source.

5.5 Noise and vibration

Sources of noise and vibration associated with activities undertaken offshore and in Darwin Harbour and the onshore environment are identified and described in this section. Modelling of onshore and offshore noise is detailed in Chapter 7 *Marine impacts and management* and Chapter 10 *Socio-economic impacts and management*.

5.5.1 Marine noise and vibration

Marine noise will primarily be generated through construction activities in both the nearshore and the offshore environment. As with light, noise is characterised by how it is propagated through different media and how it is received. Noise is therefore measured in a different way in water from that on land.

Offshore activities

Noise will be emitted through the activities associated with drilling, installation and operation on the offshore facilities. The primary sources of noise will be the following:

- operation of vessels and equipment, including the CPF, the FPSO, condensate tankers, support vessels, supply vessels, the pipelay barge, the production drilling MODU and support vessels
- vertical seismic profiling (VSP).

Operation of CPF, FPSO, maritime vessels and MODU

Noise generated from offshore facilities and vessel operations will occur during the construction, installation and subsequent phases of the Project. Most noise associated with vessel traffic will be from rig tenders and other associated support vessels, particularly those using dynamic positioning systems. Vessels will likely include module transfer barges; pipelay barges; heavy-lift-crane barges; smaller, faster-moving support and survey vessels; pipe supply vessels; and condensate offtake tankers. The main noise source during the exploration and production drilling programs will be from the rig tenders, rather than from the drilling rig or from the drilling operation itself.

Noise from maritime vessel traffic and drilling vessels is generally low- to medium-frequency broadband noise up to 186 dB re 1 μPa at 1 m.

Vertical seismic profiling

The VSP technique is used to correlate the subsurface geological layers identified through pre-drilling seismic surveys with those identified through cuttings returns and other data acquired during the drilling process (e.g. wireline logging data). It will be utilised for production drilling activities at the Ichthys Field.

Because of the water depth at the field, VSP will be conducted with a two- or three-airgun cluster; approximately 150 cubic inches (*c.*2.5 L) in capacity per airgun. The operating pressure of each airgun will be approximately 2000 psi, with the cluster positioned near the ocean's surface (approximately 5–10 m deep). The airgun cluster will typically be fired at intervals of 6–10 s, generating a sound-pressure level of around 190 dB re 1 μPa at the standard reference distance of 1 m, with a frequency typically centred around 200 Hz.

The airgun cluster is generally hung from a support vessel, which can be positioned near the drilling rig or can move away from the rig during the profiling of directionally drilled wells. These operations generally only last for 8 to 12 hours and will typically occur only once per production well drilled.

Vertical seismic profiling using this same technique can be used during operations to monitor the decline of hydrocarbons in a reservoir. However, at this stage this is not a planned monitoring technique for the Ichthys Project.

Nearshore activities

Noise will be generated by the activities associated with the installation and operation of the nearshore facilities and the dredging of the shipping channel. Primary sources of noise will include the following:

- drilling and blasting of rock in the shipping channel
- dredging of the shipping channel, approach area, turning basin and the berthing areas for the product loading jetty and module offloading facility
- piledriving for the jetty and module offloading facility.

Drilling and blasting

A marine drilling and blasting program is likely to be implemented to fracture around 170 000 m^3 of rock at Walker Shoal prior to removal by backhoe or grab dredging vessels. The rock material has been assessed as being too hard to remove by cutter-suction dredger. Detailed methods have not yet been confirmed, but it is likely that each round of blasting will detonate a total charge weight of 300 kg, separated into six approximately 50-kg charges set on micro-delays, contained in six pre-drilled holes in an area between 3 and 5.5 m^2 in extent.

Alternative techniques to drilling and blasting are being investigated to remove the hard rock material within the shipping channel. At this stage, however, it is not possible to confirm whether there are any viable alternatives.

The impact of the resultant shock waves is discussed in Chapter 7.

Dredging

The level and characteristics of noise will vary between the different types of dredging equipment. The characteristics of the four types of dredgers that may be used are considered below: cutter-suction, trailing suction hopper, backhoe, and grab (also referred to as clamshell).

Cutter-suction dredger

Measurements of underwater noise radiated from the *Queen of the Netherlands*, a giant trailing suction hopper dredger, are comparable to cutter-suction dredges. Measurements were taken during a trial dredging program in the Port of Melbourne which found that underwater sounds were primarily in the low frequencies with high-frequency tones also present. The total sound-power level for the *Queen of the Netherlands* was calculated to be in the order of 169 dB re 1 μPa at 1 m (root mean square).

Trailing suction hopper dredger

Direct measurements of underwater noise emitted from trailing suction hopper dredgers show that the level of noise fluctuates depending on operating status (Richardson et al. 1995). The noise emitted is predominantly in the low frequencies and they can be a strong source of continuous noise. A hopper dredger under load in previous studies had higher broadband source levels than other dredging equipment (Richardson et al. 1995).

Backhoe dredger and grab dredger

Noise levels from backhoe and grab-bucket dredging are highly variable depending on the phase of the operation. The strongest noises are in low frequencies centred about 250 Hz with peak measurements reported to be in the order of 150–162 dB re 1 μPa at 1 m. The strongest sounds in one study were associated with the winch motor pulling the grab bucket back to the surface (Richardson et al. 1995).

Piledriving

Piledriving operations involve hammering piles into the seabed. Piles will be required for the construction of the product loading jetty and potentially also for the module offloading facility. The action of driving a pile into the seabed will generate compressional waves along the length of the pile and radiate acoustical energy into the water column and seabed.

There is a substantial body of literature describing the characteristics of noises generated during piledriving operations. The noise generated by a pile during driving operations is a function of its material type and its size. The resultant noise is likely to be of high intensity (around 180–215 dB re 1 μPa at 1 m) and low frequency and will be generated intermittently. Typically, during piledriving activities the physical driving of piles will occur for 30–40% of each daily shift. There may be more than one piledriving spread working in the nearshore area at any one time.

General shipping and vessel traffic

Noise generated from vessel traffic associated with the Project will occur during both the construction and operations phases of the Project. The Port of Darwin contains well-established trading and recreational facilities that host a wide variety of vessels ranging from small pleasure boats to large commercial tankers. Noise is therefore currently being generated around the Project area from already present (and increasing) vessel movements.

Additional sources of noise from maritime traffic will include the following:

- the operation of vessels and equipment, including the dredging and pipelay vessels and supporting vessels and tugs during the construction phase
- the operation of tankers and associated tugs during the operations phase
- the operation of maintenance dredgers and other maintenance vessels during the operations phase.

The noise characteristics and noise levels generated by the vessels that will be present in the Ichthys Field and near Blaydin Point will vary considerably and will depend on the type of vessel being considered. The particular activity being conducted by the vessel also greatly influences the noise characteristics.

Large commercial tankers have powerful engines primarily designed to drive the vessel at a steady cruising speed. These vessels produce high sound levels, mainly at low frequencies. At these frequencies the noise is dominated by propeller cavitation noise combined with dominant tones arising from the propeller blade rate.

Noise from maritime vessel traffic will generally be low- to medium-frequency broadband noise, at levels up to 186 dB re 1 μPa at 1 m.

Discussion of the impacts of noise in the marine environment is provided in Chapter 7.

5.5.2 Airborne noise

This section describes the sources of airborne noise from construction and operation of the onshore gas-processing plant.

Onshore and nearshore construction

Project activities that will contribute to noise levels during site preparation and construction at the Blaydin Point site will include the following:

- geotechnical boring and excavation
- clearing of vegetation using, for example, bulldozers and dumper trucks
- construction traffic and equipment movement
- earthworks
- rock-armouring works
- crushing and screening plant operations
- concrete batching plant operations
- piledriving for jetty construction
- onshore blasting (if required)
- equipment erection using heavy-duty trailers and cranes
- assembly and welding work
- piping work
- compressors operation for dewatering of the pipeline
- surface protection and sand-blasting of vessels and pipework
- transport movement around the site.

With the exception of blasting and piledriving, general construction noise emissions at Blaydin Point are likely to be lower than those generated during the normal operations of the processing plant.

Operational noise

General noise sources associated with the onshore processing plant and utility areas during normal operations will include the following:

- pumps
- refrigerant compressors
- fin-fan coolers
- turbines
- motors
- flares
- general utilities.

Estimates of cumulative sound power levels for equipment during normal plant operation is estimated to be approximately 127 dB(A) at source. For the emergency flaring case, a single noise source has been identified with a cumulative sound power level of 140 dB(A) at source. This source is located 4 m above ground level and is enclosed by a 12-m-high barrier. The flare systems will be designed to mitigate noise emissions.

Airborne noise modelling has been undertaken for key noise sources—plant operations, emergency flaring, and piledriving during construction—and is presented along with a discussion on potential community impacts in Chapter 10.

5.6 Liquid discharges

Liquid discharges will be produced throughout the various activities of the Project, including offshore drilling and pipelay, installation and construction, commissioning, operations and decommissioning. The source of each discharge and its characteristics are described in this section, with dispersion modelling and a detailed assessment of selected impacts provided in Chapter 7.

5.6.1 Offshore discharges

A summary of the discharges for the various offshore components of the Project at different stages of development is presented in Table 5-2. Dredge spoil disposal is discussed in Chapter 7.

Table 5-2: Summary of liquid discharges from the offshore components of the Project

Discharge stream	Drilling (intermittently over c.20 years)	Pipelay (c.1 year)	Construction and commissioning (4–5 years)	Operations (c.40 years)	Decommissioning (c.1 year)
Drilling discharges	✓	–	–	–	–
Subsea completion and control fluids	–	–	✓	✓	–
Hydrotest water	–	–	✓	–	–
Produced water	–	–	✓	✓	–
Cooling water	–	–	✓	✓	–
Sewage and grey water	✓	✓	✓	✓	✓
Desalination reject water	✓	–	✓	✓	–
Deck drainage	✓	✓	✓	✓	✓
Ballast water	✓	✓	✓	✓	✓

Drilling discharges

Drilling will occur from the commencement of the Project through to the operations phase as more wells are drilled, up to around 50 wells in total. During drilling, the drill bit produces cuttings which become entrained in the drilling muds that will be discharged to the marine environment.

In addition to their primary function of lubricating and cooling the drill bit, drilling muds serve a number of other purposes. These include the following:

- the removal of cuttings from the bottom of the well
- the deposition of an impermeable cake on the well-bore wall to seal the formation being drilled
- the prevention of contaminants entering the mud and/or of the fluid entering the formation
- the maintenance of the structural stability of the well bore.

Drilling mud consists of the base fluid, weighting agents and chemical additives used to give the mud the required characteristics to ensure that drilling is as safe and as efficient as possible. Since well design and substrate will vary from one well to another, the composition of the drilling muds will also vary.

Drilling muds required as part of the Project's drilling activities will include both synthetic-based mud (SBM) and water-based mud (WBM). The SBM will generally be used at greater well depths with smaller drill bits where greater lubrication and other technical performance capabilities are required. SBMs will typically consist of low-toxicity muds with additives such as polymers, caustic soda, barite and starches.

For the greater part of the drilling operation, the muds and their contained cuttings will be returned to the surface where they will be separated and the muds recycled for reuse in the well. Cuttings are continuously discharged during the drilling operations. Following completion of the drilling operations, the WBMs will be discharged to the marine environment and the SBMs will be recovered and returned to the supplier onshore for reuse or disposal.

Drill cuttings are inert pieces of rock, gravel and sand removed from the well during the drilling process. The characteristics of the cuttings to be discharged can be predicted from the lithology of other wells drilled in the permit area, but are expected to consist of calcarenite, shale and sandstone. The cuttings are expected to range in size from very fine to very coarse particles, with a mean diameter of around 10 mm.

Cuttings will be continuously discharged during drilling operations in the offshore development area. Typically, drilling at the Ichthys Field will produce around 700 m^3 of drill cuttings per well. As around 50 wells will be developed, there will be approximately 35 000 m^3 of cuttings across the 800 km^2 (80 000 ha) area of the Ichthys Field.

Toxicity effects of the drill muds and cuttings are well understood and are discussed further in Chapter 7.

Subsea completion and control fluids

Once a well has been drilled, subsea well completion fluids will be required to ensure that the surface is clean and to prevent blockage in the reservoir. The type of fluid used will depend on the drilling fluid used. This may be brine when WBMs are used and a low-weight fluid such as diesel when SBMs are used. The management of completion fluids is described further in Chapter 7.

After a well has been drilled and the subsea systems have been installed, hydraulic fluids will be required to control the subsea tree valves. An open-loop system is likely to be employed; this will release hydraulic fluids to the sea when operated. These fluids are water-based and contain additives such as hydrate inhibitors, lubricants, corrosion inhibitors, biocides and surfactants.

The volumes of hydraulic fluids to be discharged over the Project's 40-year lifetime will be proportional to the level of Project activity. The volumes of hydraulic fluid used will range from 100 to 4500 m^3/a in the first year of drilling to approximately 300 m^3/a through the remainder of the Project's life.

Further discussion of the impacts of control fluid discharge can be found in Chapter 7.

Hydrotest water

During the precommissioning of the offshore facilities, pressure-testing will be required to ensure the integrity of the subsea flowlines, pipework, process vessels and the MEG service line from the facilities to the well manifold. This will be done using treated sea water or potable water, which will then be discharged to the marine environment after hydrotesting has been completed. Hydrotest water will consist of chemically treated water containing biocides, corrosion inhibitors and oxygen scavengers to prevent internal pipe corrosion, and bacterial formation and scale inhibitors to prevent the build-up of scale.

The volumes of hydrotest water required during the initial subsea installation of infield flowlines and export flowlines (one to two years into the Project's construction phase) will be approximately 19 000 m^3 with approximately 700 m^3 for transfer flowlines. Subsequent drilling campaigns will require the discharge of approximately 3000 m^3 of hydrotest water per well installation.

During precommissioning of the gas export pipeline it will be flooded with approximately 1 000 000 m^3 of filtered and chemically treated sea water sourced from Darwin Harbour. The pipeline will then be hydrotested twice using approximately 10 000 m^3 of treated water (for each operation). At the end of each hydrotest operation, the 10 000 m^3 of treated water will be discharged from the offshore facilities to return the pipeline to ambient pressure. In the highly unlikely event of mechanical failure or a cyclone passing Darwin during the hydrotest operation, this 10 000 m^3 may need to be discharged from the onshore facility into the Harbour. This scenario is discussed in Section 5.6.3 *Darwin Harbour discharges* below.

On completion of the hydrotesting, the pipeline will be dewatered and then dried and purged using nitrogen. During dewatering, the approximately 1 000 000 m^3 of treated water in the pipeline will be discharged at the offshore end. It is possible that MEG (monoethylene glycol) or TEG (triethylene glycol) will be introduced during the dewatering and drying stage to ensure that all traces of water are effectively removed from the pipeline.

Produced water

"Produced water" is water extracted from the gas reservoirs and separated from the hydrocarbon gases and liquids through a series of processes usually conducted at offshore facilities. It has two sources: one is the saline "produced formation water" found as a liquid in the geological formation along with the gas, and the other is the water vapour commingled with the gas which is condensed out during the processing phase. Produced water is the combination of produced formation water and the condensed water. Figure 5-1 shows the volumes of produced water that will be discharged from the offshore facilities over the 40-year life of the Project.

Low flow rates of produced water are expected from the Brewster Member reservoir, while significantly higher volumes are predicted from the Plover Formation reservoir. The total volumes of produced water discharged from the offshore facilities are therefore dependent on the relative proportions of gas extracted from the two reservoirs. The averaged volumes of produced water to be discharged to the marine environment will range from 480 m^3/d in the first year of production to a maximum of approximately 3200 m^3/d.

Produced water typically contains small volumes of hydrocarbons, traces of minerals, production chemicals, dissolved salts and some solid particles such as sand.

In order to comply with Clause 29 of the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009 (Cwlth), the concentration of oil in any produced water discharged to sea will be limited to not greater than an average of 30 mg/L over any period of 24 hours.

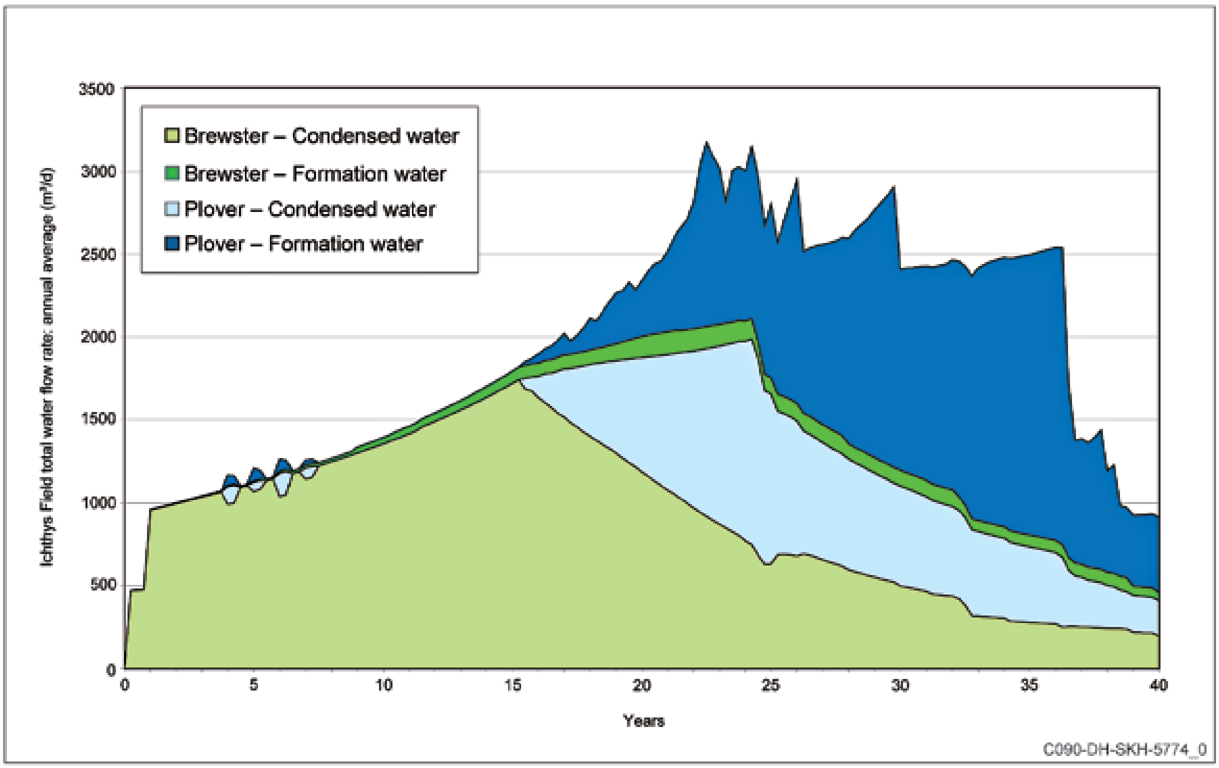

Figure 5-1: Average volumes of produced water discharged from the offshore facilities over the 40-year life of the Project

The produced water will be discharged from the FPSO through a submerged caisson in line with standard practice for offshore installations. The temperature of the water will be in the range 45–50 °C.

Chemicals added to the produced water during the extraction process will also be present in the produced water discharge. These include MEG, corrosion inhibitors, scale inhibitors and biocides.

MEG will most likely be required on a continuous basis for management of hydrate formation in the flowlines from the wells. Most of the MEG will be removed by the MEG regeneration unit on the FPSO prior to discharge.

Concentrations of MEG in produced water from the offshore development area will vary across the Project's operational life cycle depending on the amount of formation water associated with the gas extracted from the reservoirs. The Brewster reservoir, which will be developed early in the life of the Project, contains very little formation water, resulting in low concentrations of MEG (approximately 100 mg/L) in the associated produced water. The Plover reservoir contains more significant volumes of formation water and it is estimated that during years 28–33 of the Project, MEG concentrations in produced water from the offshore facilities could rise to 15 000 mg/L.

Corrosion inhibitors are intended to limit the rate of corrosion of the inner surfaces of the production process equipment. Corrosion inhibition is based on the formation of a film on the internal surface of the vessel or piping. Although a wide variety of corrosion inhibitors are available, they are mostly carboxylic acids that have had nitrogen-containing chemicals substituted. Black et al. (1994) identify four generic types of corrosion inhibitor as follows:

- imidazoline derivatives
- amines and amine salts
- quaternary ammonium salts
- nitrogen heterocyclic compounds.

Of these generic types, only imidazoline derivatives are water-soluble. The other three are all oil-soluble and therefore would not be discharged with the produced water to any significant extent. Imidazoline derivatives are normally produced from the reaction of fatty acids with amines and are readily biodegradable (Madsen et al. 2001). The maximum concentration range of corrosion inhibitor in the discharge is expected to be 7.5–30 ppm.

Scale inhibitor is used to prevent carbonate or sulfate salts of calcium, strontium, barium or radium from the reservoir water precipitating and forming scale on the inner surfaces of the production process equipment. The active ingredient of scale inhibitor is usually either a phosphate or a phosphonate ester. These chemicals are strongly water-soluble. The expected concentration range of scale inhibitor in the discharge would be 3–10 ppm.

Biocides are used to prevent or control the growth of sulfate-reducing bacteria. (A by-product of the action of sulfate-reducing bacteria is hydrogen sulfide, which is both corrosive and toxic in high concentrations.) To improve performance and avoid the potential for development of biocide-resistant bacteria, biocides are generally applied in short doses of a relatively high concentration rather than by continuous dosing. Typical active ingredients in biocides include aldehydes or amine salts: both of these types of biocide are soluble in water and would be discharged with the produced water within an expected concentration range of 10–200 ppm.

The produced water discharged from the FPSO is estimated to contain dissolved hydrocarbons and production chemicals within the ranges presented in Table 5-4.

Modelling of the produced water discharge has been conducted and is discussed in detail in Chapter 7.

Cooling water

Cooling water will be required on the offshore facilities to reduce the temperature of the gas coming from the reservoir and to provide cooling for gas compression and power generation facilities. For this purpose, sea water would be treated, used, and discharged back into the marine environment. Cooling water is sea water that has been passed through a heat exchanger and discharged to the sea at a higher temperature, in this case at approximately 45–50 °C. The cooling water will also be dosed with hypochlorite at approximately 5 ppm.

The maximum volumes of cooling water discharged from the CPF and FPSO are expected to be approximately 250 000 m^3/d and 80 000 m^3/d respectively.

Sewage and grey water

Throughout each phase of the Project, sewage waste and grey water will be produced and discharged in the offshore marine environment. Sources of sewage waste include the offshore processing and storage facilities, transport barges and support vessels.

All discharges of sewage from maritime support vessels are required to comply with the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto (MARPOL 73/78) (IMO 1978) and the *Protection of the Sea (Prevention of Pollution from Ships) Act 1983* (Cwlth).

All sewage waste discharged from the permanent CPF and FPSO will be macerated to fragments less than 25 mm in diameter prior to discharge and will not be disposed of within 12 nautical miles (approximately 22 km) of land (the Australian territorial sea). This is a requirement of Clause 222 of the Petroleum (Submerged Lands) Acts Schedule (DITR 2005).

During the construction phase, additional sources of sewage waste will include the MODU and maritime construction, transport and support vessels. During operations, product tankers and other vessels supporting operations in Darwin Harbour will be required to dispose of their sewage waste offshore, that is, beyond the 12-nautical-mile territorial sea limit, or alternatively to pump out the sewage at a port facility.

During the operations phase it is estimated that up to 100 m^3/d of sewage waste and grey water will be discharged offshore from the permanently moored CPF and FPSO (up to 50 m^3/d each).

Desalination brine

Potable water will be necessary for both process and personnel needs on the CPF and FPSO. It will be produced by reverse osmosis and will result in the discharge of saline water (brine). Offshore brine discharges are expected to be in low volumes—approximately 100 m^3/d from each facility.

Deck drainage

Deck drainage consists mainly of washdown water and rainwater. Rainwater runoff from non-contaminated areas will generally be directed overboard without treatment. The drain system will be designed so that no pollutants or contaminants will be routinely discharged by deck washdown.

Areas on the MODU and construction barge(s) that could potentially be subject to small oil spills will be drained to a sump that will in turn be directly connected to an oily-water separation system. This separation system on maritime vessels such as the MODU will be configured and monitored to ensure that any discharge has an oil-in-water concentration of less than 15 mg/L in accordance with Annex I of MARPOL 73/78 (IMO 1978).

Ballast water

Ballast water is sea water that unladen ships, drilling rigs and some offshore oil- and gas-producing facilities carry to provide stability and then discharge when their cargo is loaded.

Ballast water will be discharged from the MODU (on arrival at the offshore site), from the CPF (on arrival) and FPSO (on arrival, and then regularly during the life of the Project) and from the condensate cargo tankers (on arrival).

The use of fully segregated ballast-water tanks and other requirements for how and when ballast water can be discharged are set out in MARPOL 73/78 (IMO 1978). Tankers that do not meet these requirements are not permitted to operate in Australian offshore waters.

5.6.2 Summary of offshore liquid discharge characteristics

Liquid discharges from the offshore facilities and vessels will either be discharged directly (e.g. deck drainage) or will be directed to submerged caissons for discharge into the ocean (e.g. produced water and cooling water). Tables 5-3 and 5-4 summarise the likely volumes and characteristics of the offshore discharge streams.

5.6.3 Darwin Harbour discharges

A summary of liquid discharges into Darwin Harbour at different stages of development is presented in Table 5-5. Wastewater discharge modelling has been conducted for the onshore and offshore facilities in order to determine the dispersion characteristics of key pollutants. This is detailed in Chapter 7.

Table 5-3: Volumes of liquid discharges from the offshore facilities (CPF and FPSO)

Liquid	Estimated discharge volumes
Hydrotest water (pipeline, flowlines and risers)	Up to 2 Mm^3.
Treated produced water	Between 1000 and 5000 m^3/d. (3000 bbl/d in the first year of production to approximately 22 000 bbl/d.)
Cooling water	250 000 m^3/d (CPF) and 80 000 m^3/d (FPSO).
Treated sewage and grey water	Up to 50 m^3/d each for the CPF and FPSO.
Desalination brine	Up to 100 m^3/d each for the CPF and FPSO.
Deck drainage	Variable depending on rainfall.

Table 5-4: Characteristics of the liquid discharges from the offshore facilities (CPF and FPSO)

Parameters	Unit	Estimated wastewater characteristics (excluding hydrotest water)
Oil in water (as per OPGGS(Environment) Regulations 2009)*	mg/L	0–30
Temperature	°C	Ambient to 50
pH	–	6–9
Monoethylene glycol	mg/L	100–15 000
Corrosion inhibitor	ppm	7.5–30
Scale inhibitor	ppm	3–10
Biocide	ppm	10–200

* Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009 (Cwlth).

Table 5-5: Summary of liquid discharges from the onshore facilities

Liquid discharge	Pipelay, dredge and other construction vessels	Construction and commissioning (4–5 years)	Operations (*c*.40 years)	Decommissioning (*c*.1 year)
Hydrotest water	–	✓	–	–
Demineralisation reject water	–	✓	✓	–
Sewage and grey water	✓	✓	✓	✓
Process water	–	–	✓	–
Drainage and stormwater runoff	✓	✓	✓	✓
Ballast water (dependent on MARPOL 73/78* requirements)	✓	✓	✓	✓

* IMO 1978.

Hydrotest water

As with the offshore facilities, hydrostatic pressure-testing is required for all onshore process and storage vessels, tanks and pipework. Some hydrotesting may occur at the fabrication yards during module construction. Hydrotest water will be discharged during precommissioning as well as during the early stages of operation of the onshore facilities. In most cases potable water will be used, no chemicals will need to be added, and the water may be reused several times (e.g. to leak-test one tank after another).

If the hydrotest water is chemically treated, this may include adding biocides to prevent bacterial formation, scale inhibitors to prevent the build-up of scale, and corrosion inhibitors and/or oxygen scavengers to prevent internal pipe corrosion. Soda ash solution may also be added to the hydrotest water for some process vessels such as the AGRU. The chemicals to be used in hydrotesting have not yet been decided upon, but will be pre-approved by the regulatory authorities as is current industry practice.

The intention is to hydrotest and dewater the pipeline from onshore to offshore. In the highly unlikely event that hydrotest depressurisation cannot be undertaken offshore, as a result, for example, of a cyclone or of mechanical failures, a scenario exists where it may be necessary to discharge approximately 10 000 m^3 of hydrotest water into Darwin Harbour. During dewatering, the 1 000 000 m^3 of treated water in the pipeline will be discharged at the offshore facility.

Hydrotest water from the onshore gas-processing facilities will be discharged at either the combined outfall on the product loading jetty or through inspection pits, or similar structures, to the open-drain systems. The discharge location will be dependent on the quality of the water. Total hydrotest discharges from the onshore facility are likely to peak at 7200 m^3/d when the tanks are being hydrotested. The average discharge volumes will be substantially lower than this for the duration of the six-to-nine-month precommissioning period.

Demineralisation reject water

A demineralisation plant will be required to supply the onshore processing plant with demineralised water.

The raw water for the demineralisation plant will come from Darwin's potable water supply. Treatment will include appropriate filtering and chlorination to remove biological components and particulates. Approximately 7–16 m^3/h of demineralisation reject water will be discharged to the Harbour. Cleaning and descaling of the filtration system will also be required and this will generate small volumes of liquid wastes. These small volumes of descaling wastes will also be discharged to the Harbour.

Sewage and grey water

Sewage waste and grey water will be generated throughout the life of the Project. Approximately 20–25 m^3/h of treated sewage will be produced during the construction phase and around 2–20 m^3/h will be produced during the operations phase (allowing for fluctuations in personnel numbers during maintenance shutdowns every six years). This number is directly related to the number of people on site. The sewage treatment requirements for the different stages of the Project are likely to be met by packaged sewage treatment plants, self-contained septic-tank systems and/or ablution blocks. Sewage will either be stored on site and disposed of to existing sewage treatment facilities in the Darwin area or it will be treated and discharged to the marine environment. Ground infiltration of treated wastewater is also an option being considered, but this will depend upon its being found to be environmentally acceptable.

During the operations phase, a sewage treatment plant will be installed to produce high-quality treated wastewater suitable for discharge and for irrigation or infiltration to a designated area. The plant will be designed to meet the following discharge quality parameters:

- total nitrogen: <40 mg/L
- total phosphorus: <10 mg/L
- biochemical oxygen demand (BOD) <20 mg/L
- faecal coliforms <400 cfu/100 mL.

Treated sewage will be commingled with other wastewater streams that are directed to the jetty outfall (as shown in Figure 5-2). Temporary discharge facilities may also be required during construction prior to the completion of jetty construction.

Sewage sludge will not be discharged but will be managed as solid waste as discussed in Section 5.7.2 *Wastes generated onshore*.

Process wastewater

Various process wastewater streams will be produced from the onshore processing plant at Blaydin Point.

For example, process water is likely to be produced intermittently by the stabiliser feed separator and the warm-flare knockout drums, as well as from condensate storage tank drawdowns, the amine units during maintenance, and the gas turbines during cleaning. Wastewater from these streams will either be directed to the oily-water treatment facilities or to the neutralisation unit depending on the characteristics of the streams. The volume and concentration of contaminants entering the treatment facilities will fluctuate depending on the intensity of maintenance activities.

If a combined-cycle system is chosen as the preferred technology for power generation, steam will be required as a heating medium. A proportion of the potable water circulating in the steam system will be released through a "steam loop bleed" on a continuous basis. This steam will condense to form a wastewater stream at an estimated rate of 8–13 m^3/h and with a temperature of approximately 26–35 °C; it will have low oxygen levels.

The wastewater generated will be treated in a neutralisation unit prior to being commingled with the treated process wastewater stream. It will have a pH between 5 and 9 after treatment, prior to commingling.

The treated process wastewater stream will be discharged at the combined outfall on the product loading jetty.

Stormwater and runoff

Onshore construction stormwater and runoff

During construction and prior to final surfacing, runoff from the construction site will contain sediment and will contribute to the total suspended solids (TSS) load reaching the Harbour. The quantification of predicted sediment runoff is problematic as there are several variables to take into account, such as levels of construction activity and rainfall patterns.

Stormwater that will be discharged to Darwin Harbour during the construction phase will likely be controlled by silt fences and sedimentation ponds around the site. These will be designed to decrease the sediment load in the discharged water.

Operations stormwater and runoff

Permanent drainage systems from areas exposed to possible hydrocarbon and/or chemical contamination will be isolated and treated through separate drainage systems. Wastewater from areas that could potentially be contaminated by hydrocarbons will be directed to the oily-water treatment system. Wastewater from areas that could potentially be contaminated with other chemicals will be sent to a neutralisation unit.

The stormwater runoff will be commingled with other wastewater streams and directed to the combined outfall on the product loading jetty. Runoff from the site will fluctuate in volume from zero during the dry season to around 110 m^3/h in the wet season.

Non-contaminated runoff will include drainage from non-process areas such as paved areas and roads. These non-contaminated flows will be directed through multiple open-channel drains with suitable control devices such as inspection pits or similar structures. Where appropriate, these structures will be designed to remove settleable solids, floating litter and other debris.

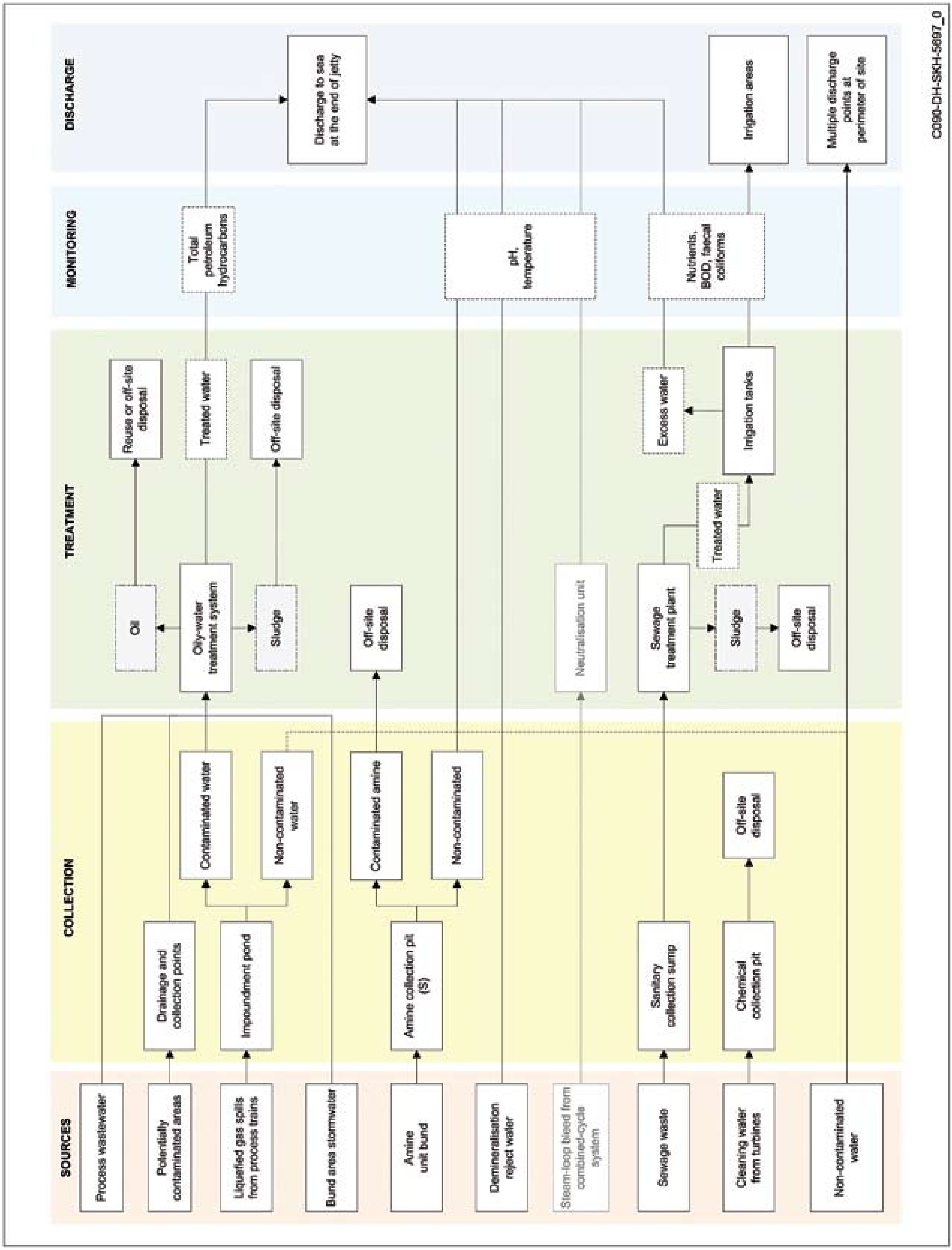

Figure 5-2: Wastewater streams and discharge or disposal points

Ballast water

Ballast water is sea water that unladen ships carry to provide stability and then discharge when their cargo is loaded. However, as ballast water pumped into a ship at a given port will contain a wide variety of marine organisms, from plankton and larvae to fish and seaweeds, there is clearly a risk of bringing marine pests to the port where the ballast water is discharged. The Australian Quarantine and Inspection Service (AQIS) deems all salt water from ports and coastal waters outside Australia's territorial sea to present a high risk of introducing exotic marine pests into Australia and has laid down mandatory ballast-water management requirements enforceable under the *Quarantine Act 1908* (Cwlth) (DAFF 2008).

In consequence, ballast water from vessels such as the larger support vessels, module transport vessels, pipelay barges, dredging vessels and product tankers, will be required to exchange ballast in accordance with AQIS requirements prior to arrival at Darwin Harbour.

The use of fully segregated ballast-water tanks and other requirements for how and when ballast water can be discharged are set out in MARPOL 73/78 (IMO 1978). Tankers that do not meet these requirements are not permitted to operate in Northern Territory waters.

The management of ballast water and potential impacts are discussed in Chapter 7.

5.6.4 Summary of nearshore discharge characteristics

Onshore, wastewater from the process water streams and the potentially contaminated drainage system, together with the continuous flow of treated water from the demineralisation plant and sewage treatment plant, will be treated, commingled and discharged at the end of the product loading jetty. Figure 5-2 above presents the wastewater streams and discharge or disposal points. The likely volumes and characteristics of the combined discharge stream are presented in Table 5-6 and Table 5-7.

The combined discharge point on the jetty, shown in Figure 5-3, will be designed to disperse potential contaminants. The quality of the discharge will also be subject to a monitoring and verification program as described in Chapter 11 *Environmental management program*.

Potential impacts on water quality are discussed in Chapter 7.

Table 5-6: Volumes of liquid discharges from the outfall on the product loading jetty

Source	Maximum discharge volumes at outfall (m^3/h)	
	Typical (continuous)	Maximum (intermittent)
Process water	0	1
Water from accidentally oil-contaminated drains	0 (dry season)	110 (wet season peak rainfall events)
Treated sewage and grey water	3	20
Demineralisation reject water	7	16
Combined-cycle steam loop bleed	8	13
Total	**18 (dry season)**	**160 (wet season peak rainfall events)**

Table 5-7: Characteristics of the liquid discharges from the outfall on the product loading jetty

Parameters		Unit	Estimated wastewater characteristics (excluding hydrotest water)
Total petroleum hydrocarbons		mg/L	≤10
Temperature		°C	26–35 °C
pH		–	5–9
Nutrients	Total nitrogen	mg/L	≤40
	Total phosphorus	mg/L	≤10
BOD		mg/L	≤20
Faecal coliform bacteria		cfu/100 mL	<400

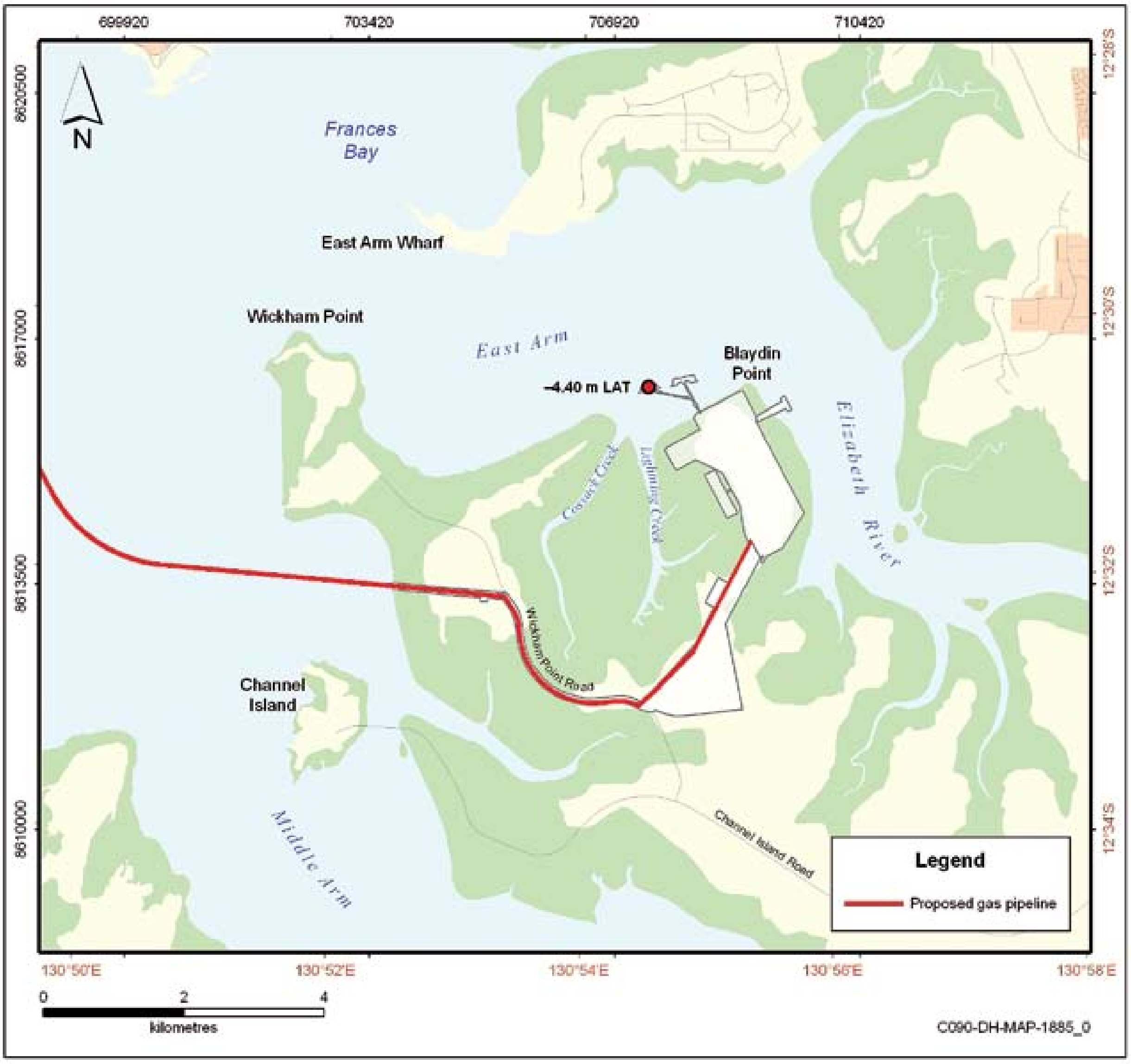

Figure 5-3: Onshore outfall location at the end of the product loading jetty

5.7 Liquid and solid wastes

Solid and liquid wastes will be produced from the construction phase of the Project through to decommissioning. Waste produced during the different stages of the Project will require treatment, storage, transport and, if necessary, disposal to licensed disposal facilities. In particular, hazardous wastes will have specific transport, disposal and/or treatment requirements as they are composed of or contain materials that may pose a threat or risk to public health, safety or the environment.

This section identifies the types and volumes of the wastes that will be generated during the course of the Project. As the Project moves into the detailed-design phase, these estimates will be refined and appropriate waste-disposal pathways will be identified and documented in INPEX's waste-management documentation.

A discussion on the potential impacts of waste handling and transport is provided in chapters 7 and 8. A detailed description of waste-management controls is provided in Chapter 11.

5.7.1 Wastes generated offshore

Non-hazardous and hazardous solid wastes will be generated during the installation, commissioning and operation of the offshore facilities, and also by drill rigs, supply and construction vessels, and pipelay barges.

General non-hazardous solid wastes will be transported to a mainland disposal facility, with the exception of food scraps and other putrescibles at the CPF and FPSO which will be macerated to fragments less than 25 mm in diameter and disposed of offshore.

Sands, sludges and scale may be generated through the well-drilling process and from the offshore processing facilities. Scale may contain naturally occurring radioactive materials (NORMs). Their disposal will be determined on a case-by-case basis in discussion with the relevant designated authority.

Other hazardous materials likely to be produced will be segregated, packaged and directed to waste transfer areas at the maritime supply base. From there they will be transported to approved waste-disposal facilities. The location of the maritime supply base is yet to be determined.

5.7.2 Wastes generated onshore

Construction waste

Large volumes of waste will be produced during the construction phase of the Project because of the level of activity and the number of personnel on site.

Most of these wastes will be non-hazardous as shown in Table 5-8. In addition, during site preparation, large volumes of plant material waste and inert material (rock, soil, etc.) will also be generated. Some of this will be reused on site for reinstatement and rehabilitation. Disposal of excess plant material will be conducted by chipping and mulching where possible.

Construction waste will include domestic and packaging waste, the volume of which will correlate directly with the number of personnel. The construction workforce will be accommodated off site at the accommodation village and elsewhere within the greater Darwin area.

Table 5-8: The types and quantities of waste likely to be produced during the Project's 60-month construction phase onshore

Waste material	Indicative total quantity (t)
General construction waste	35 000
Accommodation domestic waste	7 500
Untreated wood	3 500
Kitchen mess waste	3 500
Waste oils	950
Recyclables (commingled)	750
Scrap metal	550
Administration domestic waste	400
Recyclable packaging	350
Concrete	200
Cooking oils and grease-trap waste	170
Cardboard	70
Cable	3
Aluminium cans	1

Hazardous wastes such as fluorescent tubes, spent batteries, biological waste from medical facilities, and pickling fluids from commissioning will be produced in smaller quantities but will require specific handling and transportation controls.

Dredge spoil and acid sulfate soil waste are described in chapters 7 and 8.

Operations wastes

Solid wastes from the operations phase will include common general waste streams and process waste streams. Common waste streams will include food, domestic and packaging wastes, maintenance wastes, oily rags, clean drums and paint tins. These will be packaged and disposed of at a licensed disposal facility.

Pipeline pigging wastes and wastes accumulated in the slug catcher will consist of a slurry of removed scale, sand, rust, potential scale and possibly NORMs. The means of disposal of NORMs will be determined on a case-by-case basis in discussion with the relevant designated authority.

Other hazardous materials likely to be produced from the facility will require specialist handling; activated carbon from the mercury removal unit, for example, is sent to specialist contractors for disposal or is returned to the supplier for recycling.

Indicative types and quantities of wastes likely to be produced during the operations phase of the Project are presented in Table 5-9.

5.7.3 Decommissioning wastes

Major sources of decommissioning wastes (in addition to those likely to be produced during the operation of the facilities) will include large volumes of solid wastes derived from the dismantling of the infrastructure. The philosophy to be employed will be based on the waste hierarchy with a view to maximising reuse and/or recycling opportunities. These will include, for example:

- assessing whether there could be alternative uses for various structures such as the administration buildings, accommodation facilities, workshops, jetty and module offloading facility
- maximising opportunities to reuse materials or, where that is not feasible, to recycle them (e.g. scrap steel).

Where materials cannot be reused or recycled, steps will be taken to ensure that there are appropriate disposal pathways as part of the environmental management program.

Table 5-9: The types and quantities of waste likely to be produced during the Project's 40-year operations phase onshore

Potential hazardous waste	Estimated annual average (t/a)	Estimated maximum during maintenance shutdowns every 6 to 12 years
Liquid process wastes		
Process water contaminated with hydrocarbons, detergents and/or miscellaneous chemicals	2500	5000
Spent lube oil, seal oil and engine oils	30	200
Oil-contaminated wastes (e.g. spill equipment, rags)	50	100
Water contaminated with aMDEA*	4	32
Scale (potentially containing NORMs)	–	20
Water contaminated with chemicals from neutralisation unit	1	6
Solid process wastes		
Carbon filters, membranes, guard beds, etc.	1	350
Molecular sieves	–	200
Mercury filters and adsorbent materials	–	100
Hydrocarbon sludge	–	5
Sewage and medical wastes		
Sewage sludge	200	–
Untreated sewage and detergents from maintenance activities	6	–
Medical waste	5	–
General non-hazardous wastes		
General waste (e.g. wood from packing crates, other packaging materials, expended consumables, cable offcuts)	240	500
Metal waste	100	–
Gasket materials (e.g. silicone, rubber, neoprene)	50	–

* aMDEA = activated methyldiethanolamine. Methyldiethanolamine is a compound which absorbs the acid gases carbon dioxide (CO_2) and hydrogen sulfide (H_2S) at lower temperatures and releases them at higher temperatures. It is used to separate CO_2 and H_2S from natural gas streams.

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6 Risk assessment methodology

6 RISK ASSESSMENT METHODOLOGY

6.1 Introduction

INPEX has committed to a systematic risk assessment process as a means of achieving best practice in environmental management for its Ichthys Gas Field Development Project (the Project). The company believes that considerable advantages can be gained by communicating environmental impacts through a risk-ranking process to stakeholders and decision-makers. Understanding the risks to the environment that a development of this type can pose and the factors that govern whether such risks are likely to emerge is essential to a proactive approach to environmental management.

This chapter of the draft environmental impact statement (Draft EIS) describes the methodology used to identify and categorise environmental risks resulting from planned activities associated with the Project. The purpose of this methodology is to identify the activities and the environmental aspects associated with these activities that have the potential to result in environmental impacts. By developing management measures and controls to avoid or reduce the risks identified, the "residual risks" can be reduced to an acceptable level.

The risk assessment process used has been developed to align with Australian Standard *AS/NZS 4360:2004, Risk management* together with its associated document *Risk management guidelines—Companion to AS/NZS 4360:2004* (Handbook HB 4360:2004).

The assessment of environmental risk is an essential component of INPEX's approach to the environmental impact assessment process. It also forms the basis for ongoing management and review of significant environmental risks throughout the life of the Project. The outcomes from the risk assessment will be used in the design, construction, commissioning, operations and decommissioning phases to ensure that all risks identified will be managed appropriately, with suitable additional controls being incorporated into the design of the Project as it progresses.

Management controls identified through the risk assessment process are included in the provisional environmental management plans (EMPs) provided in this Draft EIS as annexes to Chapter 11 *Environmental management program* and documented in Chapter 7 *Marine impacts and management*, Chapter 8 *Terrestrial impacts and management* and Chapter 10 *Socio-economic impacts and management*.

The assessment of public safety was conducted through a quantitative risk assessment which is also described in Chapter 10.

6.2 Methodology

Risk-based environmental assessment is recognised as an iterative process that is subject to an inherent degree of uncertainty. In order to reduce the levels of uncertainty, this methodology allows for ongoing research, monitoring and review as part of the environmental review process outlined in Chapter 11.

The risk assessment methodology adopted for the Draft EIS ensures that a systematic approach is applied to the assessment and management of environmental risk. The methodology can be divided into three main steps:

1. risk scoping and preliminary risk assessment
2. detailed risk assessment
3. communication of residual risk.

The methodology is summarised in the flow diagram in Figure 6-1.

6.2.1 Risk scoping and preliminary risk assessment

The risk scoping and preliminary risk assessment was undertaken through two main mechanisms:

- by holding preliminary high-level environmental risk workshops
- by soliciting input from government, specialists and stakeholders.

These are described in more detail below.

Preliminary environmental risk workshops

A series of preliminary environmental risk workshops were conducted through the scoping and preliminary risk assessment stage.

The objective of the workshops was to identify and categorise the significant activities during the Project's construction, commissioning and operations phases that could have environmental aspects and impacts. Once identified, each activity with an associated impact was then ranked according to its environmental risk. The purpose of the workshop was to identify the high-level risks and uncertainties, and any gaps in knowledge, in order to direct the development of the environmental studies and surveys and to influence Project design from an early stage.

6 Risk Assessment Methodology

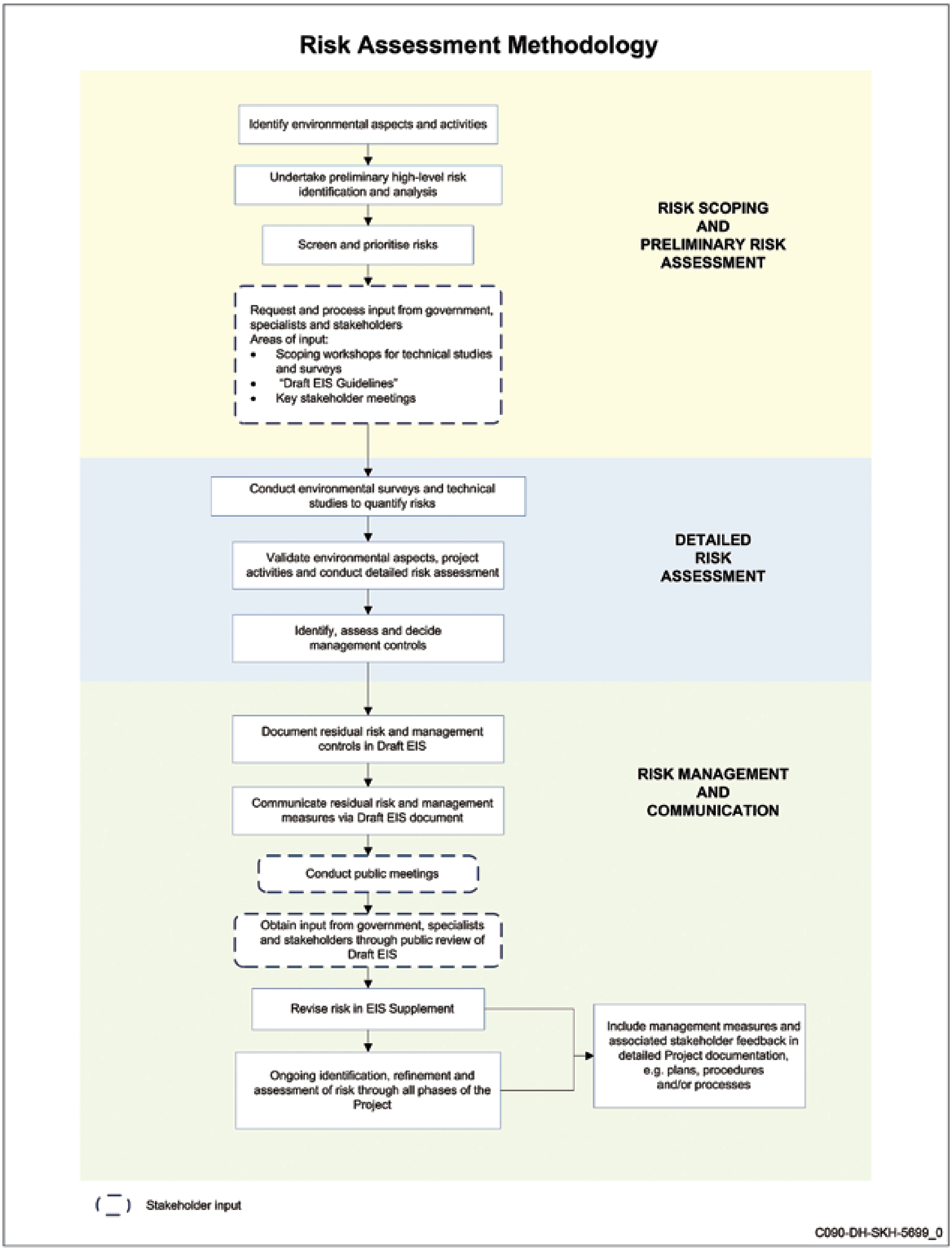

Figure 6-1: Risk assessment methodology

The workshops involved participants from a number of Project disciplines and groups, including the following:

- environmental engineers and scientists
- civil engineers
- process engineers
- onshore facilities personnel
- offshore facilities personnel
- marine operations personnel
- pipeline engineers
- operations personnel
- quality, health and safety personnel.

The outcomes of the preliminary risk workshops formed the basis of the Project's environmental risk and aspect register. This was then built upon in the subsequent detailed risk workshops.

The methods used in the workshops are summarised below.

Identification of environmental aspects

An environmental aspect is defined as follows:

> *An environmental aspect is a feature or characteristic of a project activity that has the potential to affect the environment.*[1]

Each aspect brainstormed with the workshop participants yielded a list of activities that could lead to the occurrence of that particular aspect.

The key aspects identified during the workshops are as follows:

- land and sea use (activities associated with access to Project areas and the physical presence of infrastructure)
- physical disturbance to plant and animal life as a result of Project activities, for example through dredging and clearing operations
- physical disturbance to heritage sites
- acid drainage and acid sulfate soil disposal
- drainage and runoff (stormwater, erosion, possible contaminants)
- noise and vibration
- visual impact
- accidental spills
- dredge discharges and dredge spoil disposal
- waste disposal
- air emissions
- greenhouse gas emissions
- hydrotest water disposal
- wastewater discharges
- quarantine breaches
- marine blasting.

Identification of environmental impacts

Once identification of the activities which could result in a particular environmental aspect was complete, the likely impacts of each were identified.

An environmental impact has been defined as follows:

> *any change to the environment, whether adverse or beneficial, wholly or partly resulting from an organization's environmental aspects.*[1]

Each environmental aspect has been considered in turn against each sensitive receptor in the surrounding environment for a potential pathway or interaction. Where pathways exist, each potential environmental impact has been recorded in the aspect register.

Greenhouse gases constitute a significant environmental risk. However, the standard risk assessment processes (assessing consequence versus likelihood) is not an appropriate tool for evaluating global pollutants. Greenhouse gas management is discussed in detail in Chapter 9 *Greenhouse gas management*.

Preliminary environmental risk ranking

The preliminary risk assessment required each activity that had an associated impact to be qualitatively ranked by risk categories, with severities ranging from "critical" through to "high", "medium" and "low". This method involved the identification of a high-level likelihood and consequence for each impact and, based on this, the determination of the level of risk through the application of an environmental risk matrix (see Figure 6-2 and Table 6-1 below). In addition, where standard management controls were known to exist, these were documented.

When critical risks were identified, these were addressed either by avoiding the activity or by adopting an alternative process with a lower associated risk to the environment. This qualitative ranking of the risks assisted INPEX both to prioritise the environmental risks and to identify what technical studies needed to be undertaken where risk allocation had been based on uncertainties or scanty or inadequate knowledge.

1 Adapted from *AS/NZS ISO 14001:2004, Environmental management systems—Requirements with guidance for use*

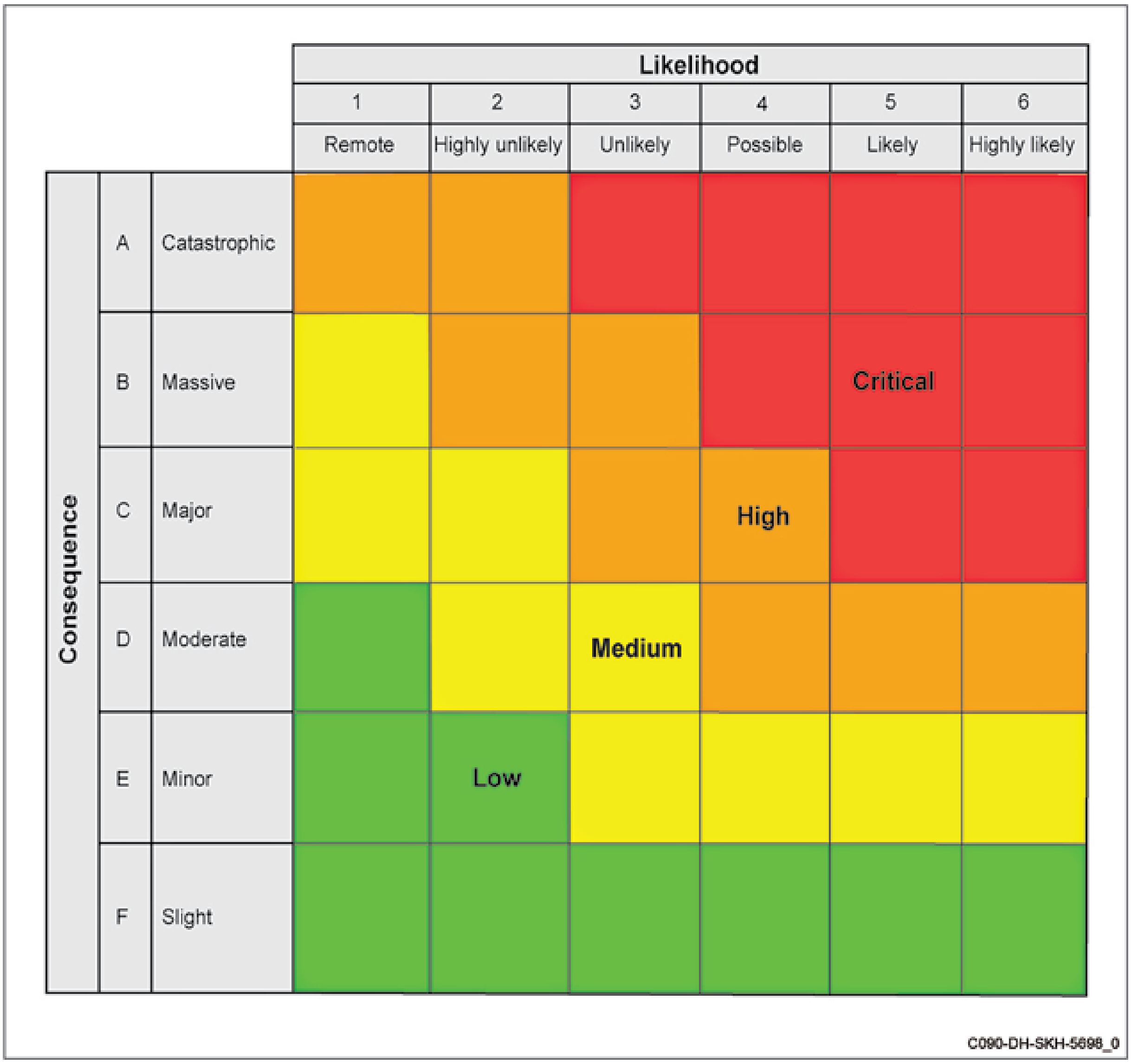

Figure 6-2: INPEX environmental risk matrix

Table 6-1: Management of corresponding risk category

	Management
Critical	Undertake an ALARP ("as low as reasonably practicable") assessment and consider risk-sharing, transfer and avoidance options.
High	Assess risk and manage to an ALARP level.
Medium	Review to ensure that appropriate barriers and controls are in place.
Low	Manage by operational documentation.

Input from government, specialists and stakeholders

Environmental impact statement guidelines

The environmental impact statement guidelines prepared for the Project by the Commonwealth's Department of the Environment, Water, Heritage and the Arts (DEWHA) and the Northern Territory's Department of Natural Resources, Environment, the Arts and Sport (NRETAS), issued in September 2008[2], identified the key matters of concern and established the scope for the environmental, social and economic studies required to assess the potential impacts of the Project.

These EIS guidelines were presented for public review in draft form in June 2008 to provide an opportunity for stakeholders to comment on issues relating to the Project. The DEWHA and NRETAS took the feedback from the review period into consideration when finalising the guidelines for publication in September 2008.

Scoping of technical studies and surveys

INPEX had earlier engaged in a workshop with various Northern Territory government departments, in April 2008, to discuss the range of baseline and impact assessment studies required for the onshore and nearshore development areas. Participants in the workshop included government experts from various divisions of NRETAS and the Department of Planning and Infrastructure[3], members of the INPEX environmental team, INPEX engineers, and environmental specialists. This process enabled the participants to identify significant environmental values within the Project area, to carry out a high-level assessment of relevant existing knowledge, and to reach agreement on the scope and methods of further investigations to be carried out by INPEX.

Stakeholder consultation

In order to identify the environmental and socio-economic aspects that could be affected by the Project, and to investigate these potential impacts with appropriate rigour, INPEX initiated stakeholder consultation following submission of the initial referrals. This process has continued through the Draft EIS preparation phase and will continue as the Project moves through its successive phases. More details on the stakeholder consultation process and its outcomes are provided in Chapter 2 *Stakeholder consultation*.

2 *Guidelines for preparation of a draft environmental impact statement: Ichthys Gas Field Development Project, Blaydin Point, Darwin, NT* (September 2008), available online at <http://www.nt.gov.au/nreta/environment/assessment/register/inpex/pdf/eisguidelinesinpex.pdf> (last accessed 1 March 2010).

3 The Northern Territory's Department of Planning and Infrastructure was restructured in December 2009 and its functions were transferred to two new departments, the Department of Lands and Planning and the Department of Construction and Infrastructure.

6.2.2 Detailed risk assessment

Conducting technical studies and surveys

In order to inform the detailed risk assessment and address the uncertainties or knowledge gaps that were identified at the risk scoping and preliminary risk assessment stage, a range of environmental surveys and modelling studies were undertaken.
These included the following:

- marine water and sediment quality studies
- marine ecology and benthic community studies
- terrestrial ecology studies
- hydrology and hydrogeology studies
- oil-spill trajectory modelling for the nearshore and offshore development areas
- dredge-plume modelling for the nearshore development areas
- plume modelling for wastewater discharges in the nearshore and offshore development areas
- air-quality modelling for the onshore and nearshore development areas
- noise modelling, both underwater and terrestrial.

A comprehensive list of the studies and modelling programs undertaken is provided in Chapter 1 *Introduction*.

Validate environmental aspects, Project activities and risks

Following the preliminary environmental risk workshops and using input from the technical studies, the modelling, and the stakeholder engagement exercise, it was possible to assess the risks to the environment in more detail. This was undertaken in a series of workshops by specialists in the various fields.

The workshop methodology and evaluation process consisted of the following steps:

- the validation of environmental aspects
- the validation of actual and potential environmental impacts
- the validation and identification of additional management measures and controls
- the determination of likelihood and consequence
- the assessment of the residual risk
- a determination of whether any additional controls would be required to reduce residual risk to ALARP.

These steps are described below.

Validation of environmental aspects and impacts

The information gathered both from the technical studies and modelling and from government agencies and stakeholders assisted the workshop team members to assess and validate the environmental aspects and impacts previously identified during the preliminary environmental risk workshops.

Determination of likelihood and consequence

The risk assessment required a more detailed approach to determining the likelihood and consequence of each impact. The definitions used for likelihood and consequence during this detailed assessment are described below and shown in tables 6-2 and 6-3, the environmental risk matrix is shown in Figure 6-2, and the categories are explained in Table 6-1.

Where relevant data were available to permit a quantitative evaluation of the likelihood and consequence of an impact, this approach was applied, as was the case with the assessment of oil-spill scenarios. Where a quantitative assessment was not possible, a qualitative evaluation was made which relied on the knowledge and experience of team members and specialists.

Likelihood can be described as the level of probability that, or the frequency with which, an aspect of an activity will impact upon the environment.
The likelihood levels applied in this detailed risk assessment have been quantified using six categories, ranging from "remote" (1) to "highly likely" (6) and is based on past experience and on frequency or probability depending on the nature of the aspect, the type of activity and the availability of data as shown in Table 6-2.

A consequence can be defined as an outcome or impact from an event occurring. Six categories, ranging from "catastrophic" (A) to "slight" (F), have been used to describe the type and severity of a consequence of an impact on the environment resulting from a planned or accidental activity of the Project. As multiple consequences may apply for a single hazard or aspect, the approach used was to take the worst credible risk (in terms of consequence versus likelihood).

Consequence columns are coded (e.g. B1, S3) to allow the user to demonstrate which consequence drove the risk score. The consequence categories are as follows:

- biodiversity and ecological processes
  - protected species (B1)
  - marine primary producers (B2)
  - ecological diversity (B3)

Table 6-2: Definitions of "likelihood" for detailed environmental risk assessment

	Likelihood →					
Historical	Unheard of in the industry	Has occurred once or twice in the industry	Has occurred many times in the industry, but not in the Company	Has occurred once or twice in the Company	Has occurred frequently in the Company	Has occurred frequently at the location
Frequency (continuous operation)	Once every 10 000–100 000 years at the location	Once every 1000–10 000 years at the location	Once every 100–1000 years at the location	Once every 10–100 years at the location	Once every 1–10 years at the location	More than once a year at the location or continuously
Probability (single activity)	1 in 100 000–1 000 000	1 in 10 000–100 000	1 in 1000–10 000	1 in 100–1000	1 in 10–100	>1 in 10
	1	2	3	4	5	6
	Remote	**Highly unlikely**	**Unlikely**	**Possible**	**Likely**	**Highly likely**

Table 6-3: Definitions of consequences of environmental risk assessments

Consequences	Biodiversity and ecological processes			Environmental quality				Societal considerations		
	Protected species	Marine primary producers	Ecological diversity	Water quality	Marine sediment quality	Air quality	Soil and groundwater contamination	Protected areas	Cultural matters	Compliance
	B1	B2	B3	E1	E2	E3	E4	S1	S2	S3
A	Eradication of local population. Loss of critical habitats or activities.	Permanent loss of primary producers on large or regional scale.	Significant and permanent effects on ecological diversity on a regional scale.	Continuous or regular contamination of water quality above background and/or national or international standards and/or known biological effect concentrations on a regional scale.	Permanent to long-term contamination above background and/or national or international quality standards and/or known biological effect concentrations on a regional scale.	Continuous exceedance over national or international air-quality standards. Human fatalities possible.	Extensive off-site contamination of groundwater and/or soil on a regional scale. Cost of effective treatment not possible. Sustained damage to the environment; human health risks likely.	Significant permanent effect on one or more of protected-areas values.	Significant permanent impact on aesthetic, heritage, economic or recreational values. Overall societal benefits do not outweigh impacts.	Significant and continuous licence or regulatory or internal target exceedances. Fines and/or prosecutions incurred or expected.
B	Extensive impact on population(s). Significant impact on critical habitats or activities.	Recoverable loss of primary producers on a large scale.	Significant and permanent effects on ecological diversity on a large scale.	Continuous or regular contamination of water quality above background and/or national or international standards and/or known biological effect concentrations on a large scale.	Permanent to long-term contamination above background and/or national or international quality standards and/or known biological effect concentrations on a large scale.	Frequent and sustained exceedance over national or international air quality standards. Human fatalities possible.	Extensive off-site contamination of groundwater and/or soil at a medium scale. Treatment difficult and/ or expensive. Damage to the environment and risk to human health possible.	Significant long-term effect on one or more of protected-areas values.	Significant long-term impact on aesthetic, heritage, economic or recreational values. Overall societal benefits do not outweigh impacts.	Frequent and significant licence or regulatory or internal target exceedances. Fines or prosecutions likely.
C	Minor disruptions to a significant portion of the population. Minor impacts on critical habitats or activities. No threat to overall population viability.	Permanent loss of primary producers on a medium scale.	Significant and permanent effects on ecological diversity on a medium scale.	Continuous or regular discharge with contamination above background and/or national or international quality standards and/or known biological effect concentrations on a medium scale.	Permanent to long-term contamination above background and/or national or international quality standards and/or known biological effect concentrations on a medium scale.	Frequent, short-term exceedances over national or international air-quality standards. Human illness and effects on the environment possible.	Extensive contamination of groundwater and/ or soil, off-site contamination probable and treatment difficult and/or expensive. Limited threat to the environment or human health.	Moderate long-term or permanent effect on one or more of protected-areas values.	Moderate impact on aesthetic, economic, heritage or recreational values. Overall societal benefits do not outweigh impacts.	Frequent, minor to moderate licence or regulatory or internal target exceedances. Fines or prosecutions possible.
D	Minor disruptions or impact on a small portion of the population. Minor and temporary impact on critical habitat or activity. No threat to overall population viability.	Recoverable loss of primary producers on a medium scale.	Loss of ecological diversity on a medium scale. Community or habitat maintains ecological integrity though some change in species composition or abundance may occur. Community, habitats and species well represented regionally.	Continuous or regular discharge with contamination above background and/or national or international quality standards and/or known biological effect concentrations on a local to medium scale.	Short- to medium-term contamination above background and/or national or international quality standards and/or known biological effect concentrations on a medium scale.	Frequent temporary exceedances over national or international air quality standards. Human illness and effects on the environment possible.	Moderate contamination to groundwater or soil, contained within site boundary and readily treated. No significant threat to the environment or human health.	Moderate medium-term effect on one or more of protected-areas values. Full recovery expected.	Moderate impact on aesthetic, heritage, economic or recreational values. Overall societal benefits outweigh impacts.	Occasional significant licence or regulatory or internal target exceedances. Fines or prosecutions possible.
E	Minor and temporary disruption to small portion of the population. No impact on critical habitat or activity.	Permanent loss of small proportion of primary producers on a localised scale.	Loss of ecological diversity on a localised scale. Community or habitat maintains ecological integrity though some change in species composition or abundance may occur. Community, habitats and species well represented regionally.	Continuous or regular discharge, with contaminants reduced to below background and/or national or international quality standards and/or known biological effect concentrations within a small mixing zone.	Short- to medium-term contamination above background and/or national or international quality standards and/or known biological effect concentrations on a localised scale.	Occasional and temporary exceedance over national or international air quality standards. No effect on human health or the environment.	Minor contamination of soil and/or groundwater, contained within site boundary and readily treated. No threat to the environment or human health.	Minor medium-term effect on one or more of protected-areas values. Full recovery expected.	Minor impact on aesthetic, heritage, economic or recreational values.	Occasional minor licence or regulatory or internal target exceedances. No fines or prosecutions.
F	Behavioural responses of inconsequential ecological significance.	Recoverable loss of small portion of primary producers on a localised scale.	Minor loss of ecological diversity on a localised scale. Communities, habitats and species well represented on a medium scale.	Occasional discharge with contaminants reduced to below background and/or national or international quality standards and/or known biological effect concentrations within a small mixing zone.	Short-term contamination above background and/or national or international quality standards and/or known biological effect concentrations over a very small area (<1 km²).	Very infrequent and temporary exceedance over national or international air-quality standards. No effect on human health or the environment.	Minor contamination of soil within site boundary and readily treated. No effect on groundwater. No threat to the environment or human health.	Negligible impact on protected-areas values.	Negligible impact on aesthetic, heritage, economic or recreational values.	Very infrequent minor licence or regulatory or internal target exceedances.

- environmental quality
  - water quality (E1)
  - marine sediment quality (E2)
  - air quality (E3)
  - soil and groundwater contamination (E4)
- societal considerations
  - protected areas (S1)
  - cultural matters (S2)
  - compliance (S3).

The consequence of an impact on the environment has to be considered in both spatial and temporal terms: is it localised or regional in its effect, is it affecting a small area or a large area, is it temporary or permanent, is it reversible or irreversible, or is it short term or long term?

This is the purpose of Table 6-3 where the definitions of each level of consequence have been tabulated.

Validation and identification of additional management measures and controls

A key component of the preliminary risk workshops and detailed risk assessment was the identification of the range of management measures and controls necessary to reduce the risks identified.

The level of management for each identified risk depended on its assigned risk-ranking category as shown in Figure 6-2 and Table 6-1.

Management controls for treating risk have been assessed in terms of the following considerations:

- their potential benefits
- their effectiveness in reducing risk
- the cost to implement the option(s)
- the impact of controls on personnel safety and other stakeholder objectives, including the introduction of new risks or issues.

The management measures and controls identified in chapters 7, 8 and 10 form the basis of the provisional EMPs in Chapter 11.

6.2.3 Communication of residual risk

Outcomes of the risk assessment process have been documented in this Draft EIS and will be communicated to stakeholders through the submission of the document for public review.

Summaries showing the outcomes of the risk assessment process have been presented in tables in chapters 7, 8 and 10.

Key aspects are listed with a summary of the associated activities, their potential impacts, management measures and controls, and residual risk. Residual risk is ranked using the INPEX environmental risk matrix in Figure 6-2 above. Table 6-4 provides an example of how risk is presented in the relevant chapters.

Table 6-4: Example of risk assessment summary table

Aspect	Activity	Potential impacts	Management controls, mitigating factors	Residual risk		
				C*	L†	RR‡
Soil erosion	Large-scale earthworks for construction of onshore processing facility. Clearing of vegetation during site preparation.	Sedimentation of mangrove areas around the onshore development area, leading to smothering of pneumatophores, which will lead to plant mortality and a reduction in plant growth.	Large-scale vegetation clearing will be undertaken preferentially in dry-season conditions to avoid the erosion risks associated with monsoon rains in the wet season. Erosion protection infrastructure (e.g. silt fencing, spoon drains, contouring and sediment ponds) will be installed to ensure that sediment is contained within the site boundaries as far as possible. If soil erosion is evident, exposed surfaces at the affected area will be stabilised with mulched vegetation, dust suppressants or slope stabilisation products. Provisional Vegetation Clearing, Earthworks and Rehabilitation Management Plan. Provisional Liquid Discharges, Surface Water Runoff and Drainage Management Plan.	F (B2)§	3	Low

* C = consequence.

† L = likelihood.

‡ RR = risk rating.

§ F – describes the level of consequence; B2 – describes the category of consequence.

It is important to note that the socio-economic aspects of the Project's operating environment are complex, and are influenced by many factors that are additional to the direct effects of the Project. For example, the local labour market will vary according to national and international economic conditions, making the consequences of the Project (which would be a relatively large employer in the Darwin region) difficult to predict at any point in time.

In addition, the consequences of certain socio-economic impacts are sometimes subjective and would be rated differently by different people. For example, the consequences of the Project employing large numbers of workers in the Darwin region could be seen as a positive opportunity for the employees joining INPEX, but a negative impact by other businesses seeking to attract or retain workers.

For these reasons, risk-ranking was not undertaken for some of the socio-economic aspects. Potential impacts have been identified for all socio-economic aspects of the Project that could affect the community, and management commitments have been developed to mitigate negative impacts and maximise benefits.

Once approved and published, the Draft EIS will be exhibited for public review and comment. During this public review period, any member of the public or government may submit comments or concerns on the environmental impacts of the Project to the DEWHA or to NRETAS through INPEX.

6.2.4 Ongoing monitoring and review

Environmental risk assessment is an iterative process. The aspect register generated as a result of the risk assessment workshop will be reviewed and updated as required. These reviews will be informed by ongoing environmental monitoring conducted as part of the environmental management system. This is critical for achieving continual improvement. The framework for environmental monitoring is outlined in Chapter 11.

In addition, as the Project progresses through the front-end engineering design phase to the construction and operations phases there will be a continuous process of identification, refinement and assessment of risk.

7 Marine Impacts and Management

7 MARINE IMPACTS AND MANAGEMENT

7.1 Introduction

This chapter of the draft environmental impact statement (Draft EIS) for INPEX's Ichthys Gas Field Development Project (the Project) describes the potential impacts to the marine environment that will be associated with the offshore and nearshore development areas of the Project. These areas are described briefly below, and in more detail in Chapter 3 *Existing natural, social and economic environment*.

The offshore development area includes the Ichthys gas and condensate field (Ichthys Field) in the Browse Basin off the coast of north-western Australia and the gas export pipeline route from the field to the mouth of Darwin Harbour. Components of the Project that will be developed in this area include subsea production wells and flowlines, the central processing facility (CPF), the floating production, storage and offtake (FPSO) facility and the major portion (some 852 km) of the gas export pipeline. Details of the offshore infrastructure and activities are summarised as follows:

- the drilling of production wells using a mobile offshore drilling unit (MODU) and support vessels
- the installation of approximately 50 subsea wells and flowlines to carry the natural gas and other reservoir fluids from the wells to the CPF
- the installation and commissioning of the CPF, FPSO and gas export pipeline
- the export of condensate from the FPSO to offtake tankers
- the ongoing operation of the CPF, FPSO and gas export pipeline
- decommissioning.

The nearshore development area includes the gas export pipeline route from the mouth of Darwin Harbour to Middle Arm Peninsula together with the coastal areas around Blaydin Point and Middle Arm Peninsula, ending at the low-water mark. The infrastructure to be constructed in this area includes the nearshore section of the gas export pipeline with a shore crossing on the west side of Middle Arm Peninsula south of Wickham Point, a product loading jetty with a marine outfall, a module offloading facility, and a shipping and navigation channel. The activities associated with the nearshore infrastructure can be summarised as follows:

- the construction of the nearshore section of the gas export pipeline, including trenching, rock armouring and the installation of the pipeline shore crossing
- the construction of a jetty and module offloading facility, with associated dredging for shipping and navigation channels
- the operation of the jetty for hydrocarbon export and the operation of the module offloading facility
- the operation of the marine outfall on the jetty
- the decommissioning process.

The environmental impact assessment provided in this chapter includes discussion of potential impacts in a regional context. This includes potential impacts to "matters of national environmental significance" as defined in the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth) (EPBC Act). Matters of national environmental significance relevant to the offshore and nearshore development areas include the following:

- listed threatened species and ecological communities
- migratory species protected under international agreements
- the Commonwealth marine environment.

In light of these potential impacts, management controls are described that will be implemented by INPEX to mitigate possible negative effects from Project activities.

In order to determine the resulting "residual risk" after management controls are applied, an assessment of the risks of the various potential impacts was undertaken according to the methods presented in Chapter 6 *Risk assessment methodology*. Summary tables of the offshore and nearshore activities, potential environmental impacts, management controls and mitigating factors, and resulting residual risk (consequence, likelihood and risk rating) are provided throughout this chapter.

The risk assessment was undertaken with consideration of sensitive environmental receptors, which include the marine benthic biota and macrofauna in the vicinity of the offshore and nearshore development areas. Because of the proximity of the nearshore development area to the cities of Darwin and Palmerston, the local community is also regarded as a key sensitive receptor in some cases. Other impacts to the community associated with activities such as recreational or commercial fishing are described in Chapter 10 *Socio-economic impacts and management*.

Management controls will be implemented to ensure that all significant potential environmental impacts associated with the Project are avoided or minimised. A number of monitoring mechanisms are also proposed that will allow INPEX to gauge the effectiveness of management controls.

A comprehensive and auditable environmental management system based on the principles of the International Organization for Standardization's ISO 14000 environmental management series of standards will be implemented to provide a systematic and structured approach to environmental management. The system proposed is described in Chapter 11 *Environmental management program*.

For some specific offshore activities, additional environmental management plans will be required under the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009 (Cwlth) (OPGGS(Environment) Regulations)[1]. These will include plans for pipeline installation, drilling, construction and operation of the CPF and FPSO, and an oil-spill contingency plan.

7.2 Offshore impacts and management

7.2.1 Alteration of habitat

Seabed disturbance

The seabed in the offshore development area will be altered through direct disturbance by drilling and anchoring, the installation of subsea equipment, pipelay and potentially by pre- or post-pipelay trenching in some areas along the gas export pipeline route. Drilling will also result in some indirect impacts, for example through the settling of drill cuttings on the seabed and the discharge of drilling fluids. These are discussed separately in Section 7.2.2 *Drilling discharges*.

While the production wells are being drilled, the MODU will be held in place by anchors. During this time, physical disturbance to the seabed will be associated with the laying and retrieval of anchor chains. As the anchors are carried out to position by the support vessel there may be some dragging of the anchor chain across the seabed. Once in place, the anchor chains are likely to remain relatively stationary, except at the "touch-down" point where the chain will move up and down depending on the state of the sea. The exact anchoring configuration that will be used will be dependent on the type of MODU selected and is therefore not yet known. A MODU typically has 8 to 12 anchors.

The CPF and FPSO will be held in place by anchors for the life of the Project. As for the MODU, these anchor chains will cause some disturbance to the seabed during installation and then may move up and down at the touch-down point. In the longer term these anchors and chains will become artificial habitat for benthic biota (discussed further below).

The layout of the field infrastructure has not yet been finalised. However, it is considered appropriate to use the layout presented in Chapter 4 *Project description* to calculate the area of seabed affected because of the following considerations:

- Any changes to the layout would be relatively minor in nature.
- The changes would not result in any significant change to the area of seabed affected.
- The benthic community in the field is widely distributed with no apparent changes in density or structure (see Appendix 4 to this Draft EIS).

The area that will be disturbed by the subsea production equipment and by the moorings of the MODU, CPF and FPSO has been estimated to be approximately 74 ha, as described in Table 7-1.

Laying and retrieving the anchor chains for the MODU, CPF and FPSO is likely to result in some temporary physical disturbance to the seabed, though this will be localised. This disturbance will likely be confined to a corridor approximately 3–5 m wide for each anchor chain. The anchor and anchor chain scars are expected to refill rapidly and the biological communities associated with these sediments are expected to recover quickly from the disturbance.

Similarly, an anchored lay barge will be used to construct infield flowlines, which will disturb the seabed for around 500 m on each side of the alignment. These anchor and chain scars will only be temporary and benthic communities will recover rapidly.

Long-term physical change of the seabed at the field will include that associated with moorings, subsea trees, flowlines, manifolds and other subsea production equipment.

The seabed to be modified by infield infrastructure has been characterised as rippled sands with regular low sand waves, flat bare sand with shell fragments and clay–silt sand (see Chapter 3). Water depths throughout the Ichthys Field vary between 235 m and 275 m. The area supports very few visible organisms and has mobile sediments that do not favour the development of a diverse epibenthic community. These sparse, low-diversity benthic infauna communities are well represented in the region (see Appendix 4), and the area to be disturbed represents only 0.09% of the area of the Ichthys Field (0.02% of the WA-37-R retention lease area). The environmental consequences of seabed disturbance in the offshore development area are predicted to be negligible.

1 The Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009 (Cwlth) (OPGGS(Environment) Regulations) replaced the Petroleum (Submerged Lands) (Management of Environment) Regulations 1999 (Cwlth) (P(SL) (MoE) Regulations) on 17 December 2009.

Table 7-1: Area of seabed at the Ichthys Field subject to direct physical disturbance

Infrastructure	Number	Area per unit (m^2)	Area (m^2)
MODU anchors	8	10	80
CPF anchors	32	70	560
FPSO anchors	20	70	1 400
CPF riser bases	15	70	980
Export gas riser base	1	525	525
Riser support structure foundations	1	2 800	2 800
FPSO riser bases	10	70	700
Drill centre	14	29 826	417 564
Subsea gas export pipeline end termination	1	45	45
Infield production flowlines (metres)	246 000	0.5	123 000
Infield MEG* and service flowlines (metres)	129 000	0.2	25 800
Infield flowline terminations	72	30	2 160
Transfer lines (metres)	35 000	0.4	14 000
Rock dump anchor berm	20	4 400	88 000
Rock dump trigger berm	40	800	32 000
Umbilicals (metres)	133 000	0.2	26 600
Subsea umbilical termination assemblies and umbilical distribution assemblies	40	15	600
Total area (m^2)	**n.a.**	**n.a.**	**736 814**
Total area (ha)	**n.a.**	**n.a.**	**73.68**

* MEG = monoethylene glycol.
n.a. = not applicable.

Construction of the gas export pipeline will create a long linear disturbance corridor. In deep offshore areas of the route, the gas export pipeline will generally be placed directly on to the seafloor, with minimal disturbance on either side. At the eastern end of the route towards Darwin Harbour, the corridor is likely to vary in width depending on the substrate and the types of preparation activities required to construct a suitable surface for pipe-laying, such as sand-wave pre-sweeping, pre- or post-lay trenching, and rock dumping. Minimal alteration of the seabed is preferred for pipeline construction from both an engineering and environmental perspective—that is, the preferred pipeline route will avoid rocky areas and reefs wherever possible because of the difficulties of pipelay operations in these areas.

Geophysical surveys have indicated that the greater part of the pipeline route (>98%) consists of featureless, unconsolidated clay or silty sands, with rare areas of rock outcrops and subcrops as described in Chapter 3. Targeted drop-camera surveys at 18 sites along the pipeline alignment recorded low-diversity benthic communities of flat bare sand with shell fragments or clay or silt sand at 10 of the sites. Rocky outcrops identified at the remaining sites hosted benthic animals that are common throughout the region, including soft corals, gorgonians (sea fans) and sponges (see Appendix 4). Disturbance of the relatively narrow pipeline corridor through these benthic communities can be considered of low consequence in the context of the vast areas of similar habitat throughout the region.

The gas export pipeline will be laid using a pipelay barge kept in position using either dynamic positioning systems or an anchor system, depending on the depth of water, the seabed conditions and vessel availability. Anchored construction barges typically have at least 8 large drag anchors. In total, the width of the disturbance corridor during the construction of the gas export pipeline could be up to 1000 m, that is, 500 m on either side of the alignment. The anchors of the pipelay barge, if used, would disturb some areas of seabed, particularly through the lateral movement of the anchor lines as the barge moves forward. Limestone pavement or isolated reefs along the pipeline route would be particularly susceptible to anchor damage, while in areas of bare sand or silty seafloor, anchor-chain scars would be naturally infilled and benthic communities would recover swiftly. Similar recovery was recorded in Mermaid Sound, Western Australia, after pipeline installation and rock-dumping by Woodside; seabed disturbance was recorded up to 500 m on either side of the alignment and evidence of rapid recolonisation and rehabilitation of the soft-sediment benthic habitats was observed within one year of the construction project. Hard corals damaged by anchor-chain drag were expected to recover within a few years (Woodside 1997).

The primary means of maintaining the stability of the gas export pipeline on the offshore seabed will be by concrete weight coating, but trenching and rock armouring may be applied where extra stability is needed. This would result in disturbance of more benthic habitat and would generate turbidity and sedimentation in the area in the short term. However, the sparse benthic communities along the greater part of the route would be expected to recover rapidly and rock armouring would create new habitat that could be colonised by benthic species (as described below).

Indirect effects are considered unlikely, given the small zone of disturbance relative to the extent of similar habitats adjacent to the pipeline corridor. The area to be disturbed by the offshore pipeline represents a very small fraction of the total habitat area and disturbance is likely to be localised.

Artificial habitat

The presence of Project infrastructure in the offshore development area provides hard substrate for the settlement of marine organisms. Colonisation of the structures over time leads to the development of a fouling community similar to that found on subsea shipwrecks. The presence of these structures and the associated fouling community also offers predator and prey refuges and visual cues for aggregation (Gallaway et al. 1981).

Investigation of the fouling communities on platforms on the North West Shelf has shown that complex ecosystems develop on the structures within two years of being set in place. Depending on water depth, these communities are primarily dominated by sponges, bryozoans, ascidians (sea squirts), crustaceans (primarily barnacles) and brittlestars. The rate of development of the fouling community for deep-water seabed structures is likely to be somewhat slower because of the lower temperatures and reduced light availability at depth. These differences are illustrated in the fouling abundance on settlement plates set in different water depths near the Titanichthys exploration well at the Ichthys Field, shown in figures 7-1 and 7-2 (RPS 2007). The depths in the figure captions are measured as “below mean sea level” (BMSL).

Source: RPS 2007.

Figure 7-1: Settlement plates from approximately 10 m BMSL at the Ichthys Field after 6 months

Source: RPS 2007.

Figure 7-2: Settlement plates from 2 m above the seabed, at approximately 248 m BMSL, at the Ichthys Field after 6 months

Once present in the field, the CPF, FPSO and supporting infrastructure will provide near-surface artificial hard substrate for colonisation by invertebrates and algae. This will provide a food source for other organisms and will encourage aggregation of fish around these facilities. While increased fish numbers could provide food for seabirds, there are very few seabird migratory paths crossing the North West Shelf region where the Ichthys Field is located. Anecdotal evidence suggests that existing offshore oil & gas facilities in north-western Australia are rarely visited by seabirds, with the exception of seagulls in some cases.

The seabed infrastructure, such as the wellheads, flowlines and gas export pipeline, will also provide new hard substrate habitat for benthic communities and is likely to result in a local increase in species abundance and biodiversity (Hixon & Beets 1993; Pollard & Matthews 1985). However, factors such as water depth, low temperature and ocean currents will decrease the potential for establishment of algae and invertebrates on the hard substrates and it is estimated that growth on the seabed infrastructure at the Ichthys Field would be only 15 mm thick after 25 years (RPS 2007). This represents a very minor change in the benthic habitat, particularly in the context of the Browse Basin region.

It is likely that the gas export pipeline will provide artificial hard substrate for colonisation by invertebrates and seaweeds in shallower waters at the eastern end of the route, and particularly in sections where rock armouring is applied. This benthic community will also attract mobile animals such as fish and squid. The artificial seabed habitat will support increased biological productivity and diversity compared with the broad areas of mainly featureless seabed surrounding the pipeline route. However, this effect will be highly localised in the context of the offshore marine environment and the impact of this change is considered minor in consequence. During the operational phase of the Project, further disturbance of the seabed along the pipeline corridor is not envisaged unless periodic inspections reveal the need for additional stabilisation for particular sections of the pipeline.

Some subsea infrastructure (e.g. mooring suction piles, infield flowlines and subsea flowlines) may remain in place following decommissioning, and the associated habitat would be left intact for the longer term. Where infrastructure is removed at decommissioning (e.g. anchor chains, risers, wellheads and subsea manifolds), it is expected that the epibenthic biota will soon return to its original abundance and composition.

Management of marine habitat

The use of a semi-submersible MODU during drilling activities will restrict the area of direct seabed disturbance during drilling to the well, the anchor points and the chains to the touch-down point.

Flowlines will be laid directly on to the seabed without trenching. The gas export pipeline will be installed with concrete weight coating, which will reduce the need for rock dumping or trenching in deep offshore waters and minimise disturbance of the seabed.

Surface structures such as the CPF and FPSO are likely to be treated with antifouling paints to limit growth of fouling communities and to maintain the operability of the infrastructure. Antifouling paints will be selected in accordance with regulatory requirements, which include the prohibition of paints based on tributyltin (TBT) compounds (see Section 7.2.3 *Liquid discharges*).

A Provisional Decommissioning Management Plan has been compiled (attached as Annexe 5 to Chapter 11), which outlines the processes to be undertaken to identify appropriate measures for the closure of the offshore facilities at the end of the Project's life, as well as management of the associated environmental risks. This plan will guide the development of more detailed plans at later stages of the Project, and includes the following prescriptions:

- Consideration of decommissioning feasibility will be incorporated into the initial design of each facility.
- The CPF and FPSO will be removed from the infield location at the end of the useful life of the field.
- The gas export pipeline will be flushed of all hydrocarbons, filled with sea water and left in place after decommissioning.
- Options for decommissioning the other subsea facilities (e.g. mooring suction piles and infield flowlines) will be investigated in advance of decommissioning, with consideration of the associated environmental impacts.
- Offshore decommissioning will also be subject to assessment under relevant legislation and international conventions and treaties, including the following:
  - the *Offshore Petroleum and Greenhouse Gas Storage Act 2006* (Cwlth), the EPBC Act and the *Environment Protection (Sea Dumping) Act 1981* (Cwlth)
  - the United Nations Convention on the Law of the Sea (UNCLOS)
  - the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto (MARPOL 73/78) (IMO 1978).

Residual risk

A summary of the potential impacts, proposed management controls, mitigating factors and residual risk for offshore marine habitats is presented in Table 7-2. Impacts to offshore marine habitat are considered to present a "low" to "medium" risk and it is likely that any effects on the environment will be localised and small in scale.

Table 7-2: Summary of impact assessment and residual risk for alteration of habitat (offshore)

Aspect	Activity	Potential impacts	Management controls and mitigating factors	Residual risk*		
				C†	L‡	RR§
Seabed disturbance	Installation, operation and decommissioning of offshore infrastructure.	Removal or disturbance of seabed sediments.	Seabed habitat at the Ichthys Field consists of unconsolidated sands with low biodiversity and is similar to wide surrounding areas. The disturbance area is a very small portion of the total field area. Flowlines will be laid directly on the seabed, not trenched. Provisional Decommissioning Management Plan.	F (B3)	6	Low
Seabed disturbance	Gas export pipeline construction and operation.	Disturbance of a variety of seabed types along the pipeline route.	The gas export pipeline to be installed with concrete weight coating, to minimise the need for trenching or rock armouring. The gas export pipeline route avoids sensitive benthic habitats. The seabed habitat at the Ichthys Field consists of unconsolidated sands with low biodiversity and is similar to wide surrounding areas.	E (B3)	6	Medium
Artificial habitat	Long-term operation of the CPF, FPSO and other surface and subsea facilities in the offshore marine environment.	Subsea and surface structures provide new habitat for marine fouling communities. Benthic community composition is altered. Biological productivity and diversity is increased.	The affected area is a very small portion of the total field area. Any antifouling paints used on surface or subsurface structures will be selected in accordance with regulatory-authority requirements. The CPF and FPSO will be removed from the infield location at decommissioning. Provisional Decommissioning Management Plan.	F (B3)	6	Low

* See Chapter 6 *Risk assessment methodology* for an explanation of the residual risk categories, codes, etc.

† C = consequence.

‡ L = likelihood.

§ RR = risk rating.

7.2.2 Drilling discharges

Seabed drilling activities will be carried out during the construction and operations phases at the offshore development area. Up to 50 subsea production wells will be drilled. These activities will generate drill cuttings that will be discharged to the marine environment. The potential effects of these discharges are described below.

Drill cuttings

Drill cuttings are inert pieces of rock, gravel and sand removed from the subsea well during the drilling process. They are composed of calcarenite, shale and sandstone. Cuttings are likely to range in size from very fine to very coarse particles, with a mean diameter of 10 mm.

Studies carried out in the Gulf of Mexico found that sediments less than 500 m from drilling locations were enhanced with coarse-grained materials predominantly derived from drill cuttings (Boehm et al. 2001). This change may be temporary as sediment redistributes and disperses over time. Where this occurs, the type and abundance of the animal species in the sediment will also change over time as those unsuited to the new characteristics are replaced by those that are suited. Field studies suggest that infauna community composition may be altered within approximately 100 m of a production platform following drilling activity (Hart, Shaul & Vittor 1989).

Smothering of an area of the seabed by drill cuttings can cause anoxic conditions to develop in the sediments over time. Encapsulated organic material that is present in the surface sediments at the time of smothering, or that is introduced with the cuttings (e.g. in drilling muds) (described below), will be biodegraded initially by organisms using the oxygen associated with the original surface sediments and deposited cuttings. Once this store of oxygen is depleted, the sediments are anoxic and biodegradation will occur more slowly by micro-organisms using electron acceptors other than oxygen (Brock & Madigan 1991). In circumstances where the drill cuttings have associated oil, either as a coating from synthetic-based muds (SBMs) (described below) or from oily sands removed from the reservoir, field studies have shown that this oil persists for long periods of time before it is fully biodegraded (Schaanning 1996). The observed persistence is considered to be primarily attributable to the reduced rates of biodegradation that occur in anoxic conditions of cuttings piles below the first few centimetres (Neff, McKelvie & Ayers 2000).

Dispersion of cuttings across the seafloor will be influenced by the prevailing currents and vertical settling forces, and a small proportion of cuttings (particularly fine material) could travel several kilometres from the drilling point.

At the Ichthys Field, the “Scientific and Environmental ROV Partnership using Existing iNdustrial Technology” (SERPENT) project recorded the changes in benthic habitat caused by drill spoil cover, using remotely operated vehicle (ROV) transects around an exploration drilling centre (SERPENT 2008). These surveys recorded “high” drill-spoil coverage within 20–35 m of the drilling point, causing complete coverage of the benthos with no evidence of bioturbation by benthic infauna. “Moderate” drill spoil cover extended out to 50–70 m from the drilling centre, with benthic infauna having re-established burrows in the drill spoil material. “Low” drill spoil coverage, where burrows made by benthic infauna were maintained under a light dusting of material, extended to the 80-m radius, which was the limit of the ROV survey area.

The drill spoil area recorded in ROV surveys was elongated along the north-west – south-east axis because of tidal currents. Overall, the extent of moderate-to-high coverage by drill cuttings at the single drilling centre was estimated at 0.7 ha (SERPENT 2008). Extrapolated across the entire 50-well drilling program, this would represent a total disturbance area at the Ichthys Field of 35 ha—equivalent to 0.0004% of the field area.

Any smothering effects on the sparse benthic communities in the offshore development area would be highly localised. As the seabed sediments in the Ichthys Field are uniform and widespread throughout the North West Shelf and Oceanic Shoals bioregions, the consequences of changes to these communities in the vicinity of the drilling locations can be considered to be low.

Discharged drill cuttings will create a temporary turbid plume. However, the seabed in the Ichthys Field is below the photic zone and benthic communities will be largely unaffected by increased turbidity. The nearest sensitive benthic communities are located at Browse Island and Echuca Shoal, respectively 33 km and 60 km from drilling locations—sufficiently distant to be outside the range of turbid plumes.

Drilling muds

Water-based muds (WBMs) can be used for the top-hole sections of the subsea wells, while SBMs are required for the lower-hole sections. Rock types change between the upper and lower portions of drill holes—SBMs are better suited to drilling in lower rock formations, which can swell when WBMs are used. portion of the top-hole sections will be drilled without a riser, with WBM being released at the seabed. Depending upon the final well design, a riserless mud return system may be used for recovery of WBM deeper in the top-hole section; alternatively returns may be achieved using a conventional riser.
It is anticipated that as much as 30% of the WBM from some top-hole sections could be lost over the shakers during high rates of penetration drilling. A conventional riser will be used to achieve a closed mud system when drilling the deeper lower-hole sections with SBM. Both WBM and SBM will be recovered and reused in subsequent wells as far as is practicable. However, as drill cuttings will be discharged overboard, some of the drilling muds attached to the drill cuttings will also be discharged to the marine environment.

The main concerns associated with the discharge of drilling muds to the marine environment are as follows:

- The muds may be toxic to marine biota.
- The muds and cuttings may cause increased turbidity.
- The muds and cuttings may alter sediment characteristics.

Water-based muds

The WBMs contain water as the base fluid along with a variety of special-purpose additives. A number of reviews have been carried out to identify common drilling-mud additives, application concentrations and toxicities. Table 7-3 contains the results of one such review presented by Swan, Neff and Young (1994). As shown, the wide range of drilling-fluid additives were all contained at extremely low concentrations relative to ecotoxicity levels for the mysid shrimp *Americamysis bahia* (formerly known as *Mysidopsis bahia*), the standard organism used in such toxicity tests. Therefore WBMs can be considered to be inert in terms of their toxicity and do not pose a risk to the marine environment at the offshore development area.

Table 7-3: Common drilling fluid additives, application concentrations and reported toxicities for the mysid shrimp *Americamysis bahia*

Product	Concentration range of application (ppb*)	96-hour LC_{50}† range (ppm‡)
Weighting agents		
Barite	0–631	>1 000 000
Haematite	0–500	>1 000 000
Calcium carbonate	10–81	>1 000 000
Viscosifiers		
Bentonite	12.5–30	>1 000 000
Extended bentonite	0–15	>1 000 000
Attapulgite	0–30	>1 000 000
Bacterially produced polymers	2	757 000
Polymers	1–2.5	78 000 – >1 000 000
Bentonite extender and flocculant	0.1–1.0	>1 000 000
Selective flocculant	0.1	>1 000 000
Thinners/deflocculants		
Sodium tetraphosphate	0–0.25	>1 000 000
Sodium acid pyrophosphate	0–0.5	>1 000 000
Quebracho compound	5	952 000
Sulfomethylated tannin	2–4	339 000 – >1 000 000
Synthetic polymers	1–4	74 000 – >1 000 000
Chrome lignosulfonate	3–23	500 000 – >1 000 000
Chrome-free lignosulfonate	4–20	310 000 – >1 000 000
Modified chrome lignite	25	201 000
Modified melanin	10	356 000
Modified calcium lignosulfonate	4	>1 000 000
Filtration control agents		
Preserved starch	0–6	472 000 – >1 000 000
Sodium carboxymethyl cellulose	0–2	>1 000 000
Polyanionic cellulose	0.5–3.0	>600 000 – >1 000 000
Sodium polyacrylate	1.5–3.0	1 000 000
Organic polymers	3–10	305 000 – >1 000 000
Processed lignite	3	>1 000 000
Causticised lignite	3–10	>1 000 000
Potassium lignite	6	>1 000 000
Pre-gelatinised starch	6–8	>1 000 000
Lubricants		
Specially prepared blend of organics	2–6	52 000 – >1 000 000
Blend of organic esters	2.0–17.5	104 000–494 000
Fatty-acid formulations	2.0–6.6	35 000 – >1 000 000
Graphite	0–6	865 000
Water-insoluble thermoplastic beads	10	>1 000 000
Shale control		
Water-dispersable asphalts	6–8	>1 000 000
Sulfonated asphaltic residuum	4–7	50 000 – >1 000 000
Aluminium compounds	5	>1 000 000

Table 7-3: Common drilling fluid additives, application concentrations and reported toxicities for the mysid shrimp *Americamysis bahia* (continued)

Product	Concentration range of application (ppb*)	96-hour LC_{50}† range (ppm‡)
Polymers	0.15–25.0	78 000 – >1 000 000
Detergents and emulsifiers		
Detergent modified fatty acids	4–8	238 000–302 000
Non-ionic surfactant	0.3	162 000 – >1 000 000
Defoamers and deflocculants		
Alcohol-based liquid defoamers	0.2–1.5	39 000 – >1 000 000
Surface-active dispersable liquid defoamers	0.15–0.7	82 000 – >1 000 000
Liquid surface-active agent tributylphosphate	0.15–3.0	51 000
Aluminium stearate	0.3	>1 000 000
Corrosion inhibitors		
Aluminium bisulfite solution	0.48	750 000
Filming amine oil	2	780 000
Modified organic inhibitor	0.5	130 000
Zinc compounds	6–7	31 000–78 000
Polyacrylate scale inhibitor	2	773 000
Bactericide		
Biocide	0.5	450 000

Source: Swan, Neff and Young 1994.

* ppb = parts per billion.

† The notation LC_{50} stands for "lethal concentration 50%". It is the concentration of a chemical in air or water that will kill 50% of a group of a specific test animal species exposed to it in a given time, for example 24 hours, 96 hours, etc. The LC_{50} is a measure of the short-term poisoning potential of a substance.

‡ ppm = parts per million.

Release of WBMs from the MODU will result in a discharge plume. Field observations have found that the plume from drilling mud discharge is visible in the upper parts of the water column for up to 1 km from the discharge point during and for a short time (*c*.24 hours) after discharge. In 1985 the US Environmental Protection Agency (US EPA) compiled data from numerous studies on the growth and dilution of drilling-mud discharge plumes. The concentrations of drilling mud in the surface waters at set distances from the point of discharge were measured at several sites. The results indicated that the mud had been diluted by approximately one million times by the time it reached a distance of 1 km from the discharge point (US EPA 1985).

Turbidity is likely to increase in the Project's offshore development area as a result of drilling-mud discharge plumes. However, this will be a short-term effect and any reductions in productivity (e.g. plankton growth) in the water column will be very localised in the context of the surrounding marine environment.

Synthetic-based muds

SBMs are composed of a base oil (such as an olefin, synthetic paraffin or ester) together with calcium chloride brine and treatment chemicals. The SBMs used in the offshore development area will be recovered in order to minimise release to the marine environment. However, small quantities will adhere to drill cuttings disposed of to sea. A number of researchers have assessed the toxicity of hydrocarbons from organic-phase drilling fluids in the water column. The acute toxicities of several base chemicals and their derivatives were presented in a literature review commissioned by the Minerals Management Service of the US Department of the Interior, which indicated that these compounds are generally toxic at high concentrations only, as shown in Table 7-4 (Neff, McKelvie & Ayers 2000).

Table 7-4: Acute toxicity to the mysid shrimp *Americamysis bahia* of several organic-phase base chemicals and their derivatives

Base chemical type	Chemical	96-hour LC_{50}* (mg/L)
Poly-a-olefins	Polypropene (MW 170)†	10 800
	Polypropene (MW 198)	30 000
	Decene dimer (MW 290)	574 330
	Polypropene (MW 310)	914 650
	Polybutene (MW 320)	>1 000 000
	Polypropene (MW 400)	>1 000 000
Internal olefins	C_{14}–C_{16} IO‡	<30 000
	C_{15}–C_{18} IO	119 658
	C_{16}–C_{18} IO	321 000
Ether	Dibutyl ether	>10 000
	Dihexyl ether	61 659
	Dioctyl ether	156 880
Esters	Methyl laurate	<10 000
	Isopropyl palmitate	271 701
	Isopropyl oleate	52 319
	C_{10}–C_{14} alcohols	<10 000
	C_{16} alcohol	30 158

Source: Neff, McKelvie and Ayers 2000.

* The notation LC_{50} stands for "lethal concentration 50%". It is the concentration of a chemical in air or water that will kill 50% of a group of a specific test animal species exposed to it in a given time, for example 24 hours, 96 hours, etc. The LC_{50} is a measure of the short-term poisoning potential of a substance.

† MW = molecular weight.

‡ IO = internal olefin.

SBMs are relatively non-toxic and readily biodegradable, and are considered to be an environmentally effective solution compared with traditional mud systems based on diesel and mineral oil. Using the toxicity ratings outlined by Cobby and Craddock (1999), most formulations range from "almost non-toxic" to "non-toxic".

Field studies of the environmental effects of ester-based drilling muds discharged on drill cuttings have shown that esters rapidly disappear from the sediments (Daan et al. 1996; Terrens, Gwyther & Keough 1998). In both studies, the authors have attributed this to rapid biodegradation and sediment relocation. Significant benthic fauna recovery has been recorded within 12 months of cessation of an ester-based mud drilling program in the North Sea (Daan et al. 1996).

Studies by the American Chemistry Council (ACC) indicate that both olefin and paraffin SBMs are non-toxic to water-dwelling organisms, and that olefin products have significantly less toxicity (4–20 times) than paraffin to sediment-dwelling organisms.

Both olefin and paraffin SBMs biodegrade in aerobic conditions (i.e. in the presence of oxygen), and in anaerobic conditions (i.e. in the absence of oxygen) olefin-based SBMs biodegrade much more extensively (>50%) than paraffin SBMs. Drilling locations in the Gulf of Mexico where olefin SBMs were used showed no significant effects on sediment quality and biological communities, and impacts were limited to the vicinity of the discharge (<250 m). Where impacts were observed, progress toward physical, chemical, and biological recovery appeared to occur within a year. The medium-term effects of paraffin SBMs were less conclusive—paraffin removal and rapid recovery were often attributed to sediment dispersion mechanisms and paraffin distributions tended to be very uneven (ACC 2006).

The effective dispersion of drill cuttings by the strong current regime in the Ichthys Field will enable aerobic breakdown of any SBMs adhering to the cuttings. Therefore the discharge of low levels of these muds is not expected to pose a risk of toxicity or contribute to anoxic conditions in marine sediments in the offshore development area.

Management of drilling discharges

A Provisional Liquid Discharges, Surface Water Runoff and Drainage Management Plan has been compiled for the Project (attached as Annexe 10 to Chapter 11). This will guide the development of more detailed plans during the construction and operations phases. The plan includes management controls for drilling discharges as follows:

- Procedural controls for preventing the accidental release of SBMs will be developed as part of a separate assessment under the OPGGS(Environment) Regulations.
- WBMs will be used instead of SBMs in the upper-hole sections of production wells.
- SBMs will be recovered after use and returned onshore for reuse or disposal.
- The concentration of SBMs on drill cuttings discharged to sea will be restricted to 10% by dry weight or less in accordance with Western Australian Government guidelines (DoIR 2006). An internal target of 5% or less of SBM on drill cuttings released to sea will be set.
- Use of cuttings driers or other options will be investigated to reduce SBMs on drill cuttings.

In addition, an environmental management plan will be developed for offshore drilling as required under the OPGGS(Environment) Regulations.

Residual risk

A summary of the potential impacts, management controls and residual risk for drilling discharges is presented in Table 7-5. After implementation of these controls, impacts from drilling discharges are considered to present risk levels of “low” to “medium” and it is likely that any effects on the marine environment will be localised and short-term.

Table 7-5: Summary of impact assessment and residual risk for drilling discharges (offshore)

Aspect	Activity	Potential impacts	Management controls and mitigating factors	Residual risk*		
				C†	L‡	RR§
Drill cuttings	Construction of offshore subsea wells.	Water quality decreased through increase in turbidity. Temporary disturbance to marine biota.	The strong ocean currents and deep water in the offshore development area will lead to rapid dispersion of turbid plumes. Drilling Environmental Management Plan as required under the OPGGS(Environment) Regulations.	F (E1)	6	Low
		Alteration of sediment characteristics.	The strong ocean currents and deep water in the offshore development area will spread cuttings piles in thin layers across the seabed. The benthic communities present are widespread and extensive in comparison with the disturbance area. Drilling Environmental Management Plan as required under the OPGGS(Environment) Regulations.	E (B3)	6	Medium
Drilling mud discharge	Discharge of WBMs to sea.	Toxicity to marine biota. Increased turbidity.	The strong ocean currents and deep water in the offshore development area will lead to rapid dispersion of cuttings and turbid plumes. Drilling Environmental Management Plan as required under the OPGGS(Environment) Regulations.	F (E1)	6	Low

Table 7-5: Summary of impact assessment and residual risk for drilling discharges (offshore) (continued)

Aspect	Activity	Potential impacts	Management controls and mitigating factors	Residual risk*		
				C†	L‡	RR§
Drilling-mud discharge	Discharge of SBMs adhering to drill cuttings.	Toxicity to marine biota. Alteration of sediment characteristics, including depletion of oxygen in surface sediments. Increased turbidity.	The strong ocean currents and deep water in the offshore development area will lead to rapid dispersion of cuttings and turbid plumes. Use WBMs in upper-hole sections instead of SBMs. Recover SBMs after drilling and reuse or dispose of onshore. The percentage by dry weight of SBMs released on drill cuttings will be restricted to 10%, with an internal target of 5% or less. Provisional Liquid Discharges, Surface Water Runoff and Drainage Management Plan. Drilling Environmental Management Plan as required under the OPGGS(Environment) Regulations.	E (B3)	6	Medium

* See Chapter 6 *Risk assessment methodology* for an explanation of the residual risk categories, codes, etc.

† C = consequence.

‡ L = likelihood.

§ RR = risk rating.

7.2.3 Liquid discharges

A variety of routine liquid wastes will be generated at the offshore development area during all stages of the Project as described in Chapter 5 *Emissions, discharges and wastes*. This section discusses the potential environmental impacts of these discharges in the context of the offshore marine environment.

Subsea control fluid

During operations, a water-based subsea control fluid will be used to control subsea tree valves remotely from the CPF. This will be likely to operate on an open-loop system, with small amounts of control fluid discharged from the wellhead valves on the seabed when they are operated. Typically, volumes of approximately 20 L of control fluid will be discharged from main valves at the base of risers and manifolds, on around two occasions per year. Smaller valves on subsea “Christmas” trees (at the wellheads) will be operated around five times per year, releasing around 4 L of control fluid each time.

Open-loop subsea control systems are an industry standard. The main properties required of a control fluid are low viscosity, low compressibility, corrosion protection, resistance to microbiological attack, compatibility with sea water, and biodegradability. The majority of subsea control fluids are based on fresh water with additives such as monoethylene glycol (MEG) (typically about 40%), lubricants, corrosion inhibitors, biocides and surfactants.

Subsea control fluids have been tested under the OSPAR Commission’s Harmonised Offshore Chemical Notification Format (HOCNF). The testing includes an assessment of the potential of each component of a product to bioaccumulate and biodegrade in the environment, as well as the performance of three out of four possible toxicity tests that are chosen in accordance with the expected fate of the materials. Based on the results of these tests, the UK HOCNF classification for various water-based subsea control fluids is “Group E”, representing the group of least environmental concern. Under this classification, up to 1000 t (approximately 1 000 000 L) of a substance may be released per annum from a single facility without prior notification to government bodies.

Given the low volumes discharged during each event, the potential impacts of this discharge are expected to be very localised, with a low impact on the marine environment. The release of subsea control fluids associated with the Project will not cause any significant impacts to listed species, migratory species or the surrounding marine environment.

Management for subsea control fluid

A Provisional Liquid Discharges, Surface Water Runoff and Drainage Management Plan has been compiled for the Project (attached as Annexe 10 to Chapter 11), which will guide the development of more detailed plans during the construction and operations phases. This plan includes the following management controls for subsea control fluids:

Table 7-6: Summary of impact assessment and residual risk for subsea control fluids

Aspect	Activity	Potential impacts	Management controls and mitigating factors	Residual risk*		
				C†	L‡	RR§
Release of subsea control fluids	Control of subsea tree valves.	Toxicity to marine biota.	Design of equipment to reduce volume of fluid released. Selection of water-soluble, low-toxicity control fluid. Provisional Liquid Discharges, Surface Water Runoff and Drainage Management Plan.	F (E1)	6	Low

* See Chapter 6 *Risk assessment methodology* for an explanation of the residual risk categories, codes, etc.

† C = consequence.

‡ L = likelihood.

§ RR = risk rating.

- Wellhead valves will be designed to minimise the volumes of subsea control fluids released.
- Water-soluble, low-toxicity hydraulic fluids will be selected to control open-loop subsea control valves.

Residual risk

A summary of the potential impacts, management controls and residual risk for subsea control fluids is presented in Table 7-6. After implementation of these controls, impacts from subsea control fluids are considered to present a "low" risk and any effects on the marine environment will be on a minor scale and highly localised.

Hydrotest water

Pressure-testing will be undertaken to determine the integrity of all facilities, including the FPSO and CPF, the gas export pipeline and the flowlines prior to commissioning. Pressure-testing is achieved by filling the lines with water, pressurising the water and monitoring for any change in pressure over time. This process is normally referred to as "hydrotesting". This is an important measure for avoiding or minimising the risk of accidental hydrocarbon leaks and is mandatory under Australian design codes.

In addition to water (either fresh water or sea water, but predominantly sea water), the hydrotest fluid normally contains a dye to aid in the detection of leaks, a biocide, an oxygen scavenger to prevent oxygen pitting of the steel, scale inhibitor and corrosion inhibitor. Fluorescein dye and a combined biocide and oxygen scavenger chemical containing acetic acid (5 to 10%), ammonium bisulfate (oxygen scavenger, 10 to 20%) and polyhexamethylene biguanide hydrochloride (PMBH, corrosion inhibitor and biocide, 10 to 20%) in fresh, brackish or sea water is a commonly used formulation for hydrotest water. It is also possible that MEG will be introduced during the dewatering and drying stage at the end of pipeline precommissioning to effectively remove water from the pipeline; the ecotoxicity of MEG is discussed below under *Produced water*.

The biocide PMBH is widely used in a variety of industries and by the general public as an alternative to chlorine for sterilising swimming pools. If fully diluted in the line, the maximum concentration of PMBH would be approximately 1000 mg/L. The reported toxicity of PMBH ranges from 0.65 to 0.9 mg/L (96-hour LC_{50} for bluegill sunfish) to 44 mg/L (96-hour LC_{50} for brown shrimp). Therefore, if discharged at sea the hydrotest fluid would need to be diluted more than 1000 times within a 96-hour period to avoid the potential for acute toxicity impacts. Given the deep waters and strong currents in the Project's offshore development area, dispersion of hydrotest water from the pipeline is expected to be rapid.

Hydrotesting for the topsides in the CPF and FPSO will be carried out at the shipyards where they are assembled. Some infield hydrotesting may be required for connection points and for the transfer line between these facilities, and this water would be discharged overboard at the sea surface. Hydrotest water from subsea flowlines and wells will be recovered through the production process and discharged at the sea surface from the CPF.

During precommissioning, the gas export pipeline will be flooded with approximately 1 GL of filtered and chemically treated sea water sourced from Darwin Harbour. The pipeline will then be hydrotested twice, using approximately 10 ML of treated water each time. At the end of each hydrotest operation, this treated water will be discharged from the offshore facilities to return the pipeline to ambient pressure. In the highly unlikely event of mechanical failure or a cyclone passing during the hydrotest operation, this water may need to be discharged from the onshore facility into Darwin Harbour. This scenario is discussed in the nearshore liquid discharges section (Section 7.3.4).

On completion of the hydrotesting, the pipeline will be dewatered and then dried and purged using nitrogen. During dewatering, the 1 GL of treated water in the pipeline will be discharged at the offshore facility.

It is expected that upon discharge of the hydrotest water, a plume of water similar in density to sea water will disperse through the water column. Given the strong current regime in the area and the considerable water depths, the hydrotest fluid is likely to disperse rapidly, minimising the potential for longer-term exposure effects. Any toxicity effects from the discharged pollutants would only impact on marine biota that happened to travel in the discharge plume for an extended period.

Management of hydrotest water

It is important to note that hydrotesting of flowlines is an important measure for avoiding and minimising risk associated with potential accidental releases of hydrocarbons and that it is mandatory under Australian design codes. The process for hydrotesting will be developed in more detail as the design of the offshore facilities progresses. Full details of the chemicals to be used, the concentrations, the quantities of water, the disposal method and their fate will be included in a Hydrotest Management Plan, subject to acceptance by Western Australia's Department of Mines and Petroleum acting on behalf of the Commonwealth Government.

A Provisional Liquid Discharges, Surface Water Runoff and Drainage Management Plan has been compiled for the Project (attached as Annexe 10 to Chapter 11). It will guide the development of more detailed plans during the construction and commissioning phases. This plan includes the following management controls for hydrotest water:

- Chemicals used in hydrotesting will be selected with consideration for their potential ecotoxicity.
- Modules will be precommissioned off site, if practicable, to minimise the discharge of hydrotest water to the marine environment.
- During dewatering of the gas export pipeline, treated water (approximately 1 GL) will be discharged at the offshore facility.
- Hydrodynamic modelling of hydrotest water plumes from the gas export pipeline will be undertaken prior to the commissioning phase in order to predict the dispersion of pollutants into the offshore marine environment.

Residual risk

A summary of the potential impacts, management controls, mitigating factors and residual risk for hydrotest water is presented in Table 7-7. Impacts from hydrotest water are considered to present a "low" risk as they are likely to be short-term and minor in scale.

Produced water

"Produced water" is water extracted from the gas reservoirs and separated from the hydrocarbon gases and liquids through a series of processes. Chemicals are added to the water from the gas reservoirs through the extraction and production process for purposes

Table 7-7: Summary of impact assessment and residual risk for hydrotest water (offshore)

Aspect	Activity	Potential impacts	Management controls and mitigating factors	Residual risk*		
				C†	L‡	RR§
Hydrotest water discharge	Commissioning of offshore gas production infrastructure.	Reduction in water quality because of dissolved chemical additives. Toxicity to marine biota.	Strong current regime and deep water in the offshore marine environment. Select hydrotest chemicals with consideration of their ecotoxicity potential. Precommission modules off site, if practicable. Hydrotest Management Plan (to be developed). Provisional Liquid Discharges, Surface Water Runoff and Drainage Management Plan.	F (E1)	6	Low

* See Chapter 6 *Risk assessment methodology* for an explanation of the residual risk categories, codes, etc.

† C = consequence.

‡ L = likelihood.

§ RR = risk rating.

such as controlling emulsion, inhibiting scale and hydrate formation, reducing corrosion and preventing the growth of bacteria. These production chemicals are soluble in produced water to varying extents. Other dissolved compounds in the produced water originate from the geological formation, such as organic acids, water-soluble hydrocarbons and salts, and some finely dispersed oils.

The characteristics of the produced water generated at the offshore development area are described in Chapter 5. For the Ichthys Project, produced water (including the dissolved fractions of production chemicals) will be discharged from the FPSO directly to the marine environment. In accordance with the requirements of the OPGGS(Environment) Regulations, the concentration of petroleum hydrocarbon in produced water discharged to sea will not be greater than an average of 30 mg/L (30 ppm) over any period of 24 hours.

Components of produced water

Metals

The metals associated with produced water are usually present as dissolved mineral salts. Because the reservoir water has been depleted of oxygen (through microbiological activity in the reservoir over millions of years), the metal ions are typically in lower oxidation states when discharged to the ocean as a component of the produced water.

Once discharged to sea the metal ions react with the oxygen in the surrounding sea water to form oxides. The metal oxides may then combine with anions such as sulfides, carbonates and chlorides and form insoluble precipitate. Precipitation as metal hydroxides or sulfides is the principal fate of heavy metals discharged with produced waters in the marine environment (E&P Forum 1994). Metals present in marine sediments as hydroxides or sulfides are not generally available for biological uptake (Jenne & Luoma 1977) and hence would not have any significant environmental impact.

Production chemicals

Production chemicals that may be discharged along with the produced water include the following types:

- hydrate inhibitors (most likely MEG)
- corrosion inhibitors
- scale inhibitors
- biocides.

The hydrate inhibitor MEG will be added in large volumes to the production process but will, in the main, be retained and recycled at the FPSO. Varying amounts of MEG will be discharged in the produced water directly to the marine environment. Worldwide, MEG is used as a chemical intermediate in the manufacture of polyesters or fibres, films and bottles, as well as for antifreeze in engine coolants or as a de-icer on airport runways and planes—runoff from these is the principal contributor of MEG to the environment (IPCS 2000).

MEG is miscible with water, does not volatilise nor undergo photodegradation, and is not adsorbed on to soil particles. Studies on a green alga (*Chlorella fusca*), a freshwater crayfish (*Procambarus* sp.) and a golden orfe carp (*Leuciscus idus melanotus*) revealed low potential for bioaccumulation of MEG in the marine environment (IPCS 2000).

MEG biodegrades readily when released to the environment, in both aerobic and anaerobic conditions, and several strains of micro-organisms capable of utilising ethylene glycol as a carbon source have been identified. Evans and David (1974) studied the biodegradation of ethylene glycol in four samples of river water under controlled laboratory conditions. The samples were dosed with 0, 2, or 10 mg of ethylene glycol per litre and incubated at either 20 °C or 8 °C. At 20 °C, primary biodegradation was complete within 3 days in all 4 samples, while at 8 °C, it was complete after 14 days and degradation rates were further reduced at 4 °C. Price, Waggy and Conway (1974) assessed the biodegradation of ethylene glycol in both fresh and salt water over a 20-day incubation period. Concentrations of up to 10 mg ethylene glycol per litre were used. In fresh water, 34% degradation was observed after 5 days, rising to 86% after 10 days and 100% after 20 days. Degradation was less in salt water—20% after 5 days and 77% after 20 days (IPCS 2000).

It is considered that MEG poses a negligible risk of ecotoxicity, as lethal effects on exposed organisms can only be caused by very high concentrations in sea water. Ecotoxicity values for the effect of MEG on a number of aquatic organisms are provided in Table 7-8; the high LC_{50} values indicate low toxicity.

In summary, given that produced water is rapidly dispersed by ambient currents, MEG would not be expected to have toxic effects on the marine environment.

Table 7-8: Ecotoxicity of monoethylene glycol (MEG) (as ethylene glycol)

Species	Life-cycle stage	Exposure (hours)	LC_{50}* (ppm)	Source
Goldfish (*Carassius auratus*)	Adult	24	5000	A
Goldfish (*Carassius auratus*)	–	72	34 250	B
Bluegill (*Lepomis macrochirus*)	Juvenile	96	27 540	A
Bluegill (*Lepomis macrochirus*)	–	–	27 540	C
Bluegill (*Lepomis macrochirus*)	–	96	34 250	B
Rainbow trout (*Oncorhynchus mykiss*)	Fry	96	60 829	A
Rainbow trout (*Oncorhynchus mykiss*)	–	–	18 000–46 000	C
Trout	–	96	41 000	B
Fathead minnow (*Pimephales promelas*)	Subadult	96	57 000	A
Water flea (*Daphnia magna*)	–	24	10 000	A
Water flea	–	48	46 300	B
Water flea (*Ceriodaphnia dubia*)	–	–	10 000–25 800	C
Brine shrimp (*Artemia salina*)	2nd–3rd instar larvae	24	180 624	A
Crayfish (*Procambarus* sp.)	Adult	96	91 430	A
Common shrimp (*Crangon crangon*)	Adult	48	100 000	A

Sources: A) PAN Pesticide Database 2010; B) ScienceLab.com, Inc. 2008; C) Old World Industries I 2003.

* The notation LC_{50} stands for "lethal concentration 50%". It is the concentration of a chemical in air or water that will kill 50% of a group of a specific test animal species exposed to it in a given time, for example 24 hours, 96 hours, etc. The LC_{50} is a measure of the short-term poisoning potential of a substance.

Other production chemicals (e.g. corrosion inhibitors, scale inhibitors and biocides) can be toxic to marine biota but will be discharged at much lower concentrations than MEG. The environmental effects of these components of produced water depend upon dosage concentrations and the sensitivity of the plant or animal receptors. Discharge modelling presented later in this section suggests that any chemicals contained in the production water at the offshore development area will be rapidly diluted and will not reach sensitive receptors.

Toxicity of produced water

The fundamental principle of toxicity is that the negative response increases as the dose increases. This is generally represented by a dose below which no response is observed (the "threshold"), to a dose causing a 100% response. It is important to note the difference between "dose" and "exposure":

- Dose is the amount that is known to enter the organism or to interact with a membrane of an organism (e.g. a fish gill) for a given exposure. The dose is specifically associated with the toxic response.
- Exposure is the amount or concentration of an agent in the ambient environment in which the organism resides. Simply being in the environment does not necessarily mean that the agent is absorbed by the organism at a dose, or for a duration of time, sufficient to reach a target site and exert a toxic effect.

"Acute" toxicity is a poisonous effect experienced by an organism, produced from a single or short dose (24 to 96 hours). Acute toxicity can result in severe biological harm or death, but survival through an episode of acute toxicity usually does not cause lasting effects. "Chronic" toxicity is the result of long-term exposure to a toxin in small repeated doses, for which symptoms may not appear for a long time and may last indefinitely.

Acute toxicities for produced-water discharges reported for various oilfields around the world have been reviewed and are summarised in Table 7-9. Note that these discharges are likely to contain a mixture of hydrocarbons, production chemicals and formation water in varying concentrations, depending on the oilfield and production systems employed. The lowest reported LC_{50} acute toxicity (i.e. the most toxic response) occurred at 8000 ppm (equivalent to dilution of 125 times), while the highest (least toxic) occurred at more than 900 000 ppm (equivalent to a dilution of 1.11 times). The mean reported measure of acute toxicity was 230 000 ppm (equivalent to a dilution of 4.35 times). For the purposes of determining potential impacts from produced water at the Ichthys Field, the highest dilution rate of 1:125 may be applied as an acute toxicity threshold.

Table 7-9: Reported produced-water acute toxicity concentrations

Group	Species	LC_{50}*, EC_{50}† toxicity range (ppm)	Reference
Algae	*Skeletonema costatum*	10 000–350 000; 50 000–680 000	Flynn, Butler and Vance 1996; Brendehaug et al. 1992
	Isochrysis sp. (Tahitian strain)	470 000	P. Farrell pers. comm. 2007
Echinoderms	*Strongylocentrotus purpuratus*	180 000–286 000	Schiff et al. 1992
Polychaetes	*Neanthes arenaceodentata*	180 000–290 000	Schiff et al. 1992
Molluscs	*Donax faba*	10 000–150 000	Din and Abu 1992
	Haliotis rufescens (larvae)	>900 000	Raimondi and Schmitt 1992
	Haliotis rufescens (settlement)	120 000	Raimondi and Schmitt 1992
	Crassostrea gigas	50 000	Somerville et al. 1987
Coelenterates	*Campanularia flexuosa*	50 000	Somerville et al. 1987
	Acropora millepora (fertilisation)	>900 000	Negri and Heyward 2000
	Acropora millepora (settlement)	80 000	Negri and Heyward 2000
Crustaceans	*Artemia salina*	160 000–180 000	Somerville et al. 1987
	Crangon crangon	20 000	Somerville et al. 1987
	Penaeus monodon	240 000	P. Farrell pers. comm. 2004
	Farfantepenaeus aztecus (larval)	8000–10 000	Rose and Ward 1981
	Farfantepenaeus aztecus (juvenile)	60 000–180 000	Rose and Ward 1981
	Litopenaeus setiferus (juvenile)	60 000–130 000	Zein-Eldin and Keney 1979
	Litopenaeus setiferus (adult)	40 000–90 000	Zein-Eldin and Keney 1979
	Balanus tintinnabulum	83 000	E&P Forum 1994
Copepods and amphipods	*Acartia tonsa*	20 000–250 000; 100 000	Flynn, Butler and Vance 1996; Somerville et al. 1987
	Tisbe battagliai	30 000–300 000	Somerville et al. 1987
	Gladioferens imparipes	310 000	P. Farrell pers. comm. 2004
	Calanus finmarchicus	100 000	Somerville et al. 1987
Fish	*Oncorhynchus mykiss*	100 000	Somerville et al. 1987
	Hypleurochilus geminatus	270 000; 160 000–410 000	Jackson et al. 1989; Rose and Ward 1981
	Cyprinodon variegatus	50 000–280 000; 70 000–340 000; 40 000–280 000	Moffitt et al. 1992; St. Pé 1990; Andreasen and Spears 1983
	Fundulus heteroclitus	>230 000	Black et al. 1994
	Lagodon rhomboides	500 000	Black et al. 1994
	Micropogonias undulatus	350 000	Black et al. 1994
	Mugil curema	500 000	Black et al. 1994
	Gasterosteus aculeatus	>750 000	Black et al. 1994

* The notation LC_{50} stands for “lethal concentration 50%”. It is the concentration of a chemical in air or water that will kill 50% of a group of a specific test animal species exposed to it in a given time, for example 24 hours, 96 hours, etc. The LC_{50} is a measure of the short-term poisoning potential of a substance.

† The notation EC_{50} stands for “effect concentration 50%”. It is the concentration of a substance that results in 50% less growth, fecundity, germination, etc., in a population. In ecology it is used as a measure of a substance’s ecotoxicity but, unlike the LC_{50} which measures lethality, the EC_{50} value measures sublethality—it demonstrates the adverse effects of a substance on a test organism such as changes in its behaviour or physiology.

The toxicity of the Ichthys condensate on marine biota has also been assessed by Geotechnical Services (2007a). These tests indicate that a dilution rate of 1:158 (equivalent to 0.127 mg/L hydrocarbons) produced no observable acute toxicity effects in fish larvae, the most sensitive of the marine biota included in the study. As hydrocarbons from the offshore facilities represent a portion of the solutes discharged to the marine environment, this dilution rate can be applied as a very conservative acute toxicity threshold for produced water.

There are relatively few studies that consider the chronic toxic effects of produced water. Black et al. (1994) cite an earlier study (Girling 1989) in which adverse chronic-toxicity effects were observed for the copepod *Acartia tonsa* at concentrations equivalent to between 0.5% and 7% produced water. A study of the chronic toxicity of produced water to species of sea urchin, mussel, shrimp and kelp by Cherr, Higashi and Shenker (1993) found adverse toxic effects occurring after exposure to 2–3% produced-water concentrations. Sublethal toxic effects of produced water, including damage to gill lamellae and impairment of iono-regulatory processes, have also been detected in fish continuously exposed for a period of 6 weeks to concentrations as low as 0.1–1.0% produced water (Stephens et al. 2000).

Mesocosm studies, which more closely approximate “real world” conditions, have demonstrated marked reduction in copepod populations after chronic exposure to concentrations equivalent to about 0.02–0.05% produced water (Davies et al. 1981).

Combining these estimates of chronic-toxicity threshold provides a range of 0.02–7% of produced water (equivalent to a dilution of 5000 to 14 times) over a period of weeks to months as the dosage required to elicit a chronic-toxicity response. The most conservative of these dilution rates (1:5000, equivalent to 0.004 mg/L hydrocarbons) can be used as a chronic-toxicity threshold level for produced-water dispersion from the Project’s offshore development area, described in the following subsection.

Dispersion of produced water

In order to predict the dispersion of produced water in the offshore development area, hydrodynamic modelling was undertaken by Asia-Pacific Applied Science Associates (APASA). Three modelling methods were integrated to simulate this dispersion: an oceanic hydrodynamic model (HYDROMAP) for current data, a near-field discharge model (UM3), and a far-field advection and dispersion model (MUDMAP). The results of the study are summarised below, while the complete technical report is provided in Appendix 6 to this Draft EIS. Further detail on the development and validation of the oceanic hydrodynamic model is provided in Appendix 5.

For the purposes of modelling, discharge rates and characteristics were estimated based on preliminary knowledge of the gas reservoirs in the Ichthys Field. The Brewster reservoir contains significantly lower volumes of formation water than the Plover reservoir and will therefore generate produced water at lower flow rates and salinity levels (see Chapter 5). Two scenarios were modelled under both summer and winter weather conditions to better understand the dispersion of produced water throughout the life of the Project:

Scenario 1 Representing the maximum flow rate of produced water from the Brewster reservoir and none from the Plover reservoir. This would occur in Year 17.

Scenario 2 Representing the maximum overall flow rate, involving declining volumes from Brewster and peak flow rates from Plover. This would occur in Year 28.

The assumed characteristics of the produced water for each scenario are summarised in Table 7-10. An initial dispersed hydrocarbon concentration of 20 mg/L was assumed for both scenarios.

Table 7-10: Summary characteristics of produced water discharged at the Ichthys Project’s offshore development area

Input	Scenario 1 (Year 17)	Scenario 2 (Year 28)
Flow rate	2000 m^3/d	5000 m^3/d
Composition	0% formation water 100% condensed water	50% formation water 50% condensed water
Temperature	50 °C	50 °C
Salinity	1 ppt	12 ppt

Produced water mixes into the marine environment in two distinct zones:

- Near-field: This is defined by the area where the levels of mixing and dilution are controlled by the plume's initial jet momentum and buoyancy flux, resulting from differences in the a density of the discharged water and the surrounding sea water. When the plume encounters a boundary such as the water surface, seabed or a density stratification layer, the near-field mixing is complete.
- Far-field: This is outside the near-field zone, where the discharge plume is transported and mixed by the ambient currents (APASA 2009a).

At the Project's offshore development area, produced water will be discharged continuously from the hull of the FPSO, 15 m below the sea surface. Near-field modelling indicated that the produced-water plume would initially plunge downward, creating a turbulent mixing zone approximately 1 m below the discharge pipe. Once the initial jet momentum ceased, the plume would remain sufficiently buoyant to rise to the surface and to continue to mix with ambient waters, though at a slower rate. As a result of mixing during the initial plunge and buoyant rise, the salinity and temperature of the discharge plume are predicted to reach background levels over a short distance (*c*.10 m), irrespective of flow rates and ambient current conditions (APASA 2009a).

Dilution levels achieved for the produced-water plume under both discharge scenarios, in both seasons, are summarised in Table 7-11. As near-field mixing does not consistently dilute the produced-water plume to low-toxicity threshold levels (i.e. it does not achieve a dilution rate of 1:158), far-field modelling is required to assess the extent and shape of the mixing zone in the offshore marine environment.

Table 7-11: Summary of dilution rates achieved by near-field mixing, within a 5-m horizontal distance of the release site

Scenario, season	Dilution rate achieved*
Scenario 1, summer	>1:120
Scenario 2, summer	>1:55
Scenario 1, winter	>1:114
Scenario 2, winter	>1:54

Source: APASA 2009a.

* Dilution rate achieved 95% of the time (95% confidence limit).

Far-field dispersion modelling indicated that the produced-water plume would remain in the surface layer (in the top 2 m), and would be transported by near-surface currents. The plume would oscillate and change direction with each flood and ebb tide, to the north-west and south-east respectively. As a result of this change in directions and current velocities, concentrations in the plume would be variable over time. Patches of higher concentrations (lower dilution rates) tend to build up at the turn of the tide, or in weaker currents. These higher-concentration patches would move as a unified group as the current speeds increased again (APASA 2009a).

Scenario 2 (maximum flow rate) is predicted to cause a much larger mixing area than Scenario 1, prior to reaching the threshold dilution rate for acute toxicity of 1:158 (see Figure 7-3). This mixing zone covers 0.0058 km^2 during summer conditions and 0.0061 km^2 during winter, and is reached within 60 m of the release site in both seasons. The 1:158 dilution threshold is reached within 10 m of the release site for Scenario 1 (low flow rate) in both seasons (APASA 2009a).

The conservative chronic-toxicity dilution rate (1:5000) is reached within 1.1 km of the release point for Scenario 1 and 3.6 km for Scenario 2. This relates to a mixing zone of 6.6 km^2 for Scenario 1 and 9.3 km^2 for Scenario 2 (APASA 2009a). Chronic-toxicity effects would only be caused to marine biota that are continuously exposed to this discharge plume in the surface water layers over time periods of weeks or months. As this area of effect remains within the open ocean surrounding the offshore facilities and is distant from Browse Island, there is no potential for impacts to sensitive shallow-water marine habitats.

Management of produced water

A Provisional Liquid Discharges, Surface Water Runoff and Drainage Management Plan has been compiled for the Project (attached as Annexe 10 to Chapter 11), which will guide the development of a series of more detailed plans during the construction and operations phases. Key inclusions in this plan include the following:

- Oil-in-water concentrations will meet the regulatory requirement under Regulation 29 of the OPGGS(Environment) Regulations of being not greater than an average of 30 mg/L over any period of 24 hours. The oil-in-water concentration of produced water discharged at the offshore development area will be measured continuously by an online analyser to ensure compliance with this regulatory criterion.
- Process chemicals will be selected with consideration of their potential ecotoxicity.

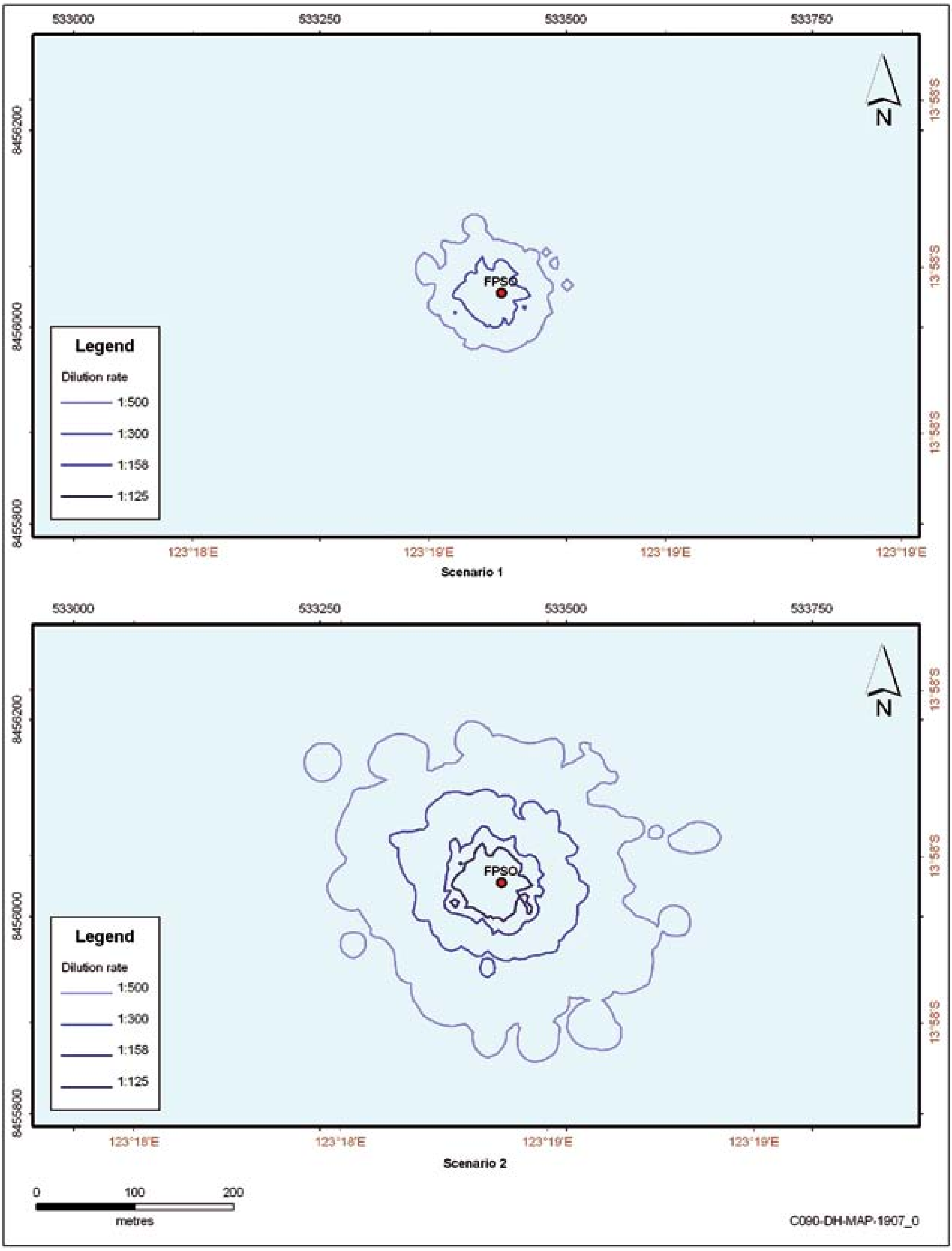

Figure 7-3: Predicted extent of produced-water mixing zones for scenarios 1 (top) and 2 (bottom) under combined summer and winter current conditions

Residual risk

A summary of the potential impacts, management controls, and residual risk for produced water is presented in Table 7-12. After implementation of these controls, impacts from produced water are considered to present a "medium" risk, as effects on the marine environment will be localised and discharges of pollutants are as low as reasonably practicable.

Table 7-12: Summary of impact assessment and residual risk for produced water (offshore)

Aspect	Activity	Potential impacts	Management controls and mitigating factors	Residual risk*		
				C†	L‡	RR§
Produced-water discharge	Routine operation of offshore gas production infrastructure.	Reduction in water quality because of elevated concentrations of dispersed oil, metals and production chemicals. Toxicity to marine biota.	The strong current regime and deep water in the offshore marine environment will disperse the discharge plume rapidly. The concentrations of oil-in-water will be ≤30 mg/L (24-hour average) and will be monitored constantly to ensure compliance. Provisional Liquid Discharges, Surface Water Runoff and Drainage Management Plan.	E (E1)	6	Medium

* See Chapter 6 *Risk assessment methodology* for an explanation of the residual risk categories, codes, etc.

† C = consequence.

‡ L = likelihood.

§ RR = risk rating.

Other wastewater discharge

Cooling water, desalination brine, and sewage and grey water will be routinely discharged from vessels and facilities to the marine environment in the offshore development area during all stages of the Project.

Large volumes of sea water used for cooling the gas-processing facilities will be discharged back to the marine environment at an elevated temperature (45–50 °C). Elevated seawater temperatures are known to cause alteration of the physiological (especially enzyme-mediated) processes of exposed biota (Wolanski 1994). These alterations may cause a variety of effects ranging from behavioural responses (including attraction and avoidance behaviour) to minor stress and potential mortality in cases of prolonged exposure. Around the offshore Project facilities, it is expected that an area of less than 0.1 ha around the discharge outfall will experience water temperatures more than 2 °C above ambient conditions for 50% or more of the time. This effect is considered very localised in the context of the offshore marine environment.

The effects of sewage discharged to the ocean have been relatively well studied (for example by Gray et al. 1992 and Weis, Weis & Greenberg 1989) and toxic effects generally only occur where high volumes are discharged into a small and poorly mixed waterbody. The small volumes of treated sewage and grey water discharged at the offshore development area are unlikely to cause toxic effects, especially considering the rapid dilution provided by the deep water and ocean currents in the area.

Sewage and grey water will also be discharged from pipeline construction vessels, except within 3 nautical miles of land, in accordance with Annex 4 of MARPOL 73/78 (IMO 1978). The volumes of sewage and grey water from these vessels will be relatively low and are expected to be fully biodegradable.

Discharges will be transient because of the constant movement of vessels along the pipeline route, reducing the impact to the marine environment to a very low level.

Desalination brine will be discharged from the CPF and FPSO, although in relatively low volumes with only very localised effects on water quality. The saline brine would be discharged at a rate of approximately 100 m^3/d from each facility and would be expected to rapidly disperse into the surrounding waters.

For all these discharged wastewater streams, the biota that could be exposed for long periods would be limited to fouling species (e.g. barnacles) in the immediate vicinity of outfall points. Planktonic species drifting with the discharge water as it disperses may also be affected, although for short periods. In the context of the offshore marine environment, however, wastewater discharges from the offshore development area will result in localised, low-scale changes in water quality.

Deck drainage discharges and management of accidental hydrocarbon spills on board the facilities are described in Section 7.2.4.

Management of wastewater

A Provisional Liquid Discharges, Surface Water Runoff and Drainage Management Plan has been compiled for the Project (attached as Annexe 10 to Chapter 11), which will guide the development of a series of more detailed plans during the construction and operations phases. Key inclusions in this plan include the following:

- Sewage wastes from the CPF and FPSO will be macerated to particles and scraps with diameters less than 25 mm prior to discharge, in accordance with Clause 222 of the Petroleum (Submerged Lands) Acts Schedule (DITR 2005).

The discharge will take place through submerged caissons.

- Construction vessels, supply vessels and the MODU will adhere to the following as permitted by the *Protection of the Sea (Prevention of Pollution from Ships) Act* (Cwlth) and the *Marine Pollution Act* (NT).
  - Sewage will not be discharged within 3 nautical miles of land.
  - Only treated sewage (with particles <25 mm in diameter) will be discharged between 3 and 12 nautical miles of land.
  - Untreated sewage may be discharged beyond 12 nautical miles of land.

Residual risk

A summary of the potential impacts, management controls and risks in relation to wastewater discharges are listed in Table 7-13. After implementation of these controls, impacts from wastewater discharges are considered to present a “low” risk, as the effects on the marine environment will be localised and discharges of pollutants are as low as reasonably practicable.

Ballast water

The ballast water contained in the MODU, CPF, FPSO and various vessels involved in construction and operations at the offshore development area will be fully segregated from fuel and product tanks in accordance with MARPOL 73/78 (IMO 1978) to remove the risk of contamination by hydrocarbons or chemicals. Therefore differences in chemical water quality between the ballast water taken on at the point of origin and the waters of the offshore development area are expected only to relate to salinity, turbidity or temperature and would be very minor in scale. Marine biota may also be transferred in ballast water to the offshore development area; the risks of transferring marine pests this way are discussed in Section 7.2.8 *Marine pests*.

Table 7-13: Summary of impact assessment and residual risk for wastewater discharges (offshore)

Aspect	Activity	Potential impacts	Management controls and mitigating factors	Residual risk*		
				C†	L‡	RR§
Sewage and grey water discharge	Routine operation of offshore vessels and facilities.	Alteration of marine environment including nutrient enrichment and toxicity.	The strong ocean currents and deep water will result in rapid dispersion in the offshore development area. Comminuted sewage (<25 mm) will be discharged from the CPF and FPSO through submerged caissons. Sewage and grey water will be treated and disposed of in accordance with *Protection of the Sea (Prevention of Pollution from Ships) Act 1983* (Cwlth) and the *Marine Pollution Act* (NT). No discharge from vessels will be made within 3 nautical miles of land. Only treated waste (macerated to <25 mm) will be discharged between 3 and 12 nautical miles from land, and untreated waste may be discharged beyond 12 nautical miles. Provisional Liquid Discharges, Surface Water Runoff and Drainage Management Plan.	F (E1)	6	Low
Cooling water discharge	Routine operation of offshore facilities.	Alteration of marine environment through increase in water temperature.	The strong ocean currents and deep water will result in rapid dispersion in the offshore development area. No specific management proposed as this is considered a negligible risk to the marine environment.	F (E1)	6	Low

* See Chapter 6 *Risk assessment methodology* for an explanation of the residual risk categories, codes, etc.

† C = consequence.

‡ L = likelihood.

§ RR = risk rating.

Ballast water discharged from the vessels and facilities at the offshore development area will disperse rapidly into the surrounding marine environment and will have little effect on water quality and marine biota in the area.

Management of ballast water

Vetting procedures for condensate tankers will be developed and implemented to ensure that ballast-water tanks are segregated from fuel and product tanks.

Residual risk

A summary of the potential impacts, management controls, and residual risk for ballast water is presented in Table 7-14. After implementation of these controls, impacts from ballast water are considered to present a "low" risk, with localised and low-scale effects on the surrounding marine environment.

Antifouling leachate

Antifouling paints commonly used on commercial vessels are formulations containing copper and "booster biocides" such as Irgarol 1051 (a triazine, $C_{11}H_{19}N_5S$), diuron, and zinc pyrithione. Booster biocides are designed to leach slowly from the paint to prevent fouling build-up. Table 7-15 presents the concentration of the most common antifouling additives, the rates at which they are expected to leach from the paints, and the reported range of their toxicities to algae and fish.

Copper is an essential nutrient for aquatic organisms but can also be toxic at elevated concentrations. Speciation plays a critical role in determining if copper is biologically available, toxic, or unavailable. In natural waters, copper and other trace metals will be complexed to both organic and inorganic ligands (Eriksen, Nowak & van Dam 2001) and therefore concentrations of free copper ion, the most biologically available form, within metres of the subsurface facilities are likely to be far less than the concentration at which toxic effects could occur.

Diuron and Irgarol 1051 are both herbicides that are highly toxic to phytoplankton and other aquatic plants and moderately toxic to animals. Both herbicides will decay in the presence of light; for diuron this occurs within a matter of days (Spectrum Laboratories 2004) while Irgarol 1051 has a much slower decay rate of about 80% after 15 weeks (Okamura et al. 2002). The concentrations of diuron and Irgarol 1051 likely to occur in surrounding waters as a consequence of leaching from antifouling paints are far less than the concentrations at which toxicity effects would occur.

Table 7-14: Summary of impact assessment and residual risk for ballast water (offshore)

Aspect	Activity	Potential impacts	Management controls and mitigating factors	Residual risk*		
				C†	L‡	RR§
Discharge of ballast water	Routine operations of offshore vessels and facilities.	Contamination of the marine environment by hydrocarbons.	Implementation of vetting procedures for condensate tankers, ensuring that ballast-water tanks are segregated from fuel and product tanks.	F (E1)	1	Low

* See Chapter 6 *Risk assessment methodology* for an explanation of the residual risk categories, codes, etc.

† C = consequence.

‡ L = likelihood.

§ RR = risk rating.

Table 7-15: Concentrations of active antifouling components in paints and their rate of leaching and toxicity to algae and fish

Additive	Minimum concentration (% w/w*)	Rate of leaching (μg/cm²·d⁻¹)	Toxicity to algae (μg/L)	Toxicity to fish (μg/L)
Copper oxide	10–50	1–101	1–8000 (Cu^{2+})	10–10 200 (Cu^{2+})
Copper thiocyanate	5–25	1–101	1–8000 (Cu^{2+})	10–10 200 (Cu^{2+})
Diuron	1–10	0.1–2.5	5–120†	8500–25 000
Irgarol 1051	0.1–5.0	2–16	1.4–2.4	400–2900
Zinc pyrithione	2	2.3–18‡	28‡	5–9§, 0.3–400‡

Source: Plymouth Marine Laboratory 2000.

* percentage weight for weight.

† US EPA 2010.

‡ DEFRA 2003.

§ Goka 1999; Okamura et al. 2002.

Both Irgarol 1051 and diuron will adsorb to suspended solids and have the potential to be sedimented. Once in sediments, the decay rates of both chemicals proceed at much slower rates, even under aerobic conditions (Okamura et al. 2000). There is therefore potential for these chemicals to be deposited on the seabed where they would remain in the sediments for months before degradation through chemical and biological mechanisms. However the quantity of diuron or Irgarol 1051 from antifouling leachate being sedimented would be extremely low and the rate of degradation, although low, would exceed the rate of sedimentation and thereby prevent concentrations from reaching levels sufficient to cause detectable environmental effects.

Zinc pyrithione is an effective microbicide widely used in antifungal and antibacterial formulations, including shampoos. It degrades rapidly in the water column by both abiotic and biotic pathways with a reported half-life in sea water of less than four minutes (DEFRA 2003). The products of pyrithione degradation are orders of magnitude less toxic than the parent compound (Turley et al. 2000).

In accordance with the requirements of the International Convention on the Control of Harmful Anti-fouling Systems on Ships (IMO 2001) and the *Protection of the Sea (Harmful Anti-fouling Systems) Act 2006* (Cwlth), no antifouling paints containing TBT compounds will be applied to vessels or equipment in the offshore development area.

The impact of antifouling leachate associated with Project vessels or equipment is predicted to be highly localised and negligible in the overall context of the offshore marine environment.

Management of antifouling leachate

Antifouling paints or methods with the least potential for environmental harm will be selected for use on subsea infrastructure, subject to meeting operational requirements.

Antifouling paints containing TBT compounds will not be used on any Project vessel, the pipelay barge or on any equipment in conformity with the requirements of the International Maritime Organization (IMO) and Australian law.

Residual risk

A summary of the potential impacts, management controls, and residual risk for antifouling leachate is presented in Table 7-16. After implementation of these controls, impacts from antifouling leachate are considered to present a "low" risk, with localised and low-scale effects on the surrounding marine environment.

7.2.4 Accidental hydrocarbon spills

Hydrocarbon characterisation

Hydrocarbons in oil and gas fields usually comprise hundreds of chemical substances. The relative balance of the constituent substances influences both the chemical and physical properties of the mixture, which in turn affect the potential for environmental impact on marine biota (Connell 1995).

The main physical properties that affect the behaviour of oil spilled at sea are its specific gravity in relation to water, its viscosity, its pour point and its volatility. Diesel fuel, for example, has a specific gravity of 0.84–0.88 and low viscosity and is therefore categorised as a light persistent oil.

Table 7-16: Summary of impact assessment and residual risk for antifouling leachate (offshore)

Aspect	Activity	Potential impacts	Management controls and mitigating factors	Residual risk*		
				C†	L‡	RR§
Antifouling leachate	Routine operation of support vessels, pipelay barge and subsea structures.	Toxic effects on marine biota from leached copper and biocide chemicals.	Leachates will be diluted rapidly in the strong-current, deep-water offshore environment. Antifouling paints or methods with the least potential for environmental harm will be used on subsea infrastructure, subject to operational requirements. Antifouling paints containing TBT compounds will not be used on any Project vessels or equipment.	F (B3)	6	Low

* See Chapter 6 *Risk assessment methodology* for an explanation of the residual risk categories, codes, etc.

† C = consequence.

‡ L = likelihood.

§ RR = risk rating.

Bunker fuel oils are often a mix of heavy residual fuel oils and marine diesel, with pour points in the range of 15–24 °C making them very viscous or even solid if released to sea.

When an oil spill occurs at sea, the compositions of hydrocarbon mixtures alter as the different chemicals undergo physical and chemical changes known as "weathering". Although the individual processes that bring about these changes act simultaneously, their relative importance during the lifetime of an oil slick varies as described below:

- *Spreading* is one of the most significant processes during the early stages of a spill. The main driving force behind the initial spreading process is the size of the spill. A large instantaneous spill will therefore spread more rapidly than a slow discharge of the same volume. Gravity-assisted spreading is quickly replaced by surface-tension effects. During these early stages the oil spreads as a coherent slick and the rate is influenced by the viscosity of the oil. Low-viscosity oils, such as condensate, spread quickly. Spreading is rarely uniform and there can be large variations in oil thickness in a slick.
- *Evaporation* occurs when the oil comes into contact with air and the more volatile compounds vaporise into the atmosphere. The initial spreading rate of the oil affects this process since the larger the surface area, the faster the light components will evaporate. Rough seas, high wind speeds and warm temperatures will also increase the rate of evaporation. Spills of condensate and refined products such as kerosene and gasoline may evaporate completely within a few hours and light crudes can lose up to 40% during the first day. In contrast, heavy crudes and fuel oils undergo little, if any, evaporation. Any residue of oil remaining after evaporation will have an increased density and viscosity, which affects further weathering processes and the choice of clean-up techniques.
- *Dispersion* is the break-up of the oil slick into droplets with a range of sizes through the action of waves and turbulence at the sea surface. Some droplets remain in suspension while the larger ones rise back to the surface, behind the advancing slick, where they may either coalesce with other droplets to re-form a slick or spread out in a very thin film. Droplets small enough to remain in suspension become mixed into the water column and the increased surface area presented by this dispersed oil can promote the rate of assimilation by other processes such as biodegradation and sedimentation.
- *Emulsification* is the absorption of water by the oil, forming a water-in-oil emulsion. Emulsions are often extremely viscous and, as a result, the other processes that would cause the oil to dissipate are retarded. In moderate to rough sea conditions, most oils rapidly form emulsions, the stability of which is dependent on the concentration of asphaltenes.
- *Dissolution* is the complete integration of oil into the water column. The solubility of hydrocarbons depends on their molecular structure and mass; as a general rule, solubility in water decreases as mass increases. The heavy components of crude oil are virtually insoluble in sea water whereas lighter compounds, particularly aromatic hydrocarbons such as benzene and toluene, are slightly soluble. However these compounds are also the most volatile and so are lost very rapidly by evaporation, typically 10 to 100 times faster than by dissolution. Concentrations of dissolved hydrocarbons thus rarely exceed one part per million and dissolution does not make a significant contribution to the removal of oil from the sea surface.
- *Oxidation* is a reaction with oxygen either to disassemble into soluble products or to form persistent tars. Many of these oxidation reactions are promoted by sunlight, and although they occur throughout the lifetime of a slick, the effect on the overall dissipation is minor in relation to other weathering processes. Under intense sunlight thin films break down at rates of no more than 0.1% per day. The final products of oil oxidation (hydroperoxides, phenols, carboxyl acids, ketones, aldehydes and others) are usually more soluble in water.
- *Biodegradation* is the degradation of hydrocarbons by marine micro-organisms. Sea water contains a range of bacteria, moulds and yeasts that can utilise oil as a source of carbon and energy. Such organisms are distributed widely throughout the world's oceans. There are about 100 species of bacteria and fungus capable of using oil products for their growth. The main factors affecting the rate of biodegradation are temperature and the availability of oxygen and nutrients, principally compounds of nitrogen and phosphorus. Each type of micro-organism tends to degrade a specific group of hydrocarbons and while a range of bacteria are capable of degrading most of the wide variety of compounds in crude oil, some components are resistant to attack.

Although spilt oil is eventually weathered and assimilated by the marine environment, the time involved depends upon variables such as the amount of oil spilled, its initial physical and chemical characteristics, the prevailing climatic and sea conditions, and whether the oil remains at sea or is washed ashore.

Properties of Ichthys Field condensate

Condensates can be dispersed into the water column, but are generally rapidly lost from the sea surface by evaporative weathering. The speed and extent of weathering in sea water is influenced by salinity, wind and wave energy, air and water temperature as well as condensate composition. In order to predict the fate of condensate released during an accidental spill at the offshore development area, weathering processes were simulated by APASA (2009b) using numerical modelling. The full technical report is provided in Appendix 7 to this Draft EIS.

Ichthys Field condensate is a light oil (API[2] gravity 58.7; density 744 kg/m^3) with a low viscosity of 0.754 cP[3] and a relatively low proportion of aromatic hydrocarbons (3.1%). Simulations of oil spills at the water surface indicate that a high proportion of the oil (70–80%) would evaporate within the first day of release. Evaporation would then slow, leaving a non-volatile residual (*c*.15%) that would resist evaporation (Figure 7-4).

For pressurised releases at the seabed, the condensate would be atomised into droplets of variable size by the gas escaping under pressure from the offshore infrastructure. Smaller droplets would rise more slowly than larger droplets and hence the supply of condensate to the surface would be extended, increasing the duration of the weathering period. Simulations of a subsea condensate release at the Ichthys Field show that a relatively high proportion of the mass

2 American Petroleum Institute (API) gravity is a measure of how heavy or light a petroleum liquid is in comparison with water.

3 The centipoise (cP) is a unit of dynamic viscosity in the centimetre-gram-second system. It is equal to 1 millipascal second (mPa·s) in the International System of Units (SI).

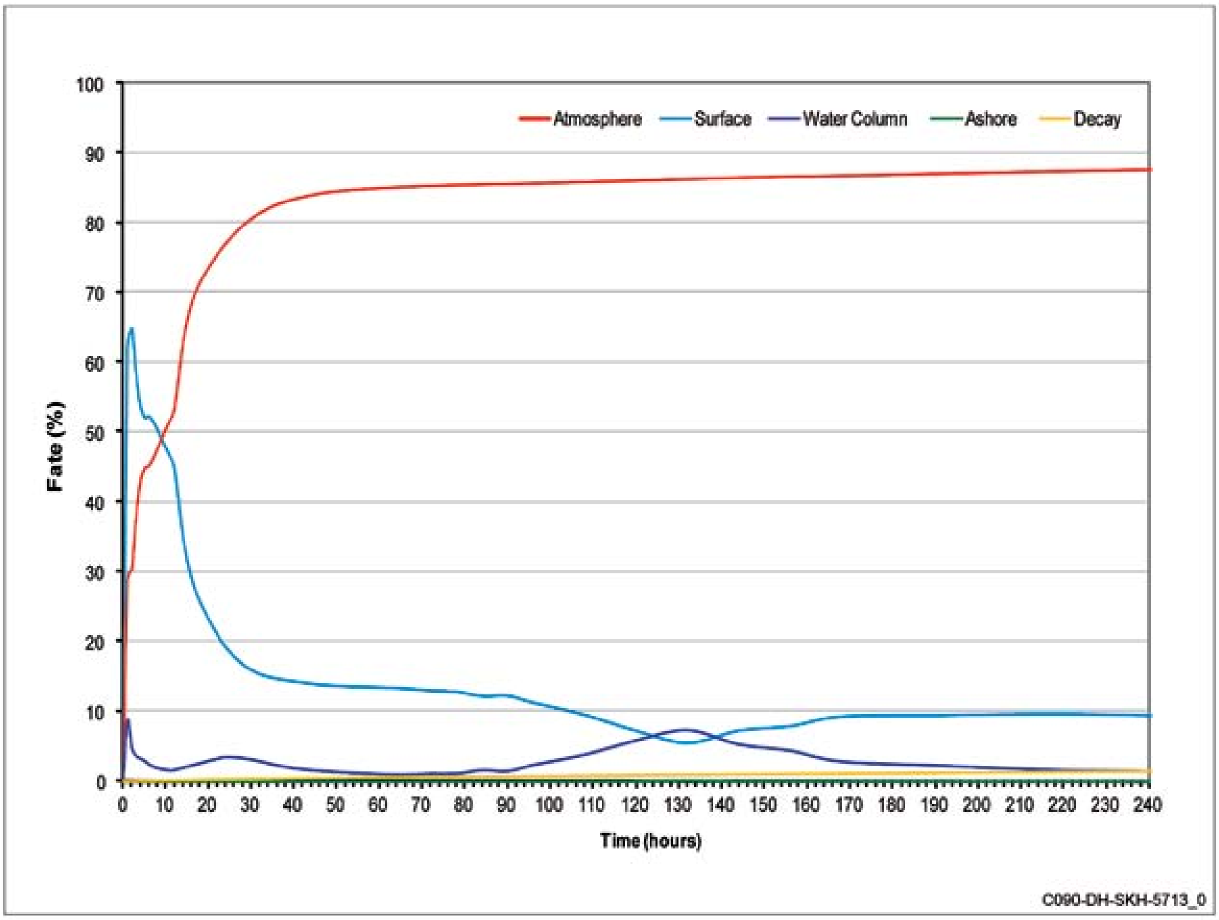

Figure 7-4: Predicted weathering and fates of a surface condensate release from the Ichthys Field

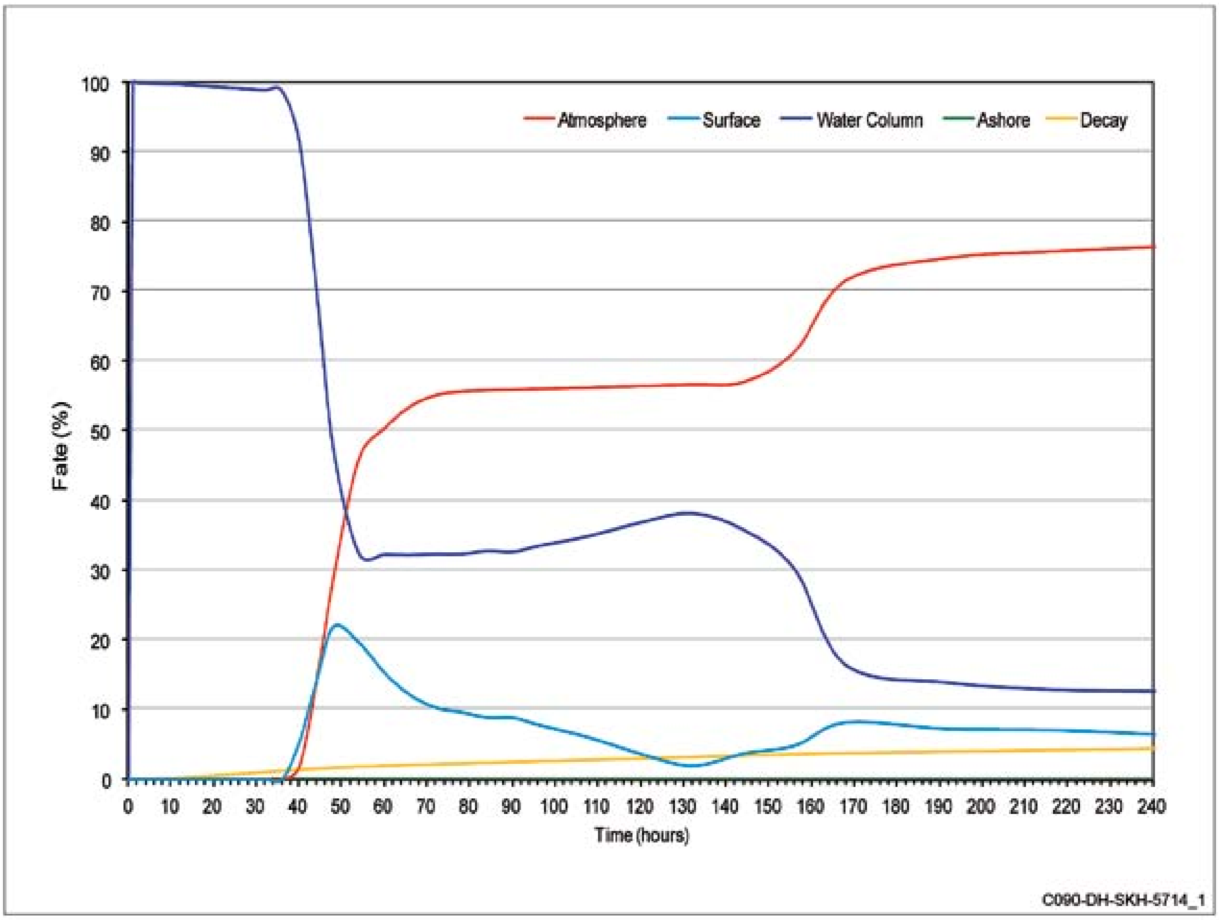

Figure 7-5: Predicted weathering and fates of a subsea condensate release from the Ichthys Field

remained entrained for up to 4 days and that the volatile components took up to 7 days to evaporate (Figure 7-5). About 40% of the mass was predicted to remain in the water column as fine droplets after this period.

Properties of diesel

Diesel fuels can be dispersed into the water column but, like condensates, are rapidly lost from the sea surface in most conditions prior to dispersion. For the purposes of predictive modelling of the weathering processes, diesel oil was characterised using the formulation of a commercial fuel and at a similar temperature to ambient conditions at the Browse Basin. This formulation has an initial API gravity of 37.6 (829.1 kg/m^3) and a viscosity of 4 cP (APASA 2009b).

Diesel is a mixture of volatile and semi-persistent hydrocarbons, with approximately 60–75% by mass predicted to evaporate over the first day or two depending upon the prevailing weather conditions. The remainder would not readily evaporate and the heavier components would tend to entrain as oil droplets into the upper water column in the presence of waves. This oil is not dissolved and can refloat to the surface if wave energies abate, and could be transported by near-surface currents (APASA 2009b).

Likelihood of spill occurrence

Accurate predictions of the source and frequency of hydrocarbon releases from oil and gas operations can be problematic. The usual method of predicting the frequency of an event occurring (known in oil-spill planning as the “primary risk”) is to consider the historical rate of occurrence worldwide and then extrapolate a similar rate into the future. The majority of these data sources are based on incident history for North Sea and European operations, where there are a number of large facilities and supporting infrastructure (e.g. pipelines and support vessels). This creates more chances for accidents involving third-party vessels (e.g. vessel collisions or anchor damage to pipelines and flowlines). The Australian offshore oil & gas industry has a relatively good performance record, and often operates in remote areas that are distant from heavy shipping traffic. Extrapolating historical data from the North Sea or Europe to predict the likelihood of spills from offshore Australian operations is therefore likely to provide particularly conservative estimates for some types of incidents (ERS 2009).

The infrastructure and activities to be undertaken in the offshore development area present a range of scenarios where a loss of containment of hydrocarbons could occur. An assessment of the likelihood of oil spills occurring was undertaken by Environmental Risk Solutions Pty Ltd (ERS) using frequency data for previous similar incidents that have occurred in the oil & gas industry worldwide.

The likelihood of a spill occurring is expressed on an annual basis—that is, the number of times per year that an incident of that type could occur. This generally results in very small numbers (e.g. 1×10^{-4}), and the order of magnitude is considered the most important component. That is, events with a likelihood of 1×10^{-2} would be considered “likely” to occur, particularly for a project several decades in duration. Events with a likelihood of 1×10^{-7} are considered to have a very remote chance of occurring, even during the life of a long project.

Nine potential spill scenarios were identified for the offshore development area; these are described in Table 7-17, along with the calculated likelihood of these events occurring. The volumes and durations of these spills are indicative only, and are considered reasonable estimates of the types of accidental spills that could occur, given the management controls that will be in place for the Project. All scenarios are relatively fixed in their location (e.g. a subsea flowline rupture can only occur within the Ichthys Field), with the exception of a refuelling spill during construction of the gas pipeline. While a spill at an indicative location has been modelled (*c*.300 km west of Darwin), a spill of this nature could occur at any position along the offshore pipeline route. Accordingly oil spill contingency planning will account for the potential for refuelling spills along the entire length of the pipeline route. Of the scenarios considered, there are four with likelihoods greater than 1×10^{-2}, relating to refuelling of vessels with diesel fuel or loading condensate into export tanker vessels. The least likely spill scenarios are subsea well failures and ruptures of transfer lines or flowlines between the offshore facilities.

The subsea well failure scenarios (7 and 8) represent accidental spill events similar to the uncontrolled well failure that occurred in August 2009 at the Montara field in the Timor Sea. As shown in Table 7-17, the likelihood of this type of event occurring is very low. Extensive management controls apply to drilling and control of subsea wells, as described below under *Prevention and management of accidental hydrocarbon spills*.

Predictive spill modelling

In order to predict whether hydrocarbons released during the potential spill scenarios could reach sensitive environmental receptors around the offshore development area, spill-trajectory modelling was undertaken by APASA (see Appendix 7). Trajectory modelling was based on current data generated by the oceanic circulation model HYDROMAP, which simulates the influence of astronomical tides, wind stress and bottom friction on ocean currents. Further detail on the development and validation of the oceanic hydrodynamic model is provided in Appendix 5.

Numerical spill simulations were carried out using a three-dimensional model known as the Spill Impact Mapping and Assessment Program (SIMAP), which accounts for weathering processes such as evaporation and spreading, as well as for seasonal climate effects. Simulations were developed for wet-season (October–February), dry-season (May–July), and transitional (March–April and August–September) conditions.

The prevailing winds during the wet and dry seasons influence the direction of spill movement. Westerly winds during the wet season push spills to the east, towards the Kimberley coast, while the dry season is characterised by easterly winds that push spills west to the open ocean and in the direction of Scott Reef and Seringapatam Reef.

Because of the strong influence of offshore winds, simulated spill trajectories were found to be highly variable. For that reason, 200 simulations were completed per season and scenario combination (i.e. 600 per scenario and 4200 in total) for the assessment. Model outputs therefore do not show the area affected by one individual spill, but show the combination of these multiple spill simulations.

The extent of offshore spills was assessed down to a threshold level of 1 g/m^2 (1 µm thickness), which corresponds with a dull yellow film or sheen on the water surface. Summaries of the modelled outcomes for surface slicks are presented in figures 7-6 to 7-12 for each of the spill scenarios in Table 7-17. These outcomes assume that no management controls (i.e. spill responses) are applied and therefore present the worst-case scenarios for hydrocarbon spread into the marine environment.

The movement of entrained oil and dissolved aromatics from subsea spills have also been modelled as part of this study. In general, plumes were predicted to reduce in concentration to less than 1 ppb within 15 km of the release point. These plumes would not reach the islands or reefs in the vicinity of the offshore development area. Full results are provided in Appendix 7.

Table 7-17: Potential hydrocarbon spills in the offshore development area and the likelihood of their occurrence

Scenario number	Description	Location	Scenario	Likelihood* (per annum)
1	Subsea flowline rupture	Ichthys Field near CPF	A flowline rupture occurs on the seabed (up to 250 m depth) between a cluster of wells and the CPF, between isolation valves. This releases pressurised gas and 100 m^3 of atomised condensate over a one-hour period.	4.9×10^{-5}
2	CPF diesel fuel leak	CPF	Either a CPF diesel storage tank overflows to sea or a diesel supply ship accident occurs. This releases 50 m^3 of diesel to the sea surface instantaneously.	4.9×10^{-2}
3	CPF–FPSO condensate transfer line rupture	Midway between CPF and FPSO	A rupture occurs in the condensate transfer line from the CPF to the FPSO. This transfer line contains condensate, water, MEG, and gas. In the worst case, a full-bore rupture of a 12-inch internal diameter transfer line up to 10 km long would release 730 m^3 of condensate at the seabed somewhere between the CPF and FPSO location, at a depth of up to 250 m and for a duration of 12 hours.	1.5×10^{-4}
4	Ship collision at FPSO	FPSO	An offtake tanker or other large ship collides with the FPSO. This releases 1000 m^3 of condensate to the sea surface at the FPSO location over 12 hours. The 1000 m^3 represents the partial loss of a single cargo storage tank from an export ship or the FPSO as a result of the collision.	3.0×10^{-4}
5	FPSO condensate hose rupture	FPSO	A loading hose ruptures or a hose coupling fails when the FPSO is loading condensate into an offtake tanker. This releases 30 m^3 of condensate to the sea surface instantaneously.	4.9×10^{-2}
6	Refuelling spill during construction	Ichthys Field near CPF	A spill occurs during the refuelling of a construction barge near the CPF and FPSO locations. This releases 2.5 m^3 of diesel to the sea surface instantaneously.	4.9×10^{-2}
6a	Refuelling spill during construction (pipeline)	Along gas export pipeline route, *c.*300 km west of Darwin	A spill occurs during the refuelling of a pipeline construction barge in the Timor Sea *c.*300 km west of Darwin. This releases 2.5 m^3 of diesel to the sea surface instantaneously.	4.9×10^{-2}
7	Subsea well failure during development drilling	Ichthys Field	Control of a subsea well is lost during the initial drilling operation inside the retention lease at the Ichthys Field. This causes an uncontrolled release of gas and condensate at the seabed at a flow rate in the order of 4000 barrels of condensate per day.	9.2×10^{-5} per well drilled
8	Subsea well failure during production	Ichthys Field	Control of a subsea well is lost during the production phase inside the retention lease at the Ichthys Field. This causes an uncontrolled release of gas and condensate at the seabed at a flow rate in the order of 4000 barrels of condensate per day.	5.0×10^{-6}

Note: The scenario numbers here are continued in Table 7-35, which contains the primary risk assessment for the nearshore development area.

* Primary risk (ERS 2009).

Spill modelling has not been included for the longer-term subsea well failure scenarios because of their very low likelihood of occurrence (Table 7-17). If a subsea well failure were to occur, spill-trajectory modelling would be undertaken at that time for current weather conditions and spill flow rates, to guide response efforts as part of the Project's oil-spill contingency plan.

Scenario 1—Subsea flowline rupture

Simulations of this scenario indicated that the condensate would rise towards the surface over time. The larger droplets would surface relatively quickly (less than 1 hour), generating thin slicks and sheens close to the release location, while the smaller droplets would rise to the surface more slowly and would drift with the prevailing currents.

During wet-season conditions, slicks would drift east and there is a slight chance (<10% probability) that surface oil could reach the waters around Browse Island and even some areas of the Kimberley coast (Figure 7-6). The probability of shoreline exposure above the 1 g/m^2 threshold level is 9%, with a maximum of 3 m^3 of oil (3% of the initial spill volume) predicted to reach the shore.

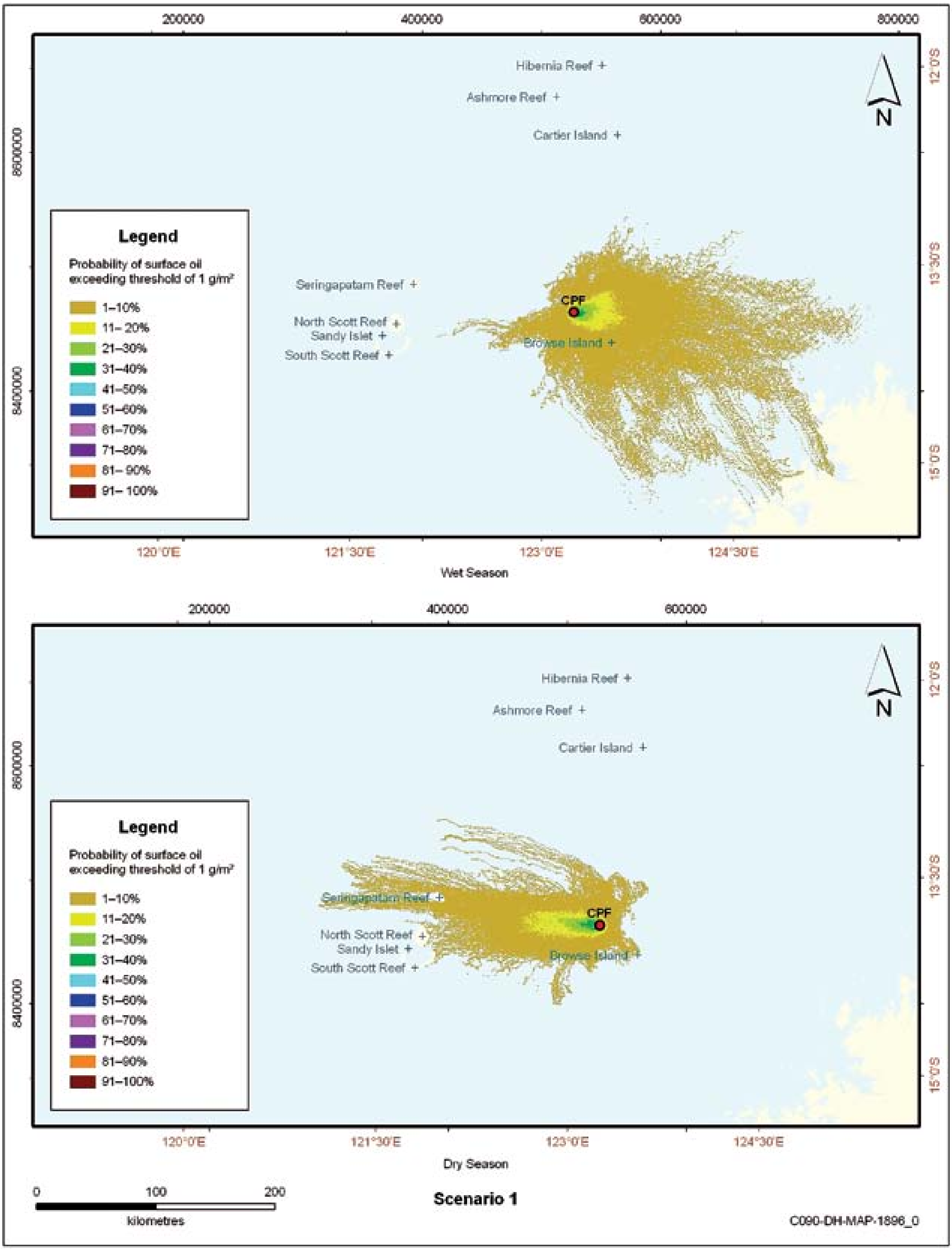

Figure 7-6: Scenario 1—subsea flowline rupture: simulated oil-spill trajectories for 100 m³ of condensate

During the dry season slicks would drift west towards Seringapatam Reef and North Scott Reef. However, because of the distance to these reefs (*c.*130 km) and the highly evaporative nature of the condensate, only a small percentage (≤1% or 1 m³) of the spill volume is expected to arrive at shore, with a 6% probability. Spills would take around 145 hours to reach any shoreline under these conditions (APASA 2009b).

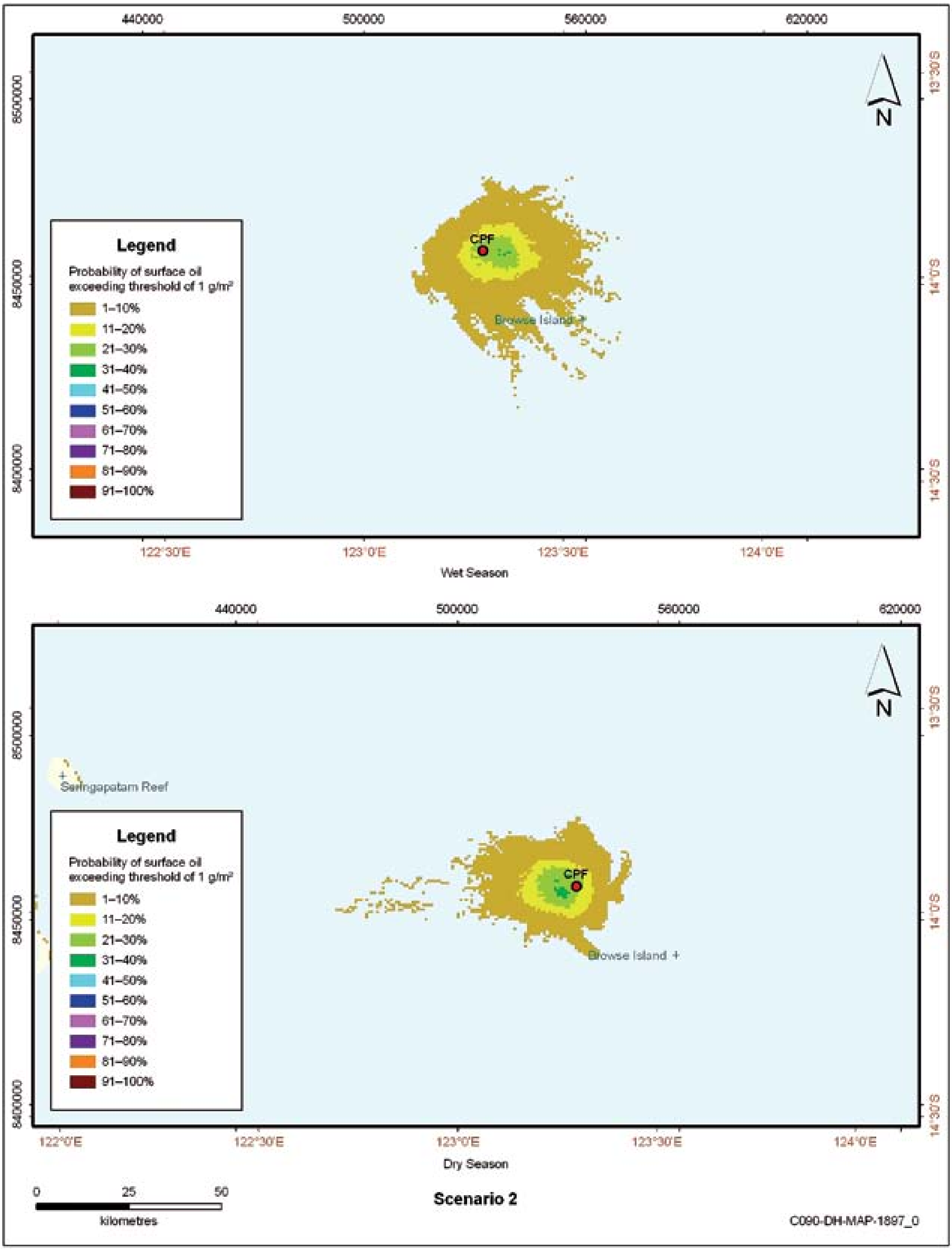

Figure 7-7: Scenario 2—CPF diesel fuel leak: simulated oil-spill trajectories for 50 m³ of diesel

Scenario 2—CPF diesel fuel leak

Spills for this scenario would travel relatively short distances, with very little probability (<1%) of exposure to shorelines at Browse Island during any season. Wet- and dry-season simulations of this scenario are presented in Figure 7-7 (APASA 2009b). The long distance to shorelines is a mitigating factor that reduces the potential environmental impacts of this spill scenario.

7 Marine Impacts and Management

Scenario 3—CPF–FPSO condensate transfer line rupture

Simulations of this scenario indicate that some condensate would surface rapidly (seconds to minutes) through entrainment by the rapidly rising gas bubbles. A larger proportion would form a subsurface plume of entrained droplets that would migrate with the prevailing currents while continuing to surface. The condensate would undergo rapid loss of its most volatile compounds over the first 3–4 hours of surfacing. Evaporation rates would then decrease over the next 20 hours as the condensate weathers to leave less volatile components (APASA 2009b).

In wet-season conditions surface slicks would drift eastward, with the potential for low concentrations of weathered condensate to reach Browse Island or the mainland (Figure 7-8). The highest load of residual condensate predicted for the shoreline of Browse Island was 2.5% of the original spill volume (18 m^3).

Browse Island is not predicted to be exposed to this spill in dry-season conditions, with surface slicks consistently predicted to drift towards the west (Figure 7-8). The Scott Reef group could be exposed at some point (22% probability), with first shoreline exposure within 127 hours of the initial release. The highest expected load received at a shoreline is estimated to be 2.8% (20 m^3) of the initial spill volume (APASA 2009b).

Scenario 4—Ship collision at FPSO

This surface condensate spill will initially form a slick that will spread under the influence of gravity and surface tension as well as of prevailing currents and wind. Evaporation of volatile components would be the primary weathering process in this scenario because of the large surface area exposed to air.

Wind conditions sufficiently strong to generate breaking waves would increase the proportion of the condensate that would entrain over time. Entrained oil will resurface when weather conditions and seas return to a calm state. The spill model accounted for these processes in calculating the fate of slicks under varying conditions.

During wet-season conditions the surface slick caused by the spill would spread mainly eastwards (Figure 7-9), with a 31.5% probability of condensate reaching some point of the shoreline on Browse Island after 16 hours. There is also a chance (2% probability) of exposure of mainland shores under these conditions. The maximum predicted volume of oil arriving at shore is 5.7% of the initial spill volume, or 57 m^3 (APASA 2009b).

In dry-season conditions, the spill would move to the west (Figure 7-9) with a 38% probability of shoreline exposure at some point on Scott Reef or Seringapatam Reef after 112 hours. A maximum of 8% of the initial spill volume (80 m^3) could reach shores under these conditions (APASA 2009b).

Scenario 5—FPSO condensate hose rupture

This type of spill would remain in a localised area, with surface slicks decreasing to below the threshold concentration within 30 km of the FPSO because of a combination of spreading, evaporation and entrainment (APASA 2009b). Exposure of shorelines at nearby islands and reefs is not expected. The predicted movement of this spill in wet- and dry-season conditions is presented in Figure 7-10.

Scenario 6—Refuelling spill during construction (at the Ichthys Field)

This spill involves a relatively small volume of diesel fuel (2.5 m^3) and is expected to form a localised slick that would not cause exposure to islands and reefs in the area. The predicted movement of this spill in wet- and dry-season conditions is presented in Figure 7-11. There may be patches of diesel visible at the surface within 15 km of the release site because of the relatively high evaporation and spreading rates for diesel oil in combination with the wind and current conditions. The spill would disperse to a silvery sheen within one or two days (APASA 2009b).

Scenario 6a—Refuelling spill during construction (along the pipeline route)

In similar fashion to Scenario 6, this spill involves a relatively small volume of diesel fuel (2.5 m^3) and would form only a localised surface slick. This would spread and evaporate very quickly upon release and would rapidly diminish below threshold limits. The predicted movement of this spill in wet- and dry-season conditions is presented in Figure 7-12. No exposure to surface oil would be expected within a 5-km radius of the release site (APASA 2009b). Shorelines and submerged reefs along the greater part of the pipeline route would remain unaffected by this type of spill from construction vessels.

Likelihood of spills affecting shorelines

The likelihood of a hydrocarbon spill reaching a particular area of environmental concern, such as a sensitive shoreline habitat is known as the “secondary risk”. This is derived by multiplying the likelihood of the spill occurring (the primary risk) by the probability of the spill moving towards sensitive areas, as shown by spill-trajectory modelling.

Large hydrocarbon spills from the offshore development area (i.e. scenarios 1, 3 and 4, as well as longer-term well-failure scenarios 7 and 8) are predicted to reach some point on the shorelines of Browse Island, Seringapatam Reef, Scott Reef and the Western Australian Kimberley coast. Spills from Scenario 2 are predicted to have a very low probability of reaching Browse Island during the wet season only. Spills from refuelling along the greater part of the pipeline route (e.g. Scenario 6a) will not affect shorelines.

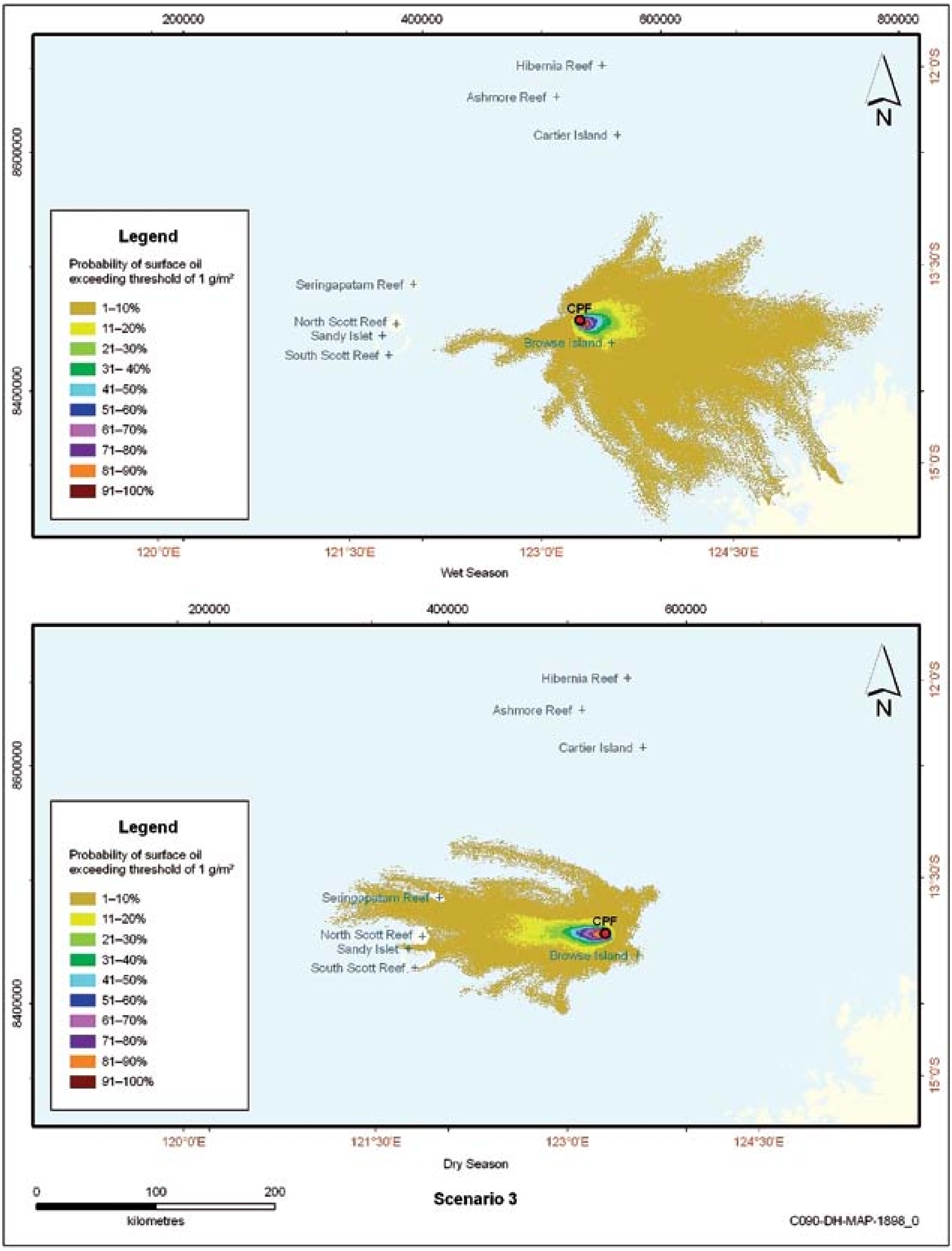

Figure 7-8: Scenario 3: CPF–FPSO condensate transfer line rupture—simulated oil-spill trajectories for 730 m³ of condensate

The remaining smaller-spill scenarios (5 and 6) are not predicted to reach any shoreline at all.

The secondary risks of impacts to sensitive marine habitats as a result of spills from the offshore development area are provided in Table 7-18.

These levels of risk (or "frequency" of an oil pollution event occurring) are considered to be very low and would be further reduced by the spill prevention and response controls to be implemented at the offshore development area.

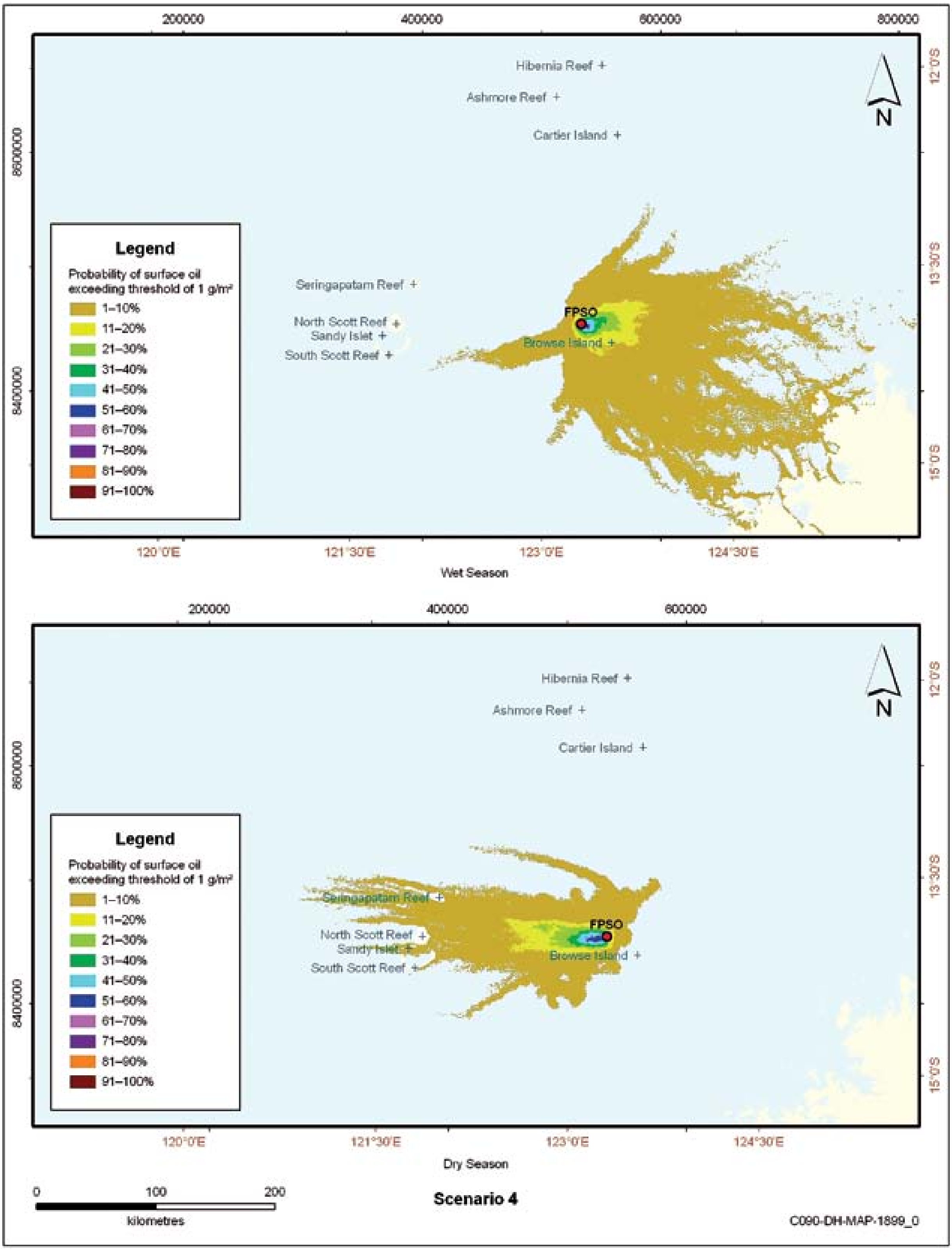

Figure 7-9: Scenario 4: ship collision at FPSO—simulated oil-spill trajectories for 1000 m³ of condensate

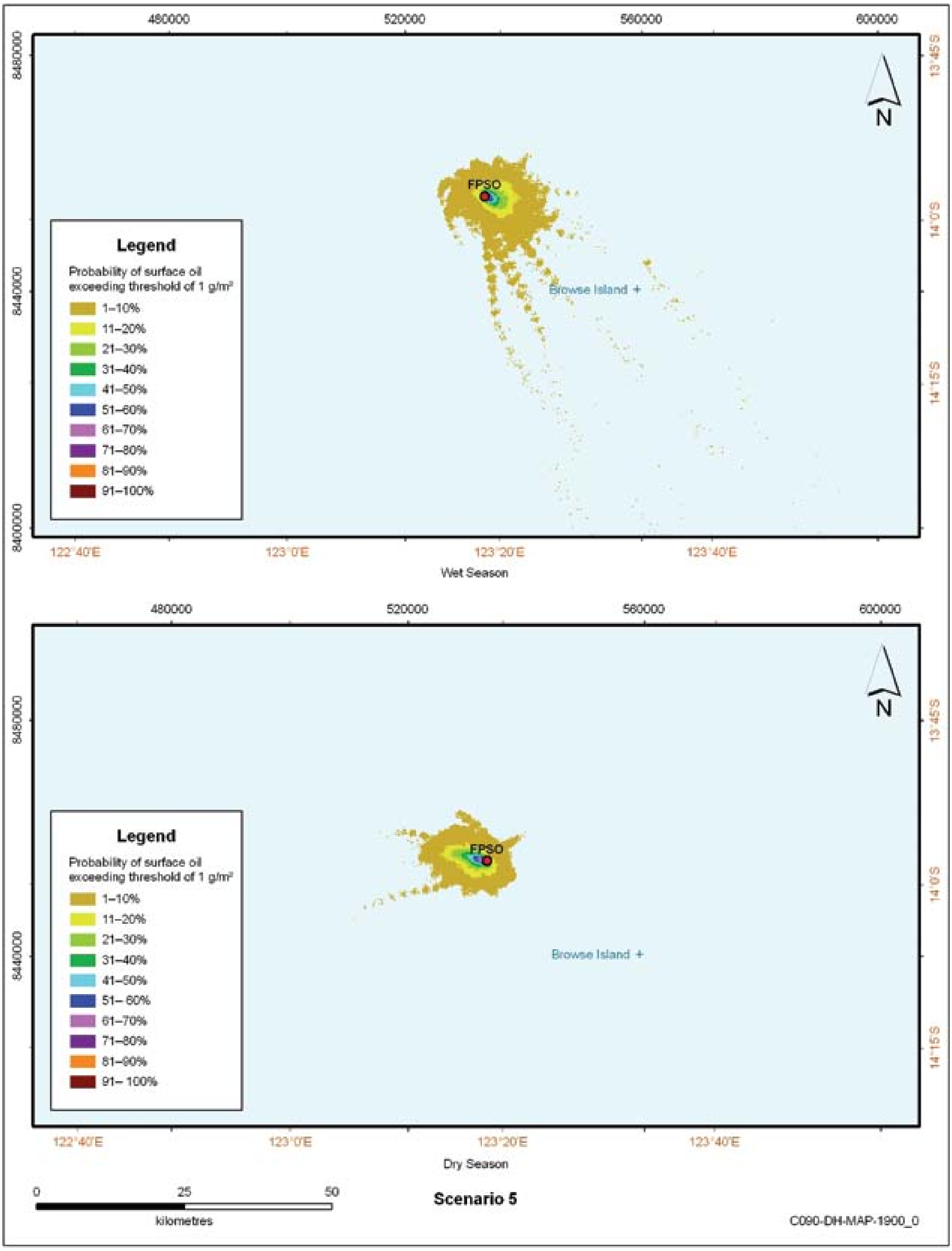

Figure 7-10: Scenario 5: FPSO condensate hose rupture—simulated oil-spill trajectories for 30 m³ of condensate

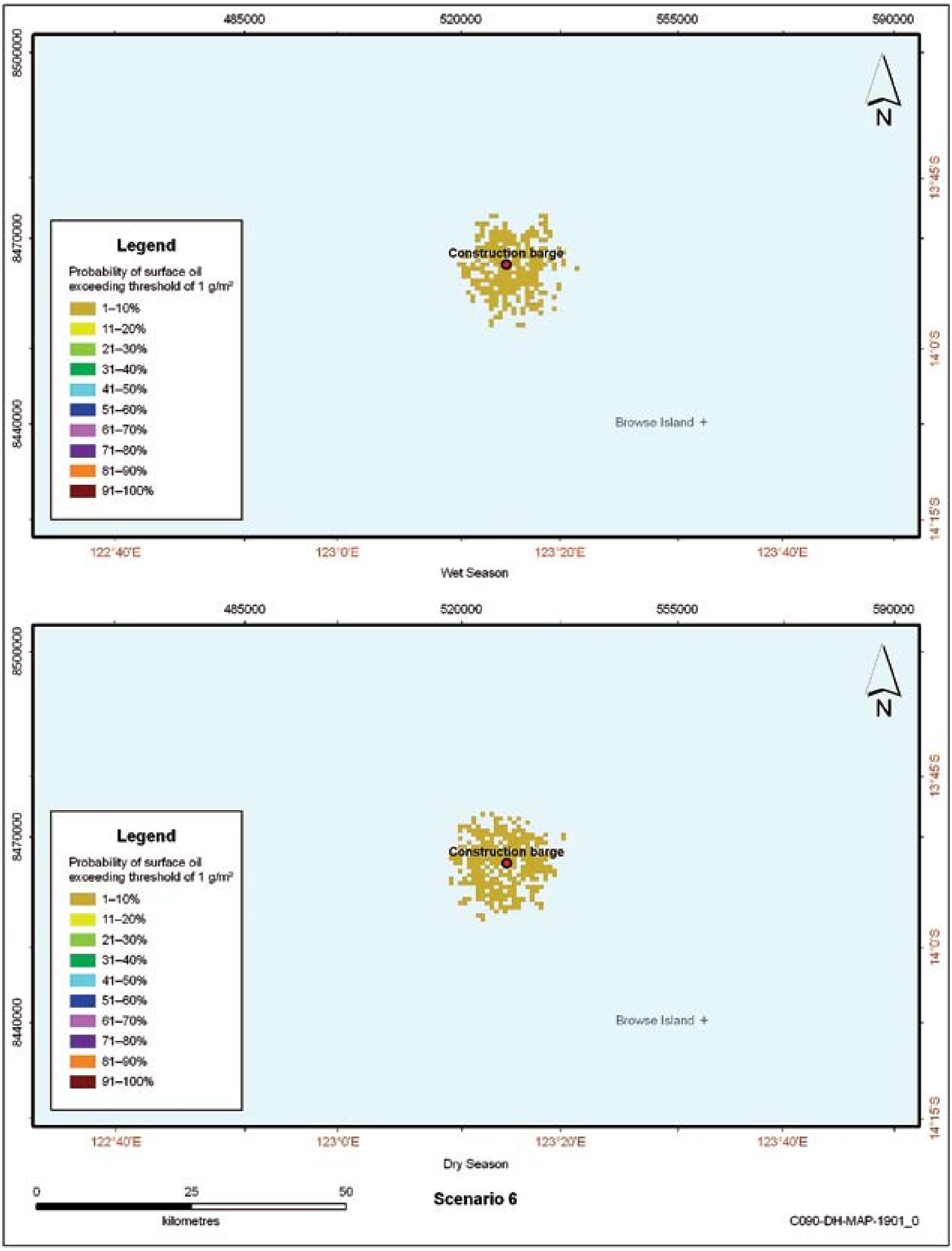

Figure 7-11: Scenario 6: refuelling spill during construction at the Ichthys Field—simulated oil-spill trajectories for 2.5 m³ of diesel

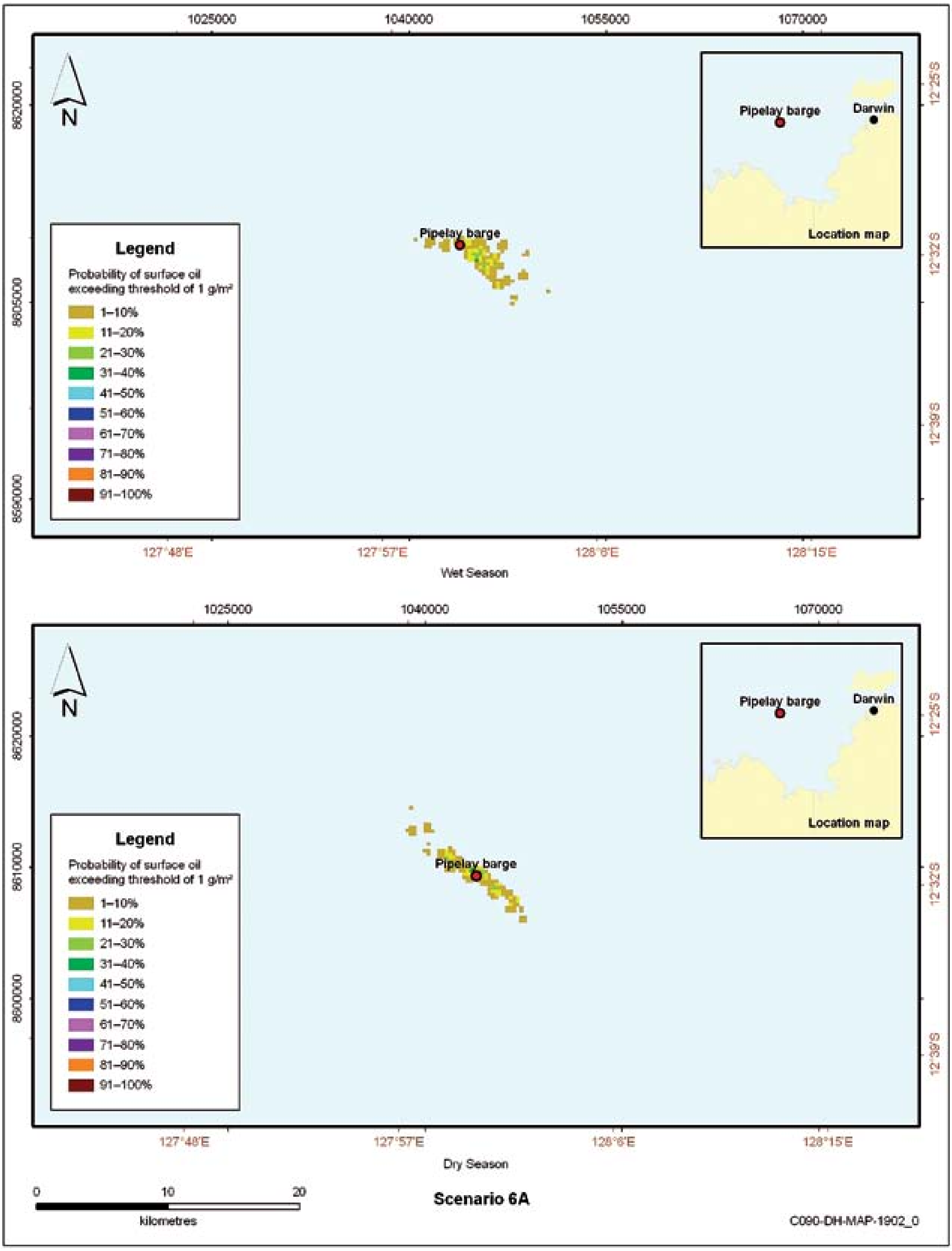

Figure 7-12: Scenario 6a: refuelling spill during construction along the pipeline route—simulated oil-spill trajectories for 2.5 m³ of diesel

Table 7-18: Likelihood of hydrocarbon spills from the offshore development area reaching sensitive shorelines

Scenario	Name	Primary risk (per year)	Secondary risk (per year)	
			Wet season	Dry season
1	Subsea flowline rupture	4.9×10^{-5}	1.84×10^{-6}	4.90×10^{-7}
2	CPF diesel fuel leak	4.9×10^{-2}	4.9×10^{-4}	None
3	CPF–FPSO condensate transfer line rupture	1.5×10^{-4}	2.57×10^{-5}	5.79×10^{-6}
4	Ship collision at FPSO	3.0×10^{-4}	4.50×10^{-5}	1.90×10^{-5}
5	FPSO condensate hose rupture	4.9×10^{-2}	None	None
6	Refuelling spill during construction (field)	4.9×10^{-2}	None	None
6a	Refuelling spill during construction (pipeline)	4.9×10^{-2}	None	None
7	Subsea well failure during development drilling	9.2×10^{-5} per well drilled	9.2×10^{-5} per well drilled	1.8×10^{-5} per well drilled
8	Subsea well failure during production	5.0×10^{-6}	5.0×10^{-6}	1.0×10^{-6}

Deck drainage

Discharges of deck drainage, both directly overboard and from oily-water separators, are likely to contain low volumes of contaminants that will disperse quickly into the marine environment without having toxic effects on the local marine biota. In the context of the offshore marine environment at the Ichthys Field and along the pipeline route, this liquid discharge is considered to pose negligible potential impact, particularly given the strong current regimes and water depths in the area.

Potential impacts of hydrocarbon spills

Research undertaken to evaluate the effect of oil on marine biota can be broadly separated into three main types:

- controlled laboratory studies to determine the acute, and less commonly the chronic, toxicity of specific hydrocarbon compounds (this type of study is by far the most common)
- controlled experiments that have been carried out in field or artificial field situations to study the effect on aspects of the marine environment
- opportunistic studies of accidental oil spills.

In addition to these relatively established fields of study there are also emerging fields of study into the potential endocrine disruptor effects of hydrocarbons and the development of biophysical models to predict impacts across a range of trophic levels (e.g. Gin et al. 2001). As yet there are very few data from which conclusions can be drawn regarding hydrocarbons as endocrine disruptor chemicals in the marine environment.

Several researchers have put forward models that integrate physico-chemical processes with biological uptake mechanisms to predict impacts on the marine environment (Volkman et al. 1994). These models, however, were considered to be of limited assistance to this risk assessment because they are either restricted to predicting the effect on a single key organism group, usually fisheries-biased, or they are still in their formative stages. Consequently biophysical models have not been used in this risk assessment.

Sources of effect

Hydrocarbons spilled to the marine environment have the potential to cause significant threats to marine life. Direct mortality can occur through toxic effects, physical coating and even asphyxiation. Sublethal effects can occur through the disruption of physiological or behavioural processes. Community-level changes can occur through mechanisms such as changes to habitat characteristics or the alteration of species interactions. Each of these sources of effect is summarised briefly in the following sections and considered in the assessment of impact to the identified sensitive community types.

Descriptions of toxicity refer to the inherent potential of a material to cause adverse effects in a living organism. The two basic types of toxicity are acute and chronic. Acute responses have a sudden onset after or during relatively high exposure that is often of short duration (typically 4–7 days). The end point can be lethal or non-lethal. A chronic response, involving end points that are realised over periods of several weeks to years, may be caused by relatively low exposures occurring over a long time. A chronic toxic response is usually characterised by slow toxic progress and long continuance.

As described in Section 7.2.3 *Liquid discharges*, it is important to distinguish between the "exposure" and the "dose" of a toxic substance received by an organism. Exposure relates to the amount or concentration of the substance in the surrounding environment, while the dose is the actual amount of the toxic substance that enters the organism and is specifically associated with the toxic response.

A very large number of studies have been published describing the toxicities of crude oils and hydrocarbon compounds. The common theme in the findings of these is that the observed toxicity of crude and refined oils is primarily attributable to volatile and water-soluble aromatic hydrocarbons (benzenes, naphthalenes and phenanthrenes) and the polycyclic aromatic hydrocarbons of higher molecular weight.

The most toxic components in oil, although having the highest solubility in water, tend to be those that are lost most rapidly through evaporation when oil is spilled. Because of this, lethal concentrations of toxic components leading to large-scale mortalities of marine life are relatively rare, localised, and short-lived, and only likely to be associated with spills of light refined products or fresh crude. At particular risk are animals and plants living in areas of poor water exchange or where special conditions, such as the incorporation of fresh oil into stable sediments, cause high concentrations of the toxic components to persist for a longer period than normal.

The sublethal effects of hydrocarbons in impairing the ability of individual marine organisms to reproduce, grow, feed or perform other functions have been demonstrated experimentally by numerous controlled laboratory studies and a smaller number of controlled field studies. The interpretation of these laboratory results is somewhat problematic because of the difficulties associated with relating what effect the loss of a small portion of embryos and larvae would have on a species' population. Long-term mesocosm[4] experiments, which more closely approximate "real world" conditions, have demonstrated marked reduction in copepod populations after chronic exposure to concentrations as low as 15 µg/L oil in water. Oviatt et al. (1982) found that No. 2 fuel oil had a significant effect on phytoplankton and zooplankton community structure at concentrations as low as 100 µg/L. More recent studies investigating developmental effects have demonstrated adverse toxic effects on salmon and herring embryos and larvae from chronic exposure to concentrations of oil in water of 1 µg/L (Carls, Rice & Hose 1999).

The toxicity of the condensate solution to the bioluminescent marine bacterium *Vibrio fischeri* was assessed using a Microtox® assay, which determines the concentration of weathered condensate required to affect 50% of the bacteria population.

4 A "mesocosm" in this context is an enclosed experimental ecosystem in which the fate and effects of oil on individual organisms or populations can be studied and evaluated.

Microtox® is a standardised toxicity test system used as a primary screening test for toxicants over time. As shown in Table 7-19, condensate from the Ichthys Field can be considered moderately toxic to the bacterium during the first 24 hours of a spill to the marine environment and decreases to non-toxic during the second day and onwards (Geotechnical Services 2007b).

Table 7-19: Microtoxicity ratings obtained from weathering tests on Ichthys Field condensate using the bacterium *Vibrio fischeri*

Time (hours)	EC_{50}* (%)	Microtoxicity rating
1	43.3	Moderately toxic
2	73.5	Non-toxic
4	65.9	Non-toxic
8	58.7	Moderately toxic
24	51.3	Moderately toxic
48	63.9	Non-toxic
72	>100	Non-toxic
96	>100	Non-toxic

Source: Geotechnical Services 2007b.

* The notation EC_{50} stands for "effect concentration 50%". It is the concentration of a substance that results in 50% less growth, fecundity, germination, etc., in a population. In ecology it is used as a measure of a substance's ecotoxicity but, unlike the LC_{50} which measures lethality, the EC_{50} value measures sublethality—it demonstrates the adverse effects of a substance on a test organism such as changes in its behaviour or physiology. In the case of *Vibrio fischeri* the EC_{50} is measured as the concentration producing a 50% reduction in bioluminescence. The concentration is measured as a percentage of the water fraction.

In addition, the toxicity to marine biota of 1-hour and 24-hour weathered samples of Ichthys condensate have been assessed for five marine species: (larval) pink snapper (*Pagrus auratus*), rock oyster (*Saccostrea commercialis*), brown kelp (*Ecklonia radiata*), phytoplankton (*Isochrysis galbana*), and the marine bacterium *Vibrio fischeri* that is used in the Microtox® screening test. As shown in Table 7-20, pink snapper are relatively sensitive to the weathered condensate, tolerating only low concentrations in surrounding waters (e.g. 5.7% after 24 hours of weathering). The brown kelp was able to tolerate the condensate, with no observable effects, in both the 1-hour and 24-hour weathered solutions.

Toxicity testing undertaken by various organisations has identified diesel as being toxic to a variety of marine species. The typical range of reported toxic concentrations (LC_{50}, EC_{50} and IC_{50}[5]) varies from

5 The notation IC_{50} stands for "inhibition concentration 50%". The IC_{50} value is the concentration of a substance that causes an inhibition of growth of 50% in a population of a target species when compared with controls.

Table 7-20: Ecotoxicity of the water-accommodated fraction for 1-hour and 24-hour weathered Ichthys condensate

Test	Weathered	EC_{50}* (%)	EC_{10}† (%)	LOEC‡ (%)	NOEC§ (%)
Microtox screening test (*Vibrio fischeri*)	1 hour	31.5	0.5	6.25	<6.25
	24 hour	38.2	0.9	6.25	<6.25
Phytoplankton (*Isochrysis galbana*)	1 hour	>83.3	>83.3	>83.3	>83.3
	24 hour	>83.3	34.4	41.7	20.8
Brown kelp (*Ecklonia radiata*)	1 hour	>100	>100	>100	100
	24 hour	>100	>100	>100	100
Rock oyster (*Saccostrea commercialis*)#	1 hour	32.0	24.3	50	25
	24 hour	33.8	26.7	50	25
Pink snapper (*Pagrus auratus*) (larval)	1 hour	14.7	10.1	1.25	0.63
	24 hour	5.6	3.9	5	2.5

Source: Geotechnical Services 2007a.

Note: All concentrations are presented as a percentage of the water fraction.

* EC_{50} (%) = "effect concentration 50%"—the concentration that causes a 50% reduction in growth, fecundity or germination (not lethality) in the test population.

† EC_{10} (%) = "effect concentration 10%"—the concentration that causes a 10% reduction in growth, fecundity or germination (not lethality) in the test population.

‡ LOEC (%) = "lowest-observable-effect concentration"—the lowest concentration that causes an observable effect in the test population.

§ NOEC (%) = "no-observable-effect concentration"—the highest concentration at which there is no observable effect in the test population.

\# Also known as *Saccostrea glomerata*.

approximately 3 to 80 mg/L. Diesel fuel appears to retain its toxicity during weathering because of the slow loss of light ends. In addition, the additives used to improve certain properties of diesel (e.g. ignition quality and cold flow improvers) contribute to its toxicity.

Effects on marine biota

Plankton

As a consequence of their presence close to the water surface, plankton may be exposed to spilt oil, especially in high-energy seas where the vertical dispersion of oil through the water column would be enhanced. Usually the eggs, larval and juvenile stages of plankton are more susceptible to oil pollution than the adults (Harrison 1999). Measures of the toxicity of the water-accommodated fraction of Ichthys condensate to phytoplankton indicate that the range for inhibiting 50% of the population is in the order of 6.5–65.0 g/L.

Plankton reproduce rapidly and natural populations would be widely dispersed throughout the offshore marine environment. Therefore accidental spills of hydrocarbons in the offshore development area are likely to have only temporary and minor effects on plankton populations.

Cetaceans

Cetaceans would be exposed to spilt oil when they surface to breathe, which may cause damage to their respiratory and nervous systems. Oil could also be ingested by cetaceans with potentially toxic effects. However, short-term inhalation of petroleum vapours at concentrations similar to those found in oceanic oil spills may not be necessarily detrimental. Cetaceans are not vulnerable to the physical effects of oiling as oils tend not to stick to their skin or affect insulation.

Blue whales and humpback whales (baleen whales) that may filter-feed near the surface would be more likely to ingest oil than gulp feeders or toothed whales and dolphins. While humpback whales have been observed feeding in the offshore development area on two occasions (see Chapter 3), the area is not considered a frequently used or critical feeding ground for this species. Vessel-based surveys of the Browse Basin area by the Centre for Whale Research (Western Australia) Inc. between June and November 2008 recorded low numbers of whales in a broad survey area, with average densities of 0.00013 large cetaceans per square kilometre. Dolphins were sighted more frequently, but still at low densities of 0.026 small cetaceans per square kilometre (Jenner, Jenner & Pirzl 2009). At these sparse distribution levels, any accidental spills from the offshore development area would not cause significant impacts to regional cetacean populations.

Experiments on bottlenose dolphins found that this species was able to detect and actively avoid a surface slick after a few brief contacts and that there were no observed adverse effects of the brief contacts with the slick (Smith, Geraci & St. Aubin 1983). It is not known if other marine mammals are able to similarly detect and avoid oil slicks. It has been observed in some oil-spill incidents that dolphins have detected oil and avoided it, but at other times have not done so and have been exposed to floating oil (Geraci & St. Aubin 1990). The strong attraction to specific areas for breeding or feeding may override any tendency for cetaceans to avoid the noxious presence of oil.

Turtles and sea snakes

There is little documented evidence of the effect of oil on turtles; they are, however considered to be vulnerable to oil spills at all stages of life. Should turtles make contact with a spill the impact is likely to include oiling of the body as well as irritations caused by contact with eyes, nasal and other body cavities and possibly ingestion or inhalation of toxic vapours. The effects of weathered oil on adult turtles include increased white blood cell count, sloughing of skin (particularly around the neck and flippers) and improper salt-gland function (Lutcavage et al. 1997).

Green turtles inhabit nearshore waters at Browse Island, Seringapatam Reef and Scott Reef, and the Kimberley coast. They nest from December to March, with peak hatchling emergence occurring during March. Flatback turtles also nest in Kimberley coastal areas, with peak nesting between November and February (see Appendix 4). Five of the eight oil-spill scenarios at the offshore development area could result in surface slicks and shoreline exposure in these areas. Of these, the ship-collision scenario (4) and the longer-term well failure scenarios (7 and 8) could cause substantial volumes of oil to reach shoreline habitats. In the highly unlikely event that these situations should occur, turtles in the local area might be affected by hydrocarbon toxicity, particularly if the spill were to coincide with the nesting season and hatchling emergence.

Seasnakes are known to occur in the offshore development area, but no information is available regarding the susceptibility or sensitivity of seasnakes to oil spills. They surface to breathe and would therefore be vulnerable to exposure to spilt oil.

Vessel-based surveys by the Centre for Whale Research recorded turtles and seasnakes in offshore waters in the Browse Basin very infrequently, that is, only 8 turtles and 21 seasnakes over a total survey area of 8126 km^2 (Jenner, Jenner & Pirzl 2009).

Fish

The impacts of exposure to hydrocarbons differ among the various life stages of fish (Volkman et al. 1994). The toxicity of dissolved hydrocarbons and dispersed oil to fish species has been the subject of a large number of laboratory studies. Generally, concentrations in the range of 0.1–0.4 µg/L have been shown to cause fish deaths in laboratory experiments (96-hour LC_{50}) for periods of continuous exposure, while a range of sublethal responses have been shown at concentrations down to about 0.01 µg/L.

Fish mortalities, however, are rarely observed to occur as a result of oil spills, especially in open waters. This has generally been attributed to the possibility that pelagic fish are able to detect and avoid waters underneath oil spills by swimming away from the affected area (Volkman et al. 1994). Where fish mortalities have been recorded as a result of these spills (for example from the groundings of the oil tanker *Amoco Cadiz* in Brittany in 1978 and the oil barge *Florida* in Massachusetts in1969) they have occurred in sheltered bays with limited water exchange, which is quite a different situation from the marine environment in the Ichthys Project's offshore development area.

Seabirds

The effects of oil spills on seabirds vary depending on the nature of the spill, the bird species and climatic conditions. Bird feathers trap a layer of air both within the feathers and between the feathers and skin, which acts to insulate the bird's body. The feathers maintain their shape by interlocking barbules that help to shed water in droplets. Oil contamination of bird plumage removes these water-repellent properties and results in the loss of thermal insulation. Birds then suffer the effects of chilling and hypothermia (which can lead to death) or may even suffer reduced buoyancy and drown (Volkman et al. 1994).

Ingestion of hydrocarbons, which may occur during feather-preening or by eating contaminated food or swallowing sea water, can cause toxic effects in seabirds or contribute to the development of abnormalities or decreased production and viability of eggs. Small quantities of fresh oil applied to the surface of eggs can kill the embryo and such deposits can be transferred by the parent bird (Volkman et al. 1994).

The offshore development area supports a low abundance of seabirds. A vessel-based survey of the Browse Basin by the Centre for Whale Research in 2008 recorded an average of 0.31 seabirds per square kilometre, with a tendency to record sightings closer to islands, for example Browse Island and Scott Reef. Browse Island, Seringapatam Reef and Scott Reef are not recognised as important habitat for seabirds, and spills that affect these areas are unlikely to result in a significant impact on seabird populations. However, Ashmore Reef and Cartier Island, as well as Roebuck Bay on the Kimberley coast, do support regionally significant populations of migratory birds and nesting seabirds. Oil-spill modelling for the scenarios described earlier in this section do not predict that hydrocarbons would reach Ashmore Reef or Cartier Island. Some of the larger-volume spills could reach the Kimberley coast in low concentrations during wet-season conditions, which corresponds with the period when migratory birds are present in the region. In these events, the volumes of oil reaching nearshore areas would be very low and would not be expected to cause widespread injury to birds.

Benthic communities

The intertidal benthic communities nearest to the Ichthys Field are located at Browse Island, approximately 33 km to the south-east. Similar communities also occur at Seringapatam Reef and Scott Reef which lie approximately 140 km to the west. Of the eight potential spill scenarios, six are predicted to result in shoreline exposure at Browse Island, although most have low secondary risk (see Table 7-18) and low concentrations because of long weathering and evaporation times. The benthic fauna of these areas is common throughout the region, although it is noted that Scott Reef harbours high coral-reef biodiversity (Done et al. 1994).

Most of the shorelines at these islands and reefs would be considered exposed and high-energy, contributing to a rapid recovery from any oil contamination event. Coral larvae, however, would be sensitive to hydrocarbon toxicity and if a large oil-spill event coincided with coral spawning, longer-term effects on coral recruitment might result. Done et al. (1994) suggest that Scott Reef forms a "stepping stone" for the dispersal of coral species from the Indonesian Arc to Rowley Shoals further south along the north-west continental shelf. Damage to coral larvae at Scott Reef could therefore impact coral recruitment over great distances. However, the extent to which the ecosystem at Rowley Shoals depends on replenishment from Scott Reef is not well known and the two areas may be primarily self-sufficient and self-seeding (Done et al. 1994).

Prevention and management of accidental hydrocarbon spills

Management of hydrocarbon spill risks in the offshore development area will be focused on preventing loss of containment through the following:

- providing facility integrity through initial design and shutdown systems
- preparing and implementing procedures for commissioning and operations (including cyclone procedures)
- ongoing maintenance, such as integrity testing of equipment and regular inspection of subsea equipment.

The *Offshore Petroleum and Greenhouse Gas Storage Act 2006* (Cwlth) requires that an accepted emergency response plan, which will include an oil-spill contingency plan (OSCP), must be in place before any offshore petroleum activities may commence. INPEX has already developed an OSCP that has been approved by Western Australia's Department of Mines and Petroleum to support exploration activities in the Ichthys Field. This OSCP aligns with the requirements and functions of state, territory and Commonwealth response plans[6]. The OSCP will be revised prior to the commencement of construction and submitted to the relevant authorities for approval; it will be periodically reviewed and updated through subsequent phases of the Project.

The OSCP for the Project will include the following:

- emergency procedures for notification and immediate response in the event of a spill
- definitions of the roles and responsibilities of personnel in the event of a spill response
- a description of procedures to deal with an oil spill
- a description of the external resources available for use in combating an oil spill and how these resources are to be coordinated
- a description of procedures for environmental monitoring in the event of a spill.

In addition, a well control manual will be maintained, providing guidance on the response required in the unlikely event of a subsea well failure.

Other industry-standard provisions will be implemented at the offshore development area in order to prevent a spill occurring. These will be incorporated into plans and procedures that are yet to be developed. The following design features and management measures and controls will be employed:

- Each component of the offshore development area, including the gas export pipeline, will be designed to meet the oceanic, climate and seismic conditions of the area.
- Industry-standard drilling practices and equipment will be used to drill the production wells at the Ichthys Field
  - Blow-out preventers (BOPs) will be in place for each well, capable of withstanding pressures higher than those likely to be encountered. A BOP is a large valve located at the subsea wellhead, which can be closed if overpressure

6 Western Australia: *Western Australian marine oil pollution emergency management plan*, administered by the State Marine Pollution Committee.

Northern Territory: *Northern Territory oil spill contingency plan*, administered by the Northern Territory (National Plan) Marine Pollution Management Committee.

Commonwealth: *National plan to combat pollution of the sea by oil and other noxious and hazardous substances*, administered by the Australian Maritime Safety Authority.

from an underground zone causes formation fluids such as oil or natural gas to enter the well bore and threaten the rig. By closing this valve (usually operated remotely by hydraulic actuators), the drilling crew can prevent explosive pressure release and thus regain control of the downhole pressure.
  - A measurement-while-drilling system will be used to measure well paths, true vertical depth, bottom-hole location and orientation of directional drilling systems, and to transmit information to the surface for real-time pore-pressure monitoring. (Note that INPEX has already successfully completed drilling for eight exploration wells in the Ichthys Field; these have provided valuable information on the reservoir pressures. Management plans for drilling and operations will be developed, which will include precautions against a range of accidental-spill scenarios.)
- Industry-standard subsea equipment such as wellheads and flowlines will be employed, together with industry-standard moorings for the CPF and FPSO. Subsea equipment will be reviewed for potential snagging and dropped object damage and appropriate measures will be taken.
- Stability and protection of the gas export pipeline will be achieved by the most appropriate construction techniques, such as the addition of concrete coating, burial of the pipeline below the seabed and, where necessary, the placement of rock berms or armouring over the pipeline.
- Hydrostatic testing of the gas export pipeline will be undertaken prior to the introduction of hydrocarbons to ensure that there are no leaks in the pipeline.
- A precautionary zone will be implemented for the gas export pipeline, in consultation with the regulatory authorities, and will be identified on navigation charts.
- Periodic internal inspections of the gas export pipeline will be undertaken to assess its integrity.
- Trading tankers will be subject to vetting procedures to ensure that vessels are acceptable for loading.
- Loading operations will be monitored by a terminal representative on board the condensate tanker.
- All valves and transfer lines will be checked for integrity before use and loading operations will be continuously monitored.
- A collision detection system will be in place for the CPF and FPSO.
- Stocks of absorbent material and appropriate spill-response equipment will be located on site. The offshore support vessels will also have oil-spill response capability. Regular emergency-response exercises will be carried out.
- INPEX will have the capability to initiate real-time oil-spill fate and trajectory modelling so that a spill can be monitored and responses optimised.

In the event of a spill of light oils at the offshore development area, the likely management response will be to monitor the spill and allow it to weather naturally. Dispersants may be applied, in consultation with relevant authorities, if the spill threatens sensitive environmental receptors. The potential for effective use of offshore containment and recovery equipment will be evaluated during detailed oil-spill contingency planning processes.

A number of management controls will be implemented to avoid or reduce the risk of spills during refuelling at sea. These are as follows:

- The CPF and FPSO design will include, for example, level devices and the careful location of overflows from tanks and drainage systems.
- The FPSO will be double-sided.
- There will be visual monitoring of hoses, couplings and the sea surface during refuelling operations.
- There will be a maintenance and inspection program for the offtake loading hoses.
- Radio contact between the support vessel and the rig will be maintained and collision prevention procedures will be put in place.
- Dry-break couplings and breakaway couplings will be used where available and practicable.

In the case of small-scale oil spills on deck, areas on the MODU, CPF and FPSO where spills are more likely to occur will have containment facilities (i.e. bunding) to prevent contamination of deck washdown and stormwater runoff. Treated deck drainage will be discharged according to the following regulations:

- Oil-in-water concentrations discharged from the CPF and FPSO (fixed facilities) will be limited to not greater than an average of 30 mg/L over any period of 24 hours in accordance with Regulation 29 of the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009 (Cwlth).
- Oil-in-water concentrations in bilge discharges from vessels will not exceed 15 mg/L in accordance with MARPOL 73/78 Annex I (IMO 1978) and the Marine Pollution Regulations (NT).

Residual risk

A summary of the potential impacts, management controls, and residual risk for accidental hydrocarbon spills is presented in Table 7-21. The “likelihood” ratings shown are derived from the quantitative assessments of primary and secondary risk presented above, and do not account for spill-response procedures, which would reduce the extent of spills. These risk ratings are therefore considered to be conservative and could be reduced further in the event of an actual spill. The risks of harm to the offshore marine environment are considered to be “medium” or “low”.

Table 7-21: Summary of impact assessment and residual risk for accidental hydrocarbon spills (offshore)

Aspect	Activity	Potential impacts	Management controls and mitigating factors	Residual risk*		
				C†	L‡	RR§
Accidental hydrocarbon spills	Scenario 1: Subsea flowline rupture at the Ichthys Field near CPF.	Exposure of large area of offshore waters to surface oil.	Facility integrity will be provided through initial design and shutdown systems. Industry standard equipment and procedures will be employed. Ongoing maintenance such as integrity testing and regular inspections will be carried out. Reviews of subsea equipment for snagging and dropped object damage. Spill-response equipment and procedures. Oil Spill Contingency Plan.	C (E1)	1	Medium
		Exposure of shorelines at Browse Island, Seringapatam Reef and Scott Reef to surface oil. Reduced growth of benthic communities.		D (B2)	1	Low
Accidental hydrocarbon spills	Scenario 2: CPF diesel fuel leak.	Exposure of moderate area of offshore waters to surface oil.	Facility integrity will be provided through initial design and shutdown systems. Ongoing maintenance such as integrity testing and regular inspections will be carried out. Spill-response equipment and procedures. Oil Spill Contingency Plan.	E (E1)	4	Medium
		Exposure of shorelines at Browse Island to surface oil. Reduced growth of benthic communities.		D (B2)	2	Medium
Accidental hydrocarbon spills	Scenario 3: CPF–FPSO transfer line rupture.	Exposure of large area of offshore waters to surface oil.	Facility integrity will be provided through initial design and shutdown systems. Industry standard equipment and procedures will be employed. Ongoing maintenance such as integrity testing and regular inspections will be carried out. Spill-response equipment and procedures. Oil Spill Contingency Plan.	C (E1)	2	Medium
		Low-level exposure of Browse Island, Seringapatam Reef and Scott Reef to surface oil. Reduced growth of benthic communities.		D (B2)	1	Low
Accidental hydrocarbon spills	Scenario 4: Ship collision at FPSO.	Exposure of large area of offshore waters to surface oil.	Radio contact between vessel and FPSO. Collision prevention procedures. Double-sided FPSO design. Spill-response equipment and procedures. Oil Spill Contingency Plan.	C (E1)	2	Medium
		Low-level exposure of Browse Island, Seringapatam Reef and Scott Reef to surface oil. Reduced growth of benthic communities.		D (B2)	1	Low

Table 7-21: Summary of impact assessment and residual risk for accidental hydrocarbon spills (offshore) (continued)

Aspect	Activity	Potential impacts	Management controls and mitigating factors	Residual risk*		
				C†	L‡	RR§
Accidental hydrocarbon spills	Scenario 5: FPSO condensate hose rupture.	Exposure of small to moderate areas of offshore waters to surface oil.	Maintenance and inspection program for condensate loading hose. Monitoring of loading operations by terminal representative on board the condensate tanker. All valves and transfer lines checked before use. Spill-response equipment and procedures. Oil Spill Contingency Plan.	F (B3)	4	Low
Accidental hydrocarbon spills	Scenario 6: Refuelling spill during construction at the Ichthys Field near the CPF.	Exposure of small areas of offshore waters to surface oil.	Visual monitoring of hoses, couplings and the sea surface during refuelling. Use of dry-break or breakaway couplings where practicable. Radio contact between vessels during refuelling. Spill-response equipment and procedures. Oil Spill Contingency Plan.	F (B3)	4	Low
Accidental hydrocarbon spills	Scenario 6a: Refuelling spill during construction along gas export pipeline route, *c.*300 km west of Darwin.	Exposure of small areas of offshore waters to surface oil.	Visual monitoring of hoses, couplings and the sea surface during refuelling. Use of dry-break or breakaway couplings where practicable. Radio contact between vessels during refuelling. Spill-response equipment and procedures. Oil Spill Contingency Plan.	F (B3)	4	Low
Accidental hydrocarbon spills	Scenario 7: Subsea well failure during development drilling.	Exposure of large areas of offshore waters to surface and entrained oil.	The installation of blow-out preventers on all subsea wells. Use of measurement-while-drilling techniques. Well control manual. Oil Spill Contingency Plan.	C (E1)	2	Medium
		Shoreline exposure at Browse Island, Seringapatam Reef and Scott Reef. Toxic effects on marine animals.		D (B2)	2	Medium
Accidental hydrocarbon spills	Scenario 8: Subsea well failure during production.	Exposure of large areas of offshore waters to surface and entrained oil.	The installation of blow-out preventers on all subsea wells. Well control manual. Oil Spill Contingency Plan.	C (E1)	1	Medium
		Shoreline exposure at Browse Island, Seringapatam Reef and Scott Reef. Toxic effects on marine animals.		D (B2)	1	Low

Table 7-21: Summary of impact assessment and residual risk for accidental hydrocarbon spills (offshore) (continued)

Aspect	Activity	Potential impacts	Management controls and mitigating factors	Residual risk*		
				C†	L‡	RR§
Deck drainage and stormwater runoff	Routine washdown of decks during operations and stormwater runoff.	Reduction in water quality caused by small quantities of oil, grease and detergents. Toxicity impacts to marine biota.	Containment of areas where small spills are more likely, and treatment of contaminated deck drainage prior to discharge. Oil-in-water concentrations will meet regulatory-authority requirements: • not greater than an average of 30 mg/L over any period of 24 hours from the FPSO and CPF • not more than 15 mg/L for the MODU and other vessels according to MARPOL 73/78 Annex I (IMO 1978) and the Marine Pollution Regulations (NT). Spill-response equipment and procedures. Provisional Liquid Discharges, Surface Water Runoff and Drainage Management Plan.	F (E1)	6	Low

* See Chapter 6 *Risk assessment methodology* for an explanation of the residual risk categories, codes, etc.

† C = consequence.

‡ L = likelihood.

§ RR = risk rating.

7.2.5 Waste

A variety of solid wastes will be produced at the offshore facilities during all phases of the Project. These are outlined in Chapter 5, and discussed in detail in this section. (Note that drill cuttings are discussed in Section 7.2.2.)

Scale

Low specific-activity scale may be present in waste generated during well-intervention work, surface equipment operation or maintenance and decommissioning. This scale may contain naturally occurring radioactive materials (NORMs).

Under certain conditions (high salinity, together with the presence of sulfates and/or carbonates together with calcium, barium and strontium) solid minerals (scales) will precipitate from produced water. The most common scales consist of barium sulfate ($BaSO_4$), strontium sulfate ($SrSO_4$) or calcium carbonate ($CaCO_3$). The most common places for scale to form are where there is a significant pressure drop or temperature change, or where two streams of different chemistry mix (e.g. one high in barium and low in sulfates, and the other low in barium and high in sulfates). Scale can precipitate in an oil production well, in associated subsea flowlines, in surface pipework, or in processing facilities.

When scale precipitates from produced water, the radium in the water will sometimes be concentrated into the solid scale at concentrations much higher than originally present in the water. However, as noted in the *Guidelines for naturally occurring radioactive materials* published by the Australian Petroleum Production & Exploration Association (APPEA 2002), uranium and thorium radionuclides are substantially less soluble in formation water than radium and NORM scale consequently contains practically no uranium or thorium.

As part of the field development planning for the Project, the potential for scale formation was assessed; this included the potential for individual wells to scale and also the scaling tendency of combinations of water from the various fields. The results indicated the possibility of scale deposition down-hole and in the processing system.

Scale inhibitor is likely to be used down-hole and throughout the production process to minimise the potential for the formation of scale. Further work may be required in this area during the next phases of the development. A detailed plan will be prepared for regulatory approval if disposal of removed scale is required.

The APPEA guidelines detail issues associated with NORMs, specifically focusing on the potential environmental effects of NORM disposal options. These include well injection or discharge of ground material into the sea for dilution and dispersion.

General non-hazardous wastes

General non-hazardous wastes that will be generated in the offshore development area include domestic and packaging wastes, cleaned oil drums, and construction materials such as plastics and metal. These non-hazardous wastes will not be dumped in the offshore marine environment but will be removed to the mainland for onshore disposal at an approved facility. This waste stream is therefore not expected to have an impact on the marine environment.

Food scraps generated on vessels and facilities in the offshore development area will mainly be discharged to the sea and are expected to be rapidly diluted, dispersed and assimilated. No measurable impact to surrounding water quality, outside a very small localised mixing zone, is expected because of the low volumes of discharge in an open ocean environment.

Some fish and oceanic seabirds may be attracted to the Project facilities and vessels by the discharge of food scraps. This attraction may be either direct, in response to increased food availability, or secondary as a result of prey species being attracted to the facilities. However the waste volumes discharged will be small and food scraps from the FPSO, CPF and MODU will be macerated, so the potential for impact is very slight.

Hazardous wastes

Hazardous wastes that will be generated at the offshore development area include excess or spent chemicals, SBMs and well completion fluids. These hazardous wastes will not be discharged to the offshore marine environment but will be removed to the mainland for onshore disposal at an approved facility. This waste stream is therefore not expected to have an impact on the marine environment.

Management of waste

A Provisional Waste Management Plan has been compiled for the Project (attached as Annexe 16 to Chapter 11), which will guide the development of a series of more detailed plans during the construction and operations phases. Key inclusions in this plan are as follows:

- Where practicable, the generation of sands and sludge will be avoided or minimised at source. The amount of sands and sludge disposed of overboard will be kept to a minimum and will only be so disposed of with the approval of the relevant regulatory authorities.
- Process equipment will be designed to restrict the potential for scale formation and scale-inhibition chemicals will be used if required.
- If scale is found to contain NORMs, a procedure will be developed for their storage and handling. NORM disposal will be determined on a case-by-case basis and will be discussed with the relevant regulatory authorities. The selected disposal method will minimise the potential for environmental impact.
- All solid wastes (with the exception of food scraps) from offshore vessels will be returned to the mainland for onshore disposal. These include:
  - plastics
  - floating dunnage, lining and packaging materials
  - paper, rags, glass, metal bottles, crockery, and similar refuse.
- Hazardous wastes will be retained on board vessels and offshore facilities and in due course transported to the mainland for disposal.
- For vessels, in accordance with the *Protection of the Sea (Prevention of Pollution from Ships) Act* 1983 (Cwlth), food scraps generated more than 12 nautical miles from shore (e.g. at the offshore development area) may be disposed of to sea untreated. Within 3–12 nautical miles of land (e.g. at some points along the pipeline route), food scraps will be ground to diameters of <25 mm before being disposed of overboard. Within 3 nautical miles of land, food scraps will not be disposed of overboard, but will be retained and disposed of onshore.
- For the CPF and FPSO, food scraps generated in the offshore development area will be ground to <25 mm diameter prior to discharge, in accordance with Clause 222 of the Petroleum (Submerged Lands) Acts Schedule (DITR 2005).
- Sufficient space will be provided on the FPSO and CPF to allow for the segregation and storage of wastes.
- Waste will be stored in the designated waste stations and appropriately segregated into hazardous waste and non-hazardous waste, and, where possible, into recyclable or reusable hazardous waste and recyclable or reusable non-hazardous waste. In the event of the discovery of any unidentified wastes, these will be treated as hazardous waste and stored accordingly.
- Chemicals and hazardous substances used during all phases of the Project will be selected and managed to minimise the potential adverse environmental impact associated with their disposal.
- Only approved and licensed waste contractors will be employed for waste disposal.
- Waste minimisation will be included in the tendering and contracting process.

Residual risk

A summary of the potential impacts, management controls, and residual risk for solid wastes is presented in Table 7-22. After implementation of these controls, impacts to the offshore marine environment are considered to present a “low” risk.

Table 7-22: Summary of impact assessment and residual risk for solid wastes (offshore)

Aspect	Activity	Potential impacts	Management controls and mitigating factors	Residual risk*		
				C[†]	L[‡]	RR[§]
Generation of scale with NORMs	Well-intervention work and surface equipment operation, maintenance and decommissioning.	Toxicity effects on marine biota as well as health risks to operators.	Process equipment will be designed to restrict the potential for scale formation and scale inhibition chemicals will be used if required. Should scale be found to contain NORMs, the disposal method will minimise the potential for environmental harm and will be selected in consultation with the regulatory authorities.	F (B3)	4	Low
Non-hazardous waste	Generation of non-hazardous waste through routine offshore operations.	Pollution of the marine environment, if disposed of overboard.	Non-hazardous wastes to be retained on board vessels, and transported to onshore facilities for disposal. Provisional Waste Management Plans.	F (B3)	4	Low
Food scraps	Routine operation of offshore vessels.	Alteration of marine environment including nutrient enrichment.	Low volume of waste, in strong current and deep-water marine environment. Dispose of to sea according to MARPOL 73/78 Annex V, Regulation 3(1b and 1c) (IMO 1978): • untreated if to be disposed of beyond 12 nautical miles of land • macerated to <25 mm if to be disposed of between 3 and 12 nautical miles from land Food scraps will be retained on board and disposed of onshore if generated within 3 nautical miles of land. Provisional Waste Management Plans.	F (E1)	6	Low
Hazardous wastes	Generation of hazardous waste through routine offshore operations.	Pollution of the marine environment, if disposed of overboard.	Chemicals and hazardous substances used will be selected to minimise adverse impacts associated with their disposal. Hazardous wastes to be retained on board vessels and offshore facilities until they can be transported to onshore facilities for disposal. Provisional Waste Management Plans.	F (B3)	3	Low

* See Chapter 6 *Risk assessment methodology* for an explanation of the residual risk categories, codes, etc.

† C = consequence.

‡ L = likelihood.

§ RR = risk rating.

7.2.6 Underwater noise emissions

The following discussion on the nature and potential impacts of underwater noise in the offshore development area is derived from a detailed literature review by URS Australia Pty Ltd, which is provided in full in Appendix 15 to this Draft EIS.

Underwater noise in the offshore environment

Sound behaves differently in water from in air, and underwater noise requires different methods of measurement and assessment from airborne noise. The scientific concepts behind underwater noise and its measurement are described below.

Sound

Sound is generated by the vibration of an object and is a form of wave energy that can travel through any elastic material or medium such as air, water or rock. Sound travels by vibrating the medium through which it is propagated. The medium's vibration (oscillation) is the back-and-forth motion of its molecules parallel to the sound's direction of travel, thereby causing a corresponding increase, then decrease, in pressure: this is measured as barometric pressure for sound in air, and hydrostatic pressure for sound in water.

The intensity or loudness of a sound is not expressed in terms of absolute pressure but in relative terms, by a logarithmic scale of decibels (dB). The pitch of a sound is related to the frequency with which the particles or molecules are oscillating, from low-frequency rumbles to high-frequency screeches and whistles, and is measured in hertz (Hz). Most sounds are complex broadband composites that have their power distributed over a spectrum of frequencies. Low-frequency sounds (<1 kHz) are least absorbed by sea water and therefore are the dominant component of ambient background noise in the marine environment.

Ambient noise refers to the overall background noise from both natural and human sources, where the contribution of a specific source is often not readily identifiable. Ambient noise levels are time-weighted averages, and include peak-level spikes or "transients" that are well above the average sound-pressure level. Where ambient noise occurs, the apparent level of individual received sounds drops, owing to the increased average background pressure from the combination of all sounds.

Broadband ambient noise levels in the open ocean range from 45–60 dB in quiet regions (with light shipping and calm seas), to 80–100 dB for more typical conditions (regular shipping and moderate sea states), and over 120 dB during periods of high winds, rain or biological choruses (Urick 1983).

Ambient noise in the 20–500 Hz (low-frequency) range is frequently dominated by distant shipping, particularly in regions of heavy traffic. Vocalisations of the great whales also contribute to this low-frequency band, with the duration and frequency of these choruses increasing in breeding, migrating and feeding areas (Croll et al. 2001; McCauley & Cato 2003). Around 300–400 Hz (in the low-frequency range) the level of weather-related sounds exceeds that of shipping noise. Wind, wave conditions and nearby rainfall dominate the 500–50 000 Hz range (low- to high-frequency range).

The main anthropogenic sources of noise in the marine environment are trading, working and recreational vessels; dredging activities; drilling and piledriving programs; the use of explosives; commercial sonar (depth sounders, fish finders and acoustic deterrents); geophysical sonar; and noise from low-flying aircraft and helicopters.

The characteristics of some common natural and anthropogenic sources of underwater noise are listed in Table 7-23.

Table 7-23: Examples of natural and anthropogenic underwater noise sources in the offshore marine environment

Source	Periodicity	Typical frequency range (Hz)	Indicative source level (dB)
Tectonic earthquakes, tremors, eruptions	Sudden irregular transients (2–20 minutes)	Low (10–100)	220–250
Lightning	Sudden short pulse	Broadband	*c*.260
Whale breaching and fluke slapping	Sudden pulse	Broadband	170–190
Baleen whale "songs"	Variable continuous or transients	Low to medium with harmonics	170–195
Delphinid whistles and squeals	Transients	High to very high (>10 kHz)	180–195
Sperm whale clicks, codas and creaks	Transients	High	180–235
Toothed whale echolocation sonar	Pulses or click bursts	High to very high (>10 kHz)	190–232
Sea ice noises	Variable transients	Broadband	120–190
Rough weather and rain	Irregular continuous	Broadband	80–120
Tide turbulence and sediment saltation	Regular continuous	Broadband	80–120
Fish choruses	Regular continuous	Low and medium-high tonals	80–120
Snapping shrimps	Regular continuous, with morning and evening peaks	Low to medium	80–120
Large tankers and bulk carriers	Variable continuous or transient	Low (10–30 Hz)	180–186
Rig supply tenders	Variable continuous or transient	Broadband	177
Powerboats with 80-hp outboard motors	Variable continuous or transient	Broadband up to several kHz	156–175
Zodiac inflatable boats with 25-hp outboard motors	Variable continuous or transient	Broadband up to several kHz	152
Drilling	Regular continuous	Medium-high (10–4000 Hz)	154–170
Seismic survey	Short pulses	Low to high (0–1000 Hz)	200–232
Cutter-suction dredgers	Regular continuous	Low (100 Hz tonal)	*c*.180
Piledriving	Short pulses	Low to high (0–1000 Hz)	180–215

Source: University of Rhode Island 2009; NOAA 2002; Cato 2000; Simon et al. 2003.

Hearing

The ability of animals and humans to hear a sound is related to both the amplitude of the received pressure waves and their frequency. "Noise" is any audible sound, that is, its frequencies lie within, or at least overlap, the sonic (or "hearing") range of humans or other animals.

The hearing process in both air and water depends on:

- the characteristics of the sound produced by its source
- the auditory properties of the receiver
- the amount and type of ambient noise.

While humans are unable to hear ultrasonic (>20 kHz) sounds, these are audible to dogs, bats, some seals, toothed whales and dolphins. Infrasonic (<20 Hz) sounds (too low-pitched for humans to hear) are known to be detectable by some land animals (e.g. elephants) as well as by manatees and probably by some of the larger baleen whales (see Appendix 15).

Detection of a sound by a distant marine animal also depends on the animal's sensitivity to the frequency peaks in the arriving sound, and the strength of these peaks relative to the local ambient noise (i.e. the degree of masking, by other sounds in the local environment). Whether or not a detectable sound becomes consciously noticed by an animal and elicits a response depends on the degree of processing (decoding) and interpretation applied by the auditory brain stem, and the nature of the signal (i.e. whether it conveys meaning).

It is acknowledged that available data on the effects of noise on marine mammals are variable in quantity and quality, and in many cases data gaps have severely restricted the development of scientifically based noise exposure criteria to manage risks to marine animals. Controlled experiments in laboratory settings have greatly expanded current understanding of marine mammal hearing and there is a reasonable understanding for representative species of odontocetes (dolphins and other toothed species of cetacean) and sirenians (e.g. dugongs) (see Appendix 15).

Furthermore, there are many more published accounts of behavioural responses of marine mammals to noise (Southall et al. 2007), although these generally do not provide a link to specific exposure conditions resulting in particular actions or behaviour. It is important to understand that behavioural responses are strongly affected by the context of the exposure as well as the animal's experience, degree of habituation, motivation and condition and the ambient noise characteristics and habitat setting (see Appendix 15).

Sound propagation and attenuation

The levels of noise received by marine animals are also dependent on the way noise is propagated through the water, and the degree of attenuation. Underwater sound propagation is a complex phenomenon influenced by a variety of factors which, depending on their context, may be of minor or major importance. The primary variables are:

- the frequency of the sound and its absorption losses. Absorption of sound by water is negligible at relatively low frequencies (up to 1 kHz), but increases with increasing frequency and is strongest for frequencies above a few kilohertz
- the sound velocity profile throughout the water column. For a specified frequency, the vertical sound–velocity structure determines how a travelling sound wave refracts or bends as it travels horizontally, which defines interactions with the seafloor and the sea surface
- the bathymetry along the sound wave's direction of travel
- the nature of the seabed. Depending on the make-up of the seabed substrate, sound energy may be absorbed and scattered, reflect off the seabed, penetrate the seafloor, or travel though the seabed to be reflected or refracted back into the water column
- the nature of the sea surface, which can also scatter, reflect or refract sound energy.

Sound propagates more efficiently than light through water. The efficiency of sound propagation allows marine mammals to use sound as a primary method of communication and to sense the presence and location of objects (Richardson et al. 1995).

In extreme conditions noise can theoretically cause injury to marine animals, but this would only happen with an exceptionally loud source and when the organism is within no more than a few metres of the source. It is more likely (but by no means certain) that noise could induce behavioural effects. This may include interference with an animal's ability to detect calls from conspecifics, echolocation pulses or other natural sounds. Another potential effect is the influence that these man-made sounds could have on behaviour. Behavioural effects could range from brief interruptions of resting, feeding or social behaviour, to short- or long-term displacement from important foraging, shelter or mating habitats (Richardson et al. 1995), or migration pathways.

Noise emissions from the Project

Underwater noise will be emitted from the offshore development area during the construction and operations phases of the Project. Underwater noise sources will include vessels, drilling, vertical seismic profiling (VSP), pipelay activities and operation of the offshore facilities. Background noise in the offshore development area was found to be around 90 dB re 1 µPa in low sea state conditions, with vessel and other anthropogenic noise sources occasionally increasing background noise levels above 100 dB re 1 µPa (McCauley 2009) (see Chapter 3).

In order to predict the propagation of underwater noise from the offshore development area, acoustic modelling was undertaken by SVT Engineering Consultants (SVT). The Monterey–Miami Parabolic Equation (MMPE) model was applied, using bathymetric data, geoacoustic parameters of the seabed (e.g. compressional sound speed, sound attenuation, and sediment density) and oceanographic parameters as inputs to the model.

The three most significant noise sources at the offshore development area are considered to be condensate tankers, support vessels and the MODU. The assumed characteristics of these noise sources are presented in Table 7-24. The offshore production facilities (the CPF and FPSO) are non-propelled vessels, whose main underwater noise emissions will be associated with pumps and machinery and will be relatively quiet compared with vessel propellers. The main processing equipment located above water will not be audible to any significant extent in the marine environment.

Table 7-24: Modelled characteristics of offshore noise sources

Source	Frequency range (Hz)	Source depth (m)	Source level (dB re 1 µPa^2/Hz at 1 m)
Condensate tanker	30–500	10	185
Support vessel	500–5000	10	182
MODU	500	10	182

These sources are low- to mid-frequency and would be generated as continuous noises, not pulses. Southall et al. (2007) suggest that a permanent threshold shift (PTS; irreversible hearing loss as a result of exposure to intense impulse or continuous sound) in whales and dolphins is caused by sound-pressure levels of 230 dB re 1 µPa, well above the levels generated by the offshore vessels at the Ichthys Field.

Southall et al. (2007) also report that there are no published criteria for temporary threshold shift (TTS; temporary loss of hearing sensitivity) in cetaceans as a result of constant, non-pulsing noise sources. In addition, it is not currently possible to derive explicit criteria for behavioural disturbance, because of the large variations that exist between groups, species and individuals of the receiving marine animals.

However, most research indicates no, or very limited, responses in baleen whales and dolphins to noises at a received level range of 90–120 dB re 1 µPa and an increasing probability of avoidance and other behavioural effects, albeit generally minor, at a range of 120–160 dB re 1 µPa (Southall et al. 2007) (see Appendix 15 for discussion). Therefore, 120 dB re 1 µPa can be applied as a “threshold” criterion to underwater noise modelling at the offshore development area, to derive a zone that marine mammals may avoid because of Project activities.

McCauley et al. (2000) report that noise levels of 175 dB re 1 µPa cause avoidance behaviour in green turtles (see Appendix 15). Therefore 120 dB re 1 µPa also provides a highly conservative threshold level for impacts to turtles in the offshore development area.

A selection of contour plots are presented in figures 7-13 to 7-16, illustrating the extent of noise propagation from vessels and drilling activities at the Ichthys Field down to the 100 dB re 1 µPa level. The horizontal plots are presented at a depth of 60 m, which is two-thirds the depth of the isothermal layer and is therefore expected to be the depth of maximum acoustic penetration (SVT 2009).

Vessel traffic

Low-frequency noise generated by condensate tankers at the Ichthys Field is predicted to abate to 120 dB re 1 µPa within about 8 km of the source location (Figure 7-13). The area receiving 130–140 dB re 1 µPa is very small, less than 1 km in radius (SVT 2009). This low-frequency noise is within the hearing range of baleen whales (e.g. pygmy blue whales, humpback whales) and turtles, but is below the range of audibility for dolphins (see Appendix 15).

Medium-frequency noise generated by support vessels at the Ichthys Field is predicted to propagate further than that produced by condensate tankers. The 120 dB re 1 µPa threshold level is generally reached at a distance of around 3.5 km from the source, but extends up to 7 km at some points (Figure 7-14). The area receiving 130–140 dB re 1 µPa is less than 1 km in radius (SVT 2009). This type of noise is within the hearing range of baleen whales, turtles and dolphins (see Appendix 15).

The noise characteristics and propagation presented above is considered representative of the variety of vessels to be used at the offshore development area during the construction and operation phases of the Project. These will include rig tenders, module transfer barges, pipelay barges, heavy-lift crane barges, pipe supply vessels, and smaller, faster-moving support and survey vessels.

Ship numbers have been increasing in the Browse Basin over recent years, largely because of the supply vessels supporting the oil & gas industry (Broome Port Authority 2007). Therefore, although this area may be considered isolated with low vessel traffic, more recent development and activities occasionally increase ambient noise levels around the Project area by up to 10 dB re 1 µPa, to 100 dB re 1 µPa (McCauley 2009). These levels of ambient noise are not expected to cause avoidance behaviour in cetaceans (Southall et al. 2007).

Drilling

Low-frequency noise generated by the MODU while drilling production wells at the Ichthys Field is predicted to abate to the 120 dB re 1 µPa threshold level within around 6 km, but may extend up to 10 km at some points (Figure 7-15). The area receiving 130 dB re 1 µPa is very small, less than 1 km in radius (SVT 2009). This low-frequency noise is within the hearing range of baleen whales and turtles, but is below the range of audibility for dolphins (see Appendix 15).

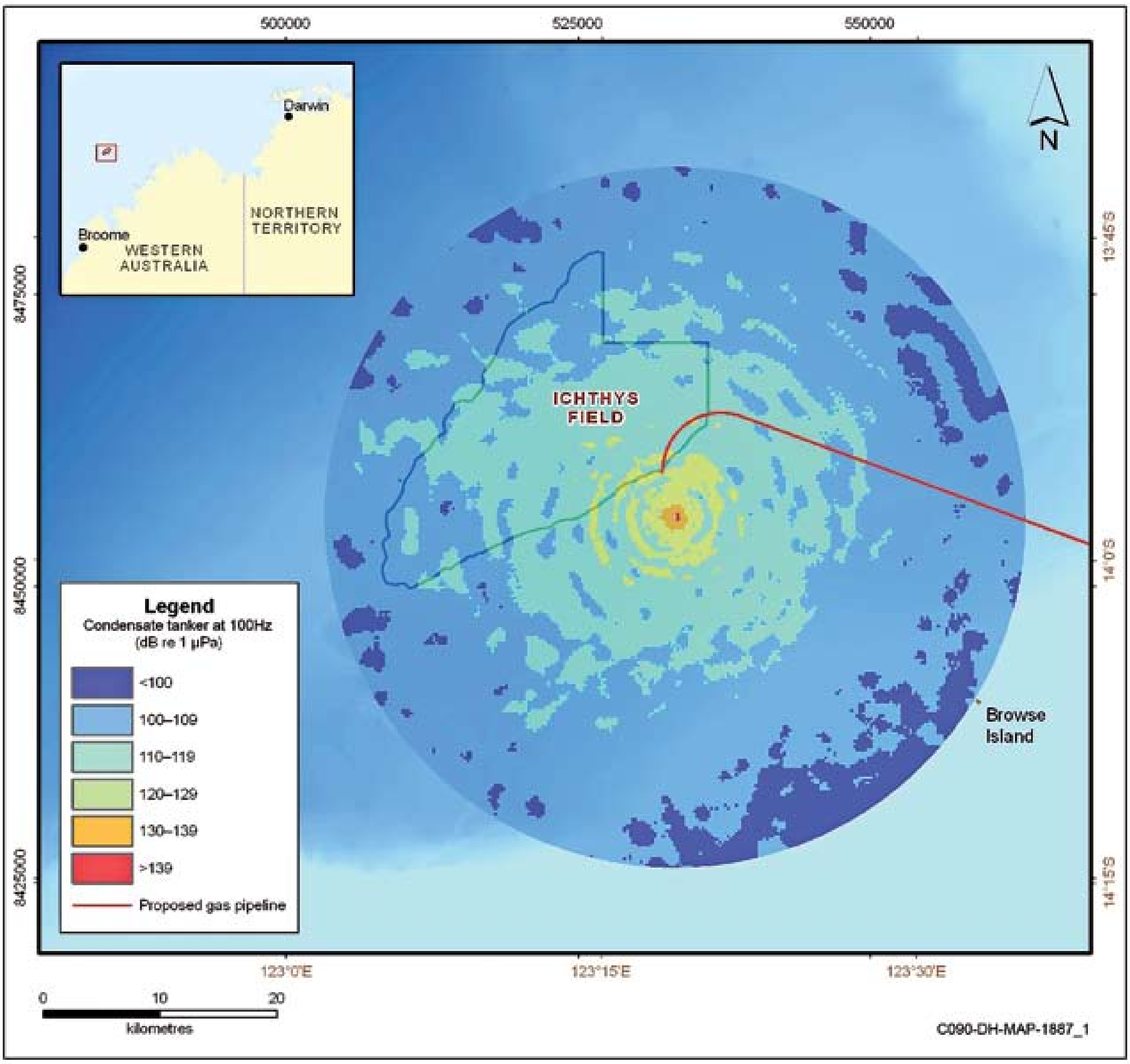

Figure 7-13: Underwater noise produced by a condensate tanker: 100-Hz contours at a depth of 60 m

Combined noise sources

During the early stages of the Project, there may be occasions where noise is generated by all three of the noise sources simultaneously. At these times, low-frequency noise may extend at the 120 dB re 1 µPa threshold level across a total horizontal distance of up to 30 km (Figure 7-16). Areas receiving 130 dB re 1 µPa or more would remain within around 2 km of each noise source (SVT 2009). As mentioned above, noise at this frequency range is within the hearing range of baleen whales and turtles, but is below the range of audibility for dolphins (see Appendix 15).

Vertical seismic profiling

VSP activities will generate low-frequency (200 Hz) pulsed noise at sound-pressure levels of around 190 dB re 1 µPa. These activities will be undertaken over short periods (8–12 hours) during the construction and early operational phases of the Project. VSP produces significantly less energy than large-scale offshore three-dimensional seismic surveys.

Southall et al. (2007) provide a criterion of 230 dB re 1 µPa as the threshold at which pulsed noise could cause injury in cetaceans. Therefore VSP in the offshore development area is unlikely to cause injury to baleen whales and dolphins that may be in the vicinity, although the noise levels of around 190 dB re 1 µPa can be expected to cause avoidance behaviour.

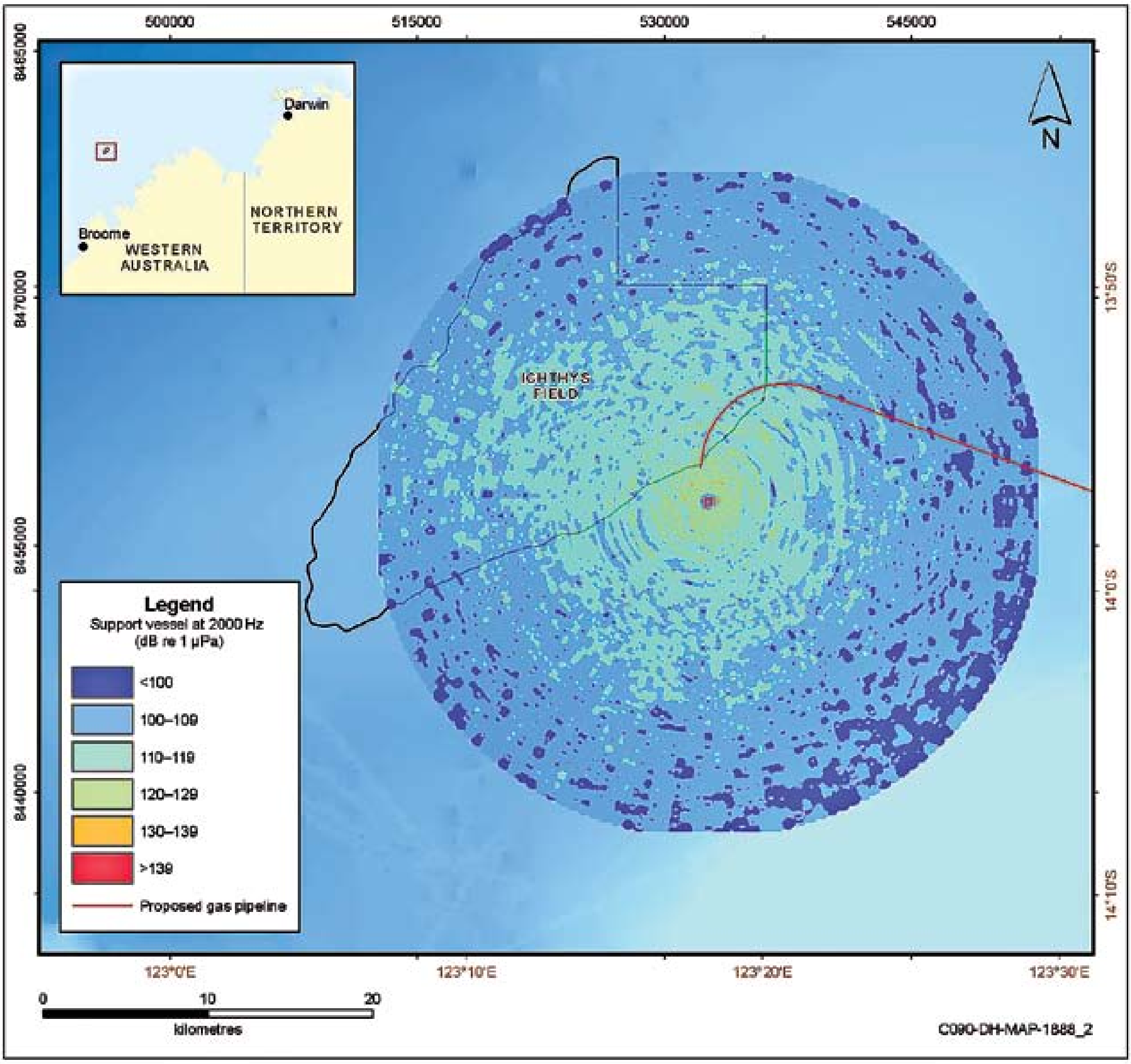

Figure 7-14: Underwater noise produced by a support vessel: 2000-Hz contours at a depth of 60 m

Attenuation of sound levels from VSP activities can be estimated using the empirical formula for practical spreading[7], as presented in Table 7-25. As shown, sound energy levels will drop rapidly with increasing distance from the VSP operation, and within 100 m will have reduced to 160 dB re 1 µPa. This sound level is within the range expected to cause minor avoidance behavioural effects in cetaceans (Southall et al. 2007).

Table 7-25: Attenuation of sound energy from vertical seismic profiling

Drop in sound intensity (dB re 1 µPa)	Received sound level (dB re 1 µPa)	Approximate distance from source (m)
10	180	4.5
20	170	22
30	160	100
40	150	464
50	140	2000

7 In deep water (e.g. 3–4 km depth), sound energy spreads outwards with negligible refraction or reflection from the seafloor or surface; in these circumstances, the spherical spreading law applies: *Transmission loss = 20 log (range).*

In shallow water (e.g. <500 m depth), the transmission of sound energy is reduced by refraction and reflection from the seafloor and surface. Under these conditions, the cylindrical spreading law can be used to estimate transmission loss: *Transmission loss = 10 log (range).*

Since sound energy is not perfectly contained by reflection and refraction, however, the true extent of spreading is often somewhere between the predictions given by spherical and cylindrical spreading. Thus, the practical spreading equation represents an intermediate condition between spherical and cylindrical spreading: *Transmission loss = 15 log (range).* This has been applied in Table 7-25.

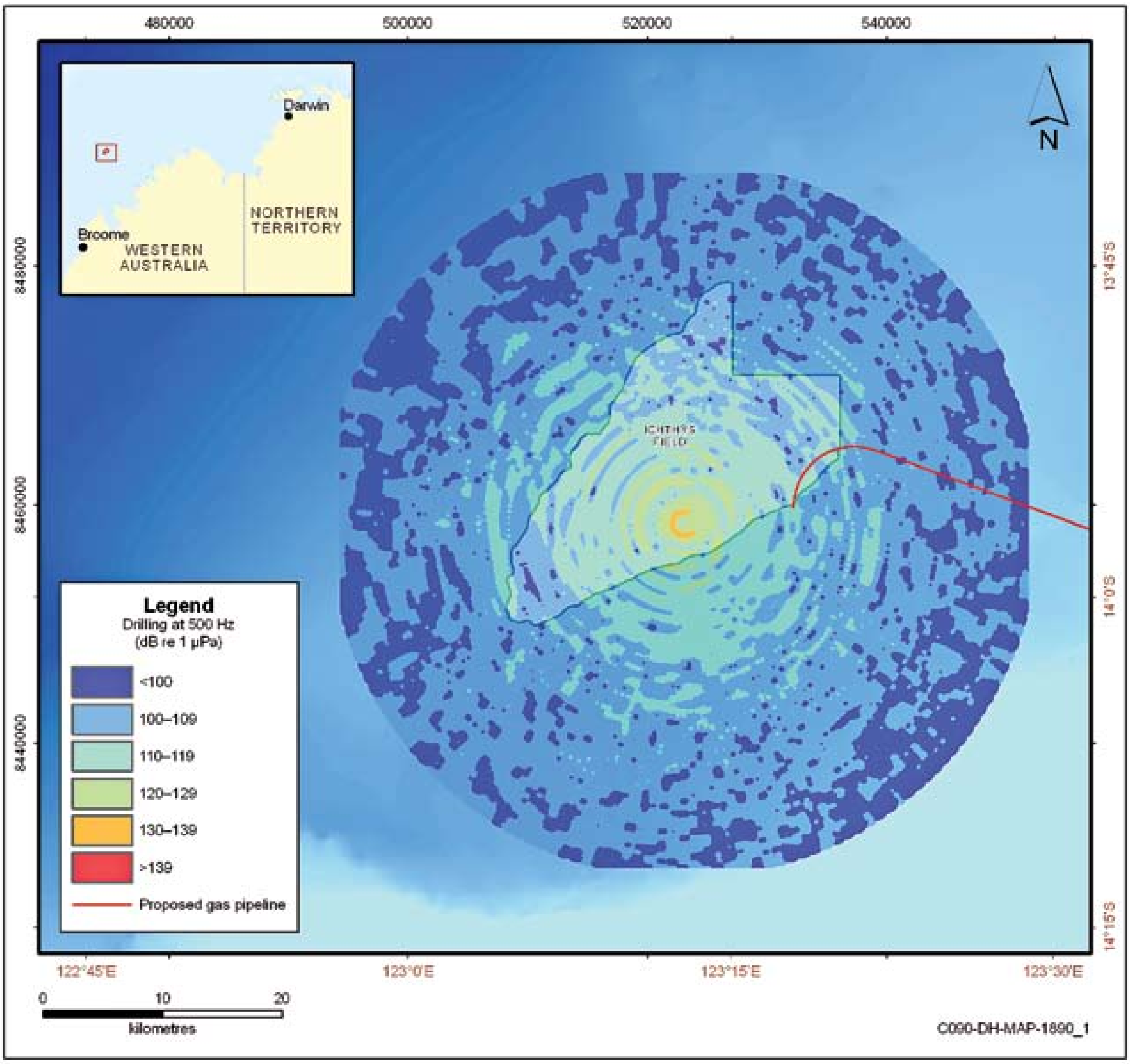

Figure 7-15: Underwater noise produced by drilling: 500-Hz contours at a depth of 60 m

Gas export pipeline

Construction of the gas export pipeline in the offshore area is unlikely to generate significant sound levels. Vessels, particularly any dynamic-positioning vessels, are likely to produce the most intense noise associated with the pipeline construction activities, and may also be used for periodic inspection and maintenance of the pipeline during operations. Any trenching or rock-dumping activities would generate only minor noise levels.

Operation of the pipeline is unlikely to generate noise of any ecological significance. Any noise that is generated would be minimal and inconsequential in comparison with ambient noise levels in the surrounding marine environment.

Potential impacts to marine animals

Baleen whales

Most of the available information on noise from vessel traffic is related to baleen whales as their optimal hearing frequency range generally coincides with the noise generated by vessels. Various researchers have suggested that low-frequency noises generated by vessel traffic may mask vocalisations by baleen whales, limiting their ability to communicate over long distances (see Appendix 15). However, vessel traffic associated with the Project is relatively small in scale and will not contribute significantly to ambient noise in the Ichthys Field or along the pipeline route.

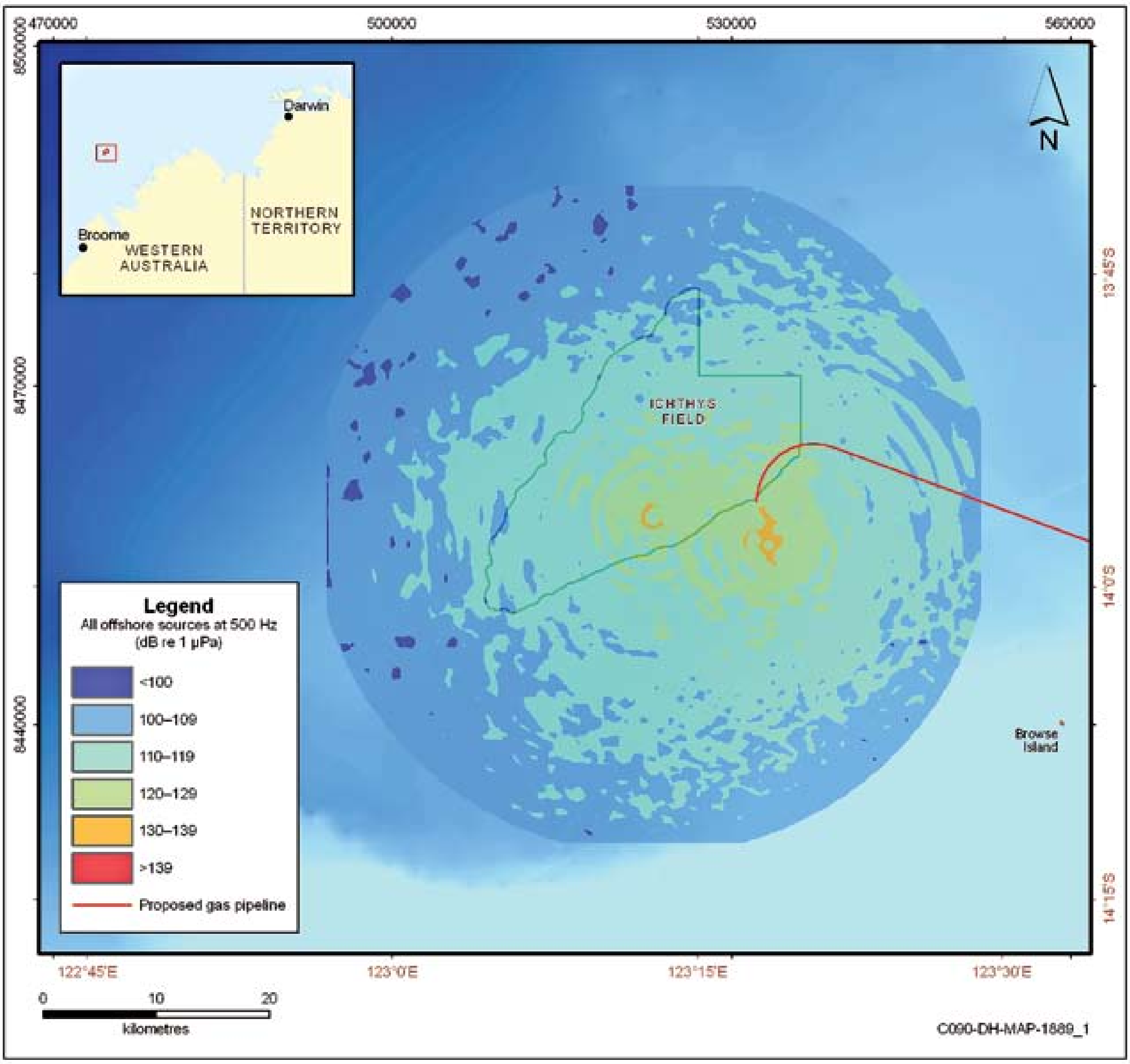

Figure 7-16: Underwater noise produced by all offshore sources combined: 500-Hz contours at a depth of 60 m

McCauley et al. (2000) observed that migrating humpback whales tended to avoid operating seismic sources when the received sound levels were greater than 157–164 dB re 1 µPa. As shown in Table 7-25, sound energy levels from VSP activities are likely to drop below this disturbance level (to 150 dB re 1 µPa) at distances of 464 m from the source. Given the extensive areas of open ocean surrounding the Ichthys Field, the area within which noise levels would disturb humpback whales is very small and is easily avoidable. VSP activities in the offshore development area will occur on a short-term basis and are unlikely to cause significant disturbance to migrating whales that pass through the area.

The offshore development area is not a critical breeding, feeding or aggregation area for baleen whales. It is noted that there is a significant humpback whale breeding area centred around Camden Sound on the Kimberley coast, 190 km south-east of the Ichthys Field (Jenner, Jenner & McCabe 2001) and that pygmy blue whale migration routes may occur in deep offshore waters to the west of the Ichthys Field (McCauley 2009).

Baleen whales are presumed to have a higher hearing sensitivity at low frequencies and therefore there is the potential for drilling noises to affect these species. However, potential effects are likely to be associated only with avoidance behaviour.

Toothed whales and dolphins

Toothed whales and dolphins have reduced hearing sensitivity in low-frequency (<1 kHz) ranges (Richardson et al. 1995), which generally correspond with the noise generated by vessels and drilling activities in the Project's offshore development area. Some species of dolphins are known to bow-ride on the wake of vessels, apparently unconcerned by shipping noise. Therefore, while toothed whales and dolphins are known to occur in the offshore development area, significant negative impacts to these species are not anticipated as a result of noise emissions from the Project.

Turtles

Information is lacking regarding potential impacts on turtles from noise associated with vessel traffic and drilling activities, although their reported auditory sensitivity range of 400–1000 Hz does correspond with the low-frequency noise generated by these sources. Sea turtles have been known to exhibit startle responses to sudden noises, including those generated by air guns used for VSP (McCauley et al. 2000).

The offshore development area does not contain critical breeding or nesting habitat for sea turtles. Turtle nesting is known to occur at Browse Island, which is 33 km south-east of the nearest drilling centre. Noise propagation modelling indicates that the offshore activities at the Ichthys Field will not be audible above background noise levels in the vicinity of Browse Island (SVT 2009).

A small number of turtles also nest at Cox Peninsula, around 2 km from the pipeline route. Pipelay activities in this area during construction will occur over a short period, passing this area of the coast within around one week. Any potential impacts to nesting activities will therefore be minor in scale.

Fish

The variation among fishes in respect to sensitivity to sound is immense. Observations of fish aggregating next to operating industrial infrastructure (such as oil and gas production platforms, wharves and shiploaders) suggests that at least some species are able to become habituated to some noise.

The hearing sensitivity of sharks is within the 20–800 Hz low-frequency range and coincides with the noise to be produced from offshore vessel, drilling and VSP activities.

Studies have shown that fish avoid approaching vessels when the radiated noise levels exceed their threshold of hearing by 30 dB or more, with this avoidance behaviour usually expressed by swimming down or horizontally away from the vessel path. These effects have been found to be temporary: for example schooling patterns resume shortly after the noise source has passed by.

Temporary threshold shifts in particular fish species have been known to occur after exposure to airgun shots such as those used during VSP (McCauley et al. 2000). Given the extensive areas of open ocean surrounding the Ichthys Field, it is anticipated that pelagic fish could rapidly escape any area in which noise levels caused discomfort or annoyance.

Although various fish species occur in the offshore development area, no critical habitat or aggregation areas have been identified.

Management of noise

A Provisional Cetacean Management Plan has been compiled (attached as Annexe 4 to Chapter 11), which will guide the development of a series of more detailed plans to minimise the impacts of underwater noise on cetaceans during the various Project phases. Key inclusions in this plan include the following:

- the implementation of observation zones around VSP activities such as:
  - visual observation before start-up, whereby an "observation zone" with a horizontal radius of 3 km is deemed to be clear of whales for 30 minutes before VSP is permitted to commence
  - a "soft-start" procedure, where the VSP acoustic source commences at the lowest power setting, with a gradual increase in power over a 20-minute period
  - continuous monitoring of the "observation zone" to identify any approaching whales during VSP activities
  - shutdown of VSP activities if a whale is sighted within 500 m
  - following a whale sighting, recommencement of VSP activities after 30 minutes, and using the soft-start procedure.
- the implementation of vessel–cetacean interaction procedures, including not intentionally approaching within 50 m of a dolphin, or within 100 m of a large cetacean, and attempting not to approach cetaceans from head-on.

Residual risk

A summary of the potential impacts, mitigating factors and residual risk for underwater noise emissions is presented in Table 7-26. The residual risks of harm to marine animals are considered to be "low", as noise emissions to the offshore marine environment will be localised and many will be short-term and transitory in nature.

Table 7-26: Summary of impact assessment and residual risk for underwater noise

Aspect	Activity	Potential impacts	Management controls and mitigating factors	Residual risk*		
				C†	L‡	RR§
Underwater noise	Noise generation during construction: • VSP • drilling • supply vessels • pipelay barge • installation of field infrastructure (heavy-lift vessels, anchor handlings, tugs, etc.).	Avoidance by marine animals of the immediate area around vessels and facilities.	The offshore development area is distant from critical breeding and feeding grounds for marine mammals and turtles. Construction noise will be generated on an intermittent basis only. Procedures put in place for cetacean observation and exclusion during VSP operations. Provisional Cetacean Management Plan.	F (B1)	6	Low
Underwater noise	Noise generation during operations: • FPSO • CPF • supply vessels.	Avoidance by marine animals of the immediate area around vessels and facilities.	The offshore development area is distant from critical breeding and feeding grounds for marine mammals and turtles. Provisional Cetacean Management Plan.	F (B1)	6	Low

* See Chapter 6 *Risk assessment methodology* for an explanation of the residual risk categories, codes, etc.

† C = consequence.

‡ L = likelihood.

§ RR = risk rating.

7.2.7 Light emissions

Low-intensity light spill will be generated from the offshore facilities such as the CPF, FPSO, MODU and service vessels as a consequence of providing safe illumination of work and accommodation areas during the construction and operation phases.

It has been suggested that light may disorient cetaceans (Pidcock, Burton & Lunney 2003), but there is in fact no evidence to suggest that artificial light sources adversely affect the migratory, feeding or breeding behaviours of these marine mammals. As cetaceans predominantly utilise their acoustic senses to monitor their environment, light is not considered to be a significant factor in cetacean behaviour or survival. It is therefore unlikely that light spillage from the MODU, installation vessels, CPF or FPSO would cause any detectable response from cetaceans.

Lights have been reported to disorientate marine turtles, particularly hatchlings and female adults returning to the sea from nesting areas on the shore (Pendoley 2005). Once in the water, turtle hatchlings are believed to use the shore wave action as a directional cue to make their way offshore, rather than any light sources (see Appendix 4). Because of the distance of the Ichthys Field from land, it is not expected that light spill from offshore infrastructure will cause disorientation to hatchlings or adult female turtles. The closest turtle habitat is Browse Island, about 33 km away from the offshore facilities. This area is used by green turtles as a nesting area and is listed as a C-class reserve for this reason (see Chapter 3).

During construction of the gas export pipeline, the pipelay barge and support vessels are likely to pass approximately 2 km off Mandorah on the Cox Peninsula, at the entrance to Darwin Harbour. As described in Chapter 3, this area also provides minor flatback turtle nesting habitat. If construction activities correspond with the nesting season, there is a slight chance that hatchlings could be attracted towards the construction vessels. This effect would last for only two to three days while the vessels pass through the area, and the likelihood of a turtle hatchling actually reaching the vessels over 2 km is low. This short-term light spill is therefore not expected to affect the survival of turtle hatchlings from the Cox Peninsula. The significant turtle nesting beaches of the Anson–Beagle Bioregion (namely North Peron Island, Five Mile Beach, Bare Sand Island, Quail Island and Indian Island) are located distant (>40 km) from the pipeline route and well outside the influence of lighting impacts from pipelay vessels.

Light spill from the offshore facilities is unlikely to attract significant numbers of migratory birds or seabirds as the offshore development area is located distant from key aggregation areas in the region, such as Ashmore Reef, Roebuck Bay and Eighty Mile Beach (see Chapter 3). Studies in the North Sea indicate that migratory birds are attracted to lights on offshore platforms when travelling within a radius of 5 km from the light source. Outside this zone their migratory paths are unaffected (Shell 2009). Discussions with current industry personnel in the Browse Basin and North West Shelf suggest that existing offshore oil & gas facilities in the region do not encourage seabird or migratory bird aggregations.

Plankton levels are known to increase around offshore infrastructure, attracted by artificial lighting overnight. This food source encourages fish to aggregate around the submerged infrastructure, where biofouling communities also provide a food source. These effects of increased productivity will be highly localised in the context of the offshore marine environment and of minor consequence to the marine ecosystem.

Residual risk and management

Lighting from the offshore development area is not considered to pose a threat to the surrounding marine environment. There are no sensitive light receptors (e.g. turtle nesting beaches) in close proximity to the infrastructure and localised effects on marine biota are consequently considered to be minor.

Lighting design and operation on the offshore facilities, the pipelay barge and support vessels will meet personnel safety requirements. The safe working levels will be determined as part of a "safety case" assessment under the *Offshore Petroleum and Greenhouse Gas Storage Act 2006* (Cwlth).

7.2.8 Marine pests

Marine pests are introduced marine species that have been moved by human activity from their natural environment to an area where they can multiply and threaten biodiversity, fisheries and other commercial or recreational interests. The marine species recognised as representing an elevated pest risk to Australia are typically coastal or shallow-water species.

Predicting the ability of a marine organism to become a "pest" in a new environment can be difficult, as the interaction of species (both native and exotic) in an ecosystem is complex. A marine species may be introduced into one area with no apparent effects, but may become invasive or hostile to native species in another location. Generally speaking, an exotic marine organism has the potential to survive, establish and spread in environments that are similar to the conditions that prevail in its ecosystem of origin—for example in temperature, salinity, water depth, distance to land and seasonality.

The incidence of new marine pest introductions in Australia has increased in recent times. It is possible that such observations are an artefact of the increased number of studies and greater awareness of the problem, but it is generally considered that potential sources of introduction are increasing and that the rate of marine species introduction is actually rising. Commercial and recreational vessels are suggested as the major sources of accidental, anthropogenic marine pest introductions, as marine pests can be spread by "hitchhiking" on vessels travelling between different areas (Marshall, Cribb & Thompson 2003).

The two most important sources of marine pests in commercial vessels are ballast water and hull biofouling, as described in the following section.

Ballast water

Large ocean-going vessels use sea water as ballast to control trim, list, draught, stability or stresses of the vessel while at sea. Ballast water may be loaded at the point of origin and discharged at the vessel's destination, providing a vector for transporting marine organisms from one region to another. It is estimated that thousands of marine species, from plankton and algae to invertebrates and fish, are transported around the world in ballast water (Goggin 2004).

The risk of introducing a marine pest into a new environment in ballast water largely depends on the species' ability to survive for long periods in the ballast tanks. Several algal or protozoan genera, including some chlorophytes and dinoflagellates, produce spores that are capable of "resting" for long periods and are able to endure relatively long voyages. Many species of crustacean larvae are also able to survive transport in ballast water. The transit time between Australian and Asian ports is relatively short (often less than 20 days), which increases the risk of marine pest introduction through this mechanism by vessels associated with the offshore development area.

In general terms, the greatest risk posed by ballast water exists when the location of ballast-water uptake is similar in environmental and habitat conditions to the location of the ballast-water discharge, for example where both the point of origin and point of discharge are tropical environments, with similar water depth and ecology. These situations provide a greater chance for any species transferred between regions to survive and establish as a "pest". Exchanging ballast water in the open ocean while a vessel is en route is commonly undertaken to reduce the risk of transporting marine pests in ballast water from one port to another.

Coastal and shallow-water habitats are considered vulnerable to marine pest introductions as the marine species recognised as representing an elevated pest risk to Australia are typically coastal or shallow-water species. Ballast water discharged from the pipelay barge and support vessels in shallow waters (<50 m depth) in the Timor Sea, Beagle Gulf and close to the mouth of Darwin Harbour could present a marine pest risk if the water originates from a similar tropical, shallow-water environment. However, this region is sufficiently distant from land to reduce the risk of marine pest introduction to a low level.

The environment in the offshore development area is likely to be vastly different from that in coastal ports, both in Australia and overseas. Therefore, any ballast water discharged by vessels at the Ichthys Field during the operations phase of the Project is unlikely to introduce a marine pest that could establish successfully.

Biofouling

Biofouling is the growth of marine organisms, such as barnacles and algae, on immersed surfaces of vessels and structures. On commercial vessels, biofouling typically occurs on the hull and underwater fittings and voids, internal bilge spaces, cable lockers, anchors and mooring tackle, free flood spaces, wet compartments, and internal seawater systems. Other submerged and floating equipment such as buoys and floating platforms associated with construction and operation of the field will also be susceptible to biofouling. All vessels are vulnerable to biofouling, with the extent and diversity of organisms influenced by a vessel's design, operations and maintenance. Commercial vessels are often treated with antifouling paints to prevent the establishment and growth of fouling communities (see Section 7.2.3 *Liquid discharges*).

Large slow-moving vessels, such as pipelay barges, are considered to pose heightened marine pest risks because of the inherent biofouling vulnerabilities of their design, with a large number and variety of niche spaces on the submerged surfaces of these vessels. The slow vessel speed characteristic of pipe-laying operations also increases biofouling levels, as organisms are better able to establish and survive on vessel surfaces while passing water speeds are low.

Prior to undertaking pipelay construction activities for the Ichthys Project, it is possible that at least some of the pipelay vessels engaged will have travelled recently through ports in South-East Asia (e.g. Singapore) where the tropical climate is similar to that of the Beagle Gulf and Darwin Harbour. This increases the chance of survival for any exotic marine species accidentally transferred. High-risk marine pest species such as the black-striped mussel (*Mytilopsis sallei*) and the Asian green mussel (*Perna viridis*) currently exist in these South-East Asian waters and not in Australia (URS 2009).

Near-surface infrastructure such as the FPSO, CPF and supporting infrastructure provide potential hard substrate habitat for marine pests, which could originate from the port or yard where the infrastructure was first constructed or could be introduced by vessels travelling to the offshore development area (e.g. from an international port). While this hard substrate habitat is very isolated in the offshore development area, transport of a marine pest species from the offshore development area back to a coastal port (e.g. in Australia or another country) could represent an opportunity for establishment or spread of the pest species into the environment on a broader scale. Marine pests could also be transferred to a coastal port if an item of offshore infrastructure were to be brought in from the field for repairs, refurbishment or maintenance.

Management of marine pests

A Provisional Quarantine Management Plan has been compiled for the Project (attached as Annexe 13 to Chapter 11), which will guide the development of a series of more detailed plans during the construction and operations phases. This plan has been developed with consideration of the likely requirements of the relevant regulatory authorities, including the Australian Quarantine and Inspection Service (AQIS), the Northern Territory's Department of Regional Development, Primary Industry, Fisheries and Resources (DRDPIFR)[8], the Darwin Port Corporation (DPC), and Western Australia's Department of Fisheries. Key elements of this plan include the following:

- INPEX will ensure that vessels engaged in the Project comply with the biofouling requirements of the regulatory authorities.
- Vessels engaged in Project work will be subjected to a biofouling risk assessment, which may result in hull inspections and cleaning.
- Relevant Project vessels will be required to maintain satisfactory records of antifoulant coatings, hull-cleaning and ballast-water exchange.
- Marine fouling inspections (using ROVs) will also be used for opportunistic marine-pest monitoring on offshore structures.

8 The Northern Territory's Department of Regional Development, Primary Industry, Fisheries and Resources (DRDPIFR) became the Department of Resources (DoR) in December 2009.

Residual risk

A summary of the potential impacts, management controls, and residual risk for marine pests in the offshore development area is presented in Table 7-27. After implementation of these controls, impacts to the offshore marine environment are considered to present a "low" to "medium" risk and this is considered as low as reasonably practicable.

7.2.9 Marine megafauna

The vessels travelling to and from the offshore development area throughout the life of the Project expose large marine animals to a slight chance of injury through collisions.

Humpback whales are the most common whale species observed in the North West Shelf Bioregion. According to Jensen and Silber (2004), humpback whales are the second most often reported cetacean species struck by vessels. Whether this is because of their relative abundance compared with other great whales or to the particular susceptibility of the species is not known. Previous research has also indicated that several great whale species, including humpback, blue and fin whales, are less responsive to approaching vessels when they are feeding. The incidence of vessel strikes on cetaceans in Australian waters and the circumstances in which they take place is not well documented.

The vessels engaged in construction activities in the offshore development area, such as module transfer barges and pipelay barges, will typically be large and slow, moving with speeds of 0.5–3 knots. Construction of the pipeline will likely progress at a rate of 2–4 km per day. Given that construction will be undertaken by groups of vessels, and that noise would be generated by these, it is probable that whales and other marine megafauna would be deterred from approaching and that vessel collisions would be highly unlikely.

Smaller, faster-moving support vessels, such as anchor-handling tugs, pipe-supply vessels and survey vessels, will transit in and out of the offshore development area during construction at average speeds of 12–14 knots and maximum speeds of up to 20 knots. Tanker vessels engaged in product export during the operations phase would reach speeds of 15–19 knots in open seas. In the open ocean environment a vessel collision with a cetacean would be extremely rare; however, at these travelling speeds such a collision could cause injury or even death to the animal. Noise from vessels would generally alert marine animals to move away, although smaller cetaceans (e.g. dolphins) are known to bow-ride with vessels of all sizes.

Helicopters will be used frequently to transfer personnel to the offshore development area, and may take off from or land close to the sea surface.

Table 7-27: Summary of impact assessment and residual risk for marine pests (offshore)

Aspect	Activity	Potential impacts	Management controls and mitigating factors	Residual risk*		
				C†	L‡	RR§
Marine pests	Operation of vessels between the offshore development area and Australian or overseas ports.	Alteration of marine ecology in biofouling communities on submerged structures at the offshore development area.	Carry out biofouling risk assessment for all vessels. Vessel compliance with regulatory-authority guidelines for biofouling. Opportunistic monitoring of submerged surfaces using ROVs. Provisional Quarantine Management Plan.	E (B3)	2	Low
Marine pests	Use of pipelay barge and support vessels in coastal areas near Darwin.	Invasion of native marine ecosystems by pests, threatening native marine plants and animals and impacting upon maritime-based industries.	Biofouling risk assessment for all vessels. Vessel compliance with regulatory-authority guidelines for biofouling. Provisional Quarantine Management Plan.	C (B3)	2	Medium

* See Chapter 6 *Risk assessment methodology* for an explanation of the residual risk categories, codes, etc.

† C = consequence.

‡ L = likelihood.

§ RR = risk rating.

Helicopters could disturb cetaceans through generation of noise, although on a very localised and infrequent basis.

The offshore development area is small relative to the expansive open ocean surrounding it, and the risk of displacement of cetaceans by construction and operational activities is very low. There are no recognised cetacean feeding or breeding grounds in the offshore development area.

The potential for impacts to third-party shipping, navigation and commercial fishing is discussed in Chapter 10.

Management of marine megafauna

A Provisional Cetacean Management Plan has been compiled (attached as Annexe 4 to Chapter 11), which will guide the development of a series of more detailed plans during the construction and operations phases of the Project. This plan is consistent with the Australian National Guidelines for Whale and Dolphin Watching 2005, administered by the Commonwealth's Department of the Environment, Water, Heritage and the Arts (DEWHA), the Northern Territory's Department of Natural Resources, Environment, the Arts and Sport (NRETAS) and Western Australia's Department of Environment and Conservation (DEC). Key inclusions in this plan are as follows:

- Vessel interactions with cetaceans will be avoided by
  - aiming to maintain a distance of 100 m from a large cetacean or 50 m from a dolphin
  - operating at a no-wash speed when within 100–300 m of a large cetacean or when within 50–150 m of a dolphin
  - not actively encouraging bow-riding by cetaceans by driving towards pods of animals; however should any cetacean(s) commence bow-riding with a vessel, the vessel master will not change course or speed suddenly.
- Helicopters in the vicinity of a cetacean will (except in take-off, landing or emergency situations)
  - not fly lower than 500 m within a 500-m radius of a cetacean, or hover over this zone
  - avoid approaching a whale or dolphin from head-on
  - avoid flying directly over, or allowing the shadow of the helicopter to pass directly over a cetacean.

Residual risk

A summary of the potential impacts, management controls, and residual risk for marine megafauna in the offshore development area is presented in Table 7-28. After implementation of these controls, potential impacts are considered to present a "low" risk, as any interactions with cetaceans will be rare and very localised.

7.3 Nearshore marine impacts and management

The nearshore development area includes a corridor for the gas export pipeline extending from the mouth of Darwin Harbour through the centre of the Harbour to the pipeline shore crossing area south of Wickham Point on Middle Arm Peninsula. The gas export pipeline route for the Ichthys Project runs parallel to the existing Bayu–Undan Gas Pipeline, which feeds ConocoPhillips' Darwin Liquefied Natural Gas (LNG) plant.

Table 7-28: Summary of impact assessment and residual risk for marine megafauna (offshore)

Aspect	Activity	Potential impacts	Management controls and mitigating factors	Residual risk*		
				C†	L‡	RR§
Marine megafauna	Use of operation and construction vessels in the offshore development area.	Physical injury to large marine animals from collision with vessel.	The offshore development area is outside the key breeding and feeding areas for humpback whales. Construction vessels travel at low speeds. General noise and activity would deter marine animals from entering the area. Procedures for avoiding interaction between vessels and helicopters, with cetaceans. Provisional Cetacean Management Plan.	E (B1)	2	Low

* See Chapter 6 *Risk assessment methodology* for an explanation of the residual risk categories, codes, etc.

† C = consequence.

‡ L = likelihood.

§ RR = risk rating.

7 Marine Impacts and Management

The nearshore development area also includes the marine environment around Blaydin Point. This area is located on the southern banks of East Arm downstream of the Elizabeth River. In addition, for the purposes of this Draft EIS, an offshore site 20 km north of Darwin Harbour is considered to be part of the nearshore development area, as it will be used as a disposal ground for dredge spoil from nearshore construction activities.

7.3.1 Alteration of habitat

Seabed and shoreline disturbance

The construction of Project facilities in the nearshore development area will disturb areas of seabed in Darwin Harbour and parts of the shoreline of Blaydin Point and Middle Arm Peninsula through the following activities:

- dredging and rock armouring for the gas export pipeline through Darwin Harbour
- dredging and blasting for the shipping channel, turning basin, approach area, and berthing area in East Arm to the north and west of Blaydin Point
- using anchors and chains for construction and support vessels
- dredging and trenching for the gas export pipeline shore crossing south of Wickham Point
- constructing the jetty and associated earthworks on the northern side of Blaydin Point
- constructing the module offloading facility and earthworks (with associated dredging) on the eastern side of Blaydin Point.

These activities will cause localised direct damage to soft bottom benthos or rock pavement communities, with biota re-establishing when the substrates have returned to a suitably stable condition. This may be, for example, when sediments deposited on rock pavement areas have been removed by tidal currents. The time frame for recolonisation will depend upon the time taken for the substrate to return to a stable condition and on the motility and reproductive modes of the colonising biota (Guerra-García, Corzo & García-Gómez 2003; Zarillo et al. 2008). An area of hard substrate to be removed at Walker Shoal by drilling and blasting for the shipping channel, represents only a small portion of the hard substrate occurring elsewhere in the Harbour.

The abundance of benthic fauna generally recovers faster than the species diversity. The diversity of recolonising communities will initially be low, with assemblages being dominated by a small number of opportunistic species (WBM Oceanics Australia 2002). Disturbed areas are likely to be recolonised rapidly (days to weeks) by motile animals, while animals with larval phases will only re-establish after the first reproductive event following the period of disturbance. In some habitats, there may need to be a succession of recolonisation events (over perhaps several years) before the community returns to its pre-disturbance composition.

Soft-bottom and subtidal rock pavement communities occur throughout Darwin Harbour (see Appendix 8 to this Draft EIS). The area of these habitats within the disturbance footprint for the nearshore development area is minor in comparison with the areas of similar habitat occurring elsewhere in the Harbour. The viability of these communities in the long term is not considered to be threatened by the seabed disturbance caused by the Project.

Artificial habitat

The presence of the jetty, the gas export pipeline and the module offloading facility in the nearshore marine environment will provide hard substrate for the settlement of marine organisms. Colonisation of the structures over time will lead to the development of a fouling community and will provide prey refuges and visual cues for marine animals such as fish and reptiles.

The gas export pipeline through the Harbour is likely to support a similar marine assemblage to the existing Bayu–Undan Gas Pipeline (see Chapter 3), with a high coverage of animal and plant life such as soft corals, gorgonians, hydroids and algae and moderately abundant fish life (see Appendix 8). This artificial increase in hard-substrate habitat may be viewed as a positive impact by some stakeholders, particularly recreational fishermen.

Overall, the new hard substrates provided by nearshore infrastructure are likely to increase biodiversity and productivity in those areas of the Harbour, similar to the effects of the existing Bayu–Undan Gas Pipeline. If infrastructure is removed at decommissioning, it is expected that the abundance of epifauna will return to its original state.

Changes to hydrodynamics

The potential changes to local hydrodynamic processes such as circulation, inundation and wave propagation as a result of dredging and nearshore construction were investigated in a comparative modelling study by APASA (2010a). The modelling was undertaken using validated hydrodynamic and wave models (BFHYDRO and SWAN respectively, as described in Appendix 5) to represent existing conditions, and modified versions of these models that represented post-construction conditions by incorporating the proposed dredging areas. The full report from this study is provided in Appendix 11 of this Draft EIS.

Investigation of the effects of wind and river flow in East Arm demonstrated that hydrodynamic processes are dominated by tidal forcing. Seasonal and inter-annual variations are therefore relatively small and useful comparisons of changes to hydrodynamics are possible using short-term simulations of 30-day periods. The simulations also included no riverine discharge or land runoff, representing “dry flow” conditions, which are the worst-case scenario for the net migration of waters from the upper reaches of East Arm (see Appendix 11).

Four key parameters were investigated, all of which indicated that the impacts of the dredging program would be minor in scale. The parameters investigated are as follows:

- flushing of East Arm—flushing rates were predicted to decrease by 3–7% in East Arm as a result of dredging. This change can be attributed to a minor decrease in current speeds over the dredging area, which will marginally slow the penetration of water from the main body of Darwin Harbour. The scale of this effect is considered to be minor, and is not expected to cause a significant change in water quality or in retention times for water-borne pollutants.
- changes in current patterns—currents were predicted to decrease by 40–45% on a localised basis over the deeper parts of the dredging area (the turning basin and berthing area), because of the larger cross-section that would be available for movement of the tidal flows. Slight decreases in current speeds were also predicted more widely in East Arm, at lower magnitudes with increasing distance from the edge of the dredging area.
- wave energy—waves in East Arm are usually locally generated by wind, with small wave heights in the order of a few tens of centimetres. Predicted changes to wave heights as a result of dredging were very small (<50 mm) throughout East Arm and should not result in significant changes to wave-generated sediment movement.
- seabed sheer stress—because the current speed in the deeper parts of the dredging area is reduced, seabed sheer stress was also predicted to decrease, resulting in minor increases in sedimentation in the dredged areas (see Appendix 11).

On the scale of East Arm, the overall effects of dredging on the hydrodynamics of the area are considered minor and are not expected to cause significant changes to inundation of intertidal mangrove areas or natural sedimentation and erosion patterns (see Appendix 11). The potential impacts of sedimentation and turbidity on marine habitats are discussed in Section 7.3.2 *Dredging*.

Management of marine habitat

A Provisional Dredging and Dredge Spoil Disposal Management Plan has been compiled (attached as Annexe 6 to Chapter 11), which will guide the development of a series of more detailed plans during the construction and operations phases of the Project. Key inclusions in this plan are as follows:

- Dredging vessels will be equipped with appropriate global positioning system (GPS) equipment and other navigational aids to ensure that dredging will occur only in the specified dredge footprint.
- Anchoring plans and procedures for construction vessels involved in dredging and pipelay will be developed (in consultation with the DPC) to avoid sensitive seabed habitats.

No specific measures are proposed to reduce the artificial habitat provided by the gas export pipeline, the module offloading facility, the product loading jetty and the associated maritime infrastructure in the nearshore development area, as the increase in hard substrate area is not considered to represent an adverse impact upon the nearshore marine environment. Consideration will be given to relocating rock removed from Walker Shoal within the Harbour.

The separate issue of marine pest introduction and establishment on coastal infrastructure is discussed in Section 7.3.9 *Marine pests*.

Residual risk

A summary of the potential impacts, management controls, and residual risk for nearshore marine habitat is presented in Table 7-29. After implementation of these controls, impacts to marine habitats are considered to present a “medium” to “low” risk and are as low as reasonably practicable.

Table 7-29: Summary of impact assessment and residual risk for marine habitat (nearshore)

Aspect	Activity	Potential impacts	Management controls and mitigating factors	Residual risk*		
				C†	L‡	RR§
Seabed disturbance	Dredging and blasting for construction of access to jetty and module offloading facility.	Removal of soft-bottom biota and habitat. Removal of some areas of hard substrate. Provision of new artificial hard substrate habitat.	Soft-bottom habitat is widespread in Darwin Harbour. The disturbance footprint will be minimised where possible within the constraints of infrastructure engineering and operability. Dredging vessels will be equipped with navigational aids to ensure that dredging occurs within the specified dredge footprint. A soft-bottom benthos monitoring program will be put in place. Provisional Dredging and Dredge Spoil Disposal Management Plan. Provisional Piledriving and Blasting Management Plan.	E (B3)	6	Medium
Seabed disturbance	Dredging, trenching and pipelay at pipeline shore crossing.	Removal of soft-bottom biota and habitat. Provision of new artificial hard substrate habitat.	The disturbance footprint will be minimised where possible within the constraints of infrastructure engineering and operability. Anchoring plans and procedures for pipelay construction vessels will be developed to avoid sensitive seabed habitats. Dredging vessels will be equipped with navigational aids to ensure that dredging occurs within the specified dredge footprint. Provisional Dredging and Dredge Spoil Disposal Management Plan.	F (B3)	6	Low
Seabed disturbance	Trenching and rock dumping for construction of gas export pipeline.	Removal of soft-bottom biota and habitat. Provision of new artificial hard substrate habitat.	The disturbance footprint will be minimised where possible within the constraints of infrastructure engineering and operability. Dredging vessels will be equipped with navigational aids to ensure that dredging occurs within the specified footprint. An increase in hard-substrate biota and attraction of fish may benefit recreational fishing resources.	E (B3)	6	Medium
Hydrodynamics	Development of nearshore infrastructure and dredging area.	Reduced flushing of East Arm. Local changes to sedimentation and hydrodynamic processes affecting benthic habitats.	Dredging channel aligned with normal current directions in East Arm. Modelling indicates localised changes to currents and sedimentation only, with minimal impact on flushing processes and waves.	E (B3)	5	Medium

* See Chapter 6 *Risk assessment methodology* for an explanation of the residual risk categories, codes, etc.

† C = consequence.

‡ L = likelihood.

§ RR = risk rating.

7 Marine Impacts and Management

7.3.2 Dredging

An extensive dredging program will be required to accommodate the construction of the shipping channel, approach area, turning basin, berthing area, module offloading facility, gas export pipeline and pipeline shore crossing in the nearshore development area, as described in Chapter 4. Disturbance of this volume of seabed sediments will cause sediment transport and deposition to adjacent parts of Darwin Harbour as well as increased turbidity in the water column over a period of time.

Maintenance dredging is expected to be required at approximately 10-year intervals during the operations phase. This would require the removal of relatively small quantities of dredged material, which would cause similar environmental effects but on a significantly lower scale.

In addition, without adequate management controls, land-clearing and excavation activities in the onshore development area could indirectly impact the marine environment through soil erosion and surface runoff. The impacts of this sedimentation are similar to those caused by dredging activities but are likely to occur on a much more localised scale. Terrestrial runoff from exposed coastal soils may also be a source of acid leachate. The marine impacts of this potential decrease in water quality are also discussed in this section.

Predictive modelling

The extent and intensity of sedimentation and turbidity impacts caused by dredging are dependent on a complex variety of factors including tidal currents and seabed morphology. In order to predict the effects of the preliminary dredging program on the nearshore marine environment, HR Wallingford (HRW) was engaged to undertake sediment fate modelling (HRW 2010; see Appendix 13 of this Draft EIS for the full report).

The model was based on a two-dimensional hydrodynamic model of Darwin Harbour, using a repeating spring–neap cycle of tides representative of the wet or dry seasons and a time series of wind data from which to generate wind waves. Flow conditions in the area were predicted using the TELEMAC-2D hydrodynamic solver, which is used to model various phenomena such as tidal flows in estuaries, coastal flows, storm surges, and floods in rivers, and is considered state-of-the-art software. The flow model was set up and validated against a selection of available in situ measurements, including logged current measurements from acoustic Doppler current profilers (ADCPs). Friction forces associated with mangrove roots in coastal areas of the Harbour were integrated into the model using coefficients derived from existing literature. Further details on the development and validation of the hydrodynamic model are provided in Appendix 12 of this Draft EIS.

Sediment plume dispersion was modelled using the SANDFLOW dynamic, non-cohesive sediment transport model developed by HRW. Results of the geotechnical and geophysical investigations of the proposed dredging areas were used as inputs to the model, as the density, consolidation and particle sizes of the substrates influence the behaviour of dredged material in the water column and its settlement on the seafloor.

The predictive modelling presented in this Draft EIS has accommodated uncertainties in source data and information by incorporating conservative assumptions at each stage of the modelling process. For example, assumptions relating to the volume of fine material to be dredged incorporated a conservative estimate, that is the highest proportion of fine fractions, into the predictive model. This approach has therefore delivered conservative modelling outcomes which provide a sound level of confidence on which to base environmental impact and management decisions.

The preliminary dredging program in East Arm was divided into ten phases, including a final 6-month post-dredging period. The nearshore pipeline dredging was also modelled as a discrete activity. Each phase was modelled separately and then added to the others to simulate the combined effect of the full dredging program. A detailed description of the proposed dredging program is provided in Chapter 4. In summary, dredging activity increases steadily over the first six phases, and Phase 6 is considered the “peak” of the program, with several vessels working simultaneously in the berthing area and turning basin. Dredging activity decreases considerably in phases 7 to 9.

The sediment fate model was not designed to provide predictions on near-field effects, which occur close to the dredging vessels. Rather, the model was designed to predict suspended-sediment concentrations and sedimentation in the mid- and far-field ranges, which represent the zones within one or more tidal excursions from the dredging operations. This was considered appropriate for the nearshore development area, as the key environmental receptors of interest (e.g. mangroves and key coral sites) in East Arm and Darwin Harbour are outside the immediate dredging footprint (see Appendix 13).

The main mechanism affecting the marine environment is the release of fine sediment particles (silts and clays) by dredging, as these can remain suspended in the water column under moderate to high current speeds and cause turbid plumes; they can be resuspended by successive tidal currents to travel long distances before settling. The cutter-suction dredger (CSD) is expected to release large volumes of fine materials when compared with a backhoe dredger (BHD) or trailing suction hopper dredger (TSHD). The fine materials released throughout the preliminary dredging

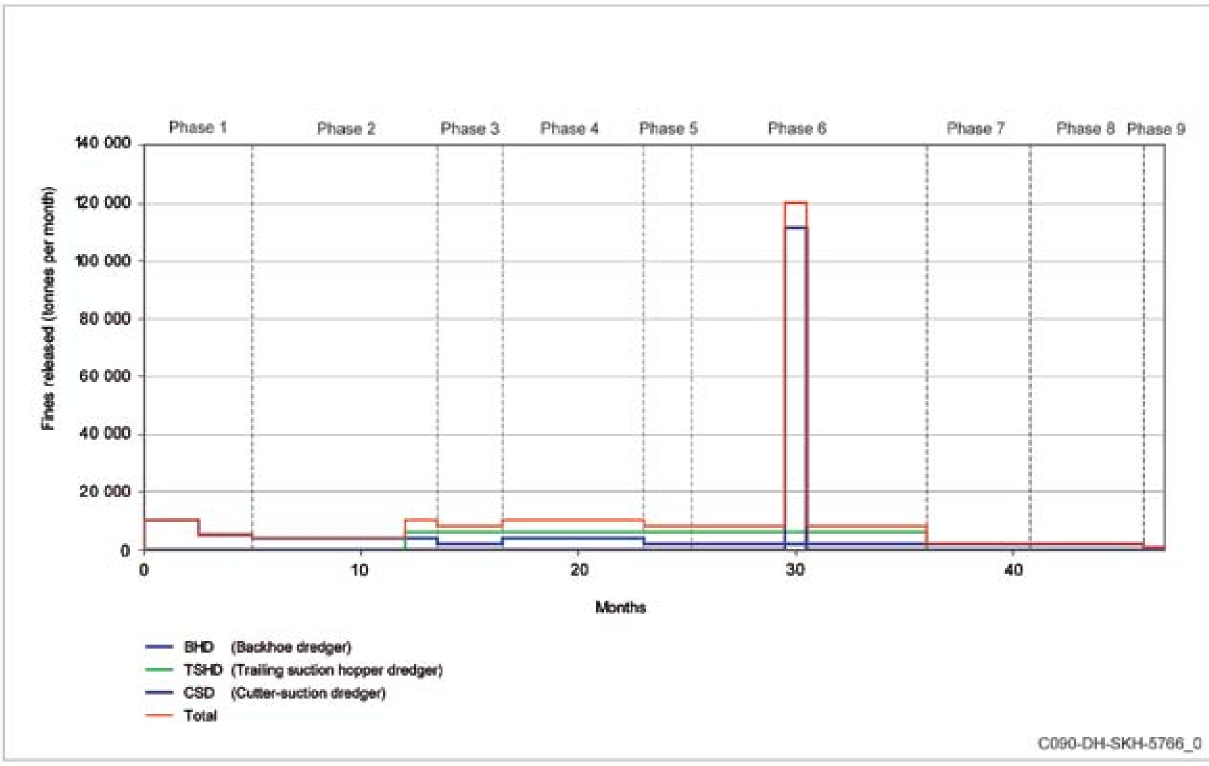

Figure 7-17: Predicted quantities of fine materials released during the dredging program in Darwin Harbour

program are shown in Figure 7-17; the large spike in fines release occurs in Phase 6 when a CSD is required to remove hard substrates from the berthing area. During all other phases of the dredging program, relatively low volumes of fines are released to the nearshore marine environment.

Three mechanisms of potential indirect environmental impacts from the dredging campaign were considered in the modelling study:

- suspended-sediment plumes, caused by the release of fine sediment particles into the water column by dredging, with later resuspension by tidal currents. Elevated suspended-sediment concentrations may lead to impacts upon biota such as corals that are sensitive to reductions in incident light, as well as smothering or damaging filter-feeders like sponges and bryozoans
- shoreline sedimentation, where fine sediments are transported by repeated settlement and resuspension into shallow coastal areas. Build-up of sediment can smother mangrove flora and invertebrate animals
- sand transport, where coarse sediments are shifted across the seabed. Sand build-up could smother benthic organisms such as corals or other invertebrates.

The impacts of sediment build-up on maritime infrastructure and heritage sites around Darwin Harbour are discussed in Chapter 10.

Suspended-sediment concentrations

Predicted suspended-sediment concentrations generated around East Arm at different stages of the dredging program are shown in figures 7-18 to 7-20. These plots represent instantaneous “snapshots” of the plumes predicted during dredging at peak periods during the tidal cycle when water velocity is at its highest. These are shown for both the ebb and flood flows of spring- and neap-tide conditions. Additional plots showing median and 95th percentile suspended-sediment concentrations during each phase are provided in Appendix 13.

The predicted suspended-sediment concentrations generated by dredging activities are provided down to a minimum of 3 mg/L above background, as anything below this concentration is not expected to have significant effects on marine biota and habitats and will rarely be visible in the naturally turbid waters of Darwin Harbour. The predicted concentrations are additional to background concentrations, which range from 1.5 to 83 mg/L in East Arm, with a mean of 15 mg/L (see Appendix 9 of this Draft EIS). As mentioned above, the model does not predict the high concentrations generated very close to the dredging vessels, which may reach levels in the hundreds or even thousands of milligrams per litre.

For all phases of the dredging program, the plumes generated during spring-tide conditions are much larger, and often reach higher concentrations, than those generated during neap tides. This is because spring tides involve greater variations in water levels, with higher current speeds and more extensive flows, than neap tides. The plumes presented for Phase 4 (Figure 7-18) can be considered representative of the spatial extent and suspended-sediment concentrations generated throughout the first two years of dredging (phases 1 to 5). These plumes are confined to East Arm and can reach up to 20 mg/L, with some smaller secondary plumes of higher concentrations developing in shallow intertidal areas (see Appendix 13).

The most intense turbid plumes are predicted for a 6-week period during Phase 6, when the CSD is operating on hard seabed material (Figure 7-19). During ebb-tide conditions at spring tides, these plumes could extend out of East Arm into the main body of Darwin Harbour, past Darwin's central business district. During flood-tide conditions at spring tides, these plumes would reach into Frances Bay, the Elizabeth River, Hudson Creek and other tributaries of East Arm, at concentrations up to 50 mg/L. During neap-tide conditions, however, the suspended sediments generated by this intensive dredging activity remain very localised around the dredging area (see Appendix 13).

The plumes presented for Phase 8 (Figure 7-20) are representative of phases 7 to 10, which include low-intensity dredging activity during the final year of the program and a 6-month period after the program is completed. Beyond the immediate vicinity of the dredgers, almost no suspended sediments above the minimum 3-mg/L level are predicted in East Arm. Some small low-concentration plumes could form in shallow intertidal areas during a spring tide as a result of resuspension (see Appendix 13).

Water-quality objectives for Darwin Harbour set by NRETAS include a long-term suspended-sediment concentration target during dry-season conditions of 10 mg/L (NRETAS 2009). This level is occasionally exceeded under natural conditions as shown in the nearshore water-quality study (see Appendix 9). Generally, dredging will generate suspended sediments above 10 mg/L only in close proximity to the dredging vessels. Under some tidal conditions, however, suspended-sediment plumes of this concentration or higher may be transported up to 10 km from the dredging area (Figure 7-19). Most of the suspended sediments caused by dredging will remain within upper-estuary waters in East Arm and will rarely reach the main body of the Harbour. Suspended-sediment concentrations are predicted to return to background levels throughout the greater part of East Arm during phases 7 to 10 of the dredging program (see Appendix 13).

Dredging for the nearshore pipeline will generate turbid plumes mainly at the shore-crossing area; dredging through the main body of the Harbour will involve low volumes of seabed material and localised short-term increases in suspended sediments only. The pipeline shore crossing is situated in an area of fine sediments across the intertidal and subtidal mudbank and will take around 5 weeks to complete. Median suspended-sediment concentrations generated during this time are predicted to be very low, below 3 mg/L. High concentrations are predicted for a short period during the approach to the second series of spring tides because of the accumulation of fine material on the seabed near the dredge during the previous neap tide. Once the tidal flows obtain sufficient energy, this material would be resuspended and generate a plume. A "snapshot" of this short-term effect is shown in Figure 7-21.

A time series of suspended-sediment concentrations for the entire dredging program at the protected Channel Island coral community is presented in Figure 7-22. Dredging at the pipeline shore crossing occurs at the start of the program (within the period Day 0 – Day 50), and generates peak concentrations of up to 18 mg/L over the coral community. The cyclical peaks in concentrations correspond to spring-tide periods. During neap-tide periods, concentrations fall as the sediments settle from the water column. There are also variations in concentrations within each day, with periods of slack water between ebb and flood tides.

Throughout the four-year dredging program, suspended-sediment concentrations of 10 mg/L above background levels at the Channel Island coral community are predicted to be extremely rare (occurring less than 0.01% of the time) (see Appendix 13).

The sediment fate model also predicts the suspended-sediment concentrations generated at other areas where corals are known to occur in East Arm (Table 7-30). Corals at South Shell Island and north-east Wickham Point will be situated closest to the dredging activities and will receive some exposure to plumes, although still at relatively low concentrations; concentrations above 20 mg/L occur less than 1% of the time at both sites. Corals at Weed Reef are predicted to be exposed to low concentration plumes (5 mg/L) only rarely (less than 0.01% of the time).

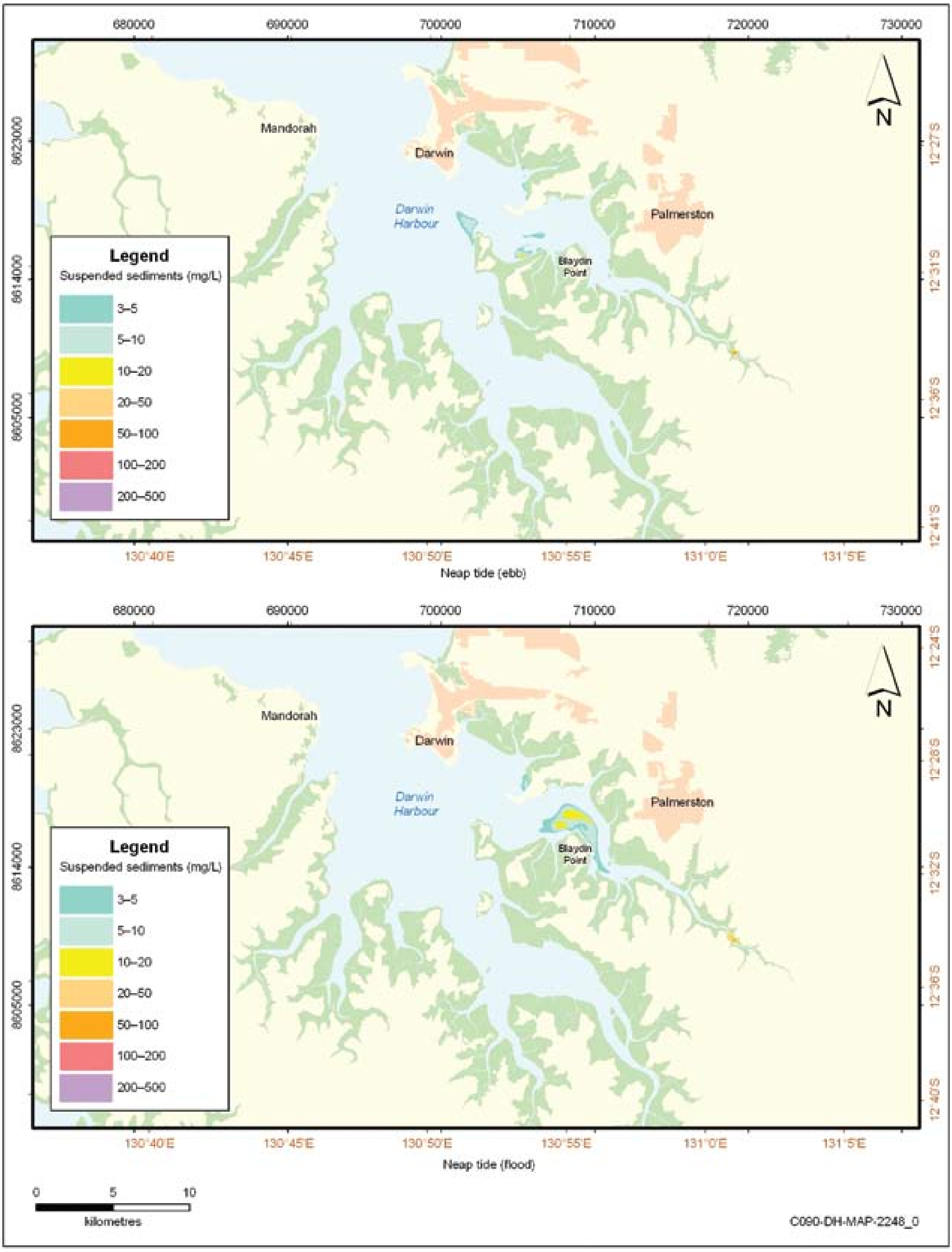

Figure 7-18 (a): Predicted instantaneous suspended-sediment concentrations during a typical tidal cycle in Phase 4 of the dredging program (duration 6.5 months)

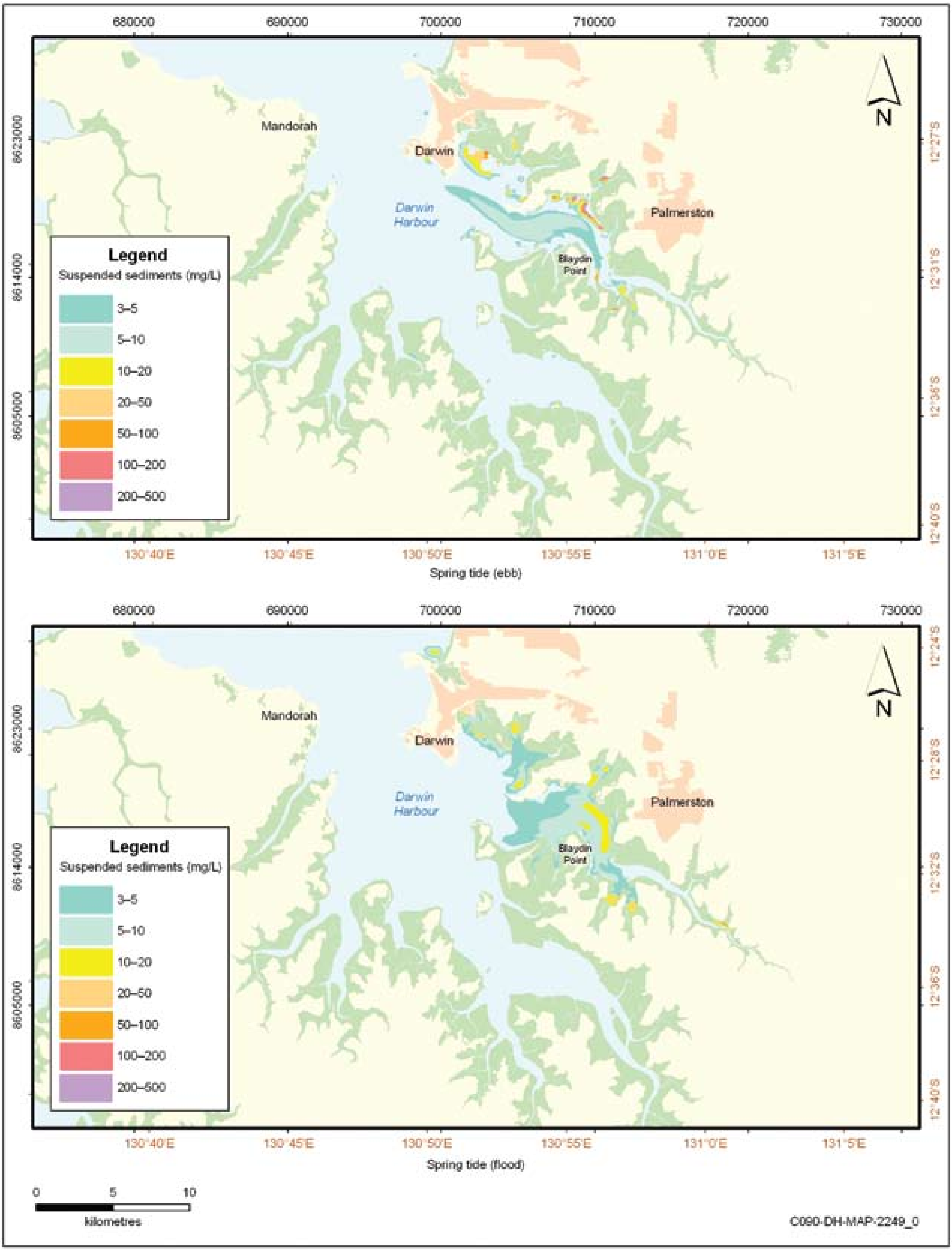

Figure 7-18 (b): Predicted instantaneous suspended-sediment concentrations during a typical tidal cycle in Phase 4 of the dredging program (duration 6.5 months)

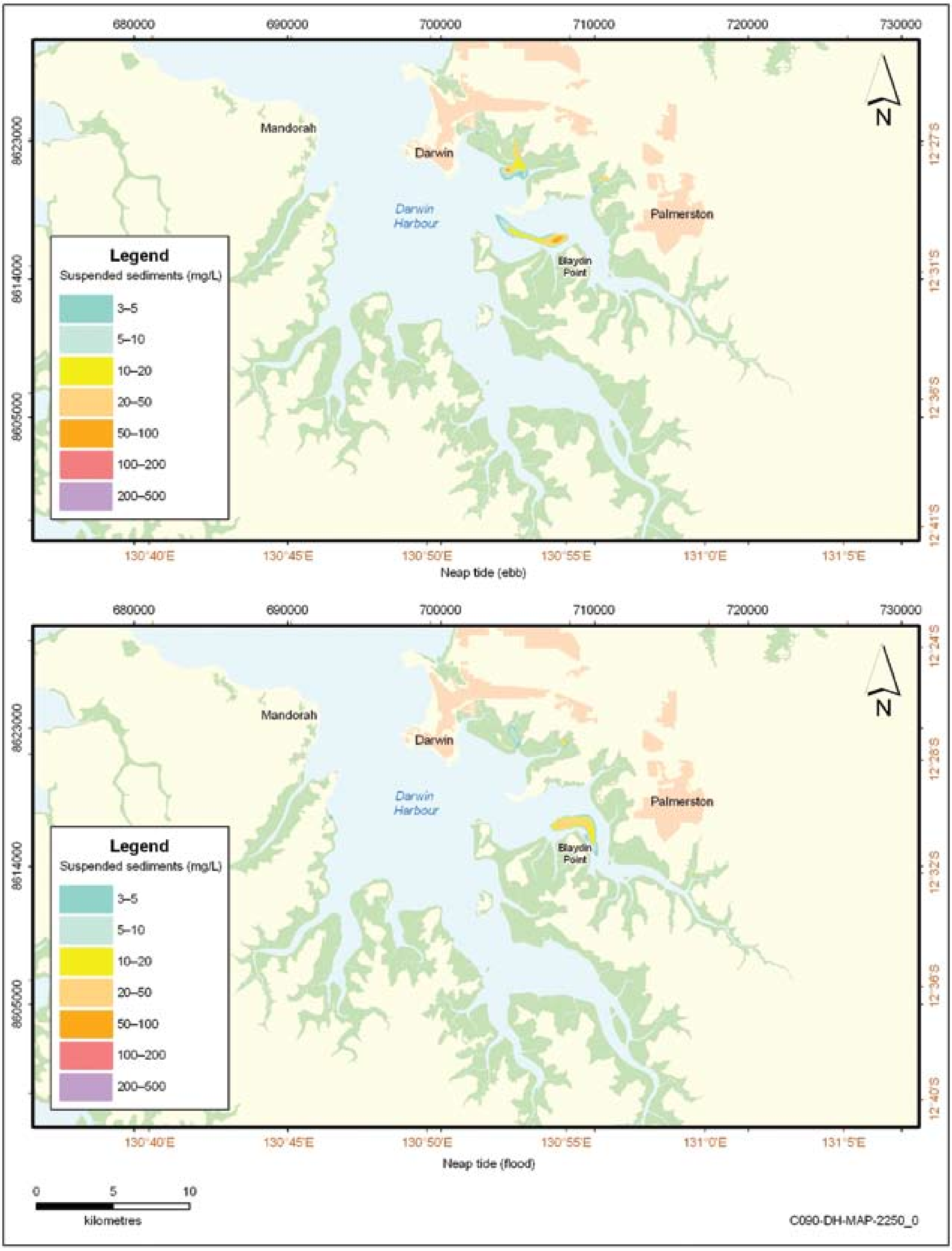

Figure 7-19 (a): Predicted instantaneous suspended-sediment concentrations during a tidal cycle at peak dredging in Phase 6 when the CSD is operating (duration 1.5 months)

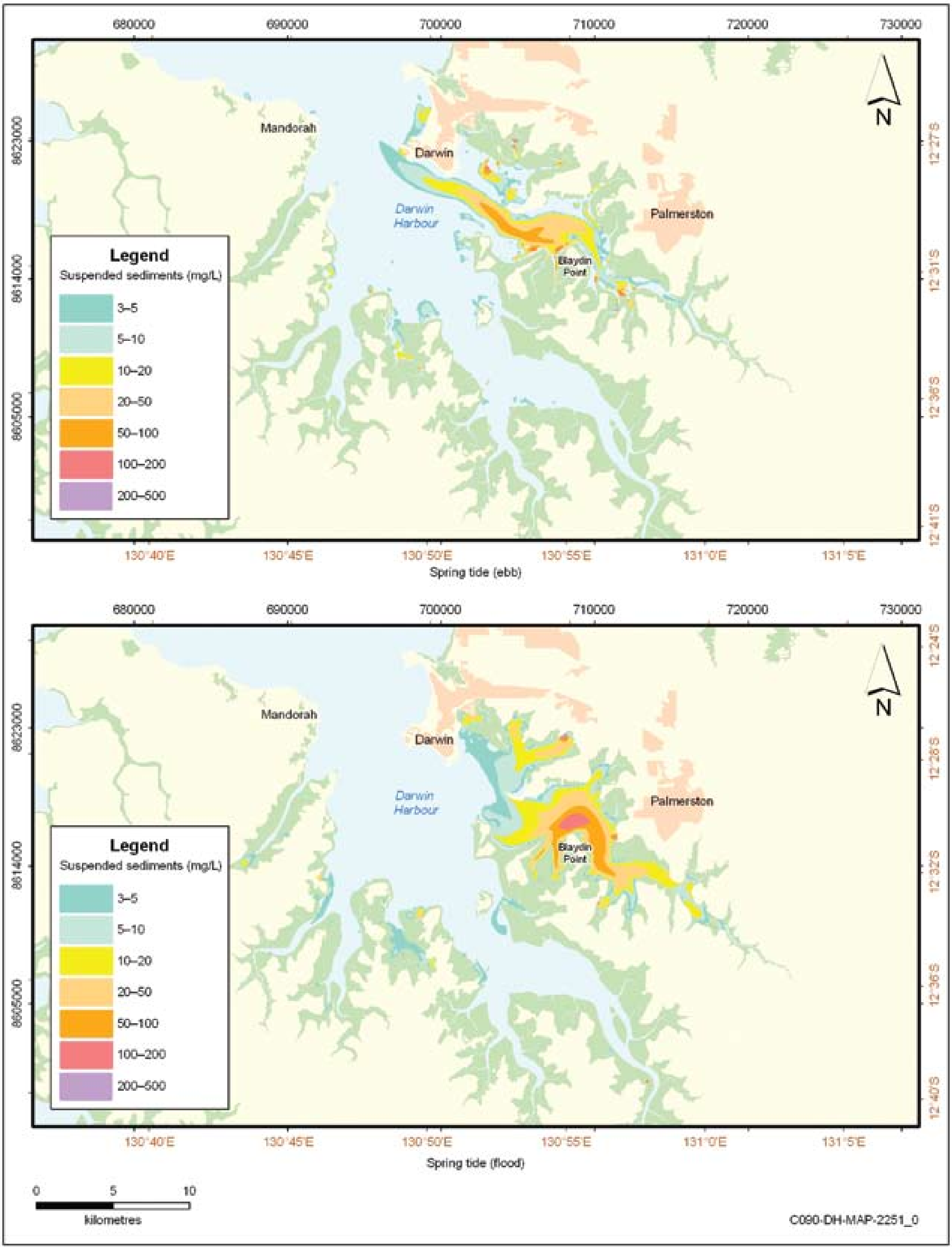

Figure 7-19 (b): Predicted instantaneous suspended-sediment concentrations during a tidal cycle at peak dredging in Phase 6 when the CSD is operating (duration 1.5 months)

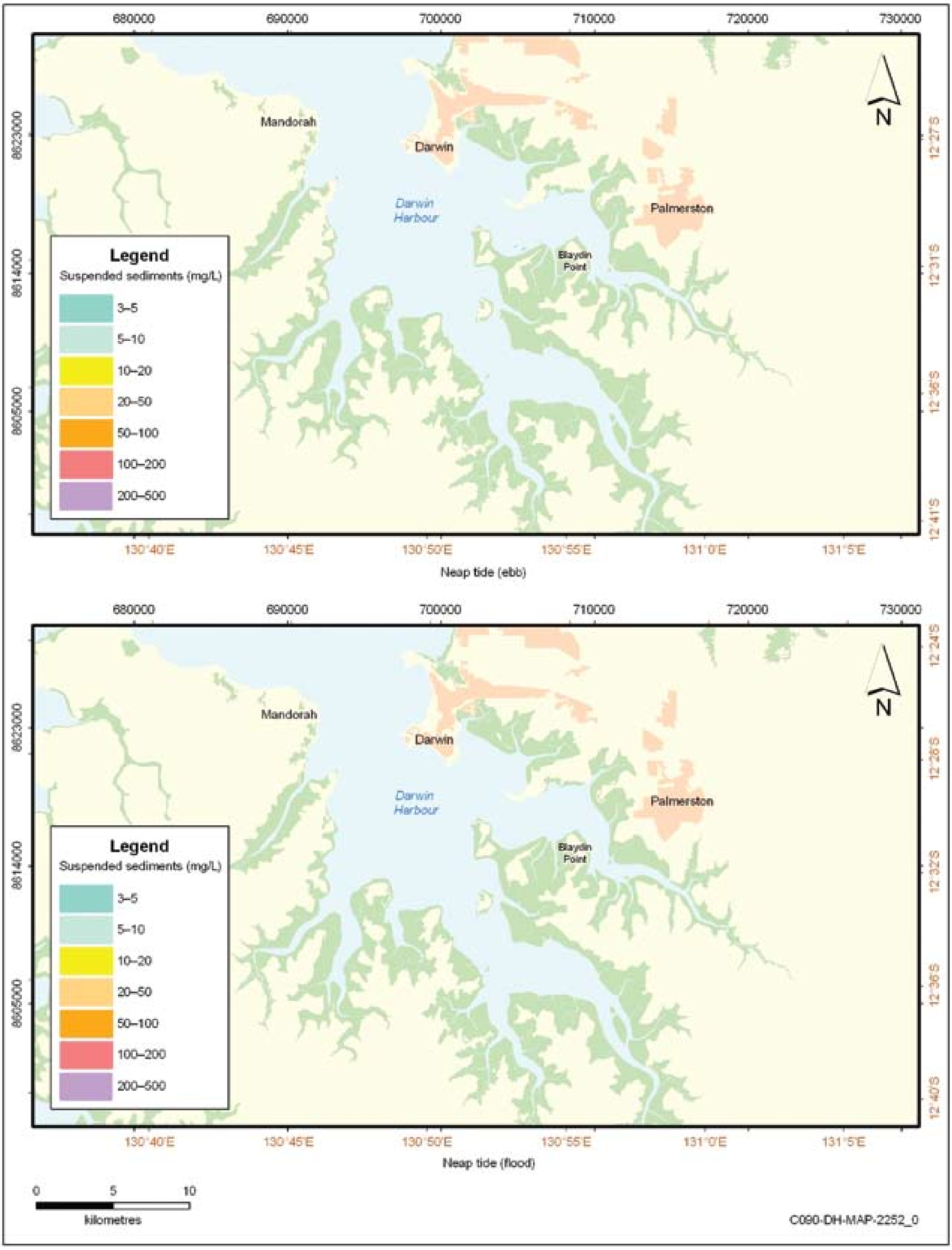

Figure 7-20 (a): Predicted instantaneous suspended-sediment concentrations during a typical tidal cycle in Phase 8 of the dredging program (duration 4.5 months)

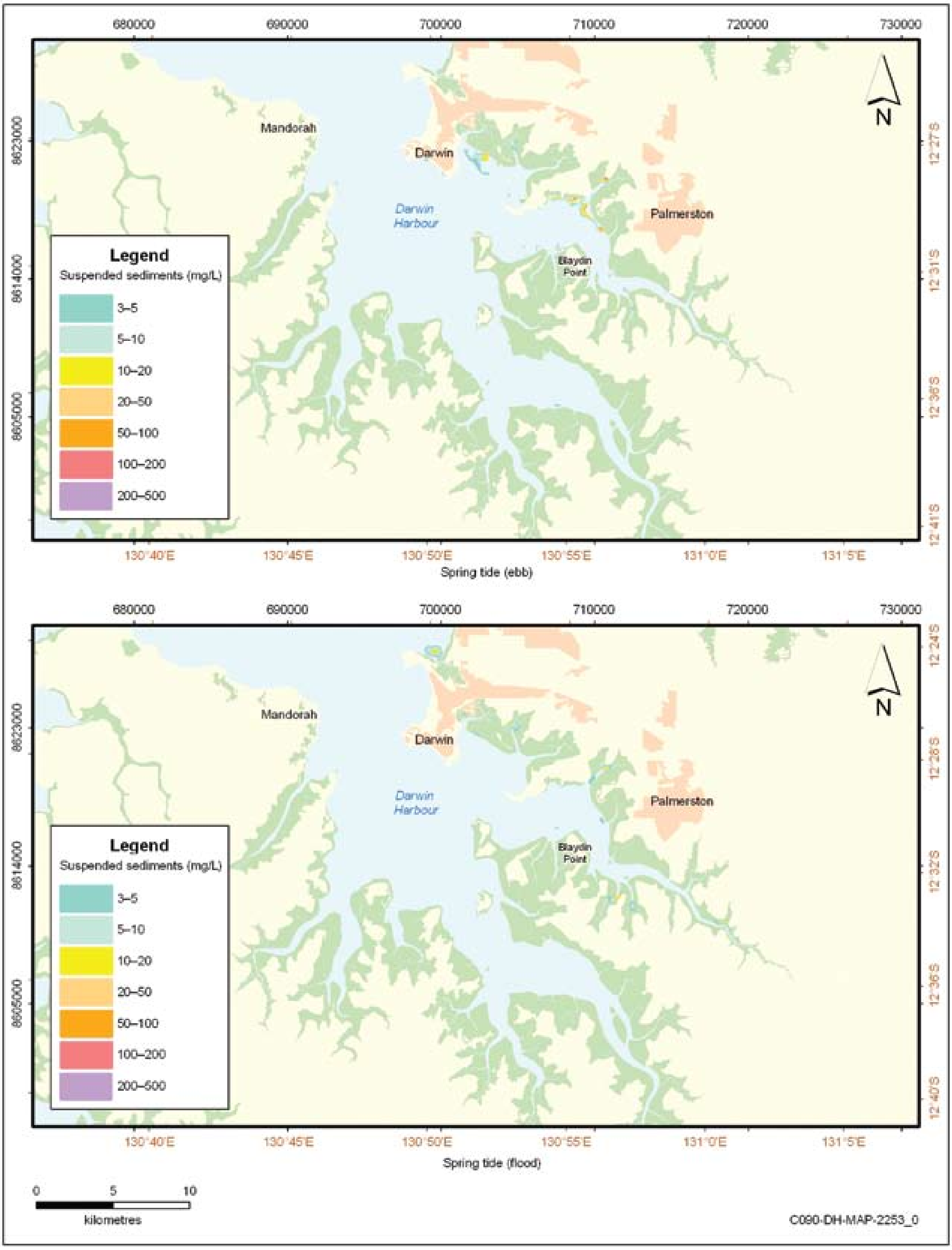

Figure 7-20 (b): Predicted instantaneous suspended-sediment concentrations during a typical tidal cycle in Phase 8 of the dredging program (duration 4.5 months)

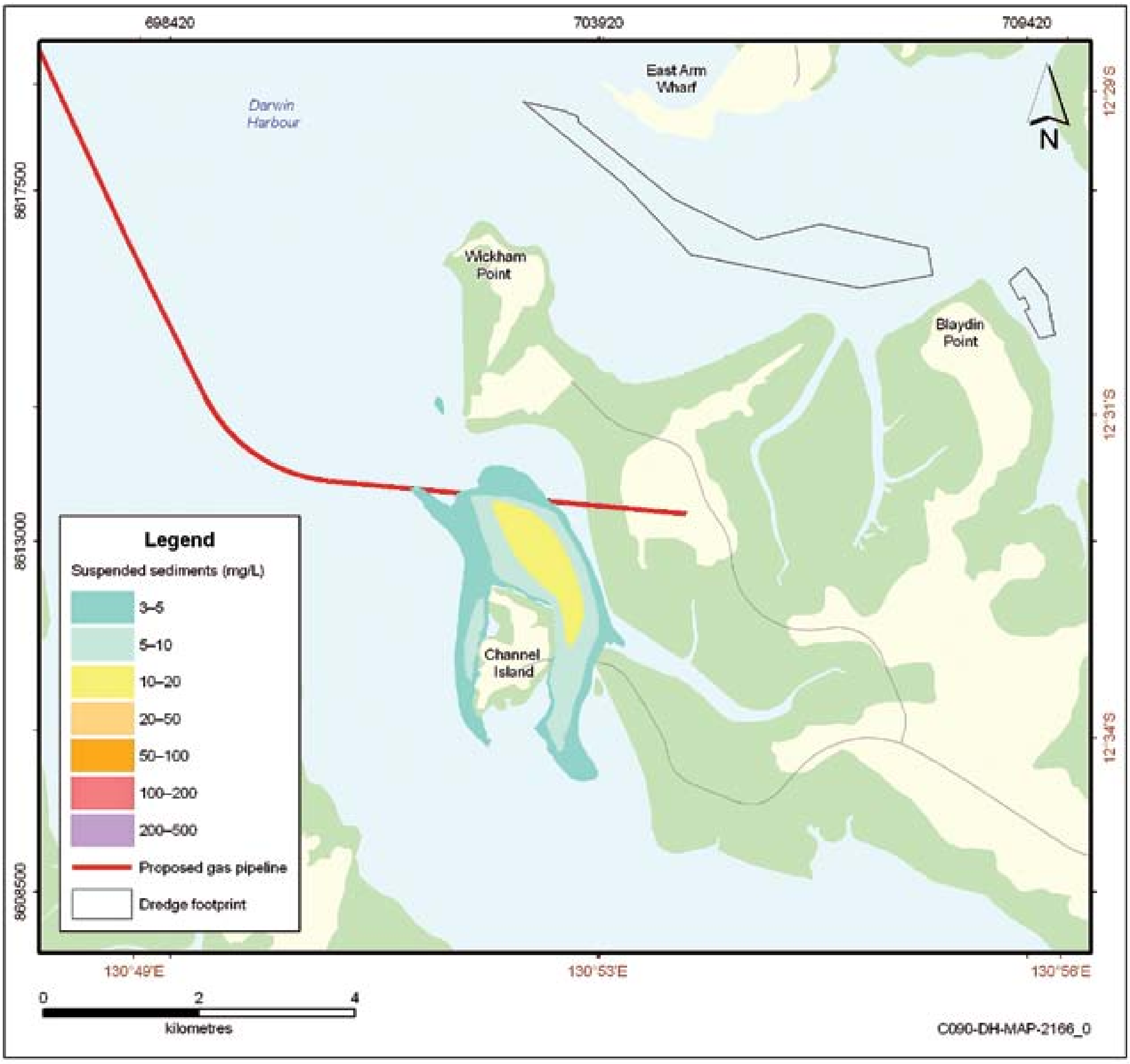

Figure 7-21: Predicted instantaneous suspended-sediment concentrations during dredging for the pipeline shore crossing during the approach to spring tide

Table 7-30: Predicted suspended-sediment concentrations at East Arm coral sites during the dredging program

Suspended-sediment concentrations (mg/L above background)	Percentage of time during which concentrations will be exceeded during the dredging program (%)		
	South Shell Island	North-east Wickham Point	Weed Reef
5	2.33	1.11	<0.01
10	1.09	0.55	0.00
20	0.50	0.16	0.00
50	0.04	0.01	0.00
100	<0.01	<0.01	0.00

Source: HRW 2010.

Shoreline sedimentation

Around the dredging area, ongoing resuspension of fine sediments is predicted to result in the gradual shunting of these materials into shallow areas, where current speeds are slow. Mangrove roots, trunks and leaves have been shown to exert high drag forces on current flows, resulting in sluggish water flow that induces settlement and trapping of suspended sediments in the mangrove fringe. Dredging for the approach area and turning basin is predicted to cause patches of sedimentation in intertidal areas throughout East Arm (Figure 7-23). These are known to be natural depositional areas (DHAC 2006) as described in Chapter 3. This sedimentation would increase gradually until the end of the peak dredging period in Phase 6 (three years into the four-year program).

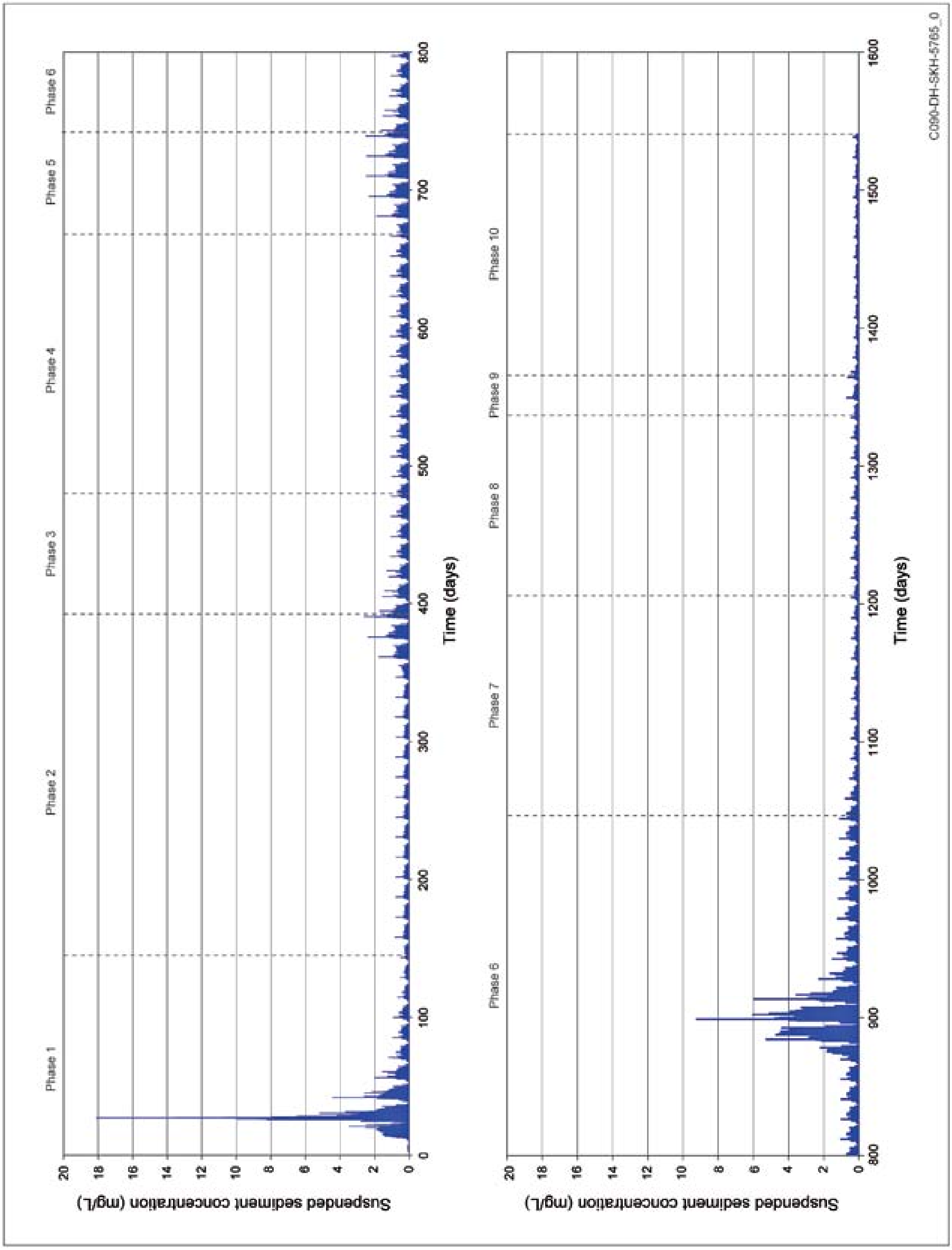

Figure 7-22: Time series of predicted suspended-sediment concentrations at the Channel Island coral community

From Phase 7 onwards, the lower levels of dredging activity result in no net increases in sediment deposition in mangrove areas. Some minor erosion of these accumulated sediments occurs during this time. Net sedimentation patterns at the end of Phase 10 (6 months after dredging) indicate that deposits of fine sediments would still be present in intertidal areas (see Appendix 13). In the long term, tidal currents may erode some of this material while some may be incorporated into the intertidal sediment profile.

Sediment accumulation as a result of pipeline dredging is low and is only predicted to occur in the immediate vicinity of the pipeline shore crossing (see Appendix 13).

Throughout East Arm, the intertidal mangrove zone varies in width and can extend up to 400 m horizontally from the mean low-water level (see the mangrove mapping provided in Chapter 3). Sediments are generally predicted to accumulate along the seaward edge of this zone, but the model also shows some accumulation higher in the profile. Overall, 30 ha of mangrove vegetation is predicted to accumulate more than 50 mm of sediment, and 2 ha of this is predicted to receive more than 100 mm (see Appendix 13).

Sediment accumulation on the subtidal seabed in Darwin Harbour is predicted to occur mainly within the dredging footprint, with little build-up for seabed features such as rock pavement. Sediment accumulation is influenced by the tidal pattern: neap tides allow sediment to settle to the seabed, while spring tides remobilise the sediment into the water column.

Sediment accumulation at coral sites around the Harbour is predicted to be negligible, with less than 1.0 mm of sediment deposition at the South Shell Island, north-east Wickham Point, Weed Reef and Channel Island communities during peak dredging (see Appendix 13).

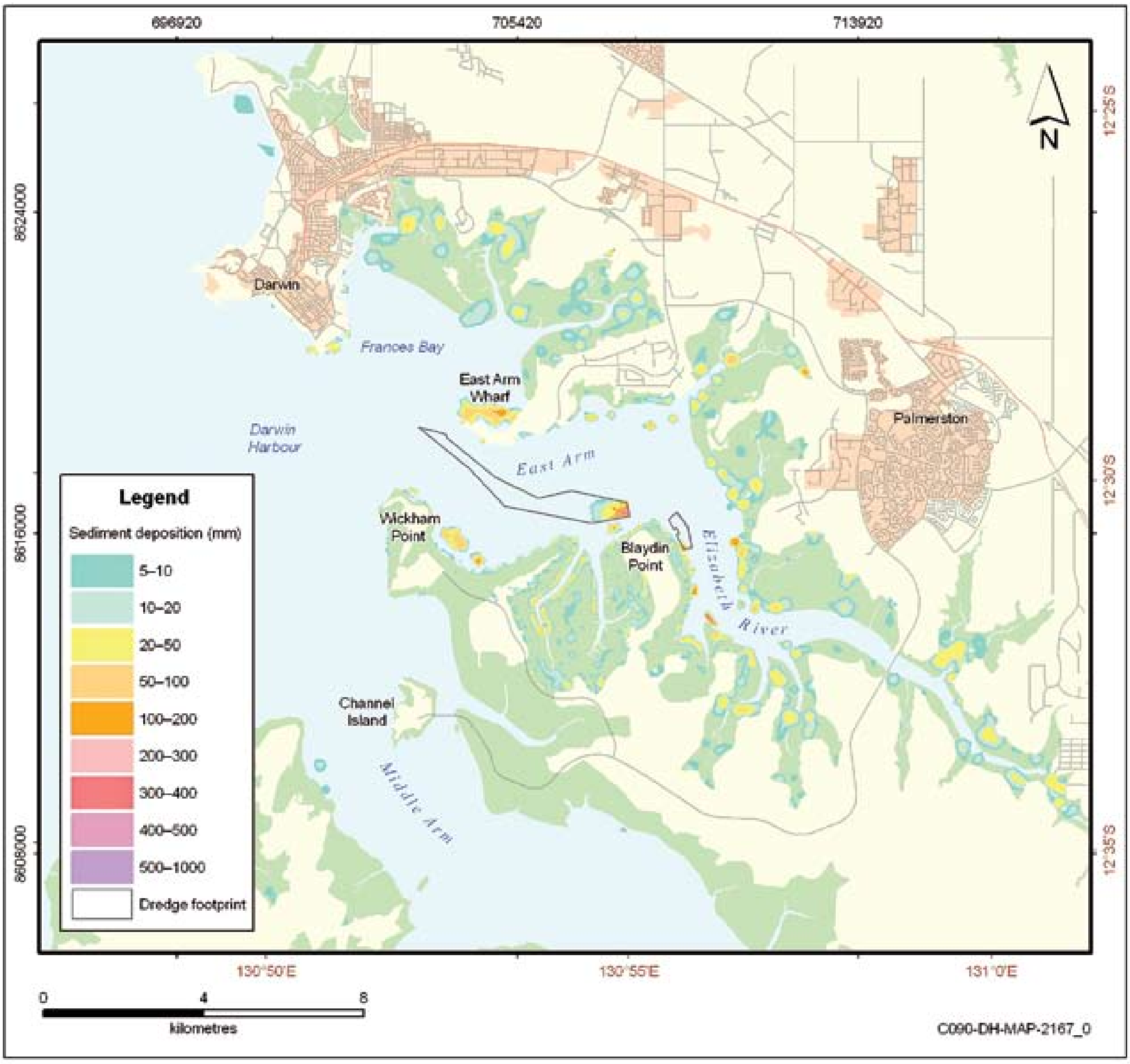

Figure 7-23: Predicted shoreline sediment accumulation at the end of peak dredging in Phase 6

Sand transport

The amount of sand released into East Arm from the dredging program is predicted to be small, in the order of 0.4 Mt, because no overflow from the TSHD is planned. Consequently, the quantities of sands migrating away from the dredging area are also predicted to be small (see Appendix 13).

Modelling of sand transport throughout East Arm indicates that the seabed is mobile under existing conditions, with a net flood-dominant transport pattern into East Arm. During and after dredging, there is predicted to be little change to the magnitude and direction of tidal currents and sand transport patterns in the western portion of the dredging area (the shipping channel). However, some sandy material could migrate from the eastern end of the dredging area (turning basin and berthing area) towards the north-east in the early stages of the dredging program. This pattern would be consistent with the alignment and migration of well-formed sand waves that already occur in this part of East Arm (Smit 2009). The total accretion outside the dredging footprint is estimated to be a few centimetres in depth (see Appendix 13).

At the end of dredging, the deepened areas in the turning basin and berthing area are predicted to cause currents to slow appreciably. Sand transport at the base of this pocket would decrease as a result and this part of the dredged area is predicted to form a trap for sandy material (see Appendix 13).

Impacts on marine habitats

Mangroves

Key adaptations of mangrove plant species to the intertidal environment are specialised aerial-root systems that allow root respiration in anaerobic, waterlogged soils. These occur in the form of cable roots and pneumatophores (vertical roots) in the genera *Sonneratia* and *Avicennia*, and in the form of prop or stilt roots, or buttressed trunks, in the genera *Rhizophora*, *Camptostemon* and *Ceriops*.

Mangroves are known to promote sedimentation in the intertidal zone, as their stems and roots can significantly reduce the velocity of tidal water through a combination of friction acting on water movement and sediment flocculation. Natural sediment accretion rates at a variety of sites worldwide were reported by Ellison (1998) at generally less than 5 mm/a, but reached up to 10 mm/a. These levels were apparently tolerable, causing no negative effects on plant growth.

Excess input of sediment to mangrove communities can cause tree stress owing to smothering and burial of root systems. Impacts can range from reduced vigour to death, depending on the amount and type of sedimentation and the mangrove species involved. A review of sediment burial of mangroves in Australia and internationally (Ellison 1998) describes mangrove degradation or death from sediment deposition depths of between 50 and 2000 mm. The response of different mangrove species to root burial does not appear to be standardised and is likely to be a function of root architecture, tidal range, sediment composition and grain size. In the Australian examples, deaths of *Avicennia marina* were caused by sedimentation depths of 120–500 mm, and deaths of *Rhizophora* spp. were linked to sediment depths of 500–700 mm (Ellison 1998).

Similar differences in species tolerance to sedimentation were observed at a cyclone-affected site north of Exmouth, Western Australia, and this was attributed to the specialised root architecture of each species (Biota 2005). The pneumatophores of *A. marina* were largely, but not completely, buried by the sediment deposited in the mangrove zone, causing widespread tree deaths. However, the more elevated and exposed "stilt" root system of *Rhizophora stylosa* remained above the new sediment level and the trees displayed minimal signs of stress. The lenticels (gas-exchange pores) on *R. stylosa* roots were typically more than 100 mm above the normal sediment height, providing a level of tolerance to changes in sediment levels (Biota 2005).

Sonneratia alba woodland dominates the seaward margin of the mangrove zone throughout East Arm (see the mangrove mapping by Brocklehurst and Edmeades (1996), provided in Chapter 3). Behind the *S. alba* zone in East Arm, the most frequently occurring assemblages include the following:

- *Rhizophora stylosa* closed forest
- *Rhizophora stylosa – Camptostemon schultzii* closed forest
- low open woodland, consisting of scattered *Sonneratia alba*, *Rhizophora stylosa* and *Avicennia marina*
- *Ceriops tagal – Avicennia marina* low closed forest
- *Ceriops tagal* low closed forest.

Of these mangrove communities, the *Ceriops tagal – Avicennia marina* low closed forest assemblage is likely to be the most sensitive to sedimentation, because of the dependence of *A. marina* on fine pneumatophores that would potentially be coated or buried by sediment.

While Ellison (1998) noted that there are insufficient data available to establish specific tolerances, on the basis of existing literature it is considered that sedimentation levels of up to 50 mm would be generally tolerable by the mangrove communities throughout East Arm, regardless of the species affected. Above this level of sedimentation, *S. alba* and *A. marina* would be most at risk of decreased growth or death. At sedimentation levels above 100 mm, tree deaths in *S. alba* and *A. marina* are considered likely. *Rhizophora* trees can be expected to tolerate higher levels of accretion, up to 200 mm.

It is also noted that many of the sediment burial events described by Ellison (1998) resulted from instances of rapid sediment deposition (e.g. from floods, cyclones or short-term human disturbance) that occurred over a few days or weeks. Therefore these threshold levels may be very conservative when applied to the sedimentation levels predicted in East Arm mangroves over four years of dredging.

As described earlier in this section, modelling predicts that around 2 ha of mangroves will be affected by sedimentation of 100 mm or more over the first three years of the dredging program, which equates to roughly 35 mm per year. In addition, there are some 28 ha predicted to receive net sedimentations of between 50 and 100 mm, or 17–35 mm per year. It is possible that the more sensitive mangrove species (e.g. *Sonneratia*, *Ceriops* and *Avicennia*) could be at risk of reduced plant growth or even localised death, at net deposition rates between 50 mm and 100 mm, and that some tree deaths are likely at net sedimentation rates of >100 mm. Given that 20 450 ha of mangrove vegetation occurs around the inner shores of Darwin Harbour (see Chapter 3), the relative scale of this potential loss as a result of sedimentation is very low, representing between 0.01% and 0.15% of the total area respectively for the 50-mm and 100-mm deposition thresholds.

Biota (2005) suggests that mangroves are well equipped to regenerate from disturbances such as sedimentation. The intertidal zone in Darwin Harbour is an inherently dynamic environment and the large tidal range, along with extreme events such as cyclones, causes natural sediment movement. In the Exmouth example, evidence of mangrove recovery was recorded in surveys five years after the cyclone damage occurred. Seedling recruitment of *Avicennia marina* was reported to be widespread and locally abundant at this stage (Biota 2005).

Invertebrate animals associated with the mangrove root zone can also be affected by increased sedimentation. Invertebrates are an important component of the intertidal ecosystem as they contribute to carbon- and nutrient-cycling and support animals at higher trophic levels. In addition, burrowing by intertidal invertebrates locally aerates the soil and creates conduits for water and nutrient exchange in the mangrove muds (OzCoasts 2010).

According to Norkko et al. (2002), sediment deposition affects mangrove invertebrates in a number of ways:

- by physically smothering the sediment surface, causing anoxia
- by changing the sediment grain size, affecting rates of invertebrate movement and sediment biogeochemistry
- by enhancing turbidity, with implications for suspension feeder and primary productivity
- by changing the sediment food quality.

In Darwin Harbour, seaward assemblages support the highest diversity and abundance of the invertebrate fauna of the mangrove zones, with peak species richness in the dry season, particularly for polychaete worms. Wet-season monsoon conditions generate wave action, typically leading to erosion of surface sediments in the seaward mangroves and subsequently lowering the abundance of invertebrate animals (Metcalfe 2007).

Polychaete diversity and density is particularly affected by sediment properties such as grain size and silt content. An increase in fine sediment deposition in the seaward mangrove zone may facilitate an increase in deposit-feeding polychaetes, which consume detritus in marine sediments.

Bivalve (mollusc) species are filter-feeders and strain suspended matter and food particles from the water column. Bivalves are found across all mangrove assemblages, but in greatest abundance on the seaward edge. These species would be disadvantaged by sedimentation and may decrease in abundance and diversity as a result (Norkko et al. 2002).

Metcalfe (2007) recorded clear differences in invertebrate species composition between landward and seaward mangrove assemblages. Changes in sediment levels and microtopography could result in a shift of species composition for species such as gastropods (snails) and crustaceans (crabs). For crab species, the size of sediment is strongly correlated with foraging and feeding mechanisms for digestion. Sediment accumulation could displace some crab species but could provide a suitable environment for others.

In terms of grain size and chemical qualities, the composition of sediments accumulating in the intertidal zone will be similar to the existing sediments in those areas. Any invertebrate fauna communities displaced by sedimentation from dredging activity will be able to recolonise the areas.

Hard-coral communities

Sedimentation and turbidity are major causes of degradation of scleractinian corals (Cortés & Risk 1985; Hodgson 1990; Pastorok & Bilyard 1985; Rogers 1983). Sediment affects coral by smothering when the particles settle out, by reducing light availability through turbidity and potentially reducing coral photosynthesis and growth (GBRMPA undated). Excessive sedimentation and turbidity can alter both biological and physical processes, may reduce growth and calcification rates and, if persistent, will cause coral bleaching and death (Rogers 1983; Torres & Morelock 2002; Wesseling et al. 1999). Sediments deposited on coral tissues can cause necrosis through smothering or bacterial infection, and suspended sediments can abrade polyps (Hodgson 1990; Rogers 1983; Wesseling et al. 1999).

Hard corals can rid themselves of sediments by exuding mucous secretions that slough off in tidal currents and return the sediments to the water column. However, this process is metabolically expensive and cannot be sustained in the long term or at high sedimentation levels.

Where mass mortality of corals occurs, the coral reef may not recover, particularly if the subsequent recruitment of corals is also affected. Species composition in these areas can shift to a community dominated by macroalgae.

Offshore coral reef communities are generally regarded as being adapted to low-turbidity and low-nutrient conditions. In contrast, nearshore and coastal communities have evolved in relatively turbid environments where suspended sediment and turbidity are primarily influenced by local wind and wave regimes (GBRMPA undated). However, the extent and severity of impacts in nearshore areas are highly variable and depend on a range of factors including the coral species affected, sediment concentration, grain size, water depth and water temperature (Rogers 1990).

Coral assemblages can persist in areas subject to periods of high natural turbidity and sedimentation (e.g. during cyclones and river floods). These events expose corals to high concentrations of suspended solids and high sedimentation rates for short periods of time. Generally, the species composition of coral communities in areas regularly exposed to these perturbations is different from the composition of clear-water communities. Taxa resilient to turbidity and sedimentation dominate in these areas and the coral assemblage can survive the short-term impacts from these stressors. Erftemeijer and Reigl (2008), for example, in a review of 53 studies exploring differences in sensitivity of corals to sedimentation and turbidity from dredging, suggested that minimum light requirements of corals can be as low as <1% of surface irradiance and that their tolerance to suspended-sediment concentrations can be up to 165 mg/L in marginal nearshore reefs. Maximum tolerable sedimentation rates of >300 $mg/cm^2 \cdot d^{-1}$ were found and the duration that corals could survive high sedimentation rates was found to be more than 14 days for very tolerant species (Erftemeijer & Riegl 2008).

Dredging in the nearshore development area will generate plumes of turbid water that will periodically impinge upon adjacent hard-coral communities, such as those at South Shell Island and off the north-east coast of Wickham Point. The extent of adverse impacts upon these communities will depend upon how close the corals are to their limits of tolerance of sedimentation and to their critical light limits, but given the naturally turbid estuarine environment in Darwin Harbour, it is likely that these species are adapted to periods of low light levels.

The predicted depths of accumulated sediment on coral sites adjacent to the dredging area are negligible (<1 mm), as tidal currents are predicted to resuspend any fine sediments that fall on these areas during periods of slack water. However, it is noted that the model does not account for the small lumps and crevices that form the outer surfaces of corals, and that some fine sediments may be trapped within these that cannot be removed by ambient currents. While some coral polyps may be able to remove this sediment by secretion of mucus, there may be small patches or parts of individual corals that suffer some reduced growth or death as a result of sedimentation.

The coral species that occur in East Arm also exist elsewhere in Darwin Harbour (see Appendix 8) and it is considered that there is good potential for the recovery over time of any areas affected by the dredging program as natural recruitment will gradually rejuvenate the communities.

The Channel Island coral community will be exposed to pulses of decreased light availability during dredging at the pipeline shore crossing. These pulses of turbid water will coincide with peaks in natural background turbidity levels (i.e. under spring-tide conditions). There will also be periods during neap tides where higher incident light levels will be available to light-sensitive biota (such as hard corals), allowing photosynthetic activity to return to natural levels. The levels of suspended sediments predicted for the Channel Island coral community are not expected to result in decreased growth or coral mortality as they are relatively low and short in duration. The area will be subject to monitoring and management controls (described below) given its status as a protected natural heritage area. In the unlikely event of impacts to the coral community as a result of dredging, it is considered that any decline in coral abundance will be reversible over time as natural recruitment replenishes the community.

Other benthic communities

Removal of soft- and hard-bottom benthic communities by dredging activities (i.e. direct impacts) are discussed in Section 7.3.1 *Alteration of habitat*. The potential for indirect impacts from turbid plumes and sand transport upon these communities is as follows:

- Soft-coral and sponge (filter-feeder) assemblages could be smothered, resulting in mortality, where relatively high rates of sedimentation occur, such as in areas of subtidal pavement or rock near the dredging area in East Arm. If the accumulated sediment is subsequently removed by natural processes, the re-exposed hard substrate is likely to be recolonised by similar soft-coral and sponge assemblages. While the sediments remain in place, they are likely to be colonised by soft bottom communities typical of those existing across broad areas of the Harbour seafloor. The low levels of sedimentation predicted for South Shell Island and north-east Wickham Point (<1 mm) are unlikely to smother filter-feeders.
- Impacts upon soft-coral and sponge assemblages will also occur where suspended-sediment loads increase to the level that clogging of their respiratory and feeding structures occurs. At sublethal levels of increased turbidity, these filter-feeding communities may benefit from the release of organic matter from the sediments by the dredging works.
- Smothering of soft-bottom communities in East Arm, which have been shown to consist predominantly of amphipods, polychaetes and bivalves (see Appendix 8), could occur in areas close to the dredging footprint. While immobile animals may be smothered by incoming sediments, some infauna may be able to tolerate thin layers of deposition. WBM Oceanics Australia (2002) cites a Florida-based study that provides several examples of polychaete and bivalve species that were able to reach the surface following burial by 210 mm of sediment, and notes that some species are able to move horizontally to escape. This corresponds with observations by Smit (2009) of polychaetes on the lee side (the most mobile part) of sand waves in East Arm. Smit hypothesised that these worms would have to grow outwards to compensate for the continuous accretion of mobile sediments, or that they may be opportunistic users of this habitat and have a high turnover.
- Benthic communities downstream from the dredging area may benefit from an increase in the availability of food resources transported in turbid plumes. A monitoring program after dredging in Moreton Bay, Queensland, recorded higher abundances and diversity of benthic organisms than normal for that area, at sites 1.5–2.0 km downstream of the dredging operation (WBM Oceanics Australia 2002).

As the soft-coral, sponge and soft-sediment communities of the nearshore development area are well represented elsewhere in the Harbour, the chance of the dredging program having significant impacts upon the ecology of these marine communities on a Harbour-wide scale is considered very low. Localised losses near the dredging area are expected to recover through recruitment from unaffected communities nearby.

Marine mammals

The most commonly recorded cetacean species in Darwin Harbour are the coastal dolphins—the Australian snubfin, the Indo-Pacific humpback and the Indo-Pacific bottlenose (as described in Chapter 3).

Various studies suggest that dolphins can forage for prey successfully in turbid waters. Although they are known to have well-developed vision, which assists in predator avoidance and social interaction, as their eyes do not point forward their use of vision in pursuit of prey may be limited and they may rather detect their prey using echolocation (Mustoe 2006). In his report, Mustoe notes that dolphins are commonly observed in turbid water where vision would not be of any significant benefit; for example, feeding by stirring up mud to find bottom-dwelling fish and crustaceans, and feeding in plumes created by vessels, where they may be exploiting demersal fish species that are exposed by propeller wash.

Similarly, Australian snubfin dolphins have often been observed foraging in turbid, shallow areas around river mouths, and Indo-Pacific humpback dolphins are found in slightly deeper waters, including dredged channels (Parra 2006). Turbid plumes that occur in East Arm as a result of dredging may be utilised similarly by dolphins for foraging.

The known foraging habitats of snubfin and Indo-Pacific humpback dolphins are in coastal and estuarine waters less than 20 m deep, close to river mouths and creeks, with foraging undertaken in mangrove communities, seagrass beds and sandy-bottom environments through to open coastal waters with rock and/or coral reefs (DEWHA 2010), as described in Chapter 3. These diverse marine environments, with the exception of seagrass beds, occur widely throughout Darwin Harbour and regionally. The river mouth, sandy-bottom substrate and mangrove areas affected by dredging in East Arm represent only a small portion of this available habitat.

Dugong foraging habitats in Darwin Harbour such as rocky reefs at Weed Reef and Channel Island are not expected to be impacted by turbid plumes from dredging. Dugongs may avoid Channel Island during the period of dredging activity at the pipeline shore crossing because of the turbid plumes, noise and general vessel movements in the area; however, this period of disturbance will last for a relatively short 5-week period.

Fish

The fish stocks in East Arm represent a food-chain link between benthic communities and carnivorous marine animals (e.g. dolphins), as well as an important resource for recreational fishing and tourism. Fish, including recreationally important species such as barramundi, mangrove jack, jewfish and bream, may be attracted into the areas disturbed by dredging to feed upon invertebrates liberated from the seafloor sediments or upon the smaller fish attracted to the disturbance. Dolphins may also feed upon fish attracted to the vicinity of the dredges. The carnivorous fish species and dolphins that feed in the upper reaches of Darwin Harbour are likely to be adapted to detecting prey in turbid water. Most fish have a lateral-line system that detects vibrations and assists them to locate prey and to avoid predators (Allsop et al. 2003).

The effects of the dredging operation upon some fish species may therefore be an increase in feeding activity and, potentially, an increase in predation. There may also be some mortality of fish because of physical clogging of their gills by turbid plumes. These types of injuries, however, are caused by very high suspended-sediment concentrations, for example 4000 mg/L as reported by Jenkins and McKinnon (2006). These concentrations are expected to be very rare during Project dredging, even adjacent to the dredging equipment.

Fish eggs and larvae are more vulnerable to suspended sediments than older life stages. Jenkins and McKinnon (2006) reported that levels of suspended sediments greater than 500 mg/L are likely to produce a measurable impact upon larvae of most fish species, and that levels of 100 mg/L will affect the larvae of some species if exposed for periods greater than 96 hours. Levels of 100 mg/L are also likely to affect the larvae of a number of marine invertebrate species (e.g. abalone, sea urchins and bivalves). The sensitivity to suspended sediments of larvae in species local to Darwin Harbour has not been researched. However, based on this assumed “threshold” concentration of 100 mg/L, suspended-sediment levels that could damage fish eggs and larvae could only occur in close proximity to the dredger.

As noted in Chapter 3, Darwin Harbour contains very little suitable spawning habitat for barramundi. It is considered unlikely that dredging activities will disrupt any migration pathways of fish out of Elizabeth River as the turbid plumes will not form a barrier across East Arm. The habitats available to fish in East Arm are similar to those that occur throughout the Harbour.

Marine reptiles

Marine turtles may utilise a wide range of habitats throughout Darwin Harbour for foraging. The potential habitat for green, hawksbill and flatback turtles is presented in maps in Chapter 3. Flatback turtles in particular are known to feed in turbid, shallow waters (DEWHA 2010) and are unlikely to be affected by plumes from dredging. Green turtles and hawksbill turtles, which feed on rocky reefs, sponge and soft-coral areas, and mangroves, may avoid turbid plumes but will be able to utilise unaffected adjacent habitats.

Seasnakes and crocodiles are likely to be accustomed to turbid conditions as they regularly frequent shallow coastal areas and mangroves. They are not expected to be impacted by plumes from the dredging program.

The risk of entrainment of turtles in dredging equipment is discussed in Section 7.3.10 *Marine megafauna*.

Acid sulfate leachate

Some soils and sediments at the pipeline shore crossing, along the onshore pipeline route, and in the ground flare and module offloading facility construction areas are potentially acid-generating if exposed to air (see sections 3.3.5 and 3.4.4 of Chapter 3 *Existing natural, social and economic environment* and Section 8.2.2 of Chapter 8 *Terrestrial impacts and management*). Sulfuric acid leachate can decrease the pH of surrounding waters and can mobilise metals in the disturbed sediments, increasing their availability to enter the food chain.

Fish deaths caused by water acidity are the most obvious and localised impacts of acid sulfate leachates in the marine environment. Chronic effects such as reduced hatching and decline in growth rates could impact marine biota on a wider scale. Acid water also affects the health of fish and other aquatic life through damage to the skin and gills—skin damage increases the susceptibility of fish to fungal infections, while both gill and skin damage reduce the ability of fish to take in oxygen or regulate their intake of salts and water (Sammut et al. 1995). In extreme cases, marine water acidity could cause damage to shellfish and corals as the acid conditions dissolve bicarbonate-based shell material.

The potential for acute impacts upon the nearshore marine environment from leachates will be limited to those periods when the cut surfaces of acid-generating soils are exposed to the air. A natural mitigating factor is the regular tidal inundation of most areas that are prone to acid generation; the lower oxygen environment underwater will suppress further leachate formation and the water will dilute and at least partially neutralise any acid generated.

Chronic impacts from leachates could only arise if acid-generating soil surfaces remained in an oxygenated environment, where ongoing leaching of metals from the sediments could occur. However, the metal loads released would decrease over time as metal concentrations in the sediments declined. Further, the large tidal exchanges occurring across the intertidal areas would lead to rapid dilution of any metals leached from the sediments.

Mangrove muds are naturally acidic as a result of the high levels of organic matter and the waterlogged conditions. Sedimentation of the shoreline by fine materials released during dredging is not expected to generate additional acidification that could affect plants and animals in the mangrove community. Testing of the subsurface marine sediments in the dredging area does indicate that many areas contain potential acid sulfate soil (see Chapter 3). However, when released into the water column, these fine sediments will be mixed with sea water and are expected to be neutralised by dissolved carbonates. Upon their arrival at the intertidal zone, fine sediments from dredging will be similar in composition to the normal marine sediments deposited in the mangroves and are not expected to represent an additional acid sulfate or heavy-metal contamination risk.

As described in Chapter 8, acid sulfate soils will be the subject of a dedicated management plan and monitoring program.

Management of dredging

A Provisional Dredging and Dredge Spoil Disposal Management Plan has been compiled for the Project (attached as Annexe 6 to Chapter 11), which will guide the development of a series of more detailed plans during the construction and operations phases. Key inclusions in this plan are discussed below.

Mangroves

An intertidal sedimentation monitoring program will be developed to assess the effects of sediment accretion on mangrove communities within selected areas of East Arm. The monitoring program will include:

- a baseline assessment of mangrove health and sediment levels at key potential impact sites and suitable reference sites
- quarterly rapid-assessment surveys of mangrove health at the monitoring sites to detect short-term and localised changes in tree condition and canopy cover. Sediment depths will also be measured, using a surveying method appropriate to the small-scale changes (i.e. centimetres) that may occur.

If mangrove tree deaths result because of sedimentation from the dredging program (and are not attributable to natural causes or activities external to the Project), rehabilitation of the affected areas will be undertaken after the completion of dredging activities through a combination of natural recruitment, facilitated natural recruitment and active planting.

East Arm

- A coral monitoring program will be developed to investigate the degree of resilience of corals in East Arm to exposure to sedimentation and elevated turbidity. Monitoring sites at South Shell Island and north-east Wickham Point that were established for previous dredging activities at East Arm Wharf (GHD Pty Ltd 2002) will be used. Video transects and photographic records of the coral communities at these sites will be established prior to the commencement of dredging, with monitoring carried out during dredging and after dredging. Any changes in coral cover or health will be assessed against turbidity data collected adjacent to the sites. As in the earlier East Arm Wharf dredge monitoring programs, coral communities at Weed Reef and Channel Island will be used as reference sites. During the construction of the pipeline shore approach and crossing, only Weed Reef will be suitable as a reference site because of the proximity of the construction activities to Channel Island. During the preparation of the pipeline route, when the dredger will be operating in the vicinity of Weed Reef, only Channel Island will be suitable as a reference site.

- A soft-bottom benthos monitoring program will be developed, with pre- and post-dredge sampling of these benthic communities to identify any changes occurring as a result of the dredging program. Monitoring sites are likely to include the embayment to the east of Wickham Point, as well as suitable reference areas.
- A marine sediments and bio-indicators monitoring program will be developed to assess any increase in bioavailable heavy metals as a result of excavation of acid sulfate soils during the construction phase.

Pipeline shore crossing

A reactive coral monitoring program will be developed to actively manage the dredging, trenching and excavation works at the pipeline shore crossing in order to protect the nearby Channel Island coral community. The program will be similar to those implemented for other developments in Darwin Harbour (e.g. the construction of East Arm Wharf and the installation of the Bayu–Undan Gas Pipeline), and will guide the implementation of management controls during dredging. The monitoring program will comprise the following:

- A 12-month baseline assessment of turbidity levels will be undertaken at the Channel Island coral community and at the reference location at Weed Reef.
- Trigger levels will be developed for turbidity at the Channel Island coral community. As turbidity in Darwin Harbour varies markedly with tidal cycle (neap vs spring tides) and season (wet vs dry season), a matrix of trigger levels may be required.
- A baseline assessment of representative colonies of the coral genera *Herpolitha*, *Mycedium* and *Turbinaria* will be undertaken at both Channel Island and Weed Reef.
- Aerial observations will be made at the commencement of dredging at the pipeline shore crossing to ascertain the potential for surface plumes to impinge upon the Channel Island coral community. These will be undertaken during spring tides when the distance travelled by the plumes will be maximised, and during neap tides when the density of the plumes will be greatest because of the slower tidal currents.
- Turbidity logging will be carried out during dredging at the pipeline shore crossing to ascertain whether near-bottom plumes (not detectable from the air) are reaching the Channel Island coral community.
- If turbidity trigger levels at the Channel Island coral community are exceeded, coral monitoring will be undertaken to determine whether significant coral mortality has occurred at Channel Island compared with the Weed Reef reference site. ("Significant coral mortality" is defined as a percentage of coral mortality relative to the baseline condition of corals at the site. This will be assessed using methods adopted for recent dredge monitoring programs in north-west Western Australia (EPA 2007)).
- If significant coral mortality is recorded along with high turbidity levels, management controls, such as temporary suspension of dredging activities during certain phases of the tidal cycle, will be implemented.
- In the event of significant coral mortality, follow-up monitoring of the Channel Island coral community will also be undertaken after the dredging program is completed. The frequency and duration of post-dredging monitoring would depend on the degree of mortality recorded and will be carried out in consultation with NRETAS.

Residual risk

A summary of the potential impacts, management controls, and residual risk for the turbidity and sedimentation effects of dredging is presented in Table 7-31. After implementation of these controls, impacts to marine habitats are considered to present a "low" to "medium" risk.

Table 7-31: Summary of impact assessment and residual risk for dredging (nearshore)

Aspect	Activity	Potential impacts	Management controls and mitigating factors	Residual risk*		
				C†	L‡	RR§
Turbid plumes	Dredging for construction of jetty, module offloading facility and pipeline.	Sedimentation and turbidity impacts to coral communities in the vicinity, leading to reduced growth or death.	Corals found in East Arm occur at other sites throughout Darwin Harbour. Tidal currents assist in removing sediment from coral surfaces. Provisional Dredging and Dredge Spoil Disposal Management Plan.	E (B3)	4	Medium
		Sedimentation and turbidity impacts to soft-coral and sponge communities.	Soft-coral and sponge communities in East Arm occur at other sites throughout Darwin Harbour. Tidal currents assist in removing sediment from soft-coral and sponge surfaces.	E (B3)	5	Medium
		Sedimentation and turbidity impacts to fish eggs and larvae.	Turbid plumes decrease to relatively low levels at mid- and far-field distances. Mangrove habitats utilised for fish breeding are extensive and widespread throughout Darwin Harbour.	E (B3)	5	Medium
		Reduction in available habitat and food resources for coastal dolphins.	No significant breeding or foraging areas for these species are known in the nearshore area. Dolphins may benefit from foraging opportunities around plumes. Other similar habitat within and near Darwin Harbour will remain unaffected by turbid plumes.	E (B1)	4	Medium
		Reduction in available habitat and food resources for marine turtles.	No significant breeding or foraging areas for these species are known in the nearshore area. Other similar habitat within and near Darwin Harbour will remain unaffected by turbid plumes.	E (B1)	4	Medium
		Reduction in available habitat and food resources for dugongs.	Key dugong habitats at Channel Island and Weed Reef are not predicted to be affected by plumes. No significant seagrass habitat exists in the nearshore area. Macroalgal communities occur throughout Darwin Harbour and most will not be affected by turbid plumes.	E (B1)	3	Medium
	Dredging for pipeline shore crossing.	Sedimentation and turbidity impacts to protected Channel Island coral community, leading to reduced growth or death of benthic biota.	The dredging program in the vicinity of Channel Island is brief in duration. The corals are likely to be adapted to a high-turbidity environment. Reactive coral monitoring program. Provisional Dredging and Dredge Spoil Disposal Management Plan.	E (B3)	3	Medium

Table 7-31: Summary of impact assessment and residual risk for dredging (nearshore) (continued)

Aspect	Activity	Potential impacts	Management controls and mitigating factors	Residual risk*		
				C†	L‡	RR§
Sand transport	Dredging for construction of jetty, module offloading facility and pipeline.	Smothering of soft-sediment biota in East Arm.	Sand transport already occurs under existing current flows. The benthic biota are sparse and likely to be adapted to sand movement. Soft-sediment biota are well represented throughout the Harbour.	F	5	Low
Coastal sedimentation	Dredging for construction of access to jetty and module offloading facility.	Sedimentation of mangroves around East Arm, causing reduced plant growth or death. Localised deaths or reduced growth of invertebrate animal communities.	If mangrove tree deaths result because of sedimentation from the dredging program (and are not attributable to natural causes or activities external to the Project), rehabilitation of the affected areas will be undertaken after the completion of dredging activities through a combination of natural recruitment, facilitated natural recruitment and active planting. The mangrove zone is likely to receive regular influxes of sediment and the invertebrate fauna is likely to be tolerant or to recover quickly. Intertidal sedimentation monitoring program. Provisional Dredging and Dredge Spoil Disposal Management Plan.	E (B2)	4	Medium
Acid sulfate soils	Excavation of mangrove mud for construction of pipeline shore crossing and module offloading facility.	Acid sulfate soil leaching, reducing marine water quality. Reduced health of intertidal marine animals as a result of acid or toxic metal levels in local waters.	Daily tidal movements will dilute nearshore waters and flush leachates from the local area. Excavation volumes will be minimised where possible. Marine sediments and bio-indicators monitoring program. Provisional Acid Sulfate Soils Management Plan.	E (E1)	3	Medium

* See Chapter 6 *Risk assessment methodology* for an explanation of the residual risk categories, codes, etc.

† C = consequence.

‡ L = likelihood.

§ RR = risk rating.

7.3.3 Dredge spoil disposal

The large volume of spoil to be dredged in the nearshore development area will be disposed of at an offshore site to the north of Darwin Harbour around 12 km north-west of Lee Point, as described in Chapter 4. Some of the spoil deposited in this area will be transported by the prevailing currents and will cause turbid plumes in surrounding waters.

Chemical properties of dredge spoil

The qualities of sediments in the nearshore development area were characterised through 151 surface samples and 18 subsurface samples as described in Chapter 3. Typically, surface sediments of fine to coarse sands and gravel-sized particles were recorded in the main shipping channel and turning-basin area, with higher proportions of fine particles in areas close to shore at the areas proposed for the pipeline shore crossing and the module offloading facility. Subsurface sediments were found to include phyllite and sandstone bedrock, as well as some silts and clays.

Sediment quality was assessed through laboratory testing, with metal and contaminant levels compared against the National Ocean Disposal Guidelines for Dredged Material (NODGDM)[9] (the full results are provided in Appendix 9). Metals concentrations were consistently low with the exception of arsenic, which is commonly recorded at elevated levels in the Darwin region and is likely to be an indication of local geology rather than the result of anthropogenic contamination. Laboratory testing using acid digests showed that arsenic in dredged material is unlikely to be toxic in the marine environment, as only very small proportions dissolved into a bioavailable form. Other contaminants such as tributyltin were not recorded above the minimum limits of laboratory testing and petroleum hydrocarbons were below the limits for the majority of sites. The recorded concentrations of tributyltin and petroleum hydrocarbons do not pose a contamination risk when disposed of in dredge spoil (see Appendix 9).

Acid sulfate soil risks were identified in over one-third of the sediment quality samples, which indicates the potential to generate sulfuric acid when the dredged sediments are exposed to oxygen (air) (see Appendix 9). Any acid-generating material deposited underwater at the offshore spoil disposal ground will be exposed to air for only a brief period, during transit from the dredging area in the hopper vessel. Hopper loads will contain a considerable amount of water, minimising the exposure of dredged material to air. Sea water is naturally alkaline and has a moderate acid-buffering capacity because it contains dissolved carbonate and bicarbonate ions. Underwater disposal is an accepted treatment method for acid sulfate soil because of its negligible potential for adversely impacting upon the marine environment through acidification or release of metals.

Dispersion of dredge spoil

As described in Chapter 4, the offshore disposal site was selected in consultation with NRETAS, the DPC, the Marine Safety Branch of the Department of Planning and Infrastructure (DPI)[10], local shipping companies and the Amateur Fishermen's Association of the Northern Territory (AFANT). Local shipping companies identified the route from Howard Passage to Darwin Harbour as an important navigation channel, where disposal of solid material could pose a hazard to the under-keel clearance of ships if not appropriately managed. AFANT identified a need to protect recreational and commercial fishing areas such as Charles Point Patches and the Lee Point artificial reefs from sedimentation impacts caused by the dredge spoil disposal activities. The main concern of NRETAS was to avoid sediment deposition on Darwin's northern beaches and adjoining seagrass zones, while the DPC wanted to be sure that sediments would not return to the Harbour to infill dredged shipping channels.

Site selection

In order to select a suitable disposal site, short-term predictive modelling of sediment dispersion was completed by APASA for a total of nine potential sites (Figure 7-24) (APASA 2010b; see Appendix 14 of this Draft EIS for the full report). A boundary-fitted hydrodynamic (BFHYDRO) model was developed for Darwin Harbour and its surrounds to simulate tidal flows, current velocities, salinity and temperature distributions. Spoil disposal by a hopper vessel was simulated at each of the test areas using the SSFATE sediment fate model (see Appendix 5 for a description of the models).

Simulations involved discharges of 5000 m^3 of spoil at regular 3-hour intervals over approximately 26 days. Modelling focused on the fate of sediments immediately after the main spoil mass had struck the seabed and caused the billowing of finer sediments back into the water column. To account for seasonal effects, simulations were repeated using wind, tide and current data samples from representative wet- and dry-season periods (see Appendix 14).

Simulations of the currents affecting Beagle Gulf and the entrance to Darwin Harbour indicated that the continental shelf bathymetry produces marked steering effects on the tidal currents. Tidal currents offshore from the headlands of Darwin Harbour flow roughly east at flood tide and west at ebb tide. The main drainage channel into the Harbour trends north-west and flooding tides are steered and accelerated along the axis of this entrance channel. Ebbing tides display the reverse trend, diverging and slowing with distance offshore along the channel. Therefore the speed and direction of tidal currents vary throughout the area, which would influence the patterns of transport of sediments suspended by disposal or subsequently resuspended by currents and waves (see Appendix 14).

Shear stress at the seabed is predicted to be highest in shallow areas near the Harbour entrance channel and to decrease with increasing depth. Wave action and swells influence seabed shear stress, reducing the stability of sediments in shallower waters. The rate of remobilisation was predicted to reduce markedly in water depths greater than 12 m (see Appendix 14).

9 It is noted that the National Ocean Disposal Guidelines for Dredged Material (NODGDM) were formally replaced by the National Assessment Guidelines for Dredging 2009 (NAGD) in May 2009, although the two sets of guidelines are very similar. The marine sediments study was completed in 2008 and referenced the NODGDM.

10 The Northern Territory's Department of Planning and Infrastructure was restructured in December 2009. The Marine Safety Branch is now part of the Department of Lands and Planning.

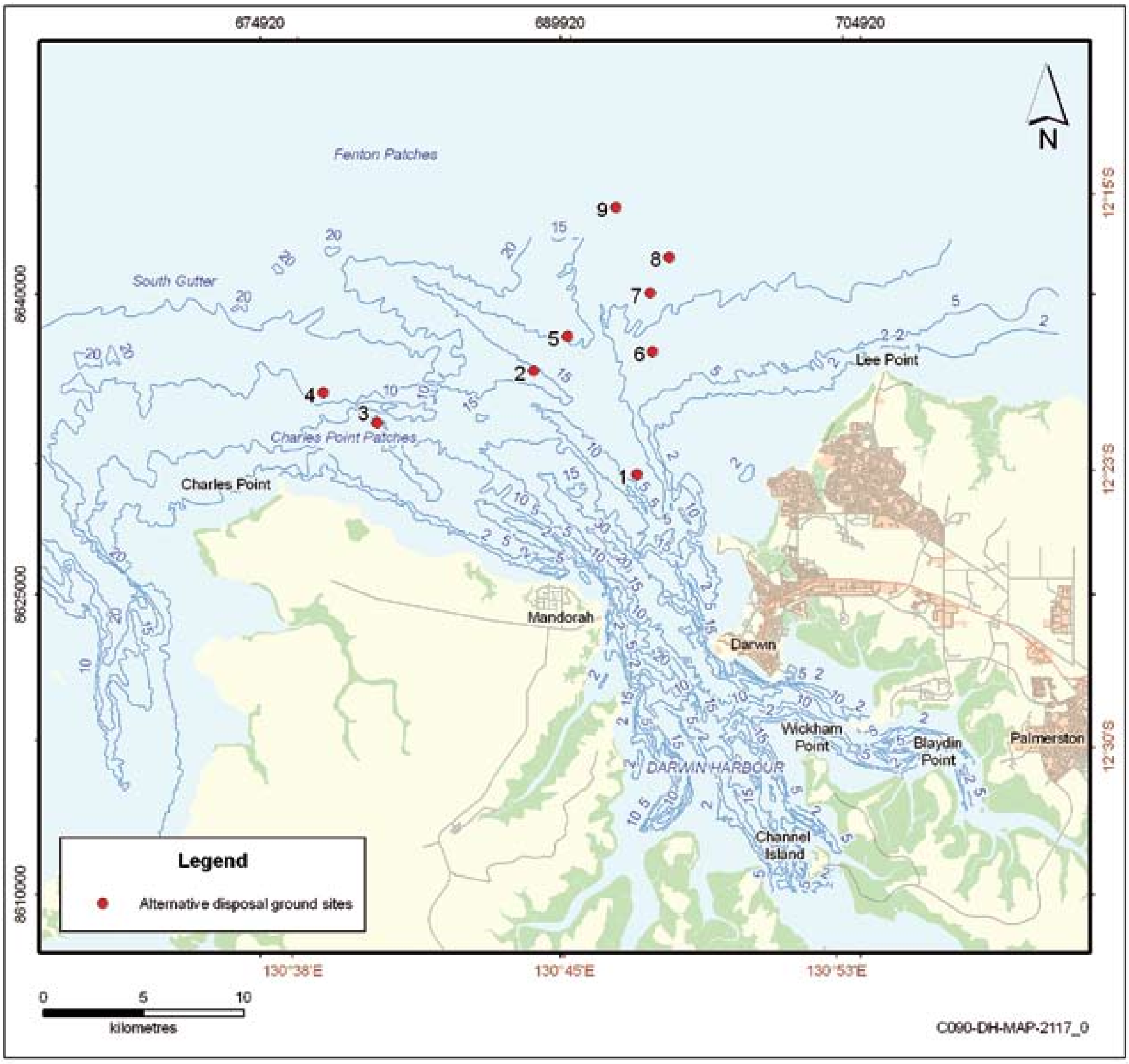

Figure 7-24: Sites outside Darwin Harbour which were considered for offshore spoil disposal

Three example simulations are presented in figures 7-25 to 7-27, showing the highest predicted deposition rates (mm/h) around each disposal site as a result of spoil disposal. Note that the outer contours represent the full field of effect over the duration of the simulation and the internal details highlight the worst expected sedimentation rate for each location. Maximum deposition values occur at different times at each location and sediments redistribute over time within the field of effect; for this reason the results should not be interpreted as cumulative loads (see Appendix 14).

Site 1 is positioned in a water depth of 12 m in the main tidal channel leading into Darwin Harbour. Plumes of fine sediments generated by spoil disposal at this site were predicted to drift up to 15 km, with low-level deposition at Darwin's northern beaches, Fannie Bay and on the shore adjacent to Darwin's central business district. Site 3 is located in a water depth of 10 m north of Charles Point Patches, where the tidal currents draw plumes of fine sediments towards the Harbour entrance. Relatively high sedimentation rates (>10 mm/h) were also predicted at Charles Point Patches when disposal at this site coincided with ebbing tides. Site 9 was positioned in the deepest water (at a depth of 15 m), it was considered optimal for spoil disposal as fine sediments drifted north-east and west with the tides without impinging upon Darwin Harbour or inshore habitats (see Appendix 14).

Site 9, while showing good potential for dispersal of dredge spoil in the long term, was found to be located close to a shipping route for vessels travelling between north-eastern Australia and Darwin Harbour.

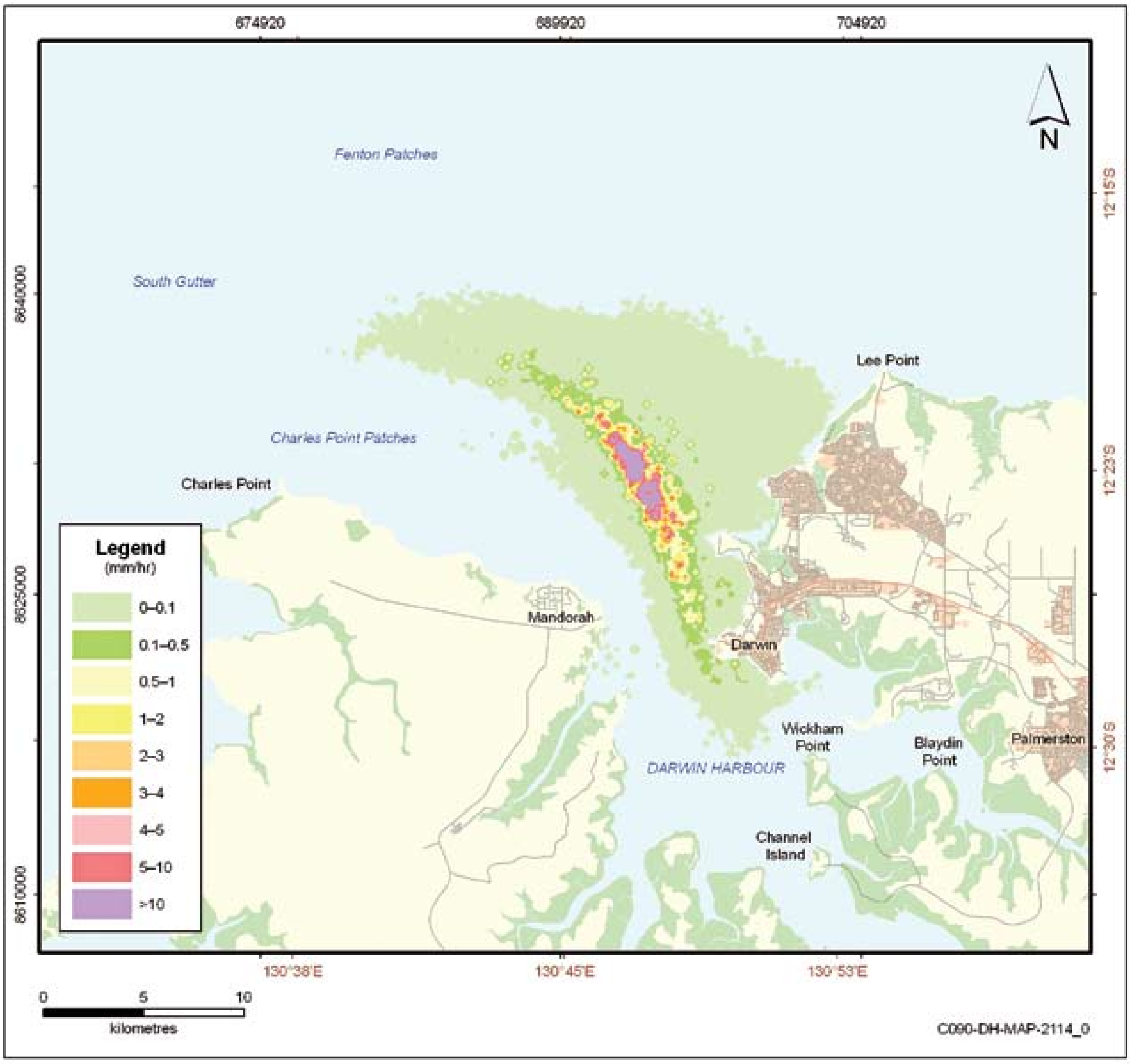

Figure 7-25: Site 1: predicted maximum hourly sediment deposition rate

In order to avoid reducing the under-keel clearance for commercial ships passing near the spoil deposits, which could affect ship handling and safe navigation, Site 9 was shifted slightly north-east to deeper water and lengthened to align with the main tidal axis. This tenth site was finally selected as the offshore spoil disposal ground.

Predictive modelling of spoil disposal

Predictive modelling of sediment dispersal at the selected offshore spoil disposal site for the preliminary dredging program was carried out by HRW, using the TELEMAC-2D flow model and the SANDFLOW sediment transport model (HRW 2010; see Appendix 13 for the full report). Similarly to the nearshore dredge modelling (see Section 7.3.2), the study provided insight into three mechanisms of environmental impact:

- suspended-sediment plumes
- shoreline sedimentation
- sand transport.

The effects of offshore spoil disposal on shipping navigation are described in Chapter 10.

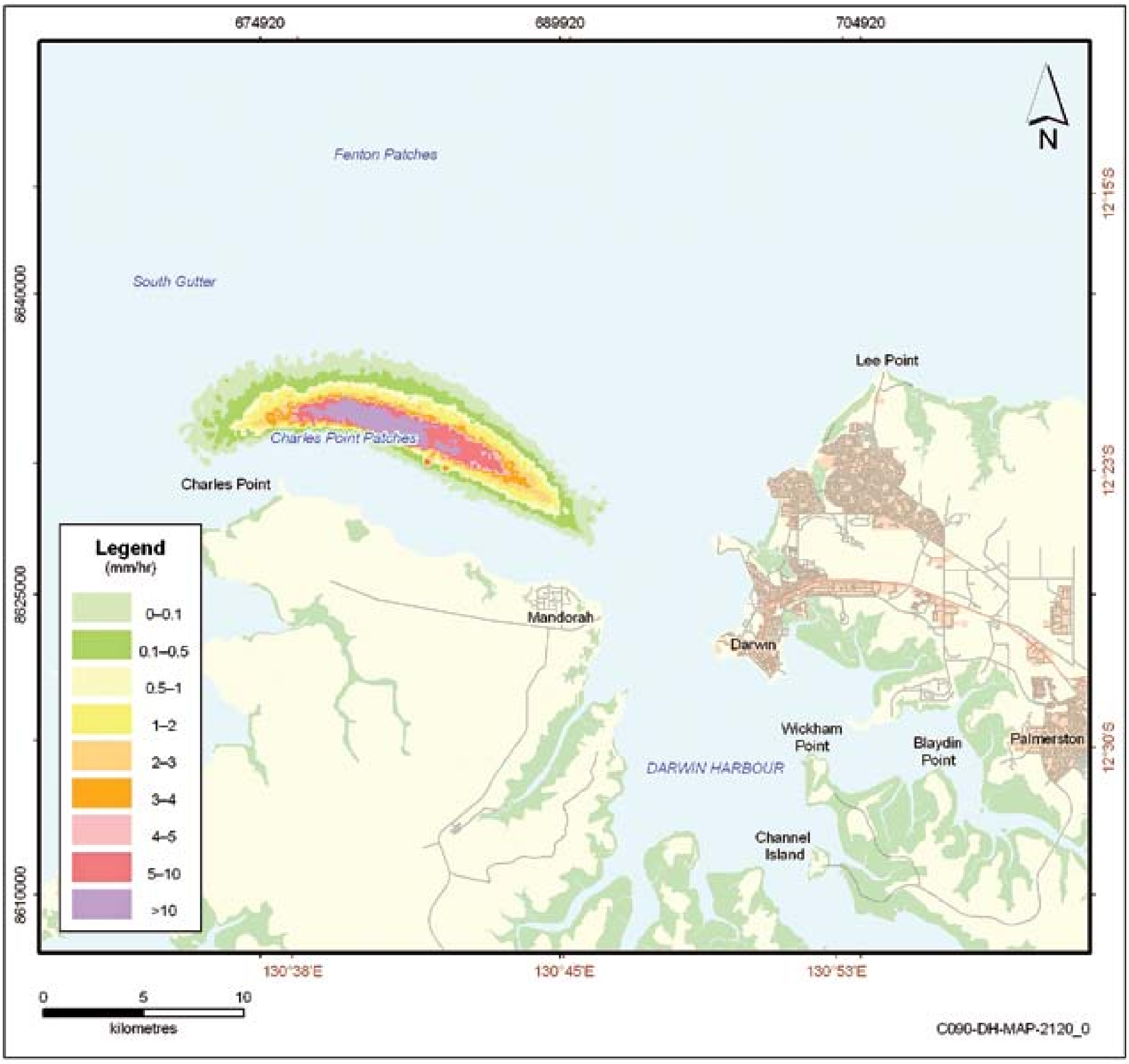

Figure 7-26: Site 3: predicted maximum hourly sediment deposition rate

Suspended-sediment plumes

Fine-grained materials will be transported mainly to the north-east of the spoil disposal ground by tidal currents. These plumes would travel close to the seabed and will rarely be visible from the ocean surface. The largest plumes will be generated during Phase 5 of the dredging program. The median size of these suspended-sediment plumes is shown in Figure 7-28; the plumes are predicted to be smaller than these half of the time, such as during neap tides, and larger half of the time, during spring tides. The predicted median suspended-sediment concentrations are low, with a maximum of 5 mg/L generated in offshore waters to the east of the spoil ground (see Appendix 13).

To understand the increased transport of sediments during spring-tide conditions, the 95th percentile suspended-sediment plume is shown in Figure 7-29. This represents the peak of spoil disposal activities. The 95th percentile concentrations represent the maximum size that plumes could reach during the majority of the worst-case conditions. These plumes are predicted to be much more extensive, reaching coastal waters from Lee Point through to Shoal Bay, Gunn Point and around the Vernon Islands at concentrations of 5–10 mg/L. Some higher concentrations, in the 10–20 mg/L range, could occur in some areas, including the Howard River. During other phases of the spoil disposal program the spatial extent of the plume is predicted to be significantly smaller and peak concentrations in the Howard River are lower, in the 5–10 mg/L range (see Appendix 13).

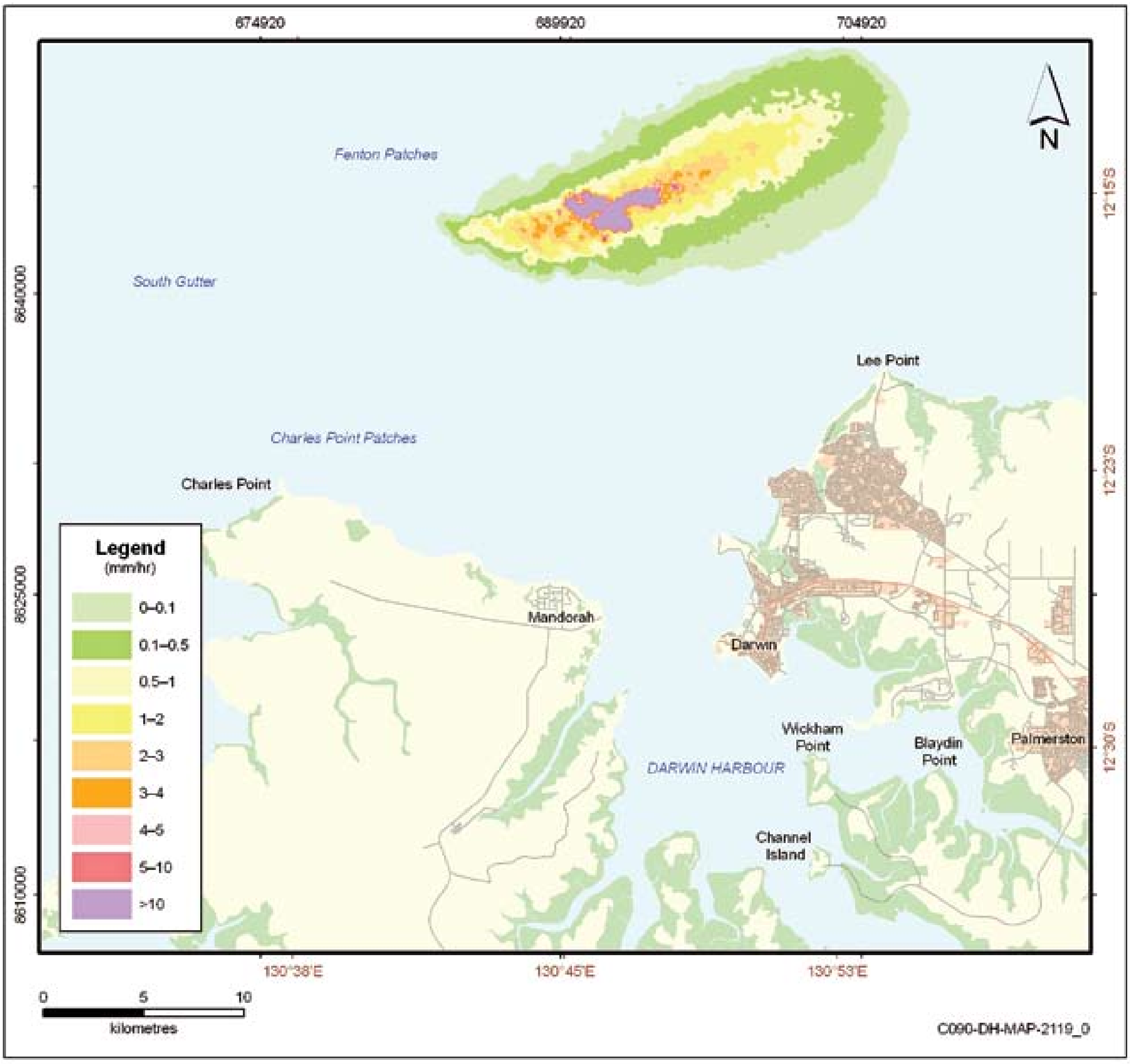

Figure 7-27: Site 9: predicted maximum hourly sediment deposition rate

The Howard River system and Gunn Point would both receive turbid plumes during multiple phases of the dredging and disposal program. Time-series graphs for indicative points reveal maximum levels of 12 mg/L at Howard River and 7 mg/L at Gunn Point during spring tides, dropping to near background levels during neap tide conditions (see Appendix 13). Overall, these peaks exist for relatively short periods of time; suspended-sediment concentrations exceed 5 mg/L above background levels for less than 1% of the entire dredging program at both Howard River and Gunn Point (see Appendix 13).

Shoreline sedimentation

Resuspension of fine sediments from the offshore spoil disposal ground by tidal currents is predicted to result in some sediment accumulation in coastal areas. Similar to the effects within Darwin Harbour, this sedimentation is predicted to peak at the end of Phase 6 (three years into the four-year dredging program) (Figure 7-30). After this time the accumulated sediment stabilises, with some minor erosion, as the contributions from dredge spoil disposal activities reduce. At the end of Phase 10, six months after dredging, deposits of fine sediments are still predicted to persist in coastal areas (see Appendix 13). While some of these sediments may erode away, others are likely to become incorporated into the intertidal sediment profile.

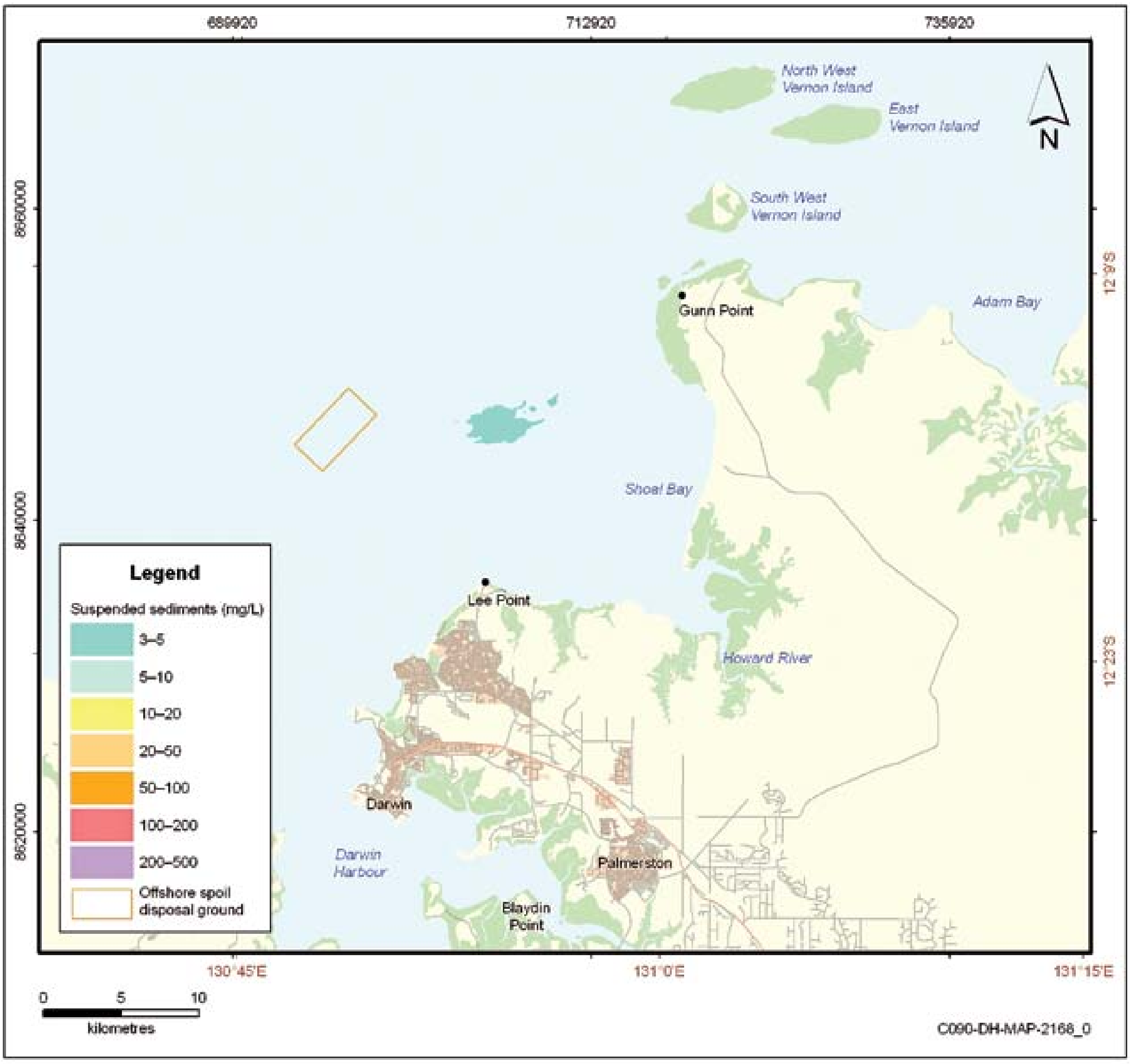

Figure 7-28: Predicted median suspended-sediment concentrations during Phase 5 of the dredging program

Sediment build-up is predicted to occur mainly between Lee Point and the Howard River, and in Shoal Bay, as well as east of Glyde Point in Adam Bay at the mouth of the Adelaide River. Sedimentation rates for most of these areas are in the order of 5–20 mm over the three-year time period; equivalent to 3–7 mm of sediment per year. The model does not represent the effects of freshwater outflow from the Howard and Adelaide rivers, which may also influence the pattern and levels of accretion in these areas (see Appendix 13).

Sand transport

Modelling of sand transport indicates that the seabed surrounding the spoil disposal ground is potentially mobile. Strong sand transport pathways were identified under flood-tide currents, in a south-westerly direction towards Darwin Harbour. This movement is neutralised and reversed when wave energy increases, as the sands are able to move north-east with the weaker, but longer, ebb tide. This situation occurs when wave heights are around one metre or higher, which would occur more frequently in the wet season but also occasionally during the dry season (see Appendix 13).

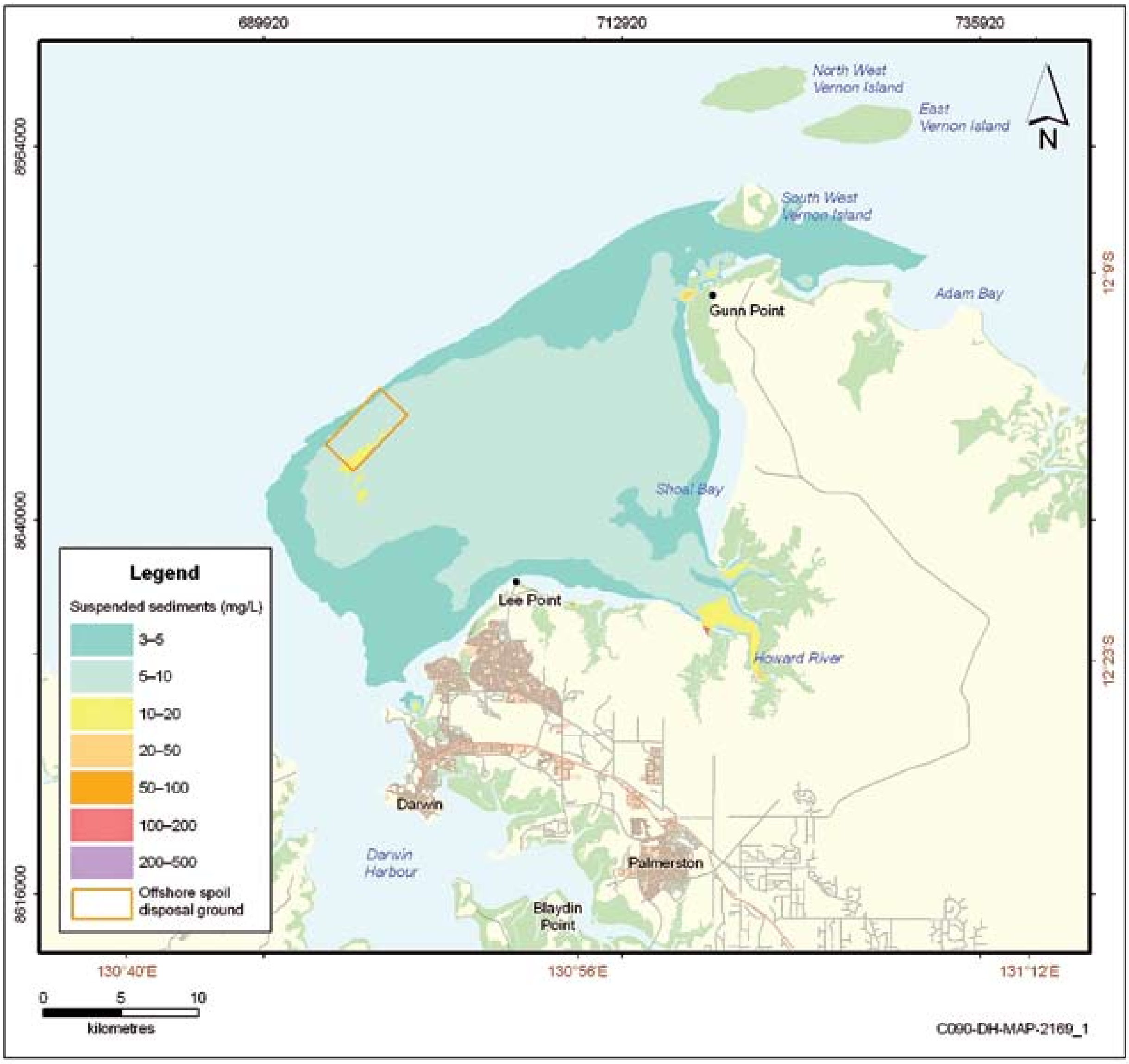

Figure 7-29: Predicted 95th percentile suspended-sediment concentrations during Phase 5 of the dredging program

The material to be disposed of at the offshore spoil disposal ground is broadly similar in texture to the silty sand that is currently found on the seabed at the site, according to a drop-camera survey (see Appendix 8). In the long term, a large proportion of the sand-sized sediments at the spoil disposal ground can be expected to migrate and mix with the surrounding seabed sediments. Some of this spoil will move towards the entrance of Darwin Harbour, which modelling shows is an active zone of erosion and deposition (see Appendix 13). This is consistent with the presence of sandbanks and subtidal bars that have been observed near the mouth of the Harbour and which are caused by natural seabed movement. Any material from the offshore spoil disposal ground that moves towards Darwin Harbour represents a very small fraction of the mobile sediments naturally transported across the seabed in this region.

Impacts to benthic habitats

Offshore

A sidescan sonar survey of the spoil ground, conducted in February 2009 (EGS 2009), showed a gently sloping seafloor composed of soft sediments, with no hard substrate. Seafloor sediments at and around the offshore disposal site are predominantly medium-to-coarse carbonate sands (Smit, Billyard & Ferns 2000). The disposal of dredge spoil on to these sediments is unlikely to markedly change the particle size distribution overall as the finer fractions of dredge spoil will drift with the tidal currents to be deposited in a thin layer across a wide area.

Upon release at the disposal site, dredge material will descend rapidly to the seabed and will smother any sparse benthic communities that may be present.

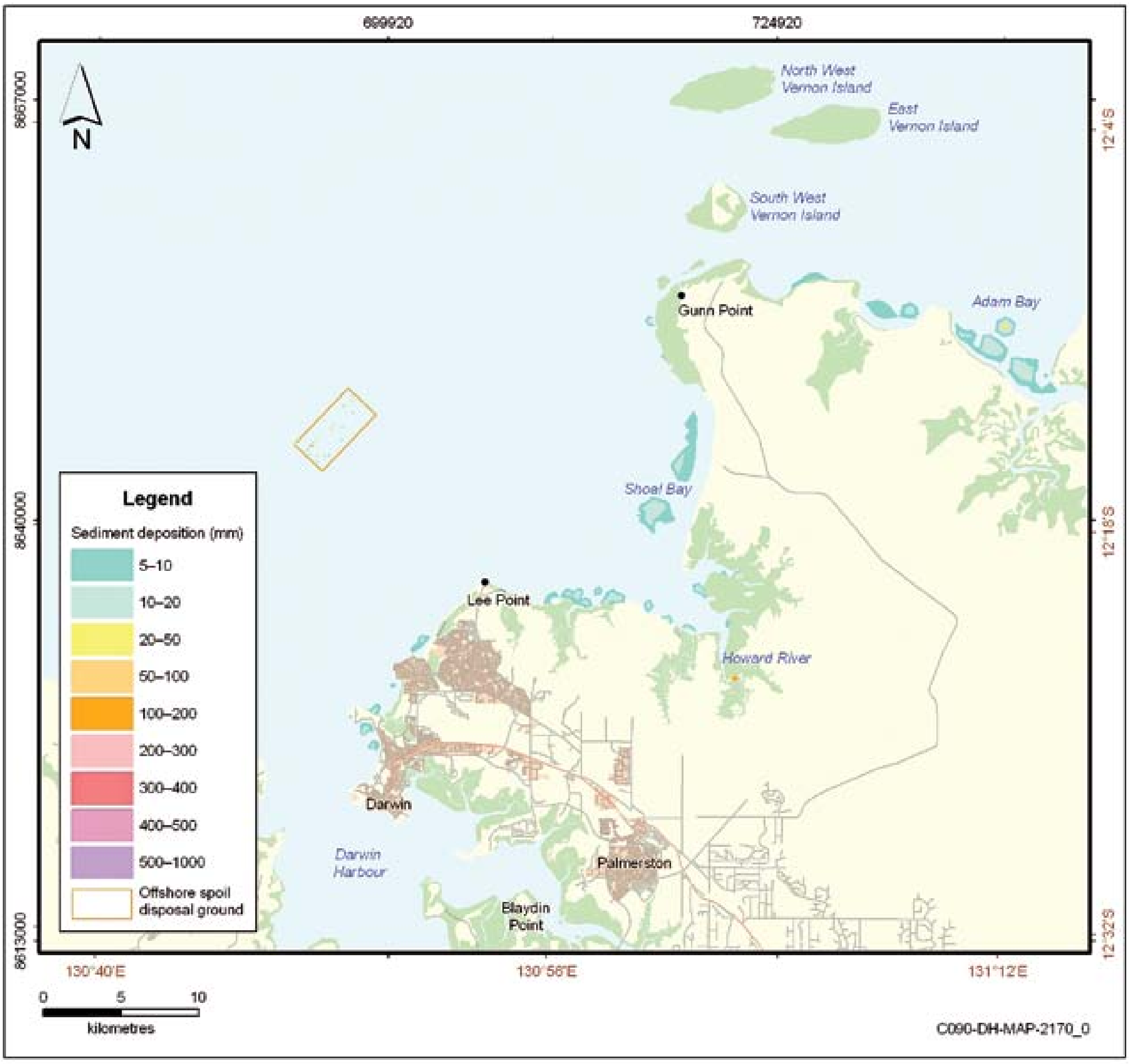

Figure 7-30: Predicted coastal sediment accumulation at the end of Phase 6 of the dredging program

Water currents will disperse the dredge material across the seabed over time, spreading it in increasingly thin layers. As the dredging campaign progresses, the seabed in the spoil ground will develop a hummocky appearance, with mounds of spoil material in various stages of dispersion.

Dredge material disposal will cause some mortality of the burrowing soft-bottom benthic biota present at the disposal site (e.g. polychaete worms and bivalve molluscs). However, sampling by Smit, Billyard and Ferns (2000) showed that the benthic communities in the vicinity of the spoil ground were also characterised by motile crustaceans (small, shrimplike amphipods and crabs) that may survive inundation by dredge material through digging their way back to the surface layer of the seabed. In the longer term, the marine sediments at the disposal area will be recolonised by benthic animal communities similar to those presently established there.

Rocks incorporated in the dredged material are likely to remain in the close vicinity of the disposal site. These rocks could provide a stable substrate upon which sessile animals such as sponges, soft corals, ascidians and bryozoans (and associated motile animals such as feather stars) could become established, representing a diversification of habitat types and biodiversity in the disposal area. Depending on the extent of this effect, fish could also be attracted to the area to forage for food. These changes, however, would be localised in the disposal area and are highly unlikely to be of regional significance.

Coastal areas

Gunn Point and Vernon Islands

Low-concentration turbid plumes travelling towards the Vernon Islands and Adam Bay will mix within the naturally turbid waters of the area. Strong ocean currents are common at this point in the coastline as the narrow channels between Melville Island, the Vernon Islands and the mainland restrict flows between Beagle Gulf and Van Diemen Gulf.

Previous marine habitat surveys in and around South Channel, between Gunn Point and South West Vernon Island, recorded waters of consistently high turbidity, with a rocky, gravelly seabed devoid of sediment deposition (I. Baxter, marine scientist, URS, pers. comm. February 2010; Smit, Billyard & Ferns 2000). Marine communities regularly consisted of filter-feeders such as soft corals, sponges, gorgonians and ascidians (I. Baxter, pers. comm. February 2010; GHD Pty Ltd, pers. comm. March 2010).

Hard corals were recorded on the seaward slopes of reef pavements around Gunn Point and South West Vernon Island. Many of the coral species were typical of turbid reefs, for example *Turbinaria* spp., *Mycedium* spp. and *Goniopora* spp. Large coral colonies were rare and deep loose coral rubble was recorded, indicative of frequent disturbances from storm waves. In general, the corals observed were in healthy condition. Mucus production and sloughing of fine sediments by corals, particularly in *Porites* and *Turbinaria*, was observed at several sites (GHD Pty Ltd, pers. comm. March 2010). Periodic peaks in suspended sediment as a result of spoil disposal are not expected to significantly damage these reef-slope coral communities as they are adapted to similar conditions.

More sheltered hard corals occur on Gunn Reef in the Blue Holes, two steep-sided channels in the reef pavement of around 200 m width and 20 m depth. They contain relatively clear water and support a diverse cover of hard corals at depths down to 2 m. Turtles and fish have been observed in high numbers in the holes. During ebb tide, when turbid waters move west through South Channel, water drains from the holes towards the channel, preventing suspended sediments from entering. During flood tides, the holes are filled from the western side of Gunn Reef (I. Baxter, pers. comm. February 2010). These incoming flows could be affected by low-concentration turbid plumes from spoil disposal during spring-tide periods (up to 4–7 mg/L as shown in Figure 7-29). Under these periodic conditions, the coral communities in the Blue Holes could be exposed to reduced light and low levels of sediment deposition. As spring-tide conditions are short in duration (1–3 days) and are interspersed with longer clear-water periods (11–13 days), these light sedimentation episodes are unlikely to cause significant reductions in coral health. The nature of the Blue Holes as deep channels in the reef flat suggests that they are not natural depositional areas for suspended sediments.

Large intertidal reef flats occur around all three of the Vernon Islands and at Gunn Point. Surveys of these areas recorded algal turf throughout the intertidal pavements (I. Baxter, pers. comm. February 2010; Whiting 2004). Patches of macroalgae in this area typically consisted of species of *Padina* and *Sargassum*, though *Laurencia* and *Udotea* were also common (I. Baxter, pers. comm. February 2010). These habitats are known to support relatively high numbers of dugongs, in the context of the Anson–Beagle Bioregion (Whiting 2004). The algal communities around Gunn Point and South West Vernon Island are predicted to receive turbid plumes from spoil disposal during spring tides, while those at North West Vernon and East Vernon islands are outside the predicted extent of the plumes. Many species of macroalgae can tolerate periodic short periods of low light conditions without reductions in productivity. However, given that plumes from spoil disposal may be reaching this area for up to two years, some species may show reduced growth.

A study on the biological effects of a dispersed sediment plume on temperate macroalgae found that many taxa are able to adjust their photosynthetic apparatus to make best use of variable light reaching the individual, maximising their photosynthetic rates. However, lower light conditions were generally associated with a drop in net 24-hour productivity (Turner 2004). Algal communities in Darwin Harbour show regular seasonal variations in productivity, with high biomass levels during the dry season and low levels in the wet season (Whiting 2004). This corresponds with light availability, which is reduced during the wet season as a consequence of the higher levels of suspended sediments from terrestrial runoff and the reduced sunlight on cloudy days. The algal communities at Gunn Point are expected to have a similar capacity to recover rapidly after a period of low light conditions. In addition, dugongs would have access to unaffected algal habitats at North West Vernon and East Vernon islands throughout the spoil disposal period.

Adam Bay

Further east into Adam Bay, previous surveys recorded coastal areas with more obvious deposition patterns of sediment veneer overlying subtidal pavements, and mudflats occurring in the bays. Seagrasses and hard corals were rarely recorded, and it was concluded that natural turbidity levels prevented their growth (I. Baxter, pers. comm. February 2010; Smit, Billyard & Ferns 2000).

Modelling predicts some low-level sedimentation of these coastal areas as a result of the Project's spoil disposal program. This material will blend with naturally deposited sediments and the rates of sedimentation across the four-year dredging program (net 10–20 mm and 2.5–5 mm/a) can be considered insignificant. Other sources of coastal sedimentation in this region include the breakdown of rocks along shorelines, terrestrial sediments washed from floodplains, and the breakdown of shells and corals.

Shoal Bay and Howard River

Further south, modelling also predicts some development of turbid plumes and low-level sedimentation around Hope Inlet and the Howard River, which are situated in the Shoal Bay conservation area (Harrison et al. 2010). This river system is believed to be a nursery area for barramundi, whose juveniles grow in extensive wetlands of grasses and sedges that are flooded during the wet season. These wetlands are very productive and also provide important habitat for the early stages of other fish species and for prawns. Juvenile barramundi, 100–250 mm in length, move into nearby rivers towards the end of the wet season and generally migrate upstream to permanent fresh water for three to four years. When they reach maturity they move downstream to marine waters. The barramundi stock of Darwin Harbour is believed to use the Shoal Bay wetlands as nursery habitat (R. Griffin, marine biologist, pers. comm. February 2010).

Suspended-sediment plumes with concentrations of 3–20 mg/L are predicted in the Howard River during spring-tide conditions, which could occur for two or three days each fortnight during each phase of the dredging program (see Appendix 13). These suspended-sediment concentrations are additional to background levels. Jenkins and McKinnon (2006) estimate that suspended-sediment concentrations greater than 500 mg/L would produce a measurable impact upon larvae of most fish species, while levels of 100 mg/L would affect larvae of some species if exposed for periods greater than 96 hours. Based on these "threshold" levels, it is unlikely that plumes from offshore spoil disposal would increase suspended sediments in the Howard River to an extent sufficient to cause damage to fish larvae.

The extensive tidal flats and freshwater wetlands of Shoal Bay are important feeding and roosting areas for migratory shorebirds such as great knots in their non-breeding season. It is also a regionally important area for waterbirds such as radjah shelducks, magpie geese and brolgas (Harrison et al. 2010).

The water in this system, particularly during the wet season, is expected to be naturally turbid because of the suspension of marine sediments by tidal currents and the influx of terrestrial sediments in freshwater runoff and stream flow. Extensive mudflats and sandflats are a common feature of Shoal Bay (Harrison et al. 2010), indicating a natural depositional environment. Suspended sediments from the Project's spoil ground with concentrations of up to 20 mg/L and the deposition of less than 10 mm of sediments per year in the lower reaches of the Howard River do not pose a threat to the barramundi breeding cycle or the use of the area by waterbirds and shorebirds.

Lee Point

Seagrass beds are known to occur in coastal waters off Casuarina Beach between Lee Point and Rapid Creek, up to around 2.5 km offshore (N. Smit, Marine Biodiversity Group, NRETAS, pers. comm. July 2009). This area is predicted to receive turbid plumes with concentration levels of 3–10 mg/L only during spring tides in Phase 5 of the dredging program (Figure 7-29) and not during the other phases (see Appendix 13). These brief exposures to low light conditions are unlikely to significantly affect seagrass growth. No sediment accumulation is predicted over these seagrass beds, although some deposition (5–10 mm) is predicted for the southern end of Casuarina Beach near the mouth of Rapid Creek (Figure 7-30).

Management of dredge spoil disposal

As described in Section 7.3.1 above, a Provisional Dredging and Dredge Spoil Disposal Management Plan has been compiled (attached as Annexe 6 to Chapter 11), which will guide the development of a series of more detailed plans during the construction phase of the Project. Key management controls include the following:

- A bathymetric survey of the disposal area and immediate surrounds will be undertaken prior to the commencement of the dredging campaign, to inform the planning of the disposal operations and to establish baseline conditions.
- Periodically during the dredging campaign, further bathymetric surveys will be undertaken to assess the distribution of dredge spoil in the disposal area and to ascertain whether the heavier sediment fractions are migrating beyond the boundary.
- Periodic bathymetric surveys will also enable the management of disposal activities in such a way that shoal areas do not develop, with deeper areas selected preferentially for dumping the spoil.
- On completion of the dredging campaign, a bathymetric survey of the entire disposal area and its immediate surrounds will be undertaken to confirm final depths.
- A soft-bottom benthos monitoring program will be developed with pre- and post-spoil disposal sampling of these benthic communities to identify any changes occurring as a result of the disposal program.

Table 7-32: Summary of impact assessment and residual risk for dredge spoil disposal

Aspect	Activity	Potential impacts	Management controls and mitigating factors	Residual risk*		
				C†	L‡	RR§
Seabed disturbance	Offshore dredge spoil disposal.	Smothering of benthic communities inside disposal area, and then outside the area as sediments disperse. Alteration of seabed sediments.	Sediment types and benthic communities are common throughout the region. Hydrodynamic modelling was used to select the disposal area in order to minimise remobilisation of sediments into sensitive locations. Soft-bottom benthos monitoring program. Provisional Dredging and Dredge Spoil Disposal Management Plan.	E (B3)	6	Medium
Coastal sedimentation	Offshore dredge spoil disposal.	Low-level deposition of sediments on to coastal subtidal and intertidal marine habitats, causing smothering and reduced growth of benthic biota.	Affected areas are naturally depositional environments, where marine communities are adapted to sedimentation. There are few seagrasses and hard corals in the affected areas. Macroalgae are more tolerant of sedimentation.	E (B3)	6	Medium
Turbid plumes	Offshore dredge spoil disposal.	Low light conditions over coastal benthic biota, causing reduced growth and primary production.	The plumes are transported to coastal areas on spring tides only. The tidal cycle results in clear water conditions between turbid spring tides. There are few seagrasses and hard corals in affected areas. Macroalgae are more tolerant of variable light conditions.	E (B3)	4	Medium

* See Chapter 6 *Risk assessment methodology* for an explanation of the residual risk categories, codes, etc.

† C = consequence.

‡ L = likelihood.

§ RR = risk rating.

The potential for interaction between dredge spoil disposal vessels and marine megafauna will be managed through the Provisional Cetacean Management Plan developed for the Project, as described in Section 7.3.10 *Marine megafauna*.

Residual risk

A summary of the potential impacts, management controls, and residual risk for dredge spoil disposal is presented in Table 7-32. After implementation of these controls, impacts to marine habitats are considered to present a "medium" risk.

7.3.4 Liquid discharges

A variety of routine liquid wastes will be generated at the onshore and nearshore development areas during all stages of the Project as described in Chapter 5. This section discusses the potential environmental impacts of these discharges in the context of the nearshore marine environment.

Routine discharges

Wastewater from the operation of the gas-processing facilities (including process water, contaminated surface runoff, demineralisation reject water, sewage and grey water) will be treated, commingled and discharged to the nearshore marine environment at a combined outfall on the product loading jetty. Some of these wastewater streams will be continuous (e.g. demineralisation reject water) while others will vary in volume and solute concentrations (e.g. process water and plant drainage). Volumes of potentially contaminated runoff from process areas will also vary markedly between seasons, with large increases in runoff during wet-season rains.

Predictive modelling has been used to optimise the design of the outfall diffuser at the jetty, providing the maximum possible near-field dilution for the wastewater. This process involved comparing a range of port diameters, spacings and port openings under varied current conditions. The selected diffuser configuration is based on 4 ports, each with a diameter of 100 mm and at a spacing of 5 m (see Appendix 10 to this Draft EIS for details).

During construction, prior to completion of the jetty outfall, treated sewage and grey water from the onshore development area will be discharged to East Arm at a location selected for high current flows and rapid dispersion.

Toxicity of wastewater

The pollutants of most concern in wastewater from the onshore development area are petroleum hydrocarbons, which reach the wastewater stream when collected in surface runoff following accidental spills, tank drainings and washdown of equipment. Other production chemicals may also reach the wastewater stream intermittently, at varying concentrations.

As described in Section 7.2.3 *Liquid discharges*, acute toxicity is a short-term and severe poisonous effect, while chronic toxicity causes long-term health effects as a result of repeated doses at lower concentrations. At present, Australian water-quality guidelines do not provide acute or chronic-toxicity threshold criteria for total petroleum hydrocarbons (TPHs). To assess the potential impacts of the Project's wastewater discharges, a conservative chronic-toxicity threshold of 0.007 mg/L TPH has been applied. This criterion was derived by Tsvetnenko (1998), who compiled a range of reported toxicity levels for various marine species and applied statistical analysis according to methods developed by the US Environmental Protection Agency. The petroleum hydrocarbons were considered to be active toxicants only in dissolved form and, because of the lack of species-specific ecotoxicology studies (particularly for tropical Australian species), an acute–chronic ratio of 25 was assumed. For these reasons, the 0.007 mg/L threshold is considered conservative (Tsvetnenko 1998).

Other pollutants in the discharged wastewater will include nutrients and faecal coliforms (from sewage), which at high concentrations might lead to eutrophication of the nearshore marine environment and even algal blooms. It is also noted that the water-quality objectives developed for Darwin Harbour (NRETAS 2009) place particular emphasis on maintaining sustainable levels of nutrients in Harbour waters. Treatment processes applied prior to discharge of sewage wastewater from the Project will result in very low levels of nutrients being released to the Harbour, and exceedances of the levels given in the water-quality objectives are not expected outside the immediate mixing zone.

Dispersion of wastewater

In order to predict the dispersion of wastewater in the nearshore development area, hydrodynamic modelling was undertaken by APASA (2009c). Three modelling methods were integrated to simulate this dispersion: a validated estuarine and coastal hydrodynamic model (BFHYDRO) for current data, a near-field discharge model (UM3) and a far-field advection and dispersion model (MUDMAP). The results of the study are summarised below, while the complete technical report is provided in Appendix 10. Further detail on the development and validation of the hydrodynamic model is provided in Appendix 5.

For the purposes of modelling, discharge rates and characteristics were derived based on preliminary estimates of the treated effluent and stormwater to be generated at the onshore development area (see Chapter 5). Two scenarios were modelled, representing the wet and dry seasons, to provide a better understanding of dispersion during varying rainfall conditions.

Characteristics of the wastewater streams that were used to inform the dispersion model are summarised in Table 7-33. These are influenced by increased surface runoff from wet-season rains, leading to higher wastewater release rates and TPH concentrations and lower salinity during the wet season.

Table 7-33: Assumed characteristics of the wastewater stream from the combined outfall

Characteristic	Dry season	Wet season
Wastewater flow rate (continuous)	18 m³/h	160 m³/h
Salinity of wastewater (ambient surface-water salinity)	0.325 ppt (35.3 ppt)	0.02 ppt (32.7 ppt)
Temperature of wastewater (ambient surface-water temperature)	26 °C (24.8 °C)	35 °C (32.7 °C)
Total petroleum hydrocarbon concentration	0.2 mg/L	10 mg/L

Dilution factors required to reach the chronic-toxicity threshold concentration of 0.007 mg/L TPH (assuming a background concentration of 0 mg/L and not accounting for natural decay) are 1:29 and 1:1428 for the dry-season and wet-season scenarios respectively.

At the nearshore development area, wastewater will be discharged from a diffuser outfall at the jetty, approximately 1 m above the seabed (*c*.14 m below Lowest Astronomical Tide (LAT)). Near-field modelling indicates that the plume is initially driven by its own momentum horizontally from the outlet. As the plume velocity decreases (<1 m from the orifice), the buoyancy of the plume will cause it to rise rapidly towards the water surface, causing turbulence and entraining water. Upon reaching the surface, the plume is predicted to remain at the sea surface and disperse with the prevailing currents. During dry-season conditions, near-field mixing provides a dilution ratio of at least 1:334 within 4 m of the outlet, well below the required threshold dilution ratio for chronic toxicity (1:29) (APASA 2009c).

During wet-season conditions, dilutions of 1:76 to 1:227 are predicted within 11 m of the outlet, depending on ambient current speeds. This rate of dilution is insufficient to avoid chronic toxicity and therefore far-field modelling was conducted to predict the extent and shape of the wet-season mixing zone (APASA 2009c).

The far-field dispersion model indicated that the wastewater plume would remain in the surface layer (the top 2 m), where the near-surface currents would affect its overall transport. The plume was predicted to oscillate with the flood and ebb tides, and patches of higher concentrations tended to build up at the turn of the tide. These patches moved as a cohesive unit as the current speeds increased again. These higher-concentration patches tended to stay within the wider plume, sometimes combining when current reversals caused patches to move back and build up (APASA 2009c).

On average, the TPH concentrations are predicted to form an elliptical shape in an east–west direction, in line with the major tidal axis (Figure 7-31). At a 95% confidence level, the wastewater is diluted to below 0.007 mg/L TPH within 330 m of the outfall during the wet season, which is at least 440 m from the nearest shoreline. At a 50% confidence level, the mixing zone is much smaller, reaching the dilution threshold within 86 m of the outfall (APASA 2009c).

Mixing zones for wastewater from the discharge outfall are considered small and are indicative of rapid dilution of the pollutants into nearshore waters. The periods of exposure to hydrocarbons would be very short for most pelagic biota and as the mixing zone is distant from sensitive benthic communities (e.g. the corals at Channel Island or Weed Reef), there is no potential for contamination of these areas.

Treated sewage and grey water discharged during both the construction and operations phases will contain elevated concentrations of nutrients compared with background levels, but the nutrients would assimilate rapidly into the nearshore marine environment without toxic effects.

Hydrotest

Hydrotesting of the onshore facilities will occur during the commissioning phase and wastewater produced by this activity will be discharged separately from other routine wastewater. Chemical additives and their concentrations have not yet been finalised for hydrotest water.

Chemicals such as biocides and corrosion inhibitors are the key potentially toxic components of process and hydrotest water. When discharged to the marine environment, they may have toxic effects on marine biota that exist close to the discharge point. However, these effects will be mitigated by the rapid dispersion of pollutants with tidal currents.

If fresh water is used for hydrotesting, its discharge into Darwin Harbour in large volumes may represent a marked change to water-quality conditions in the marine environment, particularly in the dry season when Harbour waters are at their highest salinity levels. However, tidal mixing in the nearshore area is high in all seasonal conditions and this freshwater input is not expected to cause significant impacts to marine biota beyond the immediate vicinity of the outfall.

Vessels

Vessels involved in nearshore construction activities and in ongoing product export from the onshore processing plant will produce wastewater streams including ballast water, sewage and grey water.

Sewage and grey water from ships will not be discharged into Darwin Harbour waters. The *Marine Pollution Act* (NT) and Marine Pollution Regulations (NT) prohibit sewage and grey water discharge from vessels within 3 nautical miles of the coast (this includes the whole of Darwin Harbour).

All vessels will have ballast-water tanks fully segregated from fuel tanks to minimise the risk of hydrocarbon contamination of the ballast water. The ballast water in vessels arriving at the nearshore development area is likely to originate from the open ocean in accordance with management strategies to minimise the risk of transferring marine pests (see Section 7.3.9).

Antifouling compounds will leach from the coatings of vessels in Darwin Harbour, but given the very low concentrations generated, coupled with the effects of dilution caused by tidal currents, there is again a negligible risk of pollution impacts to the marine environment.

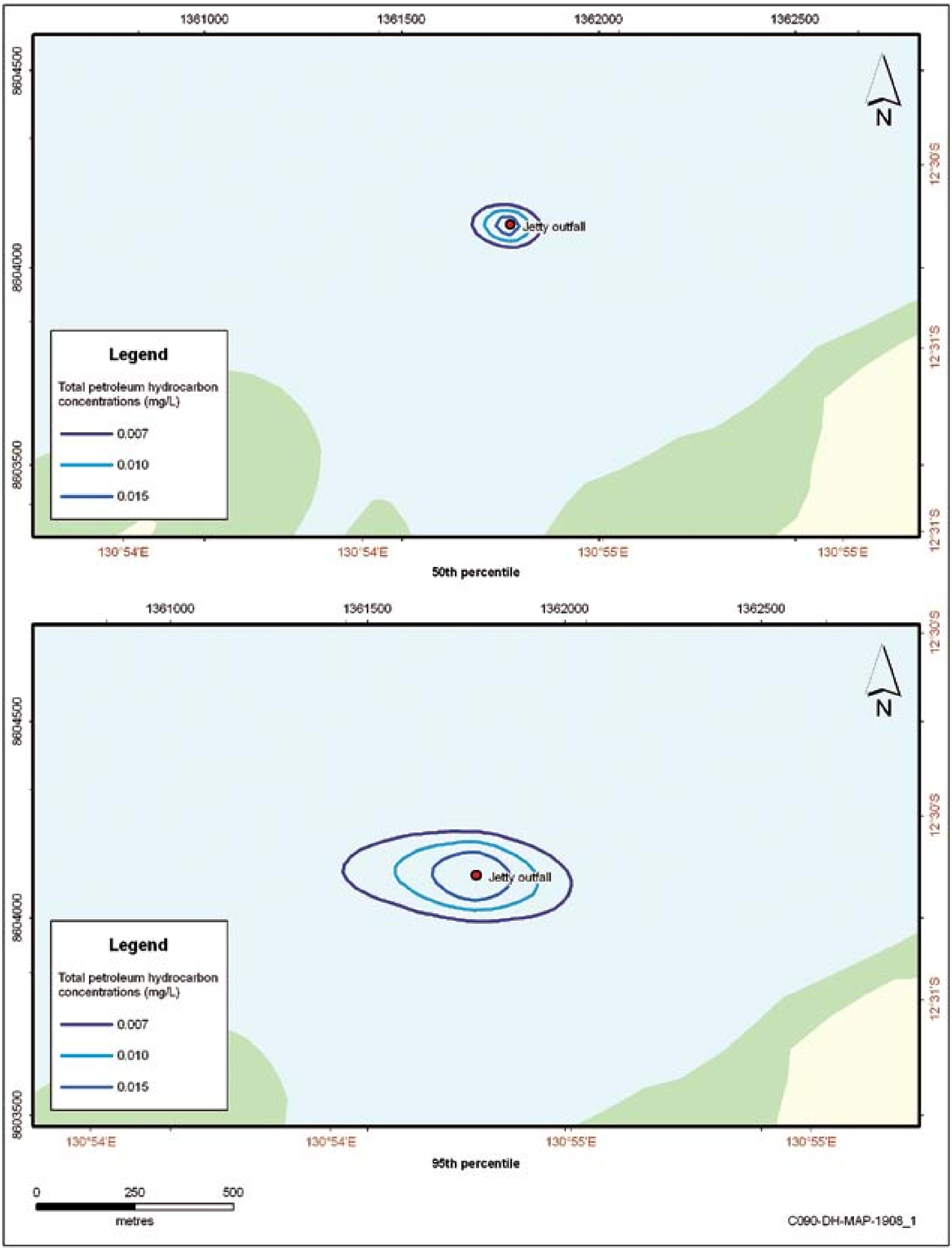

Figure 7-31: Predicted extent of wastewater mixing zones at the product loading jetty outfall during wet-season conditions

Management of wastewater

A Provisional Liquid Discharges, Surface Water Runoff and Drainage Management Plan has been compiled (attached as Annexe 10 to Chapter 11), which will guide the development of a series of more detailed plans during the construction and operations phases of the Project. Key inclusions in this plan are as follows:

- Drainage at the onshore development area will be designed to isolate areas that could be exposed to hydrocarbon contamination (as described in Chapter 5). Wastewater from these areas will be directed to an oily-water treatment system.
- The wastewater outfall diffuser will be designed to optimise near-field dispersion of the discharged wastewater.
- Wastewater streams will be sampled at appropriate frequencies and selected water-quality parameters will be documented.
- Maintenance practices during the operations phase (e.g. drainage of tanks and equipment of hydrocarbons) will avoid discharge of hydrocarbons to the oily-water treatment system.
- An on-site treatment facility will be used to treat sewage from the onshore development area to produce high-quality wastewater during the operations phase.
- A waste discharge licence will be sought for the onshore processing plant from NRETAS under the *Water Act* (NT). Discharge limits set by this licence will be met through a monitoring and verification program, developed as part of the environmental management program for the Project.
- Hydrotest management plans and supporting documents will be developed for approval under the relevant legislation prior to precommissioning.
- Production and hydrotest chemicals will be selected with consideration of their ecotoxicity.
- Where practicable, process modules will be precommissioned off site at the module yards.
- Where practicable, hydrotest water will be reused by onshore facilities (e.g. hydrocarbon storage tanks).
- No sewage or grey water from ships will be discharged into Darwin Harbour, in accordance with the Marine Pollution Regulations (NT).
- Antifouling paints on vessels and equipment will not contain TBT compounds, as required by IMO regulations.
- A Darwin Harbour water quality monitoring program will be developed to assess any impacts of the Project on water quality in the nearshore development area during the operations phase.
- Validation of wastewater dispersion modelling for the jetty outfall will be undertaken.

Waters from hydrotesting and dewatering of the gas export pipeline will be discharged offshore, at the Ichthys Field. In the highly unlikely event that hydrotest depressurisation cannot be undertaken offshore (e.g. because of a cyclone or mechanical failure) it may be necessary to discharge approximately 10 ML of hydrotest water into Darwin Harbour.

Under these circumstances, an additional assessment (e.g. chemical screening and selection) will be undertaken to minimise impacts on the nearshore marine environment. These measures will be outlined in a hydrotest management plan to be developed prior to precommissioning and approval will be sought under the *Water Act* (NT) as required.

Residual risk

A summary of the potential impacts, management controls, and residual risk for liquid discharges is presented in Table 7-33. After implementation of these controls, potential impacts from liquid discharges are considered to present a “low” to “medium” risk, as changes in water quality in the marine environment will generally be localised and short-term.

7.3.5 Accidental hydrocarbon spills

Hydrocarbon characterisation

Weathering processes that affect spilt hydrocarbons in the marine environment are described in detail in Section 7.2.4 *Accidental hydrocarbon spills*.

The processes that would influence hydrocarbon weathering in the nearshore development area differ from those in the offshore area because of different local climatic and sea conditions and the shorter distance to shore. Predicted weathering and fates for potential condensate and diesel spills from the nearshore development area are described in this subsection. These were derived through numerical modelling of oil-spill scenarios by APASA (APASA 2009b, provided as Appendix 7).

Properties of nearshore condensate

Condensate received at the onshore processing plant would have marginally lower density (API gravity 75.7; density 682.9 kg/m^3) and viscosity (0.296 cP) but a higher aromatic content (6.4%) than the offshore condensate (described in Section 7.2.4). The condensate would be highly volatile, with complete evaporation occurring within 6 hours if spilled at the sea surface (Figure 7-32) (APASA 2009b).

Table 7-34: Summary of impact assessment and residual risk for liquid discharges (nearshore)

Aspect	Activity	Potential impacts	Management controls and mitigating factors	Residual risk*		
				C†	L‡	RR§
Wastewater discharge	Routine operation of onshore processing plant.	Alteration of marine environment through nutrient enrichment, toxic discharges, etc.	A waste discharge licence will be sought for the onshore processing plant from NRETAS under the *Water Act* (NT). Drainage systems will isolate potentially contaminated areas and wastewater will be treated through separate drainage systems prior to discharge. A chemical selection process will be developed and will include consideration of the potential for ecotoxicity. Monitoring and verification will be carried out to ensure that discharge limits are maintained. Provisional Liquid Discharges, Surface Water Runoff and Drainage Management Plan.	E (E1)	6	Medium
Wastewater discharge	Hydrotesting of onshore processing plant.	Localised reduction in water quality. Toxic effects on marine biota.	A waste discharge licence will be sought for the onshore processing plant from NRETAS under the *Water Act* (NT). A chemical selection process will be developed and will include consideration of the potential for ecotoxicity. Module systems will be precommissioned off site if practicable. Hydrotest management plans. Provisional Liquid Discharges, Surface Water Runoff and Drainage Management Plan.	F (E1)	6	Low
Wastewater discharge	Operation of vessels in the nearshore development area during construction and operations.	Alteration of the marine environment including nutrient enrichment and toxicity.	Discharge of wastewater in accordance with DPC regulations. Provisional Liquid Discharges, Surface Water Runoff and Drainage Management Plan.	F (E1)	6	Low

* See Chapter 6 *Risk assessment methodology* for an explanation of the residual risk categories, codes, etc.

† C = consequence.

‡ L = likelihood.

§ RR = risk rating.

Likelihood of spill occurrence

The infrastructure and activities to be undertaken in the nearshore development area present a range of scenarios where a loss of containment of hydrocarbons could occur. An assessment of the likelihood of oil spills occurring was undertaken by ERS, using frequency data for previous similar incidents that have occurred in the oil & gas industry worldwide. In oil-spill planning this likelihood is known as the "primary risk" of a spill event.

The likelihood of a spill occurring is expressed on an annual basis—that is, the number of times per year that an incident of that type could occur. This generally results in very small numbers (e.g. 1×10^{-4}), and the order of magnitude is considered the most important component. That is, events with a likelihood of 1×10^{-2} would be considered "likely" to occur at some point, particularly for a project with a life of several decades. Events with a likelihood of 1×10^{-7} have a very remote chance of occurring, even during the life of a long project.

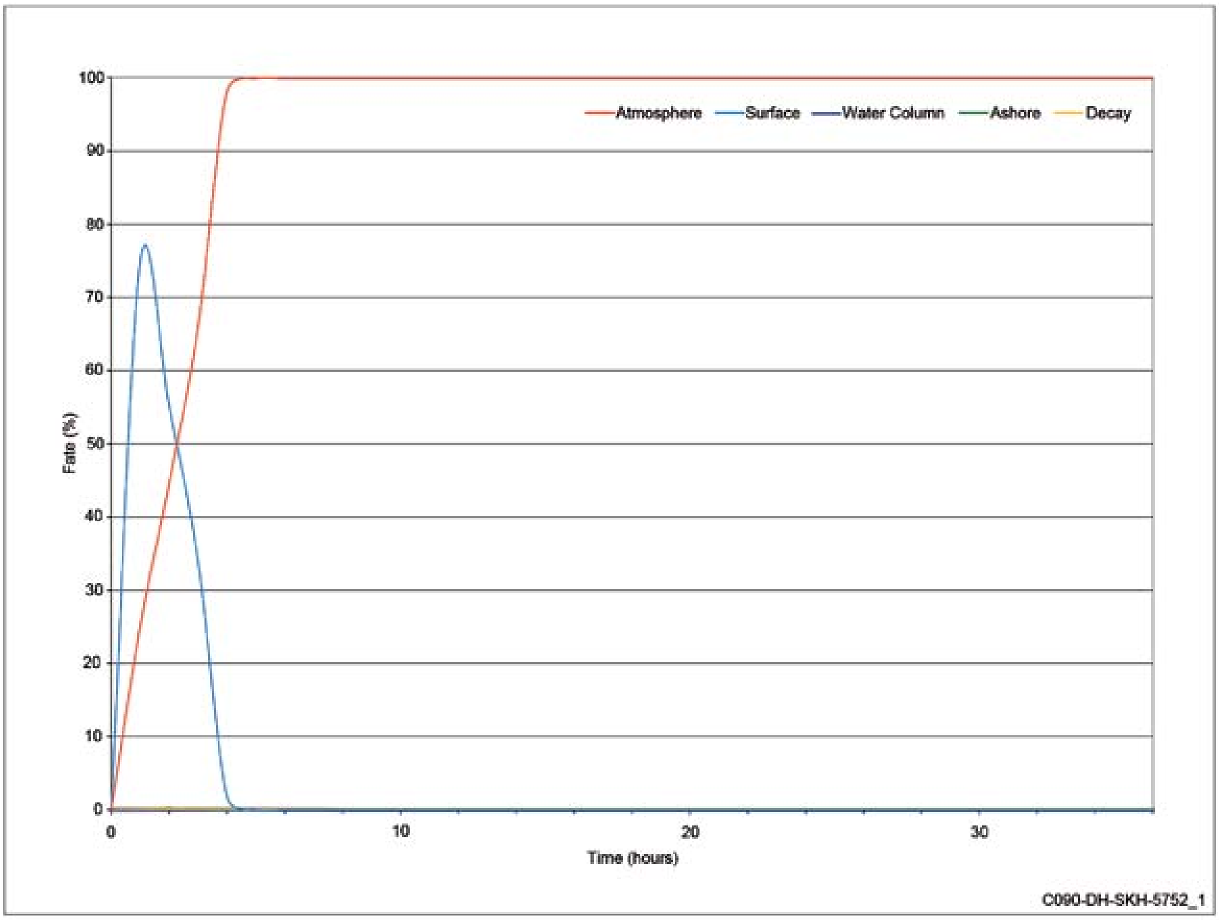

Figure 7-32: Predicted weathering and fates of a surface condensate release from the nearshore development area

Four potential spill scenarios were identified for the nearshore development area. They are described in Table 7-35, along with the calculated likelihood of these events occurring. The volumes and durations of the spills are indicative only and are considered reasonable estimates of the types of accidental spills that could occur given the management controls that will be in place for the Project. Of the scenarios considered, the refuelling spill of low volumes of diesel is the most likely. Refuelling of vessels at East Arm will occur many times during the construction and operations phases of the Project. The diesel transfer hose and its associated couplings are considered to be the most likely source of leaks from this activity (ERS 2009).

Rupture of the gas export pipeline in Darwin Harbour is the least likely loss-of-containment scenario. An incident of this nature could be caused by anchor damage from large vessels using the Harbour, such as large cargo ships or naval vessels. Rupture of the gas export pipeline at a centralised point in Darwin Harbour has been modelled; however anchor damage could be incurred at any position along the pipeline where water depths allow large vessels access. Accordingly, oil-spill contingency planning will account for the potential for a pipeline rupture (or leak) along the entire length of the pipeline route. To control an accidental event such as this, a loss of pressure in the pipeline would be detected and valves at either end of the gas export pipeline would quickly close. This system would operate automatically and the time frame to closing down the pipeline would be less than 10 minutes. Ensuring that these types of response controls are integrated into the design of the pipeline is part of the safety case to be developed for the Project under the *Energy Pipelines Act* (NT) and the *Offshore Petroleum and Greenhouse Gas Storage Act 2006* (Cwlth).

Table 7-35: Potential hydrocarbon spills in the nearshore development area and the likelihood of their occurrence

Scenario number*	Description	Location	Scenario	Likelihood† (per annum)
9	Gas export pipeline rupture	Darwin Harbour	A gas export pipeline full-bore rupture occurs in Darwin Harbour. This releases highly pressurised gas, LPGs and condensate at the seabed at a depth of around 15 m. About 5% of the condensate remains in the water column. The rest of the condensate and all of the LPGs and gas evaporate. Over 3 hours, 50 m^3 of condensate is released.	2.7×10^{-6}
10	Gas export pipeline leak	Darwin Harbour	A gas export pipeline leak from a nominal 25-mm hole occurs in Darwin Harbour. This releases highly pressurised gas, LPGs and condensate at the seabed at a depth of around 15 m but at a much lower rate than the full-bore rupture of Scenario 9. About 25% of the condensate remains in the water column. The rest of the condensate and all of the LPGs and gas evaporate. Over 24 hours, 1 m^3 of condensate is released.	1.1×10^{-5}
11	Leak of condensate loading line or a coupling failure at the jetty	Blaydin Point	A condensate loading line leaks or a coupling fails at the jetty. A 30-second leak occurs before flow across the jetty to the condensate offtake tanker can be stopped. This releases 25 m^3 of condensate to the sea surface at the loading berth.	3.5×10^{-3}
12	Refuelling spill at East Arm Wharf	East Arm Wharf	A refuelling spill occurs at a berth at East Arm Wharf. A fuel-hose rupture or other leak results in an instantaneous spill of 0.2 m^3 of diesel on to the sea surface during refuelling.	4.9×10^{-2}

* The scenario numbers are continued here from Table 7-17, which contains the primary risk assessment for the offshore development area.

† Primary risk (ERS 2009).

Spills of liquefied petroleum gases (LPGs) and LNG during loading at the jetty are not considered to pose a risk of slicks in the marine environment, as these substances are highly volatile and would evaporate very quickly. Spills of LPGs and LNG have therefore not been included in the primary risk assessment.

Predictive spill modelling

In order to predict whether hydrocarbons released during the potential spill scenarios could reach sensitive environmental receptors around the nearshore development area, spill-trajectory modelling was undertaken by APASA (see Appendix 7 for the full APASA report). Trajectory modelling was based on a boundary-fitted hydrodynamic (BFHYDRO) model developed for Darwin Harbour. This model simulated tidal elevations, current velocities, salinity and temperature distributions within the Harbour and its approaches. Further detail on the development and validation of the hydrodynamic model is provided in Appendix 5.

Numerical spill simulations were carried out using the three-dimensional model SIMAP, which accounts for weathering processes such as evaporation and spreading as well as seasonal climate effects. Simulations were developed for wet-season (October–February), dry-season (May–July) and transitional (March–April; August–September) conditions.

Simulations of spills in the nearshore development area indicated that the movement of any hydrocarbon slicks would be strongly affected by local tidal currents. Complicating these drift patterns, prevailing winds will act to spread slicks and generate a net drift over longer durations than one tidal cycle. Seasonal wind patterns are predicted to generate an increased probability of exposure to eastern shorelines during the wet season and to western shorelines during the dry season (APASA 2009b).

A total of 100 single random trajectories was simulated, per season and scenario combination (i.e. 300 per scenario and 1200 in total), for the assessment. Model outputs therefore do not show the area affected by one individual spill, but show the combination of these multiple spill simulations.

The extent of nearshore spills was assessed down to a threshold level of 1 g/m^2 (1 µm thickness), which corresponds with a yellowish-brown sheen on the water surface.

Summaries of the modelled outcomes of the spill scenarios presented in Table 7-35 are presented below. These outcomes assume that no management controls (i.e. spill responses) are applied and therefore present the worst-case scenarios for hydrocarbon spread into the marine environment.

Scenario 9—Gas export pipeline rupture

Under all seasonal conditions, the movement of the surface slick resulting from this spill is predicted to be tidally dominated. The major portion of the slick would remain in the central corridor of the Harbour, reaching upstream as far as Channel Island and downstream to the entrance to the Harbour between Mandorah and Fannie Bay (Figure 7-33).

Shoreline exposure is not predicted to occur above the threshold level (1 g/m^2) for this spill. Entrained oil is expected to occur in close proximity (<1 km) to the release site because of the initial subsurface release. Once it surfaces, condensate is unlikely to be entrained in the water again because of the relatively calm conditions inside the Harbour (APASA 2009b).

Scenario 10—Gas export pipeline leak

Movement of the slick created by this relatively small spill would be minimal and very low surface-water exposure probabilities were predicted in spill modelling (Figure 7-34). Because of the slow release rate and high volatility of the condensate, there is negligible risk of exposure to shoreline areas (APASA 2009b).

Scenario 11—Condensate loading line leak or coupling failure at jetty

Processed condensate is predicted to evaporate rapidly. However, because of the magnitude of the tidal currents in East Arm, a proportion of the condensate slick generated by this scenario is predicted to drift throughout East Arm before evaporating and could potentially expose some areas of shoreline to risk. The main area of surface-water exposure during all seasons was predicted to be within one tidal migration (about 6 hours of travel) along the tidal axis (Figure 7-35). Seasonal winds also influenced the predicted extent of surface slicks, with a <10% chance of migration west out of East Arm during wet-season conditions (APASA 2009b).

Slicks could arrive on the shore of Blaydin Point and the western headland of Lightning Creek on a flood tide as quickly as within one hour of the spill occurring. However, the maximum probability of exposure of any shoreline is fairly low, at 23%, because of the high volatility and rapid weathering of the processed condensate. The maximum volume of condensate predicted to reach the shoreline would be 4.2–5.8 m^3 (17–23% of the spill volume) (APASA 2009b).

Scenario 12—Refuelling spill at East Arm Wharf

Slicks caused by this diesel spill would generally move along an east–west axis as a result of tidal movements, and would remain within East Arm under all seasonal conditions (Figure 7-36).

As diesel is less volatile than condensate, the slick would undergo weathering processes more slowly and would persist longer in the marine environment, with a consequent potential for shoreline exposure. The spill would likely cause shoreline exposure next to East Arm Wharf (a 67–79% probability) within an hour of the spill event. Shorelines to the east and south of East Arm may also be exposed at discontinuous points, although with a much lower probability (<10%). The maximum volume of diesel predicted to reach the shoreline is relatively high, at 140–164 L (70–82% of the initial spill volume) (APASA 2009b).

Likelihood of spills affecting shorelines

The secondary risk of hydrocarbon spills occurring and then reaching sensitive shorelines in Darwin Harbour is derived by multiplying the primary risk from Table 7-36 by the probability of shoreline exposure from spill-trajectory modelling.

As discussed above, spills from the gas export pipeline in the main body of the Harbour (scenarios 9 and 10) are not predicted to affect shorelines. Spills of condensate or diesel in East Arm are more likely to reach shorelines, transported by regular tidal movements and to a lesser degree by seasonal winds.

The calculated secondary risk for nearshore spills is provided in Table 7-36. These levels of risk (or “frequency” of an oil pollution event occurring) are considered low, and would be further reduced by the spill prevention and response controls to be implemented in the nearshore development area.

Potential environmental impacts of spills

The potential impacts of hydrocarbon spills are described in Section 7.2.4, including the mechanisms by which hydrocarbons can be toxic or harmful, the ecotoxicity of the condensate from the Ichthys Field, and the potential effects of oil spills on various groups of marine biota including cetaceans, turtles, seabirds, fish, local benthic communities and plankton. The nearshore development area contains additional marine biota that could be affected by an accidental oil spill.

Benthic biota

Oil spills can be readily dispersed and incorporated into shallow, sedimentary environments by wind, waves and tides. In general, short-term effects on intertidal benthic communities are characterised by losses of sensitive species, dominance of tolerant species and early colonisation by opportunists, depending on the intensity of the oil pollution. The rate of recovery is influenced by the characteristics of the shoreline: exposed rocky-shore communities appear to recover more quickly, for example within two years, than sheltered low-energy coastlines, which can take five to eight years to recover (Volkman et al. 1994).

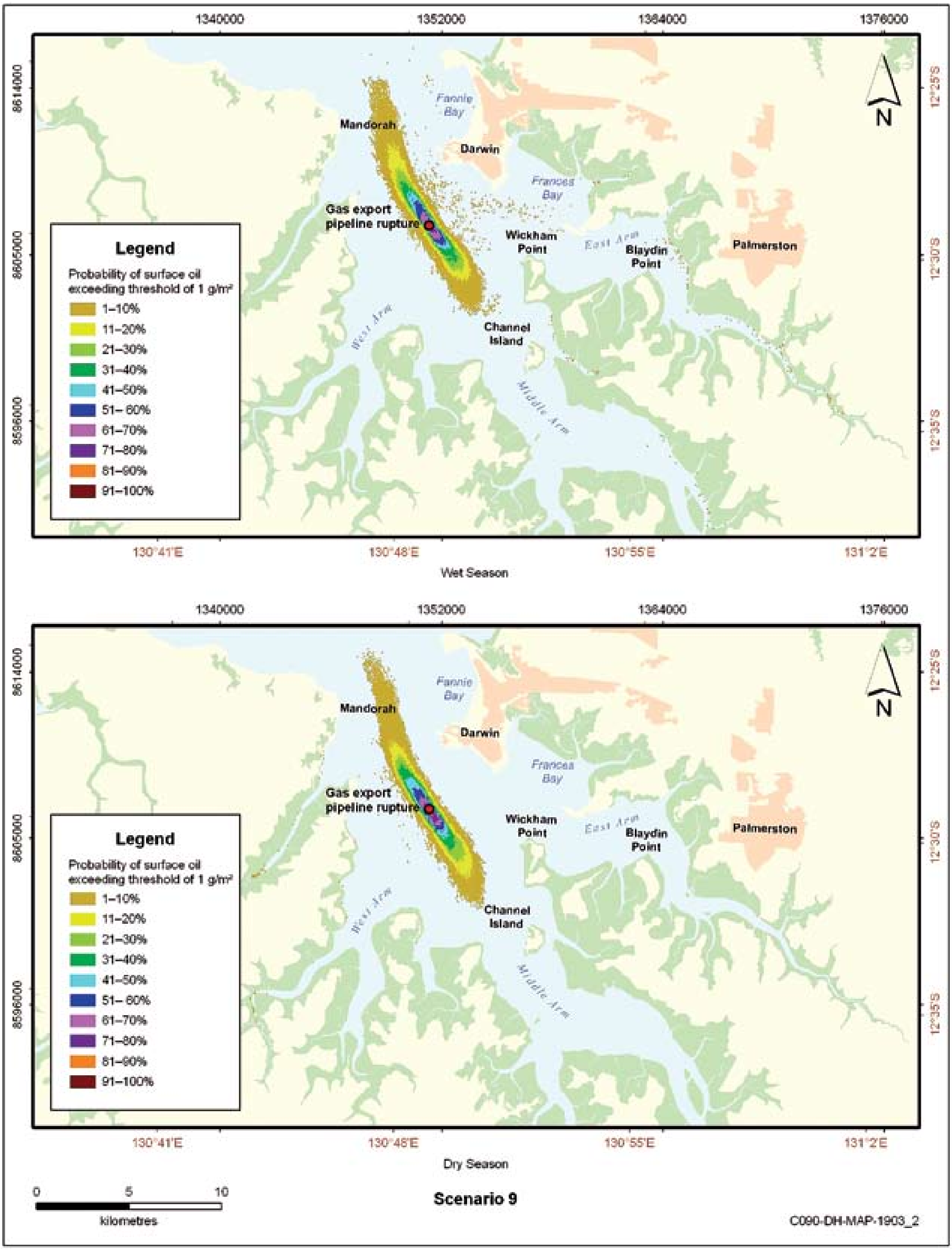

Figure 7-33: Scenario 9—gas export pipeline rupture: simulated oil-spill trajectories for 50 m³ of condensate

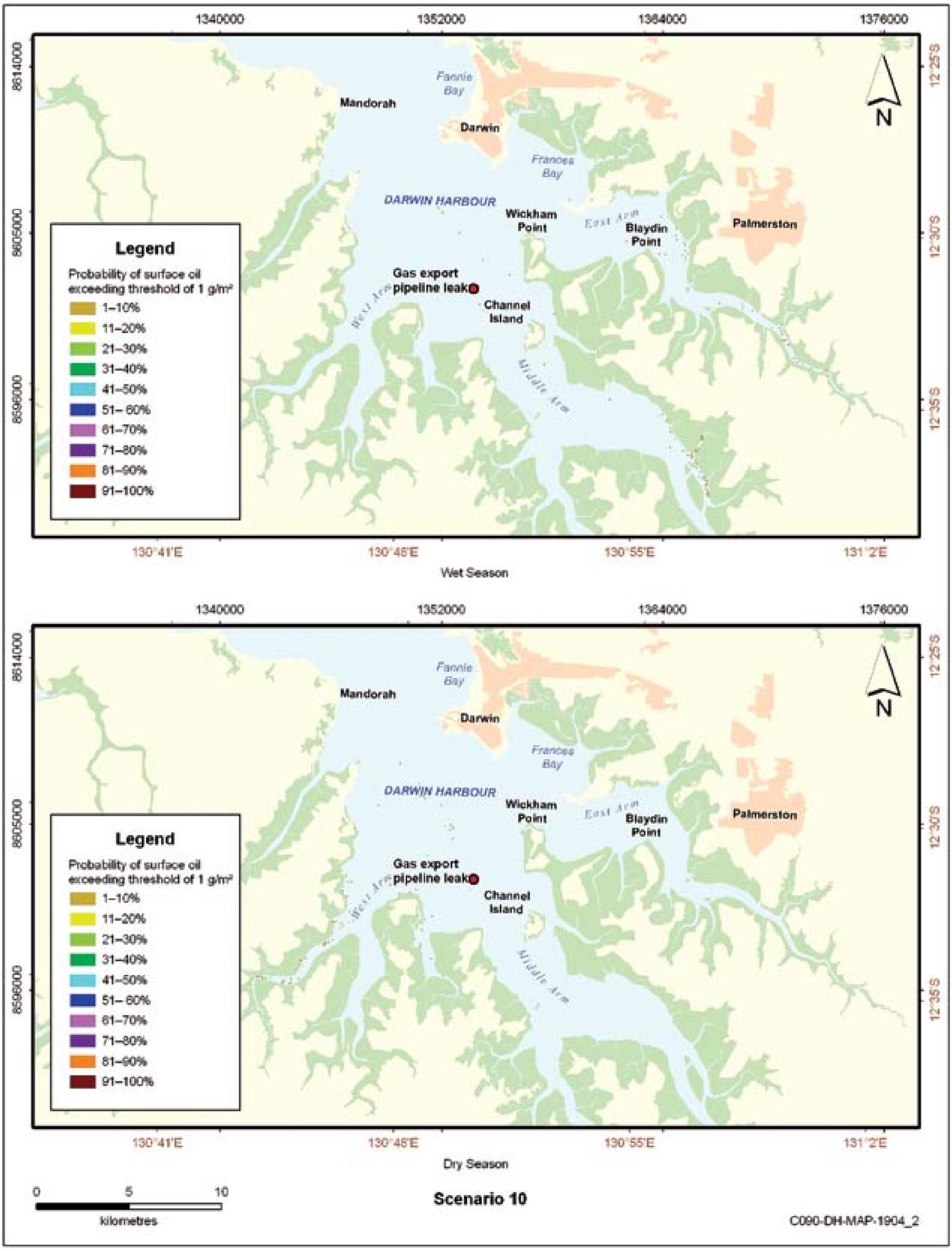

Figure 7-34: Scenario 10—gas export pipeline leak: simulated oil-spill trajectories for 1 m³ of condensate

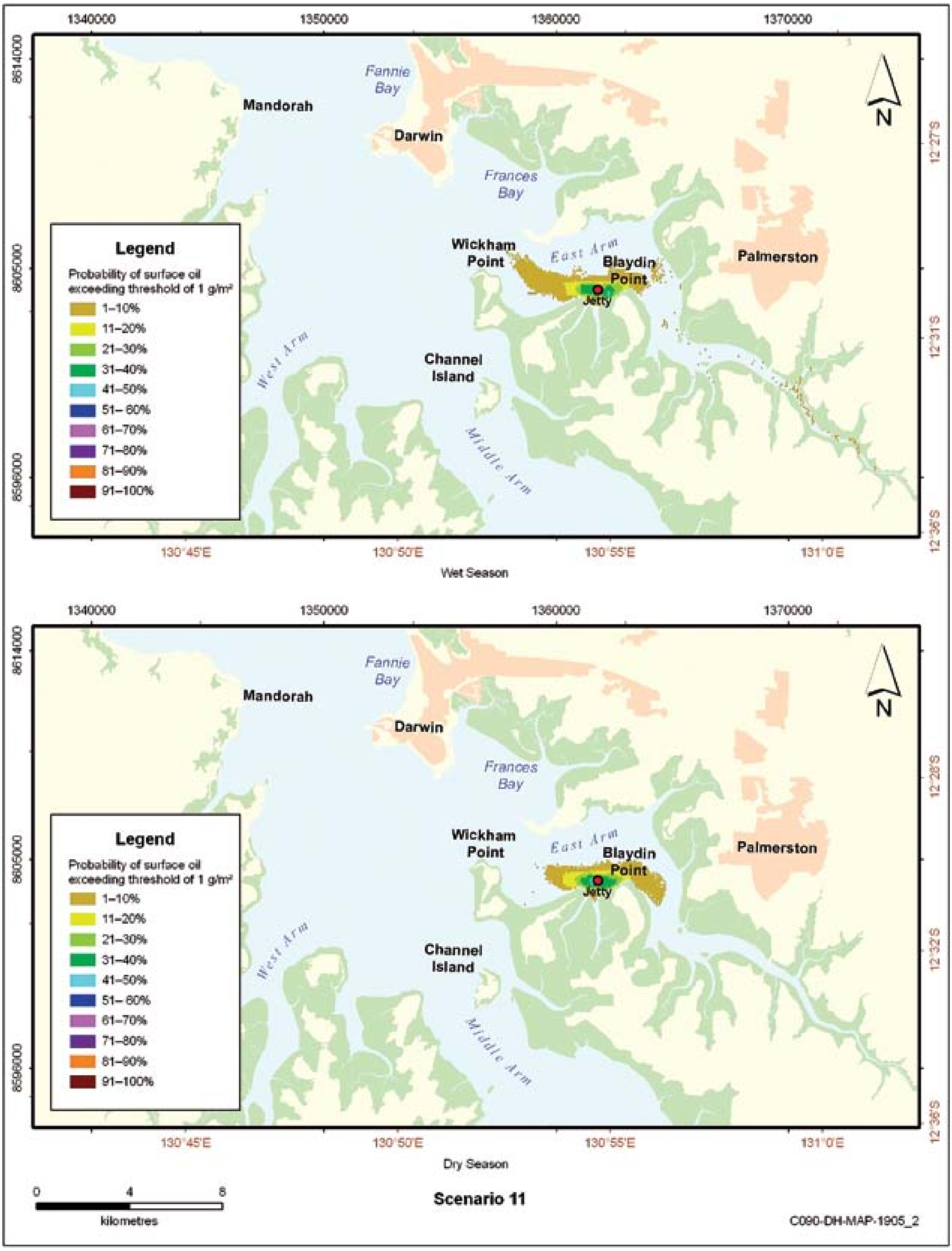

Figure 7-35: Scenario 11—condensate loading line leak or coupling failure: simulated oil-spill trajectories for 25 m³ of condensate

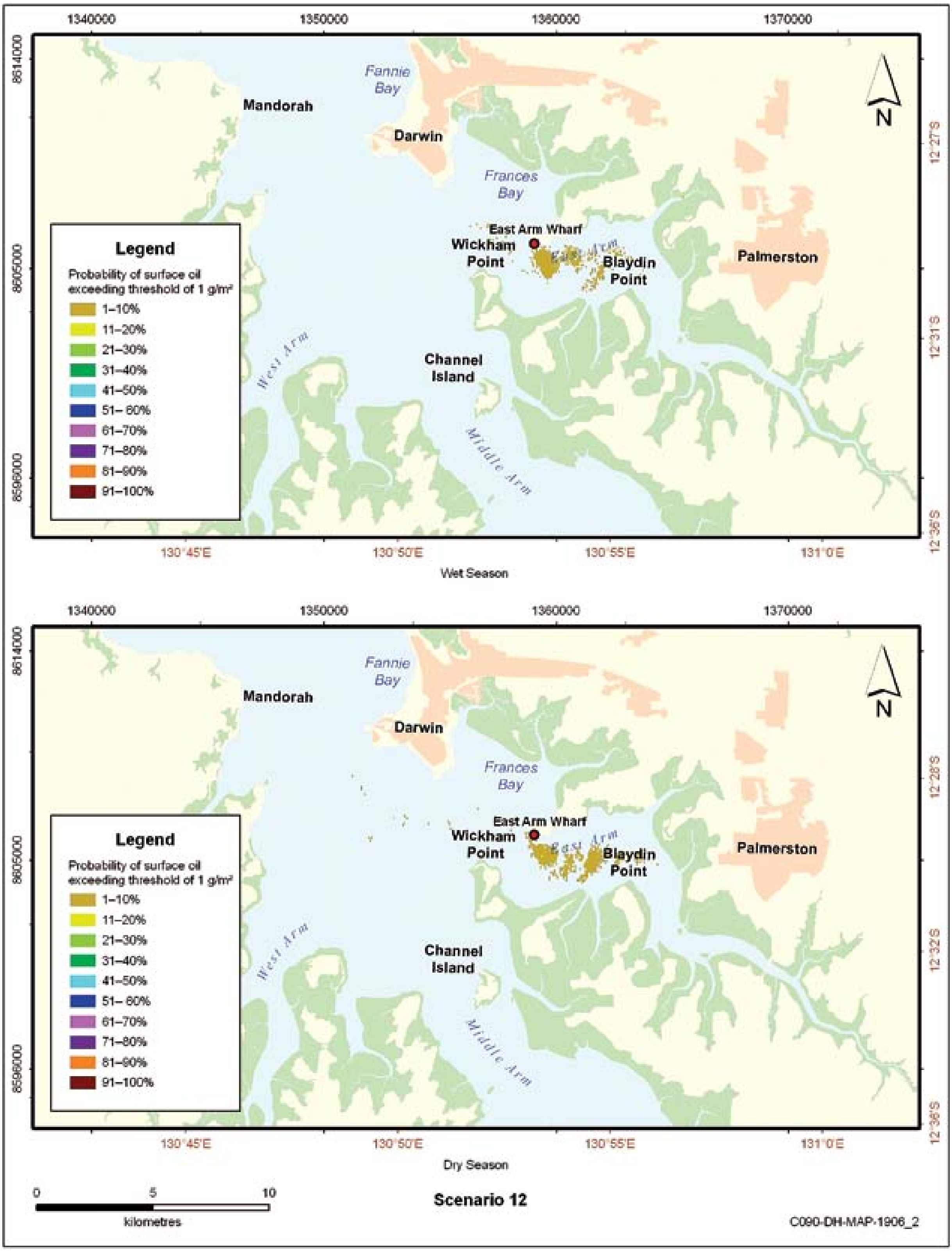

Figure 7-36: Scenario 12—refuelling spill at East Arm Wharf: simulated oil-spill trajectories for 0.2 m³ of diesel

Table 7-36: Likelihood of hydrocarbon spills from the offshore development area reaching sensitive shorelines

Scenario	Name	Primary risk (per year)	Secondary risk (per year)	
			Wet season	Dry season
9	Gas export pipeline rupture	2.7×10^{-6}	None	None
10	Gas export pipeline leak	1.1×10^{-5}	None	None
11	Leak of condensate loading line or a coupling failure at the jetty	3.5×10^{-3}	6.9×10^{-4}	4.0×10^{-4}
12	Refuelling spill at East Arm Wharf	4.9×10^{-2}	2.0×10^{-2}	1.1×10^{-2}

Corals

Areas of hard and soft corals in East Arm occur at South Shell Island, Old Man Rock and north-east Wickham Point. These communities are exposed to the water surface at low tide and therefore could be affected by a hydrocarbon spill during certain conditions. Similarly, the Weed Reef coral community is exposed at low tide and may be at slight risk from a gas export pipeline rupture, depending on the exact location of the spill. The Channel Island coral community in Middle Arm would not be affected by the modelled spill scenarios; however a pipeline rupture or leak at a location closer to Channel Island has the potential to affect these coral communities.

Corals occupy intertidal and subtidal zones and oil-exposure effects will vary depending on the extent of physical contact, the depth of immersion, tidal movements, currents, wind and waves. Oil that is immersed, solubilised and dispersed in water has a much greater effect on corals than oil floating at the surface (Volkman et al. 1994).

Corals that are exposed to or above the water surface are more vulnerable to the effects of oil that those in submerged areas. Tissue death can occur where oil adheres to corals, although sensitivities vary among different species. In an example from Panama, oil exposure caused severe damage to intertidal biota at the seaward side of reefs and flats where oil had accumulated at low tide. Seaward populations of common sessile animals such as zoanthids, hydrocorals and scleractinian corals were severely reduced. Previously abundant populations of sea urchins, snails and stomatopods (mantis shrimps) on the reef flats also showed reductions (Volkman et al. 1994).

Extensive mortality of subtidal corals (e.g. of scleractinian genera) has been observed on oiled reefs, particularly at depths of 3 m or less. Extensive sublethal effects have also been recorded, including bleaching, production of mucus and dead areas of coral tissues, which may influence the long-term survival of coral populations even more than the initial individual mortalities (Volkman et al. 1994).

Soft-bottom communities

The response of benthic invertebrates to oil spills varies widely between species. Some burrowing invertebrates such as polychaetes and copepods are relatively tolerant and elements of the infauna contribute to bioturbation and degradation of the oil in sediments. Conversely, however, burrowing bivalves are susceptible to bioaccumulation and oiling effects (Volkman et al. 1994).

Oil contamination in subtidal soft-bottom sediment communities can cause very high or even total mortality of benthic fauna, including burrowing filter-feeders, echinoderms, molluscs, amphipods and prawns. Recolonisation of the denuded oiled sediment commences with opportunistic polychaetes, followed by a succession of animals in a series of fluctuations until stability is reached. Amphipods are particularly sensitive to oil contamination and take a number of years to return (Volkman et al. 1994).

Intertidal and subtidal soft-sediment communities occur throughout East Arm. They could be affected by spill Scenario 12 and by Scenario 11 to a lesser degree.

Mangroves

Mangrove vegetation occurs throughout Darwin Harbour in the intertidal zone. Mangroves are known to be particularly susceptible to pollution from hydrocarbon spills and tree deaths have been recorded in a number of such spills internationally. Contact with mangrove roots is particularly critical, as coating and trapping of oil among the partially submerged pneumatophores affects normal respiratory and osmoregulatory functions (Volkman et al. 1994).

The impact of hydrocarbon spills on mangroves can be divided into two phases: the short-term mortality phase because of coating with fresh condensate and the longer-term effects of the weathered hydrocarbons becoming incorporated into sediments, which inhibits the growth of seedlings and larger plants (Volkman et al. 1994).

Shoreline exposure is predicted to occur in East Arm for spill scenarios 11 and 12. For Scenario 11, the mangrove fringe at the north of Blaydin Point is the most likely area of impact. Scenario 12 could expose shoreline mangroves at various points in the east and south of East Arm depending on the weather and tidal conditions at the time of the spill (APASA 2009b).

Prevention and management of accidental hydrocarbon spills

An OSCP and emergency response plan will be developed for the Project in accordance with the *Offshore Petroleum and Greenhouse Gas Storage Act 2006* (Cwlth) (as described in Section 7.2.4 *Accidental hydrocarbon spills*). The OSCP will provide details of organisational responsibilities, actions and procedures, reporting requirements and the resources available to ensure effective and timely management of an oil spill. It will, for example, make provision for appropriate spill-response equipment to be located at the nearshore facilities, for support vessels used in the nearshore area also to have oil-spill response capability, and for regular emergency response exercises to be carried out.

As part of its OSCP, INPEX will have the capability to initiate real-time oil-spill fate and trajectory modelling, so that spills can be monitored and responses optimised.

Other industry-standard provisions will be implemented at the nearshore development area in order to prevent a spill occurring. These will include the following:

- Each component of the nearshore development area, including the gas export pipeline, will be designed to meet the oceanic, climatic and seismic conditions of the area.
- Sections of the pipeline in Darwin Harbour will be laid in a trench and impact protection (rock dumping) will be placed over the trench to mitigate risks from anchor damage and ship grounding. The extent of this will be dependent on the outcomes of the final quantitative risk assessment.
- The jetty structure is being designed according to Australian Standard *AS 4997:2005, Guidelines for the design of maritime structures*, taking cyclones into account; the loading arms, for example, will be designed to allow them to be tied down should a cyclone threaten Darwin.
- A 200-m precautionary zone will be implemented around the gas export pipeline prohibiting anchoring by vessels in accordance with Section 66(5) of the *Energy Pipelines Act* (NT).
- Periodic internal inspections of the gas export pipeline will be undertaken to assess its integrity.
- Condensate tankers will be subject to vetting procedures. Product loading operations will be monitored by a terminal representative on board the export tanker.
- Approach speeds to the berth will be monitored by a speed-of-approach laser system, with the data transmitted to the vessel pilot.
- All shipping movements in Darwin Harbour will be controlled by a vessel traffic system operated by the DPC.
- Visual monitoring of hoses, couplings and the sea surface will be undertaken during refuelling of vessels. Dry-break couplings and breakaway couplings or similar technology will be used where available and practicable.
- A maintenance and inspection program will be in place for product loading arms.
- An emergency shutdown interface will be in place between vessels and the onshore processing plant.
- During product loading, radio contact will be maintained between the support vessel and the jetty, and collision prevention procedures will be implemented.

In the event of a spill of light oils at the nearshore development area, the likely management response will be to deploy spill containment and clean-up equipment such as booms. If the spill threatens sensitive environmental receptors, dispersants may be added in consultation with the relevant authorities.

Residual risk

A summary of the potential impacts, management controls, and residual risk for the identified nearshore hydrocarbon spill scenarios is presented in Table 7-37. The "likelihood" ratings shown are derived from the quantitative assessments of primary and secondary risk presented above, and do not account for spill-response procedures which would reduce the frequency and extent of spills. Therefore, these risk ratings are conservative and could be reduced further in the event of an actual spill. The risks of harm to the nearshore marine environment are considered to be "medium" or "low".

7.3.6 Waste

Solid wastes will not be discharged to the nearshore marine environment from vessels or infrastructure associated with the Project. Non-hazardous wastes generated in the nearshore development area (e.g. domestic and packaging wastes, clean oil drums, construction materials such as plastics and metal) as well as hazardous wastes (e.g. spent engine oils, batteries and paints) will be removed to the mainland for onshore disposal at an approved facility.

Table 7-37: Summary of impact assessment and residual risk for accidental hydrocarbon spills (nearshore)

Aspect	Activity	Potential impacts	Management controls and mitigating factors	Residual risk*		
				C†	L‡	RR§
Accidental hydrocarbon spills	Scenario 9: Gas export pipeline rupture in Darwin Harbour.	Exposure of moderate areas of nearshore waters to surface oil.	The gas export pipeline is designed to meet the conditions of the area. Trenching and rock dumping over sections of the gas export pipeline in Darwin Harbour for protection and stability. Precautionary zones put in place to prohibit anchoring in the vicinity. Spill-response equipment and procedures. Oil Spill Contingency Plan.	D (E1)	1	Low
Accidental hydrocarbon spills	Scenario 10: Gas export pipeline leak in Darwin Harbour.	Exposure of small areas of nearshore waters to surface oil.	The gas export pipeline is designed to meet the conditions of the area. Trenching and rock dumping over sections of the gas export pipeline in Darwin Harbour for protection and stability. Precautionary zones put in place to prohibit anchoring in the vicinity. Spill-response equipment and procedures. Oil Spill Contingency Plan.	E (E1)	1	Low
Accidental hydrocarbon spills	Scenario 11: Leak of condensate loading line or a coupling failure at jetty at Blaydin Point.	Exposure of moderate areas of nearshore waters to surface oil.	Emergency shutdown interface put in place between the vessel and the plant. Maintenance and inspection program for product loading arms. Spill-response equipment and procedures. Oil Spill Contingency Plan.	D (E1)	3	Medium
		Localised areas of mangroves, intertidal communities and possibly corals exposed to oil, leading to reduced growth or death.		E (B2)	2	Low
Accidental hydrocarbon spills	Scenario 12: Refuelling spill at East Arm Wharf.	Exposure of moderate areas of nearshore waters to surface oil.	Visual monitoring of hoses, couplings and the sea surface during refuelling of vessels. Continuous radio contact between the vessel and the wharf. Use of dry-break couplings and breakaway couplings where practicable. Spill-response equipment and procedures. Oil Spill Contingency Plan.	F (B2)	4	Low
		Localised areas of mangroves, intertidal communities and possibly corals exposed to oil, leading to reduced growth or death.		E (B2)	4	Medium

* See Chapter 6 *Risk assessment methodology* for an explanation of the residual risk categories, codes, etc.

† C = consequence.

‡ L = likelihood.

§ RR = risk rating.

Similarly, food scraps generated by vessels in the nearshore development area will be contained on board and later transported to an onshore disposal facility in accordance with the Marine Pollution Regulations (NT). Under this legislation, food scraps may not be disposed of overboard within 3 nautical miles of land. This exclusion zone includes all of Darwin Harbour and extends out past the Tiwi Islands (Melville Island and Bathurst Island); it encompasses the whole of the nearshore development area.

Management of waste

A Provisional Waste Management Plan has been compiled (attached as Annexe 16 to Chapter 11), which will guide the development of a series of more detailed plans during the construction and operations phases of the Project. Key inclusions in this plan include the following:

- All hazardous and non-hazardous solid wastes generated in the nearshore development area, including food scraps, will be retained on board vessels and transported to onshore facilities for disposal.
- Chemicals and hazardous substances used during all phases of the Project will be selected and managed to minimise the potential adverse environmental impact associated with their transport, transfer, storage, use and disposal.
- Only approved and licensed waste contractors will be employed for waste disposal.
- Waste minimisation will be included in the tendering and contracting process.

Residual risk

A summary of the potential impacts, management controls, and residual risk for solid waste is presented in Table 7-38. After implementation of these controls, potential impacts from solid wastes are considered to present a “low” risk, as wastes will be not be disposed of into the marine environment.

7.3.7 Underwater noise and blast emissions

The following discussion on the nature and potential impacts of underwater noise and blasts in the nearshore development area is derived from a detailed literature review by URS, which is provided in Appendix 15. Airborne noise emissions from the Project, and their potential impacts, are discussed in Chapter 10.

Underwater noise in the nearshore environment

Background information on noise sources in the marine environment and the propagation of sound through water to receptors such as marine animals are described in detail in Section 7.2.6 *Underwater noise emissions*. In contrast to deep offshore waters,

Table 7-38: Summary of impact assessment and residual risk for solid wastes (nearshore)

Aspect	Activity	Potential impacts	Management controls and mitigating factors	Residual risk*		
				C†	L‡	RR§
Discharge of food scraps	Routine operation of nearshore vessels.	Alteration of marine environment including nutrient enrichment.	Food scraps will be retained on board all vessels in the nearshore development area for later transport to an onshore facility for disposal. Provisional Waste Management Plan.	F (E1)	6	Low
Non-hazardous waste	Routine operation of vessels during nearshore construction and ongoing product export.	Pollution of the marine environment if disposed of overboard.	All wastes will be disposed of to onshore facilities. Waste minimisation will be included in the tendering and contracting process. Provisional Waste Management Plan.	F (B3)	4	Low
Hazardous wastes	Generation of hazardous waste through routine nearshore operations.	Pollution of the marine environment if disposed of overboard.	All wastes will be disposed of to onshore facilities. Non-hazardous chemicals will be preferentially used where practicable and cost-effective. Waste minimisation will be included in the tendering and contracting process. Provisional Waste Management Plan.	F (B3)	3	Low

* See Chapter 6 *Risk assessment methodology* for an explanation of the residual risk categories, codes, etc.

† C = consequence.

‡ L = likelihood.

§ RR = risk rating.

ambient noise levels and frequencies across shelfal and nearshore waters are far more variable with changes in season, location and time of day. While the key sources of underwater noise remain shipping and local weather conditions such as wind, rain and sea state, the contributions from marine biota as well as various fishing, boating and industrial noises in ports and harbours become significant, and change regularly with time and place (Cato 2000; Urick 1983).

The type, intensity and propagation of sources contributing to ambient noise in coastal waters are also more spatially variable as a consequence of finer-scale changes in seafloor topography and seafloor substrate. Noise levels increase where more reflective rocky substrates are prevalent and decrease where thick absorptive layers of fine sediments and mud occur.

Turbulence and seafloor saltation noise induced by strong tidal streams can also become locally dominant, particularly in coastal parts of northern Australia with large tidal ranges (such as Darwin Harbour). For example, ambient noise in embayments in the Kimberley that contain coarse gravelly sediments can exceed 110–120 dB on a diurnal basis, particularly during spring ebb and flood tides (Curt Jenner, Research Biologist, Centre for Whale Research, Fremantle, Western Australia, unpublished data).

Ambient noise monitoring carried out to characterise the existing acoustic conditions in Darwin Harbour is presented in Chapter 3.

Noise emissions from the Project

Underwater noise will be emitted from the nearshore development area during the construction and operations phases of the Project, through activities such as piledriving and drill-and-blast operations, dredging, rock dumping, dredge spoil disposal and general vessel movements. Darwin Harbour already contains an operational port that generates underwater noise from a variety of pre-existing Harbour operations, many of which were constructed and currently operate using activities similar to those proposed for the Project's nearshore development area. The key Project activities that are likely to produce noise emissions significantly different (or louder) than current port activities are piledriving and drill-and-blast operations.

Underwater noise propagation modelling is not considered appropriate for the nearshore development area as predictions would be confounded by a large number of variables in this environment.

These are as follows:

- shallow water
- the variable depth of water because of the large tidal range
- naturally occurring underwater noise caused by the flow of large volumes of water during tidal movements
- the variation in bottom type, affecting the reflection or absorption of noise
- the variation in salinity, particularly between Middle Arm and East Arm and the main body of the Harbour
- the proximity and volume of existing anthropogenic noises
- local weather conditions (e.g. thunderstorms) that can also produce underwater noise.

Each of these factors adds a degree of uncertainty to predictions of underwater noise. A predictive model would need to make generalisations and assume homogeneous states, although they may not exist. However, the potential impacts of noise from key Project activities in the nearshore development area can be assessed through available literature and experience and an understanding of the key receptors in the nearshore environment as outlined below.

Piledriving

Piledriving will be undertaken periodically during the construction phase to install steel piles for the jetty and the module offloading facility. During these construction activities, actual piledriving would be undertaken for 30–40% of an operational shift, with general vessel movement and preparation occurring at other times. While under way, piledriving would generate persistent underwater noise "pulses", with a source level of up to 200 dB re 1 μPa. Noise levels will vary depending on the substrate and the piledriving method used, with the impact piling technique likely to generate the loudest noise.

Piledriving will be a significant source of noise in the nearshore marine environment. The repetitive and pulsed nature of this activity will generate noise with the potential to startle marine animals and lead to avoidance of the affected area. Any effects arising from piledriving would be more acute during the initial start-up phase. Pulsed noise can cause temporary threshold shift (loss of hearing) in marine mammals at levels of 200 dB re 1 μPa and above (see Appendix 15). Given that this level is equivalent to the noise source level for piledriving, such effects on dolphins or dugongs in Darwin Harbour could only be expected in the immediate vicinity of the activity. This noise would be attenuated considerably within tens of metres because of the East Arm's inherently poor acoustic propagation conditions caused by the shallow water, highly variable bathymetry, variable salinity and bottom type, and the expected high ambient noise levels. Even without allowing for losses because of scattering and absorption, noise from a 200-dB source would drop to a level of about 170 dB at a distance of 100 m and to 150 dB at around 2000 m[11].

It is not currently possible to derive criteria for pulsed noise that could cause behavioural disturbance in marine mammals (Southall et al. 2007). This conclusion is based on the large degree of variability in responses between groups, species and individuals. Ambient noise levels of 150–170 dB are already generated in East Arm by existing marine activities (see Chapter 3) without apparent effects on local animal populations.

Drill and blasting

Blasting in the nearshore development area may be required where rock is encountered that cannot be removed by dredging, such as at the entrance to the shipping channel at Walker Shoal. Blasting will be undertaken using the "confined" blasting (drill-and-blast) method, which involves drilling small holes in the rock with charges placed and connected in the holes for subsequent surface firing.

In comparison with surface blasting methods, confined blasting generates reduced effects on the marine environment. This is primarily because surface blasting requires a larger charge to break up rock material (generally three times larger than for confined blasting), as the explosive energy is dispersed throughout the water column rather than being directed at the rock (Ecos 1996).

The impact of a set of underwater blasts can also be reduced by implementing micro-delays between explosions, through connected fuses. The detonation event therefore comprises a chain of individual subordinate detonations. These produce irregular and less pronounced peak pressure levels than would occur if all the explosives were detonated simultaneously, or if a single aggregate charge of the same net explosive content was detonated (see Appendix 15). For the nearshore development area, it is proposed to use around six 50-kg charges set on micro-delays (as described in Chapter 5), producing lower peak pressure levels than would result from a single 300-kg blast.

For blasting generally, the risk of mortality is confined to an area in close proximity to the point of detonation, with a surrounding wider area where injury is possible.

11 According to practical spreading laws: *Transmission loss = 15 log (range).*

Beyond the immediate vicinity of detonation there is a wider area where minor injury, in the form of permanent threshold shift, is also possible. The greatest likely effect from the use of explosives, however, is as a result of noise disturbance, rather than blast or impulse. The zone of influence of noise-related potential impacts as a result of underwater detonations is substantially larger than that for lethality or injury, but still relatively confined.

Management controls such as the establishment of protection zones around the detonation site before and during blasting activities can protect marine animals in the area, and will be implemented for the Project. The Canadian Department of Fisheries has developed a method to calculate zones of impact for marine mammals and fish (as described in Ecos 1996), with consideration of the size of the charge, the depth of detonation and the depth of the surrounding water. According to this method, the charges proposed for the nearshore development area (with a 300-kg total charge detonated at the seabed in a water depth of 15 m) produce the zones of impact presented in tables 7-39 and 7-40 for marine mammals and fish respectively. This indicates that marine mammals more than 1250 m from the source, and 10-kg fish more than 660 m away, would not receive blast-related injuries. As described above, using multiple smaller charges set on micro-delays would reduce overall peak pressure levels, so the zones of impact presented in the tables below are conservative.

Table 7-39: Zones of impact for a diving marine mammal from a 300-kg confined blast

Distance (m)	Potential impact
473	No mortality, but a high incidence of moderately severe blast injuries, including eardrum rupture.
519	High incidence of slight blast injuries, including eardrum rupture.
854	Low incidence of trivial blast injuries, but no eardrum ruptures.
1248	Safe level and no injuries.

Source: Yelverton et al. 1973, not seen, cited in Ecos 1996.

Table 7-40: Zones of impact for a 10-kg fish from a 300-kg confined blast

Distance (m)	Potential impact
263	50% mortality
342	1% mortality
657	No injuries

Source: Yelverton et al. 1973, not seen, cited in Ecos 1996.

Marine mammals, reptiles (crocodiles and turtles) and humans (scuba-divers etc.) can all be affected by underwater blasts because of the large air-filled cavities in their lungs, and would all require a similar-sized zone of protection from blasting impacts.

Small "scare" charges prior to blasting operations are used in some settings to help reduce startle responses from the main blast and to encourage any animals in the vicinity to leave the blast area. However, toothed whales and dolphins have been found to be attracted to the location of blast detonations (Richardson et al. 1995), possibly to investigate the noise or in search of dead, injured or disoriented fish as prey. Owing to the presence of coastal dolphins in Darwin Harbour, scare charges are not considered an appropriate management control for use in the nearshore development area.

Alternative techniques to drilling and blasting are being investigated for the removal of the hard rock material within the shipping channel. At this stage, however, it is not possible to confirm whether there are any viable alternatives.

Dredging

Dredging is likely to be the most persistent source of underwater noise in the nearshore development area, as it will be generated consistently through the construction phase for up to four years. Source levels from dredgers are relatively modest, at around 160–170 dB re 1 µPa, and generate low-frequency noise. This type of noise is not expected to affect marine animals negatively to any significant extent, but it may cause some species to avoid the area.

Rock dumping and dredge spoil disposal

Rock dumping and dredge spoil disposal activities will be intermittent throughout the construction phase of the Project. Noise generated by rock dumping is likely to be broadband low frequency at modest source levels. Spoil disposal is not expected to generate noise to any appreciable extent, apart from the noise generated by the vessels carrying out the activity.

Vessel movement

Noise will be generated by vessels on a variable basis during the construction phase of the Project, depending on dredging and maritime construction activities. During operations, the Project will require around 200 tanker vessels per year to load product at Blaydin Point. Ships generate broadband noise from their propellers, motors, auxiliary machinery, gearboxes and shafts, together with their hull wake and turbulence. Noise generated by merchant ships is typically in the 20–500 Hz frequency range, which contributes to ambient low-frequency noise levels, particularly in regions with heavy ship traffic.

The sound levels produced by individual ships depend on their size, the number of propellers, the number and type of propeller blades, blade biofouling and maintenance conditions. In general, larger ships generate louder source levels (see Appendix 15).

Vessel propellers can also produce "cavitation" noise, where the propeller blades form gas-filled cavities in the very low pressure water generated on their forward faces. Intense broadband sound is created when these bubbles subsequently collapse, either in a turbulent stream or against the surface of the propeller. Cavitation noise can occur in the region of 500–3000 Hz, depending on the size of the vessel (see Appendix 15).

This type of noise can be generated by tanker vessels with constant-pitch propellers, but only when travelling at relatively high speeds (typically above 7–14 knots). Tanker movement through Darwin Harbour will be conducted at low speeds, and is not likely to generate cavitation noise. Vessels equipped with variable-pitch propellers and/or thrusters, such as tugs, supply tenders and dynamically positioned vessels (e.g. pipelay barges), could produce cavitation noise more frequently and will operate in the nearshore development area during the construction phase. While this noise would be generated intermittently, it is likely to be audible to marine animals such as dolphins and may cause them to avoid the area.

It is noted that pleasure craft and other small vessels fitted with outboard motors use high-speed propellers that generate cavitation noise in the spectrum 1–15 kHz and at relatively loud source levels (150–180 dB re 1 µPa). These types of vessels are commonly used throughout Darwin Harbour and generate noise that would be audible to dolphins.

Potential impacts to marine animals

As described in Section 7.2.6 *Underwater noise emissions*, the available data on the effects of noise on marine animals are variable in quantity and quality, and data gaps often restrict the development of scientifically based noise exposure criteria for mitigating risks to marine animals. Behavioural responses are strongly affected by the context of the exposure as well as the animals' experience, degree of habituation, motivation and condition and the ambient noise characteristics and habitat setting (see Appendix 15). Therefore, while the following assessment of potential impacts to marine animals in the nearshore development area is based on the best available information, it is subject to some uncertainties because of the paucity of research.

Cetaceans

The most commonly recorded cetacean species in Darwin Harbour are three coastal dolphins—the Australian snubfin, the Indo-Pacific humpback and the Indo-Pacific bottlenose (Palmer 2008).

Confined blasting has the potential to disturb, injure or even kill dolphins. Management controls such as protection zones will therefore be implemented, as described below, to reduce the risk of physical injury to dolphins through marine blasting.

Noise from piledriving and blasting activities will mainly be generated at frequencies below the optimal hearing range of dolphins (Richardson et al. 1995). However, the Australian snubfin dolphin does use some whistles in the 1–8 kHz range during foraging and socialising behaviours (Van Parijs, Parra & Corkeron 2000). While some of the higher-frequency components of piledriving noise will be audible to these dolphins, the modulation and tonal characteristics of this noise would be different from dolphin vocalisations, and would be highly unlikely to interrupt communication between individuals.

Mustoe (2008) cites a study in Victoria Harbour in Hong Kong where Indo-Pacific humpback dolphins showed behavioural responses to percussive piledriving. Dolphins were sighted within 300–500 m of the operation and showed increased swim speeds during piledriving, which were construed by researchers as positive avoidance behaviour. Similarly, dolphins in Darwin Harbour may avoid areas close to piledriving and blasting activities, where a noise threshold for discomfort or annoyance is reached.

Generally, loud sounds that are sudden are more likely to elicit a response than those that build up slowly (Mustoe 2008). For this reason, soft-start procedures will be used during piledriving to reduce startle responses.

If a sound is not associated with additional harmful effects, it seems less likely to be avoided and habituation is possible. Structured, repeated sounds may have in-built redundancy, allowing animals to ignore them (Mustoe 2008). Given that nearshore piledriving activities will last for many months, some habituation in local dolphins may become apparent. Frequent breaks in piledriving activities will also allow dolphins to move through the area relatively freely. The potential for any impact would be further reduced because of the many noise-attenuating features of the marine environment in the area.

The majority of noise frequencies generated by dredging, shipping and piledriving activities will be below the optimum hearing ranges for dolphins.

In contrast, small vessels operating in Darwin Harbour (such as recreational boats) generate noise of much higher frequency which is audible to dolphins. Therefore impacts to dolphins as a result of noise from the Project are expected to be low.

Dugongs

Noise from the nearshore development area is likely to have similar effects on dugongs as on dolphins. Dugongs are likely to avoid areas where piledriving and blasting activities occur and physical injuries from underwater noise are not expected. Dugongs utilising the rock platforms around Channel Island or Weed Reef for foraging may be discouraged from the area while dredging activities for the gas export pipeline are under way, but these activities would be completed within a few weeks.

Marine reptiles

The low-frequency noise generated by blasting, piledriving and dredging activities will be audible to turtles, which hear in the 400–1000 Hz range. Sudden noises are known to elicit startle responses from turtles. They would also be at risk of injury from blasting activities in similar fashion to marine mammals. Although turtles are known to frequent Darwin Harbour, no significant nesting, breeding or foraging habitats have been identified in the nearshore development area.

Crocodiles are also likely to be able to hear the low-frequency noise generated by nearshore construction activities and would be at risk of injury when in close proximity to a blasting site.

Fish

The upper reaches of creeks represent breeding habitat for some of the fish species inhabiting Darwin Harbour. These areas present very poor sound propagation conditions because of the shallow water depth and soft substrate and most of the noise from nearshore construction activities is expected to attenuate before reaching these areas.

Marine blasting will result in some fish kills within the immediate blast zone. Piledriving activities may also cause some acute damage and mortality to fish at very close ranges. For pelagic fish, however, the most likely behavioural response during piledriving would be avoidance of the area.

Sharks and their relatives such as the freshwater sawfish (*Pristis microdon*) may be less susceptible to blast and impulse effects than are many fish, because of their lack of a swim bladder, their physical size and their general morphology.

Cumulative impacts

Noise generated by the Project will add to the existing periodic and transitory sounds contributing to ambient underwater noise in Darwin Harbour. The Port of Darwin already receives a wide variety of vessels. Around 1600 trading vessels and 5600 non-trading vessels visited the Harbour in 2008–09 and this number is forecast to increase. Other existing sources of underwater noise include biological sources (e.g. snapping shrimp) and weather (e.g. heavy rain, lightning storms), as described in Chapter 3.

Over the long-term operational phase of the Project, tanker vessel movements would represent an increase of 3% in vessel traffic (based on 2008–09 levels), and over time would account for less as shipping activity in the Port of Darwin continues to expand. The impacts of this increase in ambient noise levels are difficult to assess in terms of their significance to marine animals. However, disruptions to breeding, foraging or migration patterns in animal species as a result of existing noise sources in Darwin Harbour have not been recorded; this may be the result of a lack of research or may be evidence of a lack of impact. Given that no regionally significant habitat occurs in the nearshore development area, the potential for underwater noise to result in cumulative negative impacts to populations of marine animals is considered to be low.

Management of noise and blast emissions

A Provisional Piledriving and Blasting Management Plan has been compiled for the Project (attached as Annexe 12 to Chapter 11), which will guide the development of a series of more detailed plans during the construction and operations phases.

Key components of this plan that relate to management of marine blasting include the following:

- A permit-to-work (or similar) system will be implemented to ensure that areas where blasting and piledriving activities are occurring, or will occur, are clearly identified and that management measures are in place prior to work commencing.
- Only the minimum required charge will be used for nearshore blasting operations.
- Confined blasting methods will be used, with micro-delays between charges to reduce peak pressure levels of each blast in the surrounding waters.
- Fauna protection zones will be developed for nearshore blasting. The extent of these zones will be determined when detailed geotechnical investigations have been completed and further information from drill-and-blast contractors becomes available.
- Trained marine fauna observers will survey the fauna protection zones prior to the commencement of blasting. Blasting activities will be suspended if marine megafauna (e.g. cetaceans, dugongs, turtles and crocodiles) are observed to enter the fauna protection zone. Detonations will only occur if the fauna protection zone is observed to be free of marine megafauna for a period of at least 20 minutes.
- For effective surveillance, blasting will only be conducted in daylight conditions and with benign sea conditions so that observers are better able to sight any marine megafauna within the fauna protection zone.
- The potential to use passive or active acoustic monitoring to identify submerged marine animals in the fauna protection zone will be evaluated. If practicable, these methods are likely to be used to complement the precautionary marine animal observations prior to the commencement of blasting activities.
- Should fish be killed as a result of blasting activities and float to the surface, they will be retrieved in order to minimise the possibility of scavenging seabirds and other predators being injured by subsequent blasts.
- A permit to conduct marine blasting will be sought from the Department of Resources (DoR) as required under Section 16 of the *Fisheries Act* (NT).

Management controls that relate to piledriving include the following:

- An observation zone with a radius of 100 m will be implemented at the commencement of piledriving activities. This area will need to be confirmed clear of cetaceans, dugongs, turtles and crocodiles for 10 minutes prior to commencement.
- Piledriving will commence with a soft-start procedure, in which activities are gradually scaled up over a 5-minute period. This will provide an opportunity for any sensitive marine animals to leave the area before being exposed to the full intensity of underwater noise.
- Piledriving activities are planned to be undertaken during daylight hours only. Night-time piledriving would only be required if Project construction activities were to fall significantly behind schedule.

Noise impacts to the community and management controls are discussed in Chapter 10.

Residual risk

A summary of the potential impacts, management controls and mitigating factors, and residual risk for underwater noise and blasting is presented in Table 7-41. After implementation of controls, potential impacts from noise and blasting are considered to present a "low" to "medium" risk.

Table 7-41: Summary of impact assessment and residual risk of underwater noise

Aspect	Activity	Potential impacts	Management controls and mitigating factors	Residual risk*		
				C†	L‡	RR§
Underwater noise	Piledriving during jetty and module offloading facility construction.	Avoidance of the area by fish, and potentially a small number of injuries in close proximity to the piledriving activity.	Soft-start procedures will be used to reduce startle responses. Piledriving activities will only be carried out during daylight hours unless construction activities fall significantly behind schedule. Provisional Piledriving and Blasting Management Plan.	F (B3)	3	Low
Underwater noise	Piledriving during jetty and module offloading facility construction.	Avoidance of the area by marine megafauna, including threatened species.	No significant breeding, foraging or aggregation areas for threatened species are known to exist in the nearshore development area. An observation zone will be put in place to ensure that large animals are clear of the area prior to the commencement of piledriving. Soft-start procedures will be used to reduce startle responses. Piledriving activities will only be carried out during daylight hours unless construction activities fall significantly behind schedule. Provisional Piledriving and Blasting Management Plan.	F (B1)	6	Low
Underwater noise	Rock dumping and offshore spoil disposal.	Avoidance of the area by marine megafauna and fish, including threatened species.	No significant breeding, foraging or aggregation areas for threatened species are known to exist in the nearshore development area. Noise source levels from these activities are relatively low.	F (B1)	6	Low
Underwater noise	Dredging during construction of the nearshore development area.	Avoidance of the area by fish and marine megafauna, including significant species.	Predominantly low-frequency broadband noise. No significant breeding, foraging or aggregation areas for threatened species are known to exist in the nearshore development area. The greater part of Darwin Harbour will remain unaffected by changes in underwater noise levels.	F (B1)	6	Low
Underwater noise	Use of explosives on hard rock at Walker Shoal during construction.	Localised injuries or deaths to fish. Avoidance of the area by fish.	Confined blasting methods with micro-delays between blasts will be used to reduce peak pressures and the radius of impact zones. Use the minimum required charge for blasting. Provisional Piledriving and Blasting Management Plan.	E (B3)	6	Medium
Underwater noise	Use of explosives on hard rock at Walker Shoal during construction.	Localised injuries or deaths to marine megafauna, including significant species.	No significant breeding, foraging or aggregation areas for threatened species are known to exist in the nearshore development area. Confined blasting methods with micro-delays between blasts, to reduce peak pressures and radius of impact zones. Use the minimum required charge for blasting. Fauna protection zones, with blasting activities suspended if marine megafauna are observed inside the zones. Blasting during daylight and benign sea conditions only. Provisional Piledriving and Blasting Management Plan.	D (B1)	2	Medium

Table 7-41: Summary of impact assessment and residual risk of underwater noise (continued)

Aspect	Activity	Potential impacts	Management controls and mitigating factors	Residual risk*		
				C†	L‡	RR§
Underwater noise	General shipping and vessel movements	Displacement of fish and marine megafauna from the vicinity of vessels.	The nearshore area is located close to an existing port. Marine megafauna may be accustomed to vessel traffic. No significant breeding, foraging or aggregation areas for threatened species in the nearshore development area. Provisional Cetacean Management Plan.	F (B1)	6	Low

* See Chapter 6 *Risk assessment methodology* for an explanation of the residual risk categories, codes, etc.

† C = consequence.

‡ L = likelihood.

§ RR = risk rating.

7.3.8 Light emissions

Lighting systems on the onshore and nearshore infrastructure and berthed vessels will generate light emissions to the marine environment at Blaydin Point and its surrounds. Currently, artificial light sources exist at East Arm Wharf and the Darwin LNG plant at Wickham Point (4 km and 5 km from Blaydin Point respectively), as well as lighting of lower intensity from residential and urban areas throughout the northern and eastern shore areas of Darwin Harbour.

Marine turtles are known to be sensitive to artificial lighting sources during nesting and hatching (Pendoley 2005). However, the mangroves and mudflats throughout the shoreline of Darwin Harbour do not provide suitable beach habitat for turtle nesting. The closest turtle nesting beaches to the nearshore development area are at Mandorah (more than 20 km from Blaydin Point) and at Casuarina Beach, north of Darwin Harbour, where existing car-park lighting and street lighting spills on to the beach in some areas. This area is 20 km north of Blaydin Point and faces out to Beagle Bay; light spill from the nearshore development area will not be detectable at Casuarina Beach. Both beaches support only low-density turtle nesting.

Artificial light is not considered likely to have negative effects on foraging turtles, dolphins or dugongs (Mustoe 2008). There is no evidence that dugongs and dolphins in Darwin Harbour are adversely affected by the light regimes of other developments along the Harbour foreshore. Likewise, seasnakes in Darwin Harbour are not noticeably attracted to lights on jetties and wharfs and informal surveys of mangrove snakes suggest no apparent effects of foreshore development on snake numbers (Dr Michael Guinea, marine biologist, Charles Darwin University, pers. comm. August 2008).

Residual risk and management

Lighting from the nearshore development area is not considered to pose a threat to the surrounding marine environment. There are no sensitive light receptors (e.g. turtle nesting beaches) in close proximity to the proposed Project infrastructure and, in consequence, any localised effects on marine biota are considered to be minor.

Lighting design and operation for the nearshore facilities will meet personnel safety requirements.

During the operations phase, berthing and departure of tanker vessels and support vessels will be carried out mainly during daytime but occasionally at night. All vessels will be operated (and lit) according to safety requirements and in consultation with the DPC.

7.3.9 Marine pests

As described in Section 7.2.8, marine pest risks associated with the Project need to be considered closely and the appropriate management strategies defined. Of all the marine-based activities associated with the Project, the nearshore activities, particularly during the construction phase, represent the greatest risk of marine pest introduction. Marine pest risks are generally heightened in areas where water is shallow (less than 50 m deep) and close to the coastline, or near shoals and reefs, as the marine species recognised as representing an elevated pest risk to Australia are typically coastal or shallow-water species. This risk is exacerbated by the fact that coastal areas also have many features considered vulnerable to the impacts of marine pest invasions, such as coastal maritime infrastructure and aquaculture facilities.

The major mechanisms for marine pest transfer are ballast-water discharge and biofouling; an introduction to these is provided in Section 7.2.8, while the particular issues relevant to the nearshore infrastructure and Project activities are discussed below.

Biofouling

The vessels involved in nearshore construction activities, such as the barges used for module transport and pipelay and the dredgers and their supporting vessels, pose particular marine-pest risks. These vessels are generally large and slow-moving, increasing the opportunity for marine organisms to establish and grow on submerged surfaces. Dredgers and other specialist construction vessels are likely to have complex equipment and underwater surfaces, providing a variety of biofouling niches and making cleaning and inspection difficult. Some of these vessels, such as jack-up barges and dredging barges, will also be in direct contact with the Harbour floor, increasing the potential to transfer marine pests to seabed habitats.

Before construction activities commence in Darwin Harbour, it is also possible that at least some of the vessels engaged on the Project will have travelled recently through ports in South-East Asia (e.g. Singapore), where the tropical climate is similar to that of the nearshore development area. This will further increase the risk of the successful establishment of any marine pests accidentally transferred. Marine pest species such as the black striped mussel (*Mytilopsis sallei*) and Asian green mussel (*Perna viridis*) occur in South-East Asian waters (URS 2009).

The operations phase of the Project also poses a marine pest risk, although on a smaller scale. Tankers entering Darwin Harbour from international ports represent relatively low inherent risks as they are streamlined ships that present fewer opportunities for the growth of biofouling organisms. Marine pest risks for these tankers are principally related to the discharge of ballast water, which will require quarantine management.

Ballast water

Vessels engaged in construction activities will generally (although not universally) carry some ballast water, but the frequency and volume of ballast-water discharges from these vessels will be relatively modest. Ballast water in tanker vessels originating from ports in temperate waters (e.g. from Japan) is unlikely to contain marine species that could survive and become established in the tropical waters of Darwin Harbour during the operations phase. Therefore marine pest risks to the nearshore development area from ballast water do exist, but to a lesser extent than the risks posed by biofouling.

All ships in Australian coastal waters discharging ballast water which has been sourced from outside Australia are required to conform to AQIS's ballast-water requirements. In general terms, the discharge of international ballast water is prohibited unless the vessel has performed an open-ocean exchange of this water, and the exchange complies with AQIS's requirements for such exchange.

Management of marine pest risk

A Provisional Quarantine Management Plan has been compiled for the Project (attached as Annexe 13 to Chapter 11), with consideration of the requirements of the relevant regulatory agencies (which are likely to include AQIS, the DoR and the DPC). It will guide the development of a series of more detailed plans during the construction and operations phases. Key inclusions in the plan include the following:

- Discharge of ballast water into Darwin Harbour will be carried out in accordance with AQIS requirements.
- INPEX will ensure that vessels engaged in the Project comply with the biofouling requirements of the regulatory authorities.
- Vessels engaged in Project work will be subjected to a biofouling risk assessment which may result in cleaning or hull inspections.
- Relevant Project vessels will be required to maintain satisfactory records of antifoulant coatings, hull-cleaning and the exchange of ballast water.

A marine pests monitoring program will be developed for Darwin Harbour in conjunction with the relevant regulatory authorities, including NRETAS and the DoR. It is anticipated that the monitoring program methodology will be consistent with the monitoring framework developed by the National Introduced Marine Pests Coordination Group (NIMPCG). The monitoring plan will likely include the following:

- the identification of specific development areas for invasive species monitoring
- the scheduling of periodic monitoring to search for marine pests
- the assessment of any apparent impacts of any marine pests (if identified) and their association with Project activities
- the implementation of programs for the control and/or eradication of marine pests where they have been identified, in consultation with relevant regulatory agencies and the Commonwealth's Consultative Committee on Introduced Marine Pest Emergencies.

Table 7-42: Summary of potential impacts, management controls and risk for marine pests (nearshore)

Aspect	Activity	Potential impacts	Management controls and mitigating factors	Residual risk*		
				C†	L‡	RR§
Marine pests	Hull biofouling during the construction phase (e.g. on pipelay barge, dredging barge) and operations.	Invasion of native marine ecosystems by pests, threatening native marine plant and animal life and impacting maritime industries.	Biofouling risk assessment in place for all vessels. Ensuring vessel compliance with regulatory-authority guidelines for biofouling. Marine pest monitoring program. Provisional Quarantine Management Plan.	C (B3)	2	Medium
Marine pests	The discharge of ballast water during construction and operations.	Invasion of native marine ecosystems by pests, threatening native marine plant and animal life and impacting maritime industries.	Discharge of ballast water into Darwin Harbour will be carried out in accordance with AQIS requirements. Marine pest monitoring program. Provisional Quarantine Management Plan.	C (B3)	2	Medium
Marine pests	The transfer of exotic marine pests to coastal ports because of infection of vessels at the offshore development area.	Invasion of native marine ecosystems by pests, threatening native marine plants and animals and impacting maritime industries.	Biofouling risk assessment in place for all vessels. Ensuring vessel compliance with regulatory-authority guidelines for biofouling. Undertaking opportunistic ROV inspection of submerged infrastructure surfaces at offshore facilities. Provisional Quarantine Management Plan.	C (B3)	2	Medium

* See Chapter 6 *Risk assessment methodology* for an explanation of the residual risk categories, codes, etc.

† C = consequence.

‡ L = likelihood.

§ RR = risk rating.

Residual risk

A summary of the potential impacts, management controls, and residual risk for marine pests is presented in Table 7-42. After implementation of these controls, potential impacts from marine pests are considered to present a "medium" risk.

7.3.10 Marine megafauna

Marine animals that regularly swim at the water surface, such as dugongs and turtles, could interact with vessels operating in the nearshore development area during the construction phase. On very rare occasions, a marine mammal or turtle could suffer injury from a vessel collision. Large construction vessels (e.g. dredging barges, dump barges, pipelay barges and heavy-lift module transporters) are slow-moving (typically around 0.5–3 knots) and afford marine animals the opportunity to take action to avoid them. Smaller, fast-moving tender and crew-transfer vessels, which may travel at speeds of up to 20 knots, could be more hazardous to marine animals. It is noted that regular marine traffic already uses Darwin Harbour and that the construction phase will introduce an increase to these existing levels.

Product tankers operating during the operations phase will rarely exceed speeds of 10 knots in Darwin Harbour and will move slower in East Arm on their approach to Blaydin Point, with tugs in attendance. Again, marine animals will have ample opportunity to take action to avoid approaching vessels. Marine animals would also be expected to be attuned to the large slow-moving vessels which presently frequent the Harbour, especially in the vicinity of East Arm Wharf and Hudson Creek.

Trailing suction hopper dredgers (TSHDs) can occasionally injure or kill marine turtles near the seabed by accidentally sucking them into the equipment. Cutter-suction and backhoe dredgers cannot do this as they lack trailing suction dragheads (Dickerson et al. 2004). Suction into the draghead would affect the water column close to the equipment, out to a radius of around one metre. Efficient operation of the equipment can also reduce the risk of turtle entrainment, including ensuring that the suction surface is buried in the sediment while dredging and that the pumps to the TSHD are turned off when the draghead is lifted off the seabed.

It is presumed that sawfish could also be entrained in dredging equipment as they inhabit muddy seabeds. Incidents of injury or death to these animals are expected to be very rare during nearshore dredging activities as vessel noise and turbid plumes would discourage turtles and sawfish from remaining near the dredging equipment.

As described in Chapter 3, listed threatened species of marine animals do occur in the Harbour but no critical breeding or foraging areas have been identified for these in or around the nearshore development area. The potential for injury or death by vessel collisions or entrainment is very slight and would affect individuals without impacts to the broader populations of these species.

Other impacts to marine animals from noise and shockwaves as a result of piledriving and blasting activities are discussed in detail in Section 7.3.7.

Management of marine megafauna

A Provisional Cetacean Management Plan has been compiled for the Project (attached as Annexe 4 to Chapter 11), which will guide the development of a series of more detailed plans during the construction and operations phases. Key inclusions in this plan include the following:

- Vessel interactions with cetaceans in the nearshore development area will be avoided by:
  - aiming to maintain a 100-m distance from a large cetacean or a 50-m distance from a dolphin
  - operating at a "no-wash speed" when within 100–300 m of a large cetacean or 50–150 m of a dolphin
  - not actively encouraging bow-riding by cetaceans. However, should any cetacean(s) commence bow-riding, the vessel master will not change course or speed suddenly.

A Provisional Dredging and Dredge Spoil Disposal Management Plan has also been developed for the Project (Annexe 6 to Chapter 11). As part of this plan, practical options for reducing the risks of marine animal entrainment in TSHDs will be explored in consultation with the dredging contractor. These will be incorporated as management controls into the final dredging management plan. Options could include installing deflectors on dragheads and using turtle "tickler" chains on the trailing arms.

The potential impacts of underwater noise and blasting on marine megafauna are discussed in Section 7.3.7 *Underwater noise and blast emissions* and are managed through the Provisional Piledriving and Blasting Management Plan.

Residual risk

A summary of the potential impacts, management controls, and residual risk for marine megafauna is presented in Table 7-43. After implementation of these controls, potential impacts to marine megafauna as a result of Project activities in the nearshore development area are considered to present a "low" risk and would only affect individual animals on a localised scale.

7.4 Conclusion

7.4.1 Outcome of risk assessment

Offshore

Activities in the offshore development area that have the potential to impact on the environment include the installation of facilities, routine discharges and emissions (e.g. produced water, drilling muds and noise), and accidental events such as spills of condensate or diesel. Baseline surveys and modelling informed an assessment of the potential environmental impacts of these activities.

The risk assessment process, taking into account management controls and mitigating factors, identified 13 "medium" and 26 "low" residual risk potential environmental impacts associated with the offshore development area. These risk ratings are considered to be acceptably low, mitigating risks to sensitive habitats and significant or migratory species.

"Matters of national environmental significance" (as defined in the EPBC Act) associated with the offshore development area include the Commonwealth marine environment and some threatened and migratory animal species that could occur in the area, including whales and other cetaceans, turtles, sharks and seahorses. Surveys at the Ichthys Field recorded only a low number of whales and the area is not considered significant for whale breeding or feeding. Development of the offshore facilities and the gas export pipeline would affect a very small proportion of the extensive and relatively uniform marine habitats in the region, and would not reduce the available habitat for significant species. No threatened ecological communities have been identified in or near the offshore development area.

The most significant ecological habitat in the vicinity of the offshore development area is Browse Island, which is located approximately 33 km from the offshore facilities. The island is used for nesting by

Table 7-43: Summary of impact assessment and residual risk for marine megafauna (nearshore)

Aspect	Activity	Potential impacts	Management controls and mitigating factors	Residual risk*		
				C†	L‡	RR§
Vessel movements	Operation of construction and support vessels in the nearshore development area during construction phase, and tanker vessels and support vessels during operations.	Vessel collision, causing injury or death to marine megafauna. Disturbance to feeding activities and displacement from normal habitat.	No critical breeding or foraging areas for cetaceans, dugongs or turtles are known to exist in the nearshore development area. Large numbers of vessels already use Darwin Harbour regularly. Procedures for avoiding interactions between vessels and cetaceans. Provisional Cetacean Management Plan.	E	2	Low
Dredging	Operation of trailing suction hopper dredger (TSHD) in the nearshore development area during construction.	Entrainment of marine turtles and sawfish, causing injury or death.	No critical breeding or foraging areas for turtles or sawfish are known to exist in the nearshore development area. Practical options for reducing the risks of marine fauna entrainment in TSHDs will be explored and incorporated into the final dredging management plan. Provisional Dredging and Dredge Spoil Disposal Management Plan.	E (B1)	3	Medium

* See Chapter 6 *Risk assessment methodology* for an explanation of the residual risk categories, codes, etc.

† C = consequence.

‡ L = likelihood.

§ RR = risk rating.

green turtles (*Chelonia mydas*), which are listed as "vulnerable" under the EPBC Act. The only potential impact to Browse Island associated with the Project is the risk of hydrocarbons reaching shore in the unlikely event of a major condensate spill. Other emissions and discharges from the Project, including light, noise, produced water and drilling muds, are expected to remain distant from the island.

Drill cuttings from the construction of subsea production wells will generate a turbid plume in offshore waters, which will be dispersed by the strong ocean currents and deep water. While WBMs will be discharged along with drill cuttings, SBMs will be recovered for recycling and reuse prior to eventual onshore disposal. The concentration of SBMs on drill cuttings discharged to sea will be restricted to 10% by dry weight or less in accordance with Western Australian Government guidelines (DoIR 2006). An internal target of 5% or less of SBM on drill cuttings released to sea will be set.

Produced-water volumes from the offshore facilities will vary throughout the life of the Project and will contain varying concentrations of production chemicals. A comparison of expected field dilution rates against typical produced-water ecotoxicity indicates that Ichthys Field discharge concentrations should dilute to below acute toxicity levels within 10–60 m and to below chronic-toxicity levels within 1.1–3.6 km of the release point.

A large volume of water (1 GL) with low concentrations of dissolved chemicals will be discharged offshore after hydrotesting of the gas export pipeline. This "one-off" discharge is anticipated to rapidly disperse into the open ocean and will remain distant from habitats that would be sensitive to toxicity.

Discharges of drill cuttings, drilling muds, produced water and hydrotest water will comply with the requirements of offshore petroleum legislation. No wastes other than grey water, macerated sewage and food scraps will be discharged from the CPF and FPSO.

Ichthys Field condensate is a light oil with low viscosity and a relatively low proportion of aromatic hydrocarbons. In the unlikely event of accidental spills, any hydrocarbons at the water surface would undergo rapid weathering (evaporation of 70–80% of the spill volume) within the first day of release. Under certain wind conditions, however, trajectory modelling indicates that there is a chance that persistent hydrocarbons from large spills could reach points on the shorelines of Browse Island, Seringapatam Reef, Scott Reef and the Western Australian Kimberley coast. Spill scenarios of this scale include the rupturing of a subsea flowline, a CPF diesel fuel leak, the rupturing of a condensate transfer line, a ship colliding with the FPSO, or a subsea well failure. The likelihood of shoreline oil exposure from these scenarios ranges from 4.9×10^{-4} to 4.9×10^{-7} events per annum.

Because of the remote location of the Ichthys Field, emissions and discharges are very unlikely to combine with those from other facilities and contribute to cumulative impacts. The recently proposed Prelude field is located 15 km to the north of the Ichthys Field, while the fields of Jabiru, Challis and Montara are situated between 150 and 270 km to the north-east.

Nearshore

Activities in the nearshore development area that have the potential to impact on the environment include the construction of facilities and the associated dredging program, routine wastewater discharges, and accidental events such as hydrocarbon spills or the introduction of marine pests. Baseline surveys, modelling and comparison of the Project with similar past developments informed an assessment of the potential environmental impacts of these activities.

The residual risk assessment process, taking into account management controls and mitigating factors, identified 17 "medium" risk and 24 "low" risk potential environmental impacts associated with the nearshore development area. These risk ratings are considered acceptably low, mitigating the risks to sensitive habitats and significant or migratory species and minimising pollution and health impacts to the surrounding community.

"Matters of national environmental significance" associated with the nearshore development area are threatened and migratory animal species, including cetaceans, dugongs, birds, turtles, sharks and seahorses, and migratory birds that could occur in the area. While coastal dolphins, dugongs, marine turtles and sawfish are known to occur in Darwin Harbour, no significant breeding or feeding grounds have been identified for these species in or near the nearshore development area.

Dredging is required to provide a shipping channel and turning basin to provide tanker access to the product loading jetty, to provide access to the module offloading facility and to facilitate burial of the gas export pipeline. The dredging program proposed during the nearshore construction period will remove mainly soft-sediment benthic communities and some areas of rock pavement that support corals and algae. These marine communities are well represented elsewhere in the Harbour.

Dredging will generate turbid plumes that are mainly confined to East Arm. Turbid plumes will reduce the incident light levels reaching benthic biota, which could affect sensitive species such as corals and algae. However, predictive modelling shows that turbidity will be influenced by tidal currents and suspended-sediment levels in the water column in many places fall to close to background during neap tides as the sediments settle, before being resuspended by strong spring-tide movements. Hence, benthic biota will experience periods of turbidity close to background levels, throughout the dredging program and this is expected to mitigate long-term impacts upon these communities.

Turbid plumes can also release nutrients stored in marine sediments, providing a food source for fish and subsequently attracting predators such as marine mammals and reptiles. Conversely, marine megafauna may be deterred from the area because of the noise and movements of the various dredging and support vessels.

Predictive modelling of the proposed four-year dredging program indicates that some fine marine sediments will build up in shoreline areas around East Arm. Mangrove vegetation communities occur along these shorelines and some species rely on specialist root adaptations such as pneumatophores, stilt roots and buttress roots to facilitate gas exchange and respiration in anaerobic, waterlogged soils. Excess sedimentation on these structures could result in reduced mangrove tree health and even death. Around 2 ha of mangroves are predicted to receive more than 100 mm of sediment as a result of the dredging program which may cause tree deaths. An additional 28 ha of mangroves are predicted to receive between 50 mm and 100 mm of sediment which may cause reduced tree health or even localised deaths.

Sedimentation is not predicted to occur to any significant extent at coral communities in the Harbour as tidal currents would remove any settling particles relatively quickly.

Offshore disposal of dredge spoil will be carried out in an area of relatively featureless sandy seabed, with sparse benthic biota in water depths of 15–20 m. Turbid plumes generated by this spoil placement will be dispersed to the north-east and south-west by repeated tidal currents. On large spring tides, this could cause suspended-sediment concentrations of up to 7 mg/L around the Vernon Islands, and up to 12 mg/L in the Howard River in Shoal Bay. During neap tides, however, these concentrations would decrease to near-background levels. Hard corals and seagrass are rare in these areas and soft-coral and algal communities are expected to be able to withstand these periodic turbidity events without significant decreases in growth. Some low-level sedimentation of intertidal and subtidal areas could result within embayments in Shoal Bay and Adam Bay, which are naturally muddy depositional areas.

Marine blasting will be used to remove hard rock in the vicinity of Walker Shoal. This activity will generate underwater noise and blast impacts that could cause avoidance behaviour or injuries (or even death in the case of blasting) to marine megafauna in close proximity. Confined blasting methods will be used with micro-delays between blasts to reduce peak pressures and the radius of impact zones. Protection zones will be implemented for marine megafauna, with blasting activities suspended if animals are observed inside these zones. Passive and active acoustic monitoring techniques will be investigated and, if implemented, would complement vessel-based surveillance for fauna protection zones reducing risk even further. Some fish deaths are expected in close proximity to the blasting and these cannot be avoided. Marine blasting is only required during the construction phase and blasting activities will be localised.

Alternative techniques to drilling and blasting are being investigated for the removal of the hard rock material within the shipping channel. At this stage, however, it is not possible to confirm whether there are any viable alternatives.

Piledriving will be required for jetty construction. As with marine blasting, this will generate underwater noise and vibration that could cause avoidance behaviour or injuries to marine megafauna in the close vicinity. An observation zone and a soft-start procedure (in which activities are gradually scaled up over a five-minute period) will be implemented at the commencement of piledriving activities. As with marine blasting, the Project's piledriving activities are not expected to significantly disturb local populations of marine megafauna. Piledriving is only associated with the construction phase and the effects will be localised.

Predictive modelling indicates that treated wastewater discharges from the Project will dilute rapidly to below biological effect levels and that any hydrocarbons discharged from the onshore development area will degrade quickly under natural weathering processes. Similarly, freshwater discharges during hydrotesting are expected to mix quickly with nearshore marine waters without significant disturbance to biota. Other emissions, such as noise and light, will represent an incremental increase to the emissions already received by the nearshore marine environment and are not expected to significantly affect ecological processes in Darwin Harbour.

Spill-trajectory modelling indicates that accidental hydrocarbon spills during vessel refuelling or condensate loading could be transported to points on the shorelines of East Arm by tidal movements and seasonal winds. Mangroves are known to be particularly sensitive to contamination by hydrocarbons and could suffer reduced growth or death in the unlikely event of a spill. Spill prevention and response controls will decrease the likelihood of spills occurring and reaching the shore. Leaks or ruptures of the gas export pipeline are not predicted to cause shoreline exposure along the greater part of its length because of the volatility of the gas and condensate in the pipeline.

The use of large slow-moving vessels such as pipelay barges during the nearshore construction phase represents the main marine pest transfer risk for the Project, particularly where these vessels mobilise from overseas ports. Quarantine procedures will be implemented, in consultation with AQIS, to protect the marine habitats and the maritime infrastructure and industries in Darwin Harbour from marine pest introductions.

A range of monitoring programs are proposed, to measure potential effects on the receiving nearshore marine environment (see Chapter 11). These include the following:

- a Darwin Harbour water quality monitoring program, which will determine whether effluent discharges adversely impact water quality
- a marine sediments and bio-indicators monitoring program, which will identify changes in pH and heavy metal availability in marine sediments as a result of construction activities in acid sulfate soils, and the accumulation of metals and petroleum hydrocarbons in sediments and selected bio-indicators as a result of surface-water and groundwater flows
- a mangrove health monitoring program, which will assess any impacts to mangrove health around Blaydin Point and East Arm as a result of activities in the onshore development area
- coral monitoring programs, which will identify stress in corals at Channel Island during dredging (and trigger management responses if required) and which will document the dredging effects of increased turbidity and sedimentation on corals in East Arm
- a soft-bottom benthos monitoring program will be developed with pre- and post-dredging and spoil disposal sampling of these benthic communities to identify any changes occurring as a result of both the dredging and spoil disposal programs
- a marine pests monitoring program, to identify the presence of marine pests in a timely manner, consistent with the monitoring framework proposed by the Commonwealth Government's National Introduced Marine Pests Coordination Group.

It is considered that the level of management and risk reduction presented for the offshore and nearshore development areas represents a proactive and conservative approach to maintaining environmental values, while allowing progress for the Project in a sustainable fashion. The management controls to be implemented will be further developed in consultation with stakeholders and will continue to be updated throughout the various stages of the Project.

7.4.2 Environmental management plans

As described throughout this chapter, a suite of provisional management plans has been developed to outline the proposed management controls that reduce the potential for marine environmental impacts. These provisional plans will guide the development of more detailed plans as the Project progresses. The plans contain the objectives, targets, detailed actions and monitoring to be carried out to manage a variety of environmental aspects that include those listed below:

- acid sulfate soils
- cetaceans
- decommissioning
- dredging and dredge spoil disposal
- liquid discharges, surface water runoff and drainage
- piledriving and blasting
- quarantine
- waste.

For some specific offshore activities, additional environmental management plans will be required under the OPGGS(Environment) Regulations. These will include plans for pipeline installation, drilling, and construction and operation of the CPF and FPSO, as well as an oil-spill contingency plan. These plans are not provided in this Draft EIS as they will be assessed under a separate approvals process.

INPEX's Health, Safety and Environmental Management Process is described in Chapter 11 and the provisional management plans that have been developed for the Project are attached as annexes to Chapter 11.

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8 Terrestrial Impacts and Management

8 TERRESTRIAL IMPACTS AND MANAGEMENT

8.1 Introduction

This chapter of INPEX's draft environmental impact statement (Draft EIS) describes the potential impacts to the terrestrial environment and regional airshed associated with the onshore development area of the Ichthys Gas Field Development Project (the Project). This area includes land above the low-water mark on Blaydin Point and Middle Arm Peninsula in Darwin Harbour.

Components of the Project that will be constructed in this area include the onshore processing plant; support facilities such as the administration and laydown areas; access roads; and the onshore portion of the gas export pipeline from the Ichthys Field which extends 6 km across Middle Arm Peninsula from the pipeline shore crossing to the processing plant.

Details of the onshore infrastructure and activities over the Project's life may be summarised as follows:

- site preparation prior to the commencement of construction activities, such as clearing of vegetation and the development of earthworks
- construction and precommissioning of the onshore facilities
- commissioning of the onshore processing plant
- operation of the onshore processing plant and associated facilities
- decommissioning of the onshore facilities
- site closure and rehabilitation.

The environmental impact assessment provided in this chapter includes discussion of the significance of potential impacts in a regional context and presents management controls that would be implemented by INPEX to mitigate these impacts.

In order to determine the "residual risk" remaining after management controls are applied to mitigate the risks arising from the Project, a risk assessment of the various potential impacts was undertaken according to the methods presented in Chapter 6 *Risk assessment methodology*. Summary tables of the onshore activities, potential environmental impacts, management controls and mitigating factors, and resulting residual risk (consequence, likelihood and risk rating) are provided throughout the chapter.

The risk assessment was undertaken with consideration of sensitive environmental receptors, which include the plants and animals in the immediate vicinity of Blaydin Point and Middle Arm Peninsula. Because of the proximity of the onshore development area to the cities of Darwin and Palmerston, the local community is also a key sensitive receptor. Other impacts to the community associated with factors such as airborne noise and visual amenity are described in Chapter 10 *Socio-economic impacts and management*.

Management controls will be implemented to ensure that all significant potential environmental effects associated with the Project are minimised or avoided. A number of monitoring mechanisms are also proposed that will allow INPEX to gauge the effectiveness of management controls. A comprehensive and auditable environmental management system based on the principles of the International Organization for Standardization's ISO 14000 environmental management series of standards will be implemented to provide a systematic and structured approach to environmental management. The system proposed is described in Chapter 11 *Environmental management program*.

8.2 Physical disturbance

8.2.1 Soil erosion

Onshore construction activities will require large-scale cut-and-fill earthworks to provide level ground surfaces for the plant's processing infrastructure. The main environmental impacts of these earthworks include potential soil erosion of the newly created landforms and generation of dust during construction before bare surfaces are sealed. Erosion risks are described in this section, while dust risks are discussed in Section 8.4.2 *Dust*.

The soils in the onshore development area are considered to be susceptible to erosion because of the region's intense monsoonal rainfall and the structureless and sodic nature of the soils. Even very gentle slopes are prone to erosion if disturbed, and factors such as increased traffic will potentially exacerbate the rate of soil erosion (URS 2009a, provided as Appendix 17 to this Draft EIS).During field geographical studies (see Appendix 17) a 10-cm surface layer of sand was observed in mangrove soils, suggesting surface wash from the upland soils and indicating a natural sedimentation process into the mangroves. The mangroves fringing the shoreline around Blaydin Point act as a sediment trap for erosion from the land. However, the potential rate of erosion from large-scale earthworks at the onshore development area is likely to be higher than natural sedimentation rates.

Burial of mangrove pneumatophores (and other specialised aerial root structures) as a result of excessive soil deposition can lead to reduced vigour or tree death as described in Chapter 7 *Marine impacts and* *management*. The response of different mangrove species to root burial varies, and is likely to be a function of root architecture, tidal range, sediment composition and grain size. In Australian examples, deaths of *Avicennia marina* were caused by sedimentation depths of 12–50 cm, and deaths of *Rhizophora* spp. were linked to sediment depths of 50–70 cm (Ellison 1998).

Unless managed properly, soil erosion from clearing at the onshore development area could create a sedimentation risk to mangroves at the pipeline shore crossing, the onshore pipeline route, and around the boundaries of the processing plant on Blaydin Point. Other vegetation communities such as the eucalyptus woodland and monsoon vine forest along the access roads, the onshore pipeline route and at the boundaries of the processing plant could also be affected by soil erosion. These communities, however, would be less vulnerable to soil erosion impacts with damage likely to occur over a much longer time frame as a result of root exposure.

In areas where the mangrove zone is to be completely cleared from the shoreline (e.g. at the pipeline shore crossing, product loading jetty and module offloading facility) soil erosion from the onshore development area could reach the nearshore marine environment and cause sedimentation and turbidity impacts—these risks are described in Chapter 7.

Management of soil erosion

A Provisional Liquid Discharges, Surface Water Runoff and Drainage Management Plan and a Provisional Vegetation Clearing, Earthworks and Rehabilitation Management Plan have been compiled for the Project to manage soil erosion risks; they are included in Chapter 11 as annexes 10 and 15 respectively. These will guide the development of more detailed plans during the construction and operations phases and contain relevant objectives and targets, management controls, and monitoring and reporting procedures. Key management controls included in these plans are as follows:

- Large-scale vegetation-clearing and earthworks will preferentially be undertaken in dry-season conditions. Should clearing and earthworks be required to be undertaken during the wet season, adequate control measures will be implemented to avoid erosion and sedimentation impacts.
- Erosion protection infrastructure (e.g. silt fencing, spoon drains, contouring, and sediment ponds) will be installed to ensure that sediment is contained within the site boundaries as far as is practicable.
- If soil erosion becomes evident, exposed surfaces at the affected area will be stabilised with mulched vegetation, dust suppressants or slope-stabilisation products.

Table 8-1: Summary of impact assessment and residual risk for soil erosion

Aspect	Activity	Potential impacts	Management controls, mitigating factors	Residual risk*		
				C†	L‡	RR§
Soil erosion	Large-scale earthworks for construction of onshore processing facility. Clearing of vegetation during site preparation.	Sedimentation of mangrove areas around the onshore development area, leading to smothering of pneumatophores and reduced plant growth or death.	Large-scale vegetation-clearing will be undertaken preferentially in dry season conditions to avoid the erosion risks associated with monsoon rains in the wet season. Erosion-protection infrastructure (e.g. silt fencing, spoon drains, contouring, and sediment ponds) will be installed to ensure that sediment is contained within the site boundaries as far as possible. If soil erosion becomes evident, exposed surfaces at the affected area will be stabilised with mulched vegetation, dust suppressants or slope-stabilisation products. Provisional Vegetation Clearing, Earthworks and Rehabilitation Management Plan. Provisional Liquid Discharges, Surface Water Runoff and Drainage Management Plan.	F (B2)	3	Low

* See Chapter 6 *Risk assessment methodology* for an explanation of the residual risk categories, codes, etc.

† C = consequence.

‡ L = likelihood.

§ RR = risk rating.

- Surface-water drains and discharge points throughout the onshore development area will be designed to minimise erosion.

Residual risk

A summary of the potential impacts, management controls and residual risk for soil erosion is presented in Table 8-1. After implementation of these controls, impacts from soil erosion are considered to present a "low" risk and it is likely that any effects on the environment will be localised and small in scale.

8.2.2 Soil chemistry

Metals

High levels of metals in soil can be associated either with natural mineralisation or with contamination. Background heavy metal concentrations in soils at 73 sampling points across the onshore development area were assessed using a strong acid digest of the fine soil fraction (<2 mm in diameter). This measure represents mineralised metals in the more active soil fraction, for which generic guidelines are available. Following the standard methodology for soil risk assessment laid down in a "national environment protection measure" (NEPM) by the National Environment Protection Council (NEPC 1999), the recorded soil metals concentrations were below generic investigation levels for human health and environmental risk assessment. (The full results of the laboratory analysis are provided in Appendix 17.)

Heavy metals such as aluminium and iron are mobilised into solution in soils affected by acid sulfate weathering. In this instance, under the action of sulfuric acid produced when the sediments are oxidised, high dissolved metal concentrations arise from the dissolution of finely divided iron sulfides, aluminosilicate clays and metal organic complexes in mangrove sediments. The reactivity of mangrove sediments relates to high surface areas per unit volume compared with the upland soils and to higher concentrations of organic matter that will oxidise under strong acid conditions to release metals into solution. Acid sulfate soils are described in more detail below.

Metal toxicity in plants and marine biota may be caused on a localised scale during excavation of acid sulfate soils in the intertidal areas.

In higher parts of the onshore development area, disturbing soil materials will not cause heavy-metal health effects in humans or other environmental receptors.

Acid sulfate soils

Most acid sulfate soils (ASSs) were formed by natural processes over the last 10 000 years. They were originally deposited in marine, estuarine or river settings and occur predominantly in low-lying areas near the coast. Coastal estuarine and mangrove swamp environments develop ASSs because of the waterlogged and anaerobic soil environments where iron sulfide minerals (principally iron disulfide (FeS_2) or iron monosulfide (FeS)) are formed through a process of microbial sulfate reduction. While undisturbed ASSs are harmless, excavation exposes these soils to air and the iron sulfides oxidise to produce sulfuric acid. Water draining from oxidised ASSs can be strongly acidic (pH <3.5). The acid acts on soils and sediment to produce high solution concentrations of toxic metals, especially aluminium and iron, which may have deleterious effects on human health and the environment and may also result in damage to infrastructure (see Appendix 17).

The oxidation of metal sulfides is a natural weathering process that generally occurs slowly and does not pose an environmental concern. However, excavation and drainage can exponentially increase the rate of acid generation. Unmanaged disturbance of areas of ASS and consequent acid drainage from these areas can cause adverse impacts to the terrestrial and intertidal environment, including the following:

- a reduction in soil fertility caused by acidification and metal toxicity, reducing plant growth and limiting germination of new seedlings
- the creation of acid surface scalds at points where affected groundwater discharges to the soil surface
- a loss of visual amenity because of rust-coloured stains, scums and slimes from iron precipitates at the soil surface accompanied by reduced vegetation growth
- the risk of long-term infrastructure damage through acidic water corroding metallic and concrete structures such as foundations, subsurface pipes, retaining walls and roads
- a reduction in water quality in the marine environment and toxic effects on marine biota (these impacts are discussed in Chapter 7).

Soils of the Euro family in the coastal zones around Blaydin Point and Middle Arm Peninsula are particularly prone to acid generation. The Maand, Mullalgah and Rinamatta soil families also present a potential ASS risk, although to a lesser degree (see Appendix 17). Potential ASSs occur in the areas proposed for the pipeline shore crossing, onshore

Table 8-2: Volumes of potential acid sulfate soil to be excavated during site preparation at the onshore development area

Area	Length (m)	Width (m)	Depth (m)	Total volume (m^3)	Estimated weight (t)
Ground flare*	625	300	5	937 500	1 406 250
Pipeline shore crossing (coffer dam)	900	6	5	27 000	40 500
Pipeline mangrove crossing	1 200	3	2	7 200	10 800
Module offloading facility	(irregular shape)			90 000	135 000
Total				**1 061 700**	**1 592 550**

* The construction method for the ground flare has not yet been finalised and this level of excavation may be reduced in the final design.

pipeline route, the ground flare and module offloading facility (see the soil map in Section 3.4.4 *Soils* in Chapter 3 *Existing natural, social and economic environment*). The potential volumes of material to be excavated during site preparation and construction of this infrastructure are presented in Table 8-2. Most of this material is likely to pose a high risk of acid sulfate leaching, and detailed soil testing before construction commences will be used to quantify the extent and strength of ASS in these areas. In addition to the excavated material, the remaining exposed surfaces would be at risk of acid leaching, and neutralising treatment would be required before infrastructure is constructed on top of these surfaces.

The most common ASS treatments involve adding a neutralising (liming) agent sufficient to neutralise the acid from the soil as it is produced over time from the gradual oxidation of the soil sulfides. Field surveys by URS (see Appendix 17) indicated that the acid neutralising capacity of the soils in the onshore development area is low and that the amount of lime in the form of calcium carbonate ($CaCO_3$) that would be required to neutralise acid formed upon excavation of these soils would range from 2.2 to 140 kg of $CaCO_3$ per tonne of soil, with an average of 30 kg per tonne of soil (see Appendix 17). Liming activities require monitoring to identify whether the rate of neutralisation is occurring at a rate equivalent to the oxidation of iron sulfides. If not, some acid leaching may still occur and drainage from liming areas may require treatment prior to discharge. Soils treated using this method, once neutralised, could be utilised as fill material or removed off site for disposal.

The offshore spoil disposal ground used by the Project for dredge spoil (see Chapter 4 *Project description*) may also be used for the disposal of excavated ASS material from the onshore development area. Potential impacts to the marine environment as a result of these disposal activities are discussed in Chapter 7.

Nutrients and organic carbon

The surface or A horizon of the Blaydin soil family that occurs within the monsoon vine forest areas at Blaydin Point and near the pipeline shore crossing contains relatively high levels of organic carbon and nutrients, has a low erosion risk, and is therefore considered highly fertile. This soil type is highly suitable for use as topsoil in revegetation work, and is a valuable resource for rehabilitation activities (see Appendix 17).

There will be areas around the onshore processing plant site that will be cleared during construction for machinery laydown and other activities but which will not be required during operations. Revegetation of these areas will minimise the risk of erosion from bare soils. Rapid reuse of the topsoil (0–300 mm depth) removed during land-clearing, particularly that sourced from areas of monsoon vine forest, is likely to improve revegetation success in these areas.

Management of soil chemistry impacts

A Provisional Acid Sulfate Soils Management Plan has been compiled for the Project and is included in Chapter 11 as Annexe 1. This will guide the development of more detailed plans during the construction and operations phases. It contains relevant objectives and targets together with a detailed description of the management controls to be implemented to mitigate acid sulfate leaching; it also includes options for treatment and disposal methods as well as outlining monitoring and reporting procedures.

As the Project is still in a preliminary stage of engineering design, the management controls outlined in the provisional management plan primarily deal with the options available for management of ASS material. The plan will be updated with more specific controls as further geotechnical studies are carried out and as infrastructure design progresses. Additional detailed chemical testing for ASSs will be conducted on site during the front-end engineering design (FEED) phase of the Project, and still more ASS testing will take place when infrastructure designs are mature, prior to construction. Inclusions in the provisional management plan are outlined below.

Various design options are investigated to minimise the quantity of ASS excavation from the site so that minimum management of ASSs is required. Engineering design and management options for avoiding or neutralising ASSs include the following:

- installing columns or piles and a deck structure in the ASS areas in order to minimise the generation of ASSs, with Project facilities constructed on top of the deck
- monitoring of the progress of work when installing columns or piles or a deck structure in the ASS areas to avoid or minimise generation of mud waves
- mixing the soil with cement slurry to harden it, neutralise it and make it more stable.

Management options available to treat and dispose of disturbed ASSs during construction are as follows:

- placing fill material on top of ASSs to form a surface suitable for construction
- neutralising excavated ASSs by mixing them with lime, then reusing the material as backfill or disposing of it at designated onshore sites
- excavation and disposal of ASSs underwater at a designated offshore disposal site, avoiding oxidation of the soils.

A marine sediments and bio-indicators monitoring program will be developed to assess any increase in bioavailable heavy metals as a result of excavation of acid sulfate soils during the construction phase.

Residual risk

A summary of the potential impacts, management controls and residual risk for soil chemistry is presented in Table 8-3. After implementation of these controls, impacts from ASSs are considered to present a "medium" risk and any effects on the surrounding environment are likely to be only localised and minor.

8.2.3 Alteration of surface-water and groundwater flow

In order to determine the likely impacts of the Project on surface and groundwater flows at Blaydin Point, a hydrological model for the area was developed by URS in the period April–October 2008. The conclusions arrived at as a result of this model are summarised below, with the complete technical report (URS 2009b) provided in Appendix 18 to this Draft EIS.

Development of the onshore processing plant will require vegetation-clearing throughout the site and the development of sealed surfaces beneath some facilities (such as the slug catcher, the liquefied natural gas (LNG) trains and the hydrocarbon storage tanks), interspersed with cleared but unsealed areas. The groundwater beneath Blaydin Point is believed to be recharged mainly by the infiltration of rainfall (see Appendix 18) and maintaining sufficient unsealed areas throughout the onshore development area will allow natural infiltration to continue.

Without sufficient recharge of the groundwater aquifer by rainfall, the water table at Blaydin Point could decline and stabilise near mean sea level. This could result in landward migration of the interface between fresh water and sea water and might affect groundwater-dependent ecosystems as well as below-ground services and building foundations (see Appendix 18).

Table 8-3: Summary of impact assessment and residual risk for soil chemistry

Aspect	Activity	Potential impacts	Management controls, mitigating factors	Residual risk*		
				C†	L‡	RR§
Acid sulfate soils	Earthworks in the onshore development area for the pipeline shore crossing, onshore pipeline, ground flare and module offloading facility.	Acidification of soils, surface water and groundwater, reducing soil productivity and plant growth.	Facilities to be designed to minimise excavation of potential ASS. If excavation is unavoidable, management options include neutralising and re-covering with clean fill, or disposing of off site. As an alternative, excavated ASS material may be disposed of at the offshore spoil disposal ground. Provisional Acid Sulfate Soils Management Plan.	E (E4)	3	Medium

* See Chapter 6 *Risk assessment methodology* for an explanation of the residual risk categories, codes, etc.

† C = consequence.

‡ L = likelihood.

§ RR = risk rating.

The vegetation community remaining during the operations phase of the Project that is most sensitive to changes in the groundwater and surface-water regime is the hinterland fringe mangrove community (see Appendix 18). This occurs as a narrow fringe, approximately 20–30 m wide, at the interface between the terrestrial vegetation communities (such as eucalypt woodland) and the tidal flats. (The vegetation communities of the onshore development area are described in Chapter 3.) The hinterland fringe mangrove community is characterised by dependence on freshwater input and low soil salinities. Its elevation on the tidal gradient means that this community receives infrequent tidal (seawater) inundation.

Currently, the hinterland fringe mangrove zone at Blaydin Point receives freshwater runoff and fresh groundwater seepage that is marked in the wet season and less pronounced, but perennial, in the dry season. The onshore processing plant will modify water flows to the hinterland fringe mangrove zone in a number of ways:

- Surface-water flows will increase in total volume.
- Surface-water flows may be concentrated to a small number of discrete areas (near artificial surface-water drains), while other areas may be isolated from water supply and will actually receive less surface-water runoff.
- Surface-water flows will be delivered earlier in the wet season as the natural time delay resulting from soil saturation in the upper catchment will be removed.
- Water-table levels may decrease if a large proportion of the ground's surface is sealed in order to construct the onshore processing plant. If this decrease is enough to allow seawater movement into the groundwater, groundwater seepage may become more saline.

The overall effect on the hinterland mangrove community may be that there will be more luxuriant growth in some areas and dieback in others. Anecdotal evidence suggests that freshwater flows to hinterland mangrove communities have been affected in other areas of Darwin Harbour, including ConocoPhillips' Darwin LNG plant, the East Arm Wharf development area and the Bayview residential area, without significant deterioration in mangrove health.

At Blaydin Point, by distributing surface-water runoff from the onshore development area at numerous points around the perimeter rather than through a single discharge point, the surface-water flow would be partially maintained and the effects of reduced fresh groundwater seepage would be minimal.

The extensive mangrove zones up to 1 km wide that occur seaward of the hinterland fringe are reliant on tidal inundation and are adapted to conditions of higher salinity. These communities are unlikely to be affected by modifications to fresh surface-water drainage and subsurface seepage from the Blaydin Point hinterland.

Surface-water flows in the onshore development area may also be altered by the construction of infrastructure such as roads and pipelines. In particular, a causeway will need to be constructed across the tidal flat between Blaydin Point and Middle Arm Peninsula and allowances will have to be made to maintain water flow to the upper intertidal area above the causeway. Alterations to tidal surface-water flows may affect the long-term survival of localised pockets of vegetation or could result in areas of pooling water that increase the extent of biting-insect habitat.

Management of surface water and groundwater

As noted above, a Provisional Liquid Discharges, Surface Water Runoff and Drainage Management Plan has been compiled for the Project. This will guide the development of more detailed plans during the construction and operations phases. The provisional management plan contains relevant objectives and targets and provides a detailed description of all management controls and monitoring and reporting procedures to be implemented to manage drainage and groundwater. Key elements of the plan are as follows:

- Some areas of Blaydin Point will remain uncleared or unsealed to allow for some groundwater recharge by rainfall.
- Numerous surface-water drains will be constructed around the perimeter of the onshore development area, which will distribute fresh water to mangrove areas.
- A mangrove health monitoring program will be developed to assess the potential effects of changes to water supply during the operations phase.
- A groundwater quality monitoring program will be developed to check if there are any impacts on groundwater quality.
- Culverts will be installed beneath the causeway between Blaydin Point and Middle Arm Peninsula to maintain surface-water flows across the natural drainage line.

Management of contamination risks to surface-water and groundwater flows are discussed in Section 8.6 *Spills and leaks*.

Table 8-4: Summary of impact assessment and residual risk for surface water and groundwater

Aspect	Activity	Potential impacts	Management controls, mitigating factors	Residual risk*		
				C†	L‡	RR§
Surface-water management	Sealing of parts of the ground surface throughout the onshore development area for the processing plant and associated infrastructure.	Increase in total volume of surface-water runoff. Alteration of surface-water drainage direction and volumes. Isolation of groundwater system from freshwater recharge, lowering of water table and potential for seawater intrusion. Reduced health or mortality of hinterland mangrove community because of reduced access to fresh groundwater.	Some areas of Blaydin Point will remain uncleared or unsealed to allow for groundwater recharge by rainfall. Install multiple surface-water drains to distribute fresh water into mangroves. Install culverts to maintain natural tidal flows underneath the causeway from Blaydin Point to Middle Arm Peninsula. Provisional Liquid Discharges, Surface Water Runoff and Drainage Management Plan.	D (B2)	3	Medium

* See Chapter 6 *Risk assessment methodology* for an explanation of the residual risk categories, codes, etc.

† C = consequence.

‡ L = likelihood.

§ RR = risk rating.

Residual risk

A summary of the potential impacts, management controls and residual risk for surface water and groundwater is presented in Table 8-4. After implementation of these controls, the impacts on surface water and groundwater are considered to present a "medium" risk and it is likely that any effects on the environment will be localised and minor in scale.

8.3 Ecological disturbance

8.3.1 Vegetation-clearing

Construction and engineering constraints prevent any significant reductions in the size of the onshore development area because of the requirements for large areas of laydown and to allow for a permanent design that maintains safe distances between hazardous and non-hazardous areas. As a result, the Project will require approximately 352 ha of vegetation-clearing within the onshore development area. There are also 54 ha of cleared land (including borrow pits and roads) within the disturbance footprint.

The onshore development area clearing footprint will be concentrated in the upper land area, above the intertidal zone. Vegetation in this area is dominated by *Eucalyptus* woodland and there are also two patches of closed monsoon vine forest. Some smaller areas in the intertidal zone will also require clearing and are currently dominated by mangrove communities. The vegetation communities throughout the onshore development area are described in Chapter 3 and the areas of each that are proposed to be cleared are presented in Table 8-5.

The ecological significance of this vegetation-clearing from a regional perspective is discussed by GHD (2009) (provided as Appendix 16 to this Draft EIS) and is summarised below.

Table 8-5: Disturbance areas in the vegetation communities at the onshore development area

Vegetation community	Area proposed to be cleared (ha)
Casuarina **and beach forest**	**1**
Eucalyptus **woodland**	**161**
Monsoon vine forest	**66**
Mangrove communities:	
Avicennia–Ceriops open forest	5
Ceriops closed forest	25
Mixed hinterland closed forest	16
Mixed species low closed forest	8
Salt flats	20
Shoreline forest	2
Sonneratia woodland	4
Tidal creek forests	3
Transition zone	0
Subtotal – Mangrove communities	**83**
Melaleuca communities:	
Melaleuca forest	8
Mixed species low woodland	33
Subtotal – Melaleuca communities	**41**
Total*	**352**

* Note that this does not include 54 ha cleared before 2007.

Vegetation communities

Eucalyptus woodland

Eucalyptus woodland is the most widespread vegetation community throughout the Darwin Coastal Bioregion and it is also well represented in conservation reserves (GHD 2009). Although this vegetation type will be cleared more extensively than any other within the onshore development area, the extent of clearing will not significantly reduce the abundance or distribution of *Eucalyptus* woodland at a regional level.

Monsoon vine forest

Monsoon vine forest vegetation in the Darwin Coastal Bioregion is considered to have a higher conservation value than most other vegetation types found in the onshore Project area. Among other attributes, it contains fruiting and flowering plant species that provide a rich food source for some specialised animals, such as frugivorous birds.

The area of monsoon vine forest on Blaydin Point (approximately 65 ha) represents about 4% of the total extent of the vegetation type found around Darwin Harbour (Figure 8-1) and an estimated 1% of mapped monsoon vine forest in the Darwin Coastal Bioregion.

Monsoon vine forest provides habitat for frugivorous birds such as rose-crowned fruit-doves (*Ptilinopus regina*). These birds disperse the seeds of the plants and their presence may be an important factor in maintaining the existence of this vegetation community. Extensive plantings of tropical fruit-bearing trees (e.g. the palm *Carpentaria acuminata*) in suburbs of Darwin and Palmerston and the surrounding rural areas are capable of supporting some of the frugivorous bird species that inhabit monsoon vine forest (GHD 2009).

Threatening processes to the monsoon vine forest in the Darwin Coastal Bioregion include degradation by feral animals (principally pigs), infestation by invasive weeds, and the impacts of more frequent hot, late, dry-season fires (DEWHA 2008).

Mangroves

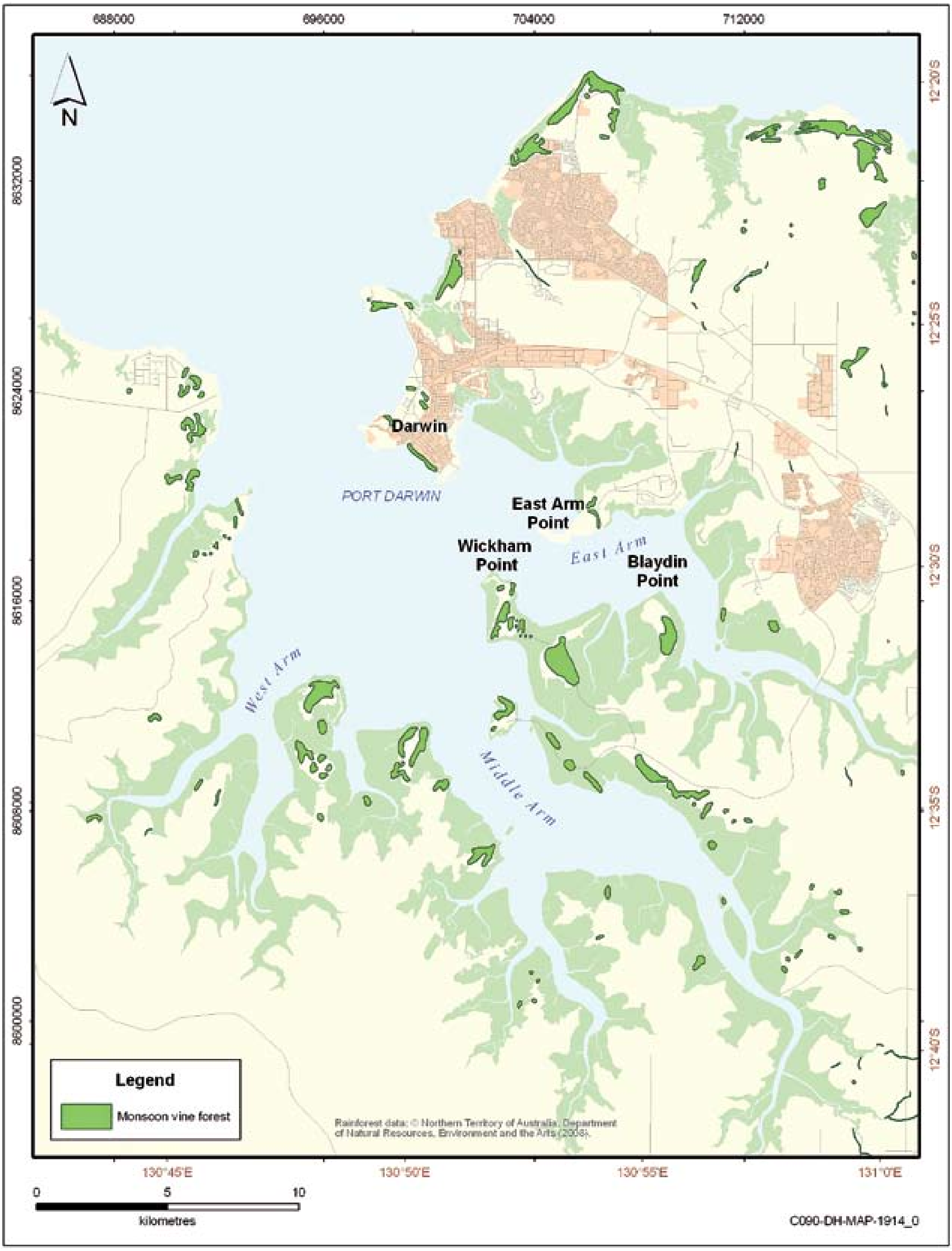
The majority of mangrove areas around Blaydin Point and throughout Darwin Harbour are zoned for "conservation" under the Northern Territory Planning Scheme (DPI 2008) in recognition of the high level of biodiversity contained in these vegetation communities. The mangrove tracts around the Harbour shoreline are extensive, occupying over 27 000 ha. The proposed disturbance of mangrove vegetation communities at the Project's onshore development area (77 ha in total) represents less than 0.3% of that vegetation type found in the Darwin Harbour region, and is an insignificant portion of the vegetation type in the overall context of the Darwin Coastal Bioregion. Clearing is not expected to significantly impact the vegetation type at a regional scale.

Melaleuca

Melaleuca forest is a common lowland vegetation type found throughout the Darwin Coastal Bioregion; it represents 9% of the total area of the bioregion. Clearing at the onshore development area will not significantly reduce the abundance or distribution of this vegetation community.

Significant plant species

As described in Chapter 3, field surveys in 2007 and 2008 indicated that no plant species listed under the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth) occur in the onshore development area.



Source: Unpublished data (2008) from the Rainforest Database of the Northern Territory's Department of Natural Resources, Environment and the Arts (NRETA)[1].

Figure 8-1: Existing monsoon vine forest patches around Darwin Harbour

1 Now the Department of Natural Resources, Environment, the Arts and Sport (NRETAS).

However, the cycad *Cycas armstrongii*, which is listed as "vulnerable" under the *Territory Parks and Wildlife Conservation Act* (NT), does occur in the onshore development area in the eucalypt woodland vegetation community. Impacts to the total population of this species as a result of land-clearing for the Project are not expected to be significant. The cycad is locally abundant across the western Top End region, the Cobourg Peninsula and the Tiwi Islands (Melville Island and Bathurst Island). It is listed as vulnerable because of its poor representation in conservation reserves and because of large-scale land-clearing threats from agriculture, horticulture and forestry (GHD 2009). Where land-clearing has been approved under the formal procedures of the Northern Territory Government (e.g. through the EIS process), no additional permit is required to take cycads for non-commercial purposes on areas designated to be cleared (Liddle 2009).

Management of vegetation-clearing

A Provisional Vegetation Clearing, Earthworks and Rehabilitation Management Plan has been compiled for the Project and is included in Chapter 11 as Annexe 15. This will guide the development of more detailed plans during the construction and operations phases. It contains details of applicable management controls, procedures, and monitoring and audit programs. Key components of this plan are as follows:

- The area of vegetation cleared will be the minimum required to safely and efficiently construct and operate the onshore facilities.
- All disturbance, including personnel and vehicle movements, will be contained within the designated onshore development area to avoid impacts to surrounding vegetation. Some additional clearances may be required around the perimeter of the site to allow for appropriate firebreaks.
- Areas to be cleared will be clearly identified prior to work commencing. Clearing boundaries will be marked in the field and on site plans, and a register of clearing activities will be maintained.
- Temporarily disturbed areas within the onshore development area (e.g. near the pipeline shore crossing, along the onshore pipeline route, and small areas around the processing plant) will be revegetated and rehabilitated following the completion of construction activities.
- A vegetation rehabilitation monitoring program will be developed to determine the success of revegetation activities.
- Some topsoil will be stockpiled from cleared areas for future use in rehabilitation.
- Cleared vegetation will be mulched and stockpiled on site boundaries or off site. Where possible, the mulch will be used both for vegetation rehabilitation and for soil stabilisation. Cleared vegetation that cannot be reused will be disposed of off site. No stockpiled vegetation will be burned.

A Provisional Decommissioning Management Plan has also been compiled and is included in Chapter 11 as Annexe 5. It outlines the processes to be undertaken to determine final landforms and potential rehabilitation activities at the end of the Project's life. This plan will guide the development of more detailed plans at later stages of the Project.

Residual risk

A summary of the potential impacts, management controls and residual risk for vegetation-clearing is presented in Table 8-6. After the implementation of controls and with consideration of mitigating factors, the impacts from vegetation-clearing are considered to present a "low" to "medium" risk and are likely to affect plant and animal populations on only a localised and minor scale. Clearing monsoon vine forest is assigned a "medium" residual risk rating as it is not possible to avoid through engineering design and represents a proportionally higher impact at a regional scale. The fact that mangroves act as primary producers providing habitat and resources to marine biota increases the ecological significance of clearing activities. Nevertheless, removal of these vegetation types in the onshore development area is not considered to threaten significant plant or animal species as similar areas of habitat do exist nearby.

Table 8-6: Summary of impact assessment and residual risk for vegetation-clearing

Aspect	Activity	Potential impacts	Management controls, mitigating factors	Residual risk*		
				C†	L‡	RR§
Vegetation	Clearing of vegetation during site preparation.	Loss of mangrove habitat. Localised reduction in biodiversity.	The vegetation-clearing footprint for the onshore development area will be minimised during the design of the onshore facilities, subject to design, construction and safety requirements. Contain all disturbance (including vehicle movement) within the development footprint. Mangrove communities are common throughout Darwin Harbour and the Darwin Coastal Bioregion. Temporarily disturbed areas within the onshore development area (e.g. near the pipeline shore crossing, along the onshore pipeline route, and small areas around the processing plant) will be revegetated and rehabilitated following the completion of construction activities. Provisional Vegetation Clearing, Earthworks and Rehabilitation Management Plan.	E (B2)	6	Medium
Vegetation	Clearing of vegetation during site preparation.	Loss of *Eucalyptus* woodland and *Melaleuca* forest habitat. Localised reduction in biodiversity.	The vegetation-clearing footprint for the onshore development area will be minimised during the design of the onshore facilities, subject to design, construction and safety requirements. Contain all disturbance (including vehicle movement) within the development footprint. Store topsoil from cleared areas in stockpiles for future use in rehabilitation. Cleared vegetation will be mulched and stockpiled on site boundaries or off site. Where possible, the mulch will be used for both rehabilitation and soil stabilisation to prevent erosion. Cleared vegetation that cannot be reused will be disposed of off site. No stockpiled vegetation will be burned. *Eucalyptus* woodland and *Melaleuca* forest communities are common throughout the Darwin Coastal Bioregion. Provisional Vegetation Clearing, Earthworks and Rehabilitation Management Plan.	F (B3)	6	Low
Vegetation	Clearing of vegetation during site preparation.	Removal of cycads, which are classed as "vulnerable" under the *Territory Parks and Wildlife Conservation Act* (NT). Localised reduction in biodiversity.	*Cycas armstrongii* is common throughout the Darwin Coastal Bioregion. Provisional Vegetation Clearing, Earthworks and Rehabilitation Management Plan.	F (B1)	6	Low

Table 8-6: Summary of impact assessment and residual risk for vegetation-clearing (continued)

Aspect	Activity	Potential impacts	Management controls, mitigating factors	Residual risk*		
				C†	L‡	RR§
Vegetation	Clearing of vegetation during site preparation.	Loss of monsoon vine forest habitat. Localised reduction in biodiversity.	The vegetation-clearing footprint for the onshore development area will be minimised during the design of the onshore facilities, subject to design, construction and safety requirements. Contain all disturbance (including vehicle movement) within the development footprint. Store topsoil from cleared areas in stockpiles for future use in rehabilitation. Cleared vegetation will be mulched and stockpiled on site boundaries or off site. Where possible, the mulch will be used for both rehabilitation and soil stabilisation to prevent erosion. Cleared vegetation that cannot be reused will be disposed of off site. No stockpiled vegetation will be burned. Other monsoon vine forest habitats exist within the region. Provisional Vegetation Clearing, Earthworks and Rehabilitation Management Plan.	E (B3)	6	Medium

* See Chapter 6 *Risk assessment methodology* for an explanation of the residual risk categories, codes, etc.

† C = consequence.

‡ L = likelihood.

§ RR = risk rating.

8.3.2 Alteration of habitat

Removal of vegetation in the onshore development area will result in some habitat loss and also potential habitat fragmentation for animal species in the area. "Edge effects" of the onshore development area on the remaining vegetation communities around Blaydin Point and Middle Arm Peninsula are also likely to have an impact on the integrity of fauna habitats throughout the life of the Project. Such edge effects could include the spread of weeds into natural vegetation from roadsides, the alteration of microclimatic conditions (such as greater sunlight intensity or exposure to wind) and a reduction in plant health (such as through smothering by dust).

As described in Section 8.3.1 *Vegetation-clearing*, removal of the monsoon vine forest from Blaydin Point is likely to be the most significant alteration of habitat at the onshore development area as this plant community provides food resources to specialised frugivorous birds. However, monsoon vine forest occurs in other areas around Darwin Harbour (see Figure 8-1) and throughout the Darwin Coastal Bioregion, and removal of this habitat does not represent a critical loss at a regional scale (GHD 2009).

The *Eucalyptus* woodland habitat contained the highest species richness for animals during surveys of the onshore development area (GHD 2009; see Appendix 16). However, this woodland occurs in large areas elsewhere on Middle Arm Peninsula and throughout the Darwin region and clearing at Blaydin Point will not represent a major reduction in availability of this habitat type.

The construction phase of the Project presents the greatest risks of injury and death to local animal life, as a result of the clearing of vegetation by heavy machinery in the onshore development area. Increased vehicle movements throughout Middle Arm Peninsula may have an impact on animals from accidental collisions. The excavation of trenches during the construction phase (e.g. at the pipeline shore crossing) will also pose an entrapment risk to some species.

Other potential edge effects that may impact on local wildlife include the invasion of new weeds and pest animals into the habitats surrounding the onshore development area. These risks and the proposed management controls are discussed in Section 8.3.4 *Introduced species*.

Domestic waste will need to be managed to avoid attracting scavengers such as rodents, seagulls, raptors and reptiles to the onshore development area. Ingestion of food scraps and other putrescible waste could have a negative effect on the health of these animals while the attraction of animals to buildings or waste facilities could increase the risk of collisions with the traffic and machinery used in these areas.

Significant animal species

The removal of habitat at the onshore development area may affect individuals of listed threatened species, and some animals may be injured or killed as a result of construction activities. However, this will not affect the survival of the species overall. The onshore development area contains suitable habitat for some threatened species, such as the northern quoll and the floodplain monitor, but these animals are found throughout the Darwin Harbour region. Most animals present at the start of land-clearing activities should be able to move to adjoining habitat on Middle Arm Peninsula or elsewhere in the vicinity.

Management of alteration of habitat

Objectives, targets, management controls and monitoring to protect animals and habitat have been incorporated into the Provisional Vegetation Clearing, Earthworks and Rehabilitation Management Plan (attached as Annexe 15 to Chapter 11).

The management controls to avoid disturbance to vegetation (see Section 8.3.1) also apply to the protection of habitat, in addition to the following prescriptions:

- Major clearing activities will be undertaken in a manner that maximises the opportunities for animal life to move into remaining vegetation in the vicinity.
- "High-risk" entrapment areas (e.g. deep trenches or pits) will be constructed with sloping egress ramps to prevent animals from being trapped. Targeted inspections will be undertaken of these areas and any trapped animals will be removed and released.

The Provisional Waste Management Plan developed for the Project (attached as Annexe 16 to Chapter 11) contains procedures for containing and storing domestic waste at the onshore development area to prevent access by animals. Waste will be transported off site for disposal at a licensed landfill facility.

Residual risk

A summary of the potential impacts, management controls and residual risk for alteration of habitat is presented in Table 8-7. After the implementation of controls and with consideration of mitigating factors, the impacts for alteration of habitat are considered to present a "medium" or "low" risk and are likely to affect animal populations on only a localised and minor scale.

Table 8-7: Summary of impact assessment and residual risk for alteration of habitat

Aspect	Activity	Potential impacts	Management controls, mitigating factors	Residual risk*		
				C†	L‡	RR§
Habitat	Clearing of vegetation for site preparation.	Loss of habitat for terrestrial fauna.	Major clearing activities undertaken to allow animals to move into the remaining vegetation in the vicinity. Habitat to be cleared is well represented elsewhere on Middle Arm Peninsula, and in the region. No significant animal species recorded in recent surveys of the onshore development area. Provisional Vegetation Clearing, Earthworks and Rehabilitation Management Plan.	E (B3)	6	Medium
Animals	Temporary creation of trenches and excavations during construction.	Entrapment of animals, with possibility of injuries or deaths.	"High-risk" entrapment areas (e.g. deep trenches or pits) will have sloping egress ramps. Targeted inspections will be undertaken and any trapped animals will be removed and released. Provisional Vegetation Clearing, Earthworks and Rehabilitation Management Plan.	F (B3)	3	Low

* See Chapter 6 *Risk assessment methodology* for an explanation of the residual risk categories, codes, etc.

† C = consequence.

‡ L = likelihood.

§ RR = risk rating.

8.3.3 Biting insects

There are two main aspects associated with biting insects at the onshore development area:

- New habitat and breeding sites may be created for biting insects.
- Biting insects may affect the health of workers or members of the public.

These impacts were considered in an assessment of the biting insects of the onshore development area carried out by the Northern Territory's Centre for Disease Control (Medical Entomology Section 2009); the findings of the assessment are summarised below. (The full report is provided in Appendix 21 to this Draft EIS.)

Creation of habitat for biting insects

Biting-insect habitat is associated with pooling surface water that allows for breeding (depths as shallow as 20 mm are sufficient) and exposed soil or vegetation substrates. If not carefully managed, disturbance to intertidal areas at the onshore development area is highly likely to create new breeding sites for mosquitoes such as *Aedes vigilax*, *Culex sitiens* and *Anopheles hilli* and members of the *Anopheles farauti* complex. This may include direct disturbance by vehicles and machinery, blockage of tidal flows by roads and other embankments, erosion from stormwater flows or the creation of mud waves by filling activities (Medical Entomology Section 2009).

Construction of the product loading jetty, the module offloading facility, the ground flare and the pipeline shore crossing will result in some disturbance to the intertidal mangrove zone. Land reclamation may also be required for the development of these areas (e.g. the ground flare, depending on final design), where the low-lying tidal flats would be built up by several metres of fill material. This would create an "island" within the mangrove zone around which tidal movements would be altered and ponding could occur.

During construction, sedimentation ponds will be established around the onshore development area to capture silty or potentially contaminated surface-water runoff from the plant site. Stormwater drains that discharge into tidal areas have the potential to create mosquito breeding sites by allowing tidewater and rainwater to collect in ponds. Borrow pits on Middle Arm Peninsula will be extended, or new pits created, to supply fill for construction activities. These pits will fill with water during wet-season rains and will likely support grassy vegetation on the exposed soils.

Artificial receptacles such as used tyres, drums, disused machinery and any rubbish items that can collect rainwater are potential mosquito breeding sites. Equipment and machinery imported from overseas or North Queensland has the potential to harbour the drought-resistant eggs of the dengue-carrying mosquito *Aedes aegypti.* This may include building material, plastic packaging, machinery and tyres or any other item capable of capturing even small amounts of water at any stage.

Prime breeding sites for mangrove biting midges (*Culicoides ornatus*) occur in the upper tidal tributaries of mangrove creeks, associated with pneumatophores of the mangrove species *Avicennia marina* (Medical Entomology Section 2009). These environments exist to the west and south-east of Blaydin Point, and also near the pipeline shore crossing. Project activities are not likely to increase the availability of biting-midge habitat and in fact there may be a minor reduction in the extent of this habitat because of mangrove clearing for the pipeline shore crossing and ground flare.

Health risks

The mangrove areas surrounding Blaydin Point are expected to be substantial seasonal sources of the mangrove biting midge, the most significant pest biting midge in coastal areas of northern Australia. While biting midges are not a disease transmission risk, their painful bites can be a major nuisance and can cause intense itching. Through scratching the bites, susceptible or allergic individuals will develop skin lesions, secondary infections and scarring. Biting-midge infestations can be expected at the onshore development area from May to November, particularly around full and new moons, with peak biting times in the hour before and the hour after both sunset and sunrise (Medical Entomology Section 2009).

There is potential for mosquito-borne disease transmission to workers at the onshore development area or to members of the public in the vicinity. Mosquitoes such as *Aedes vigilax* pose a low to moderate risk of Ross River virus and Barmah Forest virus transmission during the months from September to January, with December and January the highest-risk months because of increased mosquito longevity. This species is likely to breed in poorly draining upper tidal areas surrounding Blaydin Point (Medical Entomology Section 2009).

Culex annulirostris, *Culex sitiens* and *Verrallina funerea* will pose a minor risk of Ross River virus transmission, while *C. annulirostris* will also pose a minor risk of Barmah Forest virus, Murray Valley encephalitis virus and Kunjin virus transmission.

Management of biting insects

Management controls to avoid the creation of biting-insect habitats at the onshore development area are incorporated into the Provisional Liquid Discharges, Surface Water Runoff and Drainage Management Plan (attached as Annexe 10 to Chapter 11). This plan will guide the development of more detailed plans during the Project's construction and operations phases and includes the following strategies:

- Natural drainage will be maintained around roads by installing drains and culverts, particularly in intertidal areas (such as the causeway between Blaydin Point and Middle Arm Peninsula).
- Surface-water drainage channels throughout the onshore development area will be designed to minimise the creation of habitat for biting insects. Drains will be kept free of vegetation.
- Temporary sedimentation ponds used during construction will be designed to minimise the potential for providing biting-insect breeding habitat.
- Regular inspections will be carried out for mosquito larvae in high-risk areas and controls will be implemented as required.

Waste will be regularly removed from site for disposal at an off-site landfill, in accordance with the prescriptions of the Provisional Waste Management Plan (attached as Annexe 16 to Chapter 11).

The pest risks posed by imported equipment and machinery at the onshore development area will be managed according to the Provisional Quarantine Management Plan (attached as Annexe 13 to Chapter 11). All items of machinery will be thoroughly cleaned prior to their arrival at the onshore development area.

Protection of workers from biting insects will be achieved by implementing health and safety measures such as wearing protective clothing and using insect repellent.

Insecticide spraying for mosquito larvae may be undertaken at the onshore development area. Insecticides will be selected for their environmental acceptability.

Residual risk

As biting midges and mosquitoes exist in relatively high abundance naturally in and around the onshore development area, the normal process of risk assessment (whereby the specific impacts of the Project are identified) is not considered applicable in this case. The management controls described above will be implemented to mitigate the risks of providing new biting-insect breeding areas, but during operations it would be virtually impossible to quantify the contribution of the Project to biting-insect populations in the area.

8.3.4 Introduced species

The increased vehicle traffic and ground disturbance at Blaydin Point and throughout Middle Arm Peninsula as a result of Project activities leads to the risk of introduction of new invasive plant and animal species, or to the spread of weeds and pests that already occur in localised areas. Introduced species of concern to the area are described below, along with the proposed management controls.

Weeds

A weed is defined as any non-native plant species whose presence is due to intentional or accidental introduction and which is deemed to have the potential to become an invasive species. Weeds threaten the survival of native plants and animals if they out-compete native species for nutrients, habitat and sunlight. Once established, weed species often produce a large quantity of seed that may remain dormant but viable for long periods of time. In addition, some weed species may be capable of propagating in more than one way, which means they can reproduce rapidly and grow to occupy large areas.

As described in Chapter 3, 12 weed species were recorded in surveys of the onshore development area. Areas where weed infestations already exist are mainly associated with previous disturbance, for example around old borrow pits and access tracks through the bushland. While these weeds are already established in some areas of Blaydin Point and Middle Arm Peninsula, the construction of new roads and cleared areas and the frequent vehicle movements associated with the Project may allow them to spread further into areas of natural vegetation that are currently weed-free. Topsoil from these areas would also contain a persistent weed seed bank, reducing the value of the topsoil for rehabilitation activities.

Four of the weeds at the onshore development area are listed as Schedule Class B/C weeds under the *Weeds Management Act 2001* (NT). These are mission grass (*Pennisetum polystachion*), hyptis (*Hyptis suaveolens*), gamba grass (*Andropogon gayanus*) and lantana (*Lantana camara*). This classification obliges landholders to make "reasonable attempts" to contain the growth and prevent the spread of these species.

During the operations phase of the Project, traffic on the access road from Wickham Point Road to the onshore development area is likely to be the main vector for weed invasion. Roads are common sites of weed introduction and spread, as the surrounding soils are disturbed and weed seeds or plant material can be transported on vehicles and machinery.

It is also noted that Wickham Point Road and many parts of Middle Arm Peninsula are accessible to the general public. Private vehicles travelling through the area also pose a risk of spreading weed material along roadsides and tracks, but management of this risk is outside INPEX's control during the construction and operations phases of the Project.

Pest animals

While some introduced animal species can exist in new habitats without detriment to the existing environment, others can become established as invasive pests and have a deleterious effect on native species through competition for food and habitat and by predation. Some pest animals predate heavily on native species while others can cause changes in habitat through selective grazing of favoured plant species or degradation of land by uprooting plants and burrowing.

Pest animal species that already occur at the onshore development area include the cane toad (*Bufo marinus*), the black rat (*Rattus rattus*) and the feral pig (*Sus scrofa*). Cane toads in particular are widespread throughout the Darwin region and impact heavily on native reptile and mammal populations. No satisfactory broad-scale control methods are currently available for the toad (GHD 2009).

New pest animal species could be introduced to Blaydin Point and Middle Arm Peninsula as a result of increased vehicle and equipment movements associated with the Project, particularly where cargo arrives from overseas vessels at the module offloading facility at Blaydin Point.

Management of introduced species

Weed and pest management objectives, targets, management controls and monitoring procedures are incorporated into the Provisional Quarantine Management Plan and the Provisional Vegetation Clearing, Earthworks and Rehabilitation Management Plan (annexes 13 and 15 to Chapter 11). These plans will guide the development of more detailed plans during the construction and operations phases. The key management controls proposed are as follows:

- Machinery used for earth-moving and vegetation-clearing will be cleaned and inspected prior to the commencement of work at the onshore development area to identify any attached material that needs to be removed for quarantine reasons.
- A temporary washdown area for earth-moving and vegetation-clearing vehicles will be constructed for the construction phase.
- Infestations of listed weed species (namely mission grass, hyptis, gamba grass and lantana) in the onshore development area and along the access road from Wickham Point Road will be controlled by spraying or removal by hand, in accordance with the requirements of the *Weeds Management Act*.
- Topsoil containing high densities of weed seeds will not be used in rehabilitation.
- A weed monitoring program will be developed and will be implemented throughout the Project.
- Temporary, dedicated quarantine-approved premises (QAP) will be established on Blaydin Point during the construction phase. Vessels, equipment and modules entering from another country will be inspected here for quarantine material. The design of the QAP and the inspection procedures to be implemented will be carried out in accordance with Australian Quarantine and Inspection Service (AQIS) standards.
- Putrescible waste will be stored in covered containers on site to limit access by scavenger animals, and will be transported off site for disposal.

Residual risk

A summary of the potential impacts, management controls and residual risk for introduced species is presented in Table 8-8. After the implementation of controls, the risks of impacts from introduced species are considered to be as low as reasonably practicable and are assigned a rating of "medium" residual risk.

Table 8-8: Summary of impact assessment and residual risk for introduced species

Aspect	Activity	Potential impacts	Management controls, mitigating factors	Residual risk*		
				C†	L‡	RR§
Weeds	Machinery for earthmoving and clearing of vegetation entering the onshore development area from elsewhere in the Northern Territory or Australia.	Accidental introduction of new weed species to Blaydin Point and Middle Arm Peninsula, displacing native species and altering ecosystem function.	Control infestations of listed weeds in the onshore development area and access road. Hygiene procedures will be applied to earthmoving and vegetation-clearing equipment. Weed monitoring. Provisional Vegetation Clearing, Earthworks and Rehabilitation Management Plan.	D (B3)	3	Medium
Pest animals	Vehicles and equipment entering the onshore development area from elsewhere in the Northern Territory and Australia (overland).	Accidental introduction of new pest animal species to Blaydin Point and Middle Arm Peninsula, displacing native species and altering ecosystem function.	Inspect earthmoving and clearing vehicles etc. prior to their arrival at the onshore development area. Covering and storage of putrescible waste, with off-site disposal. Provisional Quarantine Management Plan.	D (B3)	2	Medium
Pest animals	Vessels and equipment entering from another country (overseas).	Accidental introduction of new pest animal species to Blaydin Point and Middle Arm Peninsula, displacing native species and altering ecosystem function.	Establish quarantine-approved premises during construction, according to AQIS requirements. Inspect incoming vessels, modules and equipment for quarantinable material. Provisional Quarantine Management Plan.	D (B3)	2	Medium

* See Chapter 6 *Risk assessment methodology* for an explanation of the residual risk categories, codes, etc.

† C = consequence.

‡ L = likelihood.

§ RR = risk rating.

8.3.5 Changes to fire regime

Fires initiated at the onshore development area could spread into vegetated areas around Blaydin Point and Middle Arm Peninsula. This poses a risk of damage to local vegetated areas as well as to infrastructure in the area and is a safety risk to INPEX's workforce and the general public.

The risk of fire ignition in the onshore development area mainly applies to the beginning of the construction phase when vegetation-clearing is taking place. After the site has been cleared, there will be little combustible material remaining and a much lower risk of fire, despite the presence of ignition sources such as welding and cutting equipment. Likewise, fire risks will be low during the operations phase of the Project because of the large areas of cleared and sealed surfaces, and the availability of firefighting equipment.

Pre-development ecological surveys of the onshore development area (GHD 2009) were conducted 12 to 18 months after bushfires at Blaydin Point and recorded reasonable numbers of birds and reptiles; this indicates that the fires had not rendered the area uninhabitable for these animals. However, no pre-fire data were available against which to compare this survey information. Mammal populations may have been more heavily impacted as few small mammals were recorded in the field surveys (GHD 2009).

Management of fire

A Provisional Bushfire Prevention Management Plan has been compiled for the Project and is included in Chapter 11 as Annexe 3. This will guide the development of more detailed plans during the construction and operations phases. The plan contains objectives and targets, as well as details of management controls and provisions, monitoring programs and relevant training for personnel.

Key management controls included in the plan are as follows:

- Control of grassy vegetation (described in Section 8.3.4) provides the main opportunity to limit fuel loads in the vegetation around the onshore development area. Methods are likely to include slashing or spraying. Fuel-reduction burning will not be utilised.
- Firebreaks will be established around Project infrastructure that borders woodlands. Advice will be sought from the Northern Territory's Bushfires Council on firebreak requirements for Blaydin Point.
- Mulched vegetation from clearing operations which is stored on site will be stockpiled in designated areas away from potential ignition sources.
- Stockpiled vegetation from clearing activities will not be burned, but will be reused where possible or disposed of off site.
- Firefighting equipment will be available on site at all times, along with accessible supplies of water.
- Firefighting capability will be available and strategically located firefighting stations will be established at the onshore development area.
- A "hot-work" permit system will be established for all hot-work activities, such as welding and grinding.
- Safe designated smoking areas will be established and receptacles for cigarette butts will be provided during all phases of the Project.

Residual risk

A summary of the potential impacts, management controls and residual risk for fire is presented in Table 8-9. After the implementation of controls, the risks of fire are rated "medium" or "low" and it is considered that they are as low as reasonably practicable.

Table 8-9: Summary of impact assessment and residual risk for fire

Aspect	Activity	Potential impacts	Management controls, mitigating factors	Residual risk*		
				C†	L‡	RR§
Fire	Vegetation clearing during site preparation (early construction phase).	Bushfire in vegetated areas throughout Blaydin Point and Middle Arm Peninsula. Damage to vegetation, habitat and infrastructure, and risks to public safety.	Emergency response equipment and procedures. Mulched vegetation stored on site from clearing operations will be stockpiled in designated areas, away from potential ignition sources. Stockpiled vegetation from clearing activities will not be burned, but will be reused where possible or disposed of off site. Establish firebreaks around Project infrastructure that borders woodlands, taking advice from the Northern Territory's Bushfires Council. Provisional Bushfire Prevention Management Plan.	E (B3)	4	Medium
Fire	Operating heavy machinery, undertaking "hot work" and operating the ground flare in the vicinity of vegetated areas, during construction and operations.	Bushfire in vegetated areas throughout Blaydin Point and Middle Arm Peninsula. Damage to vegetation, habitat, infrastructure and risks to public safety.	Control fuel load in grassed and vegetated areas to minimise risk of intense bushfires through weed control. Emergency response equipment and procedures. Establish firebreaks around Project infrastructure that borders woodlands, according to advice from the Northern Territory's Bushfires Council. Provisional Bushfire Prevention Management Plan.	E (B3)	2	Low

* See Chapter 6 *Risk assessment methodology* for an explanation of the residual risk categories, codes, etc.

† C = consequence.

‡ L = likelihood.

§ RR = risk rating.

8.4 Air emissions

Air emissions from the construction, commissioning and operation of the onshore development area will contribute to the Darwin regional airshed, and the potential impacts of these emissions are described in this section. The airshed in the offshore development area is remote from land and settlements, and the pollutants contained in these emissions will not impact on sensitive human, animal or plant receptors. These emissions are therefore not included in the air-quality assessment in this section. Greenhouse gases produced by the Project, and the management strategies proposed for these, are described in Chapter 9 *Greenhouse gas management*.

8.4.1 Construction phase

The key emission of potential concern during the construction phase at the onshore development area is dust (discussed in detail below). Other atmospheric emissions during the construction phase will be associated with maritime vessel engines, with additional airline flights and with the vehicles and equipment required to support the construction crew at the onshore development area. However, the volume and duration of the emissions during construction will not be significant in comparison with emission levels during the operations phase. Furthermore, construction emissions will not be concentrated in a single location for any extended period of time. Air-dispersion modelling has therefore not been undertaken for the relatively short-term construction phase (SKM 2009).

8.4.2 Dust

Fugitive dust is the air emission of potential concern during the construction phase at the onshore development area. Generation of dust can result from the following:

- the clearing of vegetation and site preparation
- earthworks (e.g. site levelling and excavation)
- drilling and blasting activities
- cut-and-fill activities
- wind erosion of stockpiled materials
- vehicle movements on unsealed roads
- loading and transport of loose soil, aggregate and/or other dust-generating material
- the operation of a crushing and screening plant
- the operation of a concrete batching plant.

The volume and duration of the dust emissions generated during construction are expected to be variable and intermittent. The emissions are unlikely to be concentrated in a single location for any extended period of time. Overall, however, the construction phase is of relatively long duration and extends over a large area. The soils at Blaydin Point are also prone to dust generation, as described in Section 8.2.1 *Soil erosion*.

Dust emissions have the potential to decrease vegetation growth by smothering leaves and blocking stomata. Loss of vegetation may in turn impact adversely on animals. The impacts of dust on vegetation around Blaydin Point are likely to be limited to dry-season conditions—rainfall during the wet season would remove dust from leaf surfaces.

Particulate matter in dust may also impact upon the health and safety of workers in the onshore development area and will therefore be reduced wherever possible within the site. Details on the adverse health effects related to dust (referred to as "particulates") are provided in Section 8.4.3 *Operations phase*.

Management of dust

A Provisional Dust Management Plan has been compiled for the Project and is included in Chapter 11 as Annexe 7. This plan will guide the development of more detailed plans during the construction and operations phases. Its key objective is the minimisation of the generation of dust through the implementation of the following controls:

- Roads required for the operations phase will be sealed as soon as practicable after clearing in order to minimise dust emissions from vehicle movements.
- Dust suppression techniques will be applied where necessary to protect worker health, vegetation health, and amenity. This may include spraying from water trucks, irrigation, or stabilisation and revegetation of cleared areas that are no longer needed as soon as practicable during construction.
- Multiple handling of soil or rock materials will be minimised.
- Loads in all trucks transporting soil, aggregate or other dust-generating materials to and from the onshore development area will be sprayed with water to suppress dust.
- Monitoring of dust generation and the effectiveness of management controls will be regularly undertaken.

Residual risk

A summary of the potential impacts, management controls and residual risk for dust is presented in Table 8-10. After the implementation of controls and with consideration of mitigating factors, the impacts from dust are considered to present a "low" risk and are likely to affect the surrounding environment on a very localised and short-term scale.

Table 8-10: Summary of impact assessment and residual risk for dust

Aspect	Activity	Potential impacts	Management controls, mitigating factors	Residual risk*		
				C†	L‡	RR§
Dust	Earthworks and vehicle movements at onshore development area during the construction phase.	Nuisance and health impacts (of PM_{10}) on the nearby community.	Residential and urban areas are located distant from the onshore development area. Prevailing winds during the dry season are mainly easterly, blowing dust away from Palmerston. Provisional Dust Management Plan.	F (E3)	2	Low
Dust	Earthworks and vehicle movements at onshore development area during the construction phase.	Dust deposition on surrounding vegetation, smothering it and reducing growth. Health impacts on the workforce.	Dust-control measures, including wetting down exposed surfaces. Roads required for the operations phase to be sealed during construction. Provisional Dust Management Plan.	F (B3)	3	Low

* See Chapter 6 *Risk assessment methodology* for an explanation of the residual risk categories, codes, etc.

† C = consequence.

‡ L = likelihood.

§ RR = risk rating.

8.4.3 Operations phase

To assess the likely impacts on regional air quality of operational emissions from the onshore development area, including their effects on human health and environmental values, air-emissions modelling was undertaken by Sinclair Knight Merz Pty Limited (SKM). This air-quality modelling utilised a three-dimensional computer-based modelling program ("The Air Pollution Model" (TAPM), developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO)), which accounts for dispersion processes such as convection, sea breezes and terrain-induced flows, and can be used to predict photochemical processes.

An assessment of the existing ambient air quality in the Darwin airshed was undertaken prior to consideration of the additional emissions from the Ichthys Project. Existing emissions sources in the Darwin region include the Darwin LNG plant, the Channel Island Power Station, shipping and vehicle emissions, and biogenic emissions from vegetation and soil. Accounting for these various sources in the air-quality model therefore provides a cumulative assessment of the Project's impacts on the Darwin airshed. The technical report produced for this study (SKM 2009) is provided in Appendix 19 to this Draft EIS.

Most of the air emissions during the operations phase of the Project at Blaydin Point will originate from the combustion of fuel gas in the process and power generation plant gas turbines. The key emissions from natural-gas processing include:

- oxides of nitrogen (NO_x, measured as NO_2)
- secondary emissions of ozone (O_3) (produced in the atmosphere from the reaction of NO_2 and volatile organic compounds (VOCs) with sunlight)
- non-combusted hydrocarbons or VOCs
- oxides of sulfur (SO_x measured as SO_2)
- hydrogen sulfide (H_2S)
- carbon dioxide (CO_2)
- particulate matter as PM_{10}[2].

The air-quality criteria applicable to assessing the effects of air emissions on human health and the environment are drawn from the National Environment Protection (Ambient Air Quality) Measure (NEPC 2003). This NEPM was created to provide planning benchmarks to ensure that people throughout Australia have protection from the adverse health effects of air pollution. The standards were developed after analysis of the most up-to-date research from around the world and took into account all available information on the state of Australia's major airsheds. Of the list above, the highest-risk NEPM "criteria air pollutants" that warrant examination in this assessment are NO_2, SO_2, O_3 and particulate matter (as PM_{10}) (SKM 2009).

The CO_2 emissions from the onshore development area are not expected to have any localised impacts on air quality or climate. However, it is acknowledged that CO_2 and other greenhouse gas emissions contribute to climate change on a global scale and require management. Details of INPEX's greenhouse gas management strategies are provided in Chapter 9.

2 Particulate matter smaller than 10 micrometres (10 μm) in diameter.

Benzene, toluene, ethylbenzene and xylenes (collectively known as BTEX) are among the VOCs that typically exist in relatively low concentrations in ambient air and represent a fraction of the compounds emitted from the combustion of fossil fuels. Of the VOCs, benzene is typically considered the highest potential risk.

The most potentially significant source of VOC emissions from Blaydin Point would be from regenerating the aMDEA solvent used to remove CO_2 from the natural gas in the acid gas removal units (AGRUs) (one ahead of each LNG train). Many gas plants around the world "cold vent" the CO_2 stream from their AGRU solvent regenerators directly to atmosphere, even although it contains a small amount of VOCs, including BTEX. However, in order to minimise VOC and BTEX emissions from the Blaydin Point site, INPEX will incinerate the aMDEA regeneration streams from both LNG trains to ensure that almost no BTEX will be emitted. The incinerators will be designed to operate successfully up to 364 days per year. In the event of an incinerator shutdown or scheduled maintenance, a bypass line will route the aMDEA vent stream to atmosphere through a tall and hot gas turbine exhaust stack. This will ensure effective dispersion of VOCs and BTEX to below NEPM monitoring investigation levels until such time as the incinerator is brought back on line.

The design basis for emissions modelling for the onshore processing plant included two gas-processing trains, each with a production capacity of 4.2 Mt/a and each equipped with the following:

- electrical power supplied by gas turbine generators equipped with dry low-NO_x burners
- process refrigeration powered by gas turbine generators with dry low-NO_x burners
- an acid gas removal unit (AGRU) incinerator
- a hot-oil furnace
- emergency flares.

Air emissions from the onshore development area are likely to change under different operating conditions, such as during emergencies or plant maintenance. Flaring is likely to be increased during upset conditions. For the purposes of this assessment, three scenarios have been modelled:

- normal operating conditions
- "upset conditions (1)" where flaring emissions are increased for up to 15 minutes (representing the worst credible case) as a result of a blocked mixed refrigerant compressor outlet. During this time, the mixed refrigerant compressor turbine would be non-operational, causing flaring of mixed refrigerant, while all other plant emissions would continue as normal
- "upset conditions (2)" where flaring emissions are increased for up to 10 hours as a result of depressurising of the propane compressor circuit. During this event, all equipment on one gas-processing train would be shut down and propane would be flared while the other train would continue to operate normally.

Oxides of nitrogen (NO_x)

Oxides of nitrogen (NO_x) is the collective term for nitrogen monoxide (NO) and nitrogen dioxide (NO_2). Nitrogen dioxide (NO_2) is an acidic, corrosive gas that can affect human health by increasing susceptibility to asthma and respiratory infections. Vegetation is adversely affected by exposure to NO_2, in the form of retarded growth rates and crop yields if exposed to very high concentrations. NO and NO_2 are also contributors to ground-level ozone production.

During routine operations at the onshore development area, the maximum cumulative concentrations of NO_2 are predicted to occur to the south-east and north-west of both the Darwin LNG plant and the INPEX onshore development area, as shown in Figure 8-2. Maximum 1-hour NO_2 concentrations on the grid are predicted to be 0.04 ppm, which equates to 34% of the NEPM criterion (see Appendix 19). It is noted that Figure 8-2 presents the highest NO_2 concentrations expected over a 1-hour averaging period—this is the "worst-case scenario", and consideration of longer averaging periods (e.g. 24 hours or one year) results in lower average concentrations of air pollutants. Ground-level concentrations of NO_2 expected in Darwin's central business district (CBD) and Palmerston are provided in Table 8-11.

The NO_2 emissions that could occur during upset conditions are equivalent to or lower than those from normal operations. During "upset conditions (1)" the 15 minutes of flaring do not contribute sufficient extra NO_2 to influence the plant emissions on a regional scale, and during "upset conditions (2)" only one LNG train is operational, reducing emissions from the plant overall (SKM 2009). These NO_2 levels are well below those at which impacts could be expected on human or environmental health in the Darwin region.

Table 8-11: Modelled NO_2 emissions in the Darwin CBD and Palmerston during operations

	Averaging period	Ground level NO_2 concentration (ppm)			
		Routine operations	Upset conditions (1)	Upset conditions (2)	NEPM criteria
Darwin CBD	1 hour	0.0350	0.0350	0.0250	0.1200
	Annual	0.0015	n.a.	n.a.	0.0300
Palmerston	1 hour	0.0250	0.0250	0.0200	0.1200
	Annual	0.0020	n.a.	n.a.	0.0300

n.a. = not applicable.

Source: SKM 2009.

Sulfur dioxide

Sulfur dioxide (SO_2) is a colourless gas with an irritating odour that can contribute to or exacerbate respiratory illnesses such as asthma or bronchitis, especially in elderly or young people. It can also have detrimental effects on the environment through its contribution to the formation of acid rain.

Emissions from the onshore development area result in an increase in maximum ground-level concentrations of SO_2 at the onshore development area, East Arm Wharf and the Darwin CBD as shown in Figure 8-3. The maximum ground-level concentration over a 1-hour averaging period is predicted to be 0.023 ppm, which is 11.5% of the NEPM criterion (SKM 2009). It is noted that air pollutant concentrations measured over a 1-hour averaging period represent the worst-case scenario, and consideration of longer averaging periods (e.g. 24 hours, or one year) results in lower average concentrations of air pollutants. Ground-level concentrations of SO_2 expected in the Darwin CBD and Palmerston over different averaging periods are provided in Table 8-12.

As with NO_2, the SO_2 emissions that could occur during upset conditions are equivalent to or lower than those from normal operations. During "upset conditions (1)" the 15 minutes of flaring do not contribute sufficient extra SO_2 to influence the plant emissions on a regional scale, and during "upset conditions (2)" only one LNG train is operational, reducing emissions from the plant overall (SKM 2009). These SO_2 levels are well below those at which impacts could be expected on human or environmental health in the Darwin region.

Dry deposition of oxides of nitrogen and sulfur

Impacts on vegetation can be caused by acid deposition ("acid rain") when SO_2 and NO_x react with water, oxygen and other oxidants in the atmosphere to form acidic compounds. These acid compounds precipitate in rain or in dry form as gases and particles. The SO_2 and NO_2 gases and their particulate matter derivatives (sulfate and nitrate aerosols) may contribute to air-quality impacts by the acidification of lakes and streams, damage to forest ecosystems and acceleration of the decay of building materials (SKM 2009).

Table 8-12: Modelled SO_2 emissions in Darwin CBD and Palmerston during operations

	Averaging period	Ground-level SO_2 concentration (ppm)			
		Routine operations	Upset conditions (1)	Upset conditions (2)	NEPM criteria
Darwin CBD	1 hour	0.0150	0.0150	0.0100	0.2000
	24 hour	0.0020	n.a.	n.a.	0.0800
	Annual	<0.0004	n.a.	n.a.	0.0200
Palmerston	1 hour	0.0100	0.0100	0.0050	0.2000
	24 hour	0.0020	n.a.	n.a.	0.0800
	Annual	<0.0004	n.a.	n.a.	0.0200

n.a. = not applicable.

Source: SKM 2009.

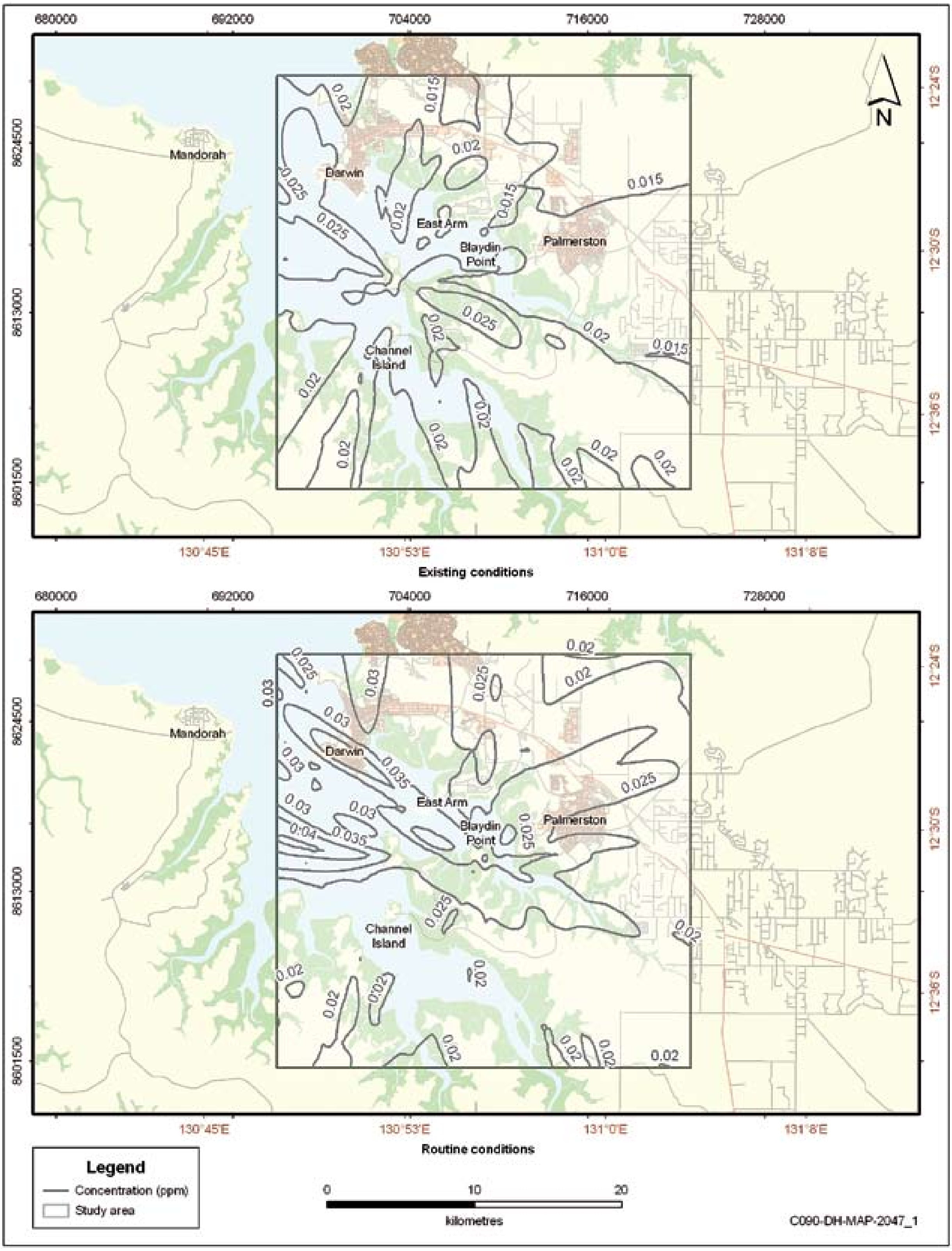


Figure 8-2: Maximum 1-hour ground-level NO_2 concentrations (ppm) during existing conditions and during routine Project operations

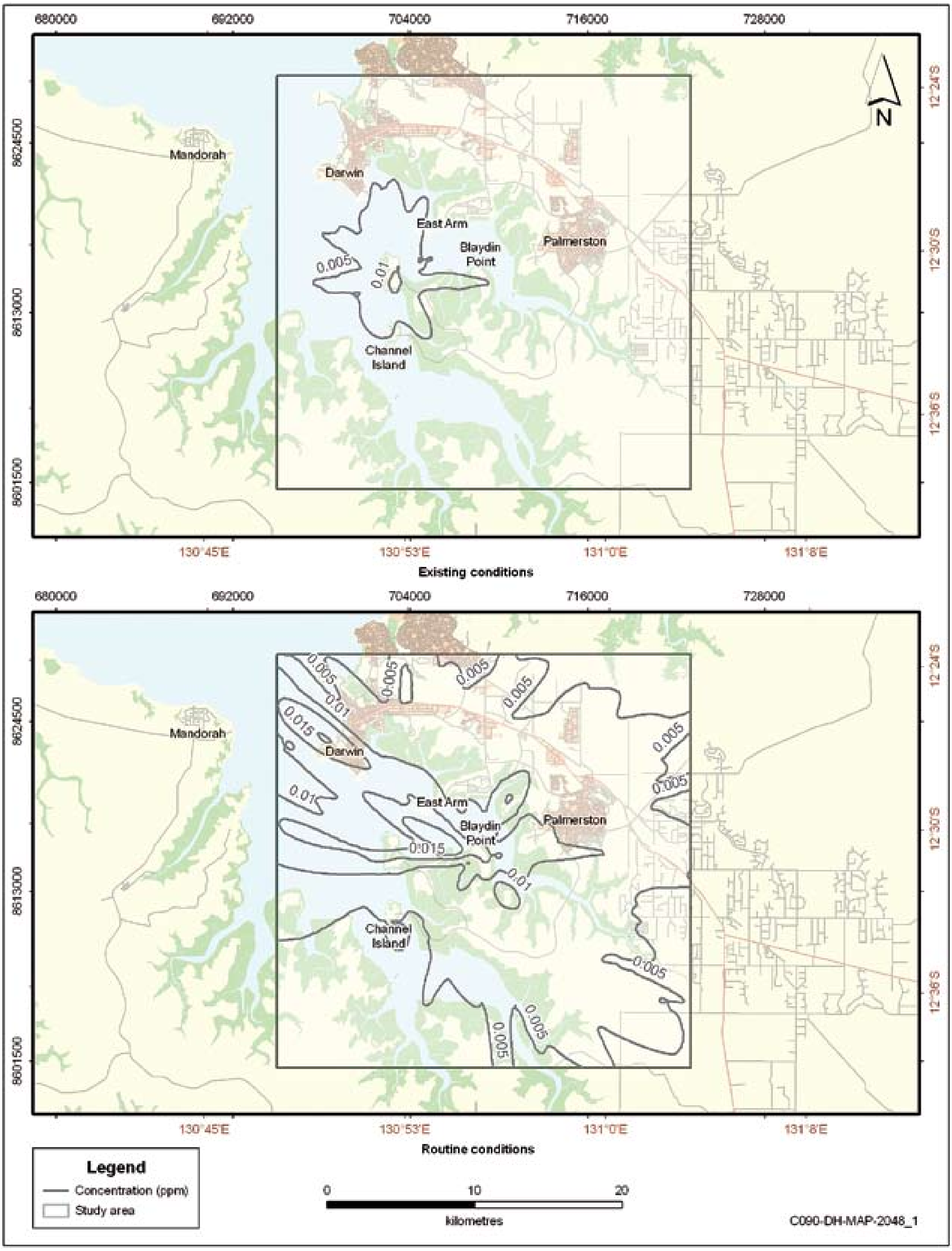


Figure 8-3: Maximum 1-hour ground-level SO_2 concentrations (ppm) during existing conditions and during routine Project operations

Modelling of acid deposition in the Darwin region, incorporating all emissions from existing sources as well as the proposed onshore processing plant, suggests that "typical high" SO_2 and NO_2 deposition levels would be 4 kg/ha·a^{-1} and 6 kg/ha·a^{-1} respectively (SKM 2009).

The World Health Organization (WHO) provides criteria for deposition of nitrogen- and sulfur-based acids below which, to the best present knowledge, significant harmful effects on specified sensitive elements of the environment do not occur. There is very little previous research on the effects of acid deposition in Australian communities or ecosystems. The modelled levels of deposition in the Darwin region as a result of the Project and other sources are well under the standards of 8–16 kg/ha·a^{-1} (SO_2) and 49–66 kg/ha·a^{-1} (NO_2) set by the WHO (2000) as noted by SKM (2009). These levels are unlikely to cause negative effects to vegetation in the region and are highly unlikely to damage buildings and structures.

Ozone

Ozone (O_3) is present in photochemical smog—it forms in the atmosphere by the reaction of NO_2 and VOCs in sunlight and at high temperatures to form a layer of visible, brown or white haze in the sky. Photochemical smog is a regional, and not localised, phenomenon in that ozone is produced relatively slowly through a series of reactions over several hours after exposure to sunlight. Maximum ozone concentrations therefore tend to occur downwind of the main source areas of precursor emissions, and can become recirculated within local and regional circulation patterns (SKM 2009).

The effects on human health of exposure to ozone in the lower atmosphere include irritation of the eyes and exacerbation of respiratory problems. Ozone can also affect plants by retarding growth and damaging leaf surfaces (SKM 2009).

Air emissions modelling shows that emissions from the Project will result in very minimal change to existing levels of ozone in the Darwin airshed (Figure 8-4). The maximum predicted ground level concentration of O_3 during routine operations is 0.06 ppm, which is identical to that predicted to occur in existing conditions (i.e. without the Project). This maximum concentration represents 59% of the NEPM criterion and occurs north of Darwin, over the ocean. The maximum ground-level concentration predicted to occur in Darwin and Palmerston is 0.05 ppm, which represents 48% of the NEPM criterion and is not expected to cause human or environmental health effects. The O_3 concentrations expected during upset conditions are equivalent to or lower than those from routine operations, as is the case for NO_2 and SO_2 as discussed above (SKM 2009). It is noted that air pollutant concentrations measured over a 1-hour averaging period represent the worst-case scenario, and consideration of longer averaging periods (e.g. 24 hours, or one year) results in lower average concentrations of air pollutants.

As described in Chapter 3, current O_3 concentrations in the Darwin airshed are predicted to be low, relative to the NEPM criterion. Both anthropogenic NO_x sources (e.g. motor vehicles) and biogenic VOC sources (e.g. tropical vegetation) contribute to ozone production. Large uncertainties can be associated with estimating biogenic VOC emissions, which sometimes vary across different vegetation types. In order to develop more accurate estimates, a passive VOC sampling program was conducted by SKM in the Darwin region, in both wet- and dry-season conditions in 2009. This research indicated that emissions estimation techniques being drawn from previous scientific literature were correctly estimating biogenic VOC emissions for the Darwin airshed. Overall, natural vegetation contributes much higher levels of ozone precursors to the Darwin airshed than industrial sources (see Appendix 19).

Particulates

Health effects of PM_{10} particulates (i.e. particulates with diameters of 10 μm or less) relate to the exacerbation of pre-existing respiratory problems. The segment of the population that is most susceptible includes the elderly, people with existing respiratory and/or cardiovascular problems, and children. Particulate matter can also enhance some chemical reactions in the atmosphere and reduce visibility. The deposition of larger particles can stain and soil surfaces, create aesthetic or chemical contamination of waterbodies or vegetation, and affect personal comfort, amenity and health (SKM 2009).

In Darwin, smoke from dry-season bushfires can contribute to air PM_{10} concentrations throughout the region. A study conducted in 2000 by the CSIRO found that 24-hour-averaged PM_{10} concentrations were below 10 μg/m³ in the wet season and averaged approximately 20 μg/m³ in the dry season. High PM_{10} concentrations recorded during the dry season coincided with days of reduced visibility caused by bushfire smoke (SKM 2009).

The Northern Territory's Department of Natural Resources, Environment, the Arts and Sport (NRETAS) also operates monitoring equipment for PM_{10} at the Charles Darwin University at Casuarina in Darwin's northern suburbs. Monitoring at this site showed no excursions above the NEPM criterion (50 μg/m³ over

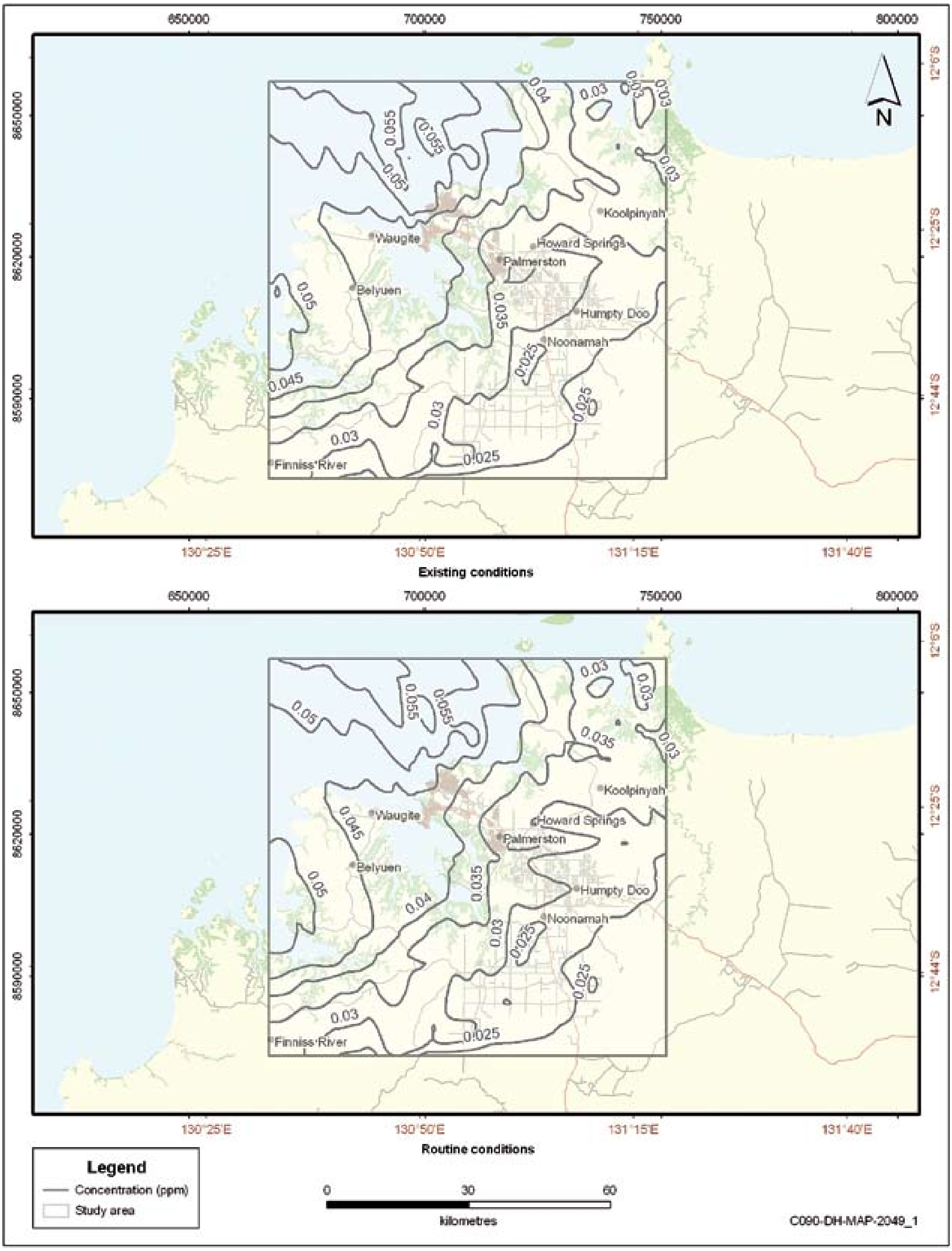


Figure 8-4: Maximum 1-hour ground-level O_3 concentrations (ppm) during existing conditions and during routine Project operations

24 hours) during 2006 and one potential excursion during 2007 (SKM 2009). Combined NRETAS and CSIRO air-quality data sets indicate that there have been four excursions above the NEPM criterion attributable to smoke from bushfires between 2004 and 2008. It is reasonable to assume that occasional PM_{10} excursions will continue to occur in the future.

During the commissioning phase of the Project, extended periods of flaring will be required while the processing equipment, storage tanks and shiploading lines are prepared for LNG production and export activities. This process involves purging with nitrogen and other inert gases and cooling the facilities to –162 °C. Gas produced during this period will be flared off intermittently over a period of several weeks for each of the two LNG trains. This flaring will produce smoke that may be visible from Palmerston and Darwin. As the ambient levels of PM_{10} in the Darwin airshed are normally well below the NEPM criterion limits, exceedances of these limits are not likely to be caused by commissioning smoke at the onshore development area unless commissioning were to coincide with a bushfire event resulting in background PM_{10} levels approaching or exceeding the NEPM limits. INPEX is also investigating ways to design flares with reduced smoke emissions.

Modelling of cumulative emissions for the Project's operations phase (including contributions from other industries, but excluding contributions from bushfire smoke) showed a maximum predicted ground level PM_{10} concentration of 10 µg/m^3 over a 24-hour averaging period, which is 21% of the NEPM criterion. During certain upset conditions, increased rates of flaring may be required and particulates are likely to be produced. Modelling was undertaken for two upset scenarios—"upset conditions (1) (a 15-minute scenario) and "upset conditions (2)" (a 10-hour scenario). "Upset conditions (1)" were predicted to result in higher concentrations of 17 µg/m^3, while "upset conditions (2)" were predicted to cause a reduction in particulate concentrations, down to 6 µg/m^3. These levels are 35% and 12% of the NEPM criterion respectively (SKM 2009). However, should they coincide with a bushfire event which results in background PM_{10} levels approaching or exceeding the NEPM limits, these events could contribute to the occasional excursion above the NEPM PM_{10} criterion for the Darwin airshed.

Odour

Hydrogen sulfide (H_2S) is a sulfurous compound that has the potential to cause odour impacts. To prevent nuisance odour emissions, the WHO air-quality guidelines state that H_2S concentrations should not exceed 7 µg/m^3 for any 30-minute period at any location outside the boundary of an operating plant (WHO 2000).

Hydrogen sulfide will normally be comingled in the AGRU incinerator. In the event that the AGRU incinerator is not functioning, exhaust gases (including H_2S) will be hot-vented through the gas turbine stacks to facilitate gas dispersion, as described in Chapter 5 *Emissions, discharges and wastes*. INPEX has conducted an ALARP ("as low as reasonably practicable") assessment and determined that the likelihood of exceeding the WHO guideline in any one year is six in a million. This is a product of the chance of the incinerator being shut down, combined with the chance of unfavourable meteorological conditions (such as low winds, or temperature inversion layers that prevent emissions from dispersing higher into the atmosphere). As a result, it is considered that nuisance odour emissions attributable to the Project are so unlikely to occur as not to warrant further management controls.

Management of air emissions

A Provisional Air Emissions Management Plan has been compiled for the Project and is included in Chapter 11 as Annexe 2. This plan will guide the development of more detailed plans during the construction and operations phases. The plan contains relevant objectives and targets, design initiatives and management controls, as well as details on monitoring and reporting requirements. Some of the key inclusions in the plan are outlined below.

The primary management control for reducing air pollutants is to integrate low-emissions infrastructure into the plant during the initial design phase. Dry low-NO_x gas turbines will be designed to achieve low-NO_x emissions. Other methods of controlling air emissions that have been integrated into the design of the onshore processing plant include the following:

- Residual hydrocarbons and H_2S will be removed from the emission stream by AGRU incinerators.
- In the unlikely event that the AGRU incinerators are shut down, exhaust gases (including H_2S and residual hydrocarbons) will be hot-vented through gas turbine exhaust stacks to facilitate safe dispersion.
- Easily accessible sampling points will be provided on major emission points such as turbines and AGRU exhausts.

In addition, the following emission reduction opportunities will be incorporated into the plant design:

- Boil-off gas from LNG storage tanks and LNG offtake tanker loading operations will be recovered by boil-off gas recompression systems.
- Boil-off gas from the butane and propane storage tanks will be recovered by butane and propane recovery systems. (Boil-off gas from butane and propane tankers will be captured by onboard recovery systems.)
- Ground and tankage flares will be designed to minimise the generation of particulates (smoke).
- The condensate storage tanks will be fitted with floating roofs.
- A commissioning plan will be developed to minimise and manage flaring during the commissioning phase.

The onshore processing plant will be designed to reduce air-pollutant emissions to levels that are as low as reasonably practicable. An air-quality monitoring program will be developed to confirm modelling predictions for ambient air quality in the Darwin airshed.

A number of energy-efficiency and greenhouse gas reduction measures will be applied to the design of the offshore facilities which will also serve to reduce air pollutant emissions in the Ichthys Field. These are described in the Provisional Air Emissions Management Plan and include the following prescriptions:

- Dry gas seals will be used on the main refrigerant compressors.
- Process monitoring systems and alarms will be installed to monitor flaring and process upsets.
- Valves will be installed in the process system to allow for inventory isolation.
- Waste-heat recovery units or heat-recovery steam generators will be installed wherever waste heat can be economically utilised.

Residual risk

A summary of the potential impacts, management controls and residual risk for air emissions is presented in Table 8-13. After the implementation of controls and with consideration of mitigating factors, the risks to air quality are rated as "low". The Project will contribute very minor changes to regional air quality, which is considered well within the required ranges for public and environmental health.

8.5 Waste

8.5.1 Non-hazardous waste

Non-hazardous wastes will be generated at the onshore development area throughout all phases of the Project. Larger volumes of waste will be generated during the construction phase than during operations, because of the higher number of people on site, the generation of offcuts of materials such as timber, cables and steel, and the use of packaging materials like cardboard and plastic. Wastes generated on an ongoing basis are likely to include cardboard and paper, plastic, food scraps, aluminium cans and other domestic waste.

Table 8-13: Summary of impact assessment and residual risk for air emissions

Aspect	Activity	Potential impacts	Management controls, mitigating factors	Residual risk*		
				C†	L‡	RR§
Air quality	Combustion of fuels (power generation, compression and process heat) during normal operations and upset conditions.	Reduction in local and regional air quality (with respect to NO_x, SO_x, O_3 and PM_{10}). Health impacts on community and local environment.	Design facilities to reduce air emissions to ALARP levels (e.g. low-NO_x technology in gas turbines, incineration of amine plant emissions, low-smoke ground flare). Undertake air-quality monitoring to confirm modelling predictions. Provisional Air Emissions Management Plan.	F (E3)	1	Low
Odour	Venting of AGRU exhaust gases (including H_2S) during AGRU incinerator shutdowns.	Nuisance odour impacts on community.	Redirect AGRU exhaust gases to the gas turbine stacks during AGRU incinerator shutdowns. Rapid dispersion of emissions by most ambient weather conditions. Provisional Air Emissions Management Plan.	F (E3)	1	Low

* See Chapter 6 *Risk assessment methodology* for an explanation of the residual risk categories, codes, etc.

† C = consequence.

‡ L = likelihood.

§ RR = risk rating.

Where these wastes cannot be practicably recycled or reused, they will be disposed of off site at a registered landfill facility. Unless properly managed, the impacts of waste generation and temporary storage on the environment at the onshore development area could include the following:

- unsightly litter
- the attraction of both native animals and pest animals
- harm caused to local animal life
- the generation of offensive odours
- increased fire risk associated with storage of wastes.

Management of non-hazardous waste

A Provisional Waste Management Plan has been compiled for the Project and is included in Chapter 11 as Annexe 16. This plan will guide the development of a series of more detailed plans during the construction and operations phases. Key inclusions in this plan are as follows:

- Sufficient space will be provided at the onshore development area to allow for the segregation and storage of wastes.
- During the early part of the construction phase, appropriate temporary containment facilities will be available for storing waste until permanent infrastructure is in place.
- Waste minimisation will be included in the tendering and contracting process.
- Positive efforts will be made to maximise recycling during all phases of the Project.
- Approved and licensed waste contractors will be engaged for waste disposal.
- All solid-waste receptacles (e.g. skips and bins) will have covers and be fit for purpose and in good condition. This will prevent scavenging animals from accessing putrescible wastes.

Residual risk

A summary of the potential impacts, management controls and residual risk for non-hazardous waste is presented in Table 8-14. After the implementation of controls, the impacts from this waste are considered to present a "low" risk and are likely to affect the surrounding environment on only a localised and minor scale.

8.5.2 Hazardous waste

Hazardous wastes are those that pose a threat or risk to public health, safety or the environment. There are a range of hazardous wastes likely to be generated at the onshore development area. These include the following:

- hydrocarbon liquid wastes, including waste oil, grease, lube and engine oils
- molecular sieves and filters
- spent solvents
- mercury filters
- excess or spent chemicals
- contaminated liquids or soils from accidental spills
- spent batteries.

The largest volumes of hazardous waste will be generated during the commissioning phase of the Project and the commencement of operations. Potential impacts to the environment at Blaydin Point

Table 8-14: Summary of impact assessment and residual risk for non-hazardous wastes

Aspect	Activity	Potential impacts	Management controls, mitigating factors	Residual risk*		
				C†	L‡	RR§
Non-hazardous waste	Generation of waste during construction and operations phases (e.g. domestic waste, packing materials, offcuts).	Littering of environment around Blaydin Point. Attraction of animals. Odours.	Reduce generation of waste through tender conditions and purchasing. Provide adequate space and facilities to segregate and contain waste. Make positive efforts to maximise recycling during all phases of the Project. Cover all bins to exclude animals and prevent windblown waste. Provisional Waste Management Plan.	F (B3)	3	Low

* See Chapter 6 *Risk assessment methodology* for an explanation of the residual risk categories, codes, etc.

† C = consequence.

‡ L = likelihood.

§ RR = risk rating.

from hazardous wastes could be associated with inappropriate handling, storage, transportation and disposal practices. Potential impacts from hazardous waste include the following:

- contamination of soil
- contamination of groundwater or the marine environment
- damage to vegetation
- deaths or injuries caused to native animals.

Management of hazardous waste

The Provisional Waste Management Plan compiled for the Project (see Section 8.5.1 *Non-hazardous waste*) will guide the development of a series of more detailed plans during the construction and operations phases. In addition to the management controls outlined for non-hazardous wastes listed in Section 8.5.1, key inclusions for hazardous wastes are as follows:

- Chemicals and hazardous substances used during all phases of the Project will be selected and managed to minimise the potential adverse environmental impact associated with their disposal.
- All hazardous liquid wastes will be stored over a bund in leakproof sealed containers.

Residual risk

A summary of the potential impacts, management controls and residual risk for hazardous waste is presented in Table 8-15. After the implementation of controls, the impacts from hazardous waste are considered to present a "medium" risk and are likely to affect the surrounding environment on only a localised scale. It is considered that these risks have been reduced to a level that is as low as reasonably practicable.

8.6 Spills and leaks

Hydrocarbons, production chemicals and hazardous wastes will be handled, stored and transported at the onshore development area in all phases of the Project. While measures to prevent the release of these materials into the environment will be in place at all times, there is potential for spills and leaks to occur through accidents and/or failure of equipment.

The potential impact from an accidental spill or leak is dependent on the location of the event and the type and volume of material released. Sealed surfaces and bunding of appropriate areas in the onshore development area, particularly in areas where hydrocarbon spills could occur, are likely to contain minor spills on site without impacts to receptors in the

Table 8-15: Summary of impact assessment and residual risk for hazardous waste

Aspect	Activity	Potential impacts	Management controls, mitigating factors	Residual risk		
				C†	L‡	RR§
Hazardous waste	Generation of hazardous waste during construction and commissioning phases.	Localised, low-to-medium-level contamination of soils and surface water from accidental spills.	Minimise waste generation through tender conditions and purchasing. Provide temporary waste-storage facilities during construction, prior to completion of permanent facilities. Make positive efforts to maximise recycling during all phases of the Project. Install appropriate bunding around facilities. Provisional Waste Management Plan.	E (E4)	4	Medium
Hazardous waste	Generation of hazardous waste during operations.	Localised, low-level contamination of soils and surface water from accidental spills.	Minimise waste generation through tender conditions and purchasing. Provide adequate space and facilities to segregate and contain waste. Make positive efforts to maximise recycling during all phases of the Project. Install appropriate bunding around facilities. Provisional Waste Management Plan.	E (E4)	3	Medium

* See Chapter 6 *Risk assessment methodology* for an explanation of the residual risk categories, codes, etc.

† C = consequence.

‡ L = likelihood.

§ RR = risk rating.

surrounding environment. There is a higher risk of loss of containment during the construction phase when ground surfaces may not yet be sealed and temporary bunding may be used to store hazardous substances.

The large volumes of liquid hydrocarbons (condensate) to be stored at the onshore development area during the operations phase presents a risk of loss of containment from the bulk storage tanks and an associated risk of contamination of the groundwater aquifer. Hydrological studies by URS at Blaydin Point (see Appendix 18) suggest that transmissive aquifers below the onshore development area may allow migration of potential contaminants into Darwin Harbour.

Contamination of the groundwater under Blaydin Point could limit any future use of that groundwater resource, both during the operations phase and after decommissioning of the onshore processing plant at the end of the Project. Contamination of soils at the onshore development area could likewise influence options for land use after decommissioning.

Mangroves are known to be particularly susceptible to pollution from hydrocarbon spills and there are well-documented records of mangrove deaths following spills in various parts of the world. Contact with mangrove roots is particularly critical, as coating and trapping of oil among the partially submerged pneumatophores affects normal respiratory and osmoregulatory functions. The impact of hydrocarbon spills on mangroves can be divided into two phases: firstly, the short-term mortality phase caused by coating with fresh condensate and, secondly, the longer-term effects of the weathered hydrocarbons becoming incorporated into sediments, inhibiting the growth of seedlings and larger plants (Volkman et al. 1994).

Management of spills and leaks

A Provisional Onshore Spill Prevention and Response Management Plan has been compiled for the Project and is included in Chapter 11 as Annexe 11. This plan will guide the development of more detailed plans during the construction and operations phases. The plan includes storage and handling procedures to avoid spills and leaks, monitoring and inspections to ensure that containment is maintained, and clean-up and remediation procedures in the event that accidental spills should occur. The following key management controls have been included in this plan:

- Onshore facilities will be designed and constructed in such a way that spills and leaks can be limited or isolated (e.g. through bunding and storage facilities), particularly in areas where there is an elevated risk of spill.
- Material safety data sheets (MSDSs) will be available on site, with information on appropriate spill clean-up and disposal methods.
- Chemicals and hazardous substances used during all phases of the Project will be selected and managed to minimise the potential adverse environmental impact associated with their transport, transfer, storage, use and disposal.
- Spill-response materials and equipment (including personal protective equipment) will be available during all Project phases and will contain equipment to combat both chemical and hydrocarbon spills.
- Personnel who routinely handle hazardous materials or wastes (e.g. refuelling personnel, pump operators, mechanics, and stores personnel) will receive training in handling, transporting and storing hazardous materials or wastes; in reporting and documentation requirements; and in spill clean-up techniques and practices.
- During construction of the onshore facilities, appropriate temporary containment facilities will be utilised for the storage of chemicals, fuel and hazardous waste until permanent infrastructure is in place.
- A groundwater monitoring program will be developed during the operations phase at the onshore development area to allow for regular assessment of groundwater quality and contamination status.
- A marine sediments and bio-indicators monitoring program will be developed to assess any increase in bioavailable heavy metals or petroleum hydrocarbons in intertidal sediments around Blaydin Point which might result from contaminated surface and groundwater flows from the onshore development area.

In addition, the Provisional Liquid Discharges, Surface Water Runoff and Drainage Management Plan (see Annexe 10 to Chapter 11) includes management controls for surface-water runoff that may be contaminated by hydrocarbon spills during the operations phase. These controls include the following:

- The drainage system will be designed to separate runoff from contaminated areas from runoff from non-contaminated areas. The contaminated wastewater streams will be directed to an oily-water treatment system.
- The oily-water treatment system will be designed to provide a discharge concentration of <10 mg/L petroleum hydrocarbon.

Table 8-16: Summary of impact assessment and residual risk for spills and leaks

Aspect	Activity	Potential impacts	Management controls, mitigating factors	Residual risk*		
				C†	L‡	RR§
Spills and leaks	Storage, handling and transfer of fuels and chemicals during construction.	Localised contamination of soils, surface water or groundwater.	Temporary storage and containment facilities installed while permanent facilities are being constructed. Training provided to personnel who routinely handle hazardous materials (e.g. refuelling personnel, pump operators, mechanics, stores personnel) in handling, transport, storage and clean-up. Provisional Onshore Spill Prevention and Response Management Plan.	E (E4)	4	Medium
Spills and leaks	Loss of containment of production chemicals (e.g. aMDEA#).	Localised contamination of soils and groundwater requiring dedicated clean-up and remediation.	Design of facilities for isolation and containment in high-risk areas. Storage facilities designed in accordance with Australian standards and the requirements of the relevant regulatory authorities. Chemicals selected and managed to minimise the potential environmental impact associated with their transport, transfer, storage, use and disposal. Provisional Onshore Spill Prevention and Response Management Plan.	D (E4)	3	Medium
Spills and leaks	Storage, handling and transfer of fuel and chemicals during operations.	Localised contamination of soils and groundwater requiring dedicated clean-up and remediation. Localised contamination of surface-water runoff. Contamination of groundwater aquifer, with potential flow into Darwin Harbour waters.	Design of facilities for isolation and containment in high-risk areas. Bunding installed in chemical and hydrocarbon storage, handling and transfer areas. Storage facilities designed in accordance with Australian standards, and the requirements of the relevant regulatory authorities. Drainage system will direct potentially contaminated surface runoff to an oily-water treatment system. Onshore Spill Prevention and Response Management Plan. Provisional Liquid Discharges, Surface Water Runoff and Drainage Management Plan.	C (B2)	2	Medium
Spills and leaks	Long-term bulk storage of liquid hydrocarbons (condensate).	Contamination of soils and groundwater that extends off site (e.g. into Darwin Harbour) and is difficult and expensive to remediate. Threats to environmental and human health. Reduction in potential for future use of land and groundwater at Blaydin Point.	Design of facilities for isolation and containment in high risk areas (e.g. condensate tanks). Storage facilities designed in accordance with Australian standards and the requirements of the relevant regulatory authorities. Groundwater monitoring program. Provisional Onshore Spill Prevention and Response Management Plan.	C (E4)	2	Medium

* See Chapter 6 *Risk assessment methodology* for an explanation of the residual risk categories, codes, etc.
† C = consequence.
‡ L = likelihood.
§ RR = risk rating.
\# activated methyldiethanolamine.

Residual risk

A summary of the potential impacts, management controls and residual risk for spills and leaks is presented in Table 8-16. After the implementation of controls, the impacts from spills and leaks are considered to present a "medium" risk and are likely to affect the surrounding environment on only a local scale. It is considered that these risks have been reduced to a level that is as low as reasonably practicable.

8.7 Conclusion

8.7.1 Outcome of risk assessment

Activities at the onshore development area that have the potential to impact on the environment include clearing and excavation for site preparation, the construction of the onshore facilities, the generation of emissions during operations (such as air pollutants and noise), and accidental occurrences such as hydrocarbon spills. Baseline surveys and modelling informed an assessment of the potential environmental impacts of these activities.

The risk assessment process, taking into account management controls and mitigating factors, has identified 15 "medium" and 10 "low" residual risk potential terrestrial environmental impacts associated with the onshore development area. These risk ratings are considered acceptably low, mitigating risks to significant or migratory species in the vicinity of the onshore processing plant and minimising pollution and health impacts to the surrounding community.

"Matters of national environmental significance"[3] associated with the onshore development area are threatened and protected animal species, including a number of small mammals, reptiles and terrestrial and migratory birds that could occur in the area. Fauna surveys on site recorded 12 migratory bird species, but no threatened mammals, reptiles or birds. The removal of vegetation for construction of the onshore facilities will reduce the available habitat for these species on a local scale. No threatened ecological communities or Ramsar wetlands[4] occur in, or near, the onshore development area.

The cycad *Cycas armstrongii*, which is listed as "vulnerable" under the *Territory Parks and Wildlife Conservation Act* (NT), occurs in the onshore development area in the eucalypt woodland vegetation community. However, the cycad is locally abundant throughout the Darwin Coastal Bioregion and clearing for the Project does not represent a significant impact to this species on a regional scale.

Important terrestrial habitats that will be affected by vegetation-clearing in the onshore development area include monsoon vine forest and mangroves, which support some specialist species (e.g. bird species that feed on particular fruits or flowers). These vegetation communities occur in other areas around the shores of Darwin Harbour and throughout the Darwin Coastal Bioregion. Mangroves are generally protected from clearing through current planning laws in the Northern Territory, and clearing for the Project represents less than 0.3% of the total area of mangroves in Darwin Harbour. Monsoon vine forest occurs in relatively isolated patches and removing individual patches may have ecological consequences for the remaining patches. At present, there are numerous areas of monsoon vine forest located around the broader Darwin Harbour region and clearing for the Project represents 4% of the total existing area. In addition, existing plantings of tropical fruit-bearing trees in the Darwin suburbs and surrounding rural areas effectively supplement the native monsoon vine forest habitat for some frugivorous animal species.

Terrestrial impacts such as soil erosion and exposure of acid sulfate soils will be minimised by management controls. These impacts will only be associated with construction activities and are likely to be short-term and localised. The onshore development area will be designed to minimise disruptions to natural surface-water flows.

The predictive air-quality model developed for the Project represents a cumulative assessment of impacts to the Darwin airshed. It incorporates the emissions from existing sources (both natural and anthropogenic) and then adds in the predicted emissions from the proposed onshore development area. The model shows that after the addition of the emissions from the INPEX facilities, ground-level air quality in the Darwin region will remain well within NEPM criteria at all times for NO_2, photochemical oxidants (as O_3) and SO_2. Based on measurements conducted by NRETAS, there are likely to be very occasional events, particularly during the dry season, where bushfires will contribute particulate material into the Darwin airshed to the extent that the NEPM criterion for PM_{10} will be approached or exceeded.

3 "Matters of national environmental significance" are defined in the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth).

4 A Ramsar wetland is a site designated for inclusion on the Ramsar List of Wetlands of International Importance. The Ramsar Convention (the "Convention on Wetlands of International Importance, especially as Waterfowl Habitat") was signed in Ramsar in Iran in 1971 and came into force in 1975. Australia signed the convention in 1971.

Under such conditions and depending on prevailing wind directions, the INPEX facilities may be a minor contributor to a potential excursion of the NEPM particulate matter criterion. However, in the absence of bushfires, the NEPM air-quality criterion for particulates (PM_{10}) will also be met comfortably at all times after the addition of the INPEX facilities.

It is considered that the level of management and risk reduction presented for the onshore development area represents a proactive and conservative approach to maintaining environmental values, while allowing progress for the Project in an economically sustainable fashion. The management controls to be implemented will be further developed in consultation with stakeholders and will continue to be updated throughout the various stages of the Project.

8.7.2 Environmental management plans

As described throughout this chapter, a suite of provisional management plans has been developed to outline the proposed management controls that reduce the potential for terrestrial environmental impacts. These provisional plans will guide the development of more detailed plans as the Project progresses. The 16 plans contain the objectives, targets, detailed actions and monitoring to be carried out to manage a comprehensive spectrum of environmental aspects. They are listed in Table 11-4 of Chapter 11.

INPEX's Health, Safety and Environmental Management Process is described in Chapter 11, and the provisional management plans that have been developed for the Project are attached as annexes to Chapter 11.

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9 Greenhouse Gas Management

9 GREENHOUSE GAS MANAGEMENT

9.1 Introduction

The use of liquefied natural gas (LNG) as an energy source has a number of advantages. The primary advantage is that the quantity of greenhouse gases (GHGs) emitted over the full life cycle (production, processing, transportation, and end-use combustion) is significantly less than the comparable life-cycle emissions from either coal or fuel oil as a means of delivering the same amount of energy. Nevertheless, the GHG emissions of LNG at the production stage are relatively high in comparison with those of other industries. INPEX recognises the potential for GHGs to impact on the environment on a global scale through their contribution to the phenomenon of global warming and is committed to actively promoting the reduction of GHGs across its operations in a safe, technically and commercially viable manner.

This chapter of the draft environmental impact statement (Draft EIS) for the Ichthys Gas Field Development Project (the Project) describes INPEX's approach to GHG management by:

- defining greenhouse gases and their global warming potentials
- giving an overview of INPEX's GHG policy position and management strategies
- discussing the Project's legislative and policy context for both the Commonwealth and Northern Territory governments.
- estimating the GHG emissions from the Project and discussing the measures the Project has already taken to minimise GHG emissions
- discussing further GHG emission reductions that INPEX is considering through:
  - technical abatement (beyond that already committed to)
  - offsetting by biosequestration
  - offsetting by geosequestration
  - purchase of emission credits
- comparing GHG emissions from the Ichthys Project with the emissions of other LNG projects
- discussing how GHG emissions from LNG production and use compare with emissions from alternative hydrocarbons such coal and fuel oil
- describing how the Project has incorporated predicted climate-change scenarios in its planning and design.

9.2 Definition of greenhouse gases and global warming potentials

Greenhouse gases absorb and emit radiation in the thermal infrared range. Elevated concentrations of GHGs in the earth's atmosphere have the effect of heating up the atmosphere, creating an "enhanced greenhouse effect."

Global warming potential (GWP) is a measure of how much a given mass of a GHG will contribute to global warming if released into the earth's atmosphere. GWP is a relative scale which compares the mass of the GHG in question with that of the same mass of carbon dioxide (CO_2), which has been conventionally assigned a GWP value of 1.

The expression "carbon dioxide equivalent" (CO_2-e) is a measure, using CO_2 as the standard, used to compare the GWPs of the different GHGs. For example, since the IPCC (2007) lists the GWP for methane (CH_4) over a 100-year period as 21, this means that the emission of 1 Mt of methane is equivalent to the emission of 21 Mt of carbon dioxide.

Table 9-1 shows the 100-year GWPs of the six types of GHGs listed by the Commonwealth Government's Department of Climate Change[1] (DCC 2009a). These were adapted from the GWPs listed in the Second Assessment Report of the Intergovernmental Panel on Climate Change in 1995 and quoted in IPCC (2007).

Table 9-1: 100-year global warming potentials of greenhouse gases

Gas	Global warming potential in CO_2-e
Carbon dioxide (CO_2)	1
Methane (CH_4)	21
Nitrous oxide (N_2O)	310
Perfluorocarbons (PFCs)	6500–9200
Hydrofluorocarbons (HFCs)	140–11 700
Sulfur hexafluoride (SF_6)	23 900

Source: DCC 2009a and IPCC 2007.

1 The Commonwealth's Department of Climate Change (DCC) became the Department of Climate change and Energy Efficiency on 8 March 2010.

9.3 INPEX greenhouse gas policy position and interim management strategy

INPEX recognises the potential for GHG emissions to impact on the environment through their contribution to global warming and is committed to managing its GHG emissions by:

- actively promoting the reduction of GHG emissions across its operations in a safe, technically and commercially viable manner
- seeking increasing energy efficiency, reducing resource consumption and reducing its overall GWP footprint.

There are a number of alternatives available for applying INPEX's policy objectives to GHG management, with varying costs and risks. As the Commonwealth Government's policy and legislative landscape is still evolving, INPEX continues to explore all practical GHG management alternatives in order to be well prepared to respond when the legislative process becomes clearer. Furthermore, the development of a portfolio approach to GHG mitigation may afford the lowest risk and cost approach for the Project, avoiding a reliance on any single solution. The main opportunities under consideration are as follows:

- engineering abatement
- biosequestration
- geosequestration
- buying offset credits on the open market.

Engineering abatement

Engineering abatement opportunities that will reduce GHG emissions and improve energy efficiency are being identified and assessed by INPEX's onshore and offshore facility engineering teams. Options that are safe, technically and commercially viable are likely to be incorporated into facility design. INPEX will also monitor and review technological developments and operational practices to identify GHG emission reduction opportunities during the Project's design phase and through its operational life.

Biosequestration

Biosequestration is the process of converting a chemical compound through biological processes to a chemically or physically isolated or inert form. With respect to GWP reduction, the term is most commonly used to refer to the "locking", through photosynthesis, of the carbon in atmospheric CO_2 into plant biomass (usually trees). Biosequestration offsets the effect of the CO_2 and other GHGs released into the earth's atmosphere by the development of natural gas fields and the burning of fossil fuels.

In Australia, the primary approach so far has been to plant "carbon sink" forests of fast-growing long-lived trees. At this stage, the number of accredited biosequestration service providers in the country is limited, though there are likely to be more in the future.

In 2008 INPEX initiated a "Biosequestration Assessment Project" with a pilot program involving the planting of 1.4 million trees to better understand the potential for biosequestration to offset large volumes of CO_2.

Related to the biosequestration approach is the improvement of forestry and land management practices to reduce CO_2 emissions. ConocoPhillips, for example, as Operator of the Darwin LNG plant, uses improved fire-management practices in savannah as a contribution to managing its CO_2 emissions. Similar options are being assessed by INPEX. At this stage, however, fire-management offsets are not recognised under the Kyoto Protocol[2] and may therefore not be compliant with Australia's proposed Carbon Pollution Reduction Scheme (CPRS) legislation.

Geosequestration

Geosequestration is the process of injecting CO_2 into deep geological formations for secure, long-term storage. The technique is also called "carbon (dioxide) capture and storage" (CCS). The technology for CO_2 injection is familiar to oil and gas companies, and has been used as an enhanced hydrocarbon recovery technique for many decades. The Sleipner Project in Norway, for example, is currently utilising this technology and the proposed Gorgon Project in Western Australia has adopted this technology for GHG management. The potential for geosequestration is being examined by INPEX for the Ichthys Project.

Buying offset credits on the open market

The following CO_2 offset credits are available for sale on the international market:

- certified emission reductions (CERs) from clean development mechanism (CDM) projects
- emission reduction units (ERUs) from joint implementation (JI) projects
- European Union allowances (EUAs) under the European Union Emissions Trading Scheme Phase 2 (EU ETS II)
- voluntary emission reductions (VERs)
- removal units (RMUs).

These credits may be acceptable as offsets in

2 The Kyoto Protocol is an agreement made under the United Nations Framework Convention on Climate Change (UNFCCC). Countries that ratify the protocol commit to reduce their emissions of CO_2 and other GHGs or to engage in activities such as emissions trading if they maintain or increase emissions of these gases. The protocol was adopted in Kyoto, Japan on 11 December 1997 and entered into force on 16 February 2005. As of November 2009, 187 states had signed and ratified the protocol.

Australia. However, this will only be known when details of the proposed CPRS and its associated legislation are finalised.

9.4 Greenhouse gas management plan

INPEX will produce a detailed GHG management plan prior to the commissioning of the onshore facilities. The plan will include an updated GHG emission estimate forecast and will consolidate INPEX's plan for technical abatement and offsets.

9.5 The legislative context: government positions on greenhouse gas management

The Commonwealth and Northern Territory governments are developing a suite of policy, strategy and legislative documents related to GHG management. As the policy and legislative landscape is still evolving, INPEX's approach has been to advance understanding of a range of practical alternatives to reduce and offset CO_2-e emissions in order to be well prepared to react positively once GHG management requirements and options become clearer.

9.5.1 Commonwealth Government position

The Commonwealth Government proposes to implement a "cap-and-trade" CO_2-e emissions reduction scheme. The scheme would require significant emitters to acquire carbon emission permits. The Government proposes to cap the total number of tonnes of CO_2-e for which permits can be acquired each year, and then gradually lower the cap over the following years and thus lower GHG emissions over time.

The CPRS proposed by the government has been incorporated into a White Paper published by the Department of Climate Change (DCC 2008). This document proposes that Australia should reduce its CO_2-e emissions by between 5% and 25% below 2000 levels by 2020 and 60% below 2000 levels by 2050. To achieve these goals, the government proposes to require all facilities with direct emissions of 25 000 t of CO_2-e per year or more to acquire a permit or establish an offset for each tonne of CO_2 emitted and acquit that permit at the end of the financial year.

The government expects that some trade-exposed activities in the economy will partially qualify for administratively allocated permits on the basis that these activities might be unable to pass on the costs of the emissions trading scheme and that this could affect their international competitiveness. The intention of providing allocated permits for a portion of the GHG emissions is that companies engaged in activities such as LNG production should not be encouraged to relocate to countries that are not subject to GHG management controls, thereby displacing income and jobs from Australia without concomitant global GHG reduction benefits. However, the government's "emissions-intensive trade-exposed" (EITE) assistance program does propose that all entities conducting activities that generate significant GHG emissions should bear at least a proportion of the carbon costs.

9.5.2 National initiatives

The National Greenhouse and Energy Reporting System (NGERS) operates under the auspices of the DCC and requires facilities that emit more than 25 000 t of CO_2-e per annum to report their CO_2-e emissions. This is the proposed mechanism whereby facilities will report under the CPRS. INPEX will report emissions from the Project facilities under the NGERS following Project start-up.

9.5.3 Northern Territory Government position

The Northern Territory Government's objective for managing GHG emissions from new and expanding operations is to minimise GHG emissions to a level that is as low as practicable. This objective is contained in the *NT Environmental impact assessment guide: greenhouse gas emissions and climate change* (NRETAS 2009). This Draft EIS has been prepared in accordance with this guide.

9.6 Project greenhouse gas emissions

9.6.1 Overview

Over its 40-year lifetime, INPEX expects the Project to emit about 280 Mt of CO_2. This amounts to an average annual emission of about 7.0 Mt. About 278 Mt will be emitted during the operations phase. On average, 2.4 Mt/a of reservoir CO_2 and 4.6 Mt/a of combustion CO_2 will be emitted from offshore and onshore power generation, compression, and other combustion sources. Approximately 2 Mt will be produced during the construction phase.

INPEX has estimated Ichthys Project GHG emissions in order to evaluate options for minimising GHGs and to satisfy the information requirements of the Commonwealth and Northern Territory governments. The methodology employed to calculate Project GHG emissions is consistent with the methodology described in the Commonwealth's publication *National greenhouse accounts (NGA) factors* (DCC 2009a).

As with other liquefied and domestic gas production projects (e.g. the Bayu–Undan – Darwin LNG, North West Shelf, Pluto and Gorgon projects, among many others), the Ichthys Project's GHG production will be made up almost entirely of CO_2 as opposed to other GHGs. These CO_2 emissions will be produced almost exclusively during the operations phase from a combination of offshore and onshore combustion sources and from CO_2 that is naturally present in the gas and condensate reservoirs.

Greenhouse gases other than CO_2

In the gas production process, combustion of hydrocarbons in equipment such as gas turbines, burners, heaters, boilers and flares will result in the formation of CO_2 and water. Small amounts of methane (CH_4) will also be released in the exhaust gases as a result of incomplete fuel combustion. Even smaller quantities of nitrous oxide (N_2O) will also be formed during fuel combustion by the reaction of nitrogen and oxygen. However, these two combustion by-products will contribute less than 5% of the total Project CO_2-e GHG emissions. As any combustion source will co-produce these two by-products, there is very little opportunity to significantly reduce Project-wide GHG emissions by trying to minimise CH_4 or N_2O emissions from equipment such as gas turbines. Turbines from different manufacturers will also produce similar trace amounts of CH_4 and N_2O in proportion to the fuel consumed.

As with other gas projects, the Ichthys Project will use small quantities of hydrofluorocarbons (HFCs) in air-conditioners, and will also use small quantities of sulfur hexafluoride (SF_6) in circuit-breakers and electrical switchgear. All these uses will employ very small volumes, in closed tightly controlled systems with very little leakage. So even if the GWPs of HFCs and SF_6 are very large, the emissions to atmosphere will be very small, perhaps of the order of a few kilograms over the life of the Project, compared with *c*.278 Mt of CO_2. The Project's use of air-conditioners, for example, will be negligible in comparison with Northern Territory, Australian, or worldwide use of air-conditioners and HFCs.

The relative amounts of CO_2 and other GHGs to be produced by the Project are presented in Figure 9-1.

Construction (pre-operations) phase emissions

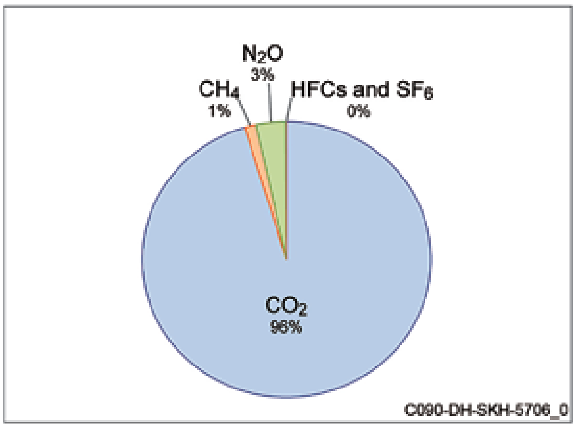


Figure 9-1: Project emissions of CO_2 compared with other greenhouse gases

The construction phase of the Project will contribute less than 0.5% of the total GHG emissions (Figure 9-2). The drilling of the 50 wells in the Ichthys Field is expected to emit <1 Mt of CO_2-e. Emissions from all other construction sources, including the clearing of vegetation, are also expected to be <1 Mt, for a total of 2 Mt CO_2-e, at most, prior to operations. In the case of construction emissions, there is very little opportunity for INPEX to change the energy efficiency of drilling rigs, pipelay barges, installation support vessels and other equipment that will be leased from world markets for relatively short periods of time.

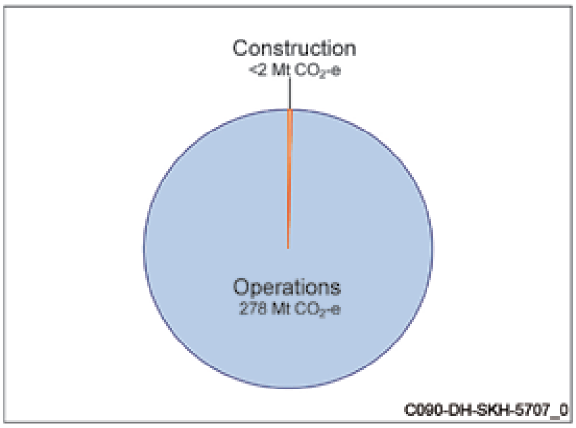


Figure 9-2: Project emissions of CO_2-e during the construction and operations phases

Conclusion

For the reasons described above, INPEX has focused attention on estimating and minimising CO_2 emissions during the operations phase[3]. Efforts to reduce already very low emissions of GHGs other than CO_2 during the operations and construction phases will be made, but will occur during the detailed design and construction phases of the Project.

9.6.2 Operational greenhouse gas emissions

Overview

Figure 9-3 provides an estimate of CO_2 emissions over the Project's 40-year life. The emissions are shown on an annual average basis; during any given year they may be slightly higher or lower depending on the timing of planned and unplanned equipment shutdowns and maintenance works. The figure was developed by considering annual emissions from the three main CO_2 source categories: reservoir CO_2, offshore combustion, and onshore combustion.

3 The "operations phase" here is taken to include the first year of commissioning, when reservoir fluids are introduced into the offshore and onshore facilities. Commissioning emissions are included in subsequent operations-phase CO_2 estimates. Commissioning will last for only a few months, whereas operations will last for the rest of the 40 years.

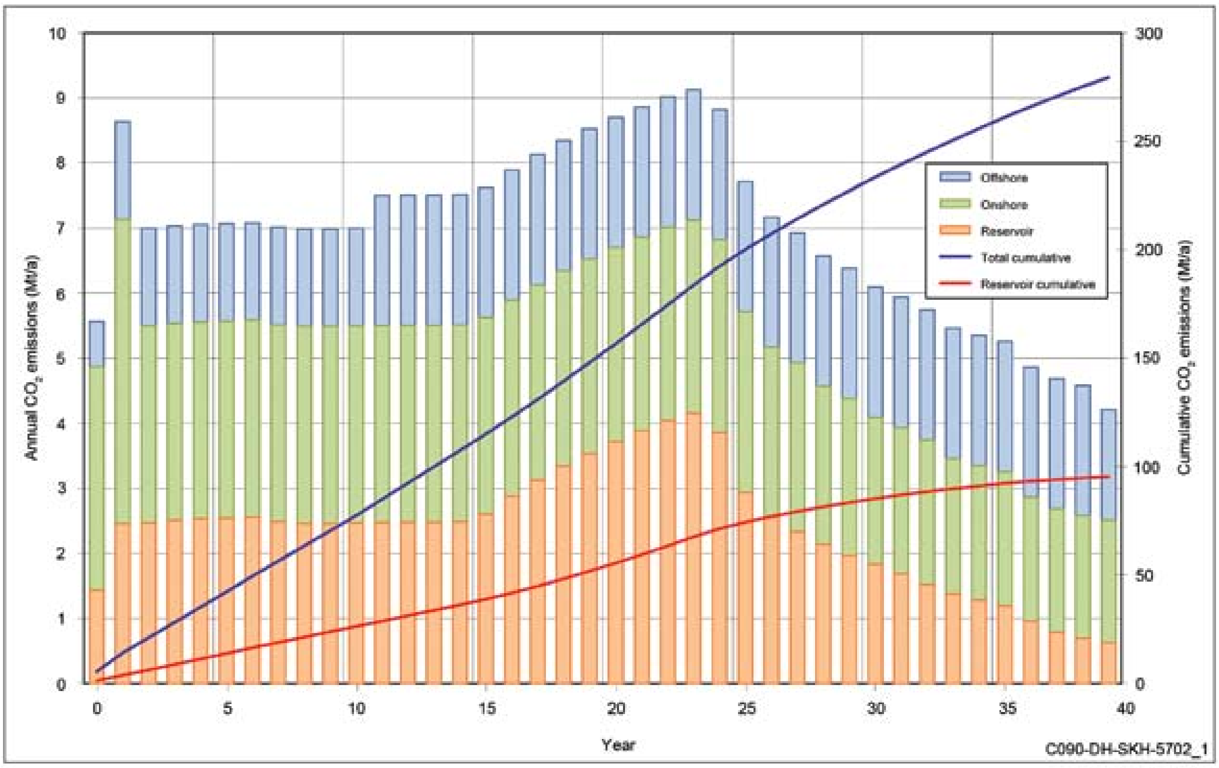


Figure 9-3: Estimated annual CO_2 emissions over the Project's 40-year operational life

INPEX plans to commission its first onshore LNG train and its offshore central processing facility (CPF) and floating production, storage and offtake (FPSO) facility within five years of the final investment decision (FID) being made; the second LNG train will be commissioned one year later. Offshore and reservoir CO_2 emissions in the first year of operation will be about half those of Year 2 onwards because gas will only be supplied to one onshore train. Onshore combustion emissions, however, may be higher in years 1 and 2 than in subsequent years, since during commissioning a much larger amount of gas than normal will need to be flared onshore to accomplish the initial "cool-down" of the two LNG trains.

The two reservoirs which make up the Ichthys Field are in the Brewster Member and the Plover Formation. The CO_2 content in the reservoirs averages about 8% in the Brewster reservoir and 17% in the Plover reservoir. Reservoir CO_2 emissions will remain at *c.*2.5 Mt/a until Year 16 since gas from the Brewster reservoir will be used for approximately the first 15 years. From Year 16 until Year 23, however, reservoir CO_2 emissions will gradually increase to *c.*4.1 Mt/a as Brewster gas begins to run out and the Project begins processing increasing amounts of Plover gas along with available Brewster gas in order to continue producing 8.4 Mt/a of LNG and maintain the required LNG production levels. From around Year 24 onwards, reservoir CO_2 emissions will gradually decrease as the Project slowly runs out of gas and continues to produce LNG, but at rates below the 8.4 Mt/a plateau.

Thus, based on the current design and operating assumptions, total CO_2 emissions over the 40-year operations period will be *c.*278 Mt.

Figure 9-4 shows that reservoir CO_2 emissions will account for approximately 34% of the Project's total CO_2 emissions and that offshore and onshore combustion processes will account for approximately 26% and 40% of the total CO_2 emissions respectively.

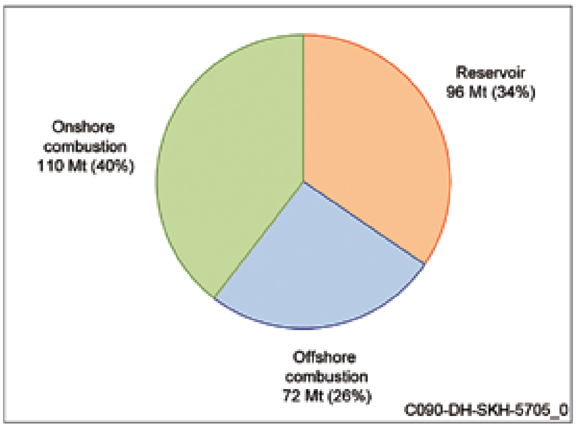


Figure 9-4: Overview of the contributions of reservoir, offshore combustion and onshore combustion CO_2 emissions to the 40-year Project total

Table 9-2 provides more detail on the contributions to expected reservoir, offshore combustion and onshore combustion CO_2 emissions.

Table 9-2: Estimated average annual CO_2 emissions during the operations phase[4]

Source	Approx. power requirement	Approx. heating requirement	40-year annual average (Mt/a)	40-year totals (Mt)
Reservoir				
Brewster	n.a.	n.a.	1.4	56
Plover	n.a.	n.a.	1.0	40
Reservoir total	**n.a.**	**n.a.**	**2.4**	**96**
Offshore combustion*				
CPF—export gas compression (four RB211 turbines)	100 MW	n.a.	0.5	20
CPF—inlet gas compression (three RB211 turbines)	0 initially; 75 MW from Year 12	n.a.	0.3†	12
CPF—power generation (three RB211 turbines)	75 MW	n.a.	0.3	12
FPSO—power generation (four RB211 turbines)	100 MW	n.a.	0.5	20
FPSO—fired heating for monoethylene glycol (MEG) regeneration, condensate heating and stabilisation	n.a.	60 MW	0.2	8
Offshore total	**275–350 MW**	**60 MW**	**1.8**	**72**
Onshore combustion‡				
Refrigerant compressor turbines (four Frame 7 turbines)	280 MW	n.a.	1.4	55
Power generation turbines (nine Frame 6 turbines, eight running)	220 MW	n.a.	0.9	35
Acid gas removal unit (AGRU) incineration	n.a.	40 MW	0.1	4
Hot-oil furnaces and possibly steam boilers	n.a.	80 MW	0.2	7
Flares (all)	n.a.	n.a.	0.2	9
Onshore total (excluding reservoir)	**500 MW**	**120 MW**	**2.8**	**110**
Total for Project			7.0	278

* Rolls-Royce RB211 turbines are assumed for offshore use for estimation purposes only. Turbine choice is subject to technical assessment in the detailed-design phase.

† CO_2 emissions will be zero for approximately the first 11 years, 0.5 Mt/a for the next 29 years, and will average to 0.3 Mt/a over 40 years.

‡ General Electric Frame 6 and Frame 7 turbines are assumed for onshore use for estimation purposes only. Turbine choice is subject to technical assessment in the detailed-design phase.

n.a. = not applicable.

4 Assuming LNG production of 8.4 Mt/a until the end of the plateau is reached.

Figures 9-5 and 9-6 delineate the sources of the Project's expected CO_2 emissions in more detail.

The following assumptions were made in estimating operations-phase CO_2 emissions:

- The Project facilities will operate for 40 years.
- During the 40 years, the facilities will on average be available for production around 90% of the time, that is, for 330 days per year. During some years (those with few shutdowns), production will be higher and the associated CO_2 emissions may therefore be around 10% higher than the levels shown in Figure 9-3 and Table 9-2.
- To prevent CO_2 from freezing during the liquefaction process (which would cause blockage and failure of the cryogenic equipment), the reservoir CO_2 will be removed from the gas stream in an acid gas removal unit (AGRU) prior to the gas entering the liquefaction equipment. The CO_2 will be emitted to atmosphere after it has passed through an acid gas incinerator unit where hydrogen sulfide (H_2S) and small amounts of absorbed hydrocarbons will be converted to sulfur dioxide (SO_2) and CO_2.
- The offshore CPF will use gas turbines for export gas compression and power generation from the start of the Project, with additional turbines being added for inlet compression from Year 12.

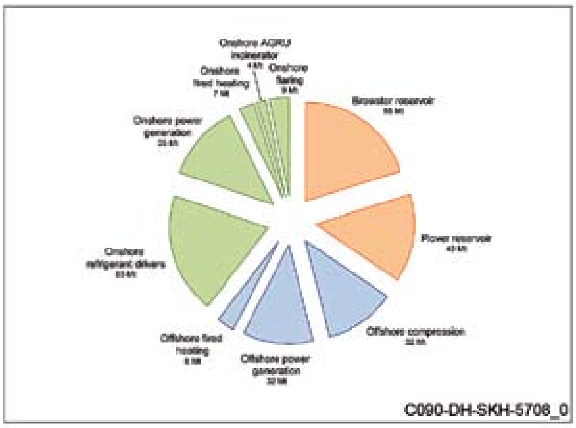


Figure 9-5: Sources of CO_2 emissions (in Mt) over the 40-year life of the Project

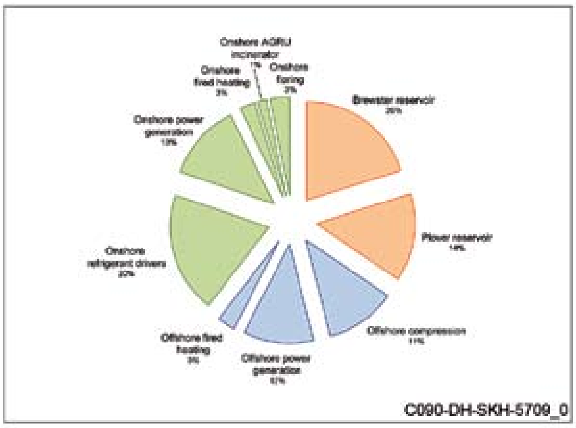


Figure 9-6: Sources of CO_2 emissions (%) over the 40-year life of the Project

- The offshore FPSO facility will also have power generation capacity that will be supplied by gas turbines and will require fired heating for condensate stabilisation and monoethylene glycol (MEG) regeneration.
- The onshore plant will use four gas turbine drivers for refrigerant propane and mixed refrigerant compression loops (GE Frame 7 or equivalent); these turbines will be operating continuously at 100% design load.
- The onshore plant will also use nine open-cycle industrial gas turbines (GE Frame 6 or equivalent) for power generation, with an operating philosophy of eight running and the ninth as backup. Loads on these will be variable.
- Waste-heat recovery systems will be installed on offshore and onshore facilities to minimise the need for fired heating during normal operations.
- The emissions from minor vented and fugitive sources will be minimal compared with the reservoir and combustion emissions and are not included in the operational GHG emission estimate.
- Emissions of GHGs other than CO_2 will also be minimal and have been excluded from the estimates.

9.7 Project greenhouse gas emissions relative to Australian and Northern Territory emissions

Table 9-3 compares the Project's estimated GHG emissions with 2007 Australian and Northern Territory GHG emissions. The relative contribution of the Project's GHG emissions compared against 2007 levels is 1.2% of the Australian CO_2-e emissions and 30% of the Northern Territory's CO_2-e emissions.

Table 9-3: Project greenhouse gas emissions relative to the greenhouse gas emissions for Australia and the Northern Territory in 2007

	CO_2-e emissions (Mt/a)	Percentage of 2007 Australian GHG emissions	Percentage of 2007 Northern Territory GHG emissions
Australian GHG emissions (2007)	597.2	n.a.	n.a.
Northern Territory GHG emissions (2007)	17.2	2.9	n.a.
Ichthys Project total GHG emissions (40-year annual average)	7.0	1.2	n.a.
Ichthys Project onshore GHG emissions (40-year annual average)*	5.2	n.a.	30

Source: DCC 2009b.

* Onshore CO_2-e emissions include onshore combustion emissions (2.8 Mt/a) and reservoir emissions (2.4 Mt/a). Even though reservoir CO_2 emissions will be sourced from Commonwealth waters outside the Northern Territory, the reservoir CO_2 will be emitted to atmosphere in the Northern Territory.

n.a. = not applicable.

9.8 Minimising Ichthys Project greenhouse gas emissions

This section outlines the options that INPEX is investigating for minimising the Project's GHG emissions through technical abatement measures.

INPEX recognises that the management of GHGs is an important consideration in the planning and design of the Project. The following range of energy-efficient technologies has been identified for use on the Project:

1. the selection of activated methyldiethanolamine (aMDEA) as the CO_2 removal solvent
2. the selection of energy-efficient turbines for compressor drivers and power generation
3. the incorporation of waste-heat recovery units to minimise the need for supplemental fired heating
4. the employment of other technical improvements, including onshore AGRU flash-gas recovery and offshore flare-gas recovery
5. the possible implementation of combined-cycle power generation onshore.

The technologies described in this section have either already been integrated into the design or are being assessed for their suitability, taking into account possible constraints such as technical feasibility and risk, safety hazard risk, economic and schedule constraints, and various environmental considerations.

The capacity of each of these measures to influence the GHG emission intensity of the Project is shown in Figure 9-7.

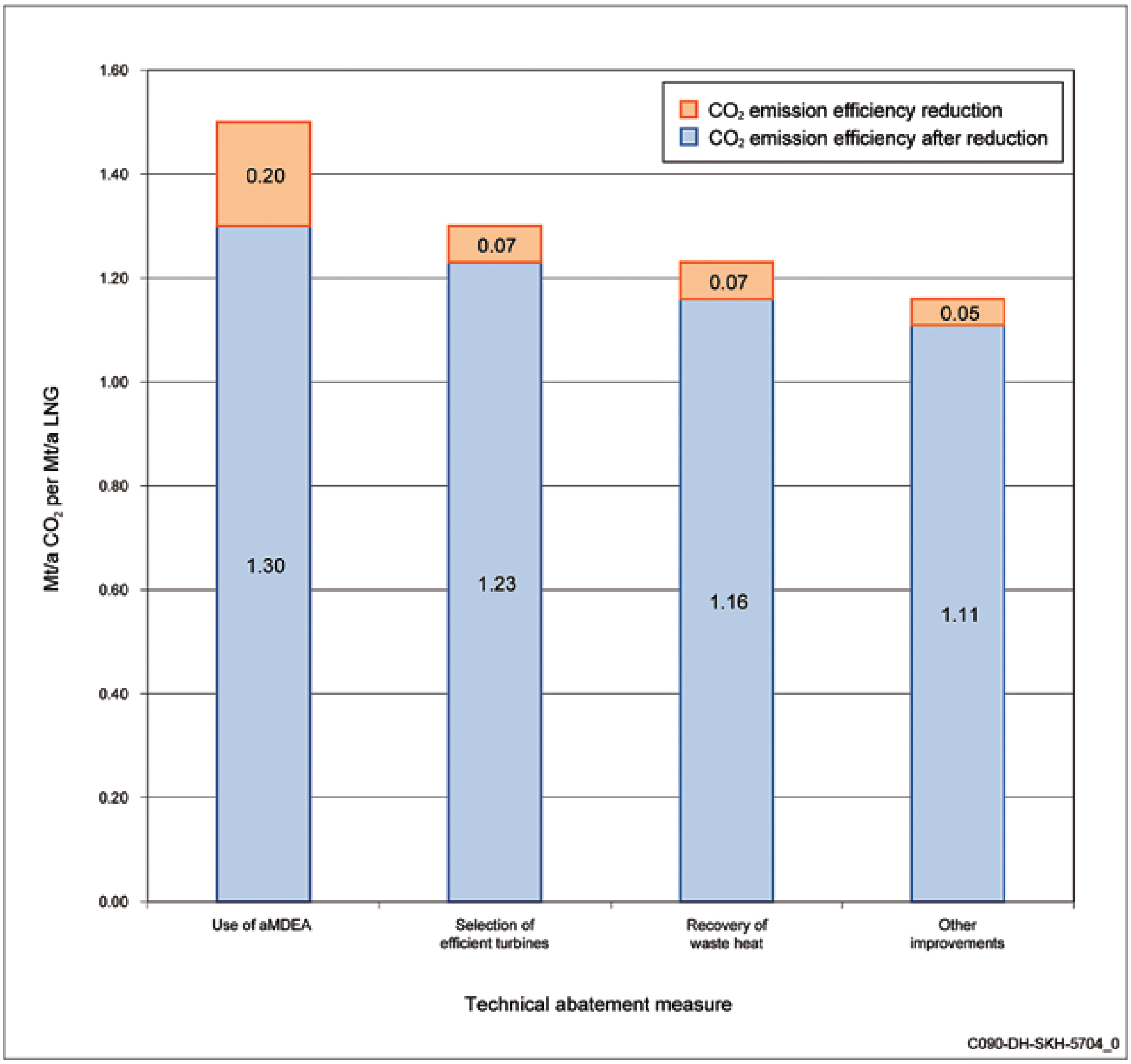


Figure 9-7: Project CO_2 emission reduction measures

9 Greenhouse Gas Management

1. The selection of aMDEA as the CO_2 removal solvent

INPEX estimates that using aMDEA rather than other possible solvents will reduce CO_2 emissions by 0.2 Mt/a of CO_2 per Mt/a of LNG produced. This equates to a CO_2 reduction of *c*.50 Mt over 40 years (assuming a 40-year average production rate of 6.3 Mt/a of LNG)[5].

The CO_2 found naturally in the gas from the reservoirs has to be taken out of the hydrocarbon gas stream prior to liquefaction. If CO_2 were to remain in the gas stream, it would freeze inside the cryogenic equipment and cause blockage and failure. In order to remove the CO_2, the gas flows upwards against a downward flow of solvent in the absorber of the acid gas removal unit (AGRU) unit. Heat from the gas turbines, using a circulating hot-oil system, is then used to drive off the CO_2 from the solvent so that the solvent can be reused.

To minimise the co-absorption of CH_4 from the AGRU, aMDEA has been selected as the preferred solvent for the removal of acid gases such as CO_2. The advantage of aMDEA is that it co-absorbs significantly smaller quantities of hydrocarbons than traditional solvents in the process of absorbing the CO_2 from the feed-gas stream. This in turn reduces the quantities of CH_4 and other hydrocarbons flashed or vented from the flash vessels and regenerator column during the regeneration process. The vented CO_2 stream is then directed to the AGRU incinerator which converts any remaining CH_4 to CO_2, which has a lower GWP. Flash-vessel vapours will also be directed to the incinerator. The use of aMDEA also reduces regeneration energy and has proved its usefulness in the field. The Project has also chosen a two-step rich-aMDEA flash process configuration for solvent regeneration; this also reduces the regeneration energy required.

2. Selection of energy-efficient turbines

INPEX estimates that selection of energy-efficient turbines for both the offshore and the onshore facilities will reduce CO_2 emissions by 0.07 Mt/a of CO_2 per Mt/a of LNG produced. This equates to a CO_2-e reduction of *c*.18 Mt over 40 years (assuming a 40-year average production rate of 6.3 Mt/a of LNG).

2a. Onshore refrigeration compressor drivers

The turbines used for driving liquefaction process refrigerant compressors are the largest users of energy in the LNG supply chain. Consequently, the choice of turbine technology will have a significant impact on the Project's GHG emissions.

Turbine selection has been conducted with an integrated approach to GHG emissions savings. This involves matching the demand for process heat with appropriate turbine selection. The process heat demand of the Ichthys LNG process is significant because of the high reservoir CO_2 content of the gas. This process heat needs to be sourced from fired heaters, or from waste-heat recovery units, or from a combination of the two. Studies indicate that the heat in the exhaust from process driver turbines fits well with the heat demand of the process and that an integrated solution of industrial turbines and waste-heat recovery units will yield a very efficient LNG plant. It is estimated that it will be only later in the Project's life, when the gas extraction rate from the Plover reservoir is at its peak, that the process driver turbines will not be able to supply sufficient heat and necessitate the supply of extra process heat.

2b. Onshore power generation

INPEX will select General Electric (GE) Frame 6 or equivalent turbines for power generation. These are more efficient than the GE Frame 5 and other power generation turbines selected by other operators in the past.

2c. Offshore compressor drivers

INPEX plans to select aeroderivative turbines for offshore export and inlet compressor drivers. This will help to increase energy efficiency.

2d. Offshore power generation

INPEX also plans to select aeroderivative turbines for offshore power generation purposes.

3. Incorporation of waste-heat recovery units

INPEX estimates that recovery of waste heat, both offshore and onshore, will reduce CO_2 emissions by 0.07 Mt/a of CO_2 per Mt/a of LNG produced. This equates to a CO_2-e reduction of around 18 Mt over 40 years (assuming a 40-year average production rate of 6.3 Mt/a of LNG).

Heat is required for many processes in the offshore and onshore gas production processes. The greatest onshore demand comes from the AGRU and the greatest offshore demand comes from the condensate-processing and MEG-regeneration processes.

In order to meet the heat demand, INPEX plans, wherever practicable, to install waste-heat recovery units on both the offshore and onshore turbines. Recovered waste heat reduces the need for operational fired heaters and boilers which would be additional sources of GHG.

5 The Ichthys Project expects to produce an average of 8.4 Mt/a of LNG for approximately the first 23 years of operation. But during the following 17 years, the Project expects production to gradually decline as gas reserves become depleted. The 40-year total LNG production is expected to be 252 Mt. The 40-year average LNG production rate is expected to be *c*.6.3 Mt/a.

The Project has designed the main refrigerant turbines onshore to incorporate waste-heat recovery systems that will provide process heat for the onshore plant. Significantly, about 360 MW of heat will be recovered, reducing fuel use by 12 million standard cubic feet of gas per day.

The current best-practice LNG driver turbine technology in Australia is to incorporate direct-drive gas turbines to power refrigerant compressors with waste-heat recovery units. This technology is currently utilised on the North West Shelf Project's fourth and fifth LNG trains and by the ConocoPhillips Darwin LNG plant; it is also proposed for the Pluto and Gorgon projects. However, in the case of the North West Shelf and Pluto projects, and to a lesser extent the Darwin LNG plant, the opportunity for heat recovery is not as great as for the Ichthys and Gorgon projects because Ichthys and Gorgon have the largest concentrations of CO_2 in their reservoir gases. The biggest source of waste-heat demand in an LNG plant is for the regeneration of the rich aMDEA or other AGRU solvent. The fact that the Ichthys and Gorgon gas fields have much higher CO_2 content in their gas than is the case with the North West Shelf, Pluto and Darwin LNG projects puts them in a better position to use more open-loop turbine waste heat than the other operators.

4. Other energy-efficiency measures

INPEX estimates that other energy-efficiency measures will reduce CO_2 emissions by an additional 0.05 Mt/a of CO_2 per Mt/a of LNG produced. This equates to a CO_2-e reduction of *c*.13 Mt over 40 years (assuming a 40-year average production rate of 6.3 Mt/a of LNG).

4a. Flaring

The offshore and onshore gas-processing facilities will be designed to avoid continuous intentional flaring during operations. The following design measures are proposed:

- Boil-off gas compressors will be sized to recover boil-off gas from the LNG tanks during holding mode and for full recovery of vapours during shiploading, rather than directing emissions to flare or vent.
- Waste streams will be recovered back into the process by reclaiming propane and light and heavy mixed refrigerant to the most reasonably practicable extent during shutdowns.
- The gas-processing plant will be designed for reliability and stability in order to minimise process and safety trips which would cause depressurisation of the whole facility and the associated flaring. Where necessary, spare equipment has been specified so that the failure of one piece of equipment can be offset by running the spare equipment.
- Options for flare-gas recovery for unintentional releases to flare headers are being investigated for the offshore and onshore flare systems to try to capture emissions to atmosphere from leakages and purge gas.

4b. Operational controls—monitoring

An important part of any abatement process is the effective collection of accurate data to allow calculation of plant performance. To achieve this, the process monitoring and control system that will be installed as part of the overall facilities will have a provision to collect and monitor data required to calculate plant emissions and efficiencies.

This will include the ability to undertake an overall material balance of the process plant, that is, to determine how much feedstock enters the plant and how much leaves the plant in terms of product (LNG, liquefied petroleum gas (LPG) and condensate) or is consumed as fuel or lost to the flare.

The value of such a monitoring system is that it can be used to give timely warning to the whole operations team when flaring is occurring or gas turbine performance is dropping below desirable levels and thus allow for management responses.

4c. Fugitive emission sources

Fugitive emissions are relatively minor contributors to overall GHG emissions at modern facilities. Measures that eliminate sources of fugitive emissions include the following:

- the installation of floating roofs on condensate storage tanks
- the specification of dry gas seals for centrifugal compressors.

4d. Alternative energy

The use of solar collectors is being considered for the off-site accommodation village in Darwin. However, INPEX does not plan to further consider solar collectors on administration and other buildings within or near the LNG plant because surplus electrical capacity from the plant's power generation turbines will be adequate to supply such electricity.

5. Combined-cycle power generation

Combined-cycle power generation is being considered for the onshore facilities. If INPEX proceeds with this proposal it would reduce CO_2 emissions by an additional 0.07 Mt/a of CO_2 per Mt/a of LNG produced. This would equate to a CO_2-e reduction of *c*.18 Mt over 40 years (assuming a 40-year average production rate of 6.3 Mt/a of LNG).

For onshore power generation, a configuration of open-cycle Frame 6 turbines has been evaluated as a base case. INPEX continues to investigate the selection of combined-cycle gas turbines (CCGTs) for power generation for the LNG process.

As with the discussion on process turbine selection, the selection of CCGTs would be based on integrated GHG reduction benefits. Some nuisance low-pressure gas streams that would not be reasonably processed could also be directed to the CCGT complex to raise more steam to generate power.

The use of CCGTs would involve installing fewer turbines and relying on one or more steam turbines downstream of the open-loop power generation turbines to recover additional waste heat as steam.

Since the liquefaction process is at the heart of LNG production, the choice of turbines will be an area of extensive research in order to secure the best technological, safety, economic and GHG outcome. A decision on final design will be made following the front-end engineering design (FEED) phase of the Project.

Summary

INPEX has identified and committed to technical-abatement and energy-efficiency measures that will reduce CO_2 emissions by around 100 Mt over the Project's 40-year life. Investigation of measures to reduce emissions by a further approximately 18 Mt is continuing.

9.9 Benchmarking

This section benchmarks the Project's expected GHG emissions against the performance of other LNG projects.

9.9.1 Overview of world LNG projects

Table 9-4 provides an overview of worldwide LNG projects and the technologies they use. This table and the previous section on technical abatement demonstrate that the Project has either already adopted, or continues to consider, technology options that are as energy-efficient or more energy-efficient than those adopted by other LNG operators.

9.9.2 Benchmark greenhouse gas efficiency of the Ichthys Project against other LNG projects

The Project's expected GHG emission efficiency can be compared with other major LNG and associated hydrocarbon liquids projects worldwide (existing and planned) through a number of benchmarking methods.

Kilograms of CO_2-e per megawatt hour (MW·h) of electricity produced in Asia is one such efficiency benchmark, often used to compare the use of LNG with the use of fuel oil and coal to produce the same amount of electricity in Asia. Figure 9-8 compares the expected GHG emissions of the Ichthys Project with estimated GHG emissions from historical Australian LNG projects (existing and under construction). The exact efficiencies of various LNG projects are difficult to determine from publicly available data, and vary based on assumptions about aspects such as when and how much export compression will be needed and when decline from a production plateau will occur as field productivity declines and so on. But how the Ichthys Project will compare with other LNG projects can be assessed reasonably accurately, as described in the following subsections.

9.9.3 Ichthys Project greenhouse gas emissions compared with other projects

Discussion

The biggest differences in CO_2 emissions efficiencies between LNG projects typically arise in relation to the following factors:

- the proportion of CO_2 naturally present in the reservoir gases used to make the LNG
- the nature of the offshore facilities (and their associated combustion CO_2 emissions) needed to get the gas to the liquefaction facility via a gas export pipeline and, in many cases, to remove a portion of the hydrocarbon liquids first.

As described in the section *Onshore combustion emissions* below, CO_2 emission efficiency at the liquefaction stage is not a particularly distinguishing factor.

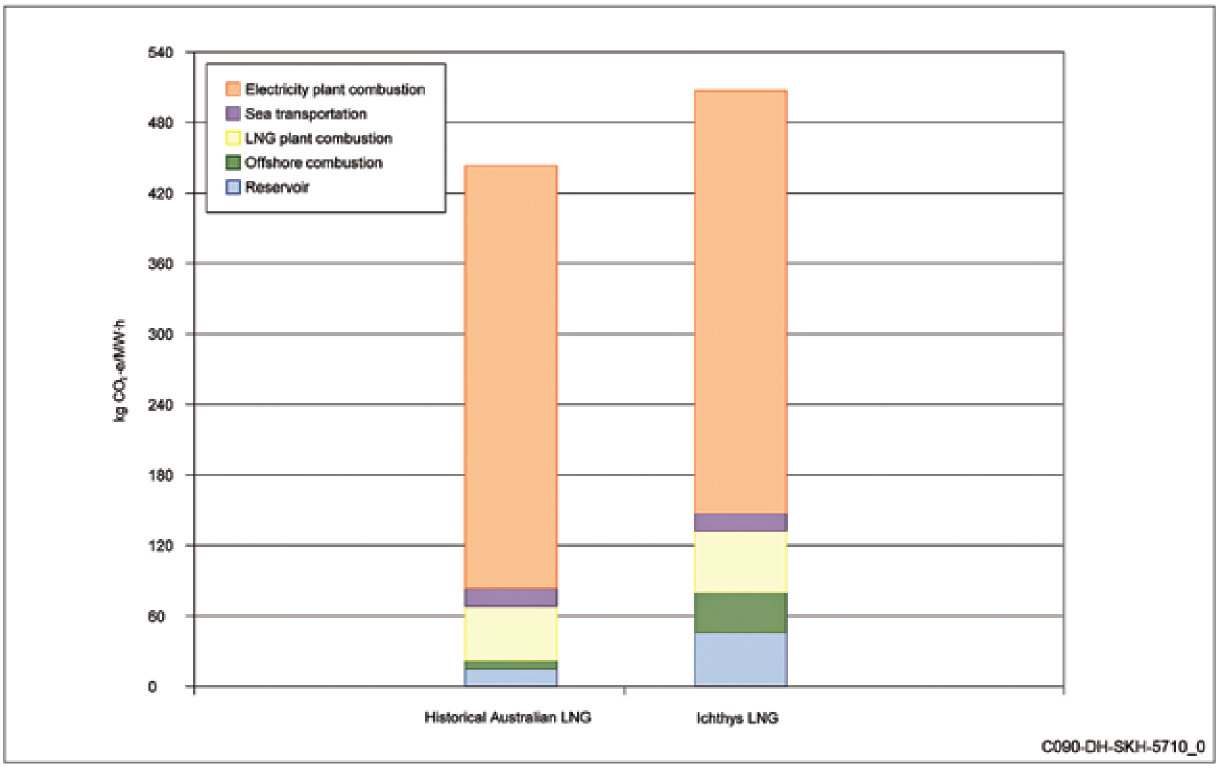
Figure 9-8 reflects the fact that the Ichthys Field's Brewster and Plover gas reservoirs have higher reservoir CO_2 levels than the gas fields that have historically supplied other LNG plants both in Australia and elsewhere. In addition, the Project will need relatively energy-intensive offshore facilities because of a combination of factors: deeper water at the field location, a greater distance between the field and the LNG plant, and the need to remove condensate from the gas at the offshore facility.

These two factors—higher reservoir CO_2 and the requirement for more energy-intensive offshore facilities—mean that the Ichthys Project will emit more CO_2 per unit of LNG or total liquid hydrocarbon produced than other projects undertaken so far, even though efficient technologies have been specified for both offshore and onshore operations, as evidenced by the mitigation technology comparisons made in Table 9-4. Future projects around the world, including

Table 9-4: Comparison of technologies employed by existing and planned major LNG plants worldwide

Project	Capacity (Mt/a)	Commissioning date	Reservoir CO_2 (mol %)	Aeroderivative turbines		Combined-cycle gas turbines		Waste-heat recovery		aMDEA solvent
				Process	Power	Process	Power	Process	Power	
Ichthys LNG	8.4	*c.*2016	8 Brewster 17 Plover	No	Under consid-eration	No	Under consid-eration	Yes	Under consid-eration	Yes
Gorgon LNG	15	*c.*2013	14 Gorgon 0.5 Jansz	No	No	No	No	Yes	No	Yes
Pluto LNG	4.2	*c.*2010	1.7	No	No	No	No	Yes	Yes	Yes
Karratha gas plant (train 5)	4.5	2008	<2	No	No	No	No	Yes	No	Yes
Snøhvit, Norway	4.3	2007	5.7	Elec-trical drive	Yes	Elec-trical drive	No	Yes	No	Yes
Darwin LNG	3.7	2006	6.0	Yes	No	No	No	Yes	No	Yes
Karratha gas plant (train 4)	4.5	2004	<2	No	Yes	No	No	Yes	No	Yes
Atlantic LNG	15.1	2005	0.8	No	No	No	No	Yes	No	No
Oman LNG	6.9	2001	1.0	No	No	No	No	No	No	Yes (No)*
Nigeria LNG	6.1	2000	1.8	No	No	No	No	No	No	Yes
RasGas, Qatar	6.4	1999	2.3	No	No	No	No	No	No	No
Qatargas (trains 1–2)	4.8	1993	2.1	No	No	No	No	No	No	No
Karratha gas plant (trains 1–3)	7.5–8	1989 (trains 1–2); 1992 (train 3)	<2	No	No	No	No	No	No	Yes (No)*

* Not originally, but currently Yes.



Adapted from APPEA 2009, J.P. Morgan Equity Research 2008, and Pace 2009.

Figure 9-8: CO_2-e emission benchmarking on the basis of electricity generated per MW·h

those in the Browse Basin, are likely to more closely resemble the Ichthys Project than already operating projects. They will often have higher CO_2 content in their feed gas and they will be located in deeper water in more remote locations.

The following subsections elaborate further on expected Project GHG emissions compared with the GHG emissions of other LNG facilities.

Reservoir CO_2

As Table 9-4 shows, the Brewster and Plover reservoirs have high CO_2 content in comparison with other currently producing gas fields in Australia and around the world. Most other existing LNG projects have had access to gas supplies with low reservoir CO_2 content. There is a general trend towards higher CO_2 content in reservoir gas between the early 1990s and projects planned for the future.

Offshore combustion emissions

Figure 9-8 and Table 9-2 also show the significance of needing energy-intensive offshore facilities.

The Project's requirement to have an offshore FPSO for the treatment, storage and offloading of condensate and for the separation and regeneration of large quantities of MEG from produced water to prevent hydrate formation increases the overall energy needs offshore and also increases CO_2 emissions from offshore. These sorts of technical issues combine to make the Project's offshore emissions comparatively greater than those of existing projects.

Onshore combustion emissions

The Ichthys Project will have emissions from its onshore gas-processing plant very similar to other LNG projects on the basis of megatonnes of CO_2 emitted per megatonne of LNG produced—this is to be expected. Over their lifetimes, most large LNG projects will emit roughly 0.4 Mt/a of CO_2-e from compressor-driver and power generation turbines (together with minor emissions from other sources) in order to liquefy each megatonne of natural gas into LNG. This is equivalent to saying that, worldwide, most large LNG facilities will on average use roughly 10% of the incoming gas to liquefy and export the remaining 90% as LNG. The 10% of gas used is combusted to CO_2 and emitted in turbine and other exhausts[6].

6 The molecular weight of CO_2 is 44. Assuming that the fuel gas is CH_4 (methane) with a molecular weight of 16, then combusting 0.1 Mt of fuel gas to liquefy 0.9 Mt of gas into LNG will generate (0.1 × 44)/16 = 0.275 Mt of CO_2. This 0.275 Mt of CO_2 divided by 0.9 Mt of LNG gives a ratio of 0.31. This ratio is typical at the plateau of LNG production. Later in facility life, CO_2 emissions per megatonne of LNG produced will increase. Factoring in this decreasing efficiency and other minor GHG sources (such as fired heaters, incinerators and flares) yields an average lifetime onshore plant efficiency of roughly 0.4 Mt of CO_2 per megatonne of LNG.

The efficiency is better in the early years when production will plateau—around 7–8% will be used to liquefy the remaining 92–93%. But efficiency will fall away later in field life as most equipment will need to keep running even as LNG production gradually declines.

Sea transportation and electricity-plant combustion emissions

For the purposes of comparing expected Ichthys Project CO_2 emissions with those of other Australian LNG projects, sea transport (ship fuel) and efficiencies at gas-fired power stations in Asian markets will not be a distinguishing factor. These factors, however, can be large if LNG is compared with coal, as described in the following subsection.

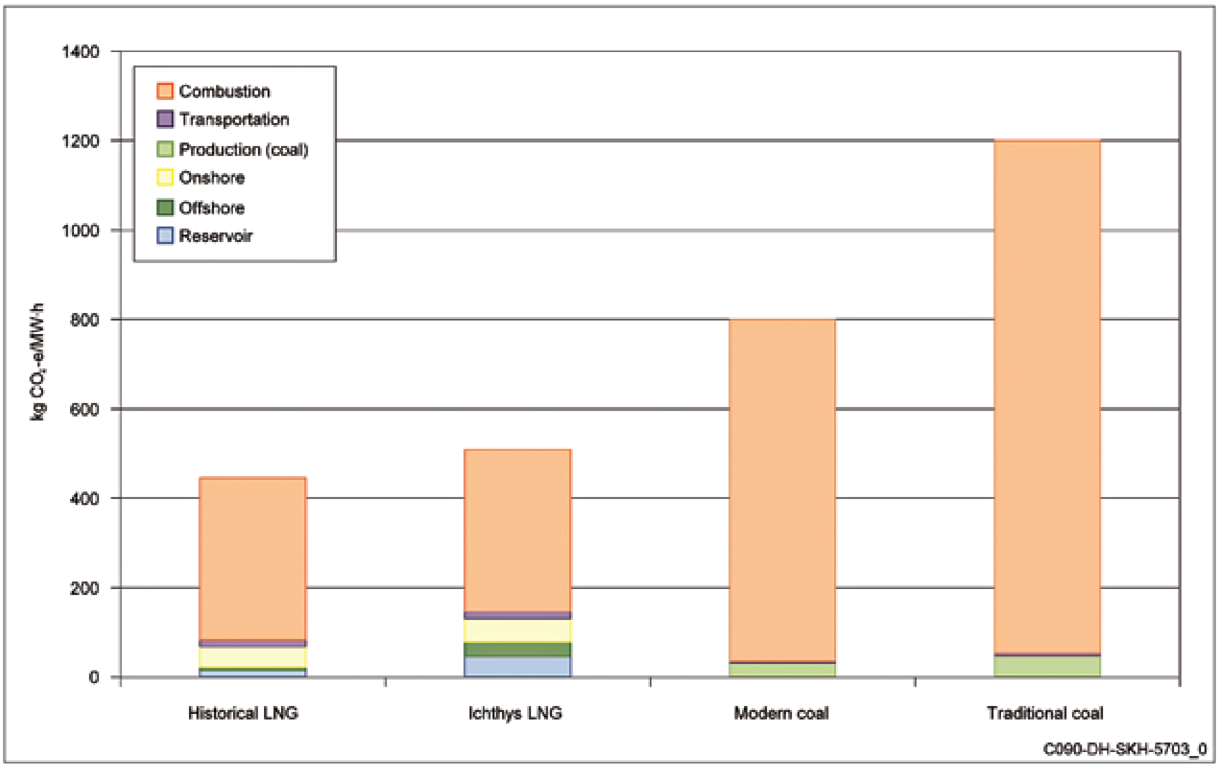
Ichthys LNG shipped from Darwin to Asian markets traverses a similar distance when compared with LNG from the Darwin LNG plant, the North West Shelf Project, or the various other projects presently under development in Western Australia, the Northern Territory and Queensland. Differences in efficiencies between different gas-fired power plants in Asia and elsewhere are also outside INPEX's control.

9.10 Greenhouse gas impacts of using LNG instead of coal for electricity generation

Use of LNG as an energy source has a number of advantages. The primary advantage is that the quantity of GHGs emitted over the full life cycle (production, processing, transportation, and combustion at end use) is significantly less than the comparable life-cycle emissions from either coal or fuel oil, as a means of delivering the same amount of energy.

Figure 9-9 illustrates a life-cycle GHG emission comparison for the use of LNG and coal to generate the same amount of electricity.

This figure shows that even if there were to be a factor of two or three differences in production, processing, and transportation efficiencies between different LNG projects, and if these emissions were not offset, the overall impact would be relatively minor compared with the end-use combustion efficiency difference between LNG and coal. This is attributable to a number of factors. Combustion of natural gas is more thermodynamically efficient that the combustion of carbon on a weight basis. In addition, natural gas, when regasified from LNG, contains essentially no water or inerts. In contrast, coal can contain significant amounts of water and inerts. The water and inerts all need to be heated in a power-plant boiler in the electricity generation process and there is an overall loss of efficiency.



Sources: adapted from APPEA 2009, J.P. Morgan Equity Research 2008, and Pace 2009.

Figure 9-9: Life-cycle CO_2-e emissions from the use of LNG and coal to produce electricity

Electricity produced from LNG generates 40–60% less CO_2 than electricity produced from coal. Every tonne of LNG used to generate electricity averts the emission of up to 4 t of CO_2 when compared with coal-fired electricity generation. Ichthys LNG will be marketed to the Asia-Pacific region and will in large part be used for power generation. In a global context, the use of Ichthys LNG to generate electricity in Asia will therefore likely result in a significant reduction in CO_2 emissions.

9.11 Carbon sequestration alternatives (offsets)

The Commonwealth Government's Carbon Pollution Reduction Scheme White Paper defines carbon sequestration as "the long-term storage of carbon dioxide in the forests, soils, oceans or underground in depleted oil and gas reservoirs, coal seams and saline aquifers" (DCC 2008).

Carbon sequestration can be an effective strategy for mitigating GHG emissions and INPEX is undertaking detailed evaluation of both biosequestration and geosequestration options. Sections 9.11.1 and 9.11.2 provide a summary of the benefits and risks of these options and summarises the work undertaken to date and planned into the future to continue the evaluation.

9.11.1 Biosequestration

Biosequestration is a means of offsetting CO_2 emissions by planting trees which "lock" the carbon in atmospheric CO_2 into plant biomass through photosynthesis at one location while CO_2 emissions to atmosphere are taking place at another. In this way, trees store carbon in their roots, trunk, branches and leaves. They are, in effect, a "carbon sink".

An advantage of biosequestration is that it can often include secondary benefits such as biodiversity improvement, soil salinity remediation and water quality and quantity improvement. Plantings in farming regions can also significantly reduce soil erosion caused by both wind and rainfall. Plantings can also attract social benefits such as providing additional income for farmers and rural communities, offering increased opportunities for Aboriginal employment and contributing to regional economic development. The industry, however, is in its infancy and there are currently only a limited number of accredited service providers available in the Australian market. There are, however, extensive tracts of Kyoto-compliant land suitable for plantings, particularly in temperate regions of Australia and relatively large plantings for biosequestration purposes are already in place. Most plantings focus on mallee eucalypts as they grow rapidly (even in lower rainfall areas), have high resistance to drought, pests and diseases, and can recover rapidly after fire.

Biosequestration risks include limitations on nursery space for raising seedlings and planting capacity of accredited service suppliers. It is also important to understand the potential errors in actual, versus predicted, carbon sequestration rates. Reliable data for growth rates of many species in different soil and rainfall conditions are limited and predictions are based on growth-rate models. In addition, taxation rules are yet to be clarified for this industry and this provides considerable uncertainty in comparative commercial evaluation with other GHG offset options.

It is a commercial necessity that extensive due-diligence and risk-assessment exercises are conducted prior to committing to any large-scale biosequestration option. To this end INPEX is conducting such exercises on potential service suppliers and has initiated a biosequestration assessment project which will provide vital information on details such as seedling survival rates, tree growth rates and logistic and operational factors relating to large-scale plantings.

Biosequestration assessment project

In order to more fully understand the potential for biosequestration, INPEX initiated a biosequestration assessment project in 2008, with an indicative budget of A$4.6 million, to trial plantings of two species of mallee on previously cleared farmland in Western Australia. This pilot project is expected to offset over 450 000 t of CO_2-e over 40 years through the planting of approximately 1.4 million trees.

The assessment project was established on a suitable scale to fully test the capacity of potential service providers and the chosen contractor's management abilities to source appropriate land, establish seedling supplies and mobilise labour. Most importantly, the trial will also be able to provide vital information on actual versus predicted seedling survival and tree growth rates. To date approximately 650 ha of *Eucalyptus loxophleba* (York gum) and *E. polybractea* (blue mallee) have been planted in south-west Western Australia.

INPEX is encouraging new service providers to enter the market and welcomes the introduction of a wider range of tree species for biosequestration plantings to improve biodiversity benefits. A number of smaller areas on the lands planted out for the biosequestration assessment project were cleared after 31 December 1989 and were therefore not suitable for plantings compliant with the Kyoto Protocol. INPEX has planted mixed species in these areas including *Eucalyptus wandoo* (wandoo), *E. occidentalis* (flat-topped yate), *E. marginata* (jarrah), *E. rudis* (flooded gum), *E. cornuta* (yate), *Corymbia calophylla* (marri), *Acacia acuminata* (jam wattle), and *A. saligna* (orange wattle). These species will provide biodiversity improvements and allow information on the growth and carbon sequestration rates of a broader range of species to be determined.

INPEX has also met with representatives from the Northern Territory Government to identify biosequestration opportunities in the Territory and will continue to evaluate these opportunities.

Aboriginal cooperation—improved savannah burning practice

ConocoPhillips currently has engaged in a project with local Aboriginal people in the Northern Territory to foster amended or improved savannah burning practices across the West Arnhem Land Plateau.

CSIRO research has shown that fires early in the dry season generate far less GHG than the bigger and hotter fires that occur later. The difference in emissions is now being measured by the West Arnhem Land Fire Abatement Project partnership, which means people in northern Australia can reduce climate-change pollution by managing fire better.

Originally developed to reintroduce traditional Aboriginal bushfire management to the plateau and to get local Aboriginal people back to the land, this unique partnership of Aboriginal expertise, fire-management science and private enterprise is now delivering a substantial income to traditional landowners, reducing GHG emissions and providing a carbon offset for a large LNG plant in Darwin.

Although these efforts would not be recognised as offsets under the currently proposed CPRS, INPEX sees involvement in such schemes as regionally beneficial both from a social and from an environmental perspective.

9.11.2 Geosequestration

Geosequestration of CO_2, also known as carbon (dioxide) capture and storage, is the process of capturing CO_2 from industrial processes and injecting it deep underground for long-term storage in secure geological formations. The primary purpose is to reduce GHG emissions to the earth's atmosphere. Geosequestration may offer significant promise for reducing the net greenhouse emissions from oil & gas projects.

Geosequestration is best suited to applications where there are significant point-source GHG emissions such as industrial processing (including LNG production), electricity generation, and petroleum operations and where there is a suitable geological formation or storage reservoir nearby.

The most obvious advantage of geosequestration is that provided the correct geology can be identified, it allows for long-term disposal of CO_2 into geological reservoirs. It also avoids utilising a potentially limited resource—land—for acquitting carbon permit liabilities.

Disadvantages include high costs both for evaluating suitable disposal locations and for the necessary infrastructure to facilitate reinjection. In addition, significantly more energy use is required for capture, transport, injection and monitoring. Legislation has only recently been passed to facilitate carbon storage in Commonwealth waters and a corresponding offshore acreage release process has started. No legislation had been prepared at the time of writing to facilitate carbon capture and storage in Northern Territory and Western Australian lands and waters. Taxation and liability issues remain uncertain, adding to the commercial uncertainty of the geosequestration option.

Geosequestration research and technology

Although geosequestration of CO_2 is a relatively new concept, much of the technology that is required in a CO_2 injection system is being applied in a range of industries, including the oil & gas industry. The drilling and operating of injection wells is currently being used for enhanced oil recovery, including *c*.20–30 Mt/a of CO_2 being injected for enhanced oil recovery in the United States and about 1.7 Mt/a of CO_2 being reinjected from the Sleipner field in the North Sea and the Snøhvit field in the Barents Sea.

In Australia, the Gorgon Joint Venture decision to geosequester the reservoir CO_2 on Barrow Island off the north-west coast of Western Australia has initiated the largest CO_2 geosequestration project in the world. The Gorgon project plans to reduce emissions from the project by *c*.3.36 Mt of CO_2-e per annum by injecting CO_2 into an aquifer underlying the joint venture's LNG plant on Barrow Island (Chevron 2008).

In addition, there are research programs being conducted around the world to investigate the viability of CO_2 injection underground. INPEX is a strong supporter of research programs such as Australia's Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC) and Geoscience Australia, both of which are undertaking geosequestration research. In addition, INPEX has joined the Global Carbon Capture and Storage Institute, an Australian-sponsored global initiative that seeks to promote emerging technologies in carbon capture and storage on an industrial scale to enable quick uptake of these technologies by industry.

Assessment of potential CO_2 injection site

INPEX has established a dedicated team to evaluate disposal of reservoir CO_2 by injection into a subsurface formation.

For geosequestration of CO_2 into a potential sink reservoir to be successful in the long term, a number of geological criteria must be satisfied. The reservoir must have:

- sufficient capacity—the reservoir must have sufficient volumetric storage capability, together with a conservative safety margin, to ensure that a build-up of pressure would not compromise the integrity of the reservoir seals
- sufficient permeability—the geology must include an appropriate combination of a sandstone and, where appropriate, another porous lithology reservoir
- sufficient security—there must be a low risk of migration out of the reservoir; the sealing horizon must be demonstrated from capillary pressure measurements (or field tests) to be fundamentally impervious to vertical CO_2 migration (typically claystone or shale, whether calcareous or non-calcareous)
- sufficient depth—the depth must be great enough to ensure that the CO_2 enters into a dense liquid state (supercritical), thereby maximising the storage potential of the injection reservoir.

Other considerations are the desirability of minimising the distance from the CO_2 capture point for operability and economic reasons and to reduce the energy required (and therefore further GHG emissions) to export and inject the CO_2.

As both the onshore and nearshore areas near Darwin have unsuitable geology for geosequestration purposes, suitable reservoirs would need to be identified some distance from the onshore processing plant at Blaydin Point.

Should a potentially suitable area be identified, evaluation using the existing available geological information would need to be undertaken to determine whether or not the area would meet key geological and technical requirements. If the criteria were met, exploration could be undertaken to further evaluate the potential sink reservoir, after successfully bidding for an associated carbon capture and storage permit.

Current assessment of the geosequestration option indicates that the cost could be prohibitively high because of the remoteness of potential injection locations from the LNG plant. Substantially more work is required before the technical suitability of injection locations can be demonstrated. Nevertheless, INPEX continues to investigate this option and may consider its implementation if technical feasibility and commercial viability can be established.

Conceptual geosequestration infrastructure

As the reservoir CO_2 will be extracted from the gas stream at the onshore gas plant, a pipeline would need to be installed between the onshore gas plant and an injection facility in the target area.

A conceptual injection facility would consist of either an offshore wellhead platform or subsea-completed wells. One or more injection wells capable of meeting injectivity requirements for disposal of reservoir CO_2 would be required, along with one or more observation wells, to monitor the movement and dispersion of the CO_2 plume within the geological formation. It is expected that approximately 70 MW of additional power would be required at the onshore processing plant for the purpose of dehydrating, compressing and transporting the reservoir CO_2 to the injection site. The onshore processing plant plot area contains sufficient space to allow for the future collection, dehydration, compression and transport of reservoir CO_2 for a potential geosequestration option.

9.12 Summary of greenhouse gas abatement measures

There are a number of alternatives available to INPEX for GHG management, all with varying costs and risks. As the policy landscape is still evolving and legislation is yet to be finalised, INPEX is exploring all practical alternatives in order to be well prepared to respond once legislative requirements become clear. To this end INPEX is developing a portfolio of GHG mitigation opportunities, which may afford the lowest risk and cost approach for the Project, and avoid a reliance on any single solution. The main opportunities under evaluation include the following:

- the adoption of additional engineering abatement techniques (e.g. the incorporation of energy-efficiency measures into the design)
- biosequestration (carbon capture through tree plantings)
- geosequestration (permanent storage of reservoir CO_2 into underground reservoirs)
- the purchase of offset credits on the open market.

Prior to starting the commissioning of the off- and onshore facilities, INPEX will produce a detailed GHG management plan that will provide an updated GHG emission forecast and consolidate plans for technical abatement and offset measures.

A Provisional Greenhouse Gas Management Plan has been provided as Annexe 8 to Chapter 11 *Environmental management program*.

9.13 Impacts of climate change

International climate-change scenarios predict higher temperatures, more droughts and floods, rising sea levels, and more extreme weather events.

More specific to the Northern Territory, the following impacts are predicted:

- an increase in average annual temperatures
- a rise in sea level
- an increase in storm-surge inundations.

The influence of these factors has been or will be incorporated into Project designs. For example, the LNG plant will be built at least 7 m above Highest Astronomical Tide (HAT) to protect against the possibility of gradually increasing seawater levels and storm surges expected over the 40-year life of the facility. This basis assumes a 1-in-1000-year storm event, together with a 0.2 m allowance for global warming and an additional 0.3 m for contingency. In addition, the fin-fan coolers used to remove waste heat from the LNG plant's liquefaction refrigerant loops have a 2 °C temperature margin built in to take into account a combination of hot-air circulation and gradually increasing ambient temperatures between now and the end of the Project.

9.14 Summary

- The Ichthys Project supports reduction of global GHG emissions by displacing more emission-intensive fuels, such as coal or oil, for power generation in Asia.
- The proposed Ichthys facilities incorporate technologies and design practices that will ensure that energy is utilised efficiently and that GHG emissions are minimised.
- The Ichthys Project will comply with any legislation introduced in Australia to manage GHG emissions, such as the proposed Carbon Pollution Reduction Scheme, by acquiring permits for CO_2 emissions.
- Geosequestration of reservoir CO_2 is under investigation but requires further definition. The remoteness from Darwin of potentially suitable injection sites identified to date may make the costs of such a scheme prohibitive.
- INPEX initiated a reforestation pilot project in 2008 to gain an understanding of the potential of biosequestration for offsetting CO_2 emissions.
- INPEX continues to assess GHG abatement options in order to define an appropriate plan to manage GHG emissions, taking into account the costs and risks associated with each option.

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10 Socio-economic impacts and management

10 SOCIO-ECONOMIC IMPACTS AND MANAGEMENT

10.1 Introduction

This chapter of the draft environmental impact statement (Draft EIS) describes the potential impacts of the Ichthys Gas Field Development Project (the Project) on the community in the vicinity of the development areas in and around Darwin Harbour, as well as on the wider regional economy.

The socio-economic impact assessment provided here includes discussion of the significance of potential impacts on a local and regional scale and presents management controls that would be implemented by INPEX to mitigate these impacts. While the assessment has focused mainly on social and community impacts in the Darwin region, consideration has also been given to the users of the offshore development area (such as commercial fishing operators) as well as to the broader Australian community, which will benefit from the economic flow-on effects generated by the Project.

A process of residual-risk assessment (explained in Chapter 6 *Risk assessment methodology*) has been applied to the social and economic impacts described in this chapter in a similar way to the methods applied to the physical and biological impacts discussed in Chapter 7 *Marine impacts and management* and Chapter 8 *Terrestrial impacts and management*. However, the socio-economic aspects of the Project's operating environment are complex, and are affected by a number of factors that are outside the direct influence of the Project. For example, the local labour market will vary according to national and international economic conditions, making the consequences of the Project (which would be a relatively large employer in the Darwin region) difficult to predict.

In addition, the consequences of certain socio-economic impacts are sometimes highly subjective and would be rated differently by different people. The consequences of reduced access to recreational fishing areas, for example, would be rated highly by those that participate in the activity and lower by those that do not. Similarly, the consequence of the Project employing large numbers of personnel in the Darwin region could be seen as a positive opportunity for employees, but a negative impact by other businesses seeking to attract or retain personnel.

For these reasons, "risk-ranking" has not been undertaken for some of the socio-economic aspects presented in this chapter. Potential impacts have been identified for all socio-economic aspects of the Project that could affect the community, and management commitments have been developed to mitigate negative impacts and maximise benefits.

Management of some socio-economic aspects (e.g. traffic and heritage) will be implemented through the Project's Health, Safety and Environmental Management Process, which is consistent with the principles of the International Organization for Standardization's ISO 14000 environmental management series of standards. This comprehensive, auditable system will provide a structured approach to environmental management and is described in Chapter 11 *Environmental management program*.

10.2 Social impact assessment methods

In order to gauge community values and opinions on the potential impacts of the Project, a social impact assessment was carried out from June to September 2008. Interviews were conducted with a number of stakeholder groups, including government authorities, business and community groups (see Chapter 2 *Stakeholder consultation*). A representative sample of stakeholders was selected in an effort to canvass as broad a range of perspectives on the Project as possible.

These stakeholder interviews provided INPEX with a deeper understanding of the local issues, values and identified key community concerns associated with the development of the onshore processing plant. In addition to this, interviews assisted in gauging the acceptability of the potential management controls for socio-economic impacts in terms of the ability to reflect local values and priorities and satisfy the needs of the local community.

Ongoing community consultation, throughout the development of this Draft EIS, has further informed this social impact assessment. A full list of stakeholders consulted to date is provided in Chapter 2.

It should be noted that the environmental and social impacts associated with the development of the accommodation village are assessed under a separate approval process. To support this approval submission, consultation with the local community and other key stakeholders has been undertaken on the potential social impacts associated specifically with the location and function of the accommodation village and with the interactions of village residents with the community. Where relevant, feedback from the consultation process and identified management and mitigation outcomes have been included in this chapter.

Summary of key issues identified during stakeholder consultation

Key socio-economic issues identified during the stakeholder consultation and which are addressed in this chapter include the following:

- concerns regarding the social integration of Project personnel with the community (Section 10.3.1)
- the potential impacts of an increase in population on the housing market, existing community services and social infrastructure, and the existing road system (sections 10.3.2, 10.3.3 and 10.3.4 respectively)
- the potential impacts on recreational activities, such as fishing and diving, in Darwin Harbour (Section 10.3.7)
- the potential impacts on Aboriginal and non-Aboriginal cultural and heritage values associated with the nearshore and onshore development areas (sections 10.3.8 and 10.3.9)
- the potential impact of the reduction in visual amenity associated with the development of the Project's onshore facilities (Section 10.3.11)
- concerns regarding public safety in Darwin Harbour and its surrounds (Section 10.3.14)
- the impacts of the Project's labour requirements on the local employment market (Section 10.4.3)
- the potential impacts on the commercial fishing and aquaculture industries in the nearshore and offshore development areas (Section 10.3.12).

In addition to the issues identified during the community consultation process, INPEX has noted additional areas of potential socio-economic impact. These have also been assessed in this chapter and include the following:

- potential impacts on non-Project-related maritime traffic generated during the construction and operations phases of the onshore facilities (Section 10.3.5)
- potential impacts on air traffic passing over the onshore development area during the operations phase (Section 10.3.6)
- potential impacts from noise generated at the onshore development area during the construction and operations phases (Section 10.3.10).

10.3 Social impacts and management

This section describes the range of potential positive and negative social impacts of the Project on the community in the Darwin region. It presents the management controls proposed to reduce or mitigate the negative impacts and to optimise the opportunities presented by the Project.

10.3.1 Social integration

Darwin and Palmerston are considered socially well equipped to absorb an increase in people from other areas of Australia and from overseas. The region has experienced significant population movement over a long period and, as described in Chapter 3 *Existing natural, social and economic environment*, is relatively diverse and multicultural.

Consultation with stakeholders highlighted a number of concerns about potential social issues arising from the influx of the 2000–3000 predominantly male construction personnel required for the Project. This includes the potential for antisocial behaviour to impact on the quality of life enjoyed by the local community and visitors.

Project personnel who choose to reside in the wider community cannot as easily be held accountable for unacceptable social behaviour outside working hours as can those living in the more controlled environment of a company-owned accommodation village. While antisocial behaviour cannot be avoided at all times, the implementation of company strategies or policies designed to deal with socially unacceptable behaviour outside working hours can assist in minimising incidents.

As discussed in Chapter 4 *Project description*, it is proposed that an accommodation village be built to house the majority of construction personnel. The preferred site is at Howard Springs to the east of Palmerston. From the point of view of social integration, the proximity of this village to the local community and the inclusion of recreational facilities in its design have the potential to result in both positive and negative impacts.

Most of the businesses in this area have expressed the view that the proximity of the village would yield benefits directly from the flow-on effect of residents using their services or facilities (Hatch Infrastructure 2009). However the use of these services as a result of community integration may also result in pressure being placed on some business services or facilities, for example on local taverns, food outlets and sporting facilities. This in turn could affect service times or availability of services to local patrons or users.

Management of social integration

The management controls to be implemented to assist in minimising the potential impacts associated with the integration of the workforce into the community include the following:

- INPEX personnel representing the Project will be expected to exhibit professional standards of behaviour as required by INPEX's Code of Conduct. Through the Project induction all personnel will be informed of the expectation that they will respect the community of the Darwin region at all times and behave accordingly.
- Project personnel will be subject to random drug and alcohol testing, which will assist in discouraging heavy drinking or other antisocial behaviour outside working hours.
- It is intended that the accommodation village will include a number of restaurants and licensed premises as well as a range of social and recreational facilities; these amenities will assist in reducing pressure on the existing facilities presently enjoyed by the local community.
- A code of conduct for the village residents will be developed and implemented.
- The preferred location for the accommodation village was selected in consultation with local government authorities and the Department of Planning and Infrastructure (DPI)[1], and will be designed and operated with consideration for reducing potential social impacts on the local community.
- A Stakeholder Communication Plan (see Chapter 2) has been developed; this will create an avenue for the broader community to raise Project-related social issues and other matters and will be updated as required. Other avenues stakeholders can use to raise concerns about social issues and other impacts include the INPEX 1800 information line (1800 705 010) and the company's web site at <http://www.inpex.com.au>.

In addition, however, it is thought that the longer working hours required of Project workers will discourage workers from patronising hotels and bars after hours during their rostered periods of work at Blaydin Point. While it is anticipated that large numbers of local people will be employed during the construction phase, it is likely that the greater part of the construction workforce will be recruited on a fly-in, fly-out basis, and that most of these workers will return to their home states during their time off.

1 The Northern Territory's Department of Planning and Infrastructure was restructured in December 2009 and its functions were transferred to two new departments, the Department of Lands and Planning (DLP) and the Department of Construction and Infrastructure.

Residual risk

It was considered that the risk assessment process could not provide a realistic outcome for social integration, as both the likelihood and consequence of potential impacts on the community are very much dependent on individual actions and circumstances. It should be noted, too, that while integration of the workforce into the broader Darwin community may be seen as a good thing by some members of the community, it may be perceived less positively by others. INPEX will implement the management approaches described above and in Table 10-1 in order to manage the social effects of integration of its workforce and the community as effectively as possible.

10.3.2 Housing

Through the consultation process, stakeholders indicated their clear concern that the Project, particularly during the construction phase, would place significant pressure on Darwin's housing market. These concerns have their origin in the stakeholders' previous experience of major projects in the Darwin region that created periods of rapid population growth which had immediate impacts upon local housing affordability and availability. The concern is compounded by the fact that the local housing market is currently constrained.

Limited availability of property for purchase or rental, combined with strong growth in both wages and population figures, has resulted in substantial increases in sale prices and rentals over the past three years. In March 2009, Darwin's median house price was $490 300 and the median unit price was $362 085, representing increases of 6.23% and 18.77% respectively since March 2008. This continued growth contrasts significantly with performance in other Australian capital cities, which almost all saw decreases in median prices over the same period (Propell National Valuers 2009).

Darwin's rental market is also under pressure, with a vacancy rate of 2.1% in the first quarter of 2009. The average weekly rent for a two-bedroom unit in Darwin decreased at the beginning of 2009, but still increased by 14.28% during the year to March 2009 (Propell National Valuers 2009).

Housing affordability in Darwin will continue to be a key issue, as population growth is anticipated to outstrip the supply of new properties into the market. During the first quarter of 2009, for example, Darwin's population grew by 3319 or 2.83%, compared with a national increase of 1.71% (Propell National Valuers 2009). Furthermore, the population of the greater Darwin region (including Palmerston) is projected to increase between now and 2012 by 19 000 people to

Table 10-1: Summary of impact assessment and residual risk for social integration

Aspect	Activity	Potential impacts	Management controls and mitigating factors	Residual risk
Social integration	Recreational activities of construction workforce.	Increase in antisocial behaviour at local recreational venues such as hotels and bars.	Personnel representing the Project will be expected to exhibit professional standards of behaviour as required by the INPEX Code of Conduct. Project personnel will be subject to random drug and alcohol testing. A code of conduct for the residents of the accommodation village will be developed and implemented. The longer workhours required from Project personnel may discourage workers from attending facilities such as hotels and bars outside the accommodation village after hours. The accommodation village will include facilities such as licensed restaurants and bars, which may reduce the use of existing local facilities by the construction workforce. A large proportion of construction workforce is likely to be recruited on a fly-in, fly-out basis, with the majority of personnel returning home during their time off.	Not applicable
Social integration	Recreational activities of construction workforce.	Increase in pressure placed on social venues such as sporting facilities, food outlets, and taverns.	The accommodation village will include a number of licensed restaurants and a range of social and recreational facilities will be established for the benefit of the residents. This will assist in limiting the pressure placed on existing facilities enjoyed by the local community. Ongoing consultation with the community will be undertaken to monitor the extent and impact of workforce integration.	

an estimated total of 133 000, with a further projected increase of 63 000 people between now and 2030. The Northern Territory Government anticipates that it will need to provide approximately 1700 new dwellings per year (Henderson 2009).

Management of housing

In order to minimise the impact of the construction workforce (which may number between 2000 and 3000 people) on the local housing market, INPEX has made the decision to establish an accommodation village to house the majority of its workforce during the construction phase. It is intended that the village will be seen as a desirable place for workers to live and it will be designed to cater for a wide range of people, both singles and couples. It is likely that only a minority of Project employees will choose to live in the broader Darwin community.

Around 300 personnel will be required during the normal operations of the onshore processing plant at Blaydin Point, with a larger number of workers required for the necessary periodic maintenance campaigns. An accommodation strategy is being developed to identify and investigate accommodation requirements and options for the operations phase.

The accommodation strategy will also identify and investigate other Project accommodation requirements, including housing solutions for personnel who will visit the onshore Project area on a short-term basis during the construction phase.

Accommodation options will give consideration to avoiding the imposition of additional pressure on the local housing market, while maximising the opportunities to attract and retain suitable employees.

Table 10-2: Summary of impact assessment and residual risk for housing

Aspect	Activity	Potential impacts	Management controls and mitigating factors	Residual risk
Housing workforce	Accommodation requirements for the construction workforce in the Darwin area.	Increased pressure placed on an already difficult housing market.	An accommodation village will be constructed to house the greater part of the construction workforce. It is intended that this village will be seen as a desirable place to live and it will be designed to cater for a wide range of people, both singles and couples. An accommodation strategy is being developed to address accommodation solutions for regular Project personnel as well as for short-term visitors during the operations phase (including teams brought in to carry out periodic maintenance operations).	Not applicable

Residual risk

It is not considered practical to apply risk assessment to the effects of the Ichthys Project on the Darwin housing market. The "consequence" of any potential impact would be considered differently by different community members—those who own property may perceive a rise in property values positively, while those wishing to buy property would view rising prices negatively. Further, wider economic conditions also affect property values and could change the "likelihood" of an impact on the local market attributable to the Project. INPEX will implement the management approaches described above and in Table 10-2 in order to manage the potential impacts of the Project on the housing market as effectively as possible.

10.3.3 Key social infrastructure and services

Social infrastructure and services that are of a communal, human or social nature will progressively be required as a community grows. The following sections discuss the potential impact on the "key" social infrastructure and services throughout the construction and operations phase of the Project. These include health services, emergency services and utilities infrastructure and services. Other potential impacts on social infrastructure and services such as the effects of the Project on housing, the effects of Project-related traffic on public roads, and the effects of Project navigation channels in Darwin Harbour, are discussed in sections 10.3.2, 10.3.4 and 10.3.5 respectively.

Key social services

Health services

Consultation with the Northern Territory's Department of Health and Families (DHF) indicated that the Royal Darwin Hospital currently has adequate capacity to cope with a possible influx of Ichthys Project personnel for high-level emergency cases (i.e. those at imminent risk of death or at high risk). The DHF's representatives, however, believed that triage services at present would be pushed to capacity with any large influx of Project personnel (Hatch Infrastructure 2009). The budget for 2009–2010 shows that funding ($421 million) has been allocated to improving hospital services in the Northern Territory; this includes an allocation of $5.08 million in Commonwealth funding which will be dedicated to reducing pressure on emergency departments. The Royal Darwin Hospital has been allocated $245 million of this budget (Northern Territory Government 2009). The DHF representatives suggested that with the upgrade of services as a result of funding it was likely that triage services would be able to cope (Hatch Infrastructure 2009).

In addition, to assist in alleviating some of these pressures in the Palmerston area the development of a new "superclinic" has been announced by the Northern Territory Government; Stage 1 of the clinic began operations in December 2008 (Vatskalis, K. (Minister for Health) 2009). The 2009 budget allocated $2 million towards the operation of this "hub" (Northern Territory Government 2009). The clinic will be a general-practice multi-service facility (i.e. with dental, general practitioner and other specialists), operating 24 hours a day and 365 days a year. The facility will not be an emergency service but will cater for urgent after-hours cases. Construction of the clinic was expected to be completed by mid-2010 (Hatch Infrastructure 2009).

As noted in Section 10.3.1, the greater part of the construction workforce is likely to be recruited under a fly-in, fly-out arrangement. Such personnel may prefer to use their own local (interstate) medical practitioners for general non-emergency medical matters, for example dentistry and health check-ups.

Emergency services

There are currently four ambulances servicing the Darwin area, one of which is located in Palmerston. Discussion with DHF representatives indicated that this level of service is less than what is provided per head of population in other parts of Australia and that the service was currently operating at or beyond its capacity (Hatch Infrastructure 2009). The recent budget has allocated funding ($960 000) to expand the ambulance service for Palmerston and surrounding areas (Northern Territory Government 2009). The DHF suggested that the Project should consider how it may assist in getting injured personnel to the Royal Darwin Hospital, given the substantial distances to be covered from both the onshore processing plant site and the preferred accommodation village location.

The Northern Territory Fire and Rescue Service (in conjunction with Bushfires NT) is the primary provider of fire and rescue services throughout the Darwin region. It is not anticipated that the Project, either during the construction phase or the operations phase, would place any pressure on either of these services during its normal operations. However in the event of a major emergency situation these services would have to be called upon.

In order to effectively plan for major emergency events such as cyclones and major accidents, INPEX will need to work with these existing emergency services to ensure that they have the capability and capacity to respond.

In addition to this, the onshore facility will need to be built to withstand the climatic conditions experienced in the Darwin region, for example, cyclones and storm surges. Fire-protection systems will need to be incorporated into the onshore processing plant design and the facility emergency response team will need to be able to act as the first responders in the event of a major emergency while waiting for outside assistance to arrive.

Utilities supply and infrastructure

As noted in Section 10.3.1, the environmental and social impacts associated with the development of the accommodation village will be assessed under a separate approvals submission. This submission will address any potential impacts on utilities infrastructure and services as well as identifying management solutions. For this reason the primary focus of this section is on the utilities infrastructure and services that may be affected as a result of the construction and operations of the onshore processing plant.

Power supply and infrastructure

Pressure on local power services and related infrastructure for the onshore Project is expected to be minimal during the construction phase and negligible during the operations phase.

The Northern Territory Government will be connecting construction headworks to the Blaydin Point site; this includes the supply of 22-kV·A overhead power to the Blaydin Point site from the Channel Island (or Weddell) power stations.

It is anticipated that diesel generators will be predominantly used to address power requirements for construction activities with some power from the Darwin grid required to support temporary construction buildings and lighting requirements.

Permanent power generation for the facility will be supplied by the main power generation turbines in the plant. Prior to these being installed and commissioned, power from diesel generators may be required, together with power from the Darwin grid. For this purpose, a transmission line may connect the facilities to the Northern Territory Government's power distribution system (operated by the Power and Water Corporation) at a point on Wickham Point Road. Distribution infrastructure, facilities and transformers may also be required. Once a permanent power supply has been established, some of the diesel generators will be available for standby service.

Water supply and infrastructure

The water supply required for both the construction and operations phases is likely to come from the existing water main located in the road reserve of Wickham Point Road, which connects into the Darwin water supply scheme through the McMinns Water Treatment Storage Facility. Current advice from the Northern Territory's Power and Water Corporation (PWC) has indicated that there will be sufficient capacity to accommodate the water demands of the Project without adversely affecting regional supplies.

Sewage infrastructure

Temporary ablution blocks will be put in place during the initial construction phase. As activities increase on site a temporary sewage treatment system will be installed. A permanent sewage treatment plant will be installed for the operations phase of the Project. Environmental impacts associated with wastewater discharge and sludge disposal from sewage treatment systems during the construction and operations phases are addressed in chapters 7 and 8. Pressure on the existing local mains sewerage infrastructure and services during both the construction and operations phases is considered to be negligible.

Landfill capability and capacity

Local waste-disposal capabilities catering for wastes generated during the construction and operations phases will be addressed during the detailed design phase of the Project. This will be done in consultation with the relevant local-government authorities.

Management of key social infrastructure and services

The following key management controls will be implemented to minimise the potential impacts on social infrastructure and services in the Darwin region.

Social services

- A first-aid capability will be available at the onshore development area during both the construction and the operations phases. In addition, a similar first-aid capability will be available at the accommodation village during the construction phase.
- INPEX will work closely with the Northern Territory Police, Fire and Emergency Services in order to effectively plan for any major emergencies.
- A firefighting capability will be available, and strategically located firefighting stations will be established at the onshore processing plant.
- Fire-protection systems for the operations phase at the onshore Project site will be designed to enable INPEX personnel to handle fires capably until outside help arrives.
- Appropriate quantities of water will be stored and made available for firefighting purposes during both the construction and operations phases at the onshore processing plant.
- An emergency-response plan will be developed and emergency-response teams will be established at the onshore Project site for both the construction and operations phases of the Project. Emergency-response plans will address cyclone and major accident scenarios and will align with the Northern Territory Police, Fire and Emergency Services plans.

Utilities infrastructure

- During construction of the onshore development area, power will predominantly be supplied using on-site diesel generators.
- The onshore processing plant will be self-sufficient in meeting its power generation requirements during operations. Backup systems will be in place to support the main power generation packages in the event of failure or emergency.
- Temporary ablution blocks and temporary sewage systems will be used during the construction phase.
- A permanent sewage treatment facility will be installed at the onshore Project site for the operations phase of the Project.
- Waste disposal facility capabilities for the construction and operations phases at the onshore development area will be addressed during the detailed design phase of the Project. This will be done in consultation with relevant local-government authorities.
- Ongoing consultation will be undertaken with local government, the Department of Lands and Planning (DLP) and the PWC in order to effectively plan for the provision of scheme water for Project requirements at the onshore processing plant.
- Development of the accommodation village will be undertaken in consultation with local government agencies, the DLP and the PWC in order to effectively plan the provision of the required power, water, sewerage infrastructure and waste disposal systems so as not to burden the existing supply systems and infrastructure.

Residual risk

An assessment of the risk for social infrastructure and services is not considered realistic, as these are generally managed by government or third-party private businesses and are therefore outside INPEX's control. As with the issue of housing market impacts (Section 10.3.2), some community members may view added pressure on infrastructure as a positive opportunity for secondary business and growth, while others may consider this to be a negative impact of the Project. INPEX will implement the management approaches described above and in Table 10-3 in order to manage the potential impacts on social infrastructure and services as effectively as possible.

Table 10-3: Summary of impact assessment and residual risk for social infrastructure and services

Aspect	Activity	Potential impacts	Management controls and mitigating factors	Residual risk
Social services for the Project	Emergency health services for construction workforce.	Increased pressure placed on emergency health services, e.g. triage services.	First-aid clinics will be established at the onshore development area and at the accommodation village. INPEX will work in conjunction with the Northern Territory Police, Fire and Emergency Services in order to effectively plan for any major emergencies. An emergency response plan will be developed for both the construction and operations phase of the Project. Emergency response teams will be established.	Not applicable
	Emergency fire services for onshore development area.	Increased pressure on existing emergency fire services.	INPEX will work in conjunction with the Northern Territory Police, Fire and Emergency Services in order to effectively plan for any major emergencies. A firefighting capability will be available, along with strategically located firefighting stations on the Project plant site. Fire-protection systems for the operations phase will be designed to enable INPEX personnel to handle fires capably until external help arrives.	Not applicable
Utilities and infrastructure	Use of existing power, water and sewage infrastructure during construction, precommissioning and commissioning.	Increased pressure on utilities supply and infrastructure.	Diesel generators will predominantly be used to deal with power requirements for construction activities, with some mains power from the Darwin electricity grid. Temporary ablution blocks and sewage treatment systems will be in place to meet sewage management and treatment requirements during construction. The PWC has advised that the water demands for the Project can be met using scheme water, without affecting regional supplies. Ongoing consultation will be undertaken with local government, the DLP and the PWC in order to effectively plan for the provision of scheme water for Project requirements.	Not applicable
	Use of existing power, water and sewage infrastructure during operations	Increased pressure on utilities supply and infrastructure.	Permanent sewage-treatment facilities will be installed for the operations phase of the Project. The onshore facilities will be self-sufficient in power generation capacity during the operations phase. The PWC has advised that the water demands for the Project can be met using scheme water, without affecting regional supplies. Ongoing consultation will be undertaken with local government, the DLP and the PWC in order to effectively plan for the provision of scheme water for Project requirements.	Not applicable

10.3.4 Road traffic

Concerns about increased traffic congestion and road-safety risks were raised during stakeholder interviews, particularly by the Litchfield Council. The construction of the Darwin Liquefied Natural Gas plant (Darwin LNG plant) by ConocoPhillips between 2003 and 2006 resulted in traffic congestion that caused some community resentment.

The main impacts of the Project on local traffic will occur during the construction phase, when the transport of materials, equipment and commuting Project personnel to and from the onshore development area will increase vehicle movements on local roads in Darwin and Palmerston and on Middle Arm Peninsula. During the operations phase, traffic to the onshore processing plant will be limited to the smaller numbers of staff commuting to site and will be low in volume.

A traffic study was undertaken by URS Australia Pty Ltd (URS) to characterise the existing traffic conditions on relevant roads and to assess the potential impacts of traffic generated as a result of Project activities (URS 2009a, provided as Appendix 22 to this Draft EIS). The study focused mainly on road intersections as these have the greatest impact on the flow of traffic through an urban network; by studying the major intersections the general performance of the entire network can be understood.

Existing traffic conditions in Darwin, East Arm, Berrimah, Palmerston and Middle Arm were characterised using data collected from the DPI (now the DLP), as well as from manual traffic counts conducted at major intersections.

The Project's impact on existing traffic was assessed using the SIDRA INTERSECTION micro-analytical evaluation software package, which is used throughout the traffic engineering industry in Australia. Population growth predictions supplied by the Australian Bureau of Statistics were used as a guide to predict future volumes of traffic on local roads, outside those generated by the Project.

Transport of equipment and materials during the construction phase will mainly be undertaken by B-double trucks, consisting of a prime mover towing two semitrailers (with two articulation points). Buses will be used to transport the majority of workers from the accommodation village to the onshore development area. The module offloading facility at Blaydin Point will be used preferentially for transport of very large loads arriving by ship; however, on occasion some large loads may be required to be offloaded at East Arm Wharf and be transported to the onshore development area by over-dimension road vehicles.

A summary of the daily traffic likely to be generated during the peak of the construction phase is provided in Table 10-4. For this assessment all activities are assumed to occur concurrently and over the whole construction period.

The existing and future performance of the major intersections along the transport routes from Darwin, East Arm and Palmerston to the onshore development area were analysed using two main indicators:

- degree of saturation (DoS)—the ratio of actual traffic volume moving through an intersection compared with the capacity for which it was designed. Generally a DoS of 0.95 or below is considered acceptable in a congested urban road network, although often intersections will be shown to be operating at capacity in existing conditions. A DoS value of 1.0 indicates that the intersection is carrying traffic equal to its maximum design capacity.
- 95% queue length—the maximum queue length (in metres), which will not be exceeded 95% of the time. Queue lengths are used to determine lengths of dedicated turn lanes when preparing function designs. These measurements are also used as a secondary performance indicator in conjunction with DoS values, to understand if changes in traffic volumes produce unrealistic queue lengths.

It should be noted that the worst-case results for DoS and 95% queue length may come from different movements within an intersection in the same model. This is attributable to the interaction between traffic volumes, signal timing and the geometric layouts of each intersection. For example, a through movement in a single exclusive lane may exhibit a very long queue length but have a lower DoS as traffic can flow through the intersection unimpeded, whereas a shared through and right-lane turning lane may have a shorter queue length but a higher DoS as the right turns block through-traffic movement.

Major intersection performance was modelled for the assumed peak of the construction phase and the commencement of the operations phase respectively. In order to assess the worst-case scenarios, modelling focused on the morning and afternoon peak hours. Peak hours observed at each intersection varied somewhat between sites, but were generally between 7.15 and 8.15 a.m. and between 4.30 and 5.45 p.m.

For the purposes of the traffic study it has been assumed that all traffic generated by the Project will use the existing road network. Each origin–destination trip (see Table 10-4) was assigned a route and round trips were assumed to use the same route in reverse.

Table 10-4: Average daily traffic generated at the peak of the construction period

Assumed average peak daily road traffic generated by construction activities			
Origin	Destination	Approximate number of round trips per day	Cargo
Blaydin Point	Shoal Bay landfill	30	Construction waste, domestic waste and recyclables, green waste and hazardous materials
Blaydin Point	Shoal Bay landfill	80*	Acid sulfate soils for disposal
Darwin	Blaydin Point	170†	Raw materials, aggregate, sand, cement, asphalt, scaffolding, tools, equipment, personnel
East Arm Wharf	Blaydin Point	74	Fuel and cargo from maritime vessels
East Arm Wharf	Darwin	2	Cargo from maritime vessels
Mount Bundy quarry	Blaydin Point	60	Rock-armour and aggregate for site construction
Mount Bundy quarry	East Arm	102	Rock-armouring for pipeline stabilisation
Mount Bundy quarry	Shore-crossing location	3	Rock-armouring for stabilisation of the shore-crossing location
Accommodation village	Blaydin Point	100	Personnel from the accommodation village (bus movements)
Accommodation village	Blaydin Point	125	Personnel from the accommodation village (light-vehicle movements)
Accommodation village	Shoal Bay landfill	2	Waste and recyclables

* Note that a number of methods for treatment and disposal of acid sulfate soils are being considered, including treatment in situ and disposal offshore. This number of vehicles would be required only if onshore landfill disposal were selected for the greater part of the material.

† This figure includes 100 cars transporting personnel.

Note: The figures presented in this table represent the base case for the traffic modelling study (see Appendix 22).

The routes used for non-personnel construction traffic (e.g. vehicles transporting construction materials) are shown in Figure 10-1, while the route used by personnel traffic from the accommodation village is shown in Figure 10-2.

In addition, at the time of modelling it was assumed that the peak of construction and the commencement of operations would be 2013 and 2015 respectively.

The analysis does not take into account the influence of the new Tiger Brennan Drive extension, which is anticipated to be complete in 2010. If this road is completed prior to the commencement of the construction phase, Project traffic will be able to utilise this more convenient route from Darwin to Palmerston. Overall the road network should operate more efficiently if this occurs.

Construction traffic (non-personnel)

Traffic modelling for the peak construction period (2013) indicates that non-personnel construction traffic will generate only very small incremental impacts at some parts of the road network, if any. A summary of DoS values and queue lengths for key intersections is provided in tables 10-5 and 10-6 respectively.

Note that not all entry points into an intersection have been shown in these tables—only the worst-affected from both a DoS value and queue-length perspective are presented. On occasion, there may be more than one entry point to consider.

Most intersections in the traffic network will be operating below the 0.95 DoS threshold even after construction traffic movements are added (Table 10-5). Exceptions are the Stuart Highway – Berrimah Road intersection in the afternoon peak hour, which is predicted to be operating at capacity (1.0 DoS) with or without Project construction traffic, and the Stuart Highway – Lambrick Avenue intersection, which is nearing its capacity (0.96 DoS). Population growth is likely to be the key influence bringing parts of the traffic network up to maximum capacity by 2013 (see Appendix 22).

Queue lengths are predicted to increase by relatively small amounts at many of the intersections as a result of non-personnel construction traffic. The largest change is a queue length increase of 54 m at the Berrimah Road – Wishart Road intersection during the afternoon peak period (Table 10-6).

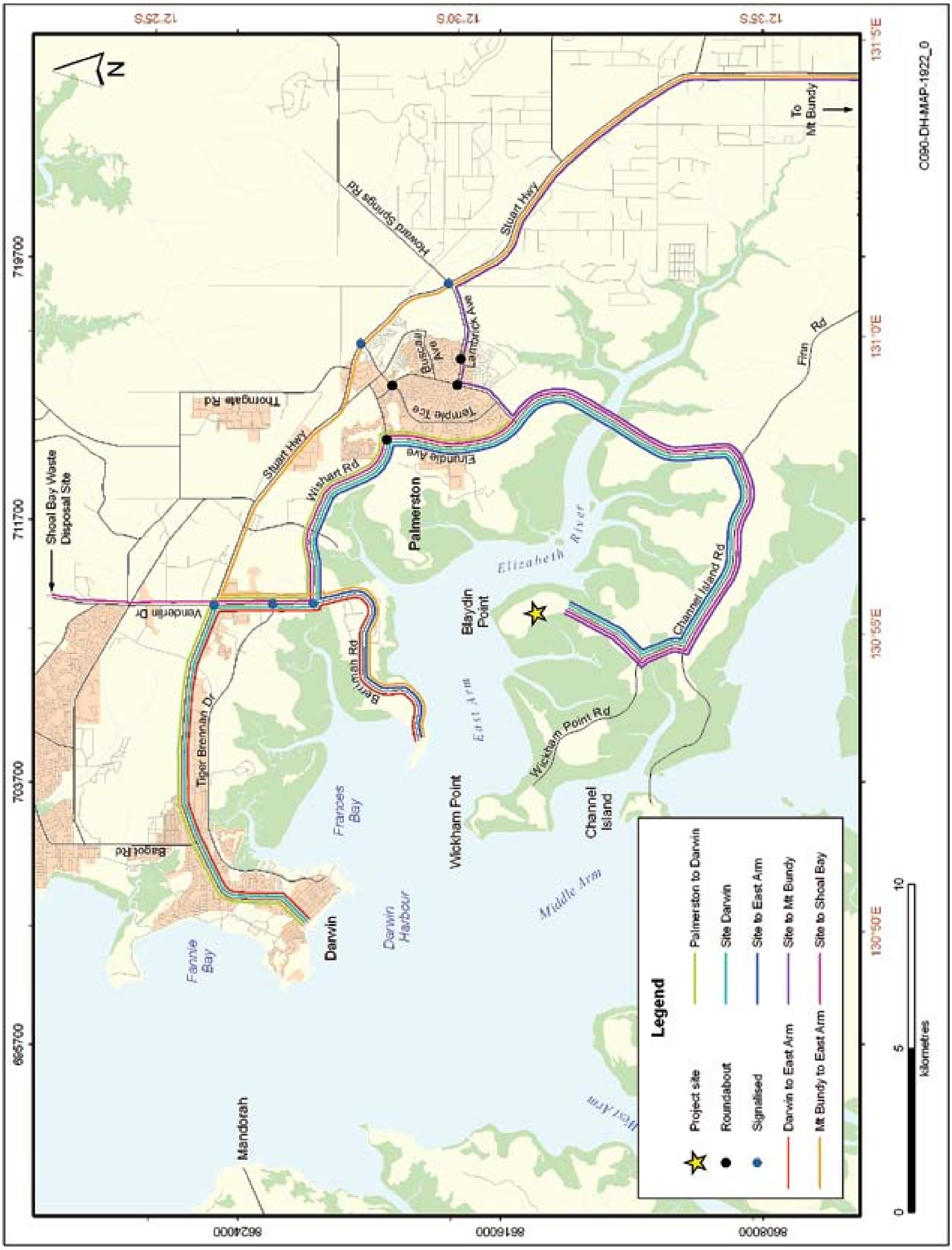

Figure 10-1: Assigned traffic routes for non-personnel construction traffic

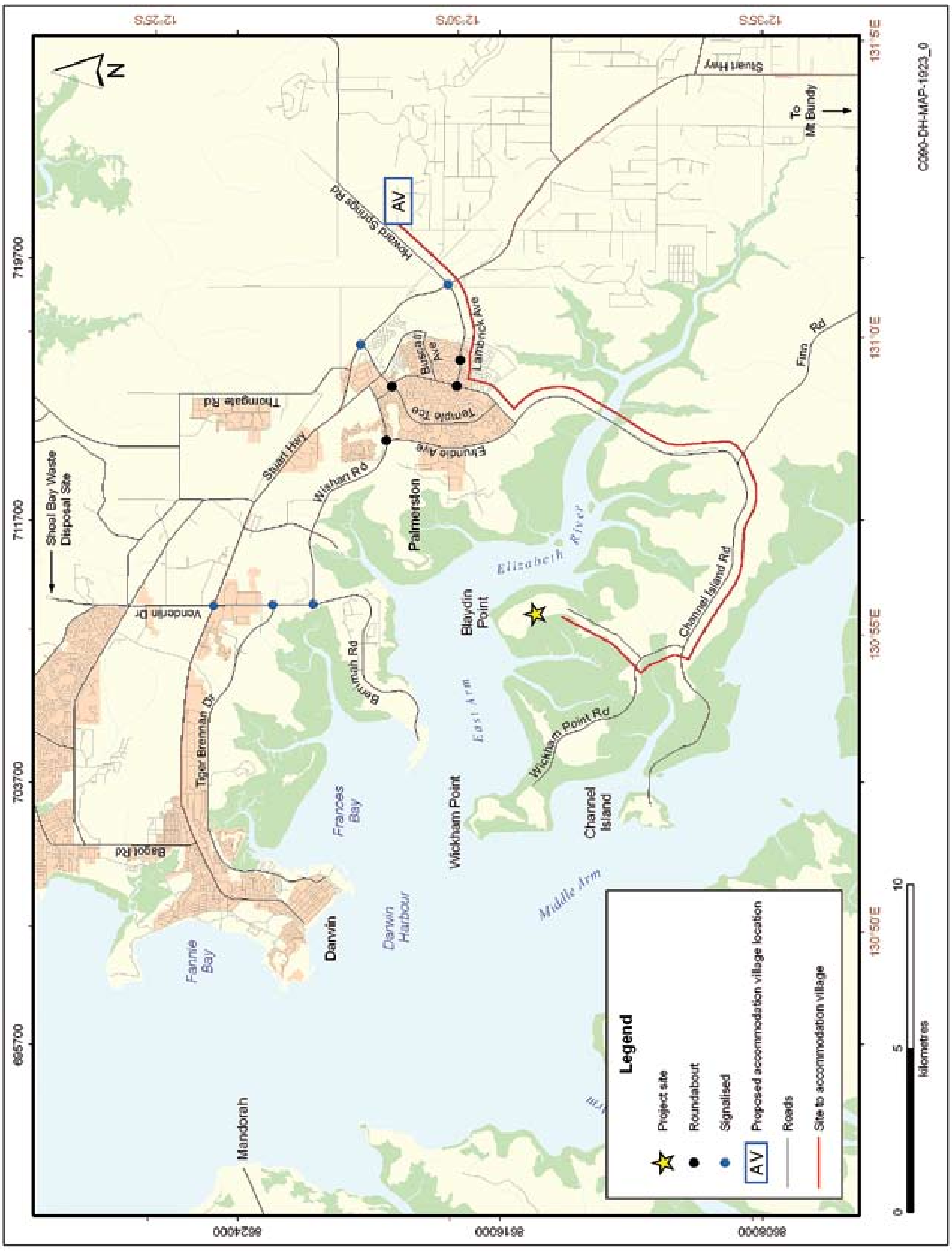

Figure 10-2: Assigned traffic route for personnel construction traffic

Table 10-5: Predicted DoS values at key intersections during the peak construction period (non-personnel construction vehicles only)

Intersection	Peak (a.m./ p.m.)	Background traffic	Background together with construction traffic	Affected intersection entry point(s)
Elrundie Avenue Wishart Road Hedley Place University Avenue	a.m.	0.77	0.82	Northbound Elrundie Avenue: left turn into Wishart Road (inbound).
	p.m.	0.79	0.81	Eastbound Wishart Road: right turn into Elrundie Avenue (outbound).
Berrimah Road Wishart Road	a.m.	0.73	0.76	Westbound Wishart Road: right turn into Berrimah Road (inbound)
	p.m.	0.90	0.91	Southbound Berrimah Road: left turn into Wishart Road (outbound).
Stuart Highway Berrimah Road Vanderlin Drive	a.m.	0.90	0.90	Southbound Vanderlin Drive: through movement into Berrimah Road.
	p.m.	1.00	1.00	Eastbound Stuart Highway: through movement (outbound).
Stuart Highway Lambrick Avenue Howard Springs Road	a.m.	0.96	0.96	South-west-bound Howard Springs Road: right turn into Stuart Highway and through movement into Lambrick Avenue.
	p.m.	0.84	0.85	South-east-bound Stuart Highway: through movement (outbound).
Elrundie Avenue Chung Wah Terrace Channel Island Road	a.m.	0.07	0.07	Northbound Elrundie Avenue: right turn into Chung Wah Terrace (inbound).
	p.m.	0.09	0.09	South-west-bound Chung Wah Terrace: left turn into Elrundie Avenue (outbound).
Channel Island Road Wickham Point Road	a.m.	0.10	0.10	North-west-bound Channel Island Road: right turn into Wickham Point Road (outbound).
	p.m.	0.11	0.11	South-east-bound Wickham Point Road: left turn into Channel Island Road (inbound).
Stuart Highway Temple Terrace	a.m.	0.86	0.87	North-west-bound Stuart Highway: through movement (inbound).
	p.m.	0.90	0.90	North-east-bound Temple Terrace: right turn into Stuart Highway (outbound).
Legend:		Degree of saturation <0.95: the intersection is operating below its maximum design capacity. Traffic levels would be considered acceptable.		
		Degree of saturation >0.95: the intersection is operating close to or above its maximum design capacity. Traffic levels would be considered too high.		

Source: URS 2009a.

Construction personnel traffic

Movement of personnel from the accommodation village on Howard Springs Road to the onshore development area at Blaydin Point will utilise a similar route to some of the non-personnel construction traffic, such as the Stuart Highway – Lambrick Avenue intersection. The personnel traffic will also affect local roads near to the village, such as Whitewood Road and Howard Springs Road. It is estimated that 50 buses (driving two round trips per day) and 125 light vehicles (driving one round trip per day) would travel from the accommodation village to the onshore development area each day.

When incorporated into the traffic model, this additional personnel traffic increases the influence on the Stuart Highway – Lambrick Avenue intersection, bringing it over maximum capacity (1.06 DoS) during the morning peak period (Table 10-7). During the afternoon peak period the intersection is predicted to operate below the 0.95 DoS threshold, although at 0.90 DoS it is nearing this upper level of traffic capacity. Relatively large increases in queue length are also predicted for this intersection, particularly in the morning (an increase of 235 m or the equivalent of 40 average-sized cars).

All the other intersections are predicted to operate well below the maximum design capacity during both morning and afternoon peaks, with minimal changes to queue lengths (see tables 10-7 and 10-8).

Table 10-6: Predicted 95% queue lengths at key intersections during the peak construction period (non-personnel construction vehicles)

Intersection	Peak (a.m./ p.m.)	Background traffic (m)	Background together with construction traffic (m)	Affected intersection entry point(s)
Elrundie Avenue Wishart Road Hedley Place University Avenue	a.m.	114	114	Northbound Elrundie Avenue: left turn into Wishart Road (inbound).
	p.m.	93	103	Westbound Wishart Road: through movement into University Avenue (outbound) and right turn into Elrundie Avenue (outbound).
Berrimah Road Wishart Road	a.m.	89	98	Westbound: Wishart Road: right turn into Berrimah Road (inbound).
	p.m.	324	378	Southbound: Berrimah Road: left turn into Wishart Road (outbound).
Stuart Highway Berrimah Road Vanderlin Drive	a.m.	341	356	Westbound Stuart Highway: through movement (inbound).
	p.m.	469	495	Eastbound Stuart Highway: through movement (outbound).
Stuart Highway Lambrick Avenue Howard Springs Road	a.m.	556	579	North-west-bound Stuart Highway: through movement (inbound).
	p.m.	224	230	South-east-bound Stuart Highway: through movement (outbound).
Stuart Highway Temple Terrace	a.m.	279	294	North-west-bound Stuart Highway: through movement (inbound).
	p.m.	214	219	South-east-bound Stuart Highway: through movement (outbound).

Source: URS 2009a.

Table 10-7: Predicted DoS at key intersections during the estimated construction peak (construction and personnel vehicles)

Intersection	Peak (a.m./ p.m.)	Background traffic	Background together with construction traffic (including personnel)	Affected intersection entry point(s)
Elrundie Avenue Chung Wah Terrace	a.m.	0.07	0.15	Westbound Chung Wah Terrace: turning left (outbound) into Elrundie Avenue.
	p.m.	0.09	0.17	Northbound Elrundie Avenue: turning right (outbound) into Chung Wah Terrace.
Stuart Highway Lambrick Avenue Howard Springs Road	a.m.	0.96	1.06	South-west-bound Howard Springs through movement (inbound) and right (inbound) turn into Stuart Highway.
	p.m.	0.84	0.90	South-east-bound Stuart Highway: through movement (outbound).
Channel Island Road Wickham Point Road	a.m.	0.10	0.19	North-west-bound Channel Island Road: Right turn into Wickham Point Road (outbound).
	p.m.	0.11	0.11	South-west-bound Wickham Point Road: left turn into Channel Island Road (inbound).
Whitewood Road Howard Springs Road	a.m.	0.55	0.79	Westbound Whitewood Road left (inbound) turn into Howard Springs Road.
	p.m.	0.70	0.83	North-east-bound Howard Springs Road right into Whitewood Road (outbound)
Legend:		Degree of saturation <0.95: the intersection is operating below its maximum design capacity. Traffic levels would be considered acceptable.		
		Degree of saturation >0.95: the intersection is operating close to or above its maximum design capacity. Traffic levels would be considered too high.		

Source: URS 2009a.

Table 10-8: Predicted 95% queue lengths at key intersections during the estimated construction peak (construction and personnel vehicles)

Intersection	Peak (a.m./ p.m.)	Background traffic (m)	Background together with construction traffic (including personnel) (m)	Affected intersection entry point(s)
Elrundie Avenue Chung Wah Terrace	a.m.	No more than one car	No more than one car	Southbound Elrundie Avenue: through movement (outbound).
	p.m.	No more than one car	No more than one car	Northbound Elrundie Avenue: through movement (inbound).
Stuart Highway Lambrick Avenue Howard Springs Road	a.m.	556	791*	North-west-bound Stuart Highway: through movement (inbound).
	p.m.	224	308*	South-east-bound Stuart Highway: through movement (outbound).
Channel Island Road Wickham Point Road	a.m.	0	0	Not applicable.
	p.m.	0	0	Not applicable.
Whitewood Road Howard Springs Road	a.m.	45	84	Westbound Whitewood Road left (inbound) and right (outbound) turns into Howard Springs Road.
	p.m.	87	125	North-east-bound Howard Springs Road right (outbound) turn into Whitewood Road.

* Large increases in queue length result from the addition of construction traffic, indicating that this intersection will be functioning poorly.

Source: URS 2009a.

Quarry traffic

Heavy-vehicle traffic will be required by the Project to transport material for rock-armouring from quarries outside Darwin to Blaydin Point and East Arm Wharf. This is likely to involve around 105 round trips per day at the peak of construction, though this would depend on the schedule and stockpiling arrangements, which are yet to be finalised.

Heavy-vehicle movements from quarries in Katherine would use Stuart Highway, while traffic from quarries at Mount Bundy would use both Stuart Highway and Arnhem Highway. Stuart Highway is regularly used by high volumes of heavy-vehicle traffic (e.g. road trains), while the Arnhem Highway carries lower volumes of heavy – and light-vehicle traffic and is occasionally closed in the wet season as a result of flooding. Both routes pass through small towns, and in the outer metropolitan areas and through Palmerston the truck route will pass through commercial areas and potentially residential areas. The route to East Arm Wharf uses Berrimah Road where there is a school zone with a 40-km/h speed limit.

This type of road traffic could cause some localised traffic congestion and noise impacts to local communities as well as an increase in the risk of accidents between turning trucks and other traffic using the highways.

Management of traffic and transport

Traffic modelling indicates that the Project is not likely to create a significant overall incremental impact on the operation of the road network when compared with background growth. However the study found that some of the key intersections would be operating at their capacity by 2013 as a result of general background growth in Darwin.

The potential impacts of Project road traffic on the surrounding community, including the vehicle movements required to access the rock quarry located at Mount Bundy and the limestone quarry at Katherine, will be managed through a traffic management plan developed in consultation with local-government authorities, schools and other local service providers. Traffic management objectives, targets, management controls and monitoring procedures have been incorporated into the Provisional Traffic Management Plan for the Project (see Chapter 11). This plan will guide the development of more detailed plans during the construction phase. The key management controls proposed are as follows:

- Bus transport from the accommodation village or designated pick-up areas will be provided for most of the construction workforce in order to minimise the number of vehicle movements.
- Designated routes for travel to and from quarries, the accommodation village, Darwin's central business district (CBD), the airport and East Arm Wharf will be set for the Project. The selection

Table 10-9: Summary of impact assessment and residual risk for traffic and transport

Aspect	Activity	Potential impacts	Management controls and mitigating factors	Residual risk*		
				C†	L‡	RR§
Traffic and transport	Daily transport of construction personnel to site. Regular transport of materials and equipment from East Arm Wharf to site during construction. Transport of rock from the quarries to site.	Increased congestion on local roads. Increased risk of road accidents.	Provisional Traffic Management Plan. Buses provided to transport a majority of the Project personnel to and from work to reduce total traffic. Designated travel routes to and from quarries, accommodation facilities, the Darwin CBD and East Arm Wharf will be set for the Project. The Project will work in conjunction with the DLP to identify any proposed road projects that may need to be brought forward or upgrades that may need to be undertaken to assist in reducing potential pressure on existing road systems.	D (S2)	3	Medium

* See Chapter 6 *Risk assessment methodology* for an explanation of the residual-risk categories, codes, etc.

† C = consequence.

‡ L = likelihood.

§ RR = risk rating.

process for the routes will give consideration to minimising disturbance to local traffic and will be communicated to all relevant personnel.

- INPEX will work together with the DLP to identify any proposed road projects that may need to be brought forward or upgrades that may need to be undertaken to assist in reducing potential pressure on existing road systems.

Residual risk

A summary of the potential impacts, management controls, and residual risk for traffic is presented in Table 10-9. After implementation of these controls, impacts from traffic are considered to present a "medium" risk and it is likely that any effects on the community will be localised and reasonably short-term, extending only through the construction phase.

10.3.5 Maritime traffic and navigation

Vessel movements

Vessels servicing the Project will be operating in offshore and nearshore waters throughout the construction and operations phases, in areas that are used by other commercial and non-trading vessels. The Project's offshore and nearshore infrastructure (both at the surface and submerged) will also present new obstacles that may affect navigation by other vessels.

There are no designated shipping lanes in the offshore development area. The location of the offshore facilities will be communicated to other ships through a "Notice to Mariners" from the Australian Hydrographic Service. Mariners would need to plan their course around this area to avoid the Project facilities. Given the vast area of open ocean around the Ichthys Field this impact to shipping activities is considered to be very minor.

The location of pipelay vessels will also be communicated by the publication of a "Notice to Mariners". These vessels pose a very minimal risk of interruptions to shipping activities along the pipeline corridor because of the transient nature of the work during the construction period and the extensive areas of open ocean around the corridor.

As described in Chapter 3, a wide variety of trading and non-trading vessels use Darwin Harbour and total vessel numbers have been increasing in recent years. The Project vessels likely to be employed in the nearshore development area during construction and operations are described in Chapter 4. While these vessels will result in an increase in maritime traffic volumes in the Harbour, the nearshore development area is located within an existing operational port equipped with facilities to manage commercial vessels. Vessel movements and activities will be undertaken according to Darwin Port Corporation (DPC) regulations.

An estimated 5–10 shipments per month of modules, steelwork and equipment will arrive in Darwin Harbour for the Project over the construction phase. This would represent an increase of 1–2% in the total monthly vessel calls to Darwin Harbour, based on 2008–09 shipping levels (Darwin Port Corporation 2009), and should be well within the existing port's capacity.

Also during the construction phase, a number of dredging vessels and support vessels will operate in the nearshore development area and will travel through the Harbour to the offshore spoil disposal ground (see Chapter 4). While the dredging program could extend for as long as four years, dredging activities will typically be centred on only one or two localised portions of the nearshore development area at any one time. At the peak of dredging, up to four separate operations could occur concurrently.
It is not envisaged that dredging will interrupt normal shipping activities through the Port of Darwin, although exclusion zones will be implemented around dredging vessels for public and operational safety (as discussed further below). Maritime vessel operations will be coordinated in conjunction with the DPC at all times.

During the operations phase, up to four tanker vessels per week (approximately 16 per month) will visit Blaydin Point, which represents an increase in shipping in the Harbour of 3%, based on 2008–09 levels (Darwin Port Corporation 2009). Each tanker will be assisted through the Harbour by a fleet of four tugs and will be under the direction of a pilot from the DPC to ensure that navigation and berthing is carried out safely.

Effects on navigation and other maritime infrastructure

The offshore spoil disposal ground has been selected to avoid interference with shipping traffic travelling from the Howard Channel between the Vernon Islands and Darwin Harbour. Dredge spoil will be spread as evenly as possible in the disposal ground and will form clumps and piles over the seabed. Hydrodynamic modelling predicts that the fine and sandy components of this material will migrate with tidal currents to the north-east and south-west and that some could blend with the sand waves that currently exist near the entrance to Darwin Harbour (see Appendix 13). The effects of this transport of sediment on seabed depth are very small, in the order of a few centimetres, and are insignificant in terms of the maintenance of shipping channels out of Darwin Harbour.

Within Darwin Harbour, fine sediments released during dredging are predicted to migrate to shoreline areas. Build-up around existing maritime infrastructure, such as East Arm Wharf, the Hudson Creek export facility, the East Arm boat ramp and Stokes Hill Wharf, is predicted to reach depths of between 5 and 50 mm (see Appendix 13). These levels are very low and are not expected to affect shipping or recreational boating activities.

Management of maritime traffic and navigation

A safety exclusion zone with a radius of 500 m will be put in place around surface and subsurface equipment in the offshore development area. This safety zone will be gazetted under the *Offshore Petroleum and Greenhouse Gas Storage Act 2006* (Cwlth) and will appear on Australian navigation charts. An additional “restricted navigation zone” 5 nautical miles wide will be implemented throughout the life of the Project. The gas export pipeline will also be gazetted on navigational charts after construction.

In Commonwealth waters there is the potential for a precautionary zone to be imposed around the gas export pipeline, but this will be the subject of further discussion with the relevant authorities. Should this zone around the pipeline be imposed, it would be gazetted under the *Offshore Petroleum and Greenhouse Gas Storage Act 2006* and will also appear on Australian navigational charts.

To ensure that under-keel clearance is maintained for seagoing vessels in the offshore spoil disposal ground and that there are no disruptions to maritime traffic, INPEX will undertake periodic bathymetric surveys to confirm sediment deposition depth and patterns. The monitoring program will have the following components:

- A baseline survey of the whole spoil ground will be undertaken prior to the commencement of dredging.
- Interim surveys will be conducted over the dredge spoil ground areas to monitor the rate of build up and distribution of spoil on the seabed; this will be done every two to four weeks initially, then less frequently as the accumulation of the spoil in the spoil ground becomes better understood. Monitoring will be conducted so that the spoil does not create an area of shoal seabed less than a predefined depth as agreed with the DPC.
- A final survey of the spoil ground will be undertaken on completion of all dredging works to confirm sediment deposition depths and that there is sufficient under-keel clearance for maritime vessels.

In addition, INPEX will liaise with the DLP to prepare a “Notice to Mariners” advising them of changes in circumstances at or adjacent to the offshore spoil disposal ground.

A range of measures will be put in place to avoid navigational problems and potential vessel collisions in the offshore development area. These will include lighting, communications, the deployment of anti-collision radar, and notification of the location of the offshore facilities and the gas export pipeline through a "Notice to Mariners". Notices will be issued to ships and appropriate navigation lights and markers will be displayed. Standard maritime communications systems will be provided on all facilities.

Exclusion zones around dredge vessels, pipe-laying vessels and jack-up barges will be identified by the DPC through the Darwin Harbourmaster and notices. Enforcement of these exclusion zones will be in accordance with the Darwin Port by-laws. The restrictions will be dependent on the location and type of operation.

An application will be made to the relevant government and other regulatory agencies to implement a safety exclusion zone and restricted navigation zone around the nearshore infrastructure (the jetty and the module offloading facility) to maintain security and public safety. The safety exclusion zone will be determined through a series of safety assessments in consultation with the DPC and the Commonwealth's Department of Infrastructure, Transport, Regional Development and Local Government (DITRDLG). The exclusion zone will be established to ensure that the safety of personnel and Harbour users is not compromised to below acceptable standards. These zones are not likely to affect navigation through the main body of the Harbour, but will preclude access by recreational boats to some areas near Blaydin Point.

Exclusion zones along the jetty trestles and the jetty heads (without a product tanker at berth) will be in the order of 500 m subject to the outcomes of the final quantitative risk assessment. These areas will be marked with buoys.

There will be an exclusion zone of 1000 m ahead and 500 m astern and on each side of the LNG carriers. This will be enforced by escort tugs. Exclusion zones around liquefied petroleum gas (LPG) and condensate vessels will be determined by the DPC.

Where the gas export pipeline lies within 3 nautical miles of the territorial sea, a precautionary zone of 200 m will be set. This zone will be gazetted and will appear on Australian navigational charts. Within this zone it is forbidden to drop or drag an anchor or perform an action that could damage the pipeline as prescribed by Section 66(5) *Threat to pipeline* of the *Energy Pipelines Act* (NT).

Vessel movements in the Harbour will be carried out according to the regulations of the DPC. In consultation with the DPC, navigation aids will be installed or relocated around the jetty and in the shipping channel to allow vessel movements by all Harbour users to continue safely and efficiently.

Maritime infrastructure zones in East Arm (e.g. the East Arm Wharf berths, the Hudson Creek export facilities and the East Arm boat ramp) will be checked periodically for sediment build-up caused by the nearshore dredging program. If sediment accumulation occurs to levels that could interrupt normal use of these facilities, cleaning or maintenance dredging will be carried out by INPEX.

Residual risk

Potential impacts to maritime traffic and navigation are presented in Table 10-10 along with the proposed management strategies to minimise these impacts during the life of the Project. After implementation of these controls, impacts to maritime traffic and navigation are considered to present a "low" to "medium" risk as any effects will be localised and should be manageable through established regulatory systems.

10.3.6 Air traffic

INPEX has consulted with the Civil Aviation Safety Authority (CASA) and the Australian Defence Force regarding the potential impact of the onshore processing plant's operations on aviation activities in the Darwin region. A specific study was undertaken by INPEX to assess the potential for the ground flare to impact on flight paths for Darwin Airport. The assessment involved the use of CSIRO and CASA software to model the exhausts, plumes and flare heights from the ground flare.

The assessment indicated that the vertical plume velocity during normal operations will not exceed the critical plume velocity of 4.3 m/s above heights of 443 m AGL (above ground level)[2]. The probability of an aircraft operating above an altitude of 451 m from the plume source that would be exposed to vertical gusts of greater than 4.3 m/s is acceptable in terms of CASA risk criteria. In addition, the Standard Terminal Arrival Routes contain a constraint of 1829 m, which will ensure that arriving aircraft remain vertically clear of the ground flare (Jones 2009).

The study also considered the risk of abnormal emergency operations at the plant site affecting flight paths. It was found that the probability of an

2 A height "above ground level" is the height above the ground at any given location. It is not the same as the Australian Height Datum, which is the datum to which all vertical control for mapping in Australia is referred.

Table 10-10: Summary of impact assessment and residual risk for maritime traffic and navigation

Aspect	Activity	Potential impacts	Management controls and mitigating factors	Residual risk*		
				C†	L‡	RR§
Maritime traffic and navigation	Construction and operation of offshore infrastructure in open ocean.	Forced alteration of shipping route.	Low level of shipping activity in the offshore development area. An application will be made to the relevant government regulatory agencies to implement a safety exclusion zone and restricted navigation zone. These zones will be gazetted on navigational charts. Standard maritime communications equipment, navigation lights and markers on all Project vessels. A "Notice to Mariners" on location of offshore infrastructure and pipeline will be issued.	E (S2)	2	Low
Maritime traffic and navigation	Use of vessels for pipeline construction in offshore development area.	Forced alteration of shipping route.	Standard maritime communications equipment installed on all vessels. Activities will be transient and short-term only.	F (S2)	2	Low
Maritime traffic and navigation	Operation of nearshore construction vessels and dredge.	Forced alteration of shipping route in the Harbour. Increase in competition for port resources with other users. Spoil disposal ground could cause hazards to shipping navigation in the area.	Cooperation with DPC to manage shipping traffic schedules and exclusion zones during construction. "Notice to Mariners" to be issued on nearshore construction activities, e.g. dredging and rock dumping. Construction-vessel traffic will be short-term in duration. Periodic bathymetric surveys to be undertaken to confirm sediment deposition depth and patterns. The spoil disposal ground is not located in a shipping route. Ensure that under-keel clearance at the spoil disposal ground is maintained for maritime vessels.	E (S2)	6	Medium
Maritime traffic and navigation	Operation of tanker vessels in nearshore area.	Forced alteration of shipping route in the Harbour. Increase in competition for port resources with other users.	Exclusion zones will be put in place around product tankers and will be enforced by tugs. Cooperation with DPC to manage shipping traffic schedules during operations.	E (S2)	6	Medium

* See Chapter 6 *Risk assessment methodology* for an explanation of the residual-risk categories, codes, etc.

† C = consequence.

‡ L = likelihood.

§ RR = risk rating.

aircraft being exposed to risk as a result of abnormal emergency operations was acceptable in terms of CASA risk criteria (Jones 2009).

The height of physical structures may also potentially impact on aviation activities in the Darwin region. Both the Airports (Protection of Airspace) Regulations 1996 (Cwlth) and Defence (Areas Control) Regulations 1989 (Cwlth) control the height of structures and the purpose for which they may be used within a 15-km radius of an aerodrome. The tallest physical structure proposed at the onshore site will be the turbine stacks with a projected height of 65 m. While it was found that the Blaydin Point site did fall within 15-km radius of Darwin International Airport, it was determined that the stacks would not penetrate the outer horizontal obstacle limitation surface for the airport (Jones 2009).

10.3.7 Recreation

There is little or no recreational activity (such as boating and fishing) in most of the offshore development area because of the distance from land and the very deep waters. However, there are some recreational fishing areas at the eastern end of the gas export pipeline route around the entrance to Darwin Harbour and near the offshore spoil disposal ground for dredged material.

The proposed offshore spoil disposal ground was selected in consultation with a number of stakeholders, including the Amateur Fishermen's Association of the Northern Territory (AFANT). This organisation identified a need to protect recreational fishing areas such as Charles Point Patches and the artificial reefs off Lee Point from sedimentation impacts caused by the spoil disposal activities. The spoil disposal ground location was selected to minimise impacts on these recreational fishing areas.

Darwin Harbour is used frequently for recreational fishing. Community consultation identified a specific concern among recreational fishermen that the development of the product loading jetty in the nearshore development area would exclude public access to Cossack Creek and Lightning Creek to the west of the Blaydin Point peninsula. While INPEX aims to minimise the impact of the facilities at Blaydin Point, including the loading jetty, on users of the Harbour, public health and safety are ultimately the paramount factors in respect of decisions on plant design and operating philosophy.

The results from the preliminary quantitative risk assessments (QRAs) conducted to date (and discussed more fully in Section 10.3.14 *Public safety*) indicate that the onshore development area and pipeline do not pose unacceptable safety risks to Harbour users (GL 2009). Where risks posed to Harbour users in the vicinity of the jetty heads and trestle are higher than acceptable for active open spaces, nominal safety exclusion zones will be established. As the risk contours show that the acceptable risk contours border the main channel of Lightning Creek, risk values will need to be confirmed by a final QRA based on a complete plant design to determine whether access to these creeks can be maintained.

An assessment of the jetty design was undertaken by INPEX and the evaluation of jetty options is presented in Chapter 4. Prior to and during the assessment of the design, INPEX engaged extensively with stakeholders because of the potential for the jetty to impact on human use and the heritage values of the area.

As discussed in Chapter 3, Aboriginal people living in the Darwin area frequently fish and forage for food and other resources in intertidal areas at low tide, as well as in Darwin Harbour. Within the Harbour itself these activities are common around Nightcliff, Coconut Grove, Kulaluk, Sadgroves Creek, Lee Point and Blaydin Point. It is predicted that there will not be any direct Project impact on the Nightcliff, Coconut Grove, Kulaluk, Sadgroves Creek and Lee Point areas and therefore impacts on traditional fishing practices will be negligible for these areas. There will be an impact on traditional fishing practices undertaken on and around Blaydin Point during both the construction and operations phase. This is because public access to the onshore site will be restricted and marine exclusion zones will be put in place to ensure that public safety is not compromised. This impact is expected to be minimal given that the fishing areas affected represent a very small portion of the areas available in Darwin Harbour.

Also of concern to fishing values is the potential removal or disturbance of mangroves around Middle Arm Peninsula, although the area of mangroves to be disturbed by the Project represents only a small proportion of this habitat type within the Harbour overall as discussed in Chapter 8. The major dredging activities associated with the construction of the nearshore infrastructure are unlikely to have a significant impact on local marine ecology and fish populations as discussed in Chapter 7. Rock-armouring along the gas export pipeline through Darwin Harbour will provide new artificial habitat for benthic biota and fish that could improve recreational fishing opportunities, similar to the increased abundance of marine life present on the existing Bayu–Undan Gas Pipeline (see Chapter 3).

Recreational diving in the southern portion of Darwin Harbour could be impacted upon by the Project, particularly during the construction stage when dredging activities will cause increased turbidity and therefore reduced underwater visibility. In addition to this, recreational diving may be impacted upon during nearshore blasting activities when exclusion zones will be imposed for public safety reasons (see Section 10.3.14); however these are short-term activities and will only temporarily affect recreational diving.

Blaydin Point is occasionally used for fishing, camping and four-wheel-drive recreation. These activities will be banned from the onshore development area from the beginning of the construction phase because of the implementation of a safety exclusion zone that will be determined in consultation with the DPC and the DITRDLG. It is not considered that this will result in a significant impact as similar bushland areas exist in many locations around Darwin Harbour and the loss of access to Blaydin Point does not represent a major reduction in recreation sites.

Residual risk

A summary of the potential impacts, management controls, and residual risk for recreation is presented in Table 10-11. After implementation of these controls, impacts to recreational values in Darwin Harbour are considered to present a "medium" risk. Three of these impacts are related to the design of nearshore infrastructure and will therefore exist for the life of the Project.

10.3.8 Aboriginal cultural heritage

The Larrakia Development Corporation (LDC) and the Northern Land Council (NLC) expressed support for the Project's potential to create business and employment opportunities for Aboriginal people. The LDC's chair, as senior custodian, had provided advice to the Aboriginal Areas Protection Authority (AAPA) that no sacred sites would be impacted by the proposed Project design.

Aboriginal sacred sites located in Darwin Harbour are outside the nearshore development area. The AAPA issued a number of "authority certificates" through a process of pre-development assessment under the *Northern Territory Aboriginal Sacred Sites Act* (NT), confirming that the activities proposed for the Ichthys Project would avoid interference with sacred sites (Table 10-12).

Table 10-11: Summary of impact assessment and residual risk for recreation

Aspect	Activity	Potential impacts	Management controls and mitigating factors	Residual risk*		
				C†	L‡	RR§
Recreation	Operation of nearshore infrastructure (jetty) with exclusion zones for security and public safety.	Reduction in access to recreational fishing grounds.	Fishing areas to be affected represent a very small proportion of the areas available in Darwin Harbour.	E (S2)	6	Medium
Recreation	Dredging during construction of nearshore infrastructure.	Reduced access to recreational diving sites (e.g. wrecks) owing to reduced visibility in turbid waters.	Dredging is a construction-phase activity and will only temporarily reduce visibility	E (S2)	6	Medium
Recreation	Construction and operation of onshore infrastructure.	Loss of access to camping and four-wheel-drive areas and traditional hunting and gathering areas at Blaydin Point.	Many other similar areas are available around Darwin Harbour.	E (S2)	6	Medium
Recreation	Construction and operation of onshore infrastructure.	Loss of access to traditional fishing and foraging grounds on Blaydin Point.	Fishing and foraging areas to be affected represent a very small proportion of the areas available in Darwin Harbour.	E (S2)	6	Medium

* See Chapter 6 *Risk assessment methodology* for an explanation of the residual-risk categories, codes, etc.

† C = consequence.

‡ L = likelihood.

§ RR = risk rating.

Table 10-12: Authority certificates provided by the AAPA for the onshore and nearshore development areas

Authority certificate	Subject area
C2008/041	Middle Arm Peninsula and nearshore waters
C2008/042	Middle Arm Peninsula and nearshore waters
C2008/191	Marine area between Cox Peninsula and Shoal Bay Peninsula, Darwin Harbour
C2009/011	Subsea pipeline corridor within Darwin Harbour in the Beagle Gulf

The buffer area designated for one site north of Mandorah is positioned adjacent to the proposed gas export pipeline corridor (see Chapter 3 for the location). Consultation with the AAPA and the Larrakia people was undertaken by INPEX in order to develop a management approach that protects this site. Vessel movements and anchoring for the Project will avoid impacts to sacred sites in accordance with the conditions laid down on the AAPA Authority Certificate.

Archaeological surveys of the onshore development area (presented in Chapter 3) indicate that nine sites (consisting mainly of shell and stone artefact scatters) and one isolated artefact are located close to, or within, the boundary of the onshore development area. All Aboriginal archaeological sites and objects are protected by the *Heritage Conservation Act* (NT) and ministerial permission is required to disturb them.

One archaeological site of high significance is located close to the proposed access road to Blaydin Point. Careful alignment of the road would allow preservation of this site, although extra signage or fencing may be warranted to protect it from damage by off-road vehicle or machinery movements. Management of this site is currently the subject of consultation with the Northern Territory's Department of Natural Resources, Environment, the Arts and Sport (NRETAS) and the Larrakia people.

Three sites will be required to be disturbed during construction: one isolated artefact located close to the pipeline corridor, a shell and stone artefact scatter and a subsurface midden/shell scatter located within the access road corridor. INPEX will request permission from the Heritage Branch of NRETAS to move or remove these sites. If permission is granted to move or remove these sites, advice will be sought from the traditional custodians on the correct procedures to be adopted for their removal.

Management of Aboriginal cultural heritage

A Provisional Heritage Management Plan has been compiled for the Project (see Annexe 9 to Chapter 11). This will guide the development of more detailed plans during the construction and operations phases. The provisional plan contains details of applicable management controls, procedures, monitoring and audit programs. Its key components are summarised as follows:

- A Larrakia Heritage Management Committee (LHMC) with a standing agenda will be established. It will be made up of representatives of the Larrakia people and INPEX.
- Prior to commencement of construction, Aboriginal sites within the onshore development area will be divided into two categories: those which will receive full protection from disturbance and those which may need to be removed.
- In the case of an Aboriginal heritage site which may have to be moved or removed, INPEX will request permission to do so from both the LHMC and the Heritage Branch of NRETAS. If permission is granted to remove the site, advice will be sought from the traditional custodians on the correct procedures to be adopted for its removal.
- Where the external boundary of an Aboriginal heritage site is 10 m or closer to any proposed construction activity, flagging, temporary fencing or similar will be erected 5 m from the site boundary and appropriate signage will be put in place. The boundary demarcation will be removed when the risk of disturbance no longer exists.
- Daily toolbox meetings, job hazard analyses, permit systems or similar will be implemented on site prior to the commencement of vegetation clearing or construction activities. These will be undertaken to ensure that work areas are clearly identified before operations commence to avoid accidental disturbance to heritage sites either inside or outside the heritage site boundaries.
- Anchor management plans will be developed to allow safe anchoring of vessels undertaking pipelay, dredging and piling activities in the vicinity of any nearshore heritage or sacred sites.
- Exclusion zones have been established around the marine sacred sites by the AAPA. No works are permitted within these exclusion zones.
- Monitoring will be undertaken for Aboriginal heritage sites. This will involve inspections by Larrakia representatives prior to and during the construction phase and during the commissioning and operations phases. Photographic records will be maintained for each of the sites.

The LDC has been engaged to develop a detailed Heritage Management Plan for the Project in consultation with the local traditional custodians. This plan will contain objectives and targets, management controls and monitoring for the ongoing protection of Aboriginal values in the vicinity of the onshore and nearshore development areas.

Residual risk

The risk assessment process for potential impacts to Aboriginal cultural heritage has been based on legal compliance with the *Heritage Conservation Act* (NT), under which these sites are protected (see Table 10-13). It is not considered appropriate to estimate the heritage value of these sites to the local community, as traditional owners of the land would attribute different values to the sites than would newcomers to the Northern Territory. After implementation of the proposed management controls, the risk of impacts to Aboriginal heritage sites is considered to be "low".

10.3.9 Non-Aboriginal cultural heritage

Terrestrial heritage sites

Three World War II historical sites exist within the onshore development footprint. One of these sites contains the foundations of an anti-aircraft searchlight and other relics; it is located on the northern extremity of Blaydin Point. The other two sites (communications insulators) are located to the south of this main site (see Chapter 3).

Table 10-13: Summary of impact assessment and residual risk for Aboriginal cultural heritage sites

Aspect	Activity	Potential impacts	Management controls and mitigating factors	Residual risk*		
				C†	L‡	RR§
Aboriginal cultural heritage	Land clearing prior to construction in the onshore development area, and vehicle movement in the vicinity of heritage sites.	Disturbance or removal of Aboriginal archaeological sites within or near the onshore development footprint protected under the *Heritage Conservation Act* (NT).	Design of infrastructure to avoid onshore heritage sites where possible. Seek ministerial permission to disturb or remove a site. If permission is granted to remove or disturb a site, advice will be sought from the traditional owners on the correct procedures to be adopted for its removal. Daily toolbox meetings, job hazard analyses, permit systems or similar will be implemented on site prior to the commencement of vegetation-clearing or construction activities. Where the external boundary of an Aboriginal heritage site is 10 m or closer to any proposed construction activity, flagging, temporary fencing or similar will be erected 5 m from the site boundary and appropriate signage will be put in place. Provisional Heritage Management Plan.	D (S3)	1	Low
Aboriginal cultural heritage	Construction vessel movements and anchoring in Darwin Harbour.	Disturbance to maritime sacred sites protected under the *Northern Territory Aboriginal Sacred Sites Act* (NT) and the *Heritage Conservation Act* (NT).	Exclusion zones have been established around the maritime sacred sites by the AAPA. No works will be permitted within these exclusion zones. Anchor management plans will be developed to allow safe anchoring of vessels undertaking pipelay, dredging and piledriving activities in the vicinity of any nearshore heritage or sacred sites. Provisional Heritage Management Plan.	D (S3)	1	Low

* See Chapter 6 *Risk assessment methodology* for an explanation of the residual-risk categories, codes, etc.

† C = consequence.

‡ L = likelihood.

§ RR = risk rating.

It is likely that all of these sites will need to be removed or disturbed during construction activities. They are not listed on the Northern Territory Heritage Register nor are they the subject of interim conservation orders, so they do not require ministerial permission to disturb. However, INPEX will consult with the Heritage Branch of NRETAS before disturbing the sites and each will be surveyed and recorded prior to removal.

Maritime wrecks

Awareness of the maritime heritage sites in the vicinity of the nearshore development area was moderately high during stakeholder consultation, in particular regarding the SS *Ellengowan* shipwreck and the six Catalina wrecks, these are discussed in Chapter 3. Maritime archaeologists indicated there was no way to remove the Catalina wrecks from the water without causing further damage and that they should remain in situ. Stakeholders generally did not identify any specific threats to the heritage values of these sites from the Project, other than the potential for direct physical disturbance during construction of nearshore infrastructure.

Three of the Catalinas are in close proximity to the dredging footprint for the shipping channel (see Figure 10-3). These particular wrecks were aircraft owned by the United States Navy and, as such, are specifically protected by the United States *Sunken Military Craft Act 2005* (SMCA) as well as by customary international law. In addition, in February 2009 the Northern Territory Heritage Advisory Council made recommendations to the Minister for Natural Resources, Environment and Heritage under Section 24 of the *Heritage Conservation Act* (NT) that all six Catalina wrecks be placed on the Northern Territory Heritage Register to afford them protection. These proposals have been subject to public consultation but have not yet been approved. At the same time as the recommendation was made, an interim conservation order was placed on the most recently discovered Catalina wreck (known as Catalina 6) by the Minister to provide legal protection to the site, additional to the provisions under US law, until a decision is made about whether to include the site on the Northern Territory Heritage Register. If the proposal to register the Catalina wrecks is approved, exclusion zones will possibly be required around each.

Sediment dispersion and accumulation modelling for the dredging program has been conducted by HR Wallingford (HRW) (the full report is presented in Appendix 13). The modelling indicated that small volumes of coarse material (sands) released by dredging could migrate into East Arm with tidal currents, moving to the north-east of the dredging area. Total accretion outside the dredging footprint is predicted to be less than a few centimetres in depth. The Catalina 3 site, located north of the approach area and turning-basin dredging area, is predicted to receive this level of sedimentation. The wreck sites south of the dredging area, including Catalinas 4, 5 and 6 and the *Kelat*, are not predicted to be affected (see Appendix 13).

The potential effects on heritage values from sedimentation were reviewed by maritime archaeologists from URS Corporation in the United States. For some marine archaeological sites (e.g. Catalinas 4 and 5, which are relatively intact) it is considered that burial with sediments may serve, under the right circumstances, to enhance their protection and preservation. This could be made possible by reducing access to the wreck by looters and through stabilising parts of the wrecks that lack structural integrity (URS Corporation 2009).

Catalinas 4, 5 and 6 are United States Navy aircraft and, as noted above, are protected by the SMCA, which is intended to confer protection from inappropriate looting, salvaging, sport-diving activities, or disturbances resulting from otherwise permitted actions. During research for the heritage assessment, the Naval Historical Centre at the Washington Navy Yard, Washington, DC, indicated that preservation in situ through avoidance is the preferred conservation approach for maritime wrecks (URS Corporation 2009).

The United States does not currently have a bilateral agreement with Australia pertaining specifically to the SMCA, but the legislation has been applied to management of American shipwrecks in Australia in the past, in conjunction with Australian authorities. When it is proposed that the remains of sunken military craft should be removed from development sites, a permit needs to be obtained from the Naval Historical Centre. Removal may also need to be conducted by archaeologists that meet United States professional standards. As mentioned above, preservation in situ is generally preferred over a salvage operation (URS Corporation 2009).

Activities that could disturb the integrity of wrecks, such as diver inspections that entail the moving of sediment to expose the remains for documentation, also require permission from the United States Naval Historical Centre (URS Corporation 2009).

Other risks of disturbance by the Project to the Catalina wrecks, and other shipwrecks such as the *Kelat* and the SS *Ellengowan*, relate to the placement and movement of anchors and cables for construction vessels in the nearshore development area (e.g. from dredgers and pipelay barges). These may be mitigated

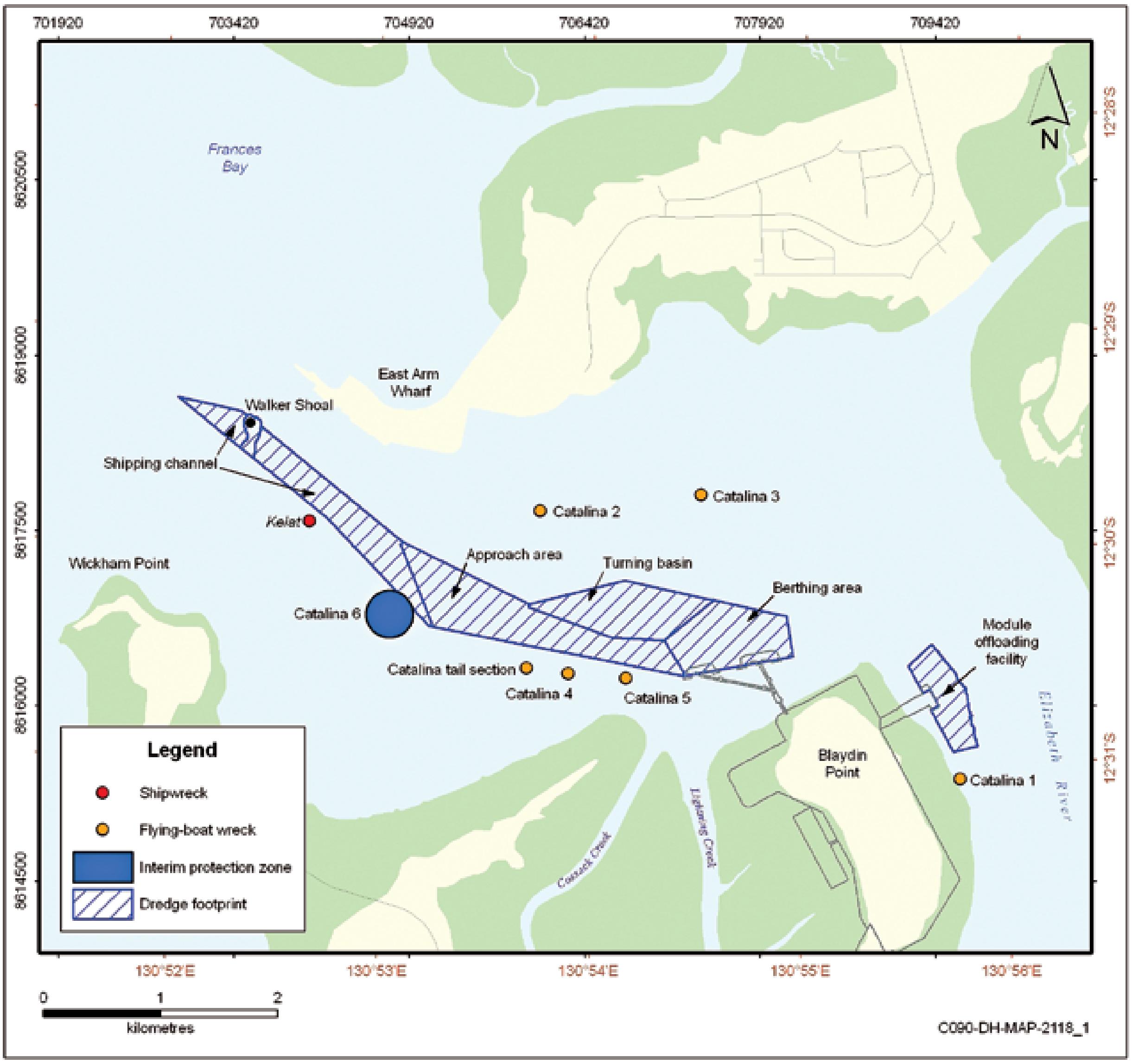

Figure 10-3: Location of Catalina wrecks in relation to the dredging footprint

through careful development of anchoring procedures and implementation of controlled zones.
It is not anticipated that any permits to disturb American wrecks under the SMCA will be required.

The potential impacts on maritime heritage sites during the operations phase will be limited to increases in sedimentation or sediment scouring on or around the Catalinas next to the navigational channel, turning basin and the berthing area arising from vessel operations and from periodic maintenance dredging.

The arrival and departure of tanker vessels at the product loading jetty will generate some resuspension of fine sediments from the seafloor because of propeller wash. While under some tidal conditions these fine sediments may be transported towards the US Navy Catalina wrecks, tidal currents would cause resuspension of this material and accumulation on the wrecks is not expected.

Preliminary studies indicate that maintenance dredging may be required approximately every 10 years. While this dredging would generate turbid plumes, seabed sedimentation effects in East Arm are expected to be similar to those generated during the construction phase, but on a smaller scale. Sediment accumulation on the wrecks is not expected as a result of maintenance dredging.

INPEX will periodically assess the sediment conditions of the Catalina wrecks adjacent to the shipping channel during the operations and in consultation with NRETAS determine whether any remedial action is required to address impacts should they arise.

Management of non-Aboriginal cultural heritage

A Provisional Heritage Management Plan has been compiled for the Project (attached as Annexe 9 to Chapter 11), which will guide the development of more detailed plans during the construction phases. This plan contains details of applicable management controls, procedures, and monitoring and audit programs. Key components of this plan are summarised as follows:

- The World War II historical sites located on Blaydin Point are not listed and do not require approval to disturb; however, INPEX will consult with NRETAS's Heritage Branch before disturbing the sites and all sites will be surveyed and recorded.
- Anchor management plans will be developed in consultation with NRETAS's Heritage Branch, to allow safe anchoring of vessels undertaking pipelay, dredging and piledriving activities in the vicinity of any heritage sites.
- To minimise disturbance, a 100-m-radius controlled zone will be established around all known Catalina flying-boat wrecks. If it is deemed necessary to have anchors or anchor cable within this zone then the appropriate anchor management procedures identified in the anchor management plan will apply.
- To minimise disturbance, a 100-m-radius controlled zone (based on the intersection of latitude 12°32'16.3"S and longitude 130°52'06.3"E on the Port of Darwin 1:50 000 map sheet AUS 26) for the SS *Ellengowan* will apply. If it is necessary to have anchors or anchor cable within this zone then the appropriate anchor management procedures identified in the anchor management plan will apply.
- To minimise disturbance, a 100-m-radius controlled zone (based on the intersection of latitude 12°29'55.4"S and longitude 130°52'40.2"E on the Port of Darwin 1:50 000 map sheet AUS 26) for the *Kelat* will apply. If it is necessary to have anchors or anchor cable within this zone then the appropriate anchor management procedures identified in the anchor management plan will apply.
- Accurate differential GPS (dGPS) locations of all wrecks near the nearshore development area will be provided to construction contractors to enable accurate positioning.
- Before dredging commences, Catalina flying-boat wrecks will be inspected to determine the current levels of sedimentation and records of these inspections will be kept.
- During the construction and operations phases, INPEX will periodically assess sediment conditions of Catalina wrecks adjacent to the shipping channel and in consultation with NRETAS determine whether any remedial action is required to address impacts should they arise.

Residual risk

The risk assessment process for potential impacts to non-Aboriginal cultural heritage has been based on legal compliance with the *Heritage Conservation Act* (NT), under which these sites are protected (see Table 10-14). It is not considered appropriate to estimate the heritage value of these sites to the local community, as different members of the community may assess the "consequence" of impacts to heritage values in different ways. For example, local historians or families of World War II veterans may consider the disturbances to wartime wrecks to be a negative impact of the Project, while newcomers to the Northern Territory may not place the same importance on these heritage features.

10.3.10 Airborne noise

The key sensitive receptors of the airborne noise generated by the onshore development area are residential suburbs and urban centres around Darwin Harbour. Darwin's CBD is located 10 km to the north-west of the onshore development area, across the Harbour waters, and the nearest residential area of Palmerston is located approximately 4 km to the east and north-east.

The main activities that could generate airborne noise in public areas around the onshore and nearshore development areas are normal plant operations and emergency flaring.

In order to assess the potential impacts of these noise sources on the community, noise propagation modelling was undertaken by SVT Engineering Consultants (SVT 2009). The modelling results were then compared against the ambient noise measurements conducted for residential areas in Bayview Haven and Palmerston (presented in Chapter 3) as a "baseline" for noise levels experienced prior to development of the Project.

An acoustic model was developed for the onshore processing plant using the SoundPLAN program, which produces noise contours over a defined area of interest. Noise reflection by the surfaces of waterbodies or by hard flat ground is integrated into the model, as is site-specific topography since noise can be absorbed by physical barriers like hills. Other physical barriers such as dense vegetation or large buildings can also absorb noise, but these are not accounted for by SoundPLAN. The model also accounts for meteorology, as climate factors such as wind direction can affect the intensity and the distance that sound travels from its source. "Worst-case" wind conditions (a soft steady wind travelling from the noise source towards sensitive receptors) are used in the model to provide a conservative estimate of noise

Table 10-14: Summary of impact assessment and residual risk for non-Aboriginal cultural heritage sites

Aspect	Activity	Potential impacts	Management controls and mitigating factors	Residual risk*		
				C†	L‡	RR§
Non-Aboriginal cultural heritage	Construction activities within the nearshore development area, including dredging and pipelay.	Accidental disturbance to maritime heritage sites listed under the *Heritage Conservation Act* (NT) or the *Historic Shipwrecks Act 1976* (Cwlth).	Design of infrastructure to avoid disturbance to sites. Anchor management plans will be developed in consultation with NRETAS's Heritage Branch to allow safe anchoring of vessels undertaking pipelay, dredging and piledriving activities in the vicinity of any heritage sites. Accurate dGPS locations of all wrecks near the nearshore development area will be provided to construction contractors to enable accurate positioning. Implementation of controlled zones around the SS *Ellengowan*, the *Kelat*, and Catalina flying-boat wrecks. Validation of dredging sedimentation modelling. Provisional Heritage Management Plan.	D (S3)	2	Medium
Non-Aboriginal cultural heritage	Vessel operations and periodic maintenance dredging activities within the nearshore development area during the operations phase.	Increases in sedimentation or sediment scouring on or around the Catalina flying-boat wrecks adjoining the shipping channel, the approach area, the turning basin and the berthing area.	INPEX will periodically assess sediment conditions in the vicinity of the Catalina wrecks adjacent to the shipping channel and, in consultation with NRETAS, will determine whether any remedial action is required to address impacts should they arise. Provisional Heritage Management Plan.	F (S2)	4	Low

* See Chapter 6 *Risk assessment methodology* for an explanation of the residual-risk categories, codes, etc.

† C = consequence.

‡ L = likelihood.

§ RR = risk rating.

propagation. The results of this study are summarised below and the full technical report (SVT 2009) is provided in Appendix 20 to this Draft EIS.

The cumulative sound power level for all equipment at the onshore processing plant during normal operations is estimated to be approximately 127 dB(A), with an increase to 140 dB(A) during emergency flaring. These raw noise levels will be attenuated as the sound travels towards receptors in the wider area. Taking into account the local topography and land and water surfaces, the expected noise-emission contours for these noise sources are presented in figures 10-4 and 10-5.

Although no noise limits are currently prescribed by legislation in the Northern Territory, the following noise limits for receiving locations have been defined for the Project in consultation with NRETAS:

- residential, institutional and education areas: 55 dB(A) during the day and 45 dB(A) at night
- industrial areas: 70 dB(A) at all times.

As the onshore processing plant will operate 24 hours a day, the night-time noise limit of 45 dB(A) is particularly relevant for noise-sensitive receivers. Predicted noise levels at key receiving locations are presented in Table 10-15, with Table 10-16 providing examples of the noise levels from common sounds to allow for comparison; the noise-level readings are taken at a point adjacent to the source.

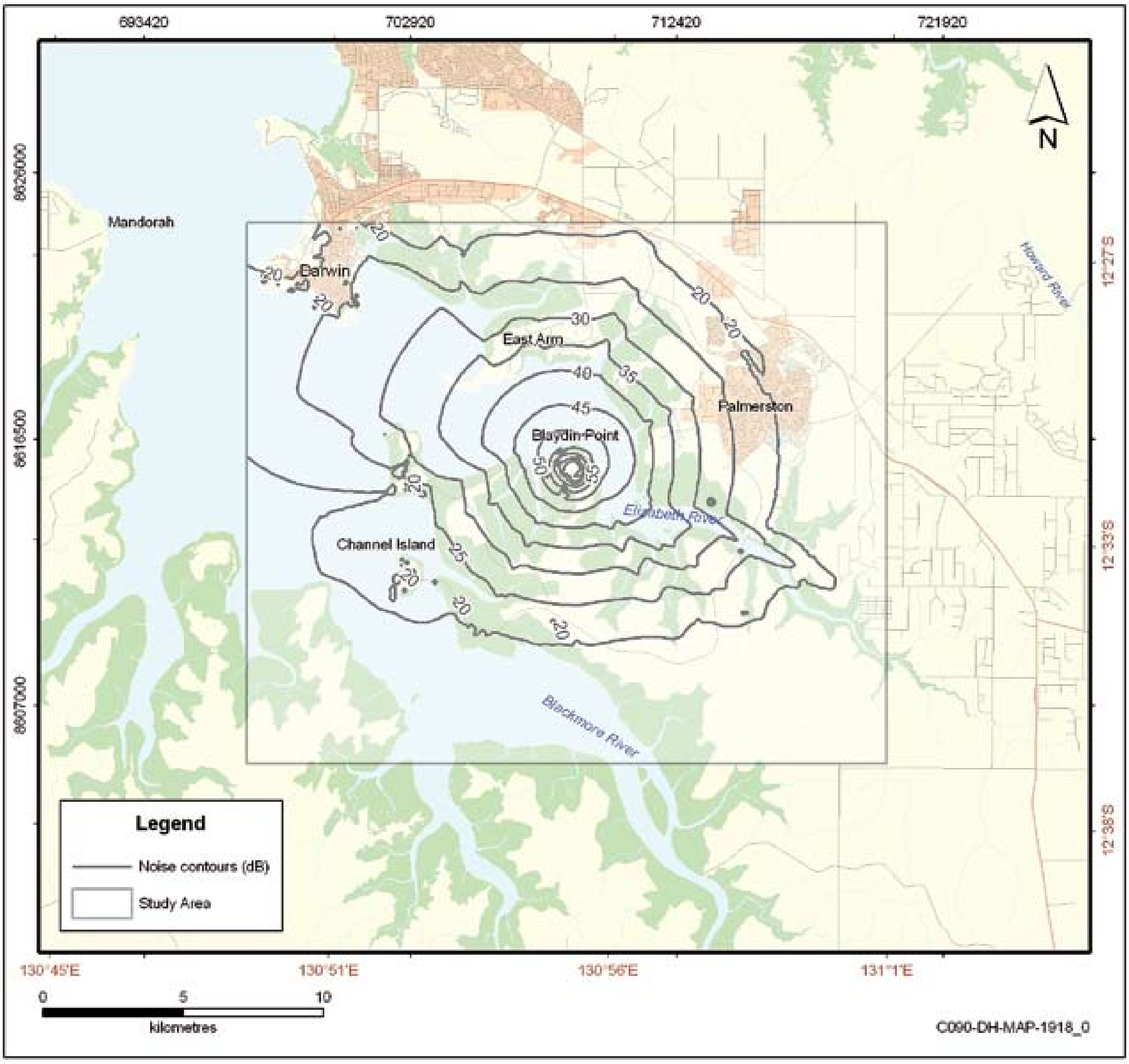

Figure 10-4: Noise contours for the onshore processing plant during normal operations

Table 10-15: Noise levels received at locations around Darwin Harbour

Location	Type of receiver	Predicted noise level received (dB(A))		Criteria limit for receiver (dB(A))
		Normal operations	Emergency flaring	
Western edge of Palmerston	Residential, institutional, education	33	40	55 (day) 45 (night)
Central Palmerston	Residential, institutional, education	25	32	55 (day) 45 (night)
East Arm Wharf	Industrial	37	45	70
Darwin LNG plant, Wickham Point	Industrial	30	40	70
Bayview Haven	Residential, institutional, education	20	35	55 (day) 45 (night)
Darwin CBD	Residential, institutional, education	24	34	55 (day) 45 (night)

Source: SVT 2009.

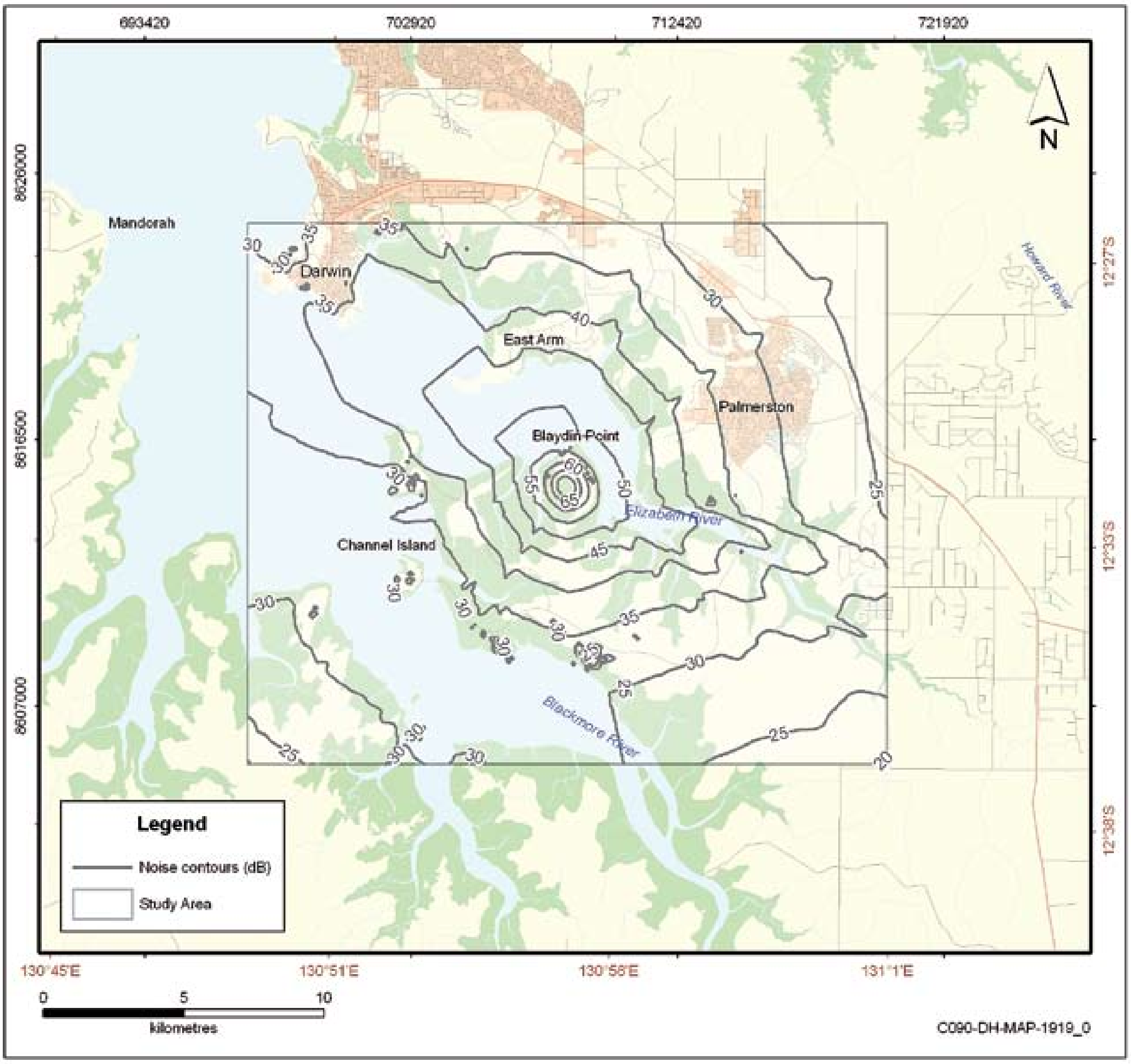

Figure 10-5: Noise contours for the onshore processing plant during emergency flaring

Table 10-16: Examples illustrating the decibel scale

Noise level in decibels (dB(A))	Noise source	Average subjective description
140	Jet engine	Intolerable
130	Rivet hammer	
120	Jet plane take-off	
110	Chainsaw	Very noisy
100	Sheet-metal workshop	
90	Lawnmower	
80	Heavy traffic	Noisy
70	Loud radio	
60	Normal conversation	
50	Low conversation	Quiet
40	Quiet radio music	
30	Whispering	
20	Quiet bedroom	Very quiet
10	Rustling leaves	
0	Threshold of hearing	

Received noise levels from normal operations and emergency flaring are well below the identified noise-limit criteria for residential and industrial receptors. The predicted noise emissions for normal operations are also below the actual ambient noise levels measured in Palmerston and Bayview Haven, as described in Chapter 3 (see Appendix 20).

Other construction noise

Piledriving for construction of the jetty will generate relatively high noise levels, which may be audible in the residential areas of western Palmerston, around 4 km away. Predictions of the propagation of piledriving noise can be difficult because there is a wide range in source levels associated with different types of equipment. Some preliminary modelling of piledriving noise is presented in Appendix 20.

Piledriving will be mainly undertaken during the day, but some night-time activities may occur if construction falls behind schedule. The significance of these received-noise levels is reduced somewhat by the nature of the activity—piledriving will be undertaken intermittently during the construction phase, with noise generated in a series of pulses interspersed with quieter periods when equipment is moved around or other construction activities are carried out. In addition, weather conditions would influence the propagation of noise: westerly winds, which are prevalent in the wet season, would carry the noise to Palmerston, while dry-season easterly and northerly winds would carry noise away from residential areas. Strong winds and rainstorms, however, would mask this noise.

Some piledriving may also be undertaken in the onshore development area. Noise source levels from this piledriving are likely to be lower, as small-diameter piles would be used. This piledriving would also be restricted to daytime hours, unless modelling indicates that noise propagation to community areas would be below permitted levels.

During the construction phase, dredging activities in the nearshore area will also generate sound-power emissions. However, these are expected to be lower than those generated by piledriving. For the Port of Melbourne channel deepening project, sound-power emissions generated by trailing suction hopper dredgers and backhoe dredgers were measured at around 110 dB(A) and 113 dB(A) respectively. Assuming no barriers or shielding, these noise emissions were expected to drop to 45 dB(A) or less within distances of around 500 m for the trailing suction hopper dredge and within 1000 m for the backhoe dredge (Jenkins & McKinnon 2006). In the context of the nearshore development area, sensitive community receptors are located at much greater distances (e.g. Palmerston is 4 km away) and would not be disturbed by dredging noise.

Airborne noise generated by marine blasting is difficult to predict, as it is highly dependent on the size of the charge, the depth of water, the rock type and ambient environmental conditions. While blasting may be audible at some areas around the shoreline of Darwin Harbour, the blasts will be intermittent and short-term only, and will be accompanied by public notification as described below.

Noise from onshore construction activities is unlikely to exceed the noise levels associated with normal plant operations and is expected to be less than 40 dB(A) (SVT 2009).

There are no criteria currently prescribed by legislation in the Northern Territory for noise emissions from construction activities. The NRETAS guidelines for construction and demolition noise controls provide recommendations for reducing noise emissions during construction. These guidelines will be considered during the design, tender and construction stages of the Project.

Management of airborne noise

The main mitigating factors for airborne noise are the large distances between the Project site and the nearest noise-sensitive receptors. No adverse impacts are therefore anticipated (SVT 2009).

The design criteria for the ground flare will include noise mitigation measures to reduce the airborne noise emissions associated with flaring.

Piledriving and blasting management plans will be developed which will include management controls to minimise noise emissions to the community during the construction phase of the Project. These management controls will include the following:

- For onshore and marine blasting, smaller staggered blasts will be carried out to minimise ground vibration and noise levels.
- Blasting activities will only be undertaken in daylight hours.
- Adequate notice will be provided to communities which could be affected by the noise relating to blasting activities (e.g. Darwin Harbour users, Palmerston and the Darwin LNG plant at Wickham Point).
- It is intended that piledriving activities will be undertaken only during daylight hours. Night-time piledriving will only be necessary if Project construction activities fall significantly behind schedule.

A traffic management plan will be developed and will include controls for the management of the impacts of traffic noise on the community. For example, bus transport will be used for most of the workforce to reduce the number of vehicles driving from the accommodation village through residential areas to the onshore development area.

Airborne noise monitoring will be undertaken to confirm modelling predictions for the construction and operations phases of the Project.

Residual risk

A summary of the potential impacts, management controls, and residual risk for airborne noise is presented in Table 10-17. The main mitigating factors for airborne noise are the large distances between the Project site and the nearest noise-sensitive receptors. The implementation of noise management controls will further reduce the risk of adverse impacts to the community. Most impacts from noise are considered to present a “medium” or “low” risk and it is likely that

Table 10-17: Summary of impact assessment and residual risk for airborne noise

Aspect	Activity	Potential impacts	Management controls and mitigating factors	Residual risk*		
				C†	L‡	RR§
Noise	Construction and commissioning activities such as piledriving, drilling and rock blasting; pneumatic testing of pipework; air blowing and flaring.	Noise and vibration causes disturbance or nuisance to the local community.	Onshore development area is located several kilometres from the nearest residential or urban area. Blasting activities will only be conducted during daylight hours. Piledriving activities are planned to be undertaken only during daylight hours; however night-time operations may be required if progress falls significantly behind schedule. Notification will be given to communities to give warning prior to blasting operations. Notification will be given to communities to give warning prior to night-time piledriving operations. Provisional Piledriving and Blasting Management Plan.	E (S2)	4	Medium
Noise	Road transport of workforce, vehicles, equipment, rock and materials during the construction phase.	Noise and vibration causes disturbance or nuisance to the local community.	Buses will be used for workforce transport to reduce the total number of vehicles on the roads. Designated traffic routes will be set for Project vehicles. Provisional Traffic Management Plan.	E (S2)	5	Medium
Noise	Generation of noise by normal operation of the onshore processing plant.	Noise and vibration causes disturbance or nuisance to the local community.	Onshore development area is located several kilometres from the nearest residential or urban area.	F (S2)	2	Low
Noise	Generation of noise by emergency flaring during operation of the onshore processing plant.	Noise and vibration causes disturbance or nuisance to the local community.	Onshore development area is located several kilometres from nearest residential or urban area. Noise mitigation measures will be incorporated into the design of the ground flare to reduce noise emissions.	E (S2)	4	Medium

* See Chapter 6 *Risk assessment methodology* for an explanation of the residual-risk categories, codes, etc.

† C = consequence.

‡ L = likelihood.

§ RR = risk rating.

any effects on the community will be localised and small in scale. Noise generated during the construction phase of the Project will be short-term in duration.

10.3.11 Visual amenity

The potential for the Project to have negative impacts on visual amenity, including light pollution, was an issue that was raised during the stakeholder consultation process.

Visual impact assessment

The construction of industrial facilities in the undeveloped vegetated areas of the Darwin Harbour shoreline represents a distinct change in the visual character of the affected site and surrounds. In order to describe the likely effects of the Project on the visual amenity of Blaydin Point, a visual impact assessment process was undertaken (URS 2009b, provided as Appendix 23 to this Draft EIS). This assessment was based on the following components:

- the selection of key viewpoints of interest around Darwin Harbour in consultation with NRETAS
- a desktop assessment of the likely viewshed from these points using a digital elevation model
- site inspections to "ground-truth" these desktop assessments
- a rating of the visual impact experienced at each viewpoint
- the development of visual simulations of the Project on digital photographs from high – and medium-impact viewpoints.

These steps are described in more detail in the sections that follow.

Selection of key viewpoints

Fourteen areas of interest around Darwin Harbour were identified in consultation with NRETAS, with review from relevant government and non-government agencies including Tourism NT. These "viewpoints" were selected to account for a range of viewing angles, potential receptor types, and residential, cultural, heritage and tourism values. The locations of viewpoints of interest to this assessment and their primary values are listed in Table 10-18 and their locations around Darwin Harbour are presented in Figure 10-6.

Viewshed analysis

Viewshed analysis identifies areas that are visible from a given location. Viewsheds were created for all 14 viewpoints of interest around Darwin Harbour by computer modelling, using a digital elevation model of the Darwin Harbour region. This accounted for the heights of major items of infrastructure within the onshore development area (such as tanks and stacks) as well as the topography within the catchments of each viewpoint. Allowance was also made for average natural vegetation heights (on top of the topography of the ground surface) in areas of uncleared bushland—this allowance was not applied to urban areas, which were presumed to be cleared. The resulting viewsheds are presented in Appendix 23.

Table 10-18: Viewpoints considered in the visual impact assessment, and their primary values

Location	Main use of site
Mandorah Jetty	Tourism, low-density residential
Darwin CBD (view from high-rise building)	Tourism, high-density urban and residential
Survivors Lookout, Darwin Wharf precinct	Tourism, heritage
Stokes Hill Wharf, Darwin Wharf precinct	Tourism, heritage
Hilly residential area at Stuart Park	Medium-density residential
Harbour foreshore at Tipperary Waters	Medium-density residential
Harbour foreshore at Bayview Haven	Medium-density residential
Charles Darwin National Park lookout	Tourism, heritage
East Arm public boat ramp	Tourism, recreation
Planned residential subdivision in Berrimah (highest ground)	Planned medium-density residential
Palmerston suburban area (highest ground)	Medium-density residential
Planned residential subdivision in Palmerston (highest ground)	Planned medium-density residential
Elizabeth River Bridge	Transport route
Planned residential subdivision in Weddell (highest ground)	Planned medium-density residential

Site inspections

Site inspections identified that some of the selected viewpoints were effectively screened from Blaydin Point by buildings, natural vegetation or topography. Photographs were taken at each viewpoint to record the existing view towards Blaydin Point; these are presented in Appendix 23.

Rating of visual impact

Visual impact at the various viewpoints of interest to the study was ranked according to the following broad criteria:

- the distance from the onshore development area
- the proportion of the view taken up by the proposed onshore and nearshore facilities
- the number of potential viewers
- the values of the viewing area.

Viewpoints from which the onshore development area was visible were broadly considered to be “medium” to “high” impact sites. Viewpoints where the views to Blaydin Point were significantly obscured by vegetation, buildings or topography were considered “low” (or “no”) impact sites. These rankings are presented in Table 10-19.

The views from the East Arm public boat ramp were considered to receive a “high” impact from the Project, as this viewpoint is relatively close to Blaydin Point and is regularly used by recreational fishermen accessing the Harbour. The tanks and stacks of the onshore processing plant will be clearly visible from this site, along with the jetty and the tankers arriving or departing from the facility.

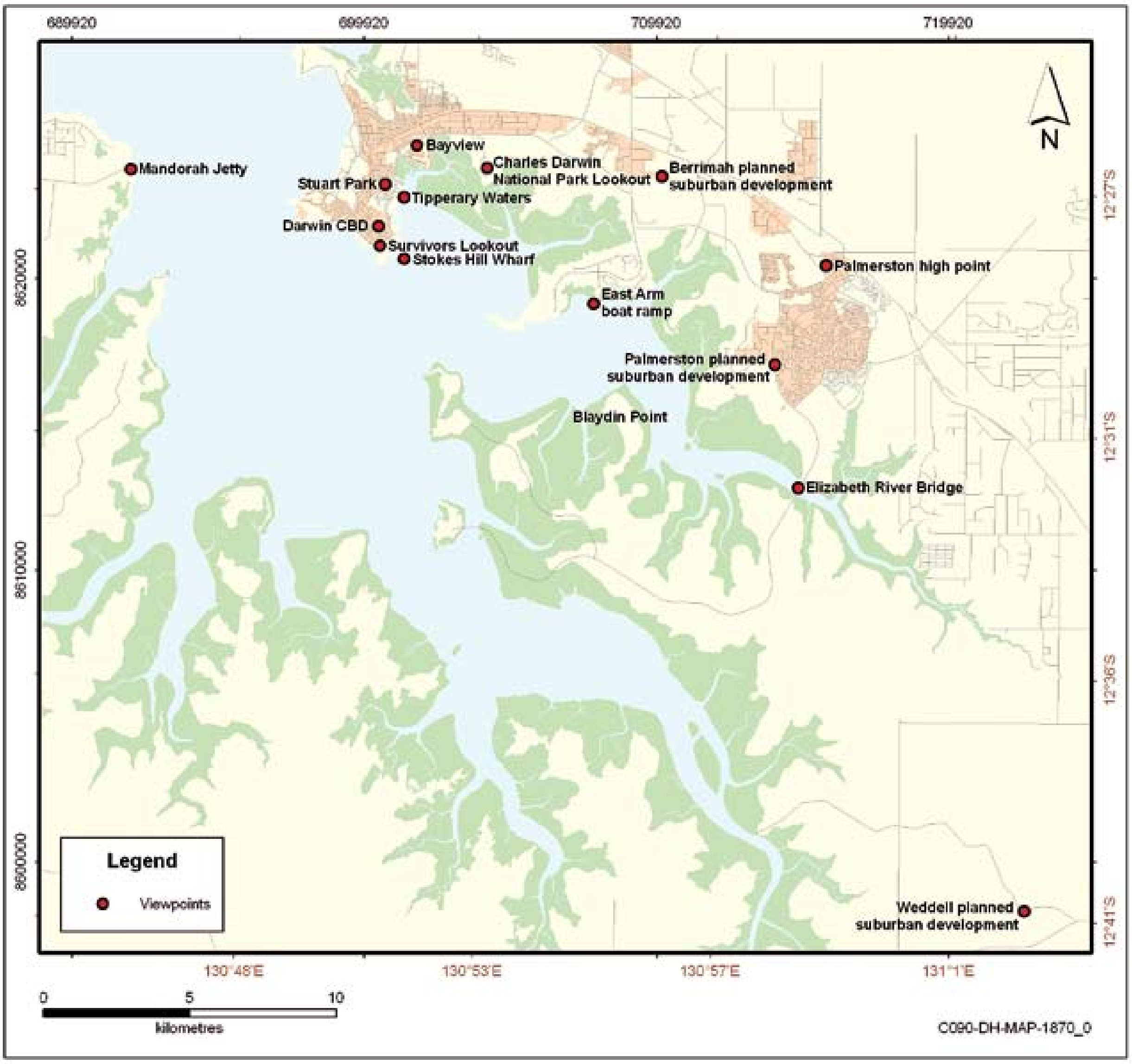

Figure 10-6: Viewpoint locations considered in the visual impact assessment

Table 10-19: Rating of the Project's potential visual impact from affected viewpoints

Site	Values	Comments	Distance (km)	Visibility
Mandorah Jetty	Tourism Low-density residential	Blaydin Point is visible in the far distance from this location, with no obstructions. The proportion of the view taken up by the Project would be extremely low.	18	Low
Darwin CBD (view from high-rise building)	Tourism High-density urban and residential	The onshore development area is visible beyond East Arm Wharf. The long distance reduces the proportion of the view taken up by the Project. Viewers from this aspect may be long-term residents (e.g. of apartments or offices).	10	Medium
Survivors Lookout, Darwin Wharf precinct	Tourism Heritage	Most of Blaydin Point is visible; the view is similar in nature to that from Stokes Hill Wharf but with buildings and wharf in the foreground. The long distance decreases the proportion of view taken up by the Project.	9	Medium
Stokes Hill Wharf, Darwin Wharf precinct	Tourism Heritage	Blaydin Point is partially obscured by East Arm Wharf. The long distance reduces the proportion of the view that would be taken up by the Project. This site is considered an important tourism location in central Darwin.	8	Medium
Hilly residential area at Stuart Park	Medium-density residential	Blaydin Point is visible from this area, although distant and partly obscured by the infrastructure at East Arm Wharf as well as buildings or vegetation close to the viewpoint.	11	Medium
Harbour foreshore at Tipperary Waters	Medium-density residential	Blaydin Point is visible from this area, although distant and partly obscured by the infrastructure at East Arm Wharf.	10	Medium
Harbour foreshore at Bayview Haven	Medium-density residential	Blaydin Point is visible from this area, although distant and partly obscured by the infrastructure at East Arm Wharf.	10	Medium
Charles Darwin National Park lookout	Tourism Heritage	Blaydin Point is not visible from this vantage point because of tree cover close to the lookout, which completely obscures the view in that direction.	9	None
East Arm public boat ramp	Tourism Recreation	Blaydin Point is clearly visible, with no obstructions across the water. This is the closest viewpoint to the onshore development area. The tanks, product loading jetty and the presence of LNG tankers in the nearshore area are all easily discernible from this site.	3.5	High
Planned residential subdivision in Berrimah (highest ground)	Planned medium-density residential	Blaydin Point is obscured from this viewpoint by a small hill in the middle distance. Some of the Project infrastructure may be partly visible at the sides of this hill. The distance to Blaydin Point is around 10 km, which reduces the proportion of the view taken up by the Project.	8	Low
Palmerston suburban area (highest ground)	Medium-density residential	Blaydin Point is completely obscured from this viewpoint by vegetation in the middle distance.	8	None
Planned residential subdivision in Palmerston (highest ground)	Planned medium-density residential	As this area is vegetated with tall trees, the view to Blaydin Point is heavily obscured for a person standing at ground level.	4	Low

Table 10-19: Rating of the Project's potential visual impact from affected viewpoints (continued)

Site	Values	Comments	Distance (km)	Visibility
Elizabeth River Bridge	Transport route	This viewpoint is relatively close to Blaydin Point but the view is partly obscured by a hill on Middle Arm. While there may be a large number of viewers from the bridge, most are likely to be in transit (i.e. in vehicles travelling across the bridge), thus reducing the viewing time.	5	Medium
Planned residential subdivision in Weddell (highest ground)	Planned medium-density residential	Blaydin Point is not visible from this vantage point because of the landform (hills) and vegetation between the two locations. The distance to Blaydin Point from this site is substantial at around 15 km.	20	None

Visual simulations

Computer-generated visual simulations were generated for onshore and nearshore development areas, for "high" and some "medium" impact viewpoints. Digital photographs were taken from the viewpoint locations, using a 50-mm camera lens. A panoramic image was developed by stitching four photographs together horizontally, presenting an image of approximately 60° width and 15° height. These dimensions were considered to represent the typical field of view of the human eye. In order to simulate the look of the Project infrastructure during the operations phase, visual simulations were developed using 3ds Max® software, which overlays a computer-simulated model of the buildings on to the base photographs from each viewpoint.

Examples of daytime and night-time views from the Darwin CBD (high-rise), Stokes Hill Wharf and the East Arm boat ramp are presented in figures 10-7, 10-8 and 10-9. A full set of simulations is provided in Appendix 23. It should be noted that night-time views have been provided for the Darwin CBD and Stokes Hill Wharf viewpoints, but not from the East Arm boat ramp which is closer to the development area. Lighting designs for the onshore processing plant and jetty are still in the preliminary stages of development and it is not possible to simulate light glows and reflections from close range with accuracy using computer imagery.

Management of visual impact

Vegetated buffers

Retaining a strip of natural mangrove vegetation around the onshore development area will provide a minor "buffer" for the visual impact of the site, although it is noted that most of the onshore infrastructure will project above the tree line. Mangrove vegetation will be maintained along the eastern and western sides of the onshore development area, which will shield the ground-based equipment at the onshore processing plant from boats in Darwin Harbour and from viewpoints such as the East Arm boat ramp and Elizabeth River Bridge. The construction of the product loading jetty and the module offloading facility on the northern edge of Blaydin Point precludes the retention of shoreline vegetation in those areas.

Lighting

Subject to safe operability of the onshore facility, the lighting design implemented at the onshore and nearshore infrastructure will be selected with consideration of their visual impact on the community. In addition, a ground flare was chosen as part of the Project design to minimise light emissions and visual impacts on the community as a result of emergency flaring. The ground flare will be enclosed to further reduce light emissions.

Air emissions

It is noted that smoke from seasonal bushfires is a reasonably common feature of the skyscape around Darwin Harbour during the dry season. Dark smoke, however, which could be produced during Project commissioning and periodically during operations by the ground flare, would likely be more intense and distinctive than seasonal bushfire smoke.

The ground and tankage flares will be designed to minimise generation of smoke through improvements in burning efficiencies and optimisation of the combustion process.

The negative impact of smoke and dust on the viewshed around Blaydin Point (and further off site) may be reduced through actions such as the following:

- Ground flares and tankage flares will be designed to minimise the generation of particulates (smoke).
- Dust-suppression techniques will be applied where necessary to protect worker health, vegetation health, and amenity.
- Multiple handling of material that has the potential to generate dust will be avoided where possible.
- Roads required for the operations phase will be sealed as soon as practicable after clearing in order to minimise dust emissions from vehicle movements.

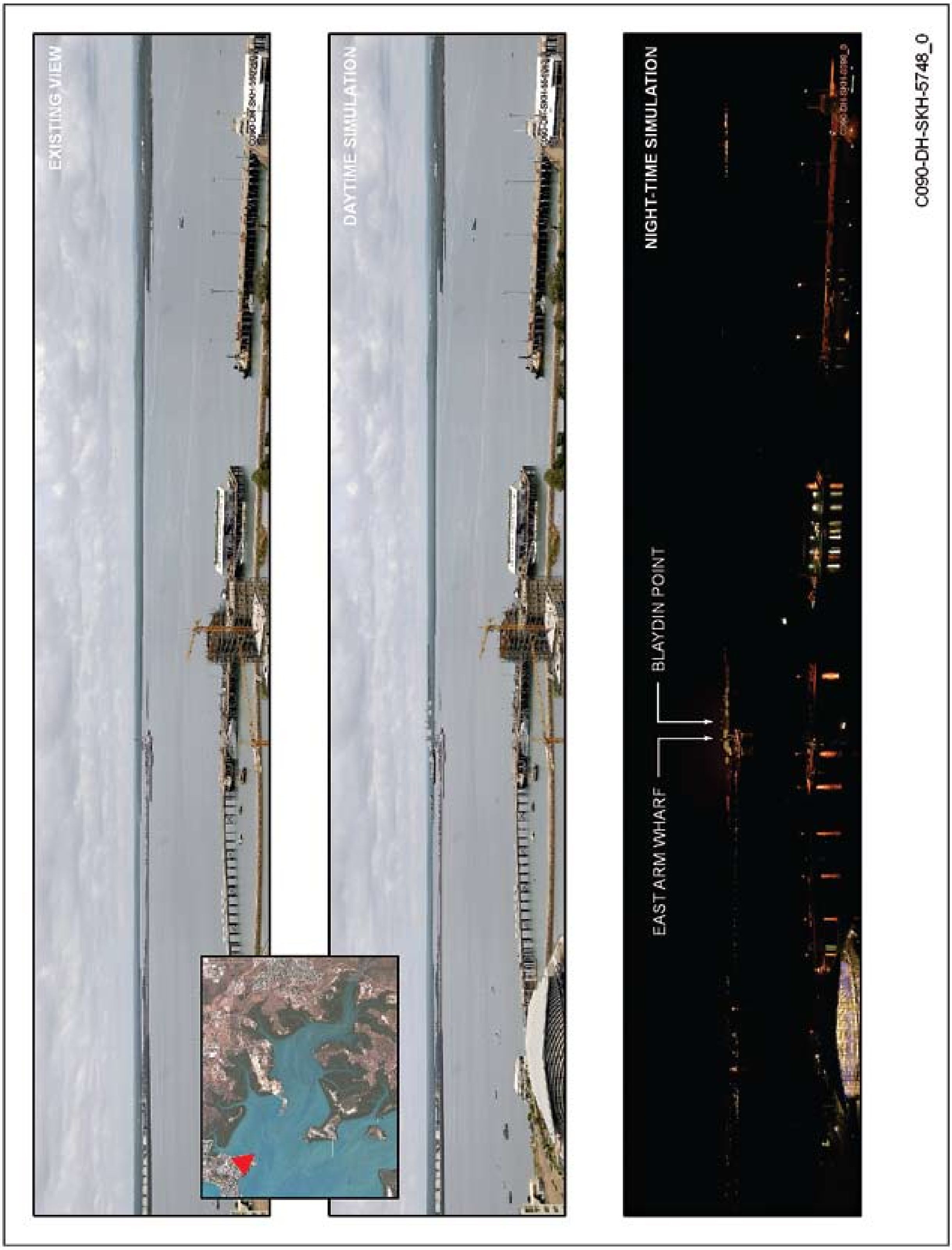

Figure 10-7: Existing and simulated views of the Project's Blaydin Point infrastructure from a high-rise building in Darwin's CBD

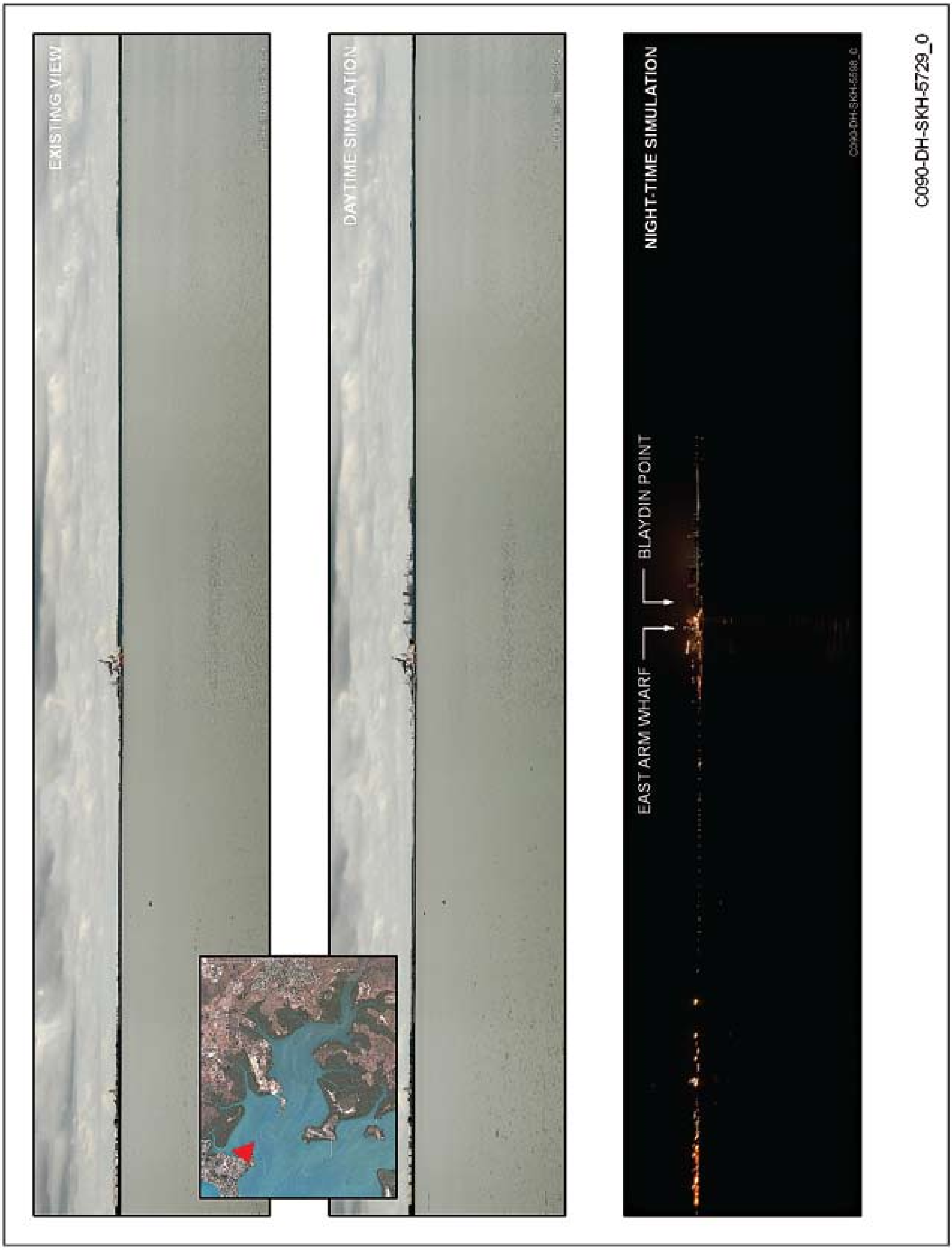

Figure 10-8: Existing and simulated views of the Project's Blaydin Point infrastructure from Stokes Hill Wharf

Figure 10-9: Existing and simulated views of the Project's Blaydin Point infrastructure from the East Arm boat ramp

These and other management controls have been included in the Provisional Air Emissions Management Plan and Provisional Dust Management Plan, attached to Chapter 11 as Annexe 2 and Annexe 7 respectively.

Residual risk

Potential impacts to visual amenity are presented in Table 10-20, along with the proposed management strategies to minimise these impacts during the life of the Project. It is not considered appropriate to apply a residual-risk rating to visual amenity issues, as different members of the community may assess the "consequence" of these impacts in different ways. For example, some community members may prefer a natural landscape free from man-made infrastructure, while others may take an interest in the construction and operation of large industrial facilities, with the associated lighting and tanker vessel traffic.

10.3.12 Commercial fishing and aquaculture

Offshore

The offshore and nearshore development areas are located within the boundaries of a number of federal and state-managed commercial fisheries. Five commercial fisheries overlap the offshore development area at the Ichthys Field. As the pipeline extends east towards the Northern Territory, it crosses a further seven commercial fisheries. These commercial fisheries are described in detail in Chapter 3.

The surface facilities and support vessels in the offshore development area during all phases of the Project could represent obstacles for commercial fishing activities (e.g. longline fishing). Pelagic longline fishing occurs to a limited extent in the region, as part of the WA North Coast Shark Fishery – Joint Authority Northern Shark Fishery, the Western Tuna and Billfish Fishery and the Southern Bluefin Tuna Fishery. A longline deployed upstream of the central processing facility (CPF) and the floating production, storage and offtake (FPSO) facility could snag surface and subsurface structures, and surface buoys on the longline could be run over by support vessels. Surface longlines are typically allowed to drift for 4–5 hours before a 10–12 hour retrieval period (Lopez et al. 1979; Sakagawa, Coan & Bartoo 1987). Assuming an average current speed of 0.25 m/s and a set time of 17 hours (5 hours drift and 12 hours recovery), longline fishers would need to avoid setting their lines within some 15 km upstream of the CPF in order to avoid snagging. In the context of the pelagic longline fishing area (which extends from the south-west coast of Western Australia northwards and eastwards to Cape York) this represents a very small area of exclusion.

Seabed infrastructure in the offshore development area, such as wellheads, flowlines, moorings and the gas export pipeline, could represent obstacles to trawling fisheries of which there are three in the vicinity of the offshore development area. The fishing efforts for two of these fisheries, the Commonwealth's Northern Prawn Fishery and North West Slope Trawl Fishery, are presented in Figure 10-10, which also shows the area utilised by Western Australia's Kimberley Prawn Managed Fishery. Note that fishing effort data can be subject to confidentiality; areas fished by five operators or fewer are not reported in publicly available databases and are not included in Figure 10-10. (The data used to create this figure were obtained from Western Australia's Department of Fisheries and the Australian Fisheries Management Authority in February 2009.)

Table 10-20: Summary of impact assessment and residual risk for visual amenity

Aspect	Activity	Potential impacts	Management controls and mitigating factors	Residual risk
Visual amenity	Construction of onshore infrastructure.	Reduction in visual amenity resulting from visible dust.	Dust suppressants use on roads and stockpiles during dry conditions. Minimising ground disturbance and the multiple handling of soil or rock materials. Sealing the main access roads throughout the site and to the junction with Wickham Point Road. Provisional Dust Management Plan.	Not applicable
	Operation of onshore processing plant.	Reduction in visual amenity resulting from smoke and light emissions from flares.	Ground flare and tankage flare will be designed to minimise the generation of particulates (smoke). The ground flares will be shielded to reduce light emissions.	Not applicable

The greater part of the fishing effort associated with the North West Slope Trawl Fishery occurs to the west and north of the Ichthys Field. However, as fishing effort data do not account for five vessels or less, there is the potential that some fishing effort may occur within the offshore development area. A precautionary zone would be established around subsea equipment in the field in order to avoid damage to fishing and subsea equipment. The Kimberley Prawn Managed Fishery is located outside the offshore development area.

The gas export pipeline crosses an area utilised by the Northern Prawn Fishery. In order to avoid damage to fishing and the pipeline, a precautionary zone would be established around the pipeline in consultation with relevant regulatory authorities and fishery stakeholders. The protected area would be small in relation to the areas available to the fishery.

During construction of the gas export pipeline, a 500-m exclusion zone will be imposed around pipelay vessels. This will represent a very minor impediment to fishing activities owing to the transient nature of the movements of the vessels along the pipeline route and the vast areas of alternative fishing areas adjacent to the route.

The Northern Demersal Finfish Association raised some concerns about the risk of losing traps as a result of Project vessel movements in the offshore area throughout the life of the Project. Further liaison with this group will occur as the Project progresses.

Darwin Harbour

There is little or no commercial fishing effort inside Darwin Harbour and therefore no threat of interference from the nearshore development area. Operators in

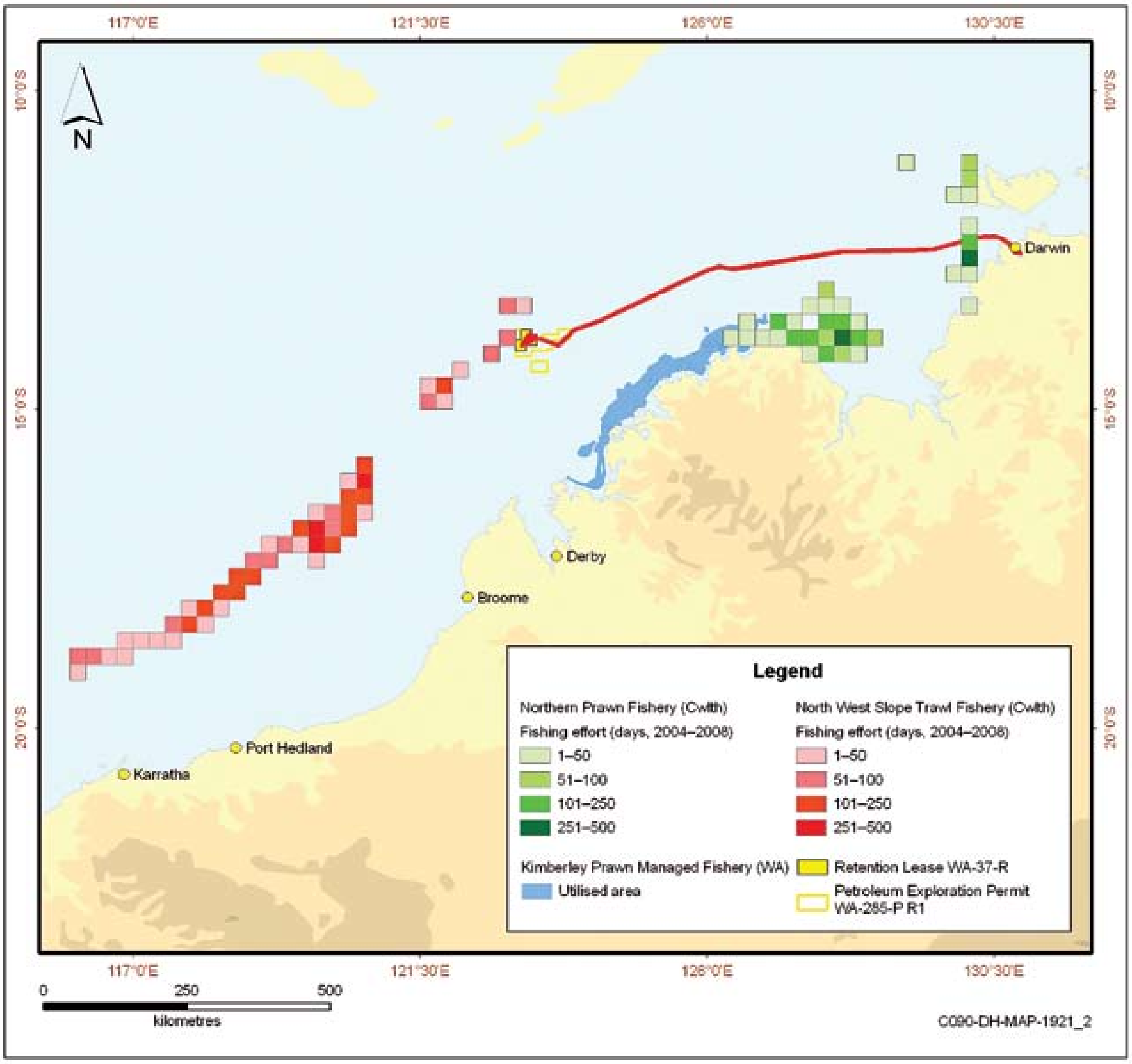

Figure 10-10: Commercial fishing effort in the vicinity of the Project

the Coastal Line Fishery managed by the Northern Territory are permitted to fish within Darwin Harbour, but rarely do so. Stakeholders from the Northern Territory seafood industry generally did not believe that the Project would impact on commercial fisheries.

The Aquarium Fishery managed by the Northern Territory includes Darwin Harbour, but as few as two operators actually fish in the area. Key marine habitat areas such as coral sites are to be protected from impacts from the Project through management controls, as described in Chapter 7, and negative effects to the aquarium fishery are not anticipated.

The Darwin Aquaculture Centre, based on Channel Island, receives water from an intake location at the south-west of the island. Modelling of turbid plumes from dredging for the nearshore development area indicated that this area could receive a small increase in suspended sediments during the 3-month period of dredging for the gas export pipeline shore crossing. As a result, filters for the seawater intake at the aquaculture centre may have to be changed more frequently during this period.

The risks of marine pest introductions associated with the Project are of concern to commercial fishing and aquaculture operators, as management controls such as limitations on border crossings and vessel movements could be implemented in the event of a pest outbreak. Marine pest risks and the measures that will be implemented to manage these risks are described in Chapter 7.

Commercial fishing operators also raised concerns about labour market impacts. During 2008, labour shortages had caused some fishing boats to operate only occasionally or on a rotational basis (with staff rotating between boats) and a number of boat owners were leaving the industry to work elsewhere. Management controls for labour issues are described in Section 10.4.3 *Employment and training*.

Management of commercial fishing and aquaculture impacts

An application will be made to the relevant government regulatory agencies to implement a safety exclusion zone with a radius of 500 m around surface and subsurface equipment in the offshore development area. This safety zone will be gazetted under the *Offshore Petroleum and Greenhouse Gas Storage Act 2006* (Cwlth) and will appear on Australian navigational charts. An additional "restricted navigation zone" 5 nautical miles wide will also be requested in this area. Notification of the location of the offshore facilities and gas export pipeline will be published through a "Notice to Mariners".

In addition, an application will be made for permission to implement a precautionary zone around the offshore pipeline in consultation with the appropriate regulatory authorities.

A precautionary zone will be implemented within 200 m of the gas export pipeline in the nearshore development area, prohibiting dropping or dragging an anchor, or performing an action that could damage the pipeline (as prescribed by Section 66(5) of the *Energy Pipelines Act* (NT)).

Residual risk

Implementation of the above controls, impacts to commercial fishing and aquaculture are considered to present a "low" to "medium" risk and, as such, any effects will be localised and minor in scale (see Table 10-21).

10.3.13 Defence

The eastern portion of the gas export pipeline route runs through the Northern Australia Exercise Area (NAXA), used by the Australian Defence Force for at-sea exercises and weapons firing training and shore-based weapons firing training. INPEX has obtained in-principle agreement from the Australian Defence Force to construct the gas export pipeline in this area. The concept will be formalised through the pipeline licensing process under the *Offshore Petroleum and Greenhouse Gas Storage Act 2006* (Cwlth) and the *Petroleum (Submerged Lands) Act* (NT).

It is proposed that a 1-km-wide exclusion zone will be implemented for live ammunition firing and grounding of submarines along the pipeline route within the NAXA. This will be incorporated into the Australian Defence Force's safety template for the area. Prior to the commencement of construction, detailed surveys will be conducted to identify any unexploded ordnance within the proposed pipeline alignment. Further management controls to ensure the safety and operability of both the gas export pipeline and the NAXA will be developed through ongoing consultation with the Australian Defence Force.

The Bayu–Undan Gas Pipeline lies immediately to the north of the NAXA (which was reduced in extent to ensure that the pipeline was outside the area; consequently no operation exclusion zones were required. The Blacktip Gas Pipeline crosses the NAXA and an exclusion zone has been implemented to ensure that the pipeline is protected from military activities in the NAXA.

Table 10-21: Summary of impact assessment and residual risk for commercial fishing

Aspect	Activity	Potential impacts	Management controls and mitigating factors	Residual risk*		
				C†	L‡	RR§
Commercial fishing	Presence of offshore infrastructure in the open ocean.	Damage to fishing equipment or pipeline.	An application will be made to the relevant government regulatory agencies to implement a safety exclusion zone around surface and subsurface equipment in the offshore development area. This will be gazetted and will appear on navigation charts. An application will be made to the relevant government regulatory agencies to implement a precautionary zone around the offshore pipeline in consultation with relevant regulatory authorities. A precautionary zone will be implemented within 200 m of the gas export pipeline in the nearshore development area. Notification of the location of the offshore facilities and gas export pipeline will be achieved through the publication of a "Notice to Mariners." Navigation lights and markers on offshore infrastructure. Standard maritime communications equipment on all Project vessels.	E (S2)	2	Low

* See Chapter 6 *Risk assessment methodology* for an explanation of the residual-risk categories, codes, etc.

† C = consequence.

‡ L = likelihood.

§ RR = risk rating.

10.3.14 Public safety

The onshore development area is located several kilometres from the major population centres of Palmerston and Darwin. Members of the public may spend time closer to the site while boating in Darwin Harbour, fishing in the "Catalina creeks" (officially named Lightning Creek and Cossack Creek) near Blaydin Point, or visiting the southern part of Middle Arm Peninsula. Since the Project will be undertaking major construction activities, processing and storing large volumes of hazardous materials (in particular, LNG, LPG and condensate) and transporting high-pressure gas in a pipeline within Darwin Harbour, there are potential risks to which the public may be exposed.

Public safety during construction

Safety reviews for construction activities will be conducted during the detailed-design phase of the Project. Preliminary assessments have indicated that blasting in the onshore and marine environments could potentially pose a risk to public safety if not managed appropriately.

Marine blasting is likely to be undertaken during the construction phase of the Project as the hard substrate at Walker Shoal cannot be dredged. The risks to public safety associated with marine blasting result from shock waves in the water, which can cause injuries to any people in the water close to the blasting zone.

Onshore blasting may also be required during construction. In this case there is the potential for flyrock to pose a risk to public safety. It is predicted, however, that the potential for flyrock to be projected beyond the plant site boundaries will be minimal, as blasting operations will be designed to ensure that flyrock is contained within the site boundaries. INPEX plans to implement controls to make certain that such risk from flyrock is minimised.

Furthermore, the blasting program will be designed to ensure that onshore and marine blasting do not impact on the structural integrity of buildings, the Bayu–Undan Gas Pipeline, wharf structures and any underwater infrastructure.

Management of public safety during the construction phase

A Provisional Piledriving and Blasting Management Plan has been compiled for the Project (attached as Annexe 12 to Chapter 11), which will guide the development of more detailed plans during the construction phase. This plan contains details of applicable management controls, procedures, and monitoring and audit programs. The key components of this plan applicable to public safety for nearshore and onshore blasting activities are summarised as follows:

- Notice will be given to the Northern Territory's DLP and the DPC advising vessel operators of any change to marine traffic conditions because of marine blasting activities.
- A safety exclusion zone for marine traffic and recreational water-users will be established around blasting areas. Public notices will be issued prior to blasting, to inform recreational water-users in any blasting area. INPEX will advise the community of the date, time and duration of the blasting activities and will provide details of the boundaries of the safety exclusion zone.
- Smaller staggered blasts will be used for onshore blasting operations, and correct "maximum instantaneous charge" and blast-hole sizes will be used to minimise flyrock generation.
- Blasting operations will only be undertaken during daylight hours and adequate notice will be provided to people who could be affected by the sound or activities (e.g. Darwin Harbour users, the citizens of Palmerston and the workforce at the Darwin LNG plant at Wickham Point).
- Public access to the onshore development area will be restricted throughout the construction period.

As noted above, the drill-and-blast program will be designed to ensure that no damage occurs to buildings, the Bayu–Undan Gas Pipeline, wharf structures or underwater infrastructure.

Public safety during operations

In accordance with Australian and international practice, all Project infrastructure will be designed and operated consistent with the principle of managing risk to "as low as reasonably practicable" (ALARP) levels. This principle is supported by various legislative requirements that include licensing of the onshore processing plant site at Blaydin Point (including the product loading jetty) as a "major hazard facility" under the *Dangerous Goods Act* (NT) and the Dangerous Goods Regulations (NT). Public risk from major hazard facilities is managed in accordance with the National Standard for Control of Major Hazard Facilities and the Code of Practice (1996) issued by Safe Work Australia, formerly the Australian Safety and Compensation Council (NOHSC 2002).

Part of the process of acquiring a dangerous goods licence for a major hazard facility such as the onshore processing plant at Blaydin Point involves undertaking hazard identification and risk management processes in order to assess the safety risk to the public in the unlikely event of major incidents resulting from activities at the onshore plant.

Potential consequences from such incidents include:

- Fires: high-pressure gas or liquid releases may form jet fires, while low-pressure liquid releases or liquid drop-out from spray may form pool fires. Heat radiation generated as a result of these fires has the potential to lead to injuries or fatalities.
- Flash fires: an unignited gas cloud could form and migrate off site. On coming into contact with an ignition source, a flash fire could occur (i.e. an intense and short-duration fire). This event may burn back to the release location, eventually forming a jet fire or pool fire. There is a potential for fatalities to occur as a result of this type of event.
- Explosion: explosions can occur with some types of gas cloud or where a cloud forms in a confined or congested area. If ignition should occur under these circumstances, an overpressure may be generated. If such an overpressure is sufficiently large, injuries and fatalities may occur both outdoors and indoors, for example as a result of doors or windows being blown inwards.

These consequence scenarios form part of the inputs into the QRA described below.

In addition, incidents could arise from the onshore and inshore sections of the pipeline as a result of third-party interference, corrosion or catastrophic failure. These risks have also been assessed.

Management of public safety during operations

In order to obtain the major hazard facility licence for the onshore plant from NT WorkSafe, a safety report needs to be produced that documents the risks identified and the controls that are being incorporated into the design of the onshore processing facilities. An approval will also be required from the Northern Territory's Department of Resources for the onshore and inshore sections of the gas export pipeline. The principal controls for the onshore and nearshore infrastructure design, construction and operations include the following:

- designing equipment and pipework to contain the range of pressures, temperatures and materials encountered in the process, in line with Australian and industry-wide standards and codes of practice

- laying sections of the nearshore gas export pipeline in Darwin Harbour in a trench and placing impact protection (dumped rock) over the trench to mitigate risks from anchor damage and ship grounding
- undertaking additional pipeline wall thickness and internal inspections of the gas export pipeline, using appropriate specialised instruments
- pressure-testing (hydrotesting) and installing leak-detection systems at the onshore gas-processing facilities and on the gas export pipeline
- positioning equipment in the facility to reduce off-site consequences by providing adequate separation distances
- providing an emergency shutdown and depressurisation system that will shut the plant down if a significant process upset should occur
- installing a fire-protection system designed to reduce the consequences of a potential accident and reduce the potential for escalation of a fire
- developing a safety-management system consistent with the requirements for a major hazard facility and pipeline. This would cover maintenance and inspection of hydrocarbon containment equipment; shipping operations; procedures and maintenance of lifting equipment; corrosion prevention systems and fire and explosion control systems
- implementing security plans, emergency plans and response procedures, prepared in consultation with the relevant emergency response authorities and others (e.g. the Darwin Port Corporation, the Northern Territory Police, the Fire and Emergency Services Authority, the Darwin LNG plant and NT WorkSafe) to mitigate consequences in the event of an incident
- restricting public access to the onshore processing plant throughout the operations phase.

Residual risk

Quantitative risk assessment

Part of the risk management process involves undertaking a series of quantitative risk assessments (QRAs). A QRA is a process by which the level of risk to individuals and groups (both of the workforce and the public) is quantified using well-established methodologies and models. INPEX has been supported in this process by an experienced risk consultancy, Germanischer Lloyd Industrial Services UK Ltd. The consultancy's report (GL 2009) is provided as Appendix 24 to this Draft EIS and provides a technical summary of the preliminary QRA work undertaken to date; it describes risk associated with the current base-case design and incorporates the prevention and mitigation controls that are currently in place.

The preliminary QRA considered the safety risks from the following sources:

- the nearshore gas export pipeline in Darwin Harbour (approximately 27 km in length)
- the onshore gas export pipeline on Middle Arm Peninsula (approximately 6 km in length)
- the onshore processing plant, including the product loading jetty.

The risk evaluation process will continue through the design phase, as the design and operating philosophies are developed, to enable a final safety demonstration to be presented in the operations safety report and in submissions to the Department of Resources. Consultation with regulatory agencies on hazard identification and risk management will be ongoing.

Public risk criteria

When the onshore risk results were calculated, they were compared with safety risk criteria suggested by government to assess the suitability of the proposed location for a major hazard facility. The risk metrics used for this purpose are location-specific risk (LSR) contours which estimate risk levels at geographical locations around the plant for land-use planning purposes. It should be noted that the Blaydin Point site was offered to INPEX by the Northern Territory Government and that the site has been earmarked for future industrial development and is classified as such under the Northern Territory Planning Scheme (DPI 2008). INPEX was advised by NT WorkSafe that the "Victorian 'Interim' offsite individual risk criteria" should be used as a guideline to assess off-site risk levels around and from the onshore processing plant. These criteria state that the 10-per-million-per-year (1×10^{-5}) risk contour should not extend outside the plant site boundary.

It should also be emphasised that the risk contour approach estimates risk on a geographical basis. It assumes that a person is permanently and continuously present in one location, unprotected and unable to escape. In reality, individuals are in the vicinity of the plant's infrastructure only occasionally and are actually exposed to much lower risk.

Results from preliminary QRAs

Preliminary off-site risk contours for the onshore and nearshore development area are provided in Figure 10-11. Further details on risk contours are provided in Appendix 24.

Risk contours associated with the gas export pipeline for even the most conservative risk levels identified in the Victorian interim risk criteria do not extend over any residential areas or population centres. A risk level of 10 per million per year (1×10^{-5}) is associated with the pipeline only in a short section close to the shore crossing, owing to a slightly higher chance of damage to the pipeline by external sources (e.g. potential future development) in this area (Appendix 24). The risk levels associated with the nearshore and onshore pipeline are considered tolerable, as risk-reduction measures are included in the preliminary design. These measures include active methods to protect against corrosion and erosion of the pipe wall, and protection from external impact by trenching and/or rock dumping in high-exposure areas.

Risk contours associated with the onshore processing plant for even the most conservative risk levels identified in the Victorian interim risk criteria do not extend over any residential areas or population centres. As shown in Figure 10-11, the risks posed to users of the Harbour in the vicinity of the jetty heads and trestle and some of the north-eastern inlets to Lightning Creek may be higher than the acceptable risk levels of 1×10^{-5}. This means that nominal safety and security exclusion zones of approximately 500 m will need to be established around the jetty head and along the jetty trestle. As the 1×10^{-5} risk contour shows that the acceptable risk contour borders the main channel of Lightning Creek, risk values will need to be confirmed by a final QRA based on the completed final plant design to determine whether access to Lightning Creek can be maintained. Further permanent development (e.g. for industrial use) within the 1×10^{-5} risk contour is considered very unlikely and should be restricted for safety reasons. The risk levels associated with the onshore gas processing plant are also considered tolerable, as risk-reduction measures are included in the preliminary plant design (as described earlier in this section). Efforts to further reduce risks to public safety will continue throughout the design, construction and operations phases of the Project.

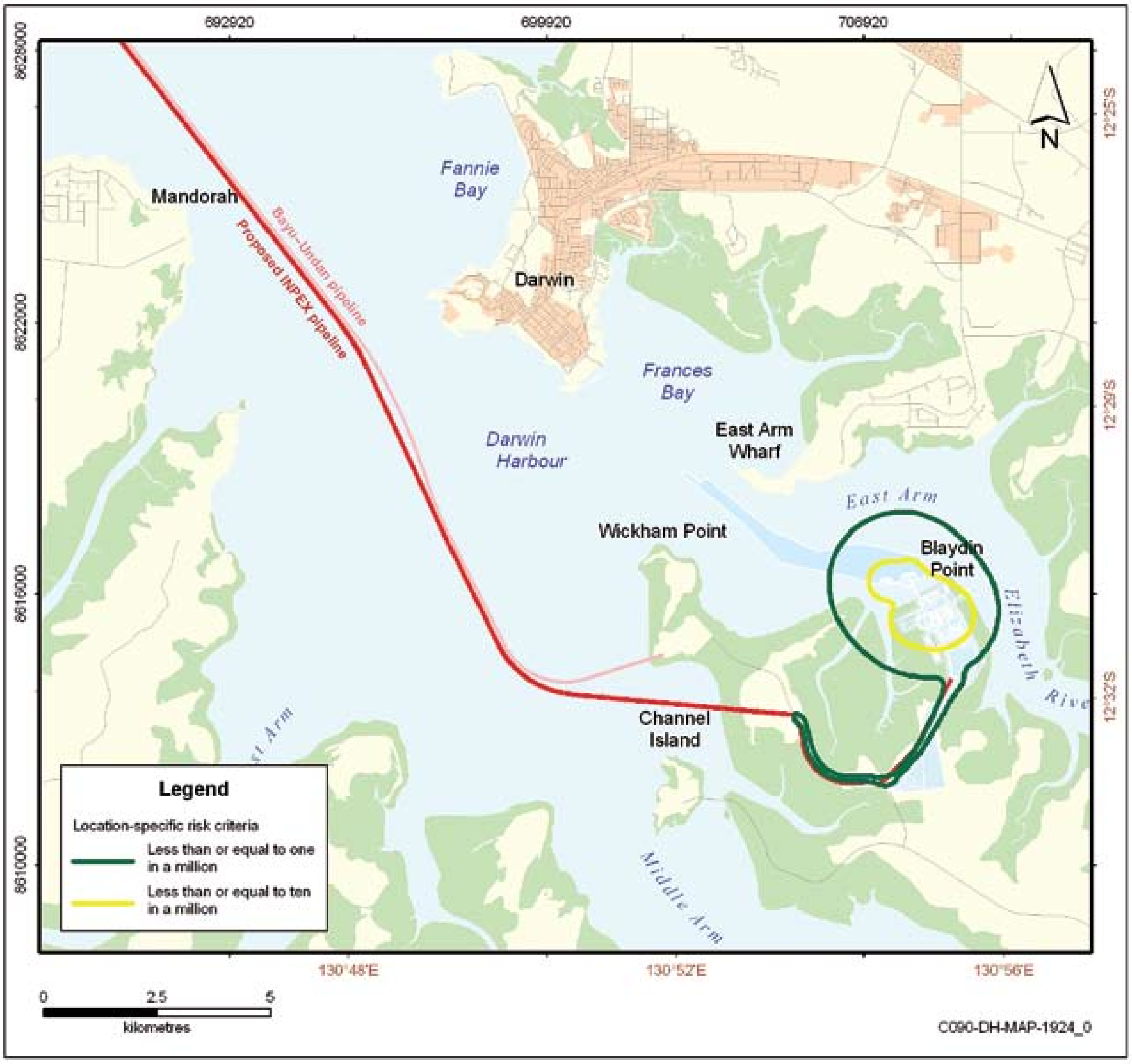

Figure 10-11: Location-specific risk contour map for the onshore development area and jetty

10.4 Economic effects and benefits

This section describes the range of potential positive and negative economic impacts of the Project on the community in the Darwin region, and presents the management controls proposed to reduce negative impacts and optimise the opportunities presented by the Project.

10.4.1 Economic impact modelling

In order to predict the economic impacts of the Project on the Northern Territory and Australian economies, URS developed an economic model in conjunction with Monash University's Centre of Policy Studies in 2008. The study employed the Monash Multi-Regional Forecasting (MMRF) model, which is used extensively by the private sector and governments in Australia to estimate the economic implications of large-scale development projects and government policy changes. (The MMRF, for example, is one of the models that the Commonwealth Treasury employed to investigate the implications of a carbon emissions trading scheme.)

The MMRF is a computable general equilibrium model and captures the indirect or "flow-on" economic impacts of a project on regional, state and national economies. The model takes into account supply constraints and the competition for available resources between the project of interest and other industries in the economy. In the MMRF model, the Australian economy is divided into any combination of eight economies representing the six states and two territories. Each region is modelled as an economy in its own right, with region-specific prices, consumers and industries.

The MMRF model shows the unfolding of the economic impacts of a project over a number of years. The analysis compares two time paths of economic development—one generated without the project (the "base case") and the other with the project. The deviations between these two time paths measure the impact of the project.

The assumptions used for the MMRF modelling for the Project are shown in Table 10-22.

INPEX plans to produce approximately 8.4 Mt of LNG and 1.6 Mt of LPG from the Blaydin Point facility each year. Approximately 85 000 barrels per day of condensate will be produced and exported from the offshore facilities, with approximately 15 000 barrels per day being produced and exported by sea from the onshore processing plant at Blaydin Point.

The construction period is approximately five years and the operating life of the Project is expected to be approximately 40 years. The Project will generate additional employment of over 2000 full-time personnel indirectly and directly. This increases the rate of employment by 3.4% over the base case.

The long-term oil (condensate) price is assumed to be US$61, and the discount rate applied is 7%.

Impact on the Australian economy

The Project is predicted to contribute A$3.5 billion (an additional 0.2%) to Australia's gross domestic product (GDP), as shown in Table 10-23.

The model predicts that the Project will contribute to an improvement in the Australian trade balance: average annual exports are A$1.8 billion a year higher, while imports are only A$438 million a year higher. The increase in the value of Australian exports is much less than the value of Project exports, because the Project's exports are predicted to cause an appreciation of the real exchange rate. This means that exports cause the Australian dollar to appreciate against other currencies, which, in turn, makes it more difficult to export. Hence the overall value of Australian exports increases by the net impact of the value of Project exports minus the decrease in exports caused by the Australian currency appreciation.

Table 10-22: Baseline assumptions for economic modelling

Factor	Baseline assumption
LNG production by the Project	8.4 Mt/a
LPG production by the Project	1.6 Mt/a
Condensate production by the Project	85 000 barrels per day (offshore facilities)
	15 000 barrels per day (onshore plant)
Construction period	5 years
Operations life	40 years
Additional employment over the base case	Over 2000 personnel
	3.4%
Long-term oil price (condensate)	US$61
Discount rate	7%

The benefit to Australians from the Project is measured by the increase in real private (or household) consumption expenditure. It is predicted that real household consumption will be on average A$1.8 billion (0.2%) higher each year as a result of the Project.

The increase in household consumption spending has a net present value (NPV) of about A$24 billion (using a real discount rate of 7% over 50 years).

In total, the Project has a relatively modest impact on the Australian economy. Although it is a large development in terms of investment and value added, the Project has limited forward and backward economic linkages in the economy as a result of its low level of operating costs relative to revenues.

Impact on the Northern Territory economy

As expected, the Project has a much larger proportionate impact on the Northern Territory economy. The gross state product (GSP) of the Northern Territory is on average almost 18% higher each year as a result of the Project, as shown in Table 10-24.

The impact on the welfare of Northern Territory residents is measured by the change in private or household consumption expenditure. On average, household spending is expected to be A$175 million a year (1.6%) higher as a result of the Project. This benefit has a net present value of around A$2.4 billion.

To place this in perspective, Figure 10-12 shows the increase in per capita consumption spending over the life of the Project. The Project contributes to an increase in per capita consumption spending of an average of A$1137 per annum in current dollar terms.

Employment—national and territory impacts

The modelling results suggest that the Project does not increase the level of employment in the Australian economy as a whole relative to the baseline scenario because a full employment assumption was made. The modelling does however produce a small increase in real wages.

While the direct impact of the Project on employment in the Northern Territory is minimal, the indirect impact is significant. The Project directly and indirectly generates additional employment equivalent to over 2000 full-time personnel. This is an increase of 3.4% compared with the baseline scenario. These jobs are derived from the increase in business activity directly related to the local spending of the Project and its employees and also because of the general increase in spending and economic activity as a result of higher household disposable income stemming from reductions in tax rates. Industries with potential for increases in employment as a result of the Project include civil engineering, maritime transport, hospitality and general supplies.

10.4.2 Business opportunity

Local government and business groups expressed strong support for the Project, believing it would potentially increase employment, salaries, training and business development in Darwin, and that it would provide impetus to the further development of the Northern Territory's infrastructure and services.

Stakeholders suggested that flow-on benefits should be optimised through a local industry plan in cooperation with agencies such as the Northern Territory Industry Capability Network (NTICN).

Table 10-23: Impact on the Australian economy over the life of the Project

	Average annual change		NPV of impact
	A$ million	% change	A$ million
Real private consumption	1840	+0.2	24 306
Real investment	648	+0.2	–
Real exports	1782	+0.5	–
Real imports	434	+0.2	–
Real GDP	3500	+0.2	–
Real wage rate	–	+0.1	–

Table 10-24: Impact on the Northern Territory economy over the life of the Project

	Average annual change		NPV of impact
	A$ million	% over base case	A$ million
Real private consumption	175	1.6	2390
Real GSP	4094	17.6	–
Persons employed	2141	3.4	–

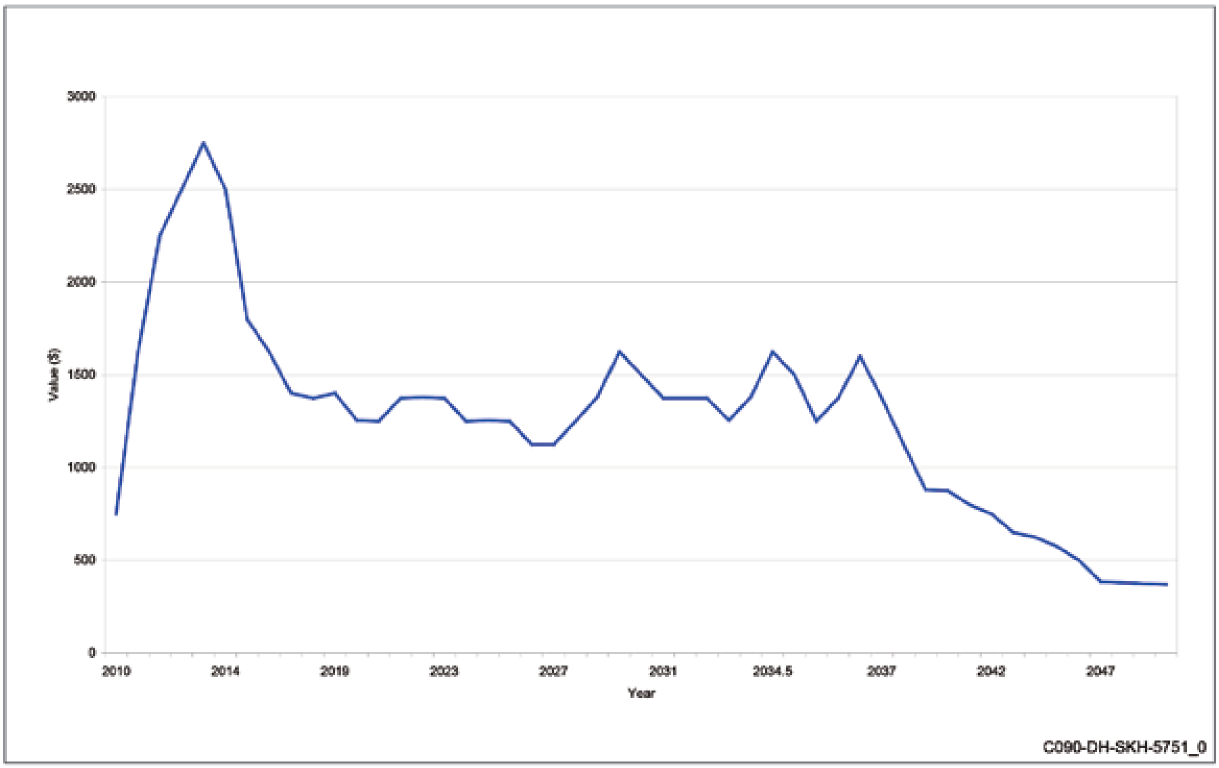

Figure 10-12: Impact of the Ichthys Project on per capita real consumption in the Northern Territory

Flow-on benefits could be expected in service industries such as the training, transport, tourism and hospitality sectors. The majority of stakeholders cautioned, however, that there were a number of existing constraints to the Northern Territory's economic development, including the limited availability of housing, skills shortages and existing infrastructure operating at close to capacity.

The Project will develop a communication and engagement plan to support three key principles of the supplier relationship program and Industry Participation Plan objectives. These are as follows:

- communication—to facilitate early identification of opportunities for Australian industry participation through all tiers of supply
- inclusion—to support the integration of Australian industry through all tiers of supply
- education and feedback—to provide specific support and feedback for locally owned, small-to-medium enterprise and Aboriginal-owned business in Australia in order to encourage the adoption of international best practice supply standards.

The communication and engagement plan will include provision to:

- prepare industry briefings to communicate requirements and share information about the Project
- use Industry Capability Network (ICN) service offerings throughout the states and territories in Australia
- advise of upcoming tenders on Internet web sites from available industry service providers of vendor and Project information at <www.projectgateway.com.au>
- contribute input to relevant newsletters and publications
- produce internal communications and briefings to ensure that INPEX Project staff are informed and aware of the local Industry Participation Plan (IPP) requirements
- produce a "supplier diversity" brochure and manual for Project Gateway and the NTICN process
- prepare government briefings to discuss requirements and share information about the Project and Northern Territory industry capability.

10.4.3 Employment and training

The Project's demand for construction labour and skilled operations staff may contribute to reducing unemployment rates. There is the possibility that some local employers—for example in the building, fisheries and government sectors—may lose staff to the Project, particularly if there is salary competition. Therefore, while local business may see important commercial opportunities in the Project, they may also face increased competition for labour and higher labour costs. Overall, however, the Project's impacts on the local employment market are likely to be highly positive.

The Northern Territory labour market is limited in its ability to meet the skill and expertise requirements of the Ichthys Project or of the oil & gas industry in general. INPEX will support targeted training programs to further develop a local skilled construction labour force; this will include specific Aboriginal programs in the region.

Apprenticeships are currently at record levels (Northern Territory Government 2010), and the Project would have a positive effect in encouraging more people to take up skills training. People with higher-level skills who remained in the Northern Territory after the construction phase of the Project would further enhance the Territory's industrial base. During consultation, a number of stakeholders noted that ConocoPhillips had brought engineers in from interstate and that these had left Darwin at the end of the construction phase.

The Project represents an important opportunity for Aboriginal people in the Darwin region to increase their participation in the labour market and to acquire critical skills and technical qualifications. There is also an established framework to increase Aboriginal participation in training and apprenticeships in the Darwin region, which the Project could readily tap into.

INPEX recognises that employment opportunities will emerge through the construction phase of the Ichthys Project and with Ichthys LNG production for Aboriginal and non-Aboriginal locals. The company will explore and take advantage of successful training and development programs, infrastructure and initiatives to develop labour capability in LNG skills within the region.

INPEX is encouraging local people to apply for construction work associated with the Ichthys Project and will ensure that its systems and processes enable skilled individuals to access employment opportunities being offered by relevant contract employers at the time. When sourcing additional Project resources, contract employers will give preference to suitable local applicants with the relevant skills, qualifications and work history. In the operations phase, the Project will also be seeking suitably skilled and experienced personnel from the local labour market.

10.4.4 Local inflationary impacts

Stakeholders expressed concerns that the Project would contribute to local inflationary pressures. It was suggested that ConocoPhillips' Darwin LNG project had reversed the trend in the Northern Territory's inflation rates, which had previously been below the national average and is now above it. It was perceived that the Ichthys Project could exacerbate this trend through higher salaries, housing and rental costs.

The risk that the Project will result in significant increases in prices for goods and services is expected to be low. Any increase in prices is likely to be a short-term issue over the construction period. If housing and labour markets are managed according to the measures identified in sections 10.3.2 and 10.4.3, the total supply of housing and labour in the region will be sufficient to meet demand and the overall inflationary effect will be minimal.

10.4.5 Infrastructure constraints

It was noted that the use of the port facilities at Darwin are expanding rapidly. Some stakeholders expressed concern about the impact of the Project on capacity at the Port and the effect this might have on other industries, such as those exporting goods through the port, and the recreational and tourism sectors.

The Project will have its own separate jetty infrastructure during the operations phase, so will not affect the berthing facilities for other users of the Port of Darwin. However, tanker vessels arriving at Blaydin Point will require other port services such as pilotage, and there may be a physical constraint on the number of ships able to safely moor in the Harbour at any one time.

INPEX will collaborate with the DPC to coordinate port activities efficiently and safely throughout the construction and operations phases.

10.5 Conclusion

10.5.1 Outcome of risk assessment

The socio-economic aspects of the Project's operating environment are complex, and are influenced by many factors that are outside the influence of the Project. These include the fluctuations in national and global economies, and the resulting effects on labour markets.

The risk assessment process, taking into account management controls and mitigating factors, identifies 11 "medium" risk and 7 "low" risk potential socio-economic impacts associated with the Project. These risk ratings are considered acceptably low, mitigating risks to the livelihoods and lifestyles of the surrounding community.

Socio-economic impacts associated with the offshore development area are limited to interactions with commercial fishing and shipping activities. Any impacts to commercial fishing are likely to be minor. Data on fishing effort indicate that the offshore facilities will be located close to an area utilised by the North West Slope Trawl Fishery. However, it should be noted that fishing effort data do not record fishing areas fished by five operators or fewer and that it is possible therefore that some low-level fishing activities may occur in the vicinity of the offshore facilities. In addition, the gas export pipeline overlaps an area utilised by the Northern Prawn Fishery. In this case, however, the standard safety exclusion zone to be established will not significantly reduce the area available for fishing.

Potential impacts to shipping activities are also likely to be minor as there are no identified shipping channels in the vicinity of the offshore development area.

The Project's most intense socio-economic impacts are likely to be associated with the construction phase of the nearshore and onshore development areas. Road transport used for ferrying Project personnel and materials to the onshore development area will increase local traffic volumes, although modelling indicates that the incremental increase attributable to the Project is minor in comparison with the effects of expected population growth in the Darwin region.

Recreational fishing activities in East Arm and along the pipeline route will be temporarily disrupted in the immediate vicinity of Project vessels during the construction phase. Exclusion zones will be established around dredging, piledriving, pipelay and drill-and-blast vessels to manage public safety. These activities will be focused on localised areas in the nearshore development area and will not prohibit fishing and recreational boating nearby, provided that safe distances are maintained.

Aboriginal people living in the Darwin area frequently fish and forage for food and other resources in intertidal areas at low tide, as well as in Darwin Harbour. Within the Harbour itself these activities are common around Nightcliff, Coconut Grove, Kulaluk, Sadgroves Creek, Lee Point and Blaydin Point. It is predicted that there will not be any direct impact on Nightcliff, Coconut Grove, Kulaluk, Sadgroves Creek and Lee Point areas and therefore impacts on traditional fishing practice will be negligible for these areas. However, there will be an impact on traditional fishing practices undertaken on and around Blaydin Point during both the construction and the operations phases. This is because public access to the onshore site will be restricted and marine exclusion zones will be put in place for safety reasons. This impact is expected to be minimal given that the fishing areas affected near Blaydin Point represent a very small proportion of the areas available in Darwin Harbour.

The Project will provide a high level of demand for personnel during its construction phase, which may be met locally in Darwin and Palmerston depending on the skill sets required, but is also likely to require fly-in, fly-out staff. An accommodation village will be developed in Howard Springs (east of Palmerston) to minimise the short-term impacts on the already constrained local housing market that might otherwise be caused by a large influx of Project personnel, many of whom will be single. The development of this facility is subject to its own approvals process.

Three Aboriginal archaeological sites will be disturbed during land-clearing for the onshore development area, subject to permission from NRETAS under the *Heritage Conservation Act* (NT). The onshore facilities have been designed around a number of other heritage sites that will remain undisturbed. Heritage sites in the vicinity of the nearshore development area will not be disturbed, as the maritime infrastructure has been designed specifically to avoid these sites. This includes a number of submerged Catalina flying-boat wrecks from World War II. Low levels of sand movement on to one of these wrecks (Catalina 3) may occur as a result of dredging activities, which represents a small increase in the natural movement of sand that already occurs throughout East Arm under ambient tidal currents. This is not expected to negatively affect the heritage values of the wreck site. The gas export pipeline has been aligned to avoid Aboriginal sacred sites in the nearshore development area.

Modelling of noise emissions from the onshore gas-processing plant indicates that received levels in the nearest residential areas (in Palmerston) will not exceed identified noise criteria and are unlikely to be audible above ambient noise in most conditions. Other impacts to the community that may be considered on a cumulative basis include light and visual amenity. In the local context, where several industrial facilities already operate on the shores of Darwin Harbour, the additional impacts imposed by the Ichthys Project are moderate. These impacts are mitigated by distance—the onshore development area is 4 km from Palmerston and 10 km from Darwin's CBD.

The Project facilities have been designed to minimise the risk to public safety associated with accidental events such as major hydrocarbon leaks or explosions. Controls to mitigate risks from major incidents include designing and constructing the facility in line with established industry standards and codes of practice, positioning equipment to reduce off-site consequences, and developing and exercising emergency plans and response procedures in consultation with the relevant emergency-response authorities.

The results from the preliminary QRAs conducted to date indicate that the onshore development area and pipeline do not pose unacceptable safety risks to the public around Darwin and neighbouring residential areas such as Marlow Lagoon (which is adjacent to Palmerston). Where risks posed to users of the Harbour in the vicinity of the jetty heads and trestle are higher than acceptable for active open spaces, nominal safety exclusion zones will be established. As the acceptable risk contours border the main channel of Lightning Creek, risk values will need to be confirmed by a final QRA based on a complete plant design to determine whether access to this creek can be maintained.

Economic modelling indicates that the Project will benefit the Northern Territory economy, contributing an increase of almost 18% to the GSP during each year of operation and increasing household spending. The Project will also benefit the Australian economy with predicted average annual contributions of A$3.5 billion (an additional 0.2%) to Australia's GDP. The Project offers opportunities for employment and training, with flow-on potential for business development and increased investment in infrastructure and services.

It is considered that the level of management and risk reduction presented in this chapter represents a proactive and conservative approach to maintaining socio-economic values, while allowing the Project to progress in a sustainable fashion. The management controls to be implemented will be further developed in consultation with stakeholders and will continue to be updated throughout the various stages of the Project. The community consultation initiated for this Draft EIS will be ongoing throughout the various stages of the Project, as described in Chapter 2.

10.5.2 Environmental management plans

As described throughout this chapter, a suite of management plans have been developed to direct the implementation of the management controls that reduce the potential for socio-economic impacts. These contain the objectives, targets, detailed actions and monitoring to be carried out to manage a variety of aspects, including the following:

- traffic
- heritage
- dredging and dredge spoil disposal
- piledriving and blasting
- air emissions
- dust.

INPEX's Health, Safety and Environmental Management Process is described in Chapter 11 and the provisional management plans that have been developed for the Project are attached as annexes to Chapter 11.

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11 Environmental Management Program

11 ENVIRONMENTAL MANAGEMENT PROGRAM

11.1 Introduction

This chapter describes how INPEX intends to implement a range of environmental management measures and controls throughout the life of the Ichthys Gas Field Development Project (the Project). These are intended to demonstrate how INPEX will avoid, or minimise to an acceptable level, the potential negative environmental impacts identified in this draft environmental impact statement (Draft EIS).

The management measures and controls, together with specified objectives, targets and indicators, are outlined in the various provisional environmental management plans (EMPs) provided as annexes to this chapter and documented in Chapter 7 *Marine impacts and management*, Chapter 8 *Terrestrial impacts and management* and Chapter 10 *Socio-economic impacts and management*. These provisional plans will be used as the basis for the development of detailed environmental documentation, for example the plans, processes and procedures that will be required for the different phases of the Project, as well as for specific activities associated with the Project.

The detailed environmental documentation for plans, processes and procedures will be prepared either directly by INPEX's Environmental Department or by specialist contractors in conjunction with INPEX.

11.2 INPEX's Health, Safety and Environmental Management Process

INPEX is committed to delivering energy in a safe and environmentally responsible manner. To assist in meeting this commitment, the company has developed a Health, Safety and Environmental Management Process (HSE Management Process). This provides INPEX with a tool for managing the impacts of its activities on the environment, as well as providing a structured approach to planning and implementing environmental protection measures.

The HSE Management Process has been based on a continuous improvement model as defined in the internationally recognised standards *AS/NZS ISO 14001:2004, Environmental management systems—Requirements with guidance for use* and *AS/NZS 4801:2001, Occupational health and safety management systems—Specification with guidance for use*. The model is shown in Figure 11-1.

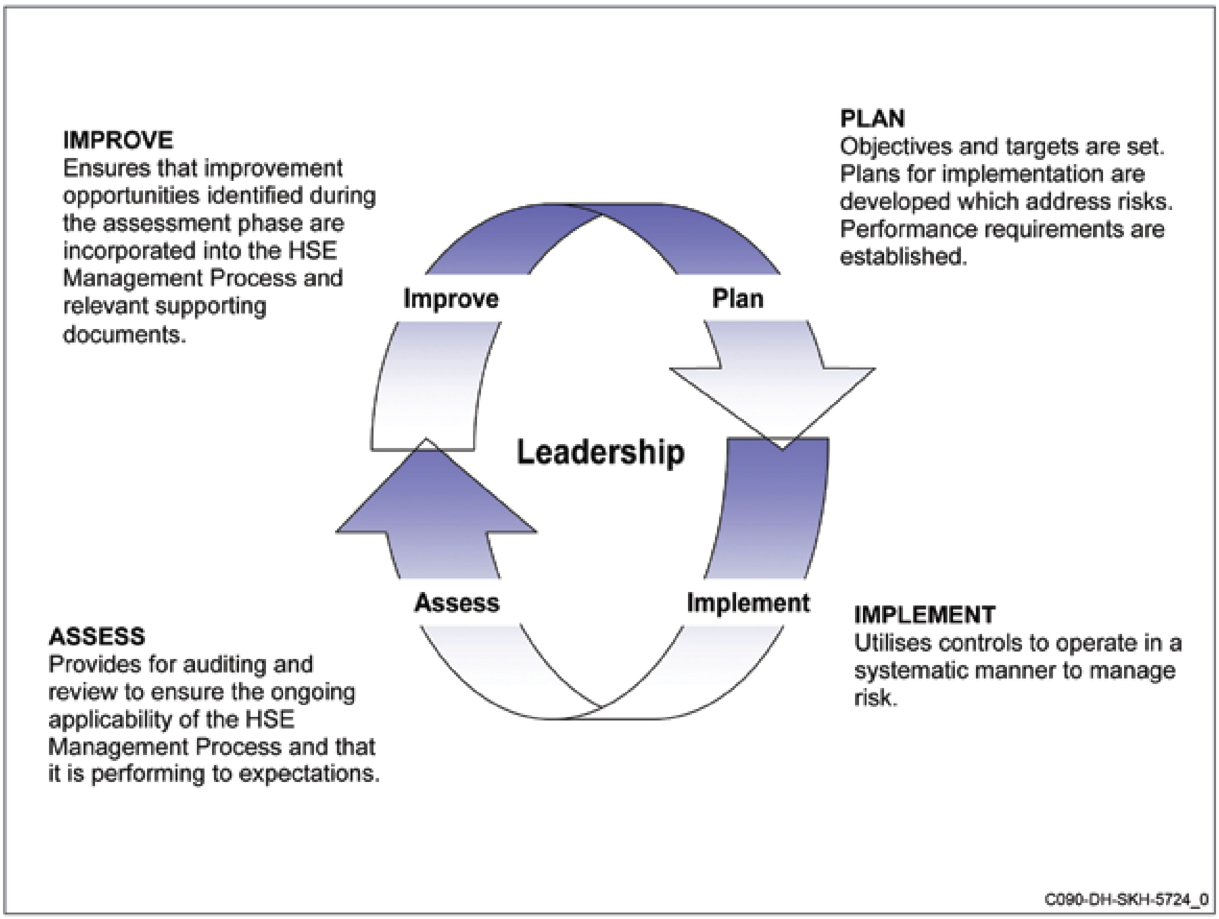

Figure 11-1: HSE management model

The HSE Management Process is structured around 10 core elements (see Table 11-1) with associated sub-elements, each of which describes an essential part in the overall management of matters relating to health, safety and the environment. The elements are interrelated and the implementation of each is essential for the effective operation of the HSE Management Process as a whole. Each of the elements is addressed in additional detail later in this chapter.

Ownership of the HSE Management Process resides with INPEX's line managers, who will make provision for the resources necessary to assure the successful implementation and sustainability of the process.

Table 11-1: Core elements of INPEX's Health, Safety and Environmental Management Process

Element	Title
1	HSE policy and leadership
2	Planning
3	Organisation and resources
4	Documents and records
5	Risk management
6	Regulatory requirements
7	Implementation, monitoring and measurement
8	Emergency and crisis management
9	Inspection and audit
10	Management review

11.2.1 Element 1: HSE policy and leadership

INPEX is committed to managing environmental, health and safety issues to the highest standards and has set out its environmental, health and safety commitment in the form of an environmental policy and a health and safety policy (see Figure 11-2 and Figure 11-3). The policies, approved by INPEX's Managing Directors, clearly state INPEX's commitment to continuous environmental performance improvement.

INPEX considers leadership accountability and visibility to be key components in the successful implementation of the HSE Management Process. The visibility of the commitment of INPEX managers will demonstrate to employees, contractors, government and the community that the company regards excellence in environmental management as a priority.

INPEX

Environmental Policy

Objective

INPEX is a worldwide oil and gas exploration and development company committed to delivering energy resources in an environmentally responsible manner.

We recognise that we have a responsibility to support the principles of sustainable development and that we owe a duty of care to both the natural environment and the communities in which we operate.

Strategy

INPEX will:

- plan and perform its business activities so that negative impacts on the environment are avoided or kept at levels that are 'as low as reasonably practicable'
- comply with all applicable laws and regulations, and apply appropriate standards where laws and regulations do not exist or are considered not to be sufficiently comprehensive
- develop, implement and maintain management processes to ensure the company's compliance with obligations and commitments and to drive continual improvement in environmental performance
- set, measure and review environmental standards, objectives and improvement targets
- endeavor to prevent pollution and seek continual improvement with respect to emissions, discharges, wastes, energy efficiency and resource consumption
- actively promote the reduction of greenhouse gas emissions across our operations in a safe and technically and commercially viable manner
- monitor the environment where we operate and adjust our practices where required
- maintain and regularly test emergency plans to ensure a quick and effective response in the event of emergencies
- provide employees with appropriate training and resources required to fulfil their environmental responsibilities and accountabilities
- engage openly with our stakeholders on environmental issues
- ensure that all INPEX employees and contractors are aware of this policy, understand their responsibility to report environmental hazards and incidents, and know they are empowered to intervene if they have environmental concerns.

Application

This policy applies to all INPEX-controlled activities in Australia and related project locations. It will be displayed at all company workplaces and on the company's intranet and it will be reviewed annually.

Seiya Ito
Managing Director
October 2009

Figure 11-2: INPEX Environmental Policy

Health and Safety Policy

INPEX

Objective

INPEX is a worldwide oil and gas exploration and development company committed to conducting all its activities in a manner that is safe and not injurious to health.

Our health and safety goal is to prevent workplace incidents and meet the performance expectations of our stakeholders.

Strategy

INPEX will:

- establish and maintain a safety culture where safety is a core value
- comply with all applicable laws and regulations and apply INPEX standards where laws and regulations do not exist or are considered insufficient
- implement management processes based on internationally accepted standards
- set, measure and review health and safety objectives and targets, and provide training and resources which will enable our business to meet them
- integrate health and safety management into our existing and planned business activities by identifying hazards and managing risks to "as low as reasonably practicable" levels
- maintain and regularly test an emergency response management process to ensure the safety of personnel, the protection of the environment, the safeguarding of assets and the protection of our assets
- communicate openly on health and safety issues with internal and external stakeholders to formulate objectives and targets, develop solutions, foster stakeholder engagement and promote industry development
- ensure that all INPEX personnel and contractors are aware of this policy, understand their responsibility to report hazards and incidents in their work areas, and know that they are empowered to intervene if they have health or safety concerns
- strive for continual improvement in health and safety performance through monitoring, audit and review processes.

Application

This policy applies to all INPEX-controlled activities in Australia and related project locations. It will be displayed at all company workplaces and on the company's intranet and it will be reviewed annually.

Seiya Ito
Managing Director
October 2009

Figure 11-3: INPEX Health and Safety Policy

11.2.2 Element 2: Planning

Planning is an essential part of the HSE Management Process as it assists INPEX in fulfilling its HSE policies. The following subsections detail the key sub-elements of the planning.

HSE plans

INPEX will develop annual HSE plans to target specific HSE issues and ensure that responsibilities for individual actions are clearly assigned. Development of HSE plans is carried out on the basis of a continuous-improvement cycle and will define objectives that are clearly measurable and achievable.

The development of HSE plans will be formalised and will be scheduled to coincide with the budget planning cycle.

Objectives and targets

INPEX will establish, implement and maintain documented objectives and targets consistent with the requirements of the HSE policies.

The HSE objectives and targets will be set alongside business targets during the business planning process to give a clear indication of the importance placed by INPEX on HSE performance. Programs will be developed to ensure that these objectives and targets are achieved.

Environmental objectives and targets for the Project have been identified in the individual provisional EMPs—see Section 11.3 and annexes 1–16 to this chapter. Objectives and targets will be reviewed regularly through the operations phase to ensure that there is continuous improvement in environmental performance.

Daily task control

INPEX will manage the planning required for daily task management through the implementation of risk assessments (e.g. through job hazard analysis, the "step back 5 × 5" approach[1], and environmental impact assessments), pre-start work reviews, and permit-to-work systems.

Contractor management

INPEX pre-evaluates contractor parties and service providers to assess their technical capabilities, their experience, and their commitment to health and safety, environmental protection and quality assurance.

The preparation of an HSE plan is required for long-term or high-risk third-party contracts. No work will be permitted to commence on site until all appropriate documentation has been approved by INPEX.

A process will be established to ensure that effective communication channels are established between INPEX and its major contractors and service providers. This communication may include regular "toolbox" or HSE meetings and will be used to discuss any relevant HSE issues, including critical interfaces, permits to work, risk assessments, process changes, and performance monitoring and evaluation.

11.2.3 Element 3: Organisation and resources

INPEX will identify and provide the resources required to implement, maintain and improve the HSE Management Process and environmental commitments. Similarly, key contractors will be required to demonstrate to INPEX's satisfaction that they have appropriate HSE resources and organisational structure to meet environmental commitments and Project conditions. Responsibilities and accountabilities for the provision of environmental management are assigned to all personnel throughout the organisation by means of management plans, procedures and position descriptions.

Roles and responsibilities

Roles and responsibilities will be documented in position descriptions for all INPEX positions. The descriptions will define the primary role and include any HSE responsibilities relevant to a specific position.

The environmental roles and responsibilities of those to be involved in the Project are shown in Table 11-2.

1 The term "step back 5 × 5" is an HSE precept and slogan encouraging workers to figuratively step back five paces and pause for five minutes to reflect upon likely hazards before embarking on an activity.

Table 11-2: Environmental roles and responsibilities for implementation of the HSE Management Process

Position(s)	Roles and responsibilities
INPEX managing directors:	• have overall responsibility for the environmental policy and activities of the organisation • have the ultimate responsibility for achieving objectives and authorising the environmental policy.
INPEX directors and managers:	• have a commitment to the environmental policy and are responsible for ensuring that employees, under their direction, are aware of the requirements of the HSE Management Process • ensure that employees, under their direction, are trained and resourced to enable them to implement the requirements of the HSE Management Process.
INPEX Environmental Manager:	• provides support services to line managers and employees in accordance with the requirements of the HSE Management Process • provides environmental training to INPEX departments in support of their continuous-improvement requirements • establishes the environmental legal compliance and requirements register • prepares operations EMPs and procedures that comply with the requirements of the relevant statutes, industry best practice and the International and Australian Standard *AS/NZS ISO 14001:2004* • reviews and approves contractor EMPs being developed as part of the Project, e.g. construction EMPs and drilling EMPs.
INPEX personnel:	• take all reasonable and practical steps to protect the environment • follow any instructions given by management in relation to the protection of the environment • participate in prescribed environmental training.
Contractors:	• operate under a health, safety and environmental management system that is consistent with the requirements set out by INPEX and the International and Australian Standard *AS/NZS ISO 14001:2004* • meet the objectives and targets set out in the provisional EMPs (see annexes 1–16 to this chapter) and carry out the management measures and controls necessary for each aspect or activity • see to the preparation of construction EMPs, drilling EMPs, etc. • liaise with INPEX's Environmental Department in the development of EMPs to ensure that they meet INPEX requirements • ensure that all services suppliers and subcontractors have an appropriate management system in place and verify the effectiveness of the proposed management and environmental management controls.

Training, awareness and competence

INPEX and contractor staff will undertake environmental awareness training to provide them with an understanding of INPEX's Environmental Policy, the environmental aspects and impacts of the proposed activities, and the HSE Management Process. This will be undertaken through staff inductions and, where required, through targeted training programs for specific activities or positions. Environmental training programs will be developed and implemented prior to the commencement of the construction and operations phases of the Project.

Contracts awarded for the construction, commissioning, operations or decommissioning phases of the Project will detail specific requirements for contractors in respect of environmental training needs.

Communication

Effective internal and external communication processes, including responding to public concerns, are an integral part of effective environmental management.

The environmental requirements of the HSE Management Process will be communicated through site HSE communication meetings, HSE committee meetings (executive and employee), HSE toolbox meetings, HSE training, inductions, and INPEX's intranet, as well as through the distribution of plans, procedures and work instructions.

Procedures have been implemented for receiving, documenting and responding to communications from external sources on environmental matters, including complaints and requests for information.

Information and opportunity for feedback on the environmental aspects and impacts of the Project will be available to the public through the environmental approval process, INPEX's Internet web site and a telephone number service which is free to the caller (1800 705 010).

11.2.4 Element 4: Documents and records

INPEX will maintain documented HSE programs and procedures to address hazards and risks, regulatory requirements, and operating standards identified in the HSE Management Process elements.

Detailed environmental documentation, for example plans, procedures and processes, will be developed for the Project to assist in the successful implementation of the HSE Management Process; these are discussed in further detail in Section 11.3.

Document control

INPEX has implemented a document control system which will be utilised for all Project documents. The information will be maintained in a suitable medium, in both printed and electronic form, to provide direction to related documentation and to describe the core elements of the management system and how these elements interact.

Control of environmental records

INPEX will ensure that all environmental records will be legible, identifiable and traceable to the activity, product or service involved. Environmental records will be stored and maintained in such a way that they are readily retrievable.

11.2.5 Element 5: Risk management

INPEX has developed an HSE Risk Management Process to describe the methods and responsibilities to be used by INPEX to ensure that risk management is planned and executed effectively. The Risk Management Process ensures the systematic assessment and management of HSE risk.

The risk assessment methodology applied in this Draft EIS is described in detail in Chapter 6 *Risk assessment methodology*.

Change control

Change in the work environment can pose HSE risks and in the oil & gas industry it is recognised that work arising from temporary and permanent changes to organisation, personnel, systems, processes, procedures, equipment, products, materials or substances, laws and regulations cannot proceed unless a "management of change" process is completed. All proposed changes will therefore be managed in accordance with INPEX's Change Management Procedure.

11.2.6 Element 6: Regulatory requirements

INPEX will implement a compliance framework to manage and monitor its regulatory obligations and ensure that performance expectations are met. In its Environmental Policy the company has committed to comply with all relevant laws, regulations and standards for the protection of the environment.

INPEX will ensure that it achieves full HSE regulatory compliance by the following means:

- It will implement awareness training for its employees and contractors.
- It will actively use and maintain the regulatory compliance framework.
- It will conduct regular audits of its systems and activities to monitor compliance.

A summary of the government approvals and legislative requirements applicable to the Project has been provided in Chapter 1 *Introduction*.

11.2.7 Element 7: Implementation, monitoring and measurement

The following subsections detail the key sub-elements of the implementation, monitoring and measurement component of the HSE Management Process.

Work procedures

Procedures will be developed to minimise the exposure to actual or potential hazards associated with the work to be performed. The need for procedures will be identified by reviewing processes, activities or tasks and assessing their potential impact from an HSE perspective on personnel, assets and the environment.

Section 11.2.4 *Element 4: Documents and records* should be referred to for the types of documents that will support the HSE Management Process.

Monitoring performance

Proactive and reactive key performance indicators (KPIs) will be developed by INPEX to monitor HSE performance against objectives and to promote continuous improvement.

The KPIs will be tracked and monitored by using HSE scorecards. These will be developed for the whole business and also for work teams to ensure that there is alignment and consistency in achieving HSE performance goals. The scorecards will consider the HSE plan and business requirements.

Performance statistics based on the scorecards will be compiled and distributed to internal and external stakeholders as appropriate.

Environmental indicators and monitoring programs associated with the aspects or activities of the Project have been described in Section 11.3.3 *Implementation of environmental management plans* and in the individual EMPs in annexes 1–16 to this chapter.

Incident notification, reporting and investigation

INPEX has developed and implemented an incident management and investigation procedure. The intention of this procedure is to ensure that all incidents, including "near misses", no matter how minor, are reported, recorded and investigated. This will achieve the following objectives:

- "at risk" behaviours will be identified
- deficiencies in workplace conditions will be identified
- improvements to methods and equipment will be identified
- failures in management systems and controls will be identified
- lessons will be learned
- regulatory-authority and industry reporting obligations will be fulfilled
- management systems will be continuously improved.

This procedure provides the guidelines to ensure that all incidents are uniformly, methodically and effectively investigated to a degree commensurate with their potential severity. The objective is to establish the facts, determine the root cause(s) and to take the appropriate action to prevent a recurrence of the event.

All incidents, investigations and corrective and preventive actions will be input into INPEX's incident reporting database and tracked until closure.

Asset integrity

INPEX will emphasise the importance of ongoing asset integrity in contributing to a safe and environmentally sound operation. Asset integrity is a key component in the prevention of major accident events.

Systems will be established to ensure the ongoing integrity of plant and equipment. These systems will include maintenance, inspection, testing, calibration and certification of equipment at frequencies appropriate for the level of risk associated with the equipment and/or as determined by manufacturers' requirements.

11.2.8 Element 8: Emergency and crisis management

Plans and procedures will be developed to identify all potential crisis and/or emergency threats associated with INPEX's operational locations. A rapid and effective response to emergency situations can significantly reduce any impact on people's safety, the environment and the community. This response is achieved by implementing prevention, preparation, response and recovery strategies.

Crisis and emergency threats will be identified utilising the hazard identification and risk assessment tools discussed in Section 11.2.5 *Element 5: Risk management*. Based on the possible emergency and crisis situations identified during this process, operating procedures will be developed in order to keep control of such situations and to reduce the risk of environmental impact. Procedures that are directly related to response to environmental incidents are presented in the relevant EMPs (e.g. onshore oil-spill prevention and response).

All emergency and crisis management plans will contain the identification of resources (personnel and equipment), key roles and responsibilities, and the procedures to be followed if the plans are activated. Relevant personnel will receive sufficient training to ensure that they have the skills and competence to respond to an emergency.

In addition to emergency and crisis management plans, a Project oil-spill contingency plan (OSCP) will be prepared to ensure that INPEX can respond rapidly and effectively to an oil spill into the marine environment.

Individual vessels, specifically oil tankers of 150 gross tonnage and above and every other ship of 400 gross tonnage and above, are also required under Regulation 37 of Annex 1 of the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto (MARPOL 73/78) to produce a shipboard oil pollution emergency plan.

11.2.9 Element 9: Inspection and audit

Review audits, both internal and external will be conducted to ensure the following:

- that there is compliance with regulatory requirements, Project approval conditions, and licence conditions
- that the identified objectives of the Project are being achieved.

A formalised audit schedule will be developed, and will define the scope and frequency of audits.

11.2.10 Element 10: Management review

In order to maintain continuous improvement, formal reviews of the suitability and effectiveness of the HSE Management Process and its associated implementation documents will be scheduled periodically.

Management reviews will be based on the following considerations:

- audit and incident investigation outcomes
- changes in organisation and/or operational practices
- changes in statutory environmental requirements
- assessments of the extent to which objectives, targets and performance standards have been met
- analyses of the continuing adequacy of the HSE Management Process.

Implementation documents (e.g. management plans, procedures and monitoring programs) will be reviewed periodically to assess their effectiveness and to ensure that they remain applicable to current operations.

Management review outcomes, including observations, conclusions and recommendations, will be documented and tracked through to completion.

11.3 Environmental management plans

A key component of the HSE Management Process is the development and implementation of EMPs which detail the environmental protection and management measures and controls necessary to avoid, reduce or mitigate the environmental impacts of the Project. Figure 11-4 shows where the EMPs are placed in relation to other HSE Management Process documentation.

Detailed EMPs will be developed prior to the construction and operations phases of the Project in order to manage the identified potential impacts on the marine and terrestrial environments of the Project area.

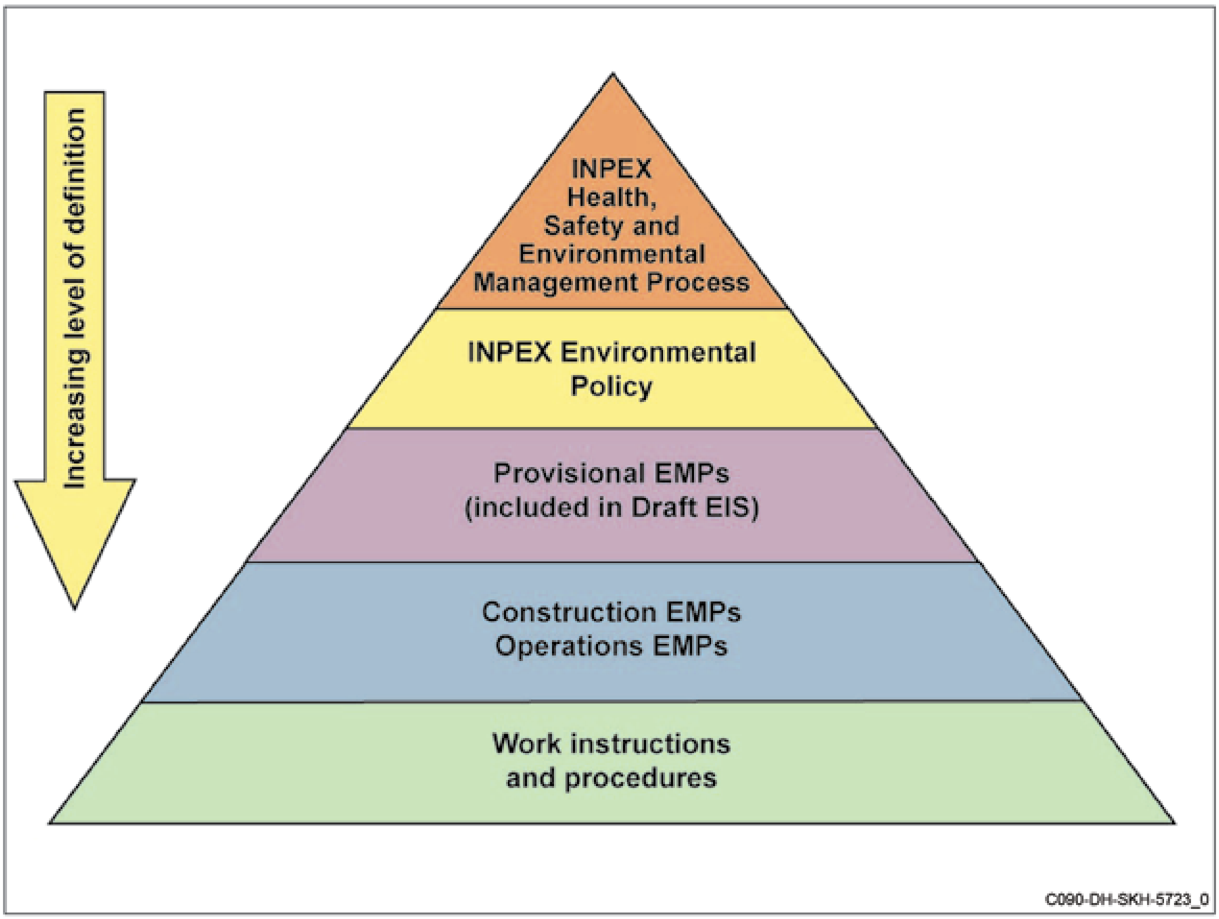

Figure 11-4: Hierarchy of environmental documentation

In addition to these, work instructions and procedures will be developed to support the EMPs and ensure that they are effectively implemented.

As the Project is currently in the design phase, provisional EMPs have been developed for significant environmental aspects, issues or specific activities and summarise the core management strategies as outlined in this Draft EIS.

A greater level of detail on the technical input and practical application of the management and control measures will become available as the Project moves towards the construction phase. These further details will be used in an ongoing program of improvement and refinement of EMP documentation to ensure that the objectives as outlined in this chapter and in the provisional EMPs are achieved. Flexibility to improve on the EMPs for implementation will be maintained; however, any additions will be over and above those outlined in this Draft EIS.

The format and content of the provisional EMPs prepared as part of this Draft EIS are outlined in Section 11.3.1 and presented in annexes 1–16 to this chapter.

Matters of national environmental significance

As part of the approvals process INPEX is required to show that it has identified suitable mitigation measures to address potential impacts on the "matters of national environmental significance" listed in Chapter 2 of the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth) (EPBC Act). Matters of national environmental significance applicable to the Project development area include the following:

- listed threatened species and ecological communities
- migratory species protected under international agreements
- the Commonwealth marine environment.

Relevant management controls to mitigate impacts on "matters of national environmental significance" are identified in chapters 7 and 8. In addition, EMPs which are applicable to "matters of national environmental significance" are listed below.

The EMPs applicable to the management of impacts on Commonwealth marine environment are as follows:

- Provisional Decommissioning Management Plan (Annexe 5)
- Provisional Liquid Discharges, Surface Water Runoff and Drainage Management Plan (Annexe 10)
- Provisional Waste Management Plan (Annexe 16).

The EMPs applicable to the management of impacts on marine threatened and migratory species are as follows:

- Provisional Cetacean Management Plan (Annexe 4)
- Provisional Piledriving and Blasting Management Plan (Annexe 12).

The EMP applicable to management of impacts on terrestrial threatened and migratory species is as follows:

- Provisional Vegetation Clearing, Earthworks and Rehabilitation Management Plan (Annexe 15).

Environmental management plans required by the Commonwealth for offshore activities

In addition to the approvals required under the EPBC Act, INPEX will develop environment plans as required under the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009 (Cwlth). Specific activities that environment plans will be developed for under these regulations will include the following:

- pipeline installation
- drilling
- installation and hook-up of the central processing facility (CPF) and the floating production, storage and offtake facility (FPSO)
- operations of the CPF and the FPSO.

In addition to the development of these EMPs, the existing OSCP will be updated to ensure that it reflects and addresses current Project activities and phases.

11.3.1 Provisional environmental management plans

The provisional EMPs have been structured so that they provide the core information required to develop construction EMPs (CEMPs) and operations EMPs (OEMPs) required under the *Waste Management and Pollution Control Act* (NT) and the *Water Act* (NT) once contracts have been awarded and construction and operations plans develop. This EMP structure was developed with input from the Northern Territory's Department of Natural Resources, Environment, the Arts and Sport (NRETAS)[2] and the Commonwealth's Department of the Environment, Water, Heritage and the Arts (DEWHA). The purpose of developing the plans at this earlier stage of the Project is to demonstrate INPEX's capacity to manage the environmental risks to an acceptable level.

2 The Northern Territory's Department of Natural Resources, Environment and the Arts (NRETA) became the Department of Natural Resources, Environment, the Arts and Sport (NRETAS) in August 2008.

The provisional EMPs outline the potential impacts, objectives, targets and indicators, some of the key management measures, and the monitoring, reporting, auditing and review requirements. These have been developed through the environmental impact assessment process and, where applicable, are in accordance with regulatory-authority requirements and are designed to meet the expectations of government and the community.

These provisional EMPs will serve as a guide and framework for the development of more detailed CEMPs and, in due course, OEMPs.

The provisional EMPs prepared as part of this Draft EIS are shown in Table 11-3 and presented in annexes 1–16.

11.3.2 EMP objectives and targets

For each of the provisional EMPs, INPEX has set out environmental objectives and targets with consideration of the following:

- INPEX's Environmental Policy
- environmental aspects and impacts
- relevant Australian and other standards
- legal and other requirements
- the measurability of objectives
- the drive for continuous improvement.

Environmental objectives and targets relating to specific aspects and activities of the Project, and which will be adopted in the detailed EMPs, are identified in the provisional EMPs in annexes 1–16 to this chapter.

Environmental objectives, targets and indicators are described and defined in this section to promote consistent application and to ensure that all parties concerned interpret them in the same way.

"Environmental objective"

Each EMP will have high-level objectives which will be consistent with INPEX's environmental policy and the commitments set out in the Draft EIS. An "environmental objective" can be defined as follows:

> *An "environmental objective" is a specific environmental goal.*
>
> Interpreted from *AS/NZS ISO 14001:2004, Environmental management systems—Requirements with guidance for use*

In order to gauge the extent to which environmental objectives have been achieved, threshold values or narrative statements will be set in the EMPs for specific indicators which, if reached, will trigger specified management responses.

Table 11-3: Provisional environmental management plans

Annexe Number	Title	Addresses "matters of national environmental significance"*
1	Provisional Acid Sulfate Soils Management Plan	no
2	Provisional Air Emissions Management Plan	no
3	Provisional Bushfire Prevention Management Plan	no
4	Provisional Cetacean Management Plan	yes
5	Provisional Decommissioning Management Plan	yes
6	Provisional Dredging and Dredge Spoil Disposal Management Plan	no
7	Provisional Dust Management Plan	no
8	Provisional Greenhouse Gas Management Plan	no
9	Provisional Heritage Management Plan	no
10	Provisional Liquid Discharges, Surface Water Runoff and Drainage Management Plan	yes
11	Provisional Onshore Spill Prevention and Response Management Plan	no
12	Provisional Piledriving and Blasting Management Plan	yes
13	Provisional Quarantine Management Plan	no
14	Provisional Traffic Management Plan	no
15	Provisional Vegetation Clearing, Earthworks and Rehabilitation Management Plan	yes
16	Provisional Waste Management Plan	yes

* "Matters of national environmental significance" are defined and discussed in Chapter 2 of the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth) and listed in *Matters of national environmental significance: significant impact guidelines 1.1* (2009), a DEWHA publication available online at <http://www.environment.gov.au/epbc/publications/pubs/nes-guidelines.pdf>.

"Environmental target"

An "environmental target" can be defined as follows:

> *An "environmental target" is a detailed project-specific performance requirement. Environmental targets are derived from environmental objectives and are used to achieve these objectives. Targets may be associated with one or many indicators.*
>
> *Interpreted from AS/NZS ISO 14001:2004, Environmental management systems—Requirements with guidance for use*

Targets specified in the EMPs will be used in this context where, if the target threshold is reached, a management response will be triggered and an investigation against the environmental standard will be undertaken.

The setting of target thresholds in the EMPs will be based on a level at or below a "standard", as defined below.

"Environmental indicator"

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) defines an "indicator" as follows:

> *[An] Indicator is taken to mean a significant physical, chemical, biological, social or economic variable which can be measured in a defined way for management purposes.*
>
> *A guidebook to environmental indicators* (CSIRO 1999) (viewed online on 1 March 2010 at <http://www.csiro.au/csiro/envind/code/pages/menu.htm>)

An example of an indicator could be the number and diversity of organisms in a stream. These can *indicate* whether an aquatic ecological system is functioning normally or not.

To be effective, an indicator must be relevant, representative and able to show concerned parties something about the system that they need to know. It must be easy to understand, even by people who are not experts. It must be reliable, so that the information the indicator provides is trustworthy. And it must be timely, so that the information is made available while there is still time to act.

11.3.3 Implementation of environmental management plans

Project components for which contractors or INPEX will be required to produce detailed EMPs will include the construction, operations, commissioning and decommissioning phases. Different Project components will require different combinations of aspect and activity EMPs. The final list of EMPs will depend on how many different contracts are set up for the Project. Table 11-4 illustrates how EMPs may be applied across various phases of the Project.

Contracts awarded for the different phases of the Project will specifically detail the requirements for contractors in respect of EMP implementation and development.

Prior to the commencement of activities, INPEX will review and approve these CEMPs to ensure that they are consistent with the provisional EMPs and, as such, meet all commitments made in the EIS as well as in any other legislative requirements or ministerial conditions.

11.4 Monitoring programs for the receiving environment

Appropriate and detailed environment monitoring programs for the receiving environment will be developed in consultation with regulatory authorities prior to the commencement of construction activities.

The aims of the monitoring programs are as follows:

- to identify environmental change in the receiving environment and validate modelling results and predicted impacts
- to allow INPEX to incorporate changes to its activities if the actual impacts are more significant than the predicted impacts
- to complement other monitoring being carried out in Darwin Harbour by government agencies and/or other Harbour users.

Each program will be conducted by appropriately qualified personnel in a systematic and scientifically defensible manner. Triggers for management responses will be identified where appropriate. A preliminary outline of the proposed receiving environment monitoring programs is outlined in Table 11-5.

Table 11-4: Implementation of EMPs through the different phases of the Project

	Construction		Commissioning		Operations		Decommissioning	
Name	Onshore	Nearshore and Offshore	Onshore	Nearshore and Offshore	Onshore	Nearshore and Offshore	Onshore	Nearshore and Offshore
Acid Sulfate Soils Management Plan	✓	✓	–	–	–	–	✓	✓
Air Emissions Management Plan	–	–	✓	✓	✓	✓	✓	✓
Bushfire Prevention Management Plan	✓	–	✓	–	✓	–	✓	–
Cetacean Management Plan	–	✓	–	✓	–	✓	–	✓
Decommissioning Management Plan	–	–	–	–	–	–	✓	✓
Dredging and Dredge Spoil Disposal Management Plan	–	✓	–	–	–	✓	–	–
Dust Management Plan	✓	–	–	–	–	–	–	–
Greenhouse Gas Management Plan	–	–	✓	✓	✓	✓	–	–
Heritage Management Plan	✓	✓	✓	–	✓	–	✓	–
Liquid Discharges, Surface Water Runoff and Drainage Management Plan	✓	✓	✓	✓	✓	✓	✓	✓
Onshore Spill Prevention and Response Management Plan	✓	–	✓	–	✓	–	✓	–
Piledriving and Blasting Management Plan	✓	✓	–	–	–	–	–	–
Quarantine Management Plan	✓	✓	–	✓	✓	✓	✓	✓
Traffic Management Plan	✓	–	–	–	–	–	–	–
Vegetation Clearing, Earthworks and Rehabilitation Management Plan	✓	–	–	–	–	–	✓	–
Waste Management Plan	✓	✓	✓	✓	✓	✓	✓	✓

Table 11-5: Summary of monitoring programs for the receiving environment

Program	Purpose	Parameters assessed or measured	Phase
Wastewater discharge model validation	To validate wastewater discharge dispersion modelling at the product loading jetty discharge location.	• concentrations and dispersion patterns determined (using fluorescent dye or similar method in conjunction with field sampling)	Operations
Darwin Harbour water quality monitoring program	To determine if the Project effluent discharges adversely impact on water quality in Darwin Harbour.	• nutrients • biochemical oxygen demand • heavy metals • pH • temperature • total petroleum hydrocarbons	Operations
Marine sediments and bio-indicators monitoring program	To determine whether construction activities in acid sulfate soils have resulted in changes in pH and heavy-metal availability in marine sediments around the onshore development area. To assess any accumulation of metals and petroleum hydrocarbons in sediments and selected bio-indicators that might result from surface-water and groundwater flows from the onshore facility.	• pH • bio-available heavy metals and petroleum hydrocarbons in sediments. • intertidal invertebrate tissue concentrations of metals and petroleum hydrocarbons	Construction Operations
Dredge-plume discharge monitoring program	To monitor dredge-plume discharges at selected coral monitoring locations in East Arm and in waters around the offshore spoil disposal ground.	• nephelometric turbidity units (NTUs) • total suspended solids	Construction
Reactive coral monitoring program (dredging)	To identify stress in corals at Channel Island, which may be caused by the dredging program, and to identify the necessary triggered management responses.	• turbidity (using turbidity loggers and a visual assessment of plumes from the air) • coral condition (judged by visual assessment and coral mortality)	Construction
Coral monitoring program (dredging)	To investigate the degree of resilience of corals in East Arm (South Shell Island and at a site north-east of Wickham Point) to exposure to sediment and elevated turbidity throughout the dredging works.	• coral condition (judged by visual assessment and coral mortality)	Construction
Soft-bottom benthos monitoring program (dredge spoil disposal)	To determine the effects of dredge spoil disposal on soft-bottom benthos communities at the offshore spoil disposal ground.	• species diversity and abundance	Construction
Soft-bottom benthos monitoring program (dredging)	To document the effect of increased suspended sediment loads and sedimentation on soft-bottom benthos communities in zones potentially impacted by dredging.	• species diversity and abundance	Construction
Intertidal sedimentation monitoring program (dredging)	To assess the effects of sedimentation on intertidal ecosystems throughout East Arm.	• sedimentation depths • mangrove canopy cover • mangrove leaf area index	Construction
Groundwater quality monitoring program	To determine if development in the onshore development area adversely impacts on groundwater quality.	• salinity • pH • total petroleum hydrocarbons • heavy metals • ground water levels	Construction Operations

Table 11-5: Summary of monitoring programs for the receiving environment (continued)

Program	Purpose	Parameters assessed or measured	Phase
Drilling discharges (SERPENT program)	To work in collaboration with the SERPENT* project to determine the impacts of production-drilling discharges on epibenthic macrofauna.	• mapping epibenthic habitat and drill-cuttings distribution • abundance and distribution of epibenthic macrofauna	Production drilling
Air quality model validation	Validation of air emissions modelling using the proposed NRETAS-established monitoring point at Darwin Airport.	• sulfur dioxide • nitrogen dioxide • particulates (PM_{10})† • photochemical oxidants (ozone)	Operations
Airborne noise model validation	Validation of airborne noise modelling.	• noise measurements in the City of Palmerston and the Darwin suburb of Bayview	Construction Operations
Marine pests monitoring program	To work in collaboration with relevant Territory regulatory authorities to develop a monitoring framework anticipated to be consistent with the monitoring framework proposed by the Commonwealth Government's National Introduced Marine Pests Coordination Group.	• to be determined in consultation with the National Introduced Marine Pests Coordination Group	Construction Operations
Weed monitoring program	To monitor the distribution and abundance of listed weed species occurring in the onshore development area.	• visual inspections in the development area to document new infestations of listed weed species	Construction Operations
Vegetation rehabilitation monitoring program	To determine the level of success of rehabilitated areas.	• species diversity of vegetation compared with surrounding environment • visual assessment of establishment of vegetation	Construction Operations
Mangrove health monitoring program	To determine if Project activities in the onshore development area adversely impact on mangrove health around Blaydin Point.	• canopy cover • leaf defoliation index	Construction Operations

* The SERPENT (Scientific and Environmental ROV Partnership using Existing iNdustrial Technology) project is a global collaborative project hosted by the DEEPSEAS group within the Ocean Biogeochemistry and Ecosystems Group at the National Oceanography Centre in Southampton, UK.

† PM_{10} = particulate matter with diameters smaller than 10 µm.

Monitoring programs for the receiving environment will be periodically reviewed and modified to ensure their continued suitability and value. Reviews, at a minimum, will consider the following:

- the timing, frequency and relevance of monitoring
- the effectiveness of monitoring design to assess environmental performance requirements
- the closing date for individual programs.

11.5 Environmental offsets

Section 9 of the EIS guidelines (see Appendix 1) prepared in September 2008 for the Ichthys Project jointly by NRETAS (then NRETA) and the DEWHA states the following:

Where impacts are reasonably unavoidable or can not be mitigated, offsets should be proposed that deliver a real conservation outcome. Proposed offsets should target the matter protected by the EPBC Act that is being impacted. Given the nature and location of the potential impacts of the proposal, direct offsets such as acquisition of habitat areas may not be suitable.

It is recommended that indirect offsets be proposed, such as:

- Implementation of recovery plan actions for threatened and/or migratory species; and
- Contributions to relevant research programs targeting threatened and/or migratory species.

While neither the DEWHA nor NRETAS have finalised and agreed policies on offsets, INPEX recognises that offsets can provide improved environmental outcomes.

The Draft EIS demonstrates that no significant environmental impacts are expected in the Commonwealth marine area[3] and INPEX therefore does not propose any additional direct offsets for this area. INPEX has, however, undertaken extensive biological surveys in Commonwealth waters and along the adjoining coastline of Western Australia which have provided (and will continue to provide) a major contribution to the scientific knowledge of ecological processes and of plant and animal distribution in the marine and terrestrial environments of north-western Australia.

The studies INPEX has undertaken include the following:

- regional-scale aerial surveys to identify marine turtle nesting locations on the mainland and on coastal islands from Broome to Cape Bougainville
- detailed surveys of marine turtle nesting activity and abundance on several islands off the Kimberley coast
- surveys to identify potential foraging areas, inter-nesting areas and migratory routes for green and flatback turtles by means of satellite-tagging and -tracking
- genetic analyses of green and flatback turtles nesting on the islands of the Kimberley region
- extensive aerial and boat-based surveys to identify the distribution ranges of the humpback whale, pygmy blue whale, and other species of marine megafauna off the Kimberley coast
- offshore sea-noise logger surveys to gather data to identify pygmy blue whale distribution and abundance
- detailed coral habitat mapping and species identification surveys on a number of Kimberley islands
- fish, algae and mollusc surveys of a number of Kimberley islands
- benthic infauna surveys in the offshore development area and at the Maret Islands.

It is important to note that these studies have been undertaken in areas where there was previously very little scientific information available for environmental management and planning. A large proportion of the scientific information generated as a result of the INPEX surveys extends beyond the environmental assessment needs of the proposed Ichthys Project and therefore constitutes a valuable indirect environmental offset for the Kimberley region and the Browse Basin. The survey data will assist the Commonwealth and Western Australian governments with the planning of marine protected areas and in the preparation of threatened and migratory species recovery planning. To date, the cost of the INPEX biological surveys amounts to more than A$15 million.

"Matters of national environmental significance" and of significance to the Northern Territory also occur in areas under Northern Territory jurisdiction, most notably in Darwin Harbour. INPEX is committed to working closely with both the DEWHA and NRETAS to identify and explore potential environmental offset opportunities in the Darwin region. Areas which currently appear to offer beneficial environmental offset opportunities include the following:

- participation in and funding of the proposed integrated marine monitoring program for Darwin Harbour
- provision of funding to government, or direct complementary research, to improve the understanding of coastal dolphin abundance, distribution and critical resource needs in Darwin Harbour.

INPEX's approach to offsetting greenhouse gas liabilities under the Commonwealth Government's proposed Carbon Pollution Reduction Scheme (CPRS) are outlined in Chapter 9 *Greenhouse gas management*.

3 The "Commonwealth marine area" is defined by the DEWHA at <http://www.environment.gov.au/epbc/protect/marine.html> as "any part of the sea, including the waters, seabed, and airspace, within Australia's exclusive economic zone and/or over the continental shelf of Australia, that is not State or Northern Territory waters".

Provisional Acid Sulfate Soils Management Plan

Annexe 1 – Chapter 11 *Environmental Management Program*

1 OVERVIEW

As part of the approvals process for the Ichthys Gas Field Development Project (the Project), it is necessary that INPEX should show that it has taken, and will take, all practicable steps to properly manage the risks associated with, and the potential environmental impacts of, disturbance of acid sulfate soils (ASSs). Disturbance to these soils could occur as a result of earthworks and reclamation activities undertaken in intertidal areas during the onshore and nearshore construction phase of the Project.

ASSs are naturally occurring soft sediments and soils containing iron sulfides, principally iron disulfide (FeS_2), but also iron monosulfide (FeS). The exposure of the sulfides in such soils to oxygen by drainage or excavation leads to oxidation of the sulfides and to the generation of sulfuric acid (H_2SO_4). The sulfuric acid may then react with other soil constituents to liberate "heavy metals" such as aluminium, manganese, iron, copper and arsenic into surface water and groundwater. Some heavy metals can be toxic to plants and animals depending on their concentration and bio-availability.

The term "acid sulfate soils" refers to both "actual acid sulfate soils" (AASSs) and "potential acid sulfate soils" (PASSs). These are defined in Section 1.2 *Plan definitions* below.

Soil mapping and soil chemical analyses conducted by URS Australia Pty Ltd (see Chapter 3 *Existing natural, social and economic environment*) have identified four of the seven soil "families" on Middle Arm Peninsula as containing some level of ASSs. The Euro soil family was identified as containing high-risk PASSs, the Mullalgah soil family as containing moderate-risk ASSs, and the Maand soil family as containing low-risk ASSs. The Rinamatta soil family contains a siltstone several metres below the surface. Groundwater monitoring near this siltstone indicated a pH as low as 5, indicating low-risk ASSs from the siltstone. All of these soil families are typically associated with mangrove swamp and melaleuca habitats. The other three soil families in the onshore development area were identified as having no risk of ASSs.

Most of the facilities in the onshore development area will be constructed in areas that presently contain woodland and vine-forest vegetation communities. As these vegetation communities are not associated with the Euro, Maand, Mullalgah or Rinamatta soil families, most of the onshore facilities will be constructed in areas with no ASS risk. In addition, as siltstone in the Rinamatta soil family is several metres below Australian Height Datum (AHD) it is unlikely that this will be excavated.

Detailed geotechnical studies including chemical testing for ASSs will be conducted during the detailed design phase of the Project. The results of these investigations will further assist the environmental and engineering teams to understand the acid-generating potential and physical extent of any ASSs in relation to the onshore development footprint. Detailed ASS testing, in accordance with guidelines developed for ASSs in Queensland (Ahern, Ahern & Powell 1998) will take place once the infrastructure designs are further developed prior to construction commencing.

As the Project is still in its FEED phase, the management controls outlined in this provisional environmental management plan (EMP) primarily deal with the potential options available to INPEX for the management of ASSs. This plan will be updated with specific management controls as infrastructure design for the Project progresses and more detailed ASS information becomes available prior to construction.

This provisional environmental management plan (EMP) for acid sulfate soils is attached as Annexe 1 to Chapter 11 *Environmental management program* of the Project's draft environmental impact statement (Draft EIS). It is one of a suite of similar EMPs dealing with different aspects and activities of the Project. These provisional EMPs will form the basis for the development of more detailed environmental management documentation, for example plans and procedures for the various phases of the Project as well as for specific activities associated with the Project. The detailed documentation will be prepared either directly by INPEX's Environmental Department or by specialist contractors in conjunction with INPEX.

1.1 Purpose and scope

The purpose of this provisional EMP is as follows:

- It demonstrates how INPEX intends to minimise the potential environmental impact of disturbance to ASSs as a result of Project activities through the identification of suitable engineering design and management strategies.
- It describes the proposed monitoring requirements for all phases of the Project.
- It describes the proposed reporting, review and audit requirements for all phases of the Project.
- It will guide the development of future more detailed environmental documentation such as the plans, procedures, etc., which will be required throughout the life of the Project.

The scope of this provisional EMP includes the onshore and nearshore construction activities that have the potential to disturb ASSs, including the onshore section of the gas export pipeline (including the shore crossing), the flare area and the module offloading facility.

1.2 Plan definitions

Acid sulfate soils

"Acid sulfate soils" include both "actual" acid sulfate soils (AASSs) and "potential" acid sulfate soils (PASSs). These two types of ASSs may be found in the same soil profile, with a disturbed AASS layer overlying an undisturbed and still anaerobic PASS layer.

Actual acid sulfate soils

"Actual acid sulfate soils" are the naturally occurring sediments and soils containing iron sulfides, principally iron monosulfide (FeS) or iron disulfide (FeS_2), which have been subjected to disturbance and exposed to air. This exposure has therefore already resulted in the oxidation of some of the (solid) sulfides and the generation of liquid and leachable sulfuric acid. This acid moving through the soil has the potential to mobilise naturally occurring heavy metals such as aluminium, manganese, copper and arsenic, which have the potential to cause secondary contamination of soils and water. As an AASS is already leaching acid it will have a very low pH.

Potential acid sulfate soils

Potential acid sulfate soils are soils which contain iron sulfides or sulfidic materials which are in an anaerobic environment and have therefore not been exposed to air and oxidised. The pH of such a soil in its undisturbed state can be 4 or higher and may even be neutral (pH 7) or slightly alkaline. However, if disturbed, exposed to air and oxidised, PASSs become AASSs and pose a considerable environmental risk as they commence to leach sulfuric acid. Disturbances that can result in the oxidisation of PASSs include the lowering of natural water tables and the excavation of soils that were previously below natural groundwater levels.

1.3 Activities that may lead to disturbance of acid sulfate soils

During the construction phase of the Project, activities that may lead to disturbance of PASSs include earthworks and construction works occurring in and around the mangrove and melaleuca forests. These construction components include the following:

- the pipeline shore crossing and the onshore pipeline route through mangrove areas
- the flare area
- the module offloading facility.

Piledriving activities associated with the construction of the product loading jetty are not likely to cause any significant disturbance to PASSs as the operations will not excavate these soils or expose them to air.

1.4 Potential impacts

The potential environmental impacts associated with the disturbance of PASSs in the onshore development area and the generation of sulfuric acid leachate around the area include the following:

- the acidification of soils, which reduces soil productivity
- the acidification of surface water and groundwater, which has a deleterious effect on plant growth and health
- the acidification of marine water affecting water quality and marine biota in the vicinity of the onshore development area.

2 OBJECTIVES, TARGETS AND INDICATORS

The objectives, targets and indicators set out by INPEX for the management of ASSs are shown in Table 2-1. The engineering and management controls to be implemented to help to achieve these targets are described in Section 3 *Management approach*.

Table 2-1: Acid sulfate soil management objectives, targets and indicators

Objectives	Targets	Indicators
Minimise disturbance to PASSs outside the designated construction and earthworks areas.	• Zero incidents of disturbance to PASSs outside the areas of unavoidable disturbance required for the construction of infrastructure.	• Number of incident reports and the area and quantity of disturbance outside the designated disturbance footprint.
Handle and dispose of all excavated ASSs in accordance with agreed ASS management strategies.	• Zero incidents of excavated ASS not handled or disposed of in accordance with the agreed ASS management strategies.	• Quantitative records of ASS removal to approved disposal facilities or locations. • Number of incident reports of non-compliance with agreed ASS management strategies.
Minimise changes in surface- and groundwater quality during construction activities.	• No significant alteration in pH or heavy-metal concentration in surface- and groundwater above the natural background range.	The exact monitoring indicators will be determined when infrastructure design and construction methodology have been further advanced.
Minimise the disturbance to and alteration of vegetation communities as a result of disturbance to ASSs.	• Zero decline in mangrove vegetation community health in areas adjoining ASS risk areas attributable to acid drainage.	The exact monitoring indicators will be determined when infrastructure design and construction methodology have been further advanced.
Minimise the potential for increases in heavy-metal concentration in the tissues of the intertidal invertebrate fauna community.	• No increase in heavy-metal concentrations in intertidal invertebrate communities above safe seafood consumption levels.	The exact monitoring indicators will be determined when infrastructure design and construction methodology have been further advanced.

3 MANAGEMENT APPROACH

Detailed ASS documentation will be developed for the construction phase of the Project. These documents will align with this provisional acid sulfate soils EMP. The detailed documentation will be prepared either directly by INPEX's Environmental Department or by specialist contractors in conjunction with INPEX. The potential management techniques will take into consideration the recommendations of Dear et al. (2002).

A summary of the main engineering and management controls to be employed in the detailed documentation to mitigate the risks associated with disturbance of ASSs are outlined below.

3.1 Engineering controls—design phase

The final design of infrastructure in the onshore development area will take into consideration, as far as is practicable, all possible options to avoid disturbing PASSs. Among these options are the following:

- mixing the PASS in situ with cement slurry to harden it, neutralise it and make it more stable
- installing columns or piles and a deck structure in PASS areas in order to minimise the generation of AASSs, with Project facilities being constructed on top of the decking.

3.2 Management controls—construction

A number of management options are available to treat and dispose of disturbed ASSs during construction. Staged levels of management and treatment will be employed, depending on the acid-generating potential and extent of these soils within the onshore development footprint. Options currently being considered for the treatment and disposal of disturbed ASSs include the following:

- soil stabilisation through the placing of fill material on top of the possible ASSs until the surface is suitable for construction
- the neutralisation of excavated ASSs through physical mixing with lime, then reuse as backfill
- the neutralisation of excavated ASSs through physical mixing with lime, then disposal at designated onshore sites
- the excavation and offshore disposal of ASSs below LAT (Lowest Astronomical Tide) to ensure that the soils do not oxidise.

Other construction techniques that may be employed to minimise the impact of earthworks on non-excavated ASSs during construction may include the following:

- the use of low-ground-pressure vehicles to reduce soil consolidation and expression of groundwater
- the laying of geotextile fabrics underneath vehicle traffic routes, soil stockpile areas, etc., to reduce soil loading and thus minimise soil consolidation and expression of groundwater in areas with an ASS risk
- the laying of geotextile fabrics along exposed soil surfaces to reduce oxidisation of the soil surface and to stabilise soil faces
- the use of lime to neutralise exposed soil surfaces and trench beds in ASS risk areas
- the storage and/or treatment of all excavated ASS material in a clay-based bunded pad with a lime guard layer
- the installation of leachate collection drains around ASS storage and/or treatment pads to trap and contain any acidic leachate or runoff. Captured leachate will be neutralised prior to disposal
- the neutralisation of any groundwater extracted from trenching and excavated areas where AASSs or PASSs are present.

4 MONITORING

Monitoring activities will be undertaken throughout the life of the Project in relation to the identified objectives and targets. For example, a marine sediments and bio-indicators monitoring program will be developed to assess whether construction activities in ASS areas have resulted in changes in pH and heavy-metal availability in marine sediments around the onshore development area.

The detail of the monitoring activities to be undertaken will be determined once infrastructure design and associated construction methodologies have been further advanced during the detailed design phase of the Project, including further ASS testing during geotechnical investigation programs.

Triggered management response

A management response will be triggered by any of the following three circumstances:

1. an ASS “incident”
2. the identification by an annual management review of a failure to meet an objective or target
3. an exceedance of monitoring criteria.

The responses to each of these three situations are outlined below.

Response to ASS incidents

Non-compliance with any of the ASS controls outlined in this document will be classified as an incident. The detection of incidents associated with ASSs will trigger internal notifications, reporting requirements, investigation and associated corrective and preventive actions. The level of investigation will be dependent on the potential risk associated with the event.

ASS incidents will include the following:

- changes in sediment, surface- or groundwater pH or heavy-metal concentrations above the natural background range levels, in comparison with preconstruction baseline monitoring data
- changes in vegetation health adjacent to ASS areas caused by acid drainage
- non-compliance with the agreed soil-protection, handling, treatment and disposal management procedures.

Corrective and preventive actions that may be triggered as a result of the investigation may include the following:

- increased sampling (both frequency and location) of sediment, surface- and groundwater pH and heavy-metal concentrations around the construction area to identify or confirm the sources of acid leaching or heavy-metal contamination
- an increased level of monitoring of vegetation communities and invertebrate animals
- the digging of leachate drains to capture acidic water for neutralisation
- the neutralising of AASSs where practicable
- providing refresher training for personnel on Project ASS management processes.

INPEX’s Incident Reporting, Recording and Investigating Procedure or the Project contractor’s document equivalent (approved by INPEX) will be used to determine incident severity, potential risk and associated reporting, recording and investigating requirements. All ASS incidents will be entered into INPEX’s and its contractors’ incident databases and corrective actions will be tracked to closure.

Response to non-compliant annual management review outcomes

Failure to meet identified objectives and targets will trigger the following responses:

- a review and audit of ASS management practices to assess the practicability of their implementation, to identify new technologies to further reduce impact, and to assess the resources required to implement the plan
- a review of current objectives and targets to assess achievability.

The response to the results of investigations and audits may include the following:

- an update of plans and associated documentation to reflect changes to management practices
- the arrangement of refresher training in appropriate management practices and processes for personnel involved in construction activities in ASS areas
- the possible sourcing of additional resources to assist in the successful implementation of the agreed management practices.

An exceedance of monitoring criteria

The response to the exceedance of monitoring criteria may include the following:

- an increase in the monitoring frequency of relevant parameters at control and impact monitoring sites
- the investigation of possible sources or causes for the exceedance
- an increase in management controls such as the installation of interception drains, the neutralisation of exposed faces and drainage water with lime, and the sealing of exposed faces with geotextile fabric.

5 REPORTING, AUDITING AND REVIEW

Reporting and auditing will be undertaken during the construction phase of the Project. A summary of the reporting and auditing requirements relating to ASS management is presented below:

- Incidents resulting from the disturbance of ASSs will be reported in accordance with INPEX's Incident Reporting, Recording and Investigating Procedure or the Project contractor's document equivalent (approved by INPEX).
- An annual INPEX environmental report for the Project will be produced. It will include details of the volumes of ASSs disturbed, the quantities and methods of ASS disposal, and monitoring results.
- INPEX and its contractors will conduct internal compliance audits on a periodic basis.
- Construction contractors will be required to produce and provide to INPEX a monthly environmental report including a record of monthly environmental incidents.
- Records will be audited periodically to ensure that all personnel on site have completed the required health, safety and environment (HSE) induction.
- Detailed ASS management documentation, for example plans and procedures, will be reviewed periodically to ensure that they remain applicable to current operations and compliant with the requirements of INPEX and the regulatory authorities.

6 SUPPORTING DOCUMENTATION

This provisional EMP is one of a suite of plans, procedures and processes designed to ensure that INPEX's acid sulfate soils management activities are undertaken in compliance with legislative requirements and in a safe and environmentally responsible manner.

Documentation or processes addressing the issues outlined below have been or will be developed to further support the implementation of INPEX's acid sulfate soil management requirements:

- incident reporting, recording and investigating
- health, safety and environment induction
- permit-to-work system.

7 APPLICABLE LEGISLATION

INPEX is committed to complying with all relevant laws, regulations and standards. Legislative instruments specifically related to ASS management include those listed below.

- *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth).
- *Soil Conservation and Land Utilization Act* (NT).
- *Waste Management and Pollution Control Act* (NT).

8 REFERENCES

Ahern, C.R., Ahern, M.R. and Powell, B. 1998. *Guidelines for sampling and analysis of lowland acid sulfate soils (ASS) in Queensland 1998*. Queensland Acid Sulfate Soils Investigation Team, Department of Natural Resources, Indooroopilly, Brisbane, Queensland.

Dear, S.E., Moore, N.G., Dobos, S.K., Watling, K.M. and Ahern, C.R. 2002. Soil management guidelines: Version 3.8. In *Queensland Acid Sulfate Soil Technical Manual*. Department of Natural Resources and Mines, Indooroopilly, Brisbane, Queensland. Viewed online on 2 February 2010 at <http://www.nrw.qld.gov.au/land/ass/pdfs/soil_mgmt_guidelines_v3_8.pdf>.

Provisional Air Emissions Management Plan

Annexe 2 – Chapter 11 *Environmental Management Program*

1 OVERVIEW

As part of the approvals process for the Ichthys Gas Field Development Project (the Project), it is necessary that INPEX should show that it has taken, and will take, all practicable steps to properly manage the risks associated with, and the potential environmental impact of, air emissions generated by the Project both onshore and offshore during its lifetime.

Emissions that will be generated over the life of the Project and which will have the potential to impact adversely on the environment include carbon dioxide (CO_2) nitrogen oxides (NO_x and N_2O); sulfur oxides (SO_x); volatile organic compounds (VOCs), including benzene, toluene, ethylbenzene and xylenes (collectively called BTEX); methane (CH_4); and particulates. They will primarily arise through the commissioning and operations phases from combustion, flaring and venting and from fugitive sources.

Dust is the key emission of concern during the construction phase at the onshore development area. Emissions such as NO_x, SO_x and particulates during the estimated five-year construction phase will come primarily from marine vessel engines, from airline flights and from the vehicles and equipment required to support the construction crew in their activities at the onshore development area. However, the volume and duration of these emissions will be very minor in comparison with the emissions generated during the commissioning and operations phases. For this reason the gas-processing facilities have been the focus of an extensive air-quality assessment and modelling program.

This provisional environmental management plan (EMP) for air emissions is attached as Annexe 2 to Chapter 11 *Environmental management program* of the Project's draft environmental impact statement (Draft EIS). It is one of a suite of similar EMPs dealing with different aspects and activities of the Project. These provisional plans will form the basis for the development of more detailed environmental management documentation, for example plans and procedures for the various phases of the Project as well as for specific activities associated with the Project. The detailed documentation will be prepared either directly by INPEX's Environmental Department or by specialist contractors in conjunction with INPEX.

Greenhouse gas emissions are specifically addressed in Chapter 9 *Greenhouse gas management* and in the Provisional Greenhouse Gas Management Plan which is attached as Annexe 8 to Chapter 11. However it should be noted that options to improve the Project's efficiency in terms of greenhouse gas emissions will generally have a concomitant benefit in reducing other air emissions.

1.1 Purpose and scope

The purpose of this provisional EMP is as follows:

- It demonstrates how INPEX will minimise the potential environment impact of the Project's air emissions through the identification of suitable management strategies.
- It describes the proposed monitoring requirements for the commissioning and operations phases of the Project.
- It describes the proposed reporting, review and audit requirements for the commissioning and operations phases of the Project.
- It will guide the development of future more detailed environmental documentation, such as the plans, procedures, etc., which will be required throughout the life of the Project.

The scope of this provisional EMP includes significant air emissions released to the atmosphere (i.e. through combustion, flaring and venting and from fugitive sources) as a result of activities in the Ichthys Gas Field Development Project area (both onshore and offshore) during the commissioning and operations phases of the Project. These emissions include NO_x, SO_x, VOCs (including BTEX), CH_4, and particulates.

It does not address the potential environmental impacts of, or the management controls for, the following:

- dust emissions produced during the construction phase
- CO_2, CH_4 and N_2O and their potential to contribute to the phenomenon of global warming.

These are addressed as separate aspects in two other provisional EMPs:

- Provisional Dust Management Plan (Annexe 7 to Chapter 11)
- Provisional Greenhouse Gas Management Plan (Annexe 8 to Chapter 11).

1.2 Plan definitions

Air pollutants

According to the National Environmental Protection Council (NEPC), which produced the National Environment Protection (Ambient Air Quality) Measure in 1998, air pollutants can be divided into three groups: criteria pollutants, air toxics and biological pollutants. Pollutants of the first two groups are the subject of this management plan.

The criteria pollutants include NO_2, sulfur dioxide (SO_2) and particulate matter, while the air toxics include the BTEX compounds.

Project air emissions

Emission sources from the Project will include both direct air emissions from the offshore and onshore production and processing facilities and diffuse air emissions from supply vessels, shipping and aircraft. Emissions from these sources that could potentially impact on air quality are NO_x, SO_2, particulates (as PM_{10}[1]) and VOCs. The BTEX compounds make up only a small fraction of the VOCs and other compounds generated from the combustion of natural gas. Ozone (O_3) can be indirectly produced by the reaction of oxides of nitrogen and VOCs in the presence of sunlight.

Flaring

Non-routine flaring is defined as an infrequent event such as would occur during processing-plant commissioning, start-ups, shutdowns, and unexpected compressor and other equipment failures. In these situations the plant will automatically flare large quantities of gas for safety reasons.

Fugitive emissions

Fugitive emissions are the gases resulting from leaks, including those from pump seals, pipe flanges and valve stems.

1.3 Air emissions

Air emissions likely to be produced during the commissioning and operations phases of the Project include the following:

- NO_x
- SO_2
- VOCs (including the BTEX compounds)
- CH_4
- particulates.

1 Particulate matter (PM) is usually categorised as PM_{10} or $PM_{2.5}$. The fraction of suspended particles whose diameter is less than 10 micrometres (10 µm) is PM_{10}.

1.4 Potential sources of air emissions

During the commissioning and operations phases, the sources of air emissions will be associated with the activities listed below.

Onshore and nearshore

- combustion of gas in the gas turbines, furnaces and incinerators
- combustion of gas through non-routine and routine flaring activities
- emergency power generation during the operations phase
- operations of vehicles and equipment.

There may also be vented and fugitive emissions from a variety of sources, including leaks from pump seals and pipe flanges.

Offshore

- combustion of gas in the gas turbines
- emergency power generation during the operations phase
- combustion of gas through non-routine and routine flaring activities
- operations of cranes and equipment.

There may also be unintended process venting and fugitive emissions from a variety of sources, including leaks from pump seals and pipe flanges.

1.5 Potential impacts

Potential impacts on the environment from Project-related air emissions resulting from onshore and offshore activities include the following:

- a reduction in ambient air quality
- a reduction in visual amenity
- the emission of air pollutants (including NO_x and SO_2) to the atmosphere, adversely impacting on the natural environment and human health.

2 OBJECTIVES, TARGETS AND INDICATORS

The objectives, targets and indicators set out by INPEX for the management of air emissions are shown in Table 2-1. The engineering and management controls to be implemented to help to achieve these targets are described in Section 3 *Management approach*.

Table 2-1: Air-emission management objectives, targets and indicators

Objectives	Targets	Indicators
Minimise flaring volumes for onshore operations phase.	• Targets yet to be defined for operations. • A baseline calculation of annual routine flaring volumes will be undertaken in the first year of operations to verify plant performance against design predictions. Total annual flaring volume reduction targets will then be identified for subsequent years.	• Total annual flaring volumes (ground and emergency flares) during first 12 months of operations. • Actual annual flaring volumes versus annual performance target volumes.
Minimise flaring volumes for offshore operations phase.	• Targets yet to be defined for operations. • A baseline calculation of annual flaring volumes will be undertaken in the first year of operations to verify plant performance against design predictions. Total annual flaring volume reduction targets will then be identified for subsequent years.	• Total annual process flaring volumes during the first 12 months of operations. • Actual annual flaring volumes versus annual performance target volumes.
Ensure that onshore stack emissions are consistent with Project design criteria and the vendor's equipment performance specification.	• Air emissions from combustion equipment should not exceed Project design criteria and equipment performance specifications.	• Stack emission testing of onshore combustion equipment. • Quantities of fuel used by equipment.

3 MANAGEMENT APPROACH

Detailed air-emission management documentation, for example plans and procedures, will be developed for the commissioning and operations phases of the Project. These detailed documents will align with this provisional air emissions EMP. The detailed documentation will be prepared either directly by INPEX's Environmental Department or by specialist contractors in conjunction with INPEX.

A summary is provided below of the main engineering and management controls to be included in the detailed documentation to mitigate the risks associated with air emissions.

3.1 Engineering controls—design phase

The engineering controls to be implemented during the design phase of the Project are outlined below.

Applicable to both onshore and offshore

- Fuel gas line flowmeters will be installed to support monitoring requirements.
- Valves will be installed in the process system to allow for inventory isolation.
- Process monitoring systems and alarms will be installed to monitor flaring events and process upsets.
- Dry gas seals will be installed on main refrigerant compressors.
- Waste-heat recovery units or heat recovery steam generators will be installed wherever waste heat can be economically utilised.

Onshore-specific

- Residual hydrocarbons and hydrogen sulfide (H_2S) will be removed from the emission stream by acid gas removal unit (AGRU) incinerators.
- In the unlikely event that the AGRU incinerators are shut down, exhaust gases (including H_2S and residual hydrocarbons) will be hot-vented through turbine exhaust stacks to facilitate safe dispersion.
- Open-cycle gas turbines will be designed to achieve a low NO_x outcome.
- Easily accessible sampling points will be provided on major emission points, such as turbines, AGRU incinerators and furnaces (where applicable).
- Boil-off gas from LNG storage tanks and LNG offtake tanker loading operations will be recovered by boil-off gas recompression systems.
- Boil-off gas from the butane and propane storage tanks will be recovered by butane and propane recovery systems. Boil-off gas from the butane and propane tankers will be captured by onboard recovery systems.

- Flare knockout drums and closed-drain systems will be installed for liquids recovery.
- Ground flares and tankage flares will be designed to minimise the generation of particulates (smoke).
- The condensate storage tanks will be fitted with floating roofs.

3.2 Management controls—commissioning and operations phases

The management controls to be implemented throughout the various phases of the Project are outlined below.

Applicable to both onshore and offshore

- Flaring will be limited to that essential during emergencies, process upsets, plant start-ups and shutdowns, commissioning and maintenance.
- There will be no continuous intentional disposal of hydrocarbon gas by venting to atmosphere. (This does not apply to unavoidable minor intermittent releases.)
- Where possible, low-sulfur diesel will be used for diesel-driven equipment during all phases of the Project.
- Regular preventive maintenance and equipment inspections will be scheduled.
- A commissioning plan will be developed to minimise and manage flaring during the commissioning phase for the onshore and offshore facilities.

4 MONITORING

Monitoring activities will be undertaken throughout the commissioning and operations phase of the Project in relation to the identified objectives and targets. The activities listed below will be undertaken as part of the air-emission monitoring program:

- Air-emission incidents will be monitored through INPEX's and its contractors' incident-reporting databases.
- The six air pollutants covered by the National Environment Protection (Ambient Air Quality) Measure will be monitored using monitoring points established by the Northern Territory's Department of Natural Resources, Environment, the Arts and Sport (NRETAS) at Darwin International Airport.
- Periodic onshore stack emission sampling will be undertaken on gas turbines, furnaces (if required) and the AGRUs. Emissions to be measured will include NO_x, SO_x, BTEX and PM_{10}.
- Data will be collated monthly from offshore and onshore facilities on the quantities of hydrocarbons burned and the volumes of gas flared.

Triggered management response

A management response will be triggered by any of the following three circumstances:

1. an emissions "incident"
2. an exceedance of the monitoring criteria set for the Project
3. the identification by an annual management review of a failure to meet an objective or target.

The responses to these are outlined below.

Response to air-emission "incidents"

A non-compliant air-emission event is classified as an "incident". This would include, for example, a public or internal complaint received regarding excessive generation of black smoke.

Detection of incidents will trigger internal notifications, reporting requirements, investigations and associated corrective and preventive actions. The level of investigation will be dependent on the potential risk associated with the event.

The level of investigation will be dependent on the potential risk associated with the event. Corrective and preventive actions triggered as a result of the investigation could include, for example, equipment maintenance.

INPEX's Incident Reporting, Recording and Investigating Procedure or the Project contractor's document equivalent (approved by INPEX) will be used to determine incident severity, potential risk and associated reporting, recording and investigation requirements. All incidents and "near misses" will be entered into INPEX's and its contractors' incident databases and corrective actions will be tracked to closure.

Response to an exceedance of air emissions monitoring criteria set for the Project

Examples of air emissions exceedances that could be detected by monitoring include the following:

- exceedance of Project design criteria and vendor equipment specifications for concentrations of NO_x emitted by gas turbines and furnaces (where applicable) during normal operating conditions and upset conditions
- exceedance of Project design criteria and vendor equipment specifications for concentrations of SO_x emitted by gas turbines
- exceedance of Project-defined flaring volumes for onshore and offshore operations.

Responses to an air emissions exceedance could include the following:

- an increase in the frequency of monitoring of relevant parameters at control and impact monitoring sites
- an investigation into the source or cause of the exceedance
- a review and update of existing management controls and procedures associated with air emissions.

Response to adverse findings by an annual management review

Failure to meet identified objectives and targets will trigger the following responses:

- a review and audit of current air-emission management practices
- investigations into the effectiveness of machinery and equipment to meet identified targets and objectives
- a review of operations equipment and machinery maintenance regimes
- a review of current objectives and targets to assess achievability.

The response to results of investigations and audits could include the following actions:

- an update of plans and associated documents to reflect changes to air-emission management
- the updating of equipment technology to improve air-emission efficiency.

5 REPORTING, AUDITING AND REVIEW

Reporting, auditing and reviews will be undertaken during the commissioning and operations phases of the Project. A summary of the reporting, auditing and review requirements relating to air-emission management is presented below:

- Incidents resulting from air emissions will be reported in accordance with INPEX's Incident Reporting, Recording and Investigating Procedure or the Project contractor's document equivalent (approved by INPEX).
- Annual National Pollutant Inventory reporting requirements will be met.
- An annual INPEX environmental report for the Project will be produced. It will include details of flaring volumes, stack test monitoring results and incidents.
- INPEX and its contractors will conduct internal compliance audits on a periodic basis.
- Detailed air-emission management documentation, for example plans and procedures, will be reviewed periodically to ensure that they remain applicable to current operations and compliant with the requirements of INPEX and the regulatory authorities.

6 SUPPORTING DOCUMENTATION

This provisional EMP is one document in a suite of plans, procedures and processes designed to ensure that INPEX's air-emission management activities are undertaken in compliance with legislative requirements and in a safe and environmentally responsible manner.

Documentation or processes addressing the issues outlined below have been or will be developed to further support the preparation of INPEX's detailed air-emission management documentation:

- air-quality sampling
- incident reporting, recording and investigating
- process equipment maintenance
- start-up and commissioning.

7 APPLICABLE LEGISLATION, STANDARDS AND GUIDELINES

INPEX is committed to complying with all relevant laws, regulations and standards. Legislative instruments, standards and guidelines specifically related to air-emission management include those listed below.

- Department of the Environment, Water, Heritage and the Arts. 2008. *National pollutant inventory*. Commonwealth Government, Canberra, ACT.
- Fuel Quality Standards Regulations 2001 (Cwlth).
- International Maritime Organization. 1978. *International convention for the prevention of pollution from ships, 1973, as modified by the protocol of 1978 relating thereto (MARPOL 73/78)*. International Maritime Organization, London, United Kingdom.
- National Environment Protection Council. 2003. *National Environment Protection (Ambient Air Quality) Measure*. Commonwealth Government, Canberra, ACT.
- Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009 (Cwlth).
- *Waste Management and Pollution Control Act* (NT).

Provisional Bushfire Prevention Management Plan

Annexe 3 – Chapter 11 *Environmental Management Program*

1 OVERVIEW

As part of the approvals process for the Ichthys Gas Field Development Project (the Project), it is necessary that INPEX should demonstrate that it has taken, and will take, all practicable steps to properly manage the risk of bushfires in the onshore development area during the lifetime of the Project.

Fire is a part of the landscape of the Northern Territory, either as a result of controlled-burning practices or as a result of uncontrolled natural or man-made wildfires. Controlled burning is carried out throughout the Northern Territory on an annual basis, usually during the early dry season. This practice assists in the reduction of fuel loads and creates strategic barriers against the spread of wildfires which may occur later in the dry season (August to November).

The onshore development area falls within the Northern Fire Protection Zone and in particular within the Vernon bushfire region. Specific management requirements are associated with the Northern Fire Protection Zone and must be adhered to throughout the Project.

This provisional environmental management plan (EMP) for bushfire prevention is attached as Annexe 3 to Chapter 11 *Environmental management program* of the Project's draft environmental impact statement (Draft EIS). It is one of a suite of similar EMPs dealing with different aspects and activities of the Project. These provisional EMPs will form the basis for the development of more detailed environmental management documentation, for example plans and procedures for the various phases of the Project as well as for specific activities associated with the Project. The detailed documentation will be prepared either directly by INPEX's Environmental Department or by specialist contractors in conjunction with INPEX.

1.1 Purpose and scope

The purpose of this provisional EMP is as follows:

- It demonstrates how INPEX will minimise the risk of a bushfire occurring in the onshore development area through suitable fire prevention management controls.
- It describes the proposed reporting, review and audit requirements for all phases of the Project.
- It will guide the development of future more detailed environmental documentation such as the plans, procedures, etc., which will be required throughout the life of the Project.

The scope of this provisional EMP includes the bushfire prevention methods to be employed in the onshore development area during the lifetime of the Project.

This provisional EMP does not address potential environmental impacts or management controls for the following:

- response to bushfire incidents in or around the onshore development area
- fire prevention controls and responses to fires occurring in the onshore facilities as a result of processing-plant operations.

These are addressed under separate construction and operations emergency response plans.

1.2 Sources of ignition

Potential ignition sources throughout all phases of the Project may include those listed below:

- "hot-work" activities such as grinding and welding
- faulty electrical equipment
- machinery and vehicles
- careless disposal of cigarette butts
- controlled-burning practices
- uncontrollable events such as lightning strikes and arson.

1.3 Potential impacts

Bushfires in the onshore development area have the potential to impact on the environment. Such potential impacts could include the following:

- damage to plant communities
- damage to Project or other infrastructure
- threats to workforce and public safety.

2 OBJECTIVES, TARGETS AND INDICATORS

The objectives, targets and indicators set out by INPEX for bushfire prevention management are shown in Table 2-1. The engineering and management controls to be implemented to help to achieve these targets are described in Section 3 *Management approach*.

Table 2-1: Bushfire prevention management objectives, targets and indicators

Objectives	Targets	Indicators
Prevent loss or damage to vegetation and habitats from unauthorised bushfires occurring during any phase of the Project.	• Zero incidents of unauthorised burning of natural vegetation within the onshore development area by Project personnel.	• Number of incident reports of unauthorised burning of natural vegetation by Project personnel.
Establish and maintain awareness of the importance of protecting the ecological values of the onshore development area during all phases of the Project.	• All workforce personnel (including contractors) to complete a health, safety and environment (HSE) induction, which will include information on the ecological values of the onshore development area and on bushfire prevention management.	• Number of people accessing the site as recorded by security. • Number of people completing HSE inductions.

3 MANAGEMENT APPROACH

Detailed bushfire prevention management documentation, for example plans and procedures, will be developed for all phases of the Project. These documents will align with this provisional bushfire prevention EMP. The detailed documentation will be developed by INPEX's Environmental Department and/or construction contractors in consultation with the Northern Territory's Bushfires Council.

A summary is provided below of the main engineering and management controls to be included in the detailed documentation and design of facilities to mitigate the risk of bushfire.

3.1 Engineering controls—design phase

The engineering controls to be included during the design phase of the Project are as follows:

- Fire protection systems for the operations phase will be designed to enable INPEX personnel to handle bushfires capably until external help arrives.
- Appropriate quantities of water will be stored and made available for firefighting purposes.

3.2 Management controls—all phases

The management controls to be implemented throughout the various phases of the Project are outlined below:

- Detailed bushfire prevention management plans or procedures will be developed in consultation with the Northern Territory's Bushfires Council.
- Grassy vegetation in the onshore development footprint will be controlled to reduce fuel loads and minimise the risk of wildfire. Control methods may include slashing or spraying.
- Firebreaks will be established around Project infrastructure which borders on woodland. Advice will be sought from the Northern Territory's Bushfires Council on firebreak requirements for Blaydin Point.
- Safe designated smoking areas will be established and receptacles for cigarette butts will be provided during all phases of the Project.
- A firefighting capability will be available and strategically located firefighting stations will be established at the onshore Project site.
- An internal "hot-work permit" system will be instituted for all hot-work activities, for example welding and grinding. The permit will specify fire-control practices to help ensure that no fires are started from conducting these activities. Permits will be managed under a permit-to-work system.
- Effective waste management practices will ensure that combustible construction wastes (e.g. timber, cardboard and paper) do not accumulate and pose a fire hazard.
- Firefighting equipment will be maintained and tested according to the relevant Australian standards and regulatory requirements.
- All fire extinguishers will be visually checked on a regular basis.
- Drills will be carried out (under the direction of the emergency response team) to ensure that all personnel are familiar with evacuation procedures and processes.
- Drills will be held periodically with simulated fire situations. Equipment will be tested and response times reviewed.
- Vehicles will be restricted to designated roads and tracks except in the event of an emergency.

- All permanent site vehicles will be equipped with a compatible and appropriately sized fire extinguisher.
- All vehicles will be serviced regularly and maintained to minimise the risk of fires from engines, exhausts, etc.
- The storage of flammable and combustible liquids will be in accordance with regulatory requirements and Australian standards.
- All construction and operations personnel will receive training in the permit-to-work system in place on site during the various phases of the Project.
- Potential ignition sources such as lighters, matches and electronic devices with batteries (cameras, mobile phones, etc) will be strictly controlled at the security gate.
- During all phases of the Project, when first reporting to site, all personnel (including contractors) will be required to attend inductions highlighting the main management controls for fire prevention, including general fire extinguisher use, hot-work permit requirements, emergency evacuation procedures, and the location of fire and emergency muster points.

3.3 Management controls—construction phase

The management controls to be implemented throughout the construction phase of the Project are outlined below:

- Stockpiled vegetation from clearing activities will not be burned, but will be reused where possible or disposed of off site.
- After clearing operations, mulched vegetation stored on site will be stockpiled in a number of designated areas, away from potential ignition sources.
- Vehicles and equipment used for clearing vegetation will be regularly cleaned to remove accumulated combustible vegetation debris.
- Adequate water storage facilities will be made available to meet construction fire prevention requirements.
- A suitable means of raising the alarm in the event of a fire or other emergency on the construction site will be established. The alarm system will be appropriate to ensure that all personnel can be notified immediately of any emergency situation and evacuation, or of any other actions required. As construction progresses and systems are commissioned in specific buildings, personnel will be informed of and trained to recognise the differences between alarm sounds.

4 MONITORING

Monitoring activities will be undertaken throughout the life of the Project in relation to the identified objectives and targets. The activities listed below will be undertaken as part of the bushfire prevention monitoring program:

- Fire incidents will be monitored through INPEX's and its contractors' incident-reporting databases.
- Emergency response drills and exercises will be undertaken periodically to identify any deficiencies in the system.
- Workplace "housekeeping" inspections will be undertaken to ensure that there is no accumulation of waste materials and other combustible substances in work areas.
- Firefighting equipment will be inspected, maintained and tested according to the requirements of the regulatory authorities and the prescriptions of the relevant Australian standards.

Triggered management response

A management response will be triggered by either of the following two circumstances:

1. a fire "incident"
2. the identification by an annual management review of a failure to meet an objective or target.

The responses to these are outlined below.

Response to fire "incidents"

Fire incidents could include the following:

- accidental bushfires caused by Project activities (but not attributable to natural uncontrollable events)
- unauthorised fires leading to a bushfire.

Detection of fire incidents will trigger internal notifications, reporting requirements, investigations and associated corrective and preventive actions.

The level of investigation will be dependent on the potential risk associated with the event. Corrective actions that may be triggered as a result of the investigation would include the review and update of procedures or plans associated with fire prevention and/or refresher training for personnel on Project fire prevention management processes.

INPEX's Incident Reporting, Recording and Investigating Procedure or the Project contractor's document equivalent (approved by INPEX) will be used to determine incident severity, potential risk and associated reporting, recording and investigation requirements. All fire incidents and "near misses" will be entered into INPEX's and its contractors' incident databases and corrective actions will be tracked to closure.

Response actions to fire incidents will be detailed in the onshore emergency response plans throughout the life of the Project.

Response to adverse findings by an annual management review

Failure to meet identified objectives and targets will initiate the following response: a review and audit of current fire prevention management practices to assess the practicability of implementation, the identification of potential new ignition sources (not previously identified), and a reassessment of resource requirements.

The response to the results of investigations and audits could include the following:

- an update of plans or procedures to reflect changes to bushfire prevention management practices if applicable
- the arrangement of refresher training for personnel covering management practices and processes for bushfire prevention on site
- the arrangement of refresher training for fire-brigade team members covering firefighting practices.

5 REPORTING, AUDITING AND REVIEW

Reporting, auditing and reviews will be undertaken throughout the lifetime of the Project. A summary of the reporting, auditing and review requirements relating to bushfire prevention is provided in the following two sections.

5.1 All Project phases

The reporting, auditing and review requirements applicable for all phases of the Project are as follows:

- The Northern Territory's Bushfires Council will be informed of any bushfires in or adjacent to the onshore development area.
- Records will be maintained for portable fire extinguisher test certificates and inspection dates.
- Records will be maintained of the testing and maintenance of other firefighting equipment (e.g. firewater pumps).
- Incidents resulting from bushfire outbreaks will be reported in accordance with INPEX's Incident Reporting, Recording and Investigating Procedure or the Project contractor's document equivalent (approved by INPEX).
- An annual INPEX environmental report for the Project will be produced and will include details of bushfire incidents.
- INPEX and its contractors will conduct internal compliance audits on a periodic basis.
- Records will be audited periodically to ensure that all personnel on site have completed the required health, safety and environment induction.
- Detailed bushfire prevention management documentation, for example plans and procedures, will be reviewed periodically to ensure that they remain applicable to current operations and compliant with the requirements of INPEX and the regulatory authorities.

5.2 Construction phase

In addition to the reporting requirements listed above, during the construction phase contractors will be required to produce and provide to INPEX a monthly environmental report including a record of environmental incidents.

6 SUPPORTING DOCUMENTATION

This provisional EMP is one document in a suite of plans, procedures and processes designed to ensure that INPEX's bushfire prevention management activities are undertaken in compliance with legislative requirements and in a safe and environmentally responsible manner.

Documentation or processes addressing the issues outlined below have been or will be developed to further support the implementation of detailed bushfire prevention management plans or procedures:

- incident reporting, recording and investigating
- maintenance of an emergency contact list
- emergency response
- health, safety and environment site induction.

7 APPLICABLE LEGISLATION

INPEX is committed to complying with all relevant laws, regulations and standards. Legislative instruments specifically related to fire management include those listed below.

- *Bushfires Act* (NT).
- Bushfires Regulations (NT).
- *Fire and Emergency Act* (NT).

Provisional Cetacean Management Plan

Annexe 4 – Chapter 11 *Environmental Management Program*

1 OVERVIEW

As part of the approvals process for the Ichthys Gas Field Development Project (the Project), it is necessary that INPEX should show that it has taken, and will take, all practicable steps to properly manage the risk and potential environmental impact of vessel, aircraft and vertical seismic profiling (VSP) interactions with cetaceans (whales and dolphins) during the lifetime of the Project, from construction and operations through to decommissioning.

This provisional environmental management plan (EMP) for cetaceans is attached as Annexe 4 to Chapter 11 *Environmental management program* of the Project's draft environmental impact statement (Draft EIS). It is one of a suite of similar EMPs dealing with different aspects and activities of the Project. These provisional plans will form the basis for the development of more detailed environmental management documentation, for example plans and procedures for the various phases of the Project as well as for specific activities associated with the Project where appropriate. The detailed documentation will be prepared by the relevant contracting parties in consultation with INPEX's Environmental Department.

1.1 Purpose and scope

The purpose of this provisional EMP is as follows:

- It demonstrates how INPEX will minimise the potential impact of vessel, aircraft and VSP activities on cetaceans.
- It describes the proposed monitoring requirements for all phases of the Project.
- It describes the proposed reporting, review and audit requirements for all phases of the Project.
- It will guide the development of future more detailed environmental documentation, such as the plans, procedures, etc., which will be required throughout the life of the Project.

The scope of this provisional EMP encompasses the activities of all vessels and aircraft operating in Australia's territorial waters which might impact upon cetaceans during the Project's lifetime. It also addresses the risks associated with vertical seismic profiling which will be conducted during production drilling.

This provisional EMP does not address the potential environmental impact of, or the management controls for, underwater noise generated by Project-related piledriving or blasting activities. This is addressed in the Provisional Piledriving and Blasting Management Plan (Annexe 12 to Chapter 11).

1.2 Activities that may lead to impacts on cetaceans

Cetaceans have the potential to be present in all marine areas where the Project will operate. The Project activities that have the potential to impact on cetaceans are addressed in this plan as follows:

- marine vessel movements and operations
- helicopter movements
- vertical seismic profiling (during production drilling).

1.3 Potential impacts

Potential impacts on cetaceans as a result of the above activities include the following:

- disruption of natural behaviour
- displacement from natural habitats
- stress or injury
- increased mortality
- reduced breeding success.

2 OBJECTIVES, TARGETS AND INDICATORS

The objectives, targets and indicators set out by INPEX for cetacean management are shown in Table 2-1. Engineering and management controls to be implemented to help to achieve these targets are described in Section 3 *Management approach*.

Table 2-1: Cetacean management objectives, targets and indicators

Objectives	Targets	Indicators
Minimise the risk of behavioural and stress-related impacts on cetaceans from vertical seismic profiling generated by underwater noise.	• Operate vertical seismic profiling at all times under predetermined, risk-assessed, acceptable operating parameters.	• Measure compliance with operating parameters through audits, inspections, records and incident reports.
Minimise the risk of disturbance to cetaceans through marine vessel and helicopter operations.	• No incidents of vessel- or helicopter-related disturbance to cetaceans.	• Audits and incident reports on compliance of vessels and helicopters with procedures governing interactions with cetaceans.
Establish and maintain awareness of the importance of protecting cetacean species.	• All members of the marine and aviation workforce (including contractors) to complete a health, safety and environment (HSE) induction, which will include information on cetacean management requirements. • Vessel masters and helicopter pilots trained in cetacean interaction procedures.	• Assessment of level of training of appropriate personnel on board vessels, aircraft and marine plant. • Assessment of level of training for vessel masters and helicopter pilots.

3 MANAGEMENT APPROACH

Detailed cetacean management documentation, for example plans and procedures, will be developed for all phases of the Project. These documents will align with this provisional cetacean EMP. The detailed construction cetacean management documentation will be developed by contractors in consultation with INPEX's Environmental Department to ensure that they meet INPEX and regulatory authority requirements. The detailed cetacean management documentation for the operations phase will be developed by INPEX's Environmental Department.

The management controls to be implemented to minimise the risk of impacts on cetaceans during vessel, aircraft and VSP activities, throughout the various phases of the Project, are outlined in the subsections below.

3.1 Vertical seismic profiling

Vertical seismic profiling (VSP) will take place during production drilling activities. A detailed description of VSP activities is provided in Chapter 5 *Emissions, discharges and wastes*, with the risk assessment provided in Chapter 7. In summary, VSP will involve the use of a two- or three-airgun cluster, fired at intervals of 6–10 s, generating a sound-pressure level of approximately 190 dB re 1 μPa at the standard reference distance of 1 m, with a frequency typically centred around 200 Hz. The VSP operations generally only last for 8–12 hours and will typically occur only once for each production well drilled.

Because of the low frequency of seismic surveys (generally less than 200 Hz), it is likely that only the baleen whales and larger toothed whales will be sensitive to VSP operations. The smaller toothed cetaceans (dolphins and beaked whales) that have much higher auditory bandwidths are not likely to be behaviourally affected by the generation of acoustic signals of such a low frequency.

Received sound levels from an acoustic source generating 190 dB re 1 μPa at 1 m will attenuate rapidly with increasing distance from the acoustic source. During drilling and all offshore operations, the most likely large cetaceans to be encountered are migrating humpback whales, but only in low numbers (McCauley 2009). In addition, McCauley et al. (2000) observed that migrating humpback whales tended to avoid operating seismic sources when the received sound levels were greater than 157–164 dB re 1 μPa rms.

It is therefore anticipated that at distances greater than 500 m from the acoustic source, where received levels should be below 150 dB re 1 μPa, there is a low probability of disturbance to cetaceans from VSP operations.

Although VSP is considered to be a low-risk operation, INPEX will implement the following management measures to ensure that the risk of disturbance to larger cetaceans (i.e. whales) by seismic profiling is minimised. Note that the "observation zone" is defined here as the area of ocean within a 3-km horizontal radius of the VSP acoustic source while the "shutdown zone" is the area of ocean within a 500-m horizontal radius of the acoustic source.

- **Visual observation before start-up**: Visual observations must be undertaken over the observation zone around the VSP acoustic source by a trained crew member for at least 30 minutes before the commencement of the "soft-start" procedure defined below. The procedure may only commence if no whales have been sighted within the shutdown zone around the acoustic source during this 30-minute period.
- **"Soft-start" procedure**: To protect any cetaceans in the vicinity and allow them to move away, the VSP acoustic source must commence operating at the lowest power setting, with a gradual increase in power over a 20-minute period until the full operating power level is reached.
- **Operating procedure**: While the VSP acoustic source is operating, both during soft-start procedures and survey operations, the following measures must be implemented:
  - Visual observations of the 3-km observation zone must be maintained continuously to monitor whale movements during daylight hours.
  - If a whale is sighted within the 3-km-radius observation zone, the operator of the VSP equipment must be placed on standby to power down the acoustic source.
  - If a whale is sighted within the 500-m-radius shutdown zone, the acoustic source must be shut down completely and not restarted until the animal has moved outside the shutdown zone or has not been sighted for 30 minutes. Restart must be carried out using the soft-start procedure.
- **Low-visibility operating procedure**: During periods of low visibility (where the 3-km observation zone cannot be clearly viewed, including night-time) the VSP acoustic source may only be utilised in accordance with the soft-start procedure and operating procedure after there has been a 30-minute period of continuous observation in good visibility to the extent of the 3-km-radius observation zone and during which no whales were sighted. At night the 30-minute observation period will be undertaken with infrared or night-vision binoculars.

Records of all VSP operations will be maintained and will include details of the following:

- the 30-minute observation periods before start-up
- the start-up and shutdown times
- all whale observations
- details of any whale-related shutdowns.

3.2 Vessel and helicopter operations

In general, the cetacean interaction requirements for vessels and helicopters stipulated in this provisional EMP are consistent with the national guidelines for whale and dolphin watching laid down by the Department for the Environment, Water, Heritage and the Arts (DEWHA 2005) and administered by the relevant Commonwealth state or territory management authorities.

Vessels operating in the offshore environment (including during the period of construction of the gas export pipeline) will be traversing unconfined deep waters, providing cetaceans with ample opportunity to hear them and to take evasive action. Vessel strikes causing harm to cetaceans are extremely rare events and smaller cetaceans frequently "bow-ride" or "wash-ride" the waves created by vessels of all sizes. The risk of disturbance or injury to cetaceans as a result of offshore vessel operations is therefore considered to be low. Within the nearshore environment the very slow operational speed of major construction vessels such as dredges, pipelay barges and other survey vessels will greatly limit the chances of vessel strikes on cetaceans.

Noise generated by the engines of vessels, including bow thrusters, could however cause disturbance to cetaceans. The noise levels generated by vessels operating in the offshore and nearshore development area will not be significantly different from routine shipping operations in these areas. However, the concentration of vessels during construction in the offshore development area may increase the risk of disturbance to cetaceans slightly.

Helicopter operations also have the potential to disturb cetaceans through the noise of their engines and rotors. However, as helicopters will only be operating near the ocean surface for very short periods, and infrequently, this is also considered to be a low-risk activity.

There are no known or anticipated whale breeding or mating areas in the vicinity of the offshore development area. However, vessels and aircraft travelling to or from the area from Broome or other coastal locations to the south may occasionally encounter migrating (particularly humpback) whales and calves.

To manage the risk of disturbance to cetaceans through marine vessel or helicopter operations, INPEX will ensure that its vessel masters and helicopter pilots are aware of and will comply with the relevant requirements of the Australian guidelines for whale and dolphin watching, as outlined below.

During all phases of the Project, the general principle guiding vessel operations will be to avoid, as far as practicable, any interaction with cetaceans. Therefore, INPEX vessels in the vicinity of a cetacean or cetaceans will (with the exception of emergency situations) adhere to the following guidelines:

- They will not intentionally approach within 50 m of a dolphin or within 100 m of a large cetacean as shown in Figure 3-1 and Figure 3-2.
- They will operate at a "no wash" speed when they are between 50 m and 150 m of a dolphin or when they are between 100 m and 300 m of a large cetacean as shown in Figure 3-1 and Figure 3-2.
- They will attempt not to approach cetaceans from an angle of less than 60° into or away from the direction of travel of the cetacean(s) as shown in Figure 3-1 and Figure 3-2.
- They will not encourage bow-riding by cetaceans. Should any cetacean(s) commence bow-riding in front of a vessel, the vessel master will not change course or speed suddenly.
- Vessel and aircraft operators will be encouraged to report cetacean sightings to INPEX and the DEWHA.

It should be noted, that in confined waters such as the embayments, estuaries, creeks, channels and river mouths in Darwin Harbour there may be occasions where it may not be possible for vessels to maintain the approach angles or distances. If such situations should arise, notwithstanding the requirement to continue with operations, all efforts will be made to minimise vessel interactions with, or disturbance to, cetaceans.

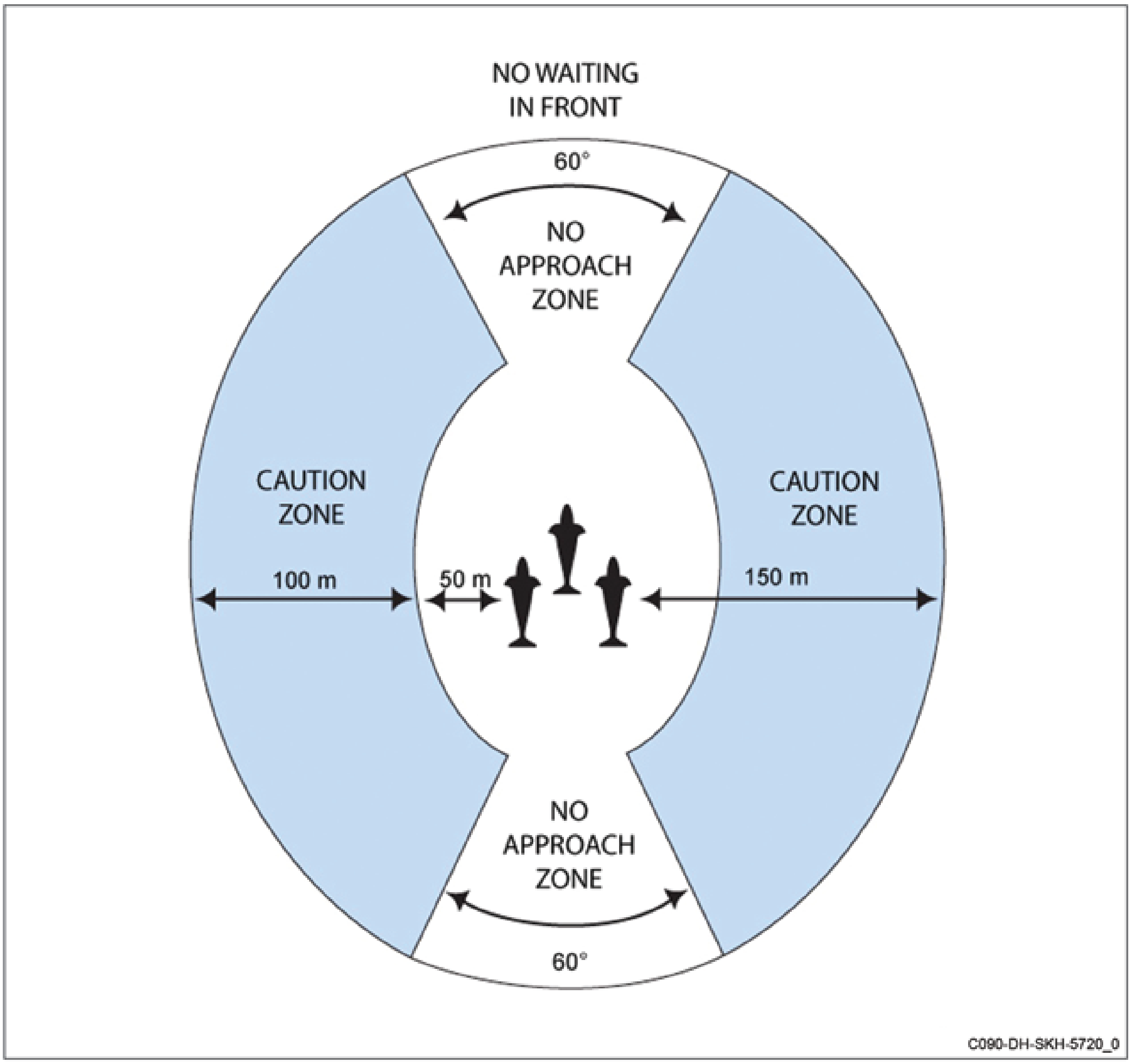

Figure 3-1: Interaction restrictions for marine vessels encountering dolphins (with acknowledgments to the DEWHA)

In accordance with the DEWHA's national guidelines for whale and dolphin watching (DEWHA 2005), INPEX helicopters in the vicinity of a cetacean will, with the exception of take-off, landing or emergency situations, adhere to the following guidelines:

- They will not fly lower than 500 m (1650 feet) or within 500 m of a cetacean as shown in Figure 3-3.
- They will not hover over the no-fly zone as shown in Figure 3-3.
- They will avoid approaching a whale or dolphin head-on.
- They will avoid flying directly over or passing the shadow of the helicopter directly over a cetacean.

Because of the critical importance of a pilot's attending to the primary task of flying the helicopter, reports of cetacean sightings will not be required from helicopters. However, should a helicopter pilot witness a significant incident of disturbance to a cetacean, an incident report must be developed.

3.3 Training and awareness

Relevant personnel involved in VSP activities will be trained in cetacean observation as well as in the appropriate start-up and shutdown operations and recording and reporting procedures. Cetacean observers will be familiar with the CD-ROM whale and dolphin guide produced by the Australian Petroleum Production & Exploration Association (APPEA) (Mustoe & Ross 2004).

Personnel routinely involved in marine vessel operations will be trained in basic cetacean observation and how to record cetacean sightings.

Vessel masters will all be trained in the appropriate vessel stand-off distances and other vessel–cetacean interaction management requirements detailed in sections 3.2.

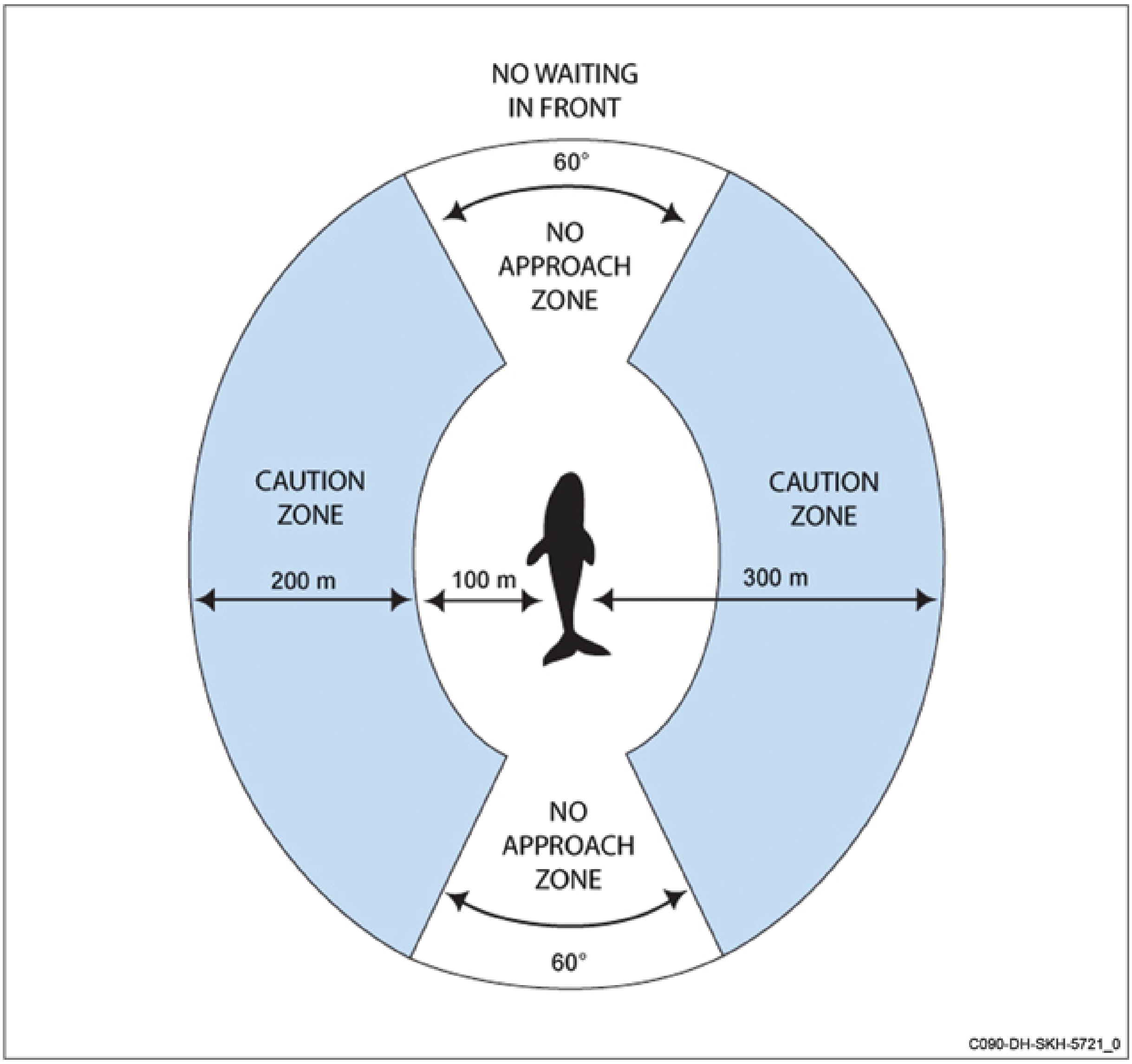

Figure 3-2: Interaction restrictions for marine vessels encountering whales (with acknowledgments to the DEWHA)

Helicopter pilots will also all be trained in the appropriate helicopter procedures as detailed in Section 3.2. However, because it is critically important that a pilot should focus on the task of flying, reports of cetacean sightings will not be required from helicopters.

The training requirements for personnel involved in dredging, piledriving and drill-and-blast operations are contained in the provisional EMPs for these operations.

4 MONITORING

Records will be kept of all cetacean sightings and cetacean-related observations and shutdown periods during VSP activities.

5 REPORTING, AUDITING AND REVIEW

Reporting, auditing and reviews will be undertaken during all phases of the Project. A summary of the reporting and auditing requirements relating to cetacean management is provided in the following two sections.

5.1 All phases

- Incidents resulting in the disturbance of a cetacean or a breach of a plan or procedure relating to cetacean management will be reported in accordance with INPEX's Incident Reporting, Recording and Investigating Procedure.
- All confirmed incidents of disturbance to a cetacean will be reported to the relevant regulatory authority.
- All confirmed "near misses" and incidents will be reported internally to all relevant personnel.

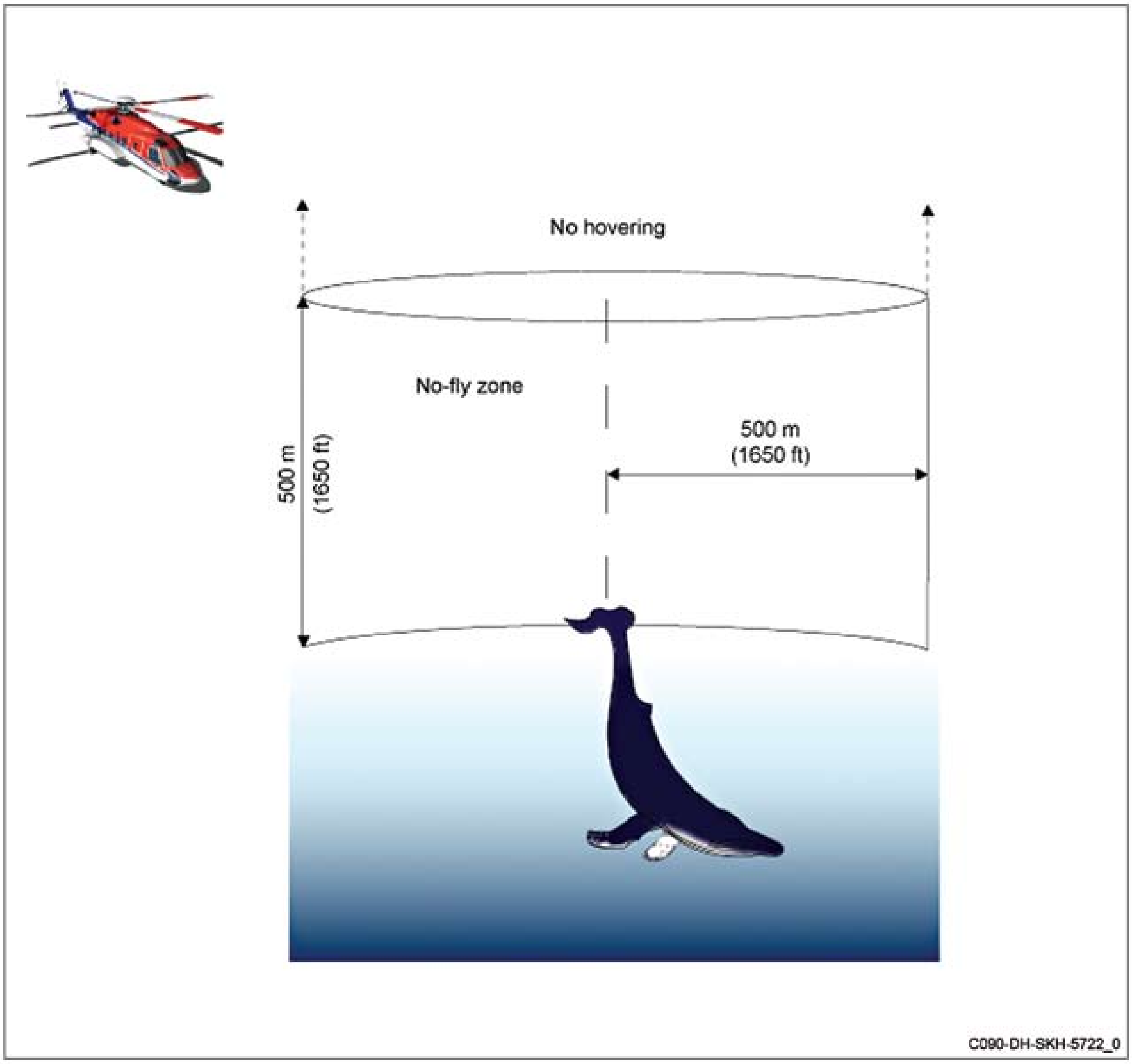

Figure 3-3: Helicopter no-fly zone in the vicinity of any cetacean (with acknowledgements to the DEWHA)

- Relevant details of VSP operations in relation to cetacean management will be recorded for every VSP activity in accordance with the record-keeping requirements stipulated in Section 3.1.
- Cetacean observations from vessel operations that are reported to INPEX will in turn report cetacean sightings to the DEWHA.
- An annual INPEX environmental report for the Project will be produced and will include, as a minimum, details of any cetacean-related incidents, and monitoring program outcomes.
- INPEX and its contractors will conduct internal compliance audits on a periodic basis. External audits will be carried out by external agencies as required.

5.2 Construction, commissioning and decommissioning phases

Construction, commissioning and decommissioning contractors will be required to provide INPEX with a monthly environmental report which will include a record of environmental incidents.

6 SUPPORTING DOCUMENTATION

This provisional EMP is one document in a suite of plans and procedures that have been or will be developed to ensure that INPEX's cetacean management activities are undertaken in compliance with legislative requirements and in a safe and environmentally responsible manner.

These plans and procedures include the following:

- incident reporting, recording and investigating procedure
- HSE site induction (onshore and offshore) presentation

7 APPLICABLE LEGISLATION, STANDARDS AND GUIDELINES

INPEX is committed to complying with all relevant laws, regulations and standards. Legislative instruments and guidelines relevant to cetacean conservation include those listed below:

- Department of the Environment, Water, Heritage and the Arts. 2005. *Australian national guidelines for whale and dolphin watching 2005*. Commonwealth Government, Canberra, ACT.
- Department of the Environment, Water, Heritage and the Arts. 2008. *Interaction between offshore seismic exploration and whales*. EPBC Act Policy Statement 2.1. Commonwealth Government, Canberra, ACT.
- *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth).
- *Territory Parks and Wildlife Conservation Act* (NT).

8 REFERENCES

Department of the Environment, Water, Heritage and the Arts. 2005. *Australian national guidelines for whale and dolphin watching 2005*. Department of the Environment, Water, Heritage and the Arts, Canberra, ACT. Viewed online on 9 February 2010 at <http://www.environment.gov.au/coasts/publications/pubs/whale-watching-guidelines-2005.pdf>.

Department of the Environment, Water, Heritage and the Arts. 2008. *Interaction between offshore seismic exploration and whales*. EPBC Act Policy Statement 2.1. Department of the Environment, Water, Heritage and the Arts, Canberra, ACT. Viewed online on 9 February 2010 at <http://www.environment.gov.au/epbc/publications/pubs/seismic-whales.pdf>.

DEWHA—*see* Department of the Environment, Water, Heritage and the Arts.

McCauley, R.D. 2009. *Ambient, biological and anthropogenic sea noise sources from Browse and Maret islands, Kimberley, 2006–2009*. Report R2008-54 prepared by the Centre for Marine Science and Technology, Curtin University of Technology, Perth, for INPEX Browse, Ltd., Perth, Western Australia.

McCauley, R.D., Fewtrell, J., Duncan, A.J., Jenner, C., Jenner, M.-N., Penrose, J.D., Prince, R.I.T., Adhitya, A., Murdoch, J. and McCabe, K. 2000. Marine seismic surveys: a study of environmental implications. *Australian Petroleum Production & Exploration Association Journal* 40: 692–708.

Mustoe, S. and Ross, G. (eds). 2004. *Search Australian whales and dolphins*. CD-ROM identification guide. Australian Petroleum Production & Exploration Association Limited, Perth, Western Australia.

Provisional Decommissioning Management Plan

Annexe 5 – Chapter 11 *Environmental Management Program*

1 OVERVIEW

As part of the approvals process for the Ichthys Gas Field Development Project (the Project), it is necessary that INPEX should show that it has taken, and will take, all practicable steps to properly manage the risks associated with, and the potential environmental impacts of, the decommissioning process that will occur at the end of the Project's expected 40-year operating life.

The extent of onshore and nearshore decommissioning and rehabilitation will be agreed with the Northern Territory Government prior to the commencement of decommissioning. Adequate notice will be given by INPEX to the Northern Territory Government to allow for discussions regarding the decommissioning management plan.

Options for decommissioning will depend upon the anticipated future land use and the requirements of the government. For example, if the land is to be used for future industrial activities, it may be desirable that the module offloading facility should be left in situ along with other valuable infrastructure such as the major access road and drainage control structures. Under this scenario, non-essential aboveground infrastructure would be removed and landforms made stable to prevent erosion. If, however, it were to be decided that the onshore development area should be rehabilitated as natural habitat, all aboveground infrastructure would be removed and an active revegetation program would be initiated.

The decommissioning of offshore facilities and infrastructure will comply with applicable regulations and industry best practice at the time of decommissioning and the detail will be agreed upon with the Northern Territory and Commonwealth governments prior to the commencement of decommissioning.

This provisional environmental management plan (EMP) for the decommissioning of the Project is attached as Annexe 5 to Chapter 11 *Environmental management program* of the Project's draft environmental impact statement (Draft EIS). It is one of a suite of similar EMPs dealing with different aspects and activities of the Project. These provisional EMPs will form the basis for the development of more detailed environmental management documentation, for example plans and procedures for the successive phases of the Project as well as for specific activities associated with the Project. The detailed documentation will be prepared either directly by INPEX's Environmental Department or by specialist contractors in conjunction with INPEX.

1.1 Purpose and scope

The purpose of this provisional EMP is as follows:

- It outlines the potential options for onshore, nearshore and offshore decommissioning and abandonment of Project facilities and infrastructure.
- It documents some of the management controls for potential decommissioning and abandonment options.
- It describes the proposed monitoring, reporting, review and audit requirements for the decommissioning phase of the Project.
- It will guide the development of the detailed environmental documentation, such as the plans, procedures, etc., which will be required for the decommissioning phase of the Project.

The scope of this provisional EMP includes the decommissioning and abandonment of the onshore, nearshore and offshore Project facilities and infrastructure.

1.2 Decommissioning activities that could lead to impacts on the environment

During the decommissioning phase, activities on site associated with the removal of infrastructure will increase in intensity relative to those occurring during the "normal" operations phase. Of particular note are the potential increases in environmental and social impacts associated with the following activities:

- the demolition of facilities and infrastructure
- equipment, vessel and vehicle movements
- earthworks
- the controlled use of explosives to demolish some facilities, such as the product storage tanks.

1.3 Potential impacts

An environmental impact assessment may be required before decommissioning commences in order to confirm that the planned activities are the most appropriate to the prevailing circumstances. This assessment would aim to demonstrate that the decommissioning activities would not cause unacceptable environmental impacts and would lead to the development of specific management controls. Potential impacts associated with decommissioning activities may include the following:

- acid sulfate soil disturbance
- erosion and sedimentation
- dust generation
- increased pressure on waste disposal facilities
- chemical and hydrocarbon spills
- disturbance to natural habitat
- disturbance to Aboriginal and non-Aboriginal heritage sites
- noise disturbance from blasting activities.

2 OBJECTIVES, TARGETS AND INDICATORS

The objectives, targets and indicators for decommissioning management will be set out by INPEX prior to the commencement of decommissioning and after consultation with the Northern Territory and Commonwealth governments.

3 MANAGEMENT APPROACH

Detailed decommissioning management documentation, for example plans and procedures, will be developed for this final phase of the Project. These detailed documents will align with this provisional decommissioning EMP. The detailed documentation will be prepared either directly by INPEX's Environmental Department or by specialist contractors in conjunction with INPEX.

A summary of some of the potential engineering and management controls to be incorporated into the detailed documentation to mitigate the risks associated with decommissioning activities is provided below.

3.1 Engineering controls—design phase

The engineering controls that may be implemented during the design phase of the Project are described below.

Applicable to offshore development area

Once the Ichthys Field has reached the end of its useful life, the central processing facility (CPF) and the floating production, storage and offtake (FPSO) facility will be uncoupled from their moorings and towed from the infield location, the reservoir will be permanently isolated, necessary well equipment will be removed and the wells will be plugged and abandoned.

The process of decommissioning the offshore facilities will necessitate the assessment of a range of options, including finding an alternative use for all or part of the CPF and the FPSO facility, the recycling of all or part of these facilities, or the final disposal onshore of all or part of these facilities. The options include leaving other subsea structures in place, including the mooring suction piles, infield flowlines and gas export pipeline. The assessment of options will be based on a range of physical factors (e.g. water depth, ocean processes, and the physical state of the facilities) and other factors (e.g. proximity to sensitive habitats and interference with fishing-industry activities).

Offshore decommissioning will also be subject to further assessment prior to decommissioning under the relevant legislation and international conventions and treaties. These include the following:

- approval requirements under the *Offshore Petroleum and Greenhouse Gas Storage Act 2006* (Cwlth), the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth) and the *Environment Protection (Sea Dumping) Act 1981* (Cwlth)
- the requirements of the United Nations Convention on the Law of the Sea (UNCLOS). Article 60(3) states: "*Any installations or structures which are abandoned or disused shall be removed to ensure safety of navigation, taking into account any generally accepted international standards established in this regard by the competent international organization. Such removal shall also have due regard to fishing, the protection of the marine environment and the rights and duties of other States. Appropriate publicity shall be given to the depth, position and dimensions of any installation or structures not entirely removed.*"
- the requirements of the International Maritime Organization (IMO) including ensuring that the complete removal of facilities is technically feasible or, if structures are left in place, ensuring that there is a clearance depth of 55 m and charting on navigational maps for safety of other users at sea.

While the requirements for decommissioning will depend on the regulations at the end of the useful life of the Project, consideration of decommissioning feasibility will be incorporated into the design of each facility.

These considerations include designing the subsea and floating components so that they can be removed in their entirety. This includes the CPF and the FPSO facility, the FPSO turret, the anchor chains, the risers and their support equipment, the subsea manifolds, and the trees.

Applicable to onshore development area

As with the offshore facility, consideration of decommissioning feasibility will be incorporated into the design of the onshore facility. However, exact design criteria are limited as there is the likelihood that technology and knowledge will advance over the 40-year lifetime of the Project. Limiting decommissioning options to those available during the design phase risks having the Project fall well short of what will be considered "best practice" at the time of decommissioning.

Design options to be investigated will include consideration of removal of some or part of the process modules in the reverse sequence of the installation process. Prefabricated structures of all sizes may be removed using this approach. However, while the plant will be sound for operational purposes, it may not have the structural integrity for removal in large portions. A structural assessment of the integrity of the plant will need to be conducted to inform the assessment of decommissioning options.

3.2 Management controls—decommissioning phase

The management controls that may be implemented during the decommissioning phase are outlined below.

Applicable to onshore, nearshore and offshore development areas

Detailed waste management documentation, for example plans and procedures, will be developed and implemented for all Project areas.

Applicable to nearshore and offshore development areas

Detailed cetacean management documentation, for example plans and procedures, will be developed and implemented for the nearshore and offshore Project areas.

Applicable to the offshore development area

The extent of offshore decommissioning will depend on the prevailing legislation and industry best practice at the time of decommissioning.

- After the reservoir has been permanently isolated, the wellheads will be removed and the wells plugged and abandoned in accordance with Clause 514 of the Petroleum (Submerged Lands) Acts Schedule (DITR 2005) or the applicable legislation in force at the time of decommissioning.
- The CPF and FPSO will be unhooked and removed entirely from the Ichthys Field.

Subject to risk assessment and with the approval of the relevant authorities the following offshore infrastructure may be left in situ:

- the mooring suction piles, infield flowlines, risers and subsea manifolds (following flushing to remove hydrocarbons)
- the anchor chains for the CPF, FPSO and risers.

Applicable to gas export pipeline

The decommissioning of the gas export pipeline will involve the flushing of all hydrocarbons prior to filling it with sea water and leaving it in place.

Applicable to the onshore development area

To what extent the following controls are applied will depend upon the agreed final use of the onshore development area, which will be defined in consultation with the relevant authorities:

- Shallow foundations for plant or tank infrastructure may be excavated, demolished and disposed of.
- Where piled foundations exist, these may be excavated to a depth of 1 m below the existing ground level.
- Excavations resulting from the removal of foundations will be backfilled.
- The controlled use of explosives may be required during some phases of the demolition of the redundant storage tanks. If this is the case, detailed blasting management documentation (plans, procedures, etc.) will be developed and implemented to manage this risk.
- If foundations and infrastructure located in areas associated with acid sulfate soils are removed, detailed acid sulfate soil documentation, for example plans and procedures, will be developed and implemented to manage this risk.
- Detailed onshore spill prevention and response management documentation will be developed and implemented to manage the risk of chemical and hydrocarbon spills.
- Detailed dust management documentation, for example plans and procedures, will be developed and implemented to manage the risk of increased dust.
- Detailed traffic management documentation, for example plans and procedures, will be developed and implemented to manage the risks associated with increased traffic.

In the event that the onshore development area should be required by the Northern Territory Government to be returned to its original state (i.e. before the Ichthys Project commenced), stable landforms will be established and the site will be rehabilitated to an agreed level of representation of the pre-Project plant communities.

4 MONITORING

Monitoring activities will be undertaken throughout the life of the Project in relation to the objectives and targets identified in the suite of provisional EMPs included as annexes to this chapter of the Draft EIS. Prior to undertaking decommissioning activities, INPEX will undertake a review of historical monitoring data (e.g. groundwater quality and mangrove health) and incidents on site that might have caused contamination. Objective, targets and indicators will be updated in the Decommissioning Management Plan to reflect the type and level of activity.

Depending on the final land use agreed for the onshore development area, all or part of the site may need to be rehabilitated. In such a circumstance, INPEX will also develop a monitoring program for completion criteria to verify that the site is being returned to the agreed representative state. Completion criteria will be included for vegetation community composition, extent of weed infestation, erosion control and visual amenity of the site. These completion criteria will be determined in consultation with the Northern Territory Government.

5 REPORTING, AUDITING AND REVIEW

Reporting, auditing and reviews will be undertaken regularly through the decommissioning phase of the Project. A summary of the reporting, auditing and review requirements relating to decommissioning is presented below:

- Incidents resulting from decommissioning activities will be reported in accordance with INPEX's Incident Reporting, Recording and Investigating Procedure or the Project contractor's document equivalent (approved by INPEX).
- An annual INPEX environmental report for the Project will be produced.
- INPEX and its contractors will conduct internal compliance audits on a periodic basis.
- Records will be audited periodically to ensure that all personnel on site have completed the required health, safety and environment induction.
- Detailed decommissioning management documentation, for example plans and procedures, will be reviewed periodically to ensure that they remain applicable to current operations and compliant with the requirements of INPEX and the regulatory authorities.
- Decommissioning contractors will be required to produce and provide to INPEX a monthly environmental report which will include a record of monthly environmental incidents and data.

6 SUPPORTING DOCUMENTATION

This provisional EMP is one document in a suite of plans, procedures and processes designed to ensure that INPEX's decommissioning management activities are undertaken in compliance with legislative requirements and in a safe and environmentally responsible manner.

Documentation or processes addressing the issues outlined below have been or will be developed to further support the implementation of detailed decommissioning management documentation:

- incident reporting, recording and investigating
- chemical and hazardous substance management
- waste management
- dust management
- traffic management
- acid sulfate soils management
- onshore blasting
- health, safety and environment site induction
- oil spill contingency.

7 REFERENCES

Department of Industry, Tourism and Resources. 2005. *Petroleum (Submerged Lands) Acts Schedule: specific requirements as to offshore petroleum exploration and production*. (Now as) Department of Resources, Energy and Tourism, Canberra, ACT. Viewed online on 1 March 2010 at <http://www.ret.gov.au/resources/Documents/Upstream%20Petroleum/PSLA_Schedule_of_Specific_Reqs_24_11_0520051124103750.pdf>.

DITR—*see* Department of Industry, Tourism and Resources.

11 Environmental Management Program

Provisional Dredging and Dredge Spoil Disposal Management Plan

Annexe 6 – Chapter 11 *Environmental Management Program*

1 OVERVIEW

As part of the approvals process for the Ichthys Gas Field Development Project (the Project), it is necessary that INPEX should show that it has taken, and will take, all practicable steps to properly manage the risks associated with, and the potential environmental impacts of, the dredging activities undertaken in the nearshore development area during the construction phase of the Project.

During the construction phase a dredging program will be undertaken for the nearshore facilities, including the product loading jetty, the navigation channel, the module offloading facility and the gas export pipeline shore crossing. Some dredging will also be carried out along the gas export pipeline route in nearshore areas when preparing the seabed for pipelay. Some post-pipelay trenching may be required along the gas export pipeline route in offshore areas, however any impacts associated with this would be localised. No dredging will be required in the offshore development area.

Dredged material will primarily be disposed of offshore, at a spoil disposal ground to the north of Darwin Harbour, around 15 km north-west of Lee Point (Figure 1-1). At the time of developing this provisional management plan, the Darwin Port Corporation (DPC) was in the early stages of planning new settlement ponds that could potentially be used for onshore dredge spoil disposal and land reclamation. Should the opportunity to use these facilities be realised closer to the start of the dredging program, INPEX will explore this option in consultation with the DPC. However, at this stage it is assumed that all dredge spoil from the Project will be disposed of offshore.

This provisional environmental management plan (EMP) for dredging and dredge spoil disposal is attached as Annexe 6 to Chapter 11 *Environmental management program* of the Project's draft environmental impact statement (Draft EIS). It is one of a suite of similar EMPs dealing with different aspects and activities of the Project. These provisional EMPs will form the basis for the development of more detailed environmental management documentation, for example plans and procedures for the various phases of the Project as well as for specific activities associated with the Project. The detailed documentation will be prepared either directly by INPEX's Environmental Department or by specialist contractors in conjunction with INPEX.

1.1 Purpose and scope

The purpose of this provisional EMP is as follows:

- It demonstrates how INPEX will minimise, through the identification of suitable management controls, the potential environmental impacts of the dredging and dredge spoil disposal activities that will be undertaken during the construction phase of the Project.
- It describes the proposed monitoring requirements for the construction phase of the Project.
- It describes the proposed reporting, review and audit requirements for the construction phase of the Project.
- It will guide the development of future more detailed environmental documentation, such as the plans, procedures, etc., which will be required for the Project.

The scope of this provisional EMP includes the dredging and dredge spoil disposal activities undertaken during the Project's construction phase. For the purposes of this EMP, the term "dredging" also includes marine trenching activities.

Maintenance dredging may be required during the operations phase of the Project to ensure the continued operability of the nearshore facilities.
While the frequency and nature of maintenance dredging cannot be accurately determined at this stage, preliminary modelling indicates that maintenance dredging may be required after 10 years with a potential volume of 200 000 m^3 of sandy material to be removed. Environmental management of any maintenance dredging required will be incorporated into an operations-phase EMP and has not been included in this provisional EMP. Discussions would also take place with Government to determine if formal impact assessment would be required for maintenance dredging activities. No maintenance dredging will be required along the gas export pipeline route.

The scope of this provisional EMP does not include management of the risks of damage to maritime heritage sites during dredging, management of drill-and-blast activities or management of the introduced marine pest risks associated with dredging vessels.

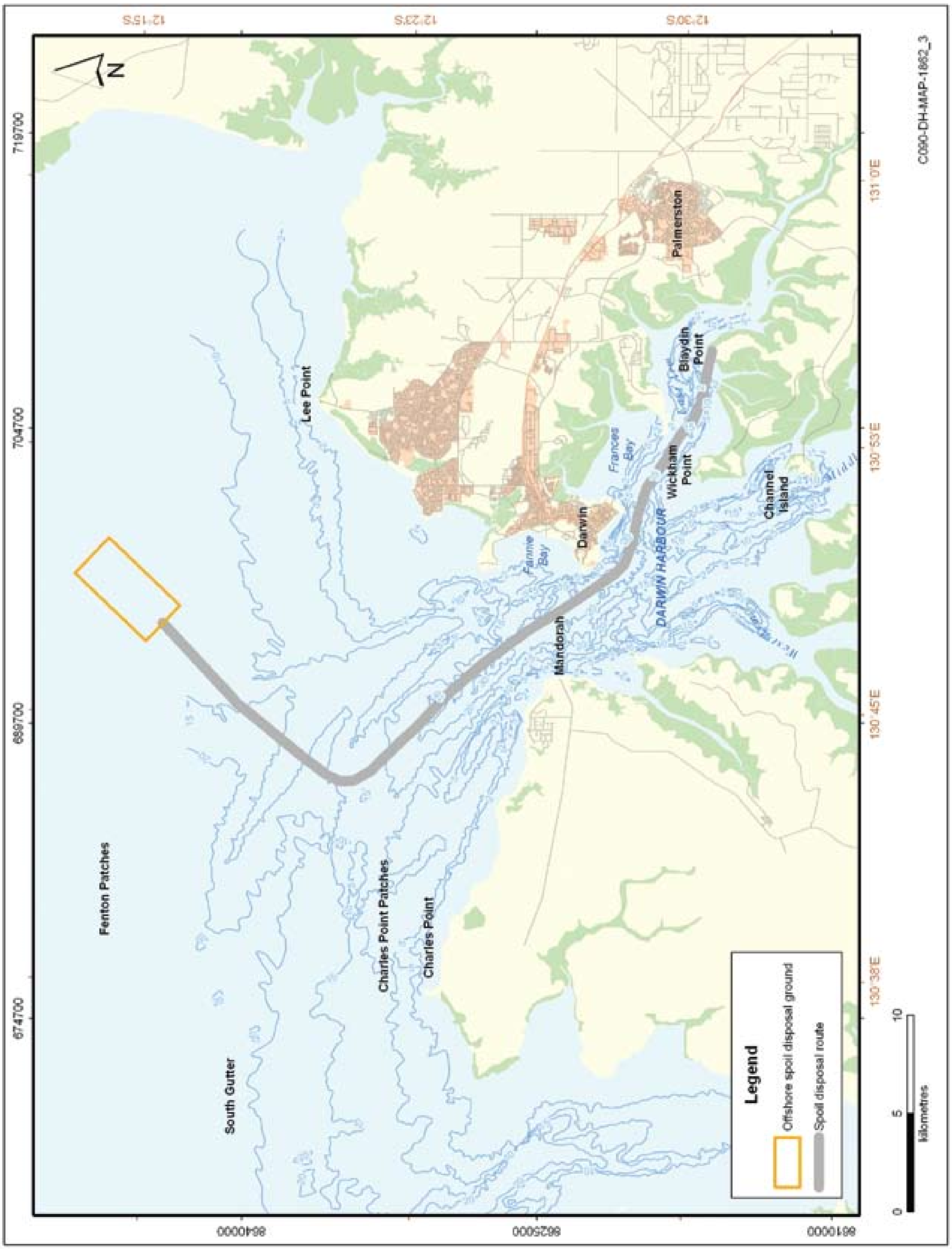

Figure 1-1: Location of the offshore spoil disposal ground

These issues are addressed as separate aspects in three other provisional EMPs:

- Provisional Heritage Management Plan (Annexe 9 to Chapter 11)
- Provisional Piledriving and Blasting Management Plan (Annexe 12 to Chapter 11)
- Provisional Quarantine Management Plan (Annexe 13 to Chapter 11).

1.2 Potential impacts

Potential impacts to marine biota and habitats associated with dredging and dredge spoil disposal include the following:

- the removal of seabed habitats within the dredging footprint
- an increase in the turbidity of Darwin Harbour waters and low-level sediment deposition in nearby benthic habitats, causing reduced growth or mortality of species such as corals
- damage to the heritage-listed Channel Island coral community
- localised noise disturbance to protected marine mammals and reptiles
- accidental entrainment of marine fauna (such as turtles) in trailing suction hopper dredges, causing injury or death
- the introduction of marine pest species
- sediment accumulation in intertidal areas and potential impacts on mangrove health
- the smothering of seabed habitats at the offshore spoil disposal ground
- increased turbidity at the offshore spoil disposal ground and sedimentation of adjacent and coastal benthic habitats.

Potential impacts to other users and to the values of the marine environment include the following:

- an increase in marine traffic in Darwin Harbour, particularly during the construction phase
- localised access restrictions for recreational vessels during dredging activities
- possible low-level accumulation of sediment on, and accidental anchor damage to, maritime heritage sites such as the Catalina flying-boat wrecks and the SS *Ellengowan*
- the creation of navigation hazards for commercial shipping at the offshore spoil disposal ground.

The potential significance of these impacts has been assessed in the Draft EIS for the Project. Specific studies undertaken to address the potential impacts have included the following:

- extensive modelling of the dispersion of sediments from dredging and dredge spoil disposal. Modelling of both turbid plumes and sediment accumulation was undertaken to identify those areas at greatest risk of impact from the activities (HRW 2010, provided as Appendix 13 to this Draft EIS)
- surveys of habitats and biological communities in key areas exposed to turbid plumes and sediment accumulation (URS 2009a, provided as Appendix 8 to this Draft EIS)
- an assessment of the risk posed by underwater noise to protected marine species (URS 2009b, provided as Appendix 15 to this Draft EIS).

The effects of localised seabed disturbance, noise and turbidity are not expected to have a significant negative impact on significant marine mammals and reptiles (e.g. the dolphins and turtles listed under the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth)) that utilise Darwin Harbour. No significant breeding or nesting habitats for these species are known to occur in the Harbour, and the foraging habitats available in the nearshore development area are widely distributed elsewhere in the Harbour and along the Northern Territory coast. Both Australian snubfin dolphins (*Orcaella heinsohni*) and Indo-Pacific humpback dolphins (*Sousa chinensis*) have been found to favour river mouths for foraging, probably because of the increased nutrient availability attracting smaller prey species (Mustoe 2008). The Indo-Pacific humpback dolphin is also known to forage in dredged channels (Parra 2006).

2 OBJECTIVES, TARGETS AND INDICATORS

The objectives, targets and indicators set out by INPEX for dredging and dredge spoil management are shown in Table 2-1. The engineering and management controls implemented to help to achieve these targets are described in Section 3 *Management approach*.

Table 2-1: Dredging and dredge spoil management objectives, targets and indicators

Objectives	Targets	Indicators
Avoid damage to the Channel Island coral community by sedimentation and turbidity.	• No significant hard coral mortality at Channel Island as a result of dredging activities.	• Reactive coral monitoring program.
Minimise direct disturbance to marine protected species.	• No incidents of adverse impacts upon marine protected species.	• Marine protected species observations and incidents records.
Avoid disturbance of navigation and shipping activities in East Arm and at the offshore spoil disposal ground.	• No incidents of damage to ships or interruption to voyages because of reduced under-keel clearance in East Arm or at the dredge spoil disposal ground.	• Periodic bathymetric surveys of seabed in East Arm and at dredge spoil disposal ground.
Avoid negative impacts to mangrove communities as a result of sediment accretion from dredging activities.	• No significant areas of mangrove mortality attributable to sedimentation.	• Intertidal sedimentation and mangrove health monitoring program.

3 MANAGEMENT APPROACH

Detailed dredging documentation, for example plans and procedures, will be developed for the construction and operations phases of the Project. These detailed documents will align with this provisional dredging and dredge spoil disposal EMP. The detailed documentation will be prepared either directly by INPEX's Environmental Department or by specialist contractors in conjunction with INPEX.

A summary is provided below of the main engineering and management controls to be included in the detailed documentation to mitigate the risks associated with dredging and dredge spoil disposal activities.

3.1 Dredging

3.1.1 Engineering controls

The engineering controls to be implemented during the design phase of the Project will include the selection of dredging methods that will minimise the release of fine sediments into the waters of the Harbour. These include the following:

- using the backhoe (BHD) and/or grab dredger (GD) in preference to the cutter-suction dredger wherever practicable
- using the trailing suction hopper dredge (TSHD) in "no overflow" mode.

Deploying silt curtains to restrict the movement of fine sediments released from the dredging equipment has been considered. However, in the strong prevailing tidal currents in Darwin Harbour silt curtains would be easily pulled from their moorings and would quickly fill with silt from the naturally turbid coastal waters. These factors preclude their use in the nearshore development area.

A range of options for reducing the risks of marine fauna entrainment (especially turtles) by trailing suction hopper dredgers will be explored in consultation with the dredging contractor. Practicable options that could be effective in reducing risks will be incorporated as management controls into the final dredging management plan.

3.1.2 Management controls

The management controls to be implemented during the dredging works are outlined below:

- An application for a waste discharge licence will be sought under the Northern Territory's *Water Act* prior to the commencement of dredging activities.
- Notice will be provided to the Northern Territory's Department of Lands and Planning (DLP) and the DPC at least three months in advance of the commencement of dredging and spoil disposal operations. This will allow for a "Notice to Mariners" to be issued, advising vessel operators of any change to maritime traffic conditions because of dredging activities.
- Dredging vessels will be equipped with appropriate global positioning system (GPS) equipment and other navigational aids to ensure that dredging will occur only in the specified dredge footprint.
- The dredge footprint has been designed to avoid maritime heritage areas and sacred sites.
- Anchoring plans and procedures for construction vessels involved in dredging will be developed to avoid sensitive seabed habitats and sacred and heritage sites.

- Controlled zones will be implemented around the *SS Ellengowan*, the *Kelat* and the Catalina flying-boat wrecks.
- Reactive management of dredging activities at the pipeline shore approach and crossing will be carried out in response to measurements of turbid plumes and sedimentation at the nearby Channel Island coral community (see sections 4.1.1 and 4.1.2 for details on trigger levels and management actions).
- Periodic assessments will be made of sediment accumulated at East Arm Wharf, the East Arm boat ramp and the Hudson Creek facilities and, if necessary, remedial dredging or clean-up will be carried out.
- Periodic assessments will be made of the sediment conditions around the Catalina flying-boat wrecks in the vicinity of the dredging activities and, if required, any necessary management controls will be implemented in consultation with NRETAS.

3.2 Dredge spoil disposal

3.2.1 Engineering controls

The engineering controls to be implemented for dredge spoil disposal are outlined below:

- The dredge spoil disposal ground location has been selected to avoid adverse impacts on commercial shipping and recreational fishing activities through the following:
  - locating it away from known shipping routes
  - locating it in an area where there is minimal potential for sediment remobilisation into current and known future shipping channels or into important recreational fishing areas (e.g. Charles Point Patches, Fenton Patches, and the artificial reefs off Lee Point).
- The dimensions of the offshore spoil disposal ground (length and width) have been designed to minimise the potential for the build-up of mounds of dredged spoil that would reduce under-keel clearance for vessels traversing the area.

The location and dimensions of the dredge spoil disposal ground were selected on the basis of comprehensive hydrodynamic and sediment dispersion modelling (APASA 2010). Details of this modelling are presented in Chapter 7 *Marine impacts and management*.

3.2.2 Management controls

The management controls to be implemented during dredge spoil disposal are as follows:

- A "Notice to Mariners" will be issued in conjunction with the DLP and the DPC, advising vessel operators of dredge spoil disposal activities and any changes to bathymetric conditions at the disposal area.
- Disposal activities will be managed in such a way that the larger sediment fractions are retained as much as possible within the spoil disposal ground boundary, and that the seabed at the completion of the spoil disposal operations is reasonably flat.

4 MONITORING

A range of monitoring programs to document the effects of the Project on the receiving environment are presented in Chapter 11. In relation to dredging activities, these monitoring programs include the following:

- dredge plume discharge monitoring
- coral monitoring (at South Shell Island and north-east Wickham Point)
- soft-bottom benthos monitoring
- intertidal sedimentation and mangrove health monitoring.

In addition to these, a reactive monitoring program will be developed for the heritage-listed Channel Island coral community. Details are provided in Section 4.1 below.

4.1 Coral monitoring

Monitoring activities will be undertaken throughout the construction phase in relation to the identified objectives and targets. Reactive monitoring of the Channel Island coral community will be carried out in recognition of its listing on the Register of the National Estate and its declaration as a "heritage place" under the *Heritage Conservation Act* (NT). The declaration is based upon the survival of a relatively diverse coral community in an area where the physical conditions—high turbidity, a strong tidal current and seasonally low salinity—appear to be suboptimal for corals.

Coral monitoring at South Shell Island and at a coral community off the north-east coast of Wickham Point will investigate the degree of resilience of corals in East Arm to exposure to sedimentation and elevated turbidity. Plume-dispersion modelling indicates that these communities will intermittently be exposed to turbid plumes but that there will be little, if any, sediment accumulation.

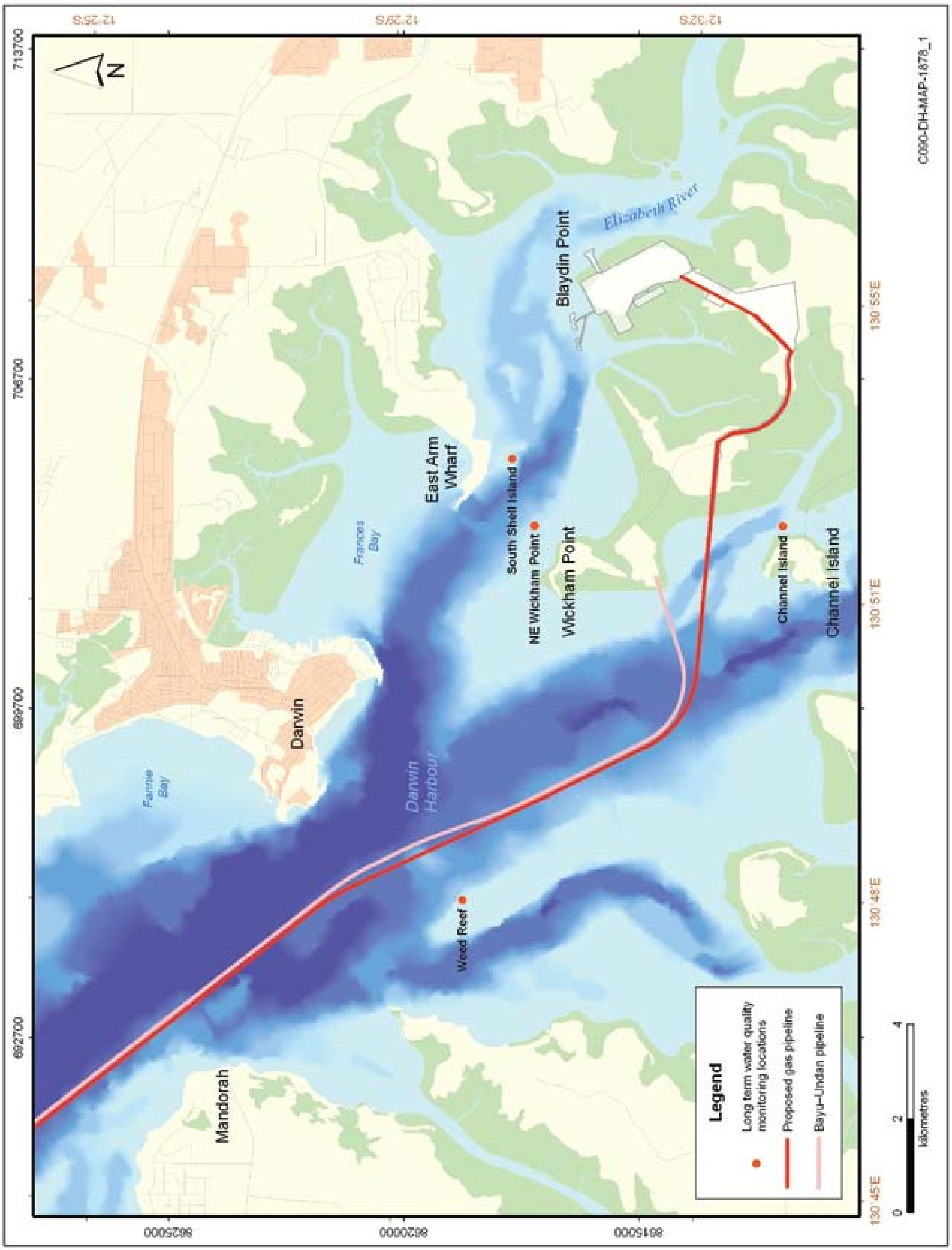

Figure 4-1: Water quality monitoring sites in Darwin Harbour

4.1.1 Water-quality baseline monitoring program

Baseline water quality will be characterised by a 12-month monitoring program prior to the commencement of dredging activities. Water-quality parameters, including turbidity, salinity and temperature, will be measured in situ using data loggers.

Water-quality data will be collected at the following four sites (see Figure 4-1), which will also be used for coral monitoring:

- the Channel Island coral community approximately 1.5 km south of the pipeline shore crossing, the impact site of primary interest
- Weed Reef, a reference site approximately 3 km south-east of Talc Head that will enable the identification of any broad-scale influences on water quality (e.g. elevated turbidity because of storm conditions)
- South Shell Island, a coral community located on the north side of the shipping channel dredging area in East Arm, approximately 0.5 km south of East Arm Wharf
- a coral community located to the south-west of the shipping channel dredging area in East Arm, approximately 0.6 km off the north-east coast of Wickham Point.

Trigger levels

The water-quality baseline monitoring program will be used to develop trigger levels for turbidity (measured as nephelometric turbidity units (NTUs) that can be used to guide management responses during the dredging program. These trigger levels will be calculated following the methodology of McArthur, Ferry and Proni (2002):

- Baseline data will be tabulated for intensity (range of NTU values), duration (range of hours) and frequency (the number of times that NTUs fell within each range for each duration).
- The 99th percentile turbidity value (i.e. the value below which natural turbidity occurs 99% of the time) will be adopted as the "Intensity Guideline".
- The 95th percentile turbidity value (i.e. the value below which natural turbidity occurs 95% of the time) will be adopted as the "Threshold Level".
- The data set will then be analysed to determine the distribution of all duration events during which the turbidity Threshold Level was exceeded. The 95th percentile longest event will be adopted as the "Duration Guideline".
- All events exceeding the turbidity Threshold Level will be grouped into classes by duration, with a fortnightly frequency distribution developed for each duration class. The 95% confidence limit will be adopted as the allowable frequency of exceedances (per fortnight) of the Threshold Level for each duration class.

Between wet and dry seasons and between neap and spring tides there are considerable differences in natural turbidity levels; hence a matrix of trigger levels will be required.

4.1.2 Reactive coral monitoring program

The purpose of the reactive coral monitoring program is to identify negative stress responses caused by the dredging program in corals at potential impact sites. Negative stress responses, if identified, may trigger modifications to dredging activities to reduce the environmental impact of the activity.

As noted in Section 1.2, the key potential mechanisms of impact on coral communities are increased turbidity in the water column, which reduces light levels reaching the corals, and direct smothering of corals by settling sediment. The reactive coral monitoring program focuses on measurements of turbidity rather than sedimentation. The latter cannot be measured in a way that accurately represents the degree to which corals are exposed to stress—sediments settle from the water column on to corals during slack tide periods (when current flow is minimal) but are then remobilised into the water column as tidal currents increase.

The reactive coral monitoring program has five main components:

1. a baseline assessment of the coral communities
2. regular measurement of turbidity during dredging activities
3. an assessment of coral condition
4. the initiation of a management response based on monitoring of turbidity trigger levels and coral mortality
5. post-dredging monitoring of coral communities.

Baseline assessment of coral communities

A baseline assessment of coral condition at each site will be made approximately one month before dredging commences. Coral condition will be assessed using the same general approach as that adopted for the East Arm Wharf monitoring program (GHD Pty Ltd 2002) and the Bayu–Undan to Darwin Pipeline Project. The coral communities at Channel Island and Weed Reef are known to be similar in composition and substrate cover.

Monitoring will be focused on hard corals of three genera:

- *Herpolitha*—This is a “slipper” coral that is flat, narrow and elongate with an axial furrow and rounded ends. Mouths are present within the furrow and over the rest of the upper surface. *Herpolitha limax* is common on partly protected reef slopes and in areas of high turbidity, low light and gentle water movement.
- *Mycedium*—This coral is highly adaptive to a wide range of habitats from turbid inshore reefs to offshore reefs in clear water. It is uncommon in areas of strong wave action. *Mycedium elephantotus* forms laminar or encrusting colonies with distinctive corallites facing outwards to the colony perimeter.
- *Turbinaria* spp.—These corals are typically dominant in shallow, turbid habitats, though they are also found in habitats ranging from shallow exposed reefs to protected lagoons. Their morphology is primarily determined by light availability and colonies are typically composed of unifacial laminae which are upright or tiered, on upper reef slopes; highly contorted and fused, in subtidal habitats; or horizontal, in deeper waters.

In previous monitoring programs (e.g. GHD Pty Ltd 2002) a fourth coral genus *Goniopora* was included. However, there is an insufficient density of *Goniopora* colonies at Weed Reef to warrant their inclusion in the present program.

Site establishment will include development of transects at the monitoring sites and tagging of individual coral colonies. If visibility permits, a photographic record will be made of the colonies and the surrounding coral communities. If turbidity levels are too high to permit photography, a semi-quantitative assessment of coral condition will be recorded from diver observations.

Each genus will be represented at each site by 25 colonies (i.e. 75 coral colonies per site). Transects will be of sufficient length to ensure that the required number of colony replicates has been obtained, and that the area covered is of sufficient size to be representative of the particular reef on which it has been placed. Transect lengths are expected to vary between sites and will be determined during site establishment.

Turbidity measurements during dredging

Two weeks prior to the start of dredging works at the gas export pipeline shore crossing, one turbidity logger will be deployed at the Channel Island coral community and another at the Weed Reef reference site. They will be serviced once a week, when data will be downloaded and the loggers redeployed. They will remain in place over the duration of dredging works for the pipeline shore crossing and approaches.

Aerial surveillance of turbid plumes arising from dredging activities at the pipeline shore crossing will also be undertaken. This will occur during daylight hours on every second day over the first two weeks of dredging. Aerial surveys will be carried out at mid-flood tide, when plume excursion “upstream” from the shore crossing would be at a maximum. Past observations (Ian Baxter, Principal Environmental Scientist, URS, pers. comm. April 2009) have shown that the initial flood-tide flow over the Channel Island coral community is in a north–south direction. This reverses after mid-flood tide as water passing around the southern side of Channel Island flows in a northerly direction under Channel Island bridge.

Over the initial surveillance period, it should be possible to develop an understanding of the behaviour of any plumes generated, with “worst case” tidal conditions defined. During spring tides, excursion of plumes towards Channel Island will be maximal because of the strong currents, though the plumes may be less distinguishable as they will be diluted by naturally turbid tidal waters. During neap tides, the plumes will more distinguishable as natural turbidity levels are lower, though they will not be carried as far by the tidal currents.

In the event that turbid water plumes from the dredging works are observed to be reaching Channel Island, data from the turbidity loggers will be downloaded within 24 hours. If there is no evidence from the aerial surveillance that turbid plumes are encroaching on the Channel Island coral community, the turbidity data from the Channel Island logger will be analysed after the first week of dredging. The turbidity data will be compared against the Threshold Level and Intensity Guideline, and the appropriate course of action to comply with the reactive dredging management response framework (Figure 4-2) will be implemented.

If the turbidity Threshold Level has been exceeded on more than the allowable number of occasions, an assessment of coral condition (see next section) will be undertaken. If required, management responses (see below) will be implemented.

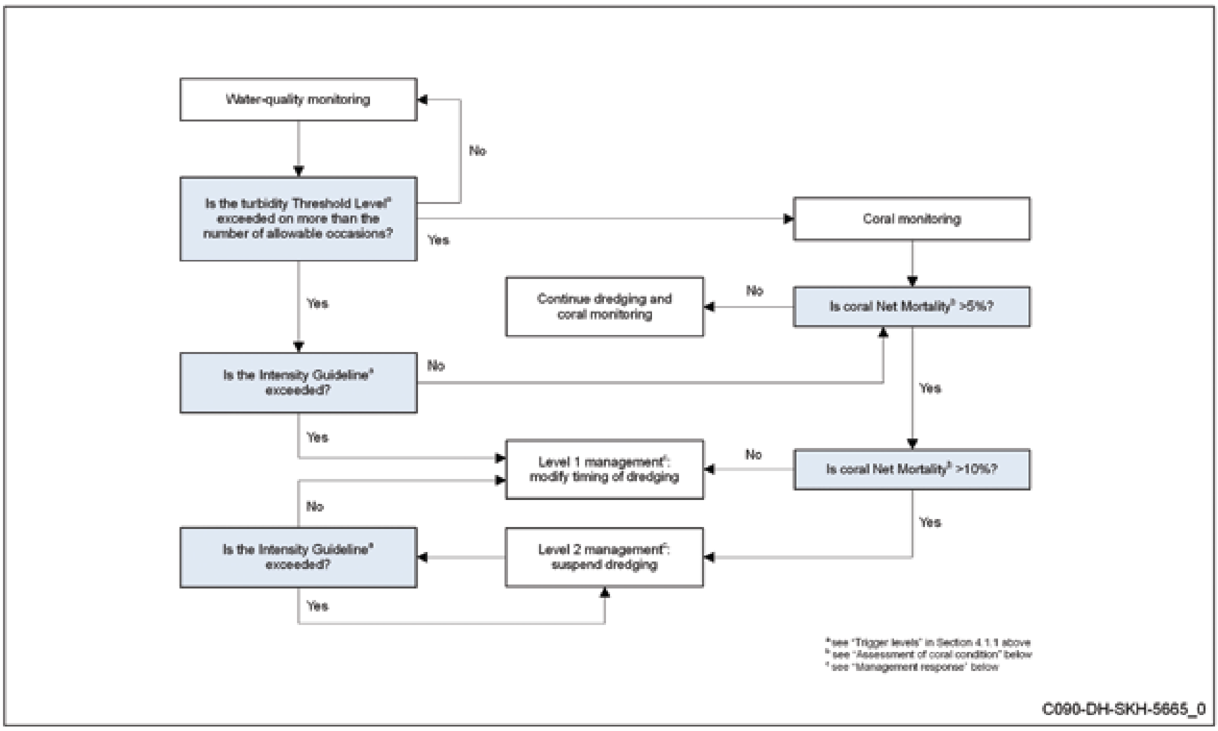

Figure 4-2: Reactive dredging management response framework

Assessment of coral condition

If median turbidity levels at the Channel Island site exceed the Threshold Level (95th percentile) at greater than the allowable frequency during dredging, then the corals tagged during the baseline survey will be rephotographed and scored for partial mortality. Each photograph will be overlain with an 8 × 8 grid and the points scored for mortality. The estimate of coral mortality at each site will be calculated by summing the percentage mortality of each colony and dividing by the number of colonies. This value will be expressed as the reduction in live coral cover as a percentage of the baseline coral cover.

Coral mortality will be evaluated as a relative increase in partial mortality above the baseline:

- MB (Gross Mortality, baseline) = nPM(i)/(nL(i) + nPM(i)), where PM(i) and L(i) are the number of points ascribed to Partial Mortality and Live respectively for each individual colony
- MS (Gross Mortality, survey) = as above
- M (Gross Mortality, at site) = (MS – MB) × 100
- MNet (Net Mortality at site) = M(Site) – M(Ref); where M(Site) is the Gross Mortality at the impact site and M(Ref) is the average Gross Mortality at the reference site. This is the value that will be used to test the coral health limit triggers (5% or 10% mortality).

The adoption of the 5% and 10% mortality triggers is in line with those adopted for recent dredge monitoring programs elsewhere in northern Australia, for example, by Western Australia's Environmental Protection Authority (EPA) for the Pluto liquefied natural gas (LNG) development on the Burrup Peninsula (EPA 2007). The upper coral health limit trigger (10% mortality) has represented the level at which management actions are required to minimise the risk of dredging-induced coral mortality eventually exceeding 30%. On the basis of findings by Connell (1997), Western Australia's EPA deemed that an exceedance of 30% mortality represented an unacceptable level of impact for the corals of Dampier Harbour (Stoddart et al. 2005). It is considered that the environmental settings of Darwin and Dampier harbours are similar enough (tropical, macrotidal, typically turbid waters) for the same criteria to be adopted.

While it would be preferable to monitor for sublethal effects rather than for mortality, this is impractical as some measurements of sublethal indicators (e.g. lipid ratios) require time frames unsuited to operational dredge management, while others (e.g. bleaching, fluorescence measurements) may be confounded by responses to factors unrelated to dredging (Stoddart et al. 2005).

Management response

If net coral mortality at the Channel Island site is less than 5%, then turbidity monitoring will continue and dredging will proceed unchanged. If coral Net Mortality is greater than 5%, then there are two levels of management response that may be implemented to reduce the risk of impacts upon the Channel Island coral community (Figure 4-2):

- Level 1—This level will be implemented if the median turbidity level at the Channel Island site exceeds the Threshold Level at greater than the allowable frequency during construction and net coral mortality is between 5% and 10%. It will also be implemented if the Intensity Guideline (99th percentile value) is exceeded and net coral mortality is less than 10%. The timing of dredging activities will be modified so that the potential for plumes to impinge upon the Channel Island coral community is reduced (e.g. restrictions on dredging around low-water periods). These measures will remain in place until the construction activities for the gas export pipeline shore crossing have been completed.
- Level 2—This level will be implemented if coral Net Mortality at the Channel Island site is greater than 10%. Dredging activity will be suspended until such time as the median turbidity level returns to below the Intensity Guideline, or the cause of mortality is demonstrated to be attributable to natural impacts such as thermal bleaching, predation or disease. When dredging recommences, it will proceed with Level 1 management measures in place until the end of the dredging program.

In the event that the median turbidity level at the Channel Island site exceeds the Threshold Level but coral monitoring cannot be undertaken because of the elevated turbidity levels, the following management responses will be implemented until such times as water clarity improves and a coral assessment can be undertaken:

- Level 1 if the median turbidity level is less than the Intensity Guideline.
- Level 2 if the median turbidity level is greater than the Intensity Guideline.

The Northern Territory's Department of Natural Resources, Environment, the Arts and Sport (NRETAS) will be notified of the results of the turbidity and coral monitoring at the earliest opportunity and will be informed of any management actions implemented in response to monitoring data.

Post-dredging monitoring

Post-dredging monitoring of coral health will be undertaken in the event that significant levels of coral mortality are recorded at Channel Island, relative to the reference site, and the mortality cannot be attributed to natural causes. The frequency and duration of any post-construction monitoring will be dependent upon the degree of mortality recorded. Recommendations for any post-construction monitoring will be presented to NRETAS at the conclusion of the dredging program.

4.2 Periodic surveys

4.2.1 Offshore spoil disposal ground

Accumulation of dredged spoil on the seabed at the offshore spoil disposal ground will be monitored during the dredging program to prevent the creation of large mounds that could affect the safe passage of ships over the area. The minimum depth to be maintained across the disposal area will be agreed in consultation with the DLP prior to commencement.

Bathymetric surveys will be conducted over the area as follows:

- prior to commencement of dredged spoil disposal, to establish baseline conditions
- periodically during dredged spoil disposal, initially every 2–4 weeks and less frequently as the accumulation of dredged spoil at the disposal area becomes better understood.
- on completion of the dredging and disposal program.

Management response

The potential for large mounds of dredge spoil to develop will be reduced by continually altering the location of disposal within the ground. Where mounds are found to be accumulating, spoil disposal vessels will be directed away from those areas towards areas of lower seabed profile.

4.2.2 East Arm

Periodic inspections will be conducted in East Arm, where sediment accumulation could potentially impact upon the operability of infrastructure such as the berths at East Arm Wharf, the Hudson Creek export facilities and the East Arm boat ramp. Any unacceptable levels of sediment accumulation that occur in these areas will be removed at the end of the dredging program, or earlier if operability is affected.

Management response

If the depths of accumulated sediment reduce under-keel clearances to less than those agreed with the DPC prior to dredging, then remedial dredging will be undertaken.

4.3 Coastal sedimentation

4.3.1 Sedimentation at vessel ramp facilities

Observations will occur periodically at locations where sediment plume modelling indicates that sedimentation in intertidal areas is likely to occur.

Observations will be conducted at the following locations:

- the East Arm boat ramp
- the Hudson Creek export facility
- East Arm Wharf.

Monitoring at these locations will occur as follows:

- prior to the commencement of dredging in order to establish baseline conditions
- periodically during dredge spoil disposal operations, initially every 2–4 weeks and less frequently once sedimentation patterns become better understood
- on completion of the dredging and dredge spoil disposal program.

Management response

Should quantities of sediment accumulate at the East Arm boat ramp, Hudson Creek export facility or East Arm Wharf that are sufficient to impede boat launching activities, or render them unsafe, these facilities will be cleaned as required.

4.3.2 Sedimentation in mangrove areas

An Intertidal Sedimentation Monitoring Program will be developed to assess the effects of sediment accretion on seaward mangrove communities throughout East Arm.

The monitoring program will include the following activities:

- A baseline assessment of mangrove health and sediment levels will be carried out at key potential impact sites and at suitable reference sites.
- Quarterly rapid assessments of mangrove health will be carried out at the monitoring sites to detect short-term and localised changes in tree condition and canopy cover. Sediment accretion will also be measured, using a surveying method appropriate to the small-scale changes (i.e. centimetres) that may occur.

Management response

If mangrove tree deaths result because of sedimentation from the dredging program (and are not attributable to natural causes or activities external to the Project), rehabilitation of the affected areas will be undertaken after the completion of dredging activities through a combination of natural recruitment, facilitated natural recruitment and active planting.

5 REPORTING, AUDITING AND REVIEW

Reporting, auditing and reviews will be undertaken throughout the construction phase of the Project. A summary of the reporting, auditing and review requirements relating to dredging and dredge spoil disposal management is presented below:

- Incidents resulting from dredging and dredge spoil disposal will be reported in accordance with INPEX's Incident Reporting, Recording and Investigating Procedure or the Project contractor's document equivalent (approved by INPEX).
- Reporting of all confirmed incidents will be made to the relevant authorities (e.g. NRETAS, the DPC and the DLP).
- An annual INPEX environmental report for the Project will be produced and will include details of dredge incidents.
- INPEX and its contractors will conduct internal compliance audits on a periodic basis.
- Records will be audited periodically to ensure that all personnel on site have completed the required health, safety and environment induction.
- Detailed dredging and dredge spoil disposal management documentation, for example plans and procedures, will be reviewed periodically to ensure that they remain applicable to current operations and compliant with the requirements of INPEX and the regulatory authorities.
- Dredging contractors will be required to produce and provide to INPEX a monthly environmental report which will include a record of all environmental incidents.

6 SUPPORTING DOCUMENTATION

This provisional EMP is one document in a suite of plans, procedures and processes designed to ensure that INPEX's dredging and dredge spoil disposal management activities are undertaken in compliance with legislative requirements and in a safe and environmentally responsible manner.

Documentation or processes addressing the issues outlined below have been or will be developed to further support the preparation of INPEX's detailed dredging and dredge spoil disposal management requirements:

- health, safety and environment site induction
- incident reporting, recording and investigating
- monitoring programs
- permit-to-work system.

7 APPLICABLE LEGISLATION, STANDARDS AND GUIDELINES

INPEX is committed to complying with all relevant laws, regulations and standards.

In recent years dredging programs have required a waste discharge licence under Section 74 of the *Water Act* (NT). In addition, under the *Darwin Port Corporation Act* (NT) the DPC may make by-laws pertaining to the control, regulation and management of dredging works within port limits.

The Northern Territory Government is presently developing guidelines for dredging activities, which will be based upon the *National assessment guidelines for dredging* prepared by the Commonwealth's Department of the Environment, Water, Heritage and the Arts (DEWHA 2009). These may influence the way in which INPEX's proposed dredging works are licensed.

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11 Environmental Management Program

Provisional Dust Management Plan

Annexe 7 – Chapter 11 *Environmental Management Program*

1 OVERVIEW

As part of the approvals process for the Ichthys Gas Field Development Project (the Project), it is necessary that INPEX should show that it has taken, and will take, all practicable steps to properly manage the risks associated with, and the potential environmental impacts of, the dust that will be generated by clearing and earthworks activities in the onshore development area during the construction and decommissioning phases of the Project.

Dust is generated when there is sufficient wind velocity to lift fine particles from the ground surface. The susceptibility of the particles to lift is dependent on the following:

- the physical characteristics of the soil (e.g. particle composition, density and size)
- the velocity of the wind
- the direction of the wind
- the moisture content and degree of compaction of the soil
- the amount of ground cover.

The susceptibility of particles to lift will also be influenced by Project activities such as vehicle and machinery movements.

Particles with diameters greater than 50 µm are unlikely to become airborne or will only remain in the air for a few minutes and settle near the source. Smaller particles, however, especially those less than 10 µm in diameter, can remain in the air for several days and can be spread by winds over wide areas or long distances from the original source. In addition, these particles can enter the lungs of humans and other animals and can create or exacerbate respiratory problems.

The most significant sources of particulates from the Project will be dust generated during the construction phase and potentially during the decommissioning phase (although the extent of this will be dependent on a government determination on what the land use for the Blaydin Point site is to be when the Project ends). Dust emissions during the operations stage are expected to be minimal as all main access roads and permanent work areas will have been sealed. Dust management will therefore be implemented primarily for the construction phase of the Project.

This provisional environmental management plan (EMP) for dust control is attached as Annexe 7 to Chapter 11 *Environmental management program* of the Project's draft environmental impact statement (Draft EIS). It is one of a suite of similar EMPs dealing with different aspects and activities of the Project. These provisional EMPs will form the basis for the development of more detailed environmental management documentation, for example plans and procedures for the various phases of the Project as well as for specific activities associated with the Project. The detailed documentation will be prepared either directly by INPEX's Environmental Department or by specialist contractors in conjunction with INPEX.

1.1 Purpose and scope

The purpose of this provisional EMP is as follows:

- It demonstrates how INPEX will reduce the potential environmental impact of dust generated as a result of Project activities through the identification of suitable dust management controls.
- It describes the proposed dust monitoring requirements for the construction phase of the Project.
- It describes the proposed reporting, review and audit requirements for the construction phase of the Project.
- It will guide the development of the detailed environmental documentation, such as the plans, procedures, etc., which will be required during the construction phase of the Project.

The scope of this provisional EMP includes dust generated as a result of onshore clearing, earthworks and drilling and blasting activities in the onshore development area during the construction phase.

This provisional EMP does not address the additional environmental impacts or management controls associated with clearing, earthworks, drilling and blasting activities and dust produced as a result of decommissioning activities. These are addressed as separate aspects under the following provisional EMPs:

- Provisional Decommissioning Management Plan (Annexe 5 to Chapter 11)
- Provisional Piledriving and Blasting Management Plan (Annexe 12 to Chapter 11)
- Provisional Vegetation Clearing, Earthworks and Rehabilitation Management Plan (Annexe 15 to Chapter 11).

1.2 Plan definitions

Micrometre (µm)

A micrometre is one-millionth of a metre (or one-thousandth of a millimetre). The symbol for the micrometre is µm. (This unit was formerly known as the micron.)

Nanometre (nm)

A nanometre is one-thousandth of a micrometre or one thousand-millionth of a metre. The symbol for the nanometre is nm.

Particulate matter (PM)

This is a term used to describe a complex group of air pollutants that are regarded as a severe health hazard. These pollutants are a mixture of fine airborne solid particles and liquid droplets (aerosols) and include, for example, smoke and dust particles, pollen, a variety of chemical compounds and trace metals. Particulate matter is usually categorised as PM_{10} or $PM_{2.5}$.

The particulate matter of concern to the Project is PM_{10} (for "particulate matter <10 µm") where the particles have an aerodynamic diameter of less than 10 µm. These particles pose a high degree of health concern because they can pass through the nose and throat and enter the lungs, creating or exacerbating respiratory problems.

1.3 Project dust sources

The following construction activities represent the greatest potential for generating dust emissions:

- all earthwork activities associated with site preparation and construction, including the clearing of vegetation, the grading of soil and fill, and excavation activities including blasting for site levelling and trenching
- materials crushing and screening operations
- loading, dumping and transport of material
- uncovered or exposed surfaces and bulk materials stockpiles
- vehicle movements on unsealed roads and hardstand areas.

1.4 Potential impacts

The potential impacts associated with dust generation include the following:

- adverse impacts on plant health by the smothering of leaves etc.
- adverse impacts on visual amenity
- nuisance to and health impacts on nearby human communities
- health impacts to the workforce.

The effects of dust on animals are likely to be of an indirect nature. Plants affected by excessive dust loads may yield less fruit and seed or they may fail to photosynthesise effectively, lose leaves and, in extreme cases, die. This in turn will affect the resources available to the animals dependent on the vegetation for shelter, food, etc.

2 OBJECTIVES, TARGETS AND INDICATORS

The objectives, targets and indicators set out by INPEX for dust management are shown in Table 2-1. The engineering and management controls to be implemented to help to achieve these targets are described in Section 3 *Management approach*.

3 MANAGEMENT APPROACH

Detailed dust management documentation, for example plans and procedures, will be developed for the construction phase of the Project. These documents will align with this provisional dust EMP. The detailed documentation will be prepared either directly by INPEX's Environmental Department or by specialist contractors in conjunction with INPEX.

A summary is provided below of the main engineering and management controls to be included in the detailed documentation and in the design of the Project facilities to mitigate the risk of dust emissions.

3.1 Engineering controls—design phase

Roads required for the operations phase will be sealed as soon as practicable after clearing in order to minimise dust emissions from vehicle movements.

Table 2-1: Dust management objectives, targets and indicators

Objectives	Targets	Indicators
Prevent any adverse impacts from dust on the environment during the construction phase of the Project.	• Zero impacts on vegetation health attributable to dust.	• Number of adverse impacts attributable to dust generation.
	• No significant visible dust attributable to the Project outside the onshore development area boundary.	• Visible dust outside the boundary.
Establish and maintain personnel awareness of the importance of dust management practices during the construction phase.	• All workforce personnel (including contractors) to complete a health, safety and environment (HSE) induction, which will include an overview of dust management practices.	• Number of people accessing the site as recorded by security, versus the number of people completing an HSE site induction.

3.2 Management controls—construction phase

The management controls to be implemented throughout the construction phase of the Project are outlined below:

- Multiple handling of material that has the potential to generate dust will be avoided where possible.
- Dust-suppression techniques will be applied where necessary to protect worker health, vegetation health, and amenity. The techniques employed may include spraying from water trucks and irrigation networks, and stabilisation and revegetation of cleared areas that are no longer needed as soon as practicable during construction.
- Dust-suppression additives may be used to increase the effectiveness and reduce the volume of the water required for dust suppression.
- All trucks transporting soil, aggregate, and/or other dust-generating materials to and from the onshore development area will have their loads wetted or covered, if required, to prevent the creation of dust.
- Blasting mats or similar will be used if blasting has to take place near sensitive receptors (e.g. mangroves).
- Areas cleared for temporary use will be rehabilitated as soon as practicable to minimise the potential for windborne dust generation.
- Personnel (including contractors) will be required to attend inductions when they first attend site during the construction phase of the Project. The induction sessions will include information on the dust-suppression techniques employed on site.

4 MONITORING

Monitoring activities will be undertaken throughout the construction phase of the Project in relation to the identified objectives and targets. The activities described below will be undertaken as part of the dust management monitoring program:

- Visual inspections of dust deposition on surrounding vegetation will be undertaken on a periodic basis.
- Visual inspections will be undertaken during activities likely to create dust (e.g. vegetation clearing and earthworks) to assess the effectiveness of the dust-mitigation measures.
- Dust exceedance incidents will be monitored using INPEX's and its contractors' incident-reporting databases.

Triggered management response

A management response will be triggered by any of the following three circumstances:

1 a dust "incident"
2 an exceedance of the monitoring criteria for dust emissions
3 the identification by an annual management review of a failure to meet an objective or target.

The responses to these are outlined below.

Response to dust "incidents"

A dust incident will be defined as a public complaint or an on-site workforce observation associated with dust. Detection of such incidents will trigger internal notifications, reporting requirements, investigations and associated corrective and preventive actions.

The level of investigation will be dependent on the potential risk associated with the event. Corrective and preventive actions that may be triggered as a result of the investigation would include the review and update of procedures or plans associated with dust management, the provision of refresher training for personnel on Project dust management practices, and/or an increase in dust-suppression activities.

The INPEX Incident Reporting, Recording and Investigating Procedure or the Project contractor's document equivalent (approved by INPEX) will be used to determine incident severity, potential risk and associated reporting, recording and investigation requirements. All dust incidents and "near misses" will be entered into INPEX's and its contractors' incident databases and corrective actions will be tracked to closure.

Response to monitoring exceedances

Exceedances of the monitoring criteria for dust emission will include the following:

- the generation of significant quantities of visible dust at the worksite and beyond its boundaries
- the deposition of significant quantities of visible dust on vegetation beyond the worksite boundaries.

Responses to exceedance of dust emission monitoring criteria could include the following:

- an increased level of application of existing dust suppression management controls
- an increased level of monitoring of vegetation communities
- additional monitoring of PM_{10} dust emissions at the boundaries of sensitive human communities
- a review and update of procedures or plans associated with dust management
- the provision of refresher training for personnel on Project dust management practices.

Response to adverse findings by an annual management review

Failure to meet identified objectives and targets will trigger the following responses:

- a review and audit of current dust management practices to assess the practicability of their implementation and to assess the resources required to implement the plan
- a review of current objectives and targets to assess achievability.

The response to the results of investigations and audits could include the following:

- the updating of plans and associated documentation to reflect changes to dust management practices
- the provision of refresher training for personnel on site dust-management practices and processes
- the possible sourcing of additional resources to assist in achieving the successful implementation of the dust management plan.

5 REPORTING, AUDITING AND REVIEW

Reporting, auditing and reviews will be undertaken during the construction phase of the Project. A summary of the reporting, auditing and review requirements for dust management is presented below:

- Incidents resulting in the injury or death of plants or animals and impacts on human health as a result of the generation of airborne dust or dust level exceedance will be reported in accordance with INPEX's Incident Reporting, Recording and Investigating Procedure or the Project contractor's document equivalent (approved by INPEX).
- Construction contractors will be required to produce and provide to INPEX a monthly environmental report which will include a record of environmental incidents and records of dust-suppression activities.
- An annual INPEX environmental report for the Project will be produced. It will include details of dust monitoring results and dust incidents.
- INPEX and its contractors will conduct internal compliance audits on a periodic basis.
- Records will be audited periodically to ensure that all personnel on site have completed a health, safety and environment induction.
- Detailed dust-management documentation, for example plans and procedures, will be reviewed periodically to ensure that they remain applicable to current operations and compliant with the requirements of INPEX and the regulatory authorities.

6 SUPPORTING DOCUMENTATION

This provisional EMP is one document in a suite of plans, procedures and processes designed to ensure that INPEX's dust management activities are undertaken in compliance with legislative requirements and in a safe and environmentally responsible manner.

Documentation or processes addressing the issues outlined below have been or will be developed to further support the implementation of detailed dust management documentation:

- incident reporting, recording and investigating
- HSE site induction.

7 APPLICABLE LEGISLATION, STANDARDS AND GUIDELINES

INPEX is committed to complying with all relevant laws, regulations and standards. Legislative instruments, standards and guidelines specifically related to dust management include the following:

- *AS/NZS 3580.1.1:2007, Methods for sampling and analysis of ambient air—Guide to siting air monitoring equipment.*
- *AS/NZS 3580.10.1:2003, Methods for sampling and analysis of ambient air—Determination of particulate matter—Deposited matter—Gravimetric method.*
- National Environment Protection Council. 2003. *National Environment Protection (Ambient Air Quality) Measure*. Commonwealth Government, Canberra, ACT.
- National Environment Protection Council. 2008. *National Environment Protection (National Pollutant Inventory) Measure 1998* (as varied). Commonwealth Government, Canberra, ACT.
- *Waste Management and Pollution Control Act* (NT).
- *Workplace Health and Safety Act* (NT).
- Workplace Health and Safety Regulations (NT).

Provisional Greenhouse Gas Management Plan

Annexe 8 – Chapter 11 *Environmental Management Program*

1 OVERVIEW

INPEX is seeking government environmental approvals for the Ichthys Gas Field Development Project (the Project). It intends to develop the Ichthys Field off the north-west coast of Western Australia to produce liquefied natural gas (LNG), liquefied petroleum gas (LPG) and condensate for export to markets in Japan and elsewhere. INPEX proposes that gas, together with a relatively small volume of condensate, will be transferred from the offshore central processing facility (CPF) through a subsea gas export pipeline to the onshore processing facility at Blaydin Point on Middle Arm Peninsula in Darwin Harbour. The greater part of the condensate will be exported from a floating production, storage and offtake (FPSO) facility adjacent to the CPF.

As part of the governmental approvals process for the Project, it is necessary that INPEX should show that it has taken, and will take, all practicable steps to properly manage the potential environmental impact of greenhouse gas (GHG) emissions generated by the Project both onshore and offshore during its lifetime.

The life-cycle emissions of carbon dioxide (CO_2) and other GHGs from LNG production and consumption are low in comparison with those of other hydrocarbon fuels such as coal and fuel oil. However, the scale of the Project's gas production and processing facilities is such that it will be a major GHG source in Australia and the largest GHG emitter in the Northern Territory.

Natural gas has a positive transitional role to play in the domestic and transport energy markets. Compared with coal and fuel oil, natural gas produces less GHG to produce the same amount of power.

The Project has two significant sources of GHG emissions: reservoir CO_2 and combustion emissions. An emissions assessment by source for GHGs produced by the Project has been conducted in order to evaluate options for minimising GHG emissions and to satisfy the information requirements of the Commonwealth and Northern Territory governments. The methodology employed to calculate GHG emissions is consistent with the methodology used by the Commonwealth's *Department of Climate Change publication National greenhouse accounts (NGA) factors* (DCC 2009).

It is estimated that the average annual emissions from the Project will be 7.0 Mt/a of CO_2, made up of 2.4 Mt/a of reservoir CO_2 emissions and 4.6 Mt/a of combustion CO_2 emissions (of which 2.8 Mt/a will be generated onshore and 1.8 Mt/a offshore) (see Table 1-1).

Total GHG emissions from reservoir CO_2 have been estimated over the 40-year life of the Project as approximately 96 Mt. This assessment indicated that during operations the reservoir GHG emissions will make up approximately 35% of the Project's emissions, while the onshore combustion and offshore combustion emissions will produce 39% and 26% respectively.

This provisional environmental management plan (EMP) for greenhouse gas emissions is attached as Annexe 8 to Chapter 11 *Environmental management program* of the Project's draft environmental impact statement (Draft EIS). It is one of a suite of similar EMPs dealing with different aspects and activities of the Project. These provisional EMPs will be used as a basis for the development of more detailed environmental management documentation, for example plans and procedures for the various phases of the Project as well as for specific activities associated with the Project. The detailed documentation will be prepared either directly by INPEX's Environmental Department or by specialist contractors in conjunction with INPEX.

1.1 Purpose and scope

The purpose of this provisional EMP is as follows:

- It demonstrates how INPEX intends to manage GHGs generated as a result of activities during the operations phase of the Project through the identification of suitable GHG management strategies.
- It describes the proposed monitoring requirements for all phases of the Project.
- It describes the proposed reporting, review and audit requirements for all phases of the Project.
- It will guide the development of a future more detailed operations-phase GHG EMP, to be developed prior to the commissioning of the onshore processing plant.

The scope of this provisional EMP takes into account all GHGs generated in association with activities in the Ichthys Project area (both onshore and offshore) during the lifetime of the Project.

1.2 Plan definitions

Biosequestration

Biosequestration is the process of converting a chemical compound through biological processes to a chemically or physically isolated or inert form. The term is most commonly used to refer to the "locking", through photosynthesis, of the carbon in atmospheric CO_2 into plant biomass (usually trees). Biosequestration offsets the effect of the CO_2 and other GHGs released by the development of natural gas fields and the burning of fossil fuels.

Table 1-1: Estimated average annual CO_2 emissions during operations

Source	Approx. power requirement	Approx. heating requirement	40-year annual average (Mt/a)	40-year totals (Mt)
Reservoir				
Brewster	n.a.	n.a.	1.4	56
Plover	n.a.	n.a.	1.0	40
Reservoir total	**n.a.**	**n.a.**	**2.4**	**96**
Offshore combustion*				
CPF—export gas compression (four RB211 turbines)	100 MW	n.a.	0.5	20
CPF—inlet gas compression (three RB211 turbines)	0 initially; 75 MW from Year 12	n.a.	0.3†	12
CPF—power generation (three RB211 turbines)	75 MW	n.a.	0.3	12
FPSO—power generation (four RB211 turbines)	100 MW	n.a.	0.5	20
FPSO—fired heating for monoethylene glycol (MEG) regeneration, condensate heating and stabilisation	n.a.	60 MW	0.2	8
Offshore total	**275–350 MW**	**60 MW**	**1.8**	**72**
Onshore combustion‡				
Refrigerant compressor turbines (four Frame 7 turbines)	280 MW	n.a.	1.4	55
Power generation turbines (nine Frame 6 turbines, eight running)	220 MW	n.a.	0.9	35
Acid gas removal unit (AGRU) incineration	n.a.	40 MW	0.1	4
Hot-oil furnaces and possibly steam boilers	n.a.	80 MW	0.2	7
Flares (all)	n.a.	n.a.	0.2	9
Onshore total (excl. reservoir)	**500 MW**	**120 MW**	**2.8**	**110**
Total for Project			**7.0**	**278**

* Rolls-Royce RB211 turbines are assumed for offshore use for estimation purposes only. Turbine choice is subject to technical assessment in the detailed-design phase.

† CO_2 emissions will be zero for approximately the first 11 years, 0.5 Mt/a for the next 29 years, and will average to 0.3 Mt/a over 40 years.

‡ General Electric Frame 6 and Frame 7 turbines are assumed for onshore use for estimation purposes only. Turbine choice is subject to technical assessment in the detailed-design phase.

n.a. = not applicable.

Carbon dioxide equivalent

The unit known as carbon dioxide equivalent (CO_2-e) is a measure, using CO_2 as the standard, used to compare the global warming potentials of the different GHGs. The measure is often expressed in millions of tonnes of carbon dioxide equivalents (Mt of CO_2-e). For example, if the global warming potential for methane (CH_4) over 100 years is taken as 21 (DCC 2009), this means that the emission of 1 Mt of CH_4 may be expressed as the emission of 21 Mt of CO_2-e.

Combustion greenhouse gases

In the context of LNG production, “combustion greenhouse gases”, as opposed to “reservoir greenhouse gases”, are created by burning any type of carbon-containing fuel in the LNG production process. They are produced, for example, from the gas turbines used for compression and power generation, from acid gas removal units (AGRUs), from hot-oil furnaces, and from flares.

Geosequestration

Geosequestration is the process of injecting CO_2 into deep geological formations for secure, long-term storage. The technique is also called “carbon (dioxide) capture and storage”.

Global warming potential

Global warming potential (GWP) is a measure of how much a given mass of a greenhouse gas is estimated to contribute to global warming. It is a relative scale which compares the global warming potential of the gas in question with that of an equivalent mass of CO_2 (which has been assigned the point-of-reference global warming potential of 1).

Greenhouse gas

Any of a number of gases found in the atmosphere which contribute to the greenhouse effect. The gases principally responsible for the greenhouse effect are defined in the *National Greenhouse and Energy Reporting Act 2007* (Cwlth) as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and sulfur hexafluoride (SF_6), together with certain specified hydrofluorocarbons and perfluorocarbons. GHGs also include water vapour, but although water vapour is the most significant GHG, CO_2 is considered the most significant man-made GHG and is the primary focus of government policy.

Methane

Methane is a colourless, odourless hydrocarbon gas. It is the principal component of natural gas. It has the capacity to cause 21 times more global warming than CO_2 per unit of weight (DCC 2009).

Nitrous oxide

Nitrous oxide is a colourless non-flammable gas. It has the capacity to cause 310 times more global warming than CO_2 per unit of weight (DCC 2009).

Reservoir carbon dioxide

Reservoir CO_2 is the CO_2 that is naturally present in a natural gas formation. It is typically vented to atmosphere when the gas is processed. It is sometimes referred to as “native CO_2”.

1.3 Potential sources of greenhouse gas emissions

Emissions of CO_2 are expected to represent about 96% of the Project’s total GHG emissions (measured in tonnes of CO_2-e). The emissions of CH_4 and N_2O combined are expected to contribute about 4% of the total GHG emissions. Significant sources of CO_2 emissions from the Project are listed in Table 1-1.

2 OBJECTIVES, TARGETS AND INDICATORS

The objectives, targets and indicators set out by INPEX for the management of GHGs are shown in Table 2-1. The engineering and management controls implemented to help to achieve these targets are described in Section 3 *Management approach*.

3 MANAGEMENT APPROACH

A GHG management plan will be developed prior to the commissioning of the onshore and offshore processing facilities. The detailed plan will align with this provisional greenhouse gas EMP. The GHG management plan for the Project will be developed by INPEX with the support of design and commissioning contractors.

A summary is provided below of the main engineering controls, management controls and offset initiatives that have been adopted or are currently being assessed through the development phase, and which will minimise INPEX’s net contribution to global GHG production.

3.1 Major engineering—design phase

The engineering strategies (each with varying degrees of GHG reduction) being investigated during the design phase of the Project are as follows.

Applicable to both onshore and offshore

- Consideration will be given to installing flare-gas recovery systems on all flare systems.
- A review of flare systems will be undertaken to minimise the number of relief valves directed to flare headers.
- Waste-heat recovery units will be installed wherever waste heat can be economically utilised.
- Selection of turbines will be based both on the Project’s power requirements and on the turbine operating efficiencies in high ambient temperatures.

Table 2-1: GHG management objectives, targets and indicators

Objectives	Targets	Indicators
Minimise GHG emissions through applying safe and cost-effective abatement technologies.	• The Ichthys Project should use up-to-date technology, e.g. it should select efficient gas turbines, use waste heat to the fullest practicable extent, and select an efficient AGRU solvent.	• Technology selection benchmarking of selected components, e.g. power generation efficiency.
Offset GHG emissions in a safe and cost-effective manner, consistent with domestic and international obligations.	• Targets for offsetting to be set once there is greater certainty in the legal and legislative framework around the Commonwealth Government’s Carbon Pollution Reduction Scheme and once the technical and economic risks associated with offset options have been assessed.	• Total quantity of CO_2-e offset.

- Flow metering and monitoring, and high-pressure alarms, will be installed on all flare systems.
- An electronic process monitoring and control system may be installed to enable monitoring of flaring and process upsets.

Onshore-specific

- Combined-cycle gas turbines will be investigated as an alternative to open-cycle gas turbines for power generation.
- Tandem dry-seal arrangements will be installed in the main refrigerant compressors.
- Condensate tanks will be fitted with floating roofs to minimise emissions.
- High-efficiency pump motors may be installed on equipment.
- The liquefaction units will include provision to reclaim propane on shutdowns instead of needing to flare this inventory.
- Provision may be made to reclaim light and heavy mixed refrigerant rather than sending it to flare.
- Activated methyldiethanolamine (aMDEA) has been selected as the preferred solvent for acid gases in the AGRUs and will help to minimise CO_2-e emissions.
- The high-pressure flash gas from the AGRUs will be directed to the fuel gas system if practicable.
- The low-pressure gas from the AGRUs will be directed to the AGRU incinerators if practicable.
- The liquefaction units may include provision to reclaim light and heavy mixed refrigerant during operating to change the mixed refrigerant composition.
- Boil-off gas recovery systems will be installed for boil-off gas produced by LNG tanks and LNG ships during normal loading operations.
- Measures may be incorporated in the LPG extraction and storage systems to maximise heat recovery and reduce compression, therefore increasing process efficiency.
- The liquefaction process will be designed to recover a significant amount of LPG from the feed gas before LNG is produced.
- High-efficiency insulation of LNG cryogenic lines will be incorporated into the process design.
- Consideration will be given to waste-heat recovery at the AGRU incinerators.
- Turboexpanders will be used in the LPG process to recover power from let-down of feed-gas pressure.

Offshore-specific

- Aeroderivative turbines will be considered for offshore applications.
- Recovery of cargo tank vapours is being considered.

3.2 Management strategies—operations phase

The management strategies to be implemented through the operations phase of the Project will include minimisation of flaring during commissioning and operations.

3.3 Offsets

There may be a number of alternatives available for offsetting the Ichthys Project's GHG emissions, with varying feasibilities, risks and costs. As the policy landscape is still evolving and regulations and legislation are yet to be finalised, INPEX continues to explore alternatives in order to be well prepared to respond once clarity is achieved. A portfolio of GHG offsets may afford the most effective approach by avoiding a high-risk reliance on any single solution for the Project.

Details of a possible range of offset opportunities are provided in this Draft EIS in Chapter 9 *Greenhouse gas management*. A summary is provided below.

Biosequestration

Biosequestration captures carbon by locking it in to plant tissues. In Australia, the primary approach so far has been to plant "carbon-sink" forests of fast-growing, long-lived trees. There are currently few accredited biosequestration service providers. In the future there may be more.

INPEX has initiated a biosequestration assessment project to better understand the potential for this technology to offset the large volumes of CO_2 produced by the Project.

Related to the biosequestration approach are improved forestry and land-management practices to reduce CO_2 emissions. The ConocoPhillips Darwin LNG project, for example, uses fire-management practices to offset CO_2 emissions. Similar options are being assessed by INPEX although at this stage the offsets are not recognised under the Kyoto Protocol and are therefore not compliant with the Commonwealth Government's proposed Carbon Pollution Reduction Scheme legislation.

Geosequestration

Geosequestration involves the injection of CO_2 into underground reservoirs. The technology for CO_2 injection is familiar to oil and gas companies and has been used as an enhanced hydrocarbon recovery technique for many decades. The Sleipner natural gas field in the North Sea is utilising this technology and it is being considered for the Gorgon Project in Western Australia.

Geosequestration is best suited to applications where there are significant point-source GHG emissions, for example industrial processing (including LNG production) and electricity generation where there is suitable storage reservoir capacity nearby.

Buying offset credits on the open market

Certified emission reductions (CERs) from clean development mechanism (CDM) projects, emission reduction units (ERUs) from joint implementation (JI) projects, European Union allowances (EUAs) under the European Union Emissions Trading Scheme Phase II (EU ETS II), voluntary emission reductions (VERs), and removal units (RMUs) are all available for sale on the international market. These offset measures may be acceptable as offsets in Australia. However, this will only be known when details of the Carbon Pollution Reduction Scheme and its associated legislation are finalised.

Prior to commissioning of the onshore processing plant, INPEX will produce a GHG management plan that will provide an updated GHG emission estimate forecast and will consolidate INPEX's plan for technical abatement and offsets.

4 MONITORING

Monitoring activities will be undertaken throughout the life of the Project to ensure that the identified objectives and targets are met. The activities listed below will be undertaken as part of the GHG monitoring program and energy-efficiency programs:

- quarterly stack emission monitoring on power generation and compressor turbines and the AGRUs
- the collection of monthly data on the quantities of fuel burned and the quantities of hydrocarbons produced
- the establishment of key performance indicators (KPIs) for the operations phase for flare performance and plant greenhouse gas efficiency.

5 REPORTING, AUDITING AND REVIEW

Reporting, auditing and reviews will be undertaken during the commissioning and operations phases of the Project. A summary of the reporting, auditing and review requirements relating to GHG management is presented below:

- INPEX will establish a greenhouse gas data management and reporting system to collate data on emissions and offsets, and to verify and report on these data.
- INPEX will report greenhouse emissions under the National Greenhouse and Energy Reporting System (NGERS).
- INPEX and its contractors will conduct internal compliance audits on a periodic basis.
- INPEX will require that commissioning contractors provide a monthly environmental report that will include a record of monthly environmental incidents and data on GHG emissions.

6 SUPPORTING DOCUMENTATION

This provisional EMP is one document in a suite of plans, procedures and processes designed to ensure that INPEX's greenhouse gas management activities are undertaken in compliance with legislative requirements and in a safe and environmentally responsible manner.

Documentation or processes addressing the issues outlined below have been or will be developed to further support the implementation of a detailed greenhouse gas management plan:

- equipment maintenance
- operations (including flaring)
- start-up and commissioning
- greenhouse gas data management system.

7 APPLICABLE LEGISLATION, STANDARDS AND GUIDELINES

INPEX is committed to complying with relevant laws, regulations and standards. Legislative instruments, standards and initiatives specifically related to GHG management include those listed below.

- the Commonwealth Government's proposed Carbon Pollution Reduction Scheme.
- the Efficiency Standards for Power Generation measure, a Commonwealth Government program to improve efficiency in the greenhouse intensity of energy supply.
- *Energy Efficiency Opportunities Act 2006* (Cwlth).
- *National Greenhouse and Energy Reporting Act 2007* (Cwlth).
- the National Greenhouse and Energy Reporting System (NGERS), a Commonwealth Government approach to the collection of information on greenhouse gas emissions and energy use and production across Australia.
- *Ozone Protection and Synthetic Greenhouse Gas Management Act 1989* (Cwlth).

8 REFERENCES

DCC—see Department of Climate Change.

Department of Climate Change. 2009. *National greenhouse accounts (NGA) factors*. Department of Climate Change, Canberra, ACT. Viewed online on 1 March 2010 at <http://www.climatechange.gov.au/~/media/publications/greenhouse-gas/national-greenhouse-factors-june-2009-pdf.ashx>.

Provisional Heritage Management Plan

Annexe 9 – Chapter 11 *Environmental Management Program*

1 OVERVIEW

As part of the approvals process for the Ichthys Gas Field Development Project (the Project), it is necessary that INPEX should show that it has taken, and will take, all practicable steps to properly manage the risks associated with, and the potential environmental impact of, activities undertaken by the Project during the construction phase which may impinge on both Aboriginal and non-Aboriginal heritage sites in the onshore and nearshore development areas.

The proposed nearshore development requires the construction of a subsea pipeline in the Harbour leading to a pipeline shore crossing on the western side of Middle Arm Peninsula; a product loading jetty and module offloading facility at Blaydin Point; and a shipping channel and turning basin in East Arm. Within this area there are a number of historic submerged maritime archaeological sites, all of which have the potential to be impacted on by the proposed development if its activities are not properly managed.

Many of these wreck sites relate to early shipping in Darwin Harbour and to military activity during World War II. In Middle Arm, the proposed subsea gas pipeline construction corridor encompasses the wreck of the SS *Ellengowan* (1888). In East Arm, the proposed jetty and turning basin are adjacent to six historic Catalina flying-boat wrecks, three belonging to the US Navy and three to the Royal Australian Air Force. The three US Navy planes were sunk during a World War II air raid in 1942. The Heritage Branch of the Northern Territory's Department of Natural Resources, Environment, the Arts and Sport (NRETAS) has indicated that there may be heritage values associated with all of the Catalinas and that these are currently being assessed. One of the US Navy flying boats ("Catalina 6") was located for the first time during site investigations for the Ichthys Project in May 2008. An "interim conservation order" was placed on this wreck in February 2009 in terms of the *Heritage Conservation Act* (NT).

In addition to non-Aboriginal maritime heritage sites, the Aboriginal Areas Protection Authority[1] (AAPA) has identified six maritime sacred sites in the nearshore development area. Sacred sites are surrounded by "restricted works" areas in which no land or maritime development works of any kind are allowed under the provisions of the *Northern Territory Aboriginal Sacred Sites Act* (NT).

In the onshore development area there are also a number of Aboriginal heritage sites and three World War II historical sites. An archaeological survey commissioned by the Northern Territory Government identified 19 Aboriginal archaeological sites and seven localities containing 20 isolated artefacts within the surveyed area (Wickham Point Industrial Estate) (Bourke & Guse 2007). Of those sites identified, nine sites (consisting mainly of shell and stone-artefact scatters) and one isolated artefact are located close to, or inside, the boundary of the onshore development area. All Aboriginal archaeological sites and objects are protected by the *Heritage Conservation Act* (NT), and require ministerial permission to disturb should there be a likelihood that Project activities might impact on those sites.

Three sites have been identified in the onshore development area as non-Aboriginal historic sites. The main site is located on the northern headland of Blaydin Point and consists of a number of features relating to World War II military activities. These include several concrete slabs, a possible searchlight foundation, a bomb-shelter trench, and buried refuse pits containing World War II and postwar materials. The two other sites 1.5 to 2 km to the south each have communications insulators and associated wire attached to trees (Bourke & Guse 2007). None of the three sites are listed on the Northern Territory Heritage Register and they are not the subject of interim conservation orders.

This provisional environmental management plan (EMP) for heritage site protection is attached as Annexe 9 to Chapter 11 *Environmental management program* of the Project's draft environmental impact statement (Draft EIS). It is one of a suite of similar EMPs dealing with different aspects and activities of the Project. These provisional EMPs will form the basis for the development of more detailed environmental management documentation, for example plans and procedures for the various phases of the Project as well as for specific activities associated with the Project. The detailed documentation will be prepared either directly by INPEX's Environmental Department or by specialist contractors in conjunction with INPEX.

1.1 Purpose and scope

The purpose of this provisional EMP is as follows:

- It demonstrates how INPEX will minimise the potential impact of Project activities on heritage sites, both Aboriginal and non-Aboriginal, through the identification of suitable management strategies.
- It describes the proposed monitoring requirements for all phases of the Project.
- It describes the proposed reporting, review and audit requirements for all phases of the Project.

1 The Aboriginal Areas Protection Authority is a statutory authority established under the *Northern Territory Aboriginal Sacred Sites Act* (NT) to administer the protection of sacred sites in the Northern Territory.

- It will guide the development of future more detailed environmental documentation, such as the plans, procedures, etc., which will be required throughout the life of the Project.

The scope of this provisional EMP includes all Aboriginal and non-Aboriginal heritage sites in the Project's onshore and nearshore development areas in Darwin.

1.2 Plan definitions

Aboriginal heritage

Aboriginal heritage may be defined as the unique and irreplaceable legacy of the ancient, diverse and complex cultures of the original inhabitants of Australia. It encompasses cultural heritage as commonly understood, but is particularly notable for its emphasis on the particular affinity that Aboriginal people have with the land and the importance they place on social values and traditions, customs and practices, aesthetic and spiritual beliefs, artistic expression and language.

Non-Aboriginal heritage

Non-Aboriginal heritage in the context of the onshore and nearshore development areas may be defined as any movable and immovable objects of archaeological, architectural, artistic and ethnographic importance which have survived from the earliest years of contact and settlement by non-Aboriginal people, including shipwrecks, artefacts, the remains of buildings and campsites, and relics from the two world wars.

1.3 Activities that may disturb Aboriginal and non-Aboriginal heritage sites

The following activities have the potential to disturb heritage sites throughout all phases of the Project:

- dredging
- pipeline construction
- product loading jetty construction
- earthworks (excavation and vibration) and clearing of vegetation
- unauthorised access or activities in undisturbed habitats adjacent to the development site
- vandalism and "souveniring".

Activities undertaken during the construction and decommissioning phases of the Project are considered more likely to have the potential to threaten Aboriginal and non-Aboriginal heritage sites than activities undertaken during the operations phase. This is attributable to the types of activity associated with these phases and to the increased numbers of personnel required to undertake these activities.

2 OBJECTIVES, TARGETS AND INDICATORS

The objectives, targets and indicators set out by INPEX for heritage management are shown in Table 2-1. The engineering and management controls to be implemented to help to achieve these targets are described below in Section 3 *Aboriginal heritage management approach* and Section 4 *Non-Aboriginal heritage management approach*.

Table 2-1: Aboriginal and non-Aboriginal heritage objectives, targets and indicators

Objectives	Targets	Indicators
Avoid disturbance to Aboriginal heritage sites (excluding sites that have been approved for removal).	• Zero incidents involving disturbance to Aboriginal heritage sites (excluding sites that have been approved for removal).	• Number of "incident reports" regarding disturbance to Aboriginal heritage sites.
Ongoing protection and preservation of known Aboriginal heritage sites, each of which will remain in place within its own designated protection zone.	• Zero occurrences of disturbances attributable to the Project to known Aboriginal heritage sites, each of which will remain in place within its own designated protection zone.	• Baseline data and photography of known Aboriginal heritage sites.
No intrusions of construction activities into sacred sites or maritime-wreck controlled zones (excluding zones where entry has been approved by the relevant authority).	• Zero occurrences of construction activities at sacred sites or in maritime-wreck controlled zones (excluding zones where entry has been approved by the relevant authority).	• Number of incidents of construction activities intruding into sacred sites or maritime-wreck controlled zones (excluding zones where entry has been approved by the relevant authority).
Establish and maintain workforce awareness of the importance of the Aboriginal and non-Aboriginal cultural values of sites in the onshore and nearshore development areas.	• All onshore and nearshore workforce personnel (including contractors) to complete a health, safety and environment (HSE) induction which will include information on the cultural values of sites in the onshore and nearshore development areas.	• Number of people accessing the site as recorded by security staff. • Record of people completing an HSE site induction.

3 ABORIGINAL HERITAGE MANAGEMENT APPROACH

Detailed Aboriginal heritage management documentation, for example plans and procedures, will be developed for all phases of the Project. These detailed documents will align with this provisional heritage EMP. The detailed Aboriginal heritage management documentation for the construction and operations phases will be developed by the Larrakia Development Corporation in consultation with INPEX's Indigenous Affairs Coordinator.

A summary of the main management controls to be employed to mitigate the risks associated with potential disturbance to Aboriginal heritage sites is outlined below.

3.1 Management controls—all phases

The management controls to be implemented throughout the various phases of the Project are as follows.

Applicable to onshore development area only

- An Aboriginal archaeological sites register for the onshore development area will be established to detail the locations and descriptions of all known archaeological sites. This will also include details of relocation sites if applicable. The register will be updated to record all new discoveries as required.
- A Larrakia Heritage Management Committee (LHMC) with a standing agenda will be established. It will be made up of representatives of the Larrakia people and INPEX.

Applicable to both onshore and nearshore development area

All personnel (including contractors) will attend inductions highlighting the Aboriginal cultural values of the onshore and the nearshore development areas in Darwin Harbour, the need to protect heritage sites, and the mitigating measures to be used when heritage site disturbance is unavoidable.

3.2 Management controls—design phase

The management controls to be implemented during the design phase of the Project are as follows.

Applicable to onshore and nearshore development areas

Sacred site "authority certificates", covering the onshore and nearshore development areas, have been obtained from the AAPA.[2]

2 An Authority Certificate is a legal document of the *Northern Territory Aboriginal Sacred Sites Act*. It sets out the conditions for using or carrying out works on land and sea in the Northern Territory and indemnifies the holder against prosecution under the Act for damage to sacred sites in the area of the certificate, provided that the work or use has been carried out in accordance with the conditions of the certificate.

Applicable to onshore development area only

The entire onshore development area has been comprehensively assessed for the presence of Aboriginal heritage sites.

Prior to commencement of construction, Aboriginal heritage sites in the onshore development area will be divided into two categories: those which will receive full protection from disturbance and those which may need to be removed.

In the case of an Aboriginal heritage site which may have to be moved, INPEX will request permission to do so from the LHMC and NRETAS's Heritage Branch. If permission is granted to remove the site, advice will be sought from the traditional custodians on the correct procedures to be adopted for its removal.

3.3 Management controls—construction phase

The management controls to be implemented throughout the construction phase of the Project are outlined below.

Applicable to onshore development area only

- A schedule of construction activities will be developed so that mitigation measures can be planned and undertaken for all heritage sites that will have to be disturbed. Mitigation measures may include recording and describing heritage sites or removing and relocating them.
- Job hazard analyses, daily toolbox meetings, permit systems or similar will be implemented on site during construction activities and particularly during the early vegetation clearing works. These will be undertaken to ensure that work areas are clearly identified before activities commence, to avoid accidental disturbance to heritage sites either inside or outside the onshore development area boundaries.
- Where the external boundary of an Aboriginal heritage site is 10 m or closer to any proposed construction activity, flagging, temporary fencing or similar will be erected 5 m from the site boundary and appropriate signage will be put in place. The boundary demarcation will be removed when the risk of disturbance no longer exists.
- Where construction activities (including the installation of temporary protection measures) are proposed within 10 m of the external boundary of an Aboriginal heritage site, a Larrakia representative or suitably qualified archaeologist will be present to supervise the activity. However, if for safety reasons this is not possible, a mutually acceptable alternative action will be agreed upon with the LHMC and the construction manager.

- If suspected archaeological material is uncovered or existing sites are damaged during construction activities, work will cease in the immediate area and INPEX's Indigenous Affairs Coordinator will be contacted. The coordinator will consult with Larrakia representatives and ensure that the AAPA and NRETAS are contacted. No further work in the immediate area will be allowed until permission is granted by NRETAS's Heritage Branch, as instructed by the Larrakia custodians.

Applicable to nearshore development area only

- The dredging program footprint has been designed to avoid maritime heritage areas.
- Anchor management plans will be developed to allow safe anchoring of vessels undertaking pipelay, dredging and piling activities in the vicinity of any maritime heritage or sacred sites.
- Exclusion zones will be established around the maritime sacred sites. No works will be permitted within these exclusion zones.

4 NON-ABORIGINAL HERITAGE MANAGEMENT APPROACH

Detailed non-Aboriginal heritage management documentation will be developed for the construction phase of the Project only. These detailed documents will align with this provisional heritage EMP. The detailed non-Aboriginal heritage management documentation for the construction phase will be prepared either directly by INPEX's Environmental Department or by specialist contractors in consultation with INPEX.

A summary of the main management controls to be employed to mitigate the risks associated with potential disturbance to non-Aboriginal heritage is outlined below.

4.1 Management controls—design phase

Applicable to onshore development area only

The entire onshore development area has been comprehensively assessed for the presence of non-Aboriginal heritage sites.

Prior to commencement of construction, non-Aboriginal heritage sites within the onshore development area will be divided into two categories: those which will receive full protection from disturbance and those which may need to be removed.

Applicable to nearshore development area only

Nearshore infrastructure has been designed to avoid impacting any heritage sites.

4.2 Management controls—construction phase

The management controls to be implemented throughout the construction phase of the Project are outlined below.

Applicable to both the onshore and nearshore development area

- All personnel (including contractors) will attend inductions highlighting the non-Aboriginal cultural values of the onshore and nearshore development areas in Darwin Harbour, the need to protect heritage sites, and the mitigating measures to be used when heritage site disturbance is unavoidable.
- A non-Aboriginal archaeological sites register for relevant onshore and nearshore development areas will be established to detail the location and description of all known archaeological sites. This will also include details of relocation sites if applicable. The register will be updated to include all new discoveries as required.

Applicable to onshore development area only

- Although the World War II historical sites on Blaydin Point do not require official approval to disturb, INPEX will consult with NRETAS's Heritage Branch before disturbing the sites and each will be surveyed and recorded.
- A schedule of construction activities will be developed so that mitigation measures can be planned and undertaken for all heritage sites that will be unavoidably disturbed. Mitigation measures may include recording and describing heritage sites and/or removing and relocating them.
- Job hazard analyses, daily toolbox meetings, permit systems or similar will be implemented on site during construction activities and particularly during the early vegetation clearing works. These will be undertaken to ensure that work areas are clearly identified before activities commence to avoid accidental disturbance to heritage sites either inside or outside the onshore development area boundaries.
- If suspected archaeological material is uncovered during construction, work will cease in the immediate area and the Heritage Branch will be contacted.

Applicable to nearshore development area only

- The dredging program footprint has been designed to avoid maritime heritage areas.
- Anchor management plans will be developed in consultation with NRETAS's Heritage Branch, to allow safe anchoring of vessels undertaking pipelay, dredging and piling activities in the vicinity of any heritage sites.
- All vessels will have global positioning system (GPS) coordinates and maps identifying the ship and flying-boat wreck locations in Darwin Harbour.
- To minimise disturbance, a 100-m-radius controlled zone will be established around all known Catalina flying-boat wrecks. If it is deemed necessary to have anchors or anchor cable within this zone then the appropriate anchor management procedures identified in the anchor management plan will apply.
- In the unlikely event that activities such as dredging would be required in the 100-m-radius controlled zone around a Catalina wreck, then a risk-based assessment will be carried out in conjunction with the relevant authorities and, based on this assessment, specific management controls will be adopted.
- INPEX will periodically assess the sediment conditions around the Catalinas closest to the shipping channel and, in consultation with NRETAS, determine whether any remedial action is required to deal with any impacts that might occur.
- To minimise disturbance, a 100-m-radius controlled zone (based on the intersection of latitude 12°32′16.3″S and longitude 130°52′06.3″E on the Port of Darwin 1:50 000 map sheet AUS 26) for the SS *Ellengowan* will apply. If it is necessary to have anchors or anchor cable within this zone then the appropriate anchor management procedures identified in the anchor management plan will apply.
- To minimise disturbance, a 150-m-radius controlled zone (based on the intersection of latitude 12°29′55.4″S and longitude 130°52′40.2″E on the Port of Darwin 1:50 000 map sheet AUS 26) for the *Kelat* will apply. If it is necessary to have anchors or anchor cable within this zone then the appropriate anchor management procedures identified in the anchor management plan will apply.

4.3 Management controls—operations phase

The potential impacts on maritime heritage sites during the operations phase will be limited to increases in sedimentation or sediment scouring on or around the Catalina wrecks adjacent to the shipping channel, turning basin and berthing area arising from vessel operations and from periodic maintenance dredging.

INPEX will periodically assess the sediment conditions around the Catalinas closest to the shipping channel and, in consultation with NRETAS, determine whether any remedial action is required to deal with any impacts that might occur.

5 MONITORING

Monitoring activities will be undertaken throughout the life of the Project in relation to the identified objectives and targets. The activities listed below will be undertaken as part of the heritage monitoring program:

Both Aboriginal and non-Aboriginal heritage

Heritage incidents will be monitored through INPEX's and its contractors' incident-reporting databases.

Aboriginal heritage only

- Onshore development area Aboriginal cultural surveys already undertaken will provide the data that will be used as the baseline when assessing performance indicators. The baseline data include photographs of all identified Aboriginal heritage sites.
- Ongoing monitoring will be undertaken for Aboriginal heritage sites. This will involve inspections by Larrakia representatives prior to and during the construction phase and during the commissioning and operations phases. Photographic records will be maintained for each of the sites.

Non-Aboriginal heritage only

Before dredging commences, Catalina flying-boat wrecks will be inspected to determine the current levels of sedimentation and records of these inspections will be kept. Ongoing periodic inspections will be undertaken throughout the dredging program to validate dredging sedimentation modelling predictions.

Triggered management response

A management response will be triggered by either of the following two circumstances:

1. a heritage "incident"
2. the identification by an annual management review of a failure to meet an objective or target.

The responses to these are outlined below.

Response to heritage "incidents"

Heritage "incidents" would include any of the following:

- the discovery of previously unknown heritage sites
- damage caused to previously unknown heritage sites
- damage caused to known heritage sites that have been identified as protected.

Detection of incidents will trigger internal notifications, reporting requirements, investigations and associated corrective and preventive actions.

The level of investigation will be dependent on the potential risk associated with the event. Heritage incidents will be dealt with on a case-by-case basis. Corrective actions that may be triggered as a result of the investigation would include the review and update of procedures or plans associated with heritage management and/or refresher training for personnel on Project heritage management processes.

INPEX's Incident Reporting, Recording and Investigating Procedure or the Project contractor's document equivalent (approved by INPEX) will be used to determine incident severity, potential risk and associated reporting, recording and investigation requirements. All heritage incidents and "near misses" will be entered into INPEX's and its contractors' incident databases and corrective actions will be tracked to closure.

The triggered management responses to the discovery of human skeletal remains, the discovery of previously unknown onshore heritage sites, or the disturbance of existing onshore Aboriginal heritage sites attributable to Project activities are outlined below.

Discovery of human skeletal remains

The process to be followed if skeletal remains should be discovered is as follows:

- All works in the immediate vicinity of the find that could possibly disturb the site must cease.
- Personnel will immediately notify the work supervisor of the find. The supervisor will then immediately notify the Northern Territory Police and INPEX's Indigenous Affairs Coordinator.
- If the Northern Territory Police should determine that the remains are likely to be historical and of Aboriginal origin, the remains will stay in situ until the AAPA, in consultation with the Larrakia people, decides how to proceed.

Discovery of previously unknown onshore heritage sites

The process to be followed if a previously unknown site of potential heritage significance is discovered is as follows:

- As soon as a previously unknown site is identified, all work in the immediate vicinity that could possibly disturb the find must cease.
- The work supervisor will be notified and will inspect the site to confirm that it is potentially a site of heritage significance. If it is deemed to have potential heritage significance, the site will be photographed and interim protection measures (e.g. temporary fencing) will be put in place.
- The work supervisor will contact INPEX's Indigenous Affairs Coordinator (if it is thought to be an Aboriginal heritage site) or the INPEX Environment Manager (if it is thought to be a non-Aboriginal heritage site) who in turn will inform the AAPA and/or NRETAS's Heritage Branch as appropriate.
- If the site is an Aboriginal site then a Larrakia representative will undertake an inspection to determine if it is potentially a heritage site. Working in conjunction with INPEX's Indigenous Affairs Coordinator, the representative will prepare advice for the LHMC on whether the site can be protected or if site disturbance is unacceptable.
- If the site is required to be disturbed, approval will be sought through NRETAS's Heritage Branch (Aboriginal and non-Aboriginal heritage).
- No further work in the immediate area will be allowed until permission, in writing, is granted by NRETAS's Heritage Branch.

Unauthorised disturbance of known onshore Aboriginal heritage sites

The process to be followed if a known heritage site is damaged or disturbed is as follows:

- If unauthorised disturbance occurs at a known heritage site, all work in the immediate vicinity of the site that could possibly cause further disturbance must cease.
- The work supervisor will be notified, the damage to the site will be photographed, and interim protection measures (e.g. temporary fencing) will be put in place.
- The work supervisor will contact INPEX's Indigenous Affairs Coordinator who will arrange for a Larrakia representative to inspect the site.
- In consultation with the Larrakia representative, INPEX's Indigenous Affairs Coordinator will prepare advice for the LHMC on the extent of the damage and recommendations for possible remedial action.
- Agreed remedial actions will be implemented and the success of remedial actions will be monitored.
- Work will not commence in close proximity to the site until confirmation has been received from the AAPA or NRETAS's Heritage Branch.

Response to adverse findings by an annual management review

Failure to meet identified objectives and targets will initiate the following responses:

- a review and audit of current heritage protection methods to assess the practicability of implementation and opportunities for improvement
- a review of current objectives and targets to assess achievability.

The response to the results of investigations and audits may include the following:

- an update of plans and associated documents to reflect changes to heritage management practices if applicable
- the arrangement of refresher training for personnel on the cultural values of the onshore and nearshore development areas and the measures INPEX has put in place to protect them.

6 REPORTING, AUDITING AND REVIEW

Reporting, auditing and reviews will be undertaken throughout the lifetime of the Project. A summary of the reporting, auditing and review requirements relating to heritage matters is provided in the following two sections.

6.1 All phases

Applicable to both Aboriginal and non-Aboriginal heritage matters

- Heritage incidents will be reported in accordance with INPEX's Incident Reporting, Recording and Investigating Procedure or the Project contractor's document equivalent (approved by INPEX).
- An annual INPEX environmental report for the Project will be produced and will include details of heritage incidents.
- INPEX and its contractors will conduct internal compliance audits on a periodic basis.
- Records will be audited periodically to ensure that all personnel on site have completed the required health, safety and environment induction.
- Detailed heritage management documentation, for example plans and procedures, will be reviewed periodically to ensure that they remain applicable to current operations and compliant with the requirements of INPEX and the regulatory authorities.

Applicable to Aboriginal heritage matters only

- The LHMC will meet to discuss Aboriginal heritage issues on a quarterly basis during the front-end engineering design phase and construction phase and on a half-yearly basis during the operations phase unless otherwise agreed.
- Where necessary, meetings will be held with the LHMC and NRETAS's Heritage Branch and the AAPA to review the implementation of heritage protection measures in the onshore development area.

6.2 Construction phase

Applicable to both Aboriginal and non-Aboriginal heritage matters

- Contractors will be required to produce and provide to INPEX a monthly environmental report including a record of any heritage incidents.
- If previously undiscovered heritage sites (either Aboriginal or non-Aboriginal) are discovered during earthworks preparation the relevant government agencies (NRETAS's Heritage Branch and/or the AAPA) will be notified.

Applicable to non-Aboriginal heritage matters

Where necessary, meetings will be held with INPEX and NRETAS's Heritage Branch to review the implementation of heritage protection measures used in the nearshore area.

7 SUPPORTING DOCUMENTATION

This provisional EMP is one document in a suite of plans, procedures and processes designed to ensure that INPEX's heritage management activities are undertaken in compliance with legislative requirements and in a safe and environmentally responsible manner.

Documentation or processes addressing the issues outlined below have been or will be developed to further support the implementation of INPEX's heritage management requirements:

- incident reporting, recording and investigating
- anchor management
- permits to work
- archaeological sites register
- archaeological site maps
- health, safety and environment induction.

8 APPLICABLE LEGISLATION

INPEX is committed to complying with all relevant laws, regulations and standards. Legislative instruments, for example, specifically related to heritage management include those listed below.

- *Aboriginal and Torres Strait Islander Heritage Protection Act 1984* (Cwlth).
- *Aboriginal Land Rights (Northern Territory) Act 1976* (Cwlth).
- *Australian Heritage Council Act 2003* (Cwlth).
- *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth).
- *Heritage Conservation Act* (NT).
- *Historic Shipwrecks Act 1976* (Cwlth).
- *Northern Territory Aboriginal Sacred Sites Act* (NT).

9 REFERENCE

Bourke, P. and Guse, D. 2007. *Archaeological survey of the proposed Wickham Industrial Estate: Indigenous and historic cultural heritage assessment*. Report (Specification No. T07-1780) prepared by Earth Sea Heritage Surveys, Darwin, for the Northern Territory Government, Darwin, Northern Territory.

Provisional Liquid Discharges, Surface Water Runoff and Drainage Management Plan

Annexe 10 – Chapter 11 *Environmental Management Program*

1 OVERVIEW

As part of the approvals process for the Ichthys Gas Field Development Project (the Project), it is necessary that INPEX should show that it has taken, and will take, all practicable steps to properly manage the risks associated with, and the potential environmental impact of, liquid discharges generated by the Project both onshore and offshore during its lifetime as well as changes to surface water runoff and groundwater infiltration as a result of the construction of Project infrastructure onshore.

This provisional environmental management plan (EMP) for liquid discharges, surface water runoff and drainage is attached as Annexe 10 to Chapter 11 *Environmental management program* of the Project's draft environmental impact statement (Draft EIS). It is one of a suite of similar EMPs dealing with different aspects and activities of the Project. These provisional plans will form the basis for the development of more detailed environmental management documentation, for example plans and procedures for the successive phases of the Project as well as for specific activities associated with the Project. The detailed documentation will be prepared either directly by INPEX's Environmental Department or by specialist contractors in conjunction with INPEX.

Liquid discharges

Routine liquid discharges will be produced through the construction, precommissioning, commissioning and operations phases of the Project and will be disposed of to the marine environment, both offshore and nearshore. A summary of the sources of these discharges for onshore and offshore activities is provided in Section 1.4 *Sources of liquid discharges*.

Offshore liquid discharges will occur in deep water well away from any sensitive shallow water habitats and will be rapidly diluted and dispersed by ocean currents. The concentration of toxic chemicals in the surrounding waters will be extremely low (away from the initial mixing zone) and unlikely to produce any significant adverse environmental or toxic effects.

Liquid discharges from onshore Project activities, however, have greater potential to produce adverse effects on water quality in Darwin Harbour if not appropriately managed.

Surface water runoff, erosion and drainage

The surface hydrology of the onshore development area will be altered by the clearing of vegetation, the construction of earthworks and the physical presence of the onshore facilities. The area covered by the onshore facilities will alter natural drainage patterns through the construction of large areas of impervious surfaces that will change the volume and pattern of surface water flows and subsurface infiltration.

Surveys of the onshore development area have shown evidence of a natural erosion and sedimentation process occurring, with the fringing mangroves acting as a natural sediment trap. However, the potential rate of erosion from large-scale earthworks at the onshore development area is likely to result in higher than natural levels of sedimentation that must be properly managed if the mangrove community's capacity to cope with sedimentation is to be maintained.

Biting insects

Project activities have the potential to create water-filled breeding sites for biting insects such as the mangrove biting midge and several species of mosquito (DHF 2005). Such activities could include the physical disturbance of intertidal and aboveground areas creating hollows for water pools; the presence of unused receptacles such as bins, drums and other containers that can fill with rainwater; and inadequate maintenance of stormwater drains and sediment ponds.

1.1 Purpose and scope

The purpose of this provisional EMP is as follows:

- It demonstrates how INPEX, through the identification of suitable management strategies, intends to minimise the potential environmental impact of the liquid discharges generated as a result of Project activities, including those resulting from alterations to surface water runoff patterns or natural drainage systems.
- It describes the proposed monitoring requirements for all Project phases.
- It describes the proposed reporting, review and audit requirements for all phases of the Project.
- It will guide the development of future more detailed environmental documentation, such as the plans, procedures, etc., which will be required throughout the life of the Project.

The scope of this provisional EMP includes the following:

- all liquid wastes generated as a result of activities in the Project area, both onshore and offshore, that are discharged through wastewater effluent systems and vessels (e.g. produced water, sewage, brine)
- surface water runoff and natural drainage issues associated with the onshore processing plant and associated facilities on Blaydin Point.

This provisional EMP does not address the potential environmental impacts of, or management controls for, the following:

- non-hazardous and hazardous liquid waste products (e.g. paints, solvents and oily wastes) from onshore and offshore activities that are not discharged to the environment (excluding food scraps from construction and support vessels or facilities)
- dredging or dredge material discharges
- ballast-water exchange discharges
- spilt liquids.

These are addressed as separate aspects under the following provisional EMPs or in other Project documentation:

- Provisional Dredging and Dredge Spoil Disposal Management Plan (Annexe 6 to Chapter 11)
- Provisional Onshore Spill Prevention and Response Management Plan (Annexe 11 to Chapter 11)
- Provisional Quarantine Management Plan (Annexe 13 to Chapter 11)
- Provisional Waste Management Plan (Annexe 16 to Chapter 11)
- oil spill contingency and shipboard oil pollution emergency plans (not provided in this Draft EIS).

1.2 Plan definitions

Liquid discharges

The collective term “liquid discharges” is used to describe both the liquids produced as a result of Project activities that are discharged to the environment and the natural discharges that will need to be managed to avoid contamination of the environment. These include the following:

- produced discharges: drill muds, subsea fluids, hydrotest water, produced water, process water, cooling water, liquids contained in non-hazardous drain systems, brine, sewage and grey water
- natural discharges: deck drainage, surface water runoff and stormwater drainage.

Construction and precommissioning

This stage starts with the construction of the major civil engineering works, including foundations, tanks, the module offloading facility, etc., and extends through the installation of the modules, the pipeline and the product loading jetty to hook-up and the end of the precommissioning of the first train (i.e. prior to the introduction of hydrocarbons or other hazardous materials).

Commissioning and operations

Commissioning starts when hydrocarbons are first introduced into the plant from offshore. It includes the first fills of refrigerants, heating oils, amines, etc. Initially this will be for the operation of one train, with the second train approaching the end of mechanical completion and scheduled to be commissioned after a further 6 to 12 months. This phase covers the ongoing operation of the 8.4-Mt/a liquefied natural gas (LNG) processing plant.

1.3 Activities that may influence natural drainage patterns

Project activities that may lead to the alteration of surface hydrology, an increase in the risk of erosion or a reduction in natural drainage include the following:

- the clearing of vegetation during site preparation
- the construction of earthworks for the onshore facilities
- the physical presence of the facilities (e.g. hardstand areas and paving).

1.4 Sources of liquid discharges

The liquid discharges for the various phases of the Project will include the following:

- drilling muds from offshore drilling operations
- subsea hydraulic control fluids for offshore operations
- hydrotest water from precommissioning of the onshore and offshore facilities
- sewage and grey water from construction and supply vessels and from the onshore and offshore facilities
- produced water from the offshore operations
- process water from the onshore operations
- discharges from the desalination plant offshore and the demineralisation plant onshore
- firewater from onshore emergency response exercises and emergency events
- drainage and surface water runoff from rainfall
- cooling water from the offshore operations.

1.5 Potential impacts

Potential impacts to the offshore and nearshore marine environment from liquid discharges include the following:

- a reduction in water quality as a result of increased turbidity
- the smothering of the benthos and alteration of sediment characteristics
- the increased loading of the marine environment with hydrocarbons, other chemicals and nutrients
- an increase in the availability of food for marine biota
- toxic effects on marine biota
- the bioaccumulation of chemicals in marine organisms
- an increase in water temperatures in the immediate vicinity of cooling-water outfalls
- detrimental changes in biological oxygen demand.

Potential impacts from the alteration to surface runoff or natural drainage as a result of construction, earthworks and the physical presence of structures within the onshore development area include the following:

- an increase in erosion and sedimentation in natural drainage systems
- an increase in erosion and sediment loads in the fringing mangrove community
- alterations to the volumes and patterns of surface water runoff
- alterations to groundwater levels and infiltration capacity
- detrimental effects on hinterland mangroves which may be dependent on surface water runoff and groundwater infiltration
- the creation of breeding habitat for biting insects.

Table 2-1: Liquid discharges, surface water runoff and drainage management objectives, targets and indicators

Objectives	Targets	Indicators
Prevent unacceptable level of environmental impacts from liquid discharges during all phases of the Project, both offshore and onshore.	• Zero environmental incidents resulting from liquid discharges.	• Number of incident reports and severity of incidents resulting from liquid discharges (including exceedance of liquid discharge limits for nutrients, oil dispersion and heavy metals).
Prevent environmental impact from the discharge of produced water from offshore operations.	• Concentration of hydrocarbons in produced water discharged will be limited to not greater than an average of 30 mg/L over any period of 24 hours in accordance with the OPGGS)(Environment) Regulations*.	• Concentration of hydrocarbons prior to discharge. • Flow rate and volume of water from oil-and-water separation system.
Minimise discharges of synthetic-based mud (SBM).	• The concentration of SBM on drill cuttings released to sea will be limited to a maximum of 10% by dry weight of the base fluid on the drilled cuttings.	• Well average for concentration of SBM in drill cuttings discharged.
Prevent environmental impact from the combined jetty discharge stream from the onshore facilities during the operations phase.	• Wastewater discharge streams will meet Project design criteria and equipment performance specifications.	• Concentration of discharge constituents from wastewater discharge streams. • Flow rate and volume of discharge. • Darwin Harbour water-quality monitoring program outcomes.
Ensure that changes to groundwater and surface water flows do not negatively impact on fringing mangrove communities.	• No significant changes to fringing mangroves communities as a result of changes to surface water and groundwater flows in the onshore development area.	• Health of fringing mangroves measured through leaf defoliation index or similar.
Establish and maintain awareness of the importance of liquid discharge and drainage management practices during all phases of the Project.	• All workforce personnel (including contractors) to complete a health, safety and environment (HSE) induction, which, where appropriate, will include information on liquid discharges and drainage management practices.	• Numbers of people accessing the site. • Number of people completing HSE inductions.

* Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009 (Cwlth).

† MARPOL 73/78 = *International convention for the prevention of pollution from ships, 1973, as modified by the protocol of 1978 relating thereto.*

2 OBJECTIVES, TARGETS AND INDICATORS

The objectives, targets and indicators set out by INPEX for the management of liquid discharges, surface water runoff and drainage are shown in Table 2-1. The engineering and management controls to be implemented to help to achieve these targets are described in Section 3 *Management approach*.

3 MANAGEMENT APPROACH

Detailed liquid discharges, surface water runoff and drainage management documentation, for example plans and procedures, will be developed for all phases of the Project. These detailed documents will align with this provisional liquid discharges, surface water runoff and drainage EMP. The detailed documentation will be prepared either directly by INPEX's Environmental Department or by specialist contractors in conjunction with INPEX.

A summary is provided below of the main engineering and management controls to be employed in the detailed documentation to mitigate the risks associated with liquid discharges generated by the Project (both onshore and offshore) and changes to surfaces water runoff and groundwater infiltration as a result of the presence of Project infrastructure onshore.

3.1 Engineering controls—design phase

The engineering controls to be included during the design phase of the Project are as follows.

Onshore-specific

- The design of appropriate drainage systems will be based on statistical data with consideration of rainwater infiltration.
- During the construction phase, surface water runoff from the Project footprint will be directed to sedimentation systems to facilitate the removal of sediment and contaminants. These systems will be located in various locations around the plant. Their design will include series of retention barriers and sedimentation ponds.
- Natural drainage will be maintained around roads by installing drains and culverts, particularly in intertidal areas such as the causeway between Blaydin Point and Middle Arm Peninsula. Any sheet-flow retention will be considered using curb and surface runoff control and containment during the construction and operations phases.
- Sedimentation systems will be designed in such a way that water will not be retained for long periods; this will prevent the breeding of biting insects. Erosion control measures will be put in place to prevent spillways from such systems from creating erosion and potential pooling.
- Sediment control and drainage interception systems infrastructure, such as culverts, drains, silt traps, sediment ponds, etc., will be employed to manage sediment loads in surface water runoff.
- As some areas on Blaydin Point will remain uncleared or unsealed there will be some groundwater recharge during rainfall events.
- On-site roads required for the operations phase will be sealed during the construction phase to minimise sediment runoff into surface drainage channels.
- Erosion protection infrastructure will be installed in areas of high erosion risk.
- All drainage will be designed to shed water away from foundations and with appropriate treatments to prevent scouring.
- Surface water drains and discharge points throughout the onshore development area will be designed to minimise erosion and pooling of water.
- Surface water drainage channels throughout the onshore development area will be designed to minimise the creation of habitat for biting insects.
- Numerous surface water drains will be constructed around the perimeter of the onshore development area and will, where applicable, distribute fresh water to mangrove areas.
- The drainage system will be designed to separate the contaminated areas from the non-contaminated areas. The oily-water contaminated wastewater streams will be directed to the oily-water treatment system.
- The oily-water treatment system will be designed to meet a <10-mg/L petroleum hydrocarbon criterion.
- The process water systems and neutralisation unit will be designed to achieve the following criteria for temperature and pH at the combined discharge point on the product loading jetty:
  - 26–35 °C
  - pH 5–9.
- The permanent sewage treatment facility will be designed to meet the following criteria for treated wastewater:
  - total nitrogen: <40 mg/L
  - total phosphorus: <10 mg/L
  - biological oxygen demand <20 mg/L
  - faecal coliforms <400 cfu/100 mL.
- Water-quality monitoring points will be installed in the drainage system to allow monitoring of selected discharge streams.
- The jetty outfall discharge point will incorporate a diffuser to maximise dilution and reduce the extent of the mixing zone.
- Bunding and sumps will be provided for storage areas for fuels, chemicals and waste.

Offshore-specific

- Wellhead valves will be designed to minimise the volumes of subsea control fluids released.
- Wells will be designed to minimise the generation of oil on cuttings within the technical constraints of drilling an operational well.
- Electronic monitoring equipment will be installed for continuous monitoring of the produced water from the floating production, storage and offtake (FPSO) facility.
- The central processing facility (CPF) drainage systems will be designed to include "open" (non-contaminated) and "closed" (contaminated) drainage flows.
- Areas on the mobile offshore drilling unit (MODU), construction barges, CPF and FPSO that are more likely to have small oil spills will have containment facilities such as bunding to prevent contamination of deck washdown and stormwater runoff.
- All sewage facilities on vessels (including the MODU and the installation, decommissioning and support vessels) will comply with the requirements of MARPOL 73/78 and the *Protection of the Sea (Prevention of Pollution from Ships) Act 1983* (Cwlth).
- A macerator will be installed on the permanent offshore facilities (the CPF and FPSO) to macerate sewage to particle sizes less than 25 mm in diameter prior to discharge.

3.2 Management controls—all phases

The management controls to be implemented throughout the successive phases of the Project are outlined below.

Applicable to both onshore and offshore

- Chemicals and hazardous substances used during all Project phases will be selected and managed to minimise the environmental impact associated with their transport, transfer, storage, use and disposal.
- Scheduled preventive equipment maintenance and regular equipment inspections will be undertaken to prevent equipment failure and potential contamination of facility drains and process areas.

Onshore-specific

Equipment and containers (e.g. buckets) which have the ability to capture and hold water will be positioned appropriately or stored under cover to prevent the creation of breeding habitat for biting insects. Equipment and vessels which are unable to be stored or positioned to avoid this will be inspected regularly during the wet season and any pooling water will be removed or treated.

Offshore-specific

- Water-soluble, low-toxicity subsea control fluids will be used.
- Sewage wastes from the CPF and FPSO facilities will be macerated to particles and scraps with diameters less than 25 mm prior to discharge in accordance with Clause 222 of the Petroleum (Submerged Lands) Acts Schedule (DITR 2005). The discharge will take place through submerged caissons.
- Produced water will be treated to reduce the oil content prior to discharge.
- The concentration of petroleum hydrocarbons in produced water discharged to sea will be limited to not greater than an average of 30 mg/L over any period of 24 hours in accordance with the requirements of Clause 29 of the OPGGS(Environment) Regulations. The oil-in-water concentration will be measured continuously by an electronic meter.

3.3 Management controls—nearshore and offshore

Construction vessels, supply vessels and the MODU will conform with the following prescriptions laid down by the *Protection of the Sea (Prevention of Pollution from Ships) Act 1983* (Cwlth) and the *Marine Pollution Act* (NT).

- Sewage will not be discharged within 3 nautical miles of land.
- Only treated sewage with particles less than 25 mm in diameter will be discharged between 3 and 12 nautical miles of land.
- Untreated sewage may be discharged beyond 12 nautical miles of land.

The water discharged to sea from construction and supply vessels will not exceed an oil-in-water concentration of <15 mg/L in accordance with Annex I of MARPOL 73/78 and the Marine Pollution Regulations (NT).

3.4 Management controls—drilling

The management controls to be implemented throughout the Project's drilling operations are outlined below.

Offshore-specific

- Low-toxicity water-based muds (WBMs) will be used for the top-hole sections of wells.
- Synthetic-based muds (SBMs) will be used in the bottom-hole sections. These muds will not be routinely discharged to the marine environment, with the exception of small amounts adhering to drill cuttings.

- SBMs will be recovered and returned to shore for recycling or reuse or, if these options are not practicable, for disposal in an approved manner.
- SBMs will be reused several times and an effort will be made to separate as much of the SBM from the cuttings as can practicably be achieved.
- The use of cuttings driers to reduce SBMs on cuttings will be investigated.
- The concentration of SBM on drill cuttings discharged to sea will be restricted to 10% by dry weight or less in accordance with Western Australian Government guidelines (DoIR 2006). An internal target of 5% or less of SBM on drill cuttings released to sea will be set.
- A drilling environmental management plan will be prepared to meet the requirements of the OPGGS(Environment) Regulations and will describe controls for preventing the accidental release of SBMs.

3.5 Management controls—construction phase

The management controls to be implemented throughout the construction phase of the Project are outlined below.

Onshore-specific

- Large-scale vegetation clearing and earthworks will preferentially be undertaken in dry-season conditions. Should clearing and earthworks be required to be undertaken during the wet season, adequate control measures will be implemented to avoid erosion and sedimentation impacts.
- Cleared vegetation will be mulched and stockpiled on site boundaries. The mulch will be used for soil stabilisation and rehabilitation purposes where possible. Mulched vegetation that will not be reused will be disposed of off site.
- Erosion protection infrastructure (e.g. silt fencing, contouring, and sediment ponds) will be installed to ensure that sediment is contained within the site boundaries as far as practicable.
- If soil erosion is evident, exposed surfaces at the affected area will be stabilised with mulched vegetation, dust suppressants or slope stabilisation products.
- Treated wastewater is being considered for use during construction, particularly for irrigation or construction purposes. If this option is adopted, water quality will meet all regulatory requirements for irrigation.
- Temporary sediment systems will be regularly maintained to clear silt and aquatic vegetation to prevent the creation of habitat suitable for breeding mosquitoes.
- All borrow pits in the onshore development area will be rendered free-draining on completion of construction.

3.6 Management controls—precommissioning phase

The management controls to be implemented throughout the precommissioning phase of the Project are outlined below. Precommissioning includes an integrity test of the LNG train and storage tanks prior to the introduction of hydrocarbons.

Applicable to both onshore and offshore

- Hydrotest management plans will be developed in consultation with regulatory authorities and will be implemented prior to precommissioning. The procedure will include hydrotest discharge water-quality requirements and discharge options.
- The biocides used in hydrotest water will be of the lowest practicable toxicity without compromising operational requirements.
- The use and choice of chemicals in hydrotest water will be based on their low potential for environmental harm and their concentration in the water will be kept to as low a level as is reasonably practicable.
- Modules will be precommissioned off site if possible.
- During dewatering of the gas export pipeline, treated water (approximately 1 GL) will be discharged at the offshore facility.

Onshore-specific

In addition to the management controls described above, hydrotest water will be reused where practicable for onshore operations. If hydrotest wastewater is discharged into Darwin Harbour then a licence will be sought under the *Water Act* (NT).

Offshore-specific

Hydrodynamic modelling of hydrotest water plumes from the gas export pipeline will be undertaken prior to the commissioning phase in order to be able to predict the dispersion of pollutants into the offshore marine environment.

3.7 Management controls—operations phase

Onshore-specific

Surface water drainage channels will be regularly maintained to clear silt and aquatic vegetation in order to prevent the creation of habitat suitable for breeding mosquitoes.

Maintenance practices during the operations phase (e.g. drainage of hydrocarbons from tanks and equipment) will avoid discharge of hydrocarbons to the oily-water treatment system.

Nearshore- and offshore-specific

Vetting procedures for condensate tankers will be developed and implemented, ensuring that ballast water tanks are segregated from fuel and product tanks.

4 MONITORING

Monitoring activities will be undertaken throughout the life of the Project in relation to the identified objectives and targets. The activities listed below will be undertaken as part of the liquid discharges, surface water runoff and drainage management monitoring program:

Water-quality monitoring of liquid discharges applicable to both onshore and offshore

The monitoring strategies to be implemented for both the offshore and onshore operations are outlined below:

- Workplace "housekeeping" inspections will be undertaken to ensure that there are no spills within drainage systems or bunded areas and that remediation measures are implemented.
- Monitoring of liquid discharge incidents will be undertaken through INPEX's and its contractors' incident-reporting databases.

Water-quality monitoring of liquid discharges from offshore facilities

The monitoring strategies to be implemented for offshore operations and drilling activities are outlined below:

- The oil-in-water concentration in produced water will be measured continuously by an electronic meter and records will be retained.
- Periodic sampling of produced water discharges will be undertaken for full characterisation of the chemical components. Ecotoxicity testing of the produced water will be undertaken following water production.
- Calculations will be performed to determine well averages for SBM concentrations on dry drill-cutting discharges.
- Work will be carried out in collaboration with the SERPENT project[1] to determine the impacts of production drilling discharges on epibenthic macrofauna in the offshore area.

Water-quality monitoring of liquid discharges into Darwin Harbour

Water-quality monitoring strategies to be implemented for onshore operations are outlined below:

- Wastewater streams will be sampled at appropriate frequencies and selected water quality parameters will be documented.
- A Darwin Harbour water quality monitoring program will be developed by INPEX to determine if the Project's effluent discharges adversely impact on water quality in the Harbour.
- Validation of wastewater discharge dispersion modelling will be undertaken at the product loading jetty discharge location.

Surface water runoff and groundwater monitoring

The monitoring strategies to be implemented for onshore operations are outlined below:

- Baseline groundwater analysis will be used as the benchmark for comparisons of groundwater levels and quality.
- A groundwater quality monitoring program will be developed to determine if development in the onshore development area adversely impacts on groundwater quality.
- A mangrove health monitoring program will be developed to determine if Project activities in the onshore development area adversely impact on mangrove health.
- A marine sediments and bio-indicators monitoring program will be developed to assess any accumulation of metals and petroleum hydrocarbons in sediments and selected bio-indicators that might result from surface water and groundwater flows from the onshore facility.
- Periodic visual monitoring for soil erosion will be carried out during the construction phase.
- Regular inspections will be carried out in locations identified as high-risk areas for the breeding of mosquitoes, for example low-lying areas and sediment ponds during the construction phase, or holding basins and similar structures during the operations phase.

1 The SERPENT (Scientific and Environmental ROV Partnership using Existing iNdustrial Technology) project is a global collaborative project hosted by the DEEPSEAS group within the Ocean Biogeochemistry and Ecosystems Group at the National Oceanography Centre in Southampton, UK.

Triggered management response

A management response will be triggered by any of the following three circumstances:

1. a liquid discharge, surface water runoff or drainage "incident"
2. an exceedance of monitoring criteria
3. the identification by an annual management review of a failure to meet an objective or target.

The responses to these are outlined below.

Response to liquid discharge, surface water runoff or drainage "incidents"

A non-compliant liquid discharge, surface water runoff or drainage event will be classified as an "incident". Detection of incidents will trigger internal notifications, reporting requirements, investigation and associated corrective and preventive actions.

Liquid-discharge and related incidents will include the following:

- an event such as a spill that has led to the contamination of a wastewater stream and has the potential to significantly alter combined jetty discharge outputs
- disposal of sewage from construction and supply vessels not in accordance with MARPOL 73/78 prescriptions and the Marine Pollution Regulations (NT).

The level of investigation will be dependent on the potential risk associated with the event. Corrective and preventive actions that may be triggered as a result of a liquid-discharge or related incident investigation could include the following:

- the reviewing and updating of procedures and plans associated with the management of liquid discharges, surface water and drainage and of accidental spills
- the provision of refresher training for personnel on the Project processes laid down for liquid discharge, surface water and drainage management as well as on spill clean-up techniques.

INPEX's Incident Reporting, Recording and Investigating Procedure or the Project contractor's document equivalent (approved by INPEX) will be used to determine incident severity, potential risk and associated reporting, recording and investigating requirements. All liquid-discharge, surface water runoff and drainage incidents and "near misses" will be entered into INPEX's and its contractors' incident databases and corrective actions will be tracked to closure.

Response to an exceedance of liquid discharge, surface water or drainage monitoring criteria

Liquid-discharge, surface water or drainage monitoring criteria exceedances could include any of the following scenarios:

- The combined jetty discharge from the onshore facility exceeds identified design specifications.
- Petroleum hydrocarbons in produced water discharged to sea exceeds an average of 30 mg/L over any 24-hour period (in contravention of Regulation 29 of the OPGGS(Environment) Regulations 2009 (Cwlth)).
- Discharges to sea from oil-and-water separation systems on offshore and nearshore construction and supply vessels exceed the oil-in-water concentration of <15 mg/L set by MARPOL 73/78.
- Well averages for SBM concentrations on dry drill-cutting discharges are greater than 10% by weight.
- Reduced vigour or die-offs are noted in hinterland mangroves which may be dependent on groundwater infiltration or surface water runoff.
- The presence of mosquito larvae within high-risk breeding areas, sediment ponds and holding basins or similar.
- There is evidence of soil erosion in the onshore development area.

Responses to exceedance of liquid-discharge, surface water or drainage monitoring criteria could include the following:

- the identification of the cause (or source) of the liquid discharge exceedance, the reduction in loads of the contaminant of concern (i.e. source control), and in situ remedial work
- the stabilisation of exposed surfaces of eroded areas with mulched vegetation, dust suppressants or slope stabilisation products
- the institution of a spraying program for mosquito larvae, the maintenance of sediment ponds (removal of aquatic vegetation, clearing of silt, etc.), and the removal of pooled areas through levelling
- an increase in the monitoring frequency of relevant parameters at control and impact monitoring sites
- a review and update of existing management controls and procedures associated with liquid discharges, surface water runoff and drainage.

Response to adverse findings by an annual management review

Failure to meet identified objectives and targets will trigger the following responses:

- a review and audit of current liquid discharge and drainage management practices to assess the practicability of their implementation, to identify new sources of liquid discharges, and to assess the resources required to implement the management plan
- a review of current internal objectives and targets to assess achievability.

The response to the results of investigations and audits may include the following actions:

- an update of plans and associated documentation to reflect changes to liquid-discharge and drainage management practices
- the arrangement of refresher training for personnel, to cover site liquid-discharge and drainage management practices and processes.

5 REPORTING, AUDITING AND REVIEW

Reporting, auditing and reviews will be undertaken throughout all phases of the Project. A summary of the reporting, auditing and review requirements relating to liquid-discharge, surface water runoff and drainage management is provided in the following two sections.

5.1 All phases

The following reporting, auditing and review measures will be put in place for all phases of the Project:

- The quantities of liquids discharged to the marine environment or treated and reused will be recorded.
- Incidents resulting from mismanagement of liquid discharges will be reported in accordance with INPEX's Incident Reporting, Recording and Investigating Procedure or the Project contractor's document equivalent (approved by INPEX).
- An annual INPEX environmental report for the Project will be produced and will include details of all incidents relating to liquid discharges, surface water runoff and drainage management.
- INPEX and its contractors will conduct internal compliance audits on a periodic basis.
- Records will be audited periodically to ensure that all personnel on site have completed the required HSE induction.
- Detailed liquid discharges, surface water runoff and drainage management documentation, for example plans and procedures, will be reviewed periodically to ensure that they remain applicable to current operations and compliant with the requirements of INPEX and the regulatory authorities.

5.2 Construction, commissioning and decommissioning phases

In addition to the reporting requirements described above, during the construction, commissioning and decommissioning phases of the Project all contractors will be required to produce and provide to INPEX a monthly environmental report which will include a record of environmental incidents.

6 SUPPORTING DOCUMENTATION

This provisional EMP is one document in a suite of plans, procedures and processes designed to ensure that INPEX's liquid discharges, surface water runoff and drainage management activities are undertaken in compliance with legislative requirements and in a safe and environmentally responsible manner.

Documentation or processes addressing the issues outlined below have been or will be developed to further support the implementation of INPEX's liquid discharges, surface water runoff, and drainage management requirements:

- incident reporting, recording and investigating
- chemical and hazardous substance management
- equipment maintenance
- bunding and sump inspection
- hydrotest discharge
- health, safety and environment site induction (offshore and onshore).

7 APPLICABLE LEGISLATION, STANDARDS AND GUIDELINES

INPEX is committed to complying with all relevant laws, regulations and standards. Legislative instruments, standards and guidelines specifically related to liquid discharges, surface water runoff and drainage include the following:

- Department of Industry and Resources. 2006. *Petroleum guidelines: drilling fluids management*. Environment Division, Department of Industry and Resources, Perth, Western Australia.
- Department of Industry, Tourism and Resources. 2005. *Petroleum (Submerged Lands) Acts: schedule—specific requirements as to offshore petroleum exploration and production*. Department of Industry, Tourism and Resources (now the Department of Resources, Energy and Tourism), Canberra, ACT.

- Department of Natural Resources, Environment and the Arts. 2006. *Environmental guidelines for reclamation in coastal areas*. Information guidelines originally prepared by the Environment Protection Agency (now the Environment, Heritage and the Arts Division of the Department of Natural Resources, Environment, the Arts and Sport) for the Northern Territory Government, Darwin, Northern Territory.
- *Environment Protection (Sea Dumping) Act 1981* (Cwlth).
- International Maritime Organization. 1978. *International convention for the prevention of pollution from ships, 1973, as modified by the protocol of 1978 relating thereto (MARPOL 73/78)*. International Maritime Organization, London, United Kingdom.
- *Marine Pollution Act* (NT).
- Marine Pollution Regulations (NT).
- *Offshore Petroleum and Greenhouse Gas Storage Act 2006* (Cwlth).
- Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009 (Cwlth).
- *Protection of the Sea (Prevention of Pollution from Ships) Act 1983* (Cwlth).
- *Waste Management and Pollution Control Act* (NT) and the associated "Compliance Guidelines" prepared by the Department of Natural Resources, Environment and the Arts (now the Department of Natural Resources, Environment, the Arts and Sport), Darwin, Northern Territory.
- Waste Management and Pollution Control (Administration) Regulations (NT).
- *Water Act* (NT).

8 REFERENCES

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DHF—*see* Department of Health and Families.

DITR—*see* Department of Industry, Tourism and Resources.

DoIR—see Department of Industry and Resources.

Provisional Onshore Spill Prevention and Response Management Plan

Annexe 11 – Chapter 11 *Environmental Management Program*

1 OVERVIEW

As part of the approvals process for the Ichthys Gas Field Development Project (the Project), it is necessary that INPEX should show that it has taken, and will take, all practicable steps to properly manage the risks associated with, and the potential environmental impact of, hydrocarbon and chemical spills that may occur during the lifetime of the Project in the onshore development area.

During all phases of the Project, chemicals, hydrocarbons and liquid wastes will be handled, stored and transported in and around the onshore development area. While preventive measures to stop the release of these materials into the environment will be in place, there is the possibility that spills and leaks could occur through accidents or equipment failure.

The potential impact from an accidental spill or leak at the onshore facility will depend on the location of the spill or leak, the nature of the receiving environment, the type of material released, and its volume. Spills or leaks in areas of the onshore facilities that have appropriate preventive measures in place (e.g. bunded hardstand areas for fuel storage) will have less effect on environmental receptors than a spill or leak in an area outside the boundaries of the facilities such as a leak from a pipeline.

During the early construction phase of the Project the storage and handling of chemicals and hazardous substances (including wastes) will need to be carefully managed as there will not be permanent infrastructure (e.g. hardstand bunded areas) in place for the management and control of spills or leaks.

This provisional environmental management plan (EMP) for onshore spill prevention and response is attached as Annexe 11 to Chapter 11 *Environmental management program* of the Project's draft environmental impact statement (Draft EIS). It is one of a suite of similar EMPs dealing with different aspects and activities of the Project. These provisional EMPs will form the basis for the development of more detailed environmental management documentation, for example plans and procedures for the various phases of the Project as well as for specific activities associated with the Project. The detailed documentation will be prepared either directly by INPEX's Environmental Department or by specialist contractors in conjunction with INPEX.

1.1 Purpose and scope

The purpose of this provisional EMP is as follows:

- It demonstrates how INPEX, through identifying suitable spill prevention and response management controls, intends to minimise the environmental impact of accidental spills as a result of Project activities.
- It describes the proposed monitoring requirements for all phases of the Project.
- It describes the proposed reporting, review and audit requirements for all phases of the Project.
- It will guide the development of future more detailed environmental documentation such as the plans, procedures, etc., which will be required throughout the life of the Project.

The scope of this provisional EMP includes all spills which may occur inside the boundaries of the onshore facilities as well as all spills which may take place in the onshore terrestrial environment, throughout all phases of the Project.

This provisional EMP does not apply to spills to the offshore and nearshore marine environment or spills on support vessels as these are addressed under separate oil-spill contingency plans and shipboard oil-pollution emergency plans.

1.2 Potential sources of onshore spills or leaks

During all phases of the Project, potential sources of chemical or hydrocarbon spills or leaks will include the following:

- earthmoving equipment (e.g. excavators, graders and scrapers)
- construction or operations vehicles (e.g. cranes, trucks and forklifts)
- accidental release of wastewater from bunds and sumps containing hydrocarbons or chemicals
- process equipment maintenance
- process equipment and piping failure
- storage vessel or distributor line failures
- refuelling and transfer operations
- incorrect storage and handling of chemicals or hydrocarbons
- long-term slow leaks from tanks or vessels.

1.3 Potential impacts

Potential impacts associated with onshore spills and leaks of chemicals or hydrocarbons as a result of Project activities include the following:

- contamination of soil
- contamination of surface water
- contamination of groundwater which could flow into Darwin Harbour
- toxic effects to plant and animal life.

The potential environmental impact from an accidental spill or leak will depend on the nature of the material released, the volume of the material released, and the location and receiving environment of the spill or leak.

2 OBJECTIVES, TARGETS AND INDICATORS

The objectives, targets and indicators set out by INPEX for onshore spill prevention and response management are shown in Table 2-1. The engineering and management controls to be implemented to help to achieve these targets are described in Section 3 *Management approach*.

3 MANAGEMENT APPROACH

Detailed onshore spill prevention and response management documentation, for example plans and procedures, will be developed for all phases of the Project. These detailed documents will align with this provisional onshore spill prevention and response EMP. The detailed documentation will be prepared either directly by INPEX's Environmental Department or by specialist contractors in conjunction with INPEX.

A summary is provided below of the main engineering and management controls to be included in the detailed documentation to mitigate the risks associated with chemical and hydrocarbon spills and leaks.

3.1 Engineering controls—design phase

The engineering controls to be implemented during the design phase of the Project include the following:

- Onshore facilities will be designed and constructed in such a way that spills and leaks can be constrained or isolated, particularly in areas where there is an elevated risk of spill.
- Bunding will be provided for chemical and hydrocarbon storage, handling and transfer areas. It will be designed in accordance with the relevant Australian standards as well as with the requirements of the regulatory authorities.
- Storage facilities for hazardous goods and wastes will be designed in accordance with the prescriptions of the relevant Australian standards as well as with the requirements of the regulatory authorities.

3.2 Management controls—all phases

The management controls to be implemented throughout all phases of the Project are outlined below:

- Detailed spill prevention and response management plans or procedures will identify potential spill sources, the material type (hydrocarbon, chemical, etc.), clean-up methods for various material types, and the locations and contents of spill response kits.
- Chemicals and hazardous substances used during all phases of the Project will be selected and managed to minimise the potential adverse environmental impact associated with their transport, transfer, storage, use and disposal.
- Chemicals and hazardous substances will be stored, transported and handled in accordance with Australian standards and regulatory requirements.
- A tiered management response approach will be developed and implemented for the management of spills of hydrocarbons or chemicals.

Table 2-1: Onshore spill prevention and response management objectives, targets and indicators

Objectives	Targets	Indicators
Prevent environmental impacts from chemical spills during all phases of the Project.	• Zero environmental incidents resulting in environmental impact from chemical spill events.	• Number of incident reports and severity of incidents resulting from chemical spill events.
Prevent environmental impacts from hydrocarbon spills during all phases of the Project.	• Zero environmental incidents resulting in environmental impact from hydrocarbon spill events.	• Number of incident reports and severity of incidents resulting from hydrocarbon spill events.
Establish and maintain personnel awareness of the importance of good spill prevention and response management practices during all phases of the Project.	• All workforce members (including contractors) to complete a health, safety and environment (HSE) induction, which will include information on spill management practices.	• Number of people accessing the site as recorded by security. • Number of people completing an HSE site induction.

- All spills of hydrocarbons and chemicals are to be cleaned up immediately and reported to a supervisor. An incident report will be raised and it will contain, as a minimum, details of the quantity of spilt material, the type of spill (hydrocarbon or chemical), a description of the receiving environment, the location of the spill incident, and how the spill was dealt with. Notifications to government will be made in accordance with detailed onshore spill prevention and response plans or procedures.
- Spill response materials and equipment (including personal protective equipment) will be available during all phases and will contain equipment to combat both chemical and hydrocarbon spills.
- Material safety data sheets (MSDSs) will be available on the facilities to aid in the identification of appropriate spill clean-up and disposal methods.
- Disposal of spill clean-up materials will be managed as prescribed in the detailed waste management plans. Materials (e.g. contaminated absorbents) will be contained and taken to a hazardous-waste storage facility. All containers will be appropriately marked with, as a minimum, labels identifying the type of contaminant they hold. The materials used to construct the containers will be compatible with the chemicals they will contain.
- Whenever practical, refuelling will take place at permanent locations designed and constructed in accordance with Australian standards and regulatory authority requirements.
- Safe fuel transfer procedures will be developed and implemented.
- Bund drain valves will remain closed during normal operations.
- Bunds and sumps will be inspected on a regular basis, in particular prior to extreme weather events and after rain has fallen.
- Regular inspections and preventive maintenance of storage areas and equipment will be undertaken to prevent spills through equipment failure.
- Where practicable, maintenance activities will be performed in areas that are purpose-built with catchments and sumps.
- Where required, bunds and sumps will be drained of standing clean water during the wet season to prevent the contamination of large volumes of water should a spill occur and the overflow of potentially contaminated water to grade during heavy rains.
- Equipment and activities will preferentially be sited in established containment systems, or temporary systems will be used where this is not feasible or effective.
- Stormwater drains are to be kept clean of hydrocarbon or chemical spills.
- Soil contaminated by an onshore spill will either be treated in situ or be removed for treatment and appropriately disposed of in accordance with the detailed onshore waste management plan.
- Personnel (including contractors) will be required to attend inductions when first attending site during the construction, commissioning and operations phases of the Project. The induction sessions will include specific information on the appropriate handling and storage of hazardous materials (e.g. petroleum products), the best practices both for preventing and for cleaning up spills, and training in the site incident reporting procedure.
- Personnel who routinely handle hazardous materials or wastes (e.g. refuelling personnel, pump operators, mechanics, and stores personnel) will receive training in handling, transporting and storing hazardous materials or wastes; in reporting and documentation requirements; and in spill clean-up techniques and practices.
- Personnel forming the emergency response team will receive training on response actions to be taken in the event of a chemical and/or hydrocarbon spill.

3.3 Management controls—construction phase

During the construction phase, appropriate temporary containment facilities will be provided for the storage of chemicals and hydrocarbons and for the storage of hazardous waste until permanent infrastructure is in place.

3.4 Management controls—commissioning and operations phases

Management controls to be implemented throughout the commissioning and operations phases of the Project are outlined below:

- Hydrocarbon or chemical spills in bunds and sumps will be cleaned using absorbent materials, skimmers, or similar (if safe and practical to do so), prior to washing down to an oil-and-water separator for treatment.
- Chemicals and hazardous substances proposed for use by contractors will be submitted for review and approved for use prior to reaching site. This will apply, for example, to external contractors who may be required for such activities as non-routine maintenance activities, large maintenance shutdowns, and cleaning.

4 MONITORING

Monitoring activities will be undertaken throughout the life of the Project in relation to the identified objectives and targets. The activities listed below will be undertaken as part of the hydrocarbon and chemical spill monitoring:

- Hydrocarbon and chemical spill incidents will be monitored through INPEX's and its contractors' incident-reporting databases.
- Records of liquids received, stored and dispensed will be maintained and reconciled.
- Inspections of the process and storage facilities for signs of spills or leaks will be undertaken on a regular basis.
- Bunds and sumps will be inspected regularly and kept free of hydrocarbon or chemical accumulations.
- A periodic analysis will be undertaken of data in incident-reporting databases in order to identify areas with more frequent spill occurrences.
- A groundwater quality monitoring program will be developed to assess water quality and to detect signs of spills or leaks that may occur during the operations phase.
- A marine sediments and bio-indicators monitoring program will be developed to assess any accumulation of metals and petroleum hydrocarbons in sediments and selected bio-indicators that might result from surface water and groundwater flows from the onshore facility.

Triggered management response

A management response will be triggered by either of the following two circumstances:

1. a spill or leak "incident"
2. the identification by an annual management review of a failure to meet an objective or target.

The responses to these are outlined below.

Response to spill or leak "incidents"

Any spill or leak will be classified as an "incident". Spill incidents could include the following:

- a chemical or hydrocarbon spill or leak that is contained and not released to the environment, but had the potential to do so
- a hydrocarbon or chemical spill or leak that has not been contained in a hardstand bunded area and has been released to the environment.

The detection of incidents associated with chemical or hydrocarbon spills or leaks will trigger internal notifications, reporting requirements, investigations and associated corrective and preventive actions.

The level of investigation will depend on the potential risk associated with the event. Corrective and preventive actions that may be triggered as a result of the investigation would include spill clean-up, ongoing monitoring of the affected site, the review and update of procedures or plans associated with spill management and/or refresher training for personnel on Project spill-management processes.

INPEX's Incident Reporting, Recording and Investigating Procedure or the Project contractor's document equivalent (approved by INPEX) will be used to determine incident severity, potential risk and associated reporting, recording and investigation requirements. All hydrocarbon and chemical spills, "near misses" and incidents will be entered into INPEX's and its contractors' incident databases and corrective actions will be tracked to closure. As a minimum, details of the quantity of spilt material, the type of spill (hydrocarbon or chemical), a description of the receiving environment, the location of the spill incident, and how the spill was dealt with are required when reporting spills.

Response to adverse findings by an annual management review

Failure to meet identified objectives and targets will initiate the following responses:

- a review of existing internal objectives and targets to reassess achievability
- an interrogation of incident data to determine the frequency and location of spills on site, to assist in identifying areas where problems recur.

The response to the results of investigations and audits may include the following:

- increased maintenance requirements for problem equipment or the replacement of equipment
- ongoing monitoring (e.g. of groundwater, vegetation) of a spill-affected area to determine if mitigation measures have been effective
- an update of plans or procedures to reflect changes to the management of spill prevention and response
- refresher training for personnel on the practices and processes developed for the Project on how to prevent and respond to spills
- refresher training for personnel on the storage and handling of chemicals and hydrocarbons.

5 REPORTING, AUDITING AND REVIEW

Reporting, auditing and reviews will be undertaken over the various phases of the Project. A summary of the reporting, auditing and review requirements relating to hydrocarbon and chemical spills is provided in the following two sections.

5.1 All phases

The reporting, auditing and review requirements applicable to all phases of the Project are as follows:

- Incidents resulting in any hydrocarbon or chemical spills as a result of Project activities will be reported in accordance with INPEX's Incident Reporting, Recording and Investigating Procedure or the Project contractor's document equivalent (approved by INPEX).
- An annual INPEX environmental report for the Project will be produced. It will include details of the occurrences of hydrocarbon and chemical spills, their frequency, and the volumes spilled.
- INPEX and its contractors will conduct internal compliance audits on a periodic basis.
- Records will be audited periodically to ensure that all personnel on site have completed the required HSE induction.
- Detailed onshore spill prevention and response management documentation, for example plans and procedures, will be reviewed periodically to ensure that they remain applicable to current operations and compliant with the requirements of INPEX and the regulatory authorities.

5.2 Construction, commissioning and decommissioning phases

In addition to the reporting requirements described above, during the construction, commissioning and decommissioning phases of the Project, contractors will be required to produce and provide to INPEX a monthly environmental report which will include a record of environmental incidents.

6 SUPPORTING DOCUMENTATION

This provisional plan is one document in a group of plans, procedures and processes designed to ensure that INPEX's onshore spill prevention and response management activities are undertaken in compliance with legislative requirements and in a safe and environmentally responsible manner.

Documentation or processes addressing the issues outlined below have been or will be developed to further support the preparation of INPEX's detailed onshore spill prevention and response management documentation:

- equipment maintenance
- chemical and hazardous substance management
- fuel transfer
- incident reporting, recording and investigating
- waste
- oil spill contingency
- HSE site induction.

7 APPLICABLE LEGISLATION, STANDARDS AND GUIDELINES

INPEX is committed to complying with all relevant laws, regulations and standards. Legislative instruments, standards and guidelines specifically related to spills or storage and handling requirements for hydrocarbons and chemicals include the following:

- *AS 1940:2004, The storage and handling of flammable and combustible liquids*.
- *AS/NZS 2243.10:2004, Safety in laboratories—Storage of chemicals*.
- *AS 3780:2008, The storage and handling of corrosive substances*.
- *AS/NZS 3833:2007, The storage and handling of mixed classes of dangerous goods, in packages and intermediate bulk containers*.
- *AS 4326:2008, The storage and handling of oxidizing agents*.
- *AS/NZS 4452:1997, The storage and handling of toxic substances*.
- *AS/NZS 4681:2000, The storage and handling of Class 9 (miscellaneous) dangerous goods and articles*.
- Petroleum (Occupational Health and Safety) Regulations (NT).
- *Waste Management and Pollution Control Act* (NT) and the associated "Compliance Guidelines" prepared by the Northern Territory's Department of Natural Resources, Environment and the Arts (now the Department of Natural Resources, Environment, the Arts and Sport).
- Waste Management and Pollution Control (Administration) Regulations (NT).

Provisional Piledriving and Blasting Management Plan

Annexe 12 – Chapter 11 *Environmental Management Program*

1 OVERVIEW

As part of the approvals process for the Ichthys Gas Field Development Project (the Project), it is necessary that INPEX should show that it has taken and will take all practicable steps to properly manage the risks associated with, and the potential environmental impacts of, the piledriving and blasting activities undertaken both onshore and offshore during the construction phase of the Project.

Terrestrial blasting activities during the construction phase (should they be required) will cause some ground vibration but this will be limited. Animals close to blasting sites are expected to be affected by the percussion shock from the explosions. However, it is expected that the human activity in an area prior to the commencement of blasting will drive most of the larger animals temporarily away.

Marine piledriving and blasting activities have the potential to affect marine mammals (i.e. whales, dolphins and dugongs) and other animal groups (e.g. fish, turtles and birds). Underwater noise is influenced by a number of factors, including the frequency of the sound, absorption losses, the sound speed profile throughout the water column, the bathymetry of the area, and the nature of the seabed.

This provisional environmental management plan (EMP) for piledriving and blasting is attached as Annexe 12 to Chapter 11 *Environmental management program* of the Project's draft environmental impact statement (Draft EIS). It is one of a suite of similar EMPs dealing with different aspects and activities of the Project. These provisional EMPs will form the basis for the development of more detailed environmental management documentation, for example plans and procedures for the various phases of the Project as well as for specific activities associated with the Project. The detailed documentation will be prepared either directly by INPEX's Environmental Department or by specialist contractors in conjunction with INPEX.

1.1 Purpose and scope

The purpose of this provisional EMP is as follows:

- It demonstrates how INPEX will minimise the potential environmental impact of piledriving and blasting activities undertaken during the construction phase (both offshore and onshore) through the identification of suitable management controls.
- It demonstrates how INPEX will minimise the potential impacts of piledriving and blasting activities on "matters of national environmental significance"[1] during the construction phase (both offshore and onshore) through the identification of suitable management controls.
- It describes the proposed monitoring requirements for all phases of the Project.
- It describes the proposed reporting, review and audit requirements for all phases of the Project.
- It will guide the development of future more detailed environmental documentation such as the plans, procedures, etc., which will be required for the construction phase of the Project.

The scope of this provisional EMP includes piledriving and blasting (marine and terrestrial) activities undertaken in the Project's construction phase.

1.2 Potential impacts

Potential impacts on marine and terrestrial fauna which are associated with piledriving and blasting activities include the following:

- temporary displacement or disturbance of marine and terrestrial animals
- temporary or permanent hearing-threshold shifts in marine animals
- physical injuries caused to marine animals
- deaths of marine animals.

1 "Matters of national environmental significance" are defined in the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth).

2 OBJECTIVES, TARGETS AND INDICATORS

The objectives, targets and indicators set out by INPEX for piledriving and blasting management are shown in Table 2-1. The engineering and management controls to be implemented to help to achieve these targets are described in Section 3 *Management approach*.

Table 2-1: Piledriving and blasting management objectives, targets and indicators

Objectives	Targets	Indicators
Avoid potential impact to cetaceans, dugongs, turtles or crocodiles during blasting activities.	• Zero incidents from blasting activities impacting on cetaceans, dugongs, turtles or crocodiles.	• Number of incident reports from blasting activities impacting on cetaceans, dugongs, turtles or crocodiles.
Avoid potential physiological damage to cetaceans, dugongs, turtles or crocodiles during blasting activities.	• No cetaceans, dugongs, turtles or crocodiles within the fauna protection zone (see Section 3.1) during the detonation of a blast.	• Number of cetaceans, dugongs, turtles or crocodiles within the fauna protection zone during the detonation of a blast.
Avoid potential physiological damage to cetaceans, dugongs, turtles or crocodiles during piledriving activities.	• No cetaceans, dugongs, turtles or crocodiles within a radius of 100 m of the piledriving activity area prior to the "soft start" (see table footnote) of a piledriving session.	• Number of cetaceans, dugongs, turtles or crocodiles observed to be within a radius of 100 m during the "soft start" of a piledriving session.
Avoid deaths of seabirds or other scavenging species foraging for dead fish in blast zones.	• No seabird or other scavenging animal deaths attributable to blasting activities.	• Number of dead animals found.
Establish and maintain awareness of piledriving and blasting impacts on the environment and the management measures put in place to mitigate them during all phases of the Project.	• Relevant workforce personnel (including contractors) to complete activity-specific health, safety and environment (HSE) induction, which will include information on piledriving and blasting impacts and management practices.	• Number of people completing HSE inductions.
Maintain appropriate safety exclusion zone (see Section 3.1) around blasting activities to ensure public safety.	• Zero incidents of marine traffic or recreational water-users identified in the safety exclusion zone.	• Records of safety exclusion zone breaches during blasting operations.

Note: The "soft-start" technique involves gradually scaling up piledriving activities over a 5-minute period. The piledriving blows start at low-impact levels and work up to full impact, providing an opportunity for any impact-sensitive animals that happen to be in the vicinity to leave the area before they are exposed to the full intensity of underwater noise.

3 MANAGEMENT APPROACH

Detailed piledriving and blasting documentation, for example plans and procedures, will be developed for the construction phase of the Project. These documents will align with this provisional piledriving and blasting EMP. The detailed documentation will be prepared either directly by INPEX's Environmental Department or by specialist contractors in conjunction with INPEX.

A summary of the main management controls to be employed in the detailed documentation to mitigate the risks associated with piledriving or blasting activities is provided below.

3.1 Blasting management controls—construction phase

The management controls to be implemented for blasting activities during the construction phase of the Project are as follows.

Applicable to both onshore and nearshore environments

- Blasting operations will only be undertaken during daylight hours and adequate notice will be provided to people who could be affected by the sound or activities (e.g. Darwin Harbour users, the citizens of Palmerston and the workforce at the Darwin Liquefied Natural Gas plant at Wickham Point).
- Only the minimum required charge will be used for onshore and nearshore blasting operations.
- A permit-to-work (or similar) system will be implemented on site to ensure that areas where onshore and nearshore blasting activities are occurring, or will occur, are clearly identified and that management measures are in place prior to work commencing.
- The drill-and-blast program will be designed to ensure that no damage occurs to buildings, the Bayu–Undan Gas Pipeline, wharf structures or any other underwater infrastructure.

Onshore-specific

- Smaller staggered blasts will be carried out to minimise vibration and noise levels from blasting activities.
- Blasting teams will ensure that the correct "maximum instantaneous charge" and blast-hole sizes are used in order to minimise flyrock generation.
- Access to the onshore development area will be managed to ensure that there are no members of the public within the site boundaries.

Nearshore-specific

- Confined blasting methods will be used, with micro-delays between charges to reduce peak pressure levels of each blast in the surrounding waters.
- Fauna protection zones will be developed for nearshore blasting. The extent of these zones will be determined once detailed geotechnical investigations have been completed and further information from drill and blast contractors has become available.
- Trained marine fauna observers will survey the fauna protection zones prior to the commencement of blasting. If marine megafauna (e.g. cetaceans, dugongs, turtles and crocodiles) are observed to enter the fauna protection zone, blasting activities will be suspended. Detonations will only be permitted if the fauna protection zone is observed to be free of marine megafauna for a period of at least 20 minutes.
- For effective surveillance, blasting will only be conducted during the hours of daylight and in benign sea conditions so that observers will be better able to sight any large marine animals within the fauna protection zone.
- The potential to use passive or active acoustic monitoring to identify submerged marine animals within the fauna protection zone will be evaluated by field testing. If shown to be practicable, these methods are likely to be used to complement vessel-based surveys prior to the commencement of blasting activities.
- Notice will be given to the Northern Territory's Department of Lands and Planning and the Darwin Port Corporation advising vessel operators of any change to marine traffic conditions because of marine blasting activities.
- A safety exclusion zone for marine traffic and recreational water-users will be established around blasting areas. Public notices will be issued prior to blasting, to inform recreational water-users in any blasting area. INPEX will advise of the date, time and duration of the blasting activities and will provide details of the boundaries of the safety exclusion zone.
- Explosive casings will be selected to minimise the risk of floating debris which, if ingested, could be harmful to marine mammals, birds, turtles and fish.
- Should fish be killed as a result of blasting activities and float to the surface of the water, they will be retrieved in order to minimise the possibility of scavenging seabirds and other predators being injured by subsequent blasts.
- A permit to conduct marine blasting will be sought from the Department of Resources (formerly the Department of Regional Development, Primary Industry, Fisheries and Resources), as required under Section 16 of the *Fisheries Act* (NT).

3.2 Piledriving management controls—construction phase

The management controls to be implemented for piledriving activities during the construction phase of the Project are as follows.

Nearshore-specific

- It is intended that piledriving activities will be undertaken only during daylight hours. Night-time piledriving will only be resorted to if Project construction activities fall significantly behind schedule.
- A watch will be maintained for cetaceans, dugongs, turtles and crocodiles for a duration of 10 minutes prior to the "soft start" of piledriving activities. If any animal is observed within the "fauna observation zone", that is, within a radius of 100 m of the piledriving location, the "soft start" will not proceed until the animal has been observed to have moved outside the zone or is not sighted for 10 minutes.
- Piledriving will commence with the "soft-start" procedure, where activities are gradually scaled up over a 5-minute period. This will provide an opportunity for any sensitive marine animals to leave the area before being exposed to the full intensity of underwater noise.
- If piledriving is required after dark, the "soft-start" procedure will be the primary means of providing an opportunity for any sensitive marine animals to leave the area before being exposed to the full intensity of underwater noise.
- A permit-to-work (or similar) system will be implemented on site to ensure that areas where onshore and nearshore piledriving activities are occurring, or will occur, are clearly identified and that management measures are in place prior to work commencing.

4 MONITORING

Monitoring activities will be undertaken throughout the life of the Project in relation to the identified objectives and targets. The activities below will be undertaken as part of the piledriving and blasting monitoring program:

- Piledriving and blasting incidents will be monitored through INPEX's and its contractors' incident-reporting databases.
- Visual monitoring for cetaceans, dugongs, turtles and crocodiles will be undertaken for 10 minutes within a 100-m-radius fauna protection zone around the piledriving activity area prior to the "soft start".
- Visual monitoring for cetaceans, dugongs, turtles and crocodiles within the designated fauna protection zone for blasting work activity will be undertaken for 20 minutes prior to detonation.
- Visual monitoring of marine traffic and recreational water-users approaching the nearshore blasting area will be carried out.
- Visual monitoring of pedestrian, road and marine traffic will be undertaken to ensure that no one approaches active onshore blasting areas.

Triggered management response

A management response will be triggered by any of the following four circumstances:

1. a piledriving or blasting "incident"
2. a sighting of a cetacean, dugong, turtle or crocodile within a designated fauna protection zone
3. the detection of marine vessels or recreational water-users within a designated safety exclusion zone for blasting activities
4. the identification by an annual management review of a failure to meet an objective or target.

The responses to these are outlined below.

Response to piledriving or blasting "incidents"

Incidents likely to trigger an investigation will include the following:

- the death of or injury to a cetacean, dugong, turtle or crocodile as a result of piledriving or blasting activities
- a failure to provide observers for cetaceans, dugongs, turtles and crocodiles during piledriving or blasting activities
- a failure to adhere to the requirement that piledriving should be gradually scaled up over a 5-minute period before operating at full impact
- a failure to adhere to the requirement that piledriving or blasting activities may not commence until the fauna protection zone has been declared free of large marine animals after a designated period of observation.

Management responses to incidents will include the following:

- the reporting of death or injury to a cetacean, dugong, turtle or crocodile to the relevant regulatory authorities
- the provision of refresher training for personnel on Project piledriving and blasting management processes and procedures.

The detection of incidents associated with piledriving and blasting will trigger internal notifications, reporting requirements, investigation and associated corrective and preventive actions. The level of investigation will be dependent on the potential risk associated with the incident.

The INPEX Incident Reporting, Recording and Investigating Procedure or the Project contractor's document equivalent (approved by INPEX) will be used to determine incident severity, potential risk and associated reporting, recording and investigation requirements. All incidents will be entered into INPEX's and its contractors' incident databases and corrective actions will be tracked to closure.

Response to large marine animals within the designated fauna protection zone

Cetaceans, dugongs, turtles or crocodiles entering the fauna protection zone for blasting or piledriving activities will trigger the following responses:

- The piledriving activity "soft start" will not commence until the animal moves outside the 100-m-radius fauna protection zone or is not sighted for 10 minutes.
- Blasting activities will cease and work will not recommence until the cetacean, dugong, turtle or crocodile has moved outside the fauna protection zone or is not sighted for 20 minutes.

Response to detection of marine vessels or recreational water-users within the designated safety exclusion zone

Marine vessels and recreational water-users within the designated safety exclusion zone will trigger the following response:

- Blasting activities will cease and work will not recommence until marine vessels or recreational water-users have moved out of the safety exclusion zone.

Response to adverse findings by an annual management review

Failure to meet identified objectives and targets will trigger the following responses:

- a review and audit of current piledriving and blasting management practices to assess the practicability of their implementation, to identify new technology or methodology to further reduce impacts, and to assess resource requirements to enable the management plan to be implemented
- a review of current objectives and targets to assess achievability.

The response to the results of investigations and audits might include the following:

- an update of plans and associated documentation to reflect changes to piledriving and blasting management practices
- the provision of refresher training for personnel on Project piledriving and blasting management processes.

5 REPORTING, AUDITING AND REVIEW

Reporting, auditing and reviews will be undertaken during the construction phase of the Project. A summary of the reporting, auditing and review requirements relating to piledriving and blasting management is outlined below:

- Incidents resulting from piledriving and blasting will be reported in accordance with INPEX's Incident Reporting, Recording and Investigating Procedure or the Project contractor's document equivalent (approved by INPEX).
- Reporting of all confirmed incidents will be made to the relevant regulatory authorities (especially where an animal species is involved and is listed under the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth)).
- An annual INPEX environmental report for the Project will be produced and will include details of piledriving and blasting incidents.
- INPEX and its contractors will conduct internal compliance audits on a periodic basis.
- Records will be audited periodically to ensure that all personnel on site have completed the required HSE induction.
- Detailed piledriving and blasting management documentation, for example plans and procedures, will be reviewed periodically to ensure that they remain applicable to current operations and compliant with the requirements of INPEX and the regulatory authorities.
- Construction contractors will be required to produce and provide to INPEX a monthly environmental report which will include a record of all environmental incidents.

6 SUPPORTING DOCUMENTATION

This provisional EMP is one document in a suite of plans, procedures and processes designed to ensure that INPEX's piledriving and blasting management activities are undertaken in compliance with legislative requirements and in a safe and environmentally responsible manner.

Documentation or processes addressing the issues outlined below have been or will be developed to further support the implementation of detailed piledriving and blasting management documentation:

- incident reporting, recording and investigating
- visual monitoring of cetaceans, dugongs, crocodiles and turtles
- health, safety and environment site induction
- permit-to-work system.

7 APPLICABLE LEGISLATION, STANDARDS AND GUIDELINES

INPEX is committed to complying with all relevant laws, regulations and standards. Legislative instruments, standards and guidelines specifically related to noise and vibration management include the following:

- *AS 1055.1:1997, Acoustics—Description and measurement of environmental noise—General procedures.*
- *AS 2436:1981, Guide to noise control on construction, maintenance and demolition sites.*
- Environment Protection Agency Program. 2007. *Noise guidelines: construction sites*. Draft guidelines prepared by the Environment Protection Agency Program, Department of Natural Resources, Environment and the Arts (now the Department of Natural Resources, Environment, the Arts and Sport), Darwin, Northern Territory.
- *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth).
- Environment Protection and Biodiversity Conservation Regulations 2000 (Cwlth).
- *Fisheries Act* (NT).
- Petroleum (Occupational Health and Safety) Regulations (NT).
- *Waste Management and Pollution Control Act* (NT).

Provisional Quarantine Management Plan

Annexe 13 – Chapter 11 *Environmental Management Program*

1 OVERVIEW

As part of the approvals process for the Ichthys Gas Field Development Project (the Project), it is necessary that INPEX should show that it has taken, and will take, all practicable steps to properly manage the risks associated with, the potential introduction and establishment of marine or terrestrial invasive plant or animal species during all phases of the Project.

Invasive species of plants and animals can only colonise new habitats using the pathways available to them. Historically, natural pathways included wind, currents, rivers and mobile vectors such as birds and bats. In the case of the Project, the importation of materials and equipment as well as the importation and use of vehicles, boats and aircraft (and associated personnel) will create a number of new pathways that could be utilised by opportunistic and potentially invasive species.

The introduction of marine invasive species ("marine pests") into waters of the Project area can potentially threaten biodiversity, fisheries and other biological, commercial and recreational marine values of the area. The Commonwealth's Department of Agriculture, Fisheries and Forestry (DAFF), for example, estimates that in recent years more than 250 exotic marine species have been introduced into Australian waters, although not all have become pests (DAFF 2009).

Of all the marine-based activities associated with the Project, the nearshore activities, particularly during construction, present the greatest risk of introduction of marine pests. Introduction of a marine pest into the offshore development area is considered to pose only a minimal risk because of the depth of water in which the offshore infrastructure is located and the distance of the Ichthys Field from the Australian mainland (around 220 km).

Project activities also have the potential to introduce new terrestrial species of plants and animals into the onshore Project area on Middle Arm Peninsula in Darwin Harbour. This is likely to pose the biggest risk during the construction phase of the Project because of the increased number of international imports required at this time, and the use of excavation vehicles.

This provisional environmental management plan (EMP) for quarantine is attached as Annexe 13 to Chapter 11 *Environmental management program* of the Project's draft environmental impact statement (Draft EIS). It is one of a suite of similar EMPs dealing with different aspects and activities of the Project. These provisional EMPs will form the basis for the development of more detailed environmental management documentation, for example plans and procedures for the various phases of the Project as well as for specific activities associated with the Project. The detailed documentation will be prepared either directly by INPEX's Environmental Department or by specialist contractors in conjunction with INPEX.

1.1 Purpose and scope

The purpose of this provisional EMP is as follows:

- It demonstrates how INPEX will minimise the likelihood of any invasive species being introduced into the Project area and minimise the potential environmental impact of such an introduction, should it occur, through identified preventive quarantine management controls.
- It describes the proposed monitoring requirements for all phases of the Project.
- It describes the proposed reporting, review and audit requirements for all phases of the Project.
- It will guide the development of future more detailed environmental documentation, such as the plans, procedures, etc., which will be required throughout the life of the Project.

The scope of this provisional EMP includes the following:

- the quarantine requirements for international vessels sailing to or from the waters surrounding the offshore and nearshore Project areas
- the quarantine requirements for prefabricated modules and other direct imports from outside Australia, which are shipped directly to the module offloading facility on Blaydin Point
- the quarantine requirements for the mobilisation of clearing and excavation vehicles to the onshore development area.

This provisional EMP does not address the potential environmental impact of, or the management controls for, reducing the further spread of existing weed species in the onshore development area and their ongoing control, the sequestered quarantine waste from maritime vessels, or the direct imports from overseas offloaded at East Arm Wharf.

These are addressed as different aspects under the following EMPs:

- Provisional Vegetation Clearing, Earthworks and Rehabilitation Management Plan (Annexe 15 to Chapter 11)
- Provisional Waste Management Plan (Annexe 16 to Chapter 11).

As East Arm Wharf has common-user quarantine and customs facilities available, quarantine management of goods passing through that facility falls outside the scope of this EMP.

1.2 Plan definitions

Australian Quarantine and Inspection Service

The Australian Quarantine and Inspection Service (AQIS) is part of the Commonwealth's Department of Agriculture, Fisheries and Forestry. AQIS provides quarantine inspection services for the arrival of international passengers, cargo, mail, animals and plants or their products into Australia, and inspection and certification for a range of animal and plant products exported from Australia. It monitors products being imported that may present a risk to the health of Australia's people, plant life or animal life.

Biofouling

Biofouling in terms of the Ichthys Project can be defined as the growth of or fouling by marine species of plants and animals on the submerged portions of ships' hulls, oil and gas platforms, jetties, etc. Biofouling on maritime vessels can assist in the introduction, spread and potential establishment of marine pest species.

Ballast water

Ballast water is sea water that unladen ships carry to provide stability and then discharge when their cargo is loaded. However, as ballast water pumped into a ship at a given port will contain a wide variety of marine organisms, from plankton and the larvae of various marine organisms to fish and seaweeds, there is clearly a risk of bringing marine pests to the port where the ballast water is discharged. AQIS deems all salt water from ports and coastal waters outside Australia's territorial sea to present a high risk of introducing exotic marine pests into Australia (DAFF 2008a).

AQIS requires masters of vessels plying international waters to manage ballast water prior to arrival in Australia's territorial sea. (The territorial sea is the area out to 12 nautical miles from the Australian territorial sea baseline along the coast.)

Invasive species

Invasive species are defined by the International Union for Conservation of Nature and Natural Resources (IUCN) as "organisms—usually transported (directly or indirectly) by humans—which successfully establish themselves in, and then overcome, otherwise intact pre-existing native ecosystems" (IUCN 2008). They inevitably damage environmental, agricultural or other social resources once they take hold.

Invasive species of particular concern are recognised under Commonwealth, state, and territory laws. These laws will provide the basis for a list of species of concern to the Project.

Marine invasive species ("marine pests")

Marine pests in Australia are marine plants or animals that are not native to Australia and which have been translocated to Australian waters by various vectors, including ballast water discharged by commercial shipping; biofouling on hulls and inside internal seawater pipes of commercial and recreational vessels; aquaculture operations, by accident or by intention; and aquarium imports.

They may have a significant impact on human health, fisheries and aquaculture, shipping and ports, tourism, environmental values, biodiversity and ecosystem health. Marine pest infestations also have a large financial impact.

Quarantine

The definition of quarantine in this EMP is essentially the same as that laid down by the *Quarantine Act 1908* (Cwlth). The Act takes the scope of quarantine as including measures for the examination, exclusion, detention, observation, segregation, isolation, protection, treatment and regulation of vessels, installations, human beings, animals, plants or other goods or things. It also makes provision for the seizure and destruction of animals, plants or other goods or things. These measures have as their objective the prevention or control of the introduction, establishment or spread of diseases or pests that could cause significant damage to the ecosystems of the Project area, its animal and plant species, and the people who work there.

Quarantine-approved premises

Quarantine-approved premises (QAP) are post-border premises approved by the AQIS where post-entry quarantine activities (such as detailed inspections, fumigation, or the safe and secure removal of unwanted material, etc.) may be carried out responsibly so that the AQIS can be sure that quarantine tasks are performed with a minimal degree of risk.

Terrestrial invasive species

Terrestrial invasive species in the context of the Project's onshore development area in Darwin Harbour are plants and animals that are not native to northern Australia, which have the potential to survive in the onshore development area and which may threaten the environmental or social resources in the area by the damage they can cause.

1.3 Project quarantine pathways

The key Project pathways that have the potential to allow invasive species to become introduced or spread within the Project area are outlined in the following sections.

Marine quarantine pathways

The marine quarantine pathways for marine pest transfer into the offshore and nearshore Project areas are as follows:

- ballast-water exchange from vessels (domestic and international) sailing to or from the waters surrounding the offshore and nearshore Project areas
- biofouling by marine organisms on the hulls and other submerged parts of maritime vessels such as pipelay barges, dredgers and mobile offshore drilling units (MODUs) and other maritime infrastructure such as the central processing facility (CPF) and the floating production, storage and offtake (FPSO) facility.

Terrestrial quarantine pathways

The terrestrial quarantine pathways for terrestrial invasive species into the onshore Project area are as follows:

- prefabricated modules, equipment and other goods shipped from overseas direct to the module offloading facility on Blaydin Point
- earthmoving equipment mobilised to the onshore development area.

1.4 Project quarantine impacts

Potential impacts associated with the introduction and successful establishment of introduced species as a result of Project activities in either the marine or the terrestrial environment include the following:

- the displacement of native species
- the alteration and degradation of habitats and ecosystems
- the potential for impact on maritime-based activities and industries such as fishing and shipping.

2 OBJECTIVES, TARGETS AND INDICATORS

The objectives, targets and indicators set out by INPEX for marine and terrestrial quarantine management are shown in Table 2-1. The engineering and management controls to be implemented to help to achieve these targets are described under Section 3 *Management approach*.

3 MANAGEMENT APPROACH

Detailed quarantine management documentation, for example plans and procedures, will be developed for all phases of the Project. These detailed documents will align with this provisional quarantine EMP and will be prepared either directly by INPEX's Environmental Department or by specialist contractors in conjunction with INPEX.

Table 2-1: Quarantine management objectives, targets and indicators

Objectives	Targets	Indicators
Minimise the risk of introduction of marine pests into the offshore and nearshore Project areas.	• Zero introductions of marine pests attributable to the Project into offshore and nearshore Project areas.	• Confirmed reports of introductions of marine pests into nearshore and offshore Project areas.
	• Zero breaches of marine biofouling and ballast-water management requirements.	• Record-keeping, auditing, investigations and incident reports relating to marine biofouling and ballast-water management requirements.
Minimise the risk of introduction of terrestrial invasive species into the onshore Project area.	• Zero introductions of terrestrial invasive species attributable to the Project into the onshore Project area.	• Confirmed reports of terrestrial invasive species in the onshore Project area.
	• Zero breaches of terrestrial quarantine management requirements.	• Record-keeping, auditing, investigations and incident reports relating to terrestrial quarantine management requirements.
Establish and maintain personnel awareness of the importance of good terrestrial quarantine management practices during all phases of the onshore Project.	• All workforce personnel (including contractors) to complete a health, safety and environment (HSE) induction, which will include information on quarantine management practices.	• Number of people accessing the site as recorded by security staff. • Record of people completing an HSE site induction.

A summary is provided below of the main engineering and management controls to be included in the detailed documentation to mitigate the risks associated with quarantine breaches.

3.1 Engineering controls—design phase

The engineering controls to be implemented throughout the various phases of the Project are outlined below:

- A temporary, dedicated QAP will be established on Blaydin Point during the construction phase. Vessels, equipment and modules entering from another country will be inspected here for quarantine material. The design of the QAP and the inspection procedures to be put in place will be according to AQIS standards. A temporary washdown area for earthmoving and other clearing vehicles will be constructed for the construction phase.

3.2 Management controls—all phases

Management controls to be implemented throughout all phases of the Project are outlined below:

- Ballast-water management of vessels engaged in Project activities will be undertaken in accordance with AQIS requirements.
- Biofouling management of all Project-associated vessels will be undertaken in accordance with the relevant regulatory requirements of the time. Anticipated regulatory requirements are outlined in a draft overview of proposed Australian biofouling management requirements prepared by the Department of Agriculture, Fisheries and Forestry (DAFF 2008b).
- INPEX will undertake a marine biofouling risk assessment of international vessels engaged in Project activities to assist in the early identification of biofouling risk and the determination of an appropriate management approach.
- Relevant quarantine information will be provided to international vessels engaged in Project activities to assist operators to meet AQIS requirements for biofouling.
- Baiting and trapping programs will be in place on international vessels engaged in Project activities in accordance with AQIS requirements.
- Topsides of international vessels will be inspected prior to commencement of Project activities to ensure that they meet AQIS requirements.
- Specific AQIS requirements identified during the prequalification period and through to final award and implementation will be developed.
- A packaging specification, applicable to all suppliers, contractors and subcontractors, will be developed to outline the requirements for packaging of prefabricated modules and other direct imports from international ports to the module offloading facility on Blaydin Point or East Arm Wharf.
- During the contracting process, international suppliers and contractors will be provided with relevant quarantine information to assist in the preparation of quarantine goods into a state acceptable to AQIS.
- Advice will be sought from AQIS regarding the development of inspection procedures and plans associated with overseas module fabrication facilities.

3.3 Management controls—construction phase

Management controls to be implemented throughout the construction phase of the Project are outlined below:

- Vehicle hygiene requirements for earthmoving and other clearing vehicles will be included in any clearing and earthworks contracts.
- Prior to arrival at the onshore development area, all earthmoving and other vehicles used for clearing purposes will be expected to meet vehicle hygiene requirements. This may include pressure-hosing of vehicles to remove any vegetation debris, earth, seeds, etc.
- Prior to commencing activities, all earthmoving and other vehicles used for clearing purposes will be inspected on arrival at the onshore development area.
- Any earthmoving or other vehicles used for clearing purposes that fail to meet vehicle hygiene requirements, will undergo remedial cleaning at the temporary vehicle washdown area prior to commencement of work at the onshore development area.
- Prior to departing from the onshore development area, all earthmoving and other clearing vehicles will be washed down to remove vegetation, dirt, seeds, etc.
- All imports arriving from international ports at either the Blaydin Point module offloading facility or East Arm Wharf will need to meet both AQIS and INPEX requirements. All goods will be inspected prior to mobilisation into the onshore development area.
- The designated QAP on Blaydin Point will be used for more detailed inspections, isolation or cleaning of equipment that does not meet AQIS and INPEX requirements for imports arriving from international ports at the module offloading facility on Blaydin Point (e.g. prefabricated modules, equipment and machinery).

4 MONITORING

Monitoring activities will be undertaken throughout the life of the Project in relation to the identified objectives and targets. The activities listed below will be undertaken as part of the marine and terrestrial quarantine monitoring programs:

- Quarantine incidents will be monitored through INPEX's and its contractors' incident-reporting databases.
- All earthmoving and other vehicles used for clearing purposes will be inspected prior to commencing activities in the onshore development area.
- Periodic audits of vessel ballast-water exchange records will be carried out to ensure that they meet AQIS requirements.
- Periodic audits of vessel antifouling records will be carried out to ensure that they meet the requirements of both INPEX and the regulatory authorities.
- All goods arriving at the QAP will be scrutinised against INPEX and AQIS quarantine requirements.
- Remotely operated vehicle (ROV) video footage obtained from marine fouling inspections (for wave-loading purposes) will also be used for opportunistic marine pest monitoring on offshore structures.
- A marine pest monitoring program will be developed for Darwin Harbour in conjunction with the relevant regulatory authorities, including the Northern Territory's Department of Natural Resources, Environment, the Arts and Sport and Department of Resources. It is anticipated that the monitoring program methodology will be consistent with the monitoring framework proposed by the Commonwealth Government's National Introduced Marine Pest Coordination Group.

Triggered management response

A management response will be triggered by any of the following three circumstances:

1. a quarantine breach "incident"
2. the identification of a potential marine pest species through Darwin Harbour or offshore development area marine pest monitoring
3. the identification by an annual management review of a failure to meet an objective or target.

The responses to these are outlined below.

Response to quarantine breach "incidents"

Quarantine breach incidents could include the following:

- Maritime vessel ballast-water exchange records or ballast-water exchange practices do not meet AQIS requirements.
- Maritime vessel biofouling management requirements, as determined through the vessel risk assessment process, have not been undertaken in accordance with INPEX's requirements.
- Maritime vessel antifouling records have not been maintained to a standard that meets the requirements of both INPEX and the regulatory authorities.
- Earthmoving machinery or vehicles used for clearing purposes are found not to meet the specified vehicle hygiene requirements on arrival at the onshore development area.
- Modules, equipment, containers or other direct imports received at the module offloading facility or the QAP do not meet AQIS importing requirements.

The detection of incidents associated with quarantine breaches will trigger internal notifications, reporting requirements, investigations and associated corrective and preventive actions.

The level of investigation will be dependent on the potential risk associated with the event. Corrective and preventive actions that may be triggered as a result of the investigation would include the remedial cleaning of equipment, the isolation of equipment, the review and update of procedures or plans associated with quarantine management, and/or the provision of refresher training for personnel on Project quarantine management processes.

INPEX's Incident Reporting, Recording and Investigating Procedure or the Project contractor's document equivalent (approved by INPEX) will be used to determine incident severity, potential risk and associated reporting, recording and investigation requirements. All quarantine incidents will be entered into INPEX's and its contractors' incident databases and corrective actions will be tracked to closure.

Response to the identification of a potential marine pest species

The response to the identification of a potential marine pest species will be to notify the relevant regulatory agencies and confer with the Consultative Committee on Introduced Marine Pest Emergencies on the appropriate actions to be taken in response to the incident.

Specimens of the suspected organism would be collected as soon as practicable for formal identification.

Response to adverse findings by an annual management review

Failure to meet identified objectives and targets will trigger the following responses:

- a review of existing internal objectives and targets to reassess achievability
- the interrogation of incident data to determine if there are deficiencies in quarantine management.

The response to the results of investigations and audits may include the following:

- an update of plans or procedures to reflect changes to the quarantine management
- refresher training for personnel on the practices and processes developed for quarantine management for the Project.

5 REPORTING, AUDITING AND REVIEW

Reporting, auditing and reviews will be undertaken throughout all phases of the Project. A summary of the reporting, auditing and review requirements relating to quarantine management is provided in the following two sections.

5.1 All phases

The following reporting, auditing and review requirements will be put in place for all phases of the Project:

- Incidents resulting in any quarantine breaches as a result of Project activities will be reported in accordance with INPEX's Incident Reporting, Recording and Investigating Procedure or the Project contractor's document equivalent (approved by INPEX).
- An annual INPEX environmental report for the Project will be produced.
- Ballast-water management and antifouling management records will be maintained for all relevant Project vessels.
- INPEX and its contractors will conduct internal compliance audits on a periodic basis.
- Maritime vessel ballast-water and antifouling management records will be audited periodically to ensure that they meet AQIS and INPEX requirements.
- Records will be audited periodically to ensure that all personnel on site have completed the required health, safety and environment induction.
- Detailed quarantine management documentation, for example plans and procedures, will be reviewed periodically to ensure that they remain applicable to current operations and compliant with the requirements of INPEX and the regulatory authorities.

5.2 Construction, commissioning and decommissioning phases

In addition to the reporting, auditing and review requirements described above, during the construction, commissioning and decommissioning phases of the Project contractors will be required to produce and provide a monthly environmental report to INPEX which will include a record of environmental incidents.

6 SUPPORTING DOCUMENTATION

This provisional EMP is one document in a suite of plans, procedures and processes designed to ensure that INPEX's quarantine management activities are undertaken in compliance with legislative requirements and in a safe and environmentally responsible manner.

Documentation or processes addressing the issues outlined below have been or will be developed to further support the implementation of INPEX's detailed quarantine management documentation:

- contract quarantine information packages
- incident reporting, recording and investigation procedure
- health, safety and environment site induction (offshore and onshore).

7 APPLICABLE LEGISLATION, STANDARDS AND GUIDELINES

INPEX is committed to complying with all relevant laws, regulations and standards. Legislative instruments, standards and guidelines specifically related to quarantine management include those listed below.

- Australian Quarantine and Inspection Service. 2007. *Guide to completing the quarantine pre-arrival report (pratique) form for vessel clearance*. Department of Agriculture, Fisheries and Forestry, Canberra, ACT.
- Australian Quarantine and Inspection Service. 2008. *Treatments and fumigants: AQIS heat treatment standard: Version 1*. Department of Agriculture, Fisheries and Forestry, Canberra, ACT.
- Australian Quarantine and Inspection Service (AQIS). 2008. *Australian ballast water management requirements*. Department of Agriculture, Fisheries and Forestry, Canberra, ACT.

- Australian Quarantine and Inspection Service. 2008. *Importer's information for offshore inspections of machinery & equipment*. Department of Agriculture, Fisheries and Forestry, Canberra, ACT.
- Australian Quarantine and Inspection Service. 2009. *Cargo containers: quarantine aspects and procedures*. Department of Agriculture, Fisheries and Forestry, Canberra, ACT.
- Australian Quarantine and Inspection Service. 2010. *AQIS methyl bromide fumigation standard: Version 1.4*. Department of Agriculture, Fisheries and Forestry, Canberra, ACT.
- Commonwealth Government. 2009. *National biofouling management guidance for the petroleum production and exploration industry*. The National System for the Prevention and Management of Marine Pest Incursions, Canberra, ACT.
- Fisheries Regulations (NT).
- International Maritime Organization. 1978. *International convention for the prevention of pollution from ships, 1973, as modified by the protocol of 1978 relating thereto (MARPOL 73/78)*. International Maritime Organization, London, United Kingdom.
- International Maritime Organization. 1998. *Guidelines for the control and management of ships' ballast water to minimize the transfer of harmful aquatic organisms and pathogens*. International Maritime Organization, London, United Kingdom.
- *Protection of the Sea (Harmful Anti-fouling Systems) Act 2006* (Cwlth).
- *Quarantine Act 1908* (Cwlth).
- Quarantine Proclamation 1998 (Cwlth).
- Quarantine Regulations 2000 (Cwlth).

8 REFERENCES

DAFF—*see* Department of Agriculture, Fisheries and Forestry.

Department of Agriculture, Fisheries and Forestry. 2008a. *Australian ballast water management requirements*. Department of Agriculture, Fisheries and Forestry, Canberra, ACT. Viewed online on 1 March 2010 at <http://www.daff.gov.au/__data/assets/pdf_file/0004/713884/bw-requirements.pdf>.

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Department of Agriculture, Fisheries and Forestry. 2009. *Introduced marine pests*. Fact Sheet 1. Department of Agriculture, Fisheries and Forestry, Canberra, ACT. Viewed online on 1 March 2010 at <http://www.daff.gov.au/__data/assets/pdf_file/0009/5985/fs1_introducedpests.pdf>.

International Union for Conservation of Nature and Natural Resources. 2008. *What are alien invasive species?* International Union for Conservation of Nature and Natural Resources, Gland, Switzerland. Viewed online on 1 March 2010 at <http://www.iucn.org/congress_08/about/special_events/sailing/protecting_oceans/ais/what_are_ais/>.

IUCN—*see* International Union for Conservation of Nature and Natural Resources.

Provisional Traffic Management Plan

Annexe 14 – Chapter 11 *Environmental Management Program*

1 OVERVIEW

As part of the approvals process for the Ichthys Gas Field Development Project (the Project), it is necessary that INPEX should show that it has taken, and will take, all practicable steps to properly manage the risks associated with, and the potential social impacts of, the changes to pre-existing traffic conditions that will occur during the construction phase of the Project.

The greatest impact on normal traffic conditions that would be attributable to the Project will be the increase in vehicle movements generated during the construction and decommissioning phases. The magnitude of the increase in traffic during the decommissioning phase, however, will be dependent on as yet undetermined government requirements for the final land use at Blaydin Point when the Project ends. The additional traffic generated during the construction and decommissioning phases will be primarily attributable to employee transport between the onshore development area and the accommodation village and to truck movements.

Changes to normal traffic conditions during the operations phase are expected to be minimal as the numbers of vehicles and people accessing the onshore processing plant and related facilities will be greatly reduced from the numbers that are planned for the construction phase.

Nevertheless, a traffic impact assessment undertaken in 2008 by URS Australia Pty Ltd (see Appendix 22) concluded that the overall traffic impact of the onshore Project on the existing Darwin and Palmerston road networks will be minimal in comparison with the impact of the general growth in background traffic because of population growth.

This provisional environmental management plan (EMP) for traffic is attached as Annexe 14 to Chapter 11 *Environmental management program* of the Project's draft environmental impact statement (Draft EIS). It is one of a suite of similar EMPs dealing with different aspects and activities of the Project. These provisional EMPs will form the basis for the development of more detailed environmental management documentation, for example plans and procedures for the various phases of the Project as well as for specific activities associated with the Project. The detailed documentation will be prepared either directly by INPEX's Environmental Department or by specialist contractors in conjunction with INPEX.

1.1 Purpose and scope

The purpose of this provisional EMP is as follows:

- It demonstrates how INPEX intends to minimise the potential social impact of changes to normal traffic conditions that will be attributable to Project activities during the construction phase, through the identification of suitable traffic management systems and controls.
- It describes the proposed monitoring requirements for all phases of the Project.
- It describes the proposed reporting, review and audit requirements for all phases of the Project.
- It will guide the development of future more detailed environmental documentation, such as the plans, procedures, etc., which will be required throughout the life of the Project.

This provisional EMP does not address additional environmental impacts or management controls associated with maritime vessel traffic and changes to normal traffic conditions attributable to decommissioning activities. These will be addressed as separate aspects as follows:

- Maritime vessel traffic will be managed in accordance with the Darwin Port Corporation's requirements.
- Decommissioning traffic management is discussed in the Provisional Decommissioning Management Plan (Annexe 5 to Chapter 11 of this Draft EIS).

1.2 Activities that will lead to changes to onshore traffic conditions

Activities that will lead to changes in normal traffic conditions during the construction phase of the Project will include the following:

- the commuting of the construction workforce between the accommodation village and the onshore development area
- the transport of materials from quarries to the onshore development area
- the transport of equipment from East Arm Wharf to the onshore development area
- the movement of oversized vehicles through residential communities and business zones to the onshore development area
- the use of public transport by construction workers after hours
- normal local deliveries to the construction site.

1.3 Potential impacts

The potential impacts associated with changes to traffic conditions as a result of Project activities during the construction phase include the following:

- disruption and delays to local traffic
- localised traffic congestion
- additional pressure on existing public transport
- accidents on public roads involving Project vehicles
- loss of construction material during transport (e.g. aggregate, soil, stones).

2 OBJECTIVES, TARGETS AND INDICATORS

The objectives, targets and indicators set out by INPEX for traffic management are shown in Table 2-1. The engineering and management controls to be implemented to help to achieve these targets are described in Section 3 *Management approach*.

3 MANAGEMENT APPROACH

Detailed traffic management documentation, for example plans and procedures, will be developed for the construction phase of the Project. These detailed documents will align with this provisional traffic EMP. The detailed documentation will be prepared either directly by INPEX's Environmental Department or by specialist contractors in conjunction with INPEX.

A summary is provided below of the main engineering and management controls to be included in the detailed documentation to mitigate the risks associated with changes in normal traffic conditions attributable to the Project.

3.1 Engineering controls

The engineering controls that may be considered during the construction phase of the Project are possible upgrades to roads and intersections.

3.2 Management controls

The management controls to be implemented during the construction phase of the Project are outlined below:

- Bus transport from the accommodation village or designated pick-up areas will be provided for the majority of construction personnel.
- Where possible, transport of workers to and from the accommodation village to the onshore development area will be conducted outside normal peak-hour traffic times.
- Locally employed workers will be transported by bus to the onshore development area. Workers will be collected from designated bus pick-up areas; these areas will include a car park where personnel can park their vehicles during their shifts.
- Designated routes for travel to and from quarries, the accommodation village, the Darwin central business district, airport and East Arm Wharf will be set for the Project. The selection process for the routes will give consideration to minimising disturbance to local traffic.
- Designated routes of travel will be provided to all persons using vehicles for Project activities (such as for the collection and delivery of materials and equipment, and the transport of workers).
- The use of unsealed roads outside the onshore development area by Project vehicles will be avoided as far as is practicable.
- Permits will be obtained for any oversized vehicles required for onshore Project activities in accordance with the *Motor Vehicles Act* (NT) and the Motor Vehicles (Standards) Regulations (NT).
- The provision of shuttle buses or similar transport for the workforce to local community areas, for example to the central business districts of Palmerston and Darwin after hours, will be given consideration by the Project.

Table 2-1: Traffic management objectives, targets and indicators

Objectives	Targets	Indicators
Prevent impacts from the transport of workers to and from the onshore development area during the construction phase.	• Zero incidents of buses using unauthorised traffic routes to access the onshore development area from the accommodation village, or vice versa.	• Number of incident reports and severity of incidents resulting from buses using unauthorised transport routes to access the onshore development area from the accommodation village.
Prevent impacts from the transport of materials by heavy vehicles to and from the onshore development area during the construction phase.	• Zero incidents of heavy vehicles using unauthorised traffic routes to gain access to or depart from the onshore development area from or to East Arm Wharf, the Darwin central business district, the airport or quarries.	• Number of incident reports and severity of incidents resulting from heavy vehicles using unauthorised transport routes to gain access to or depart from the onshore development area from or to East Arm Wharf, the Darwin central business district, the airport or quarries.

- Location-dependent speed limits will be imposed in the onshore development area to reduce the potential for vehicle accidents, the creation of dust, and accidental collisions with animals.
- The Project will work in conjunction with the Northern Territory's Department of Planning and Infrastructure to identify any proposed road projects that may need to be brought forward or upgrades that may need to be undertaken to assist in reducing potential pressure on existing road systems.

4 MONITORING

Monitoring activities will be undertaken throughout the life of the Project in relation to the identified objectives and targets. The activities listed below will be undertaken as part of the traffic monitoring program:

- Traffic incidents will be monitored through INPEX's and its contractors' incident-reporting databases.
- Periodic analyses of the data in the incident-reporting databases will be undertaken to identify deficiencies in traffic management practices.
- Vehicle (including bus) safety inspections will be undertaken periodically.

Triggered management response

A management response will be triggered by either of the following two circumstances:

1. a traffic "incident"
2. the identification by an annual management review of a failure to meet an objective or target.

The following two sections outline the responses to each of these two situations.

Response to traffic "incidents"

Project traffic "incidents" are taken to include the following:

- Project vehicles involved in traffic accidents
- Project vehicle breakdowns on public roads
- public complaints regarding traffic management
- unauthorised deviations from designated travel routes.

The detection of incidents associated with Project traffic will trigger internal notifications, reporting requirements, investigations and associated corrective and preventive actions.

The level of investigation will depend on the potential risk associated with a traffic incident. Corrective and preventive actions that may be triggered as a result of an investigation would include the review and update of procedures or plans associated with traffic management and/or refresher training for personnel on Project traffic management processes.

The INPEX Incident Reporting, Recording and Investigating Procedure or the Project contractor's document equivalent (approved by INPEX) will be used to determine incident severity, potential risk and associated reporting, recording and investigation requirements. All traffic incidents will be entered into INPEX's and the Project contractors' incident databases and corrective actions will be tracked to closure.

Response to adverse findings by an annual management review

Failure to meet identified objectives and targets will trigger the following responses:

- a review of existing internal objectives and targets to reassess achievability
- an interrogation of incident data to determine deficiencies in traffic management practices.

The response to the results of investigations and audits may include the following:

- an update of plans or procedures to reflect changes to the traffic management systems
- refresher training for personnel on the traffic management practices and processes developed for the Project.

5 REPORTING, AUDITING AND REVIEW

Reporting, auditing and reviews will be undertaken throughout the construction phase of the Project. A summary of the reporting, auditing and review requirements relating to changes in traffic conditions is provided below:

- Incidents resulting from Project activities will be reported in accordance with INPEX's Incident Reporting, Recording and Investigating Procedure or the Project contractor's document equivalent (approved by INPEX).
- An annual INPEX environmental report for the Project will be produced.
- INPEX and its contractors will conduct internal compliance audits on a periodic basis.
- Records will be audited periodically to ensure that all personnel on site have completed the required health, safety and environment (HSE) induction.

- Detailed traffic management documentation, for example plans and procedures, will be reviewed periodically to ensure that they remain applicable to current operations and compliant with the requirements of INPEX and the regulatory authorities.
- Construction contractors will be required to produce and provide to INPEX a monthly environmental report which will include a record of all environmental incidents.

6 SUPPORTING DOCUMENTATION

This provisional EMP is one document of a suite of plans, procedures or processes designed to ensure that INPEX's traffic management objectives are achieved and undertaken in compliance with legislative requirements and in a safe and environmentally responsible manner.

Documentation or processes addressing the issues listed below have been or will be developed to further support the implementation of detailed traffic management documentation:

- traffic routes and maps
- driving conduct
- incident reporting, recording and investigating
- health, safety and environment site induction.

7 APPLICABLE LEGISLATION, STANDARDS AND GUIDELINES

INPEX is committed to complying with all relevant laws, regulations and standards. Legislative instruments, for example, specifically related to traffic management include those listed below.

- *Motor Vehicles Act* (NT).
- Motor Vehicles (Standards) Regulations (NT).
- *Traffic Act* (NT).
- Traffic Regulations (NT).

Provisional Vegetation Clearing, Earthworks and Rehabilitation Management Plan

Annexe 15 – Chapter 11 *Environmental Management Program*

1 OVERVIEW

As part of the approvals process for the Ichthys Gas Field Development Project (the Project), it is necessary that INPEX should show that it has taken, and will take, all practicable steps to properly manage the risks associated with, and the potential environmental impact of, vegetation clearing and earthworks undertaken for the Project in the onshore development area during the construction phase. The company must also demonstrate that it will be able to successfully rehabilitate any areas that are temporarily disturbed during the life of the Project.

This provisional environmental management plan (EMP) for vegetation clearing, earthworks and rehabilitation is attached as Annexe 15 to Chapter 11 *Environmental management program* of the Project's draft environmental impact statement (Draft EIS). It is one of a suite of similar EMPs dealing with different aspects and activities of the Project. These provisional EMPs will form the basis for the development of more detailed environmental management documentation, for example plans and procedures for the various phases of the Project as well as for specific activities associated with the Project. The detailed documentation will be prepared either directly by INPEX's Environmental Department or by specialist contractors in conjunction with INPEX.

Surveys undertaken by GHD Pty Ltd (see Appendix 16 to this Draft EIS) indicated that there are three broad vegetation units within the onshore development area: eucalyptus woodlands, monsoon vine thickets and mangroves.

The highest animal species richness found in the onshore development area was associated with the eucalyptus woodlands (see Chapter 8 *Terrestrial impacts and management*). This vegetation type is well represented elsewhere on Middle Arm Peninsula, and the loss of these woodlands from the onshore development area is not likely to have a significant overall impact.

Monsoon vine forest has unique features and is regarded as having a high conservation value in the Darwin Coastal Bioregion. The area of monsoon vine forest on the Blaydin Point peninsula is relatively large compared with other patches around Darwin Harbour and has probably been isolated from fire damage to some extent by the intertidal salt flats around the island–peninsula. However, the monsoon vine forest at Blaydin Point represents just 1.0% of the total area of this vegetation type in the bioregion.

Fringing mangrove communities occupy much of the intertidal areas of the onshore development area. Under the Northern Territory Planning Scheme these communities are zoned for "conservation". Clearing associated with the onshore development and pipeline shore crossing will cause localised disturbance to the mangrove systems in these areas. However Darwin Harbour as a whole has extensive areas of mangrove forest and the proposed disturbance associated with these areas is not expected to have any significant impact on the distribution of mangroves in the Harbour.

Only one species of plant in the onshore development area is considered "vulnerable" under the *Territory Parks and Wildlife Conservation Act* (NT): this is the cycad *Cycas armstrongii*. No plant species or vegetation communities in the onshore development area have been identified as "matters of national environmental significance" under the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth) (EPBC Act).

Four of the weeds identified in the onshore development area are listed as Schedule Class B/C weeds under the *Weeds Management Act 2001* (NT). These are mission grass (*Pennisetum polystachion*), hyptis (*Hyptis suaveolens*), lantana (*Lantana camara*) and gamba grass (*Andropogon gayanus*). This classification obliges landholders to make "reasonable attempts" to contain the growth and prevent the spread of these species.

No animal species listed as threatened under either the EPBC Act or the *Territory Parks and Wildlife Conservation Act* was recorded during field surveys although a number of birds listed as migratory under the EPBC Act were observed. Database searches, however, indicate that there are a number of threatened and migratory species that could potentially occur in and around the onshore development area.

1.1 Purpose and scope

The purpose of this provisional EMP is as follows:

- It demonstrates how INPEX, through the identification of suitable management controls, intends to minimise the potential environment impact of clearing and earthworks activities during the construction phase in the onshore development area.
- It describes the proposed rehabilitation controls during all phases of the Project.
- It describes the proposed monitoring requirements for clearing and rehabilitation activities.
- It describes the proposed reporting, review and audit requirements for all phases of the Project.
- It will guide the development of future more detailed environmental documentation such as the plans, procedures, etc., which will be required throughout the life of the Project.

The scope of this provisional EMP includes all clearing and earthwork activities undertaken in the onshore development area during the Project's construction phase as well as the ongoing terrestrial vegetation rehabilitation programs which will be undertaken as the Project progresses.

This provisional EMP does not address the potential environmental impact of, or the management controls for, the following:

- dust generated as a result of clearing activities
- drainage and erosion
- the excavation of acid sulfate soil or potential acid sulfate soil
- onshore spill prevention and response
- the discovery or removal of Aboriginal or non-Aboriginal heritage sites
- bushfire prevention requirements
- the quarantine management of equipment before and after its arrival on the onshore development area
- decommissioning activities.

These are addressed as separate aspects or activities under the following provisional management plans:

- Provisional Acid Sulfate Soils Management Plan (Annexe 1 to Chapter 11)
- Provisional Bushfire Prevention Management Plan (Annexe 3 to Chapter 11)
- Provisional Decommissioning Management Plan (Annexe 5 to Chapter 11)
- Provisional Dust Management Plan (Annexe 7 to Chapter 11)
- Provisional Heritage Management Plan (Annexe 9 to Chapter 11)
- Provisional Liquid Discharges, Surface Water Runoff and Drainage Management Plan (Annexe 10 to Chapter 11)
- Provisional Onshore Spill Prevention and Response Management Plan (Annexe 11 to Chapter 11)
- Provisional Quarantine Management Plan (Annexe 13 to Chapter 11).

1.2 Clearing and earthworks activities

The onshore infrastructure associated with the development will require clearing and earthworks activities. These will include the following:

- clearing works during construction
- earthworks for site preparation and construction
- the disposal and/or storage of cleared vegetation
- the establishment of borrow pits
- vehicle movements to and from the onshore development area.

1.3 Potential impacts

Potential impacts associated with clearing and earthworks activities in the onshore development area include the following:

- the loss of eucalyptus woodlands, monsoon vine forest and mangrove habitat
- a localised reduction in the biodiversity of native animals and plants
- the removal of cycads classed as "vulnerable" under the *Territory Parks and Wildlife Conservation Act*
- death or injury to animals as result of accidental entrapment
- the clearing of vegetation outside the approved Project footprint
- further spread of existing weed species in the onshore development area.

2 OBJECTIVES, TARGETS AND INDICATORS

The objectives, targets and indicators set out by INPEX for vegetation clearing, earthworks and rehabilitation management are shown in Table 2-1. The engineering and management controls to be implemented to help to achieve these targets are described in Section 3 *Management approach*.

Table 2-1: Vegetation clearing, earthworks and rehabilitation management objectives, targets and indicators

Objectives	Targets	Indicators
Avoid disturbance to animals and plants outside the approved clearing footprint during the construction phase of the Project.	• Zero incidents of unauthorised clearing and disturbance.	• Area cleared outside authorised clearing footprint.
Avoid injury or death to animals resulting from accidental entrapment during construction of the onshore development area infrastructure.	• Zero incidents of death or injury to animals resulting from accidental entrapment.	• Number of incident reports relating to death or injuries of animals attributable to accidental entrapment.
Timely and successful rehabilitation of selected disturbance areas.	• Rehabilitation work is completed in a timely manner once an area is no longer required. • Rehabilitation of vegetation is successful.	• Rehabilitation work is completed within a specified period of time. • Revegetation indicates that the flora composition of rehabilitated areas is comparable to the pre-existing vegetation.
Prevent the spread of listed weed species within the onshore development area.	• Weeds confined to existing areas of infestation only.	• Extent of listed weed infestations within the onshore development area.
Establish and maintain awareness of the importance of protecting the ecological and heritage values associated with the onshore development area.	• All workforce personnel (including contractors) to complete a health, safety and environment (HSE) induction, which will include information on the ecological and heritage values associated with the onshore development area.	• Number of people accessing the site as recorded by security. • Number of people completing an HSE site induction.

3 MANAGEMENT APPROACH

Detailed clearing and earthworks documentation, for example plans and procedures, will be developed for the construction phase of the Project. Similarly detailed rehabilitation documentation will be developed for other Project phases and activities. These documents will align with this provisional vegetation clearing, earthworks and rehabilitation EMP. The detailed documentation will be prepared either directly by INPEX's Environmental Department or by specialist contractors in conjunction with INPEX.

A summary is provided below of the main engineering and management controls to be included in the detailed documentation in order to mitigate the risks associated with clearing and earthworks activities. Such controls will assist with later rehabilitation works.

3.1 Engineering controls—design phase

The vegetation clearing footprint for the onshore development area will be minimised through the appropriate design of the onshore facilities, subject to constructibility and safety operating requirements.

3.2 Management controls—all phases

Control methods will be developed to deal with infestations of listed weeds as described in the *Weeds Management Act 2001* (NT) and that are identified as occurring in the onshore development area (e.g. along roadsides, cleared areas, firebreaks and easements).

3.3 Management controls—construction phase

The management controls to be implemented for vegetation clearing, earthworks and rehabilitation during the construction phase of the Project are outlined below:

- Large-scale vegetation clearing and earthworks will preferentially be undertaken in dry-season conditions. Should clearing and earthworks be required to be undertaken during the wet season, adequate control measures will be implemented to avoid erosion and sedimentation impacts. INPEX's proposed erosion and sedimentation controls are described in the Provisional Liquid Discharges, Surface Water Runoff and Drainage Management Plan (Annexe 10 to Chapter 11).
- Major clearing activities will be undertaken in such a manner as to allow animal movement into remaining or surrounding vegetation.
- Areas to be cleared will be pegged and clearly delineated using high-visibility flagging tape or a similar device, so that operators are aware of the site boundaries.
- Areas to be cleared will be clearly marked on the construction and design plans and these plans will be readily available to personnel.

- All forms of disturbance, including personnel and vehicle movements, will be contained within the designated onshore development area to avoid impacts to surrounding vegetation. Some additional clearances may be required around the perimeter of the site to allow for appropriate firebreaks.
- Temporary fencing may be erected to assist in defining the construction site works area boundary to prevent personnel and machinery from accessing areas outside the approved footprint of the Project.
- Job hazard analyses, daily toolbox meetings, permit systems or similar will be implemented on site to ensure that areas to be cleared are clearly identified prior to work commencing and to avoid disturbance to Aboriginal heritage sites both inside and outside the site boundaries.
- If it is determined that specimens of the cycad *Cycas armstrongii* are to be moved off site and used for commercial purposes, a permit under the *Territory Parks and Wildlife Conservation Act* will be applied for and obtained prior to this being undertaken.
- Cleared vegetation will be mulched and stockpiled on site boundaries or off site. Where possible, the mulch will be used for both rehabilitation and soil stabilisation to prevent erosion. Mulched vegetation that will not be used will be disposed of off site. No stockpiled vegetation will be burned.
- Previously disturbed areas that have large infestations of listed weed species will either be cleared separately from undisturbed areas to avoid spreading weeds and their seeds to weed-free areas or will be managed through weed control programs. These will possibly include a combination of herbicide spraying and burning during appropriate seasonal conditions to remove the weed infestation before clearing commences.
- Any cleared vegetation infested with listed weeds where weed control measures have not been taken will be separately stockpiled and removed from site.
- Some topsoil which has not been infested with seed from listed weed species will be retained on site for reuse in rehabilitation and landscaping or will be integrated into cut and fill.
- Any topsoil from cleared areas where the vegetation was recorded as having been infested by a listed weed and where weed control has not been applied, will either be removed from site or be used as fill and covered.
- Temporarily disturbed areas such as those in the vicinity of the pipeline shore crossing and onshore pipeline route and areas around the plant that do not need to remain cleared will be reinstated and rehabilitated.
- "High-risk" entrapment areas (e.g. deep trenches or pits) will be provided with sloping egress ramps to allow animals to escape. Targeted inspections of these areas will be undertaken and any remaining trapped animals will be removed and released.
- Personnel (including contractors) will be required to attend inductions which will provide information on the importance of protecting the ecological and heritage values associated with the onshore development area.

4 MONITORING

Monitoring activities will be undertaken throughout the life of the Project in relation to the identified objectives and targets. The activities described below will be undertaken as part of the vegetation clearing, earthworks and rehabilitation monitoring program:

- Incidents resulting from clearing, earthworks or rehabilitation activities will be monitored through INPEX's and its contractors' incident-reporting databases.
- Clearing will be monitored to ensure that there is no unauthorised clearing beyond the approved onshore development footprint. This will be determined using GPS (global positioning system) equipment to establish the boundaries of the cleared areas.
- A vegetation rehabilitation monitoring program will be developed to assess the progress and success of any rehabilitation works.
- A weed monitoring program will be developed to monitor the distribution and abundance of listed weed species in the onshore development area.
- Target inspections of "high-risk" entrapment areas will be undertaken during the construction phase.

Triggered management response

A management response will be triggered by either of the following two circumstances:

1. a vegetation clearing and earthworks "incident"
2. the identification by an annual management review of a failure to meet an objective or target.

The responses to these are outlined below.

Response to clearing or earthworks "incidents"

A non-compliant event is classified as an "incident". Detection of incidents will trigger internal notifications, reporting requirements, investigations and associated corrective and preventive actions.

Incidents that may occur as a result of clearing activities include the following:

- clearing outside the approved Project footprint
- new infestations of listed weed species appear along access roads or in disturbed areas in the Project footprint
- the death or injury of an animal as a result of its being struck by a vehicle, becoming trapped in a pit, etc.

The level of investigation will be dependent on the potential risk associated with the event. Corrective actions that may be triggered as a result of the investigation would include the following:

- the implementation of control measures such as the spraying of infestations of weeds with herbicides
- a review and update of the procedures, processes and plans associated with vegetation clearing, earthworks and rehabilitation.

INPEX's Incident Reporting, Recording and Investigating Procedure or the Project contractor's document equivalent (approved by INPEX) will be used to determine incident severity, potential risk and associated reporting, recording and investigation requirements. All clearing incidents and "near misses" will be entered into INPEX's and its contractors' incident databases and corrective actions will be tracked to closure.

Response to adverse findings by an annual management review

Failure to meet identified objectives and targets will initiate the following responses:

- a review and audit of current clearing, earthworks and rehabilitation management practices to assess the practicability of their implementation
- a review of current objectives and targets to assess achievability.

The response to the results of investigations and audits will include the following:

- an update of plans and associated documentation to reflect changes to clearing, earthworks and rehabilitation management practices (if applicable)
- the arrangement of refresher training courses for personnel, covering site-clearing, earthworks and rehabilitation management practices and processes
- the possible sourcing of additional resources to assist in the successful implementation of good site-clearing, earthworks and rehabilitation management practices.

5 REPORTING, AUDITING AND REVIEW

Reporting, auditing and reviews will be undertaken for earthworks and clearing activities during the construction phase and for rehabilitation activities in successive phases. A summary of the reporting, auditing and review requirements relating to clearing and rehabilitation management is outlined in the following two sections.

5.1 All phases

The reporting, auditing and review requirements applicable during all phases of the Project are as follows:

- Incidents will be reported in accordance with INPEX's Incident Reporting, Recording and Investigating Procedure or the Project contractor's document equivalent (approved by INPEX).
- An annual INPEX environmental report for the Project will be produced.
- INPEX and its contractors will conduct internal compliance audits on a periodic basis.
- Records will be audited periodically to ensure that all personnel on site have completed the required health, safety and environment induction.
- Detailed vegetation clearing, earthworks and rehabilitation management documentation, for example plans and procedures, will be reviewed periodically to ensure that they remain applicable to current operations and compliant with the requirements of INPEX and the regulatory authorities.

5.2 Construction phase

The reporting requirements applicable to the construction phase are as follows:

- A register will be maintained to record all clearing activities being undertaken.
- Project contractors will be required to provide INPEX with a monthly environmental report including details of monthly environmental incidents.

6 SUPPORTING DOCUMENTATION

This provisional EMP is one document in a suite of plans, procedures or processes designed to ensure that INPEX's vegetation clearing, earthworks and rehabilitation management activities are undertaken in compliance with legislative requirements and in a safe and environmentally responsible manner.

The following supporting INPEX documents have been or will be developed and should be read in conjunction with this provisional EMP:

- Provisional Acid Sulfate Soils Management Plan (Annexe 1 to Chapter 11)
- Provisional Dust Management Plan (Annexe 7 to Chapter 11)
- Provisional Heritage Management Plan (Annexe 9 to Chapter 11)
- Provisional Liquid Discharges, Surface Water Runoff and Drainage Management Plan (Annexe 10 to Chapter 11)
- Provisional Onshore Spill Prevention and Response Management Plan (Annexe 11 to Chapter 11)
- Provisional Quarantine Management Plan (Annexe 13 to Chapter 11).

Documentation or processes addressing the issues outlined below have been developed to further support the implementation of detailed clearing, earthworks and rehabilitation management documentation:

- incident reporting, recording and investigating
- permit-to-work system
- health, safety and environment site induction.

7 APPLICABLE LEGISLATION, STANDARDS AND GUIDELINES

INPEX is committed to complying with all relevant laws, regulations and standards. Legislative instruments, standards and guidelines specifically related to vegetation clearing, earthworks and rehabilitation management include those listed below.

- Environment Protection Authority. 2006. *Environmental guidelines for reclamation of coastal areas*. Northern Territory Government, Darwin.
- *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth).
- Department of Natural Resources, Environment, the Arts and Sport. 2006. *Land clearing guidelines*. (Originally published as Technical Report No. 27/2002 in 2002 and revised in 2006). Northern Territory Government, Darwin.
- *Soil Conservation and Land Utilization Act* (NT).
- *Territory Parks and Wildlife Conservation Act* (NT).
- *Weeds Management Act 2001* (NT).

Provisional Waste Management Plan

Annexe 16 – Chapter 11 *Environmental Management Program*

1 OVERVIEW

As part of the approvals process it is necessary that INPEX should show that it has taken, and will take, all practicable steps to properly manage the risks associated with, and the potential environmental impacts of, waste generated by the Project during its lifetime.

At different periods during the life of the Project varying quantities of waste of different types will be generated. It is expected, for example, that the quantities of waste material produced during the construction and decommissioning phases of the Project will be considerably higher than that produced during the operations phase over a similar time period.

In addition to this, the main waste types generated during the construction and decommissioning phases will differ from those produced during the operations phase, which will be dominated by hydrocarbon processing.

The waste types addressed here include solid and liquid hazardous wastes (e.g. oily rags and absorbents, solvents, batteries, fluorescent tubes, oily sludge, paints and oil filters) and non-hazardous wastes (e.g. paper, food waste, domestic waste, scrap metal, plastics, wood, glass and cardboard).

This provisional environmental management plan (EMP) for waste is attached as Annexe 16 to Chapter 11 *Environmental management program* of the Project's draft environmental impact statement (Draft EIS). It is one of a suite of similar EMPs dealing with different aspects and activities of the Project. These provisional EMPs will form the basis for the development of more detailed environmental management documentation, for example plans and procedures for the various phases of the Project as well as for specific activities associated with the Project. The detailed documentation will be prepared either directly by INPEX's Environmental Department or by specialist contractors in conjunction with INPEX.

1.1 Purpose and scope

The purpose of this provisional EMP is as follows:

- It demonstrates how INPEX will minimise the potential environmental impact of wastes generated as a result of Project activities through the identification of suitable waste management strategies.
- It describes the proposed monitoring requirements for all phases of the Project.
- It describes the proposed reporting, review and audit requirements for all phases of the Project.
- It will guide the development of future more detailed environmental documentation such as the plans, procedures, etc., that will be required throughout the life of the Project.

The scope of this provisional EMP includes all wastes (liquid and solid) that will be generated in association with activities in the Project area (both onshore and offshore), including non-hazardous and hazardous wastes.

This provisional EMP does not address potential environmental impacts or waste management controls for the following:

- process-generated wastes that are emitted to atmosphere (e.g. through flaring or as fugitive emissions)
- liquid wastes discharged through liquid effluent systems (e.g. produced water, wastewater, or drilling muds)
- dredge spoil
- acid sulfate soils
- contaminated materials or soil from onshore spill clean-up operations.

These are addressed as separate aspects under the following provisional EMPs:

- Provisional Acid Sulfate Soils Management Plan (Annexe 1 to Chapter 11)
- Provisional Air Emissions Management Plan (Annexe 2 to Chapter 11)
- Provisional Dredging and Dredge Spoil Disposal Management Plan (Annexe 6 to Chapter 11)
- Provisional Liquid Discharges, Surface Water Runoff and Drainage Management Plan (Annexe 10 to Chapter 11)
- Provisional Onshore Spill Prevention and Response Management Plan (Annexe 11 to Chapter 11).

1.2 Plan definitions

Listed wastes

Appendix A to this EMP contains the "listed wastes" prescribed under Schedule 2 of the Waste Management and Pollution Control (Administration) Regulations (NT).

Only listed wastes that have been determined under the New South Wales Environment Protection Authority Waste Guidelines (DECC 2008; DECCW 2009) as acceptable for disposal by burial may be disposed of at the Northern Territory's Shoal Bay Waste Disposal Site (DIPE 2005).

Under the *Waste Management and Pollution Control Act* (NT) waste contractors collecting, transporting, storing, recycling, treating or disposing of listed wastes are required to have an environmental protection licence.

Hazardous waste

Hazardous wastes (recyclable and non-recyclable) are wastes composed of or containing materials that may pose a threat or risk to public health, safety or the environment (including plants and animals). They include substances which are toxic, infectious, mutagenic, carcinogenic, teratogenic, explosive, flammable, corrosive, oxidising or radioactive. The hazardous waste generated may include medical waste, excess or spent chemicals, contaminated scrap metals or drums, oily rags and absorbents, solvents, batteries, fluorescent tubes, oily sludge, paints, oil filters, and naturally occurring radioactive materials (NORMs).

Non-hazardous waste

Non-hazardous wastes (recyclable and non-recyclable) are wastes composed of or containing materials which are not harmful to humans and which would not have a serious impact on the environment (including plants and animals) if released. They are made up of a combination of putrescible solids and liquids, and inert solids, including paper, food waste, domestic waste, scrap metal, plastics, wood, glass, cardboards, and sewage sludge.

Quarantine waste

In the context of the Ichthys Project, quarantine waste means materials or goods of quarantine concern as determined by the Australian Quarantine and Inspection Service (AQIS) and which are subject to and/or identified under the *Quarantine Act 1908* (Cwlth) and associated legislative instruments. It includes materials used to pack and stabilise imported goods; galley food and other waste from overseas vessels; human, animal or plant waste brought into Australia; refuse or sweepings from the hold of an overseas vessel; and any other waste or other material that has come into contact with the quarantine wastes listed above (EPA 2009).

1.3 Project waste sources

Waste generated onshore and offshore throughout the various phases of the Project will be a result of the operations and associated activities of the following:

- construction and development work. Sources of waste will include building and excavation operations; spill incidents; office, accommodation and kitchen operations; medical facility operations; and international vessels
- supply and logistics bases. Sources of waste will include day-to-day operations, packaging, administration operations, and spill incidents
- the mobile offshore drilling unit (MODU). Sources of MODU waste will include drilling activities, galley and accommodation operations, and spill incidents
- pipelay, supply and support vessels and third-party contractor vessels. Sources of waste will include galley waste, quarantine wastes (e.g. packaging), operations, and maintenance
- the central processing facility (CPF) and the floating production, storage and offtake (FPSO) facility. Sources of CPF and FPSO waste will include maintenance operations, the day-to-day operations of the process facilities, spill incidents, office and accommodation operations, kitchen operations, and medical facility operations
- the liquefied natural gas (LNG) processing plant on Blaydin Point. Sources of waste will include maintenance operations, pigging operations, the day-to-day operations of the processing facilities, spill incidents, office operations, medical facility operations, and international vessels.

1.4 Potential impacts

Project activities associated with waste generation, storage and disposal have the potential to impact on the onshore and offshore environment if not managed effectively. The following impacts could occur:

- localised, low-to-medium-level contamination of soils and surface water
- native animals being attracted to waste collection sites
- marine animals being attracted to waste discharge sites, potentially resulting in indirect impacts through predation
- the attraction of pest animals (e.g. seagulls) to waste collection sites
- the generation of offensive odours
- pollution of the marine environment from inappropriate handling and storage of waste, for example through nutrient enrichment
- toxic effects on marine biota
- an increase in fire risk associated with the storage of waste materials
- risks to human health.

2 OBJECTIVES, TARGETS AND INDICATORS

The objectives, targets and indicators set out by INPEX for waste management are shown in Table 2-1. The engineering and management controls to be implemented to help to achieve these targets are described in Section 3 *Management approach*.

Table 2-1: Waste management objectives, targets and indicators

Objectives	Targets	Indicators
Prevent environmental impacts from waste generated during all phases of the Project.	• Zero environmental incidents (including "near misses") resulting from waste mismanagement.	• Number of incident reports and severity of incidents resulting from waste mismanagement (including incorrect storage, spills, etc.).
Minimise the generation of waste during all operations. (See note below.)	• Targets will be defined. • A baseline calculation of annual waste volumes will be undertaken in the first twelve months of full operations (two LNG trains) and total waste reduction targets will be identified for subsequent years.	• Total annual waste volumes (including types, disposal method, etc.) during the first 12 months of full operations (two LNG trains).
Minimise the amount of waste sent to landfill during the operations phase of the Project.	• 10% of the total volume of waste to be recycled by the end of the first year of full production.	• Annual volumes of waste produced. • Annual volumes of wastes recycled.
Establish and maintain awareness of the importance of good waste-management practices during all phases of the Project.	• All workforce personnel (including contractors) to complete a health, safety and environment (HSE) induction, which will include information on waste-management practices.	• Number of people accessing the site as recorded by security. • Number of people completing an HSE site induction.

Note: During the construction and decommissioning phases of the Project, it is expected that the quantities of waste generated will fluctuate significantly both annually and from the start to the end of each phase in comparison with the volumes expected from steady normal operations.

As the annual waste amounts during these phases will vary greatly, it is difficult to identify meaningful annual reduction target percentages. Targets for the reduction of waste have therefore not been set for these phases, although management strategies have been identified and will be implemented to reduce the volumes of waste.

3 MANAGEMENT APPROACH

Detailed waste management documentation, for example plans and procedures, will be developed for all phases of the Project. These documents will align with this provisional waste EMP. The detailed documentation will be prepared either directly by INPEX's Environmental Department or by specialist contractors in conjunction with INPEX.

A summary is provided below of the main engineering and management controls to be included in the detailed documentation in order to mitigate the risks associated with waste generated by the Project.

3.1 Engineering controls—design phase

The engineering strategies to be implemented during the design phase of the Project are as follows.

Applicable to both onshore and offshore

- Storage areas for hazardous or dangerous goods wastes will comply with applicable regulatory requirements and Australian design standards.
- Sufficient space will be provided on or within the CPF, the FPSO facility and the onshore gas plant to allow for the segregation and storage of wastes.

Offshore- and nearshore-specific

Macerators will be installed on support and construction vessels, the CPF, the FPSO facility, and the MODU in order to manage food wastes in accordance with the requirements of Annex V to the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto (MARPOL 73/78) and Clause 222 of the Petroleum (Submerged Lands) Acts Schedule (DITR 2005). Accordingly, all food scraps will be ground to a size capable of passing through a screen with openings no greater than 25 mm prior to discharge, with such discharges occurring no closer than 12 nautical miles from the nearest land.

3.2 Management controls—all phases

The waste management controls to be implemented throughout all phases of the Project are outlined below.

Applicable to both onshore and offshore

- Responsible waste management will be accomplished through the application of the practices outlined in the waste management hierarchy—from source reduction, reuse and recycling to recovery, treatment and responsible disposal.

- Positive efforts will be made to maximise recycling during all phases of the Project, with a goal of 10% of all waste to be recycled by the end of the first year of full production during operations.
- An inventory including descriptions of foreseeable waste types produced throughout the various phases of the Project will be provided in the detailed waste management plans and will include instruction on appropriate waste handling and disposal practices.
- Only approved and licensed waste contractors will be employed for waste disposal.
- Waste minimisation will be included in the tendering and contracting process.
- Chemicals and hazardous substances used during all phases of the Project will be selected and managed to minimise the potential adverse environmental impact associated with their transport, transfer, storage, use and disposal.
- Material safety data sheets (MSDSs) will be available on the facilities to aid in the identification of appropriate spill clean-up and disposal methods.
- Where possible, required materials and chemicals will be purchased in bulk in order to reduce the amount of packaging waste. For example, chemicals could be supplied in intermediate bulk containers in preference to drums.
- Waste will be stored in the designated waste stations and appropriately segregated into hazardous waste and non-hazardous waste, and, where possible, into recyclable or reusable hazardous waste and recyclable or reusable non-hazardous waste. In the event of the discovery of any unidentified wastes, these will be treated as hazardous waste and stored accordingly.
- Bins containing food or other putrescible wastes will be covered to prevent scavenging by animals or infestation by flies.
- All hazardous liquid wastes will be stored over a bund in leak-proof sealed containers.
- All waste receptacles will be clearly labelled as to the nature of the materials that may be placed in them in order to avoid contamination or mixture of incompatible materials.
- Waste receptacles will not be permitted to be overfilled with materials.
- Management of "listed waste" will meet Northern Territory and Commonwealth regulatory requirements with regard to storage, transport and disposal.
- General "good housekeeping" practices will be undertaken to ensure that there is no accumulation of waste materials in the facilities, accommodation buildings, etc.
- All waste generated, stored and disposed of will be recorded, manifested and tracked to ultimate disposal. The facility logistics coordinators and onshore supply base will retain records and manifests of the quantities and types of waste stored and transported for disposal. Vessels and vehicles transporting waste will retain records and manifests of the quantities and types of wastes transported.
- The waste contractors will be required to retain records of the quantities and types of waste received and disposed of, as well as of the disposal method. Waste-disposal contractors will be required to provide INPEX with waste-disposal records.
- Waste-generation impacts will be taken into consideration during job hazard analyses (JHAs) where appropriate.
- Special arrangements will be made in advance for waste generated as a result of maintenance activities, for example the disposal of sizeable quantities of various non-hazardous wastes or non-routine hazardous waste.
- Spill kits will be placed in areas where liquid wastes are stored.
- Disposal of spill clean-up materials will be managed as prescribed in the detailed waste management plans. Materials (e.g. contaminated absorbents) will be contained and taken to a hazardous-waste storage facility. All containers will be appropriately marked with, as a minimum, labels identifying the type of contaminant they contain. The materials used to construct the containers will be compatible with the chemicals they will hold.
- During all phases of the Project all personnel, when first attending site, will be required to attend inductions highlighting the facility or vessel waste-management controls.

Nearshore-specific

The waste-management controls for international vessels docking at East Arm Wharf or at the onshore facility during all phases of the Project are outlined below:

- Food scraps from construction and support vessels working in the nearshore area (i.e. Darwin Harbour, but including the dredge spoil disposal ground north of Darwin Harbour) will not be discharged into the sea, but will be returned to shore for onshore disposal, in accordance with the provisions of the *Marine Pollution Act* (NT).
- All international vessels will comply with AQIS requirements with regard to the appropriate disposal of quarantine waste.

- All quarantine wastes from visiting international vessels will be segregated from onshore domestic wastes. Where domestic and quarantine wastes are mixed, they will be classified and disposed of as quarantine waste.
- Quarantine waste will be removed by an authorised contractor to an approved quarantine waste disposal area off site.

Offshore-specific

Offshore-specific waste-management strategies to be implemented during all phases of the Project are outlined below:

- All hazardous wastes returned to the mainland will be clearly labelled in accordance with the Australian Code for the Transport of Dangerous Goods by Road and Rail and/or the International Maritime Dangerous Goods (IMDG) Code. In addition, waste chemicals, hazardous substances or dangerous goods returned to the mainland for disposal must be accompanied by copies of the MSDSs and dangerous goods declarations (if required).
- All non-hazardous wastes from vessels and offshore facilities (with the exception of food scraps) will be returned to the mainland for disposal.
- Food scraps from the CPF and the FPSO will be disposed of in accordance with the requirements of Annex V of MARPOL 73/78 and Clause 222 of the Petroleum (Submerged Lands) Acts Schedule (DITR 2005). Accordingly, all food scraps will be ground to a size capable of passing through a screen with openings no greater than 25 mm prior to discharge, with such discharges occurring no closer than 12 nautical miles from the nearest land.
- Food scraps from construction and support vessels will be disposed of in accordance with the *Protection of the Sea (Prevention of Pollution from Ships) Act 1983* (Cwlth). The following prescriptions apply:
  - between 3 and 12 nautical miles of land, food scraps will be ground to diameters of less than 25 mm prior to being discharged
  - beyond 12 nautical miles of land, unground food scraps may be discharged without treatment, except when a vessel is within 500 m of a fixed or floating platform.

Nearshore- and offshore-specific

In addition to the above, all solid wastes (with the exception of food scraps) from offshore and nearshore construction and support vessels will be returned onshore for disposal. These will include the following:

- plastics
- floating dunnage, lining and packaging materials
- paper, rags, glass, metal, crockery, and similar refuse.

All hazardous wastes will be retained on board vessels and offshore facilities, and transported to the mainland for disposal.

3.3 Management controls—construction phase

Onshore-specific

During the early construction phase for the onshore facilities, appropriate temporary containment facilities will be utilised for the storage of wastes until permanent infrastructure is in place.

3.4 Management controls—operations phase

Offshore-specific

Where practicable, the generation of sands and sludge will be avoided or minimised at source. The amount of sands and sludge disposed of overboard will be kept to a minimum and will only be so disposed of with the approval of the relevant regulatory authorities.

Process equipment will be designed to restrict the potential for scale formation; scale-inhibition chemicals will be used if required.

If NORMs are generated in a waste stream, a procedure will be developed for their storage and handling requirements. The disposal of NORMs will be determined on a case-by-case basis and will be discussed with the relevant regulatory authorities. The selected disposal method will minimise the potential for environmental impact.

4 MONITORING

Monitoring activities will be undertaken throughout the life of the Project in relation to the identified objectives and targets. The activities listed below will be undertaken as part of the waste monitoring program:

- Waste incidents will be monitored through INPEX's and its contractors' incident-reporting databases.
- Records will be maintained of the quantities of waste generated, the quantities transported and disposed of, and the methods of disposal (e.g. landfill or recycling) for all phases of the Project. Records will include waste manifests and disposal certificates.

- Workplace "housekeeping" inspections will be undertaken to ensure that there is no accumulation of waste materials in work areas and that wastes are appropriately stored.

Triggered management response

A management response will be triggered by either of the following two circumstances:

1. a waste "incident"
2. the identification by an annual management review of a failure to meet an objective or target.

The responses to these are outlined below.

Response to waste incidents

Waste incidents would include the following:

- liquid waste spills to the environment
- discovery of an unknown or unidentified waste product
- unaccounted for waste (at any stage from generation to disposal)
- incorrect recording of waste type or quantity
- incorrect storage or transport of waste.

Detection of incidents associated with waste mismanagement will trigger internal notifications, reporting requirements, investigations and associated corrective and preventive actions.

The level of investigation will be dependent on the potential risk associated with the event. Corrective and preventive actions that may be triggered as a result of the investigation include spill clean-up, treatment and isolation of the item, an audit of the waste tracking system, a review and update of procedures or plans associated with waste management, and/or refresher training for personnel on Project waste management processes.

INPEX's Incident Reporting, Recording and Investigating Procedure or the Project contractor's document equivalent (approved by INPEX) will be used to determine incident severity, potential risk and associated reporting, recording and investigation requirements. All waste incidents and "near misses" will be entered into INPEX's and its contractors' incident databases and corrective actions will be tracked to closure.

Response to adverse findings by an annual management review

Failure to meet identified objectives and targets will trigger the following responses:

- a review and audit of current waste management practices to assess the practicability of their implementation, to identify new sources of waste, to assess resource requirements and to investigate further opportunities for recycling or reuse of products
- a review of current objectives and targets to assess achievability.

The response to the results of investigations and audits may include the following actions:

- an update of plans and associated documentation to reflect changes to waste management practices (if applicable)
- the arrangement of refresher training for personnel, to cover site waste management practices and processes
- the possible sourcing of additional resources to assist in the successful implementation of good waste management practice; such resources might include personnel, storage areas, waste receptacles, etc.

5 REPORTING, AUDITING AND REVIEW

Reporting, auditing and reviews will be undertaken throughout all phases of the Project. A summary of the reporting, auditing and review requirements relating to waste management is provided in the following two sections.

5.1 All phases

The following reporting, auditing and review requirements will be implemented for all phases of the Project:

- The quantities of waste generated, stored and disposed of will be recorded and tracked to its ultimate disposal.
- Incidents will be reported in accordance with INPEX's Incident Reporting, Recording and Investigating Procedure or the Project contractor's document equivalent (approved by INPEX).
- Monthly internal environmental reporting will be undertaken and will detail quantities of non-hazardous, hazardous and recyclable waste materials produced.
- An annual INPEX environmental report for the Project will be produced and will include details of waste incidents.
- INPEX and its contractors will conduct internal compliance audits on a periodic basis.

- Verification and compliance audits of waste contractors will be periodically undertaken.
- Records will be audited periodically to ensure that all personnel on site have completed the required HSE induction.
- Detailed waste management documentation, for example plans and procedures, will be reviewed periodically to ensure that they remain applicable to current operations and compliant with the requirements of INPEX and the regulatory authorities.

5.2 Construction and decommissioning phases

During the construction and decommissioning phases, in addition to the reporting requirements described above, contractors will be required to produce and provide to INPEX a monthly environmental report which will include a record of all environmental incidents.

6 SUPPORTING DOCUMENTATION

This provisional EMP is one document in a suite of plans, procedures and processes designed to ensure that INPEX's waste-management activities are undertaken in compliance with legislative requirements and in a safe and environmentally responsible manner.

Documentation or processes addressing the issues outlined below have been or will be developed to further support the preparation of INPEX's detailed waste-management documentation:

- incident reporting, recording and investigating
- chemical and hazardous substance management
- management of NORMs
- logistics guidelines for the transport of waste
- waste tracking
- HSE induction.

7 APPLICABLE LEGISLATION, STANDARDS AND GUIDELINES

INPEX is committed to complying with all relevant laws, regulations and standards. Legislative instruments, standards and guidelines specifically related to waste management include those listed below.

- *AS/NZS 1596:2008, The storage and handling of LP gas.*
- *AS 1940:2004, The storage and handling of flammable and combustible liquids*.
- *AS/NZS 2243.10:2004, Safety in laboratories—Storage of chemicals.*
- *AS 3780:2008, The storage and handling of corrosive substances.*
- *AS/NZS 3833:2007, The storage and handling of mixed classes of dangerous goods, in packages and intermediate bulk containers.*
- *AS 4326:2008, The storage and handling of oxidizing agents.*
- *AS 4332:2004, The storage and handling of gases in cylinders.*
- *AS/NZS 4452:1997, The storage and handling of toxic substances.*
- *AS/NZS 4681:2000, The storage and handling of Class 9 (miscellaneous) dangerous goods and articles.*
- Australian Petroleum Production & Exploration Association. 2008. *Code of environmental practice*. Australian Petroleum Production & Exploration Association, Canberra, ACT.
- Australian Pipeline Industry Association Ltd. 2009. *Code of environmental practice*: onshore pipelines. Australian Pipeline Industry Association Ltd, Canberra, ACT.
- *Dangerous Goods Act* (NT).
- Dangerous Goods Regulations (NT).
- Department of Industry, Tourism and Resources. 2005. *Petroleum (Submerged Lands) Acts Schedule: specific requirements as to offshore petroleum exploration and production*. Department of Industry, Tourism and Resources (now the Department of Resources, Energy and Tourism), Canberra, ACT.
- *Environmental Offences and Penalties Act 1996* (NT).
- Environmental Protection (National Pollutant Inventory) Objective [Northern Territory].
- *Environment Protection (Sea Dumping) Act 1981* (Cwlth).
- Environment Protection (Sea Dumping) Regulations 1983 (Cwlth).
- *Hazardous Waste (Regulation of Exports and Imports) Act 1989* (Cwlth).
- *Hazardous Waste (Regulation of Exports and Imports) Amendment Act 1996* (Cwlth).
- International Maritime Organization. 1978. *International convention for the prevention of pollution from ships, 1973, as modified by the protocol of 1978 relating thereto (MARPOL 73/78).* International Maritime Organization, London, United Kingdom.
- International Maritime Organization. 1972. *Convention on the prevention of marine pollution by dumping of wastes and other matter* [as modified by the 1996 protocol]. International Maritime Organization, London, United Kingdom.
- International Maritime Organization. 2004. *International maritime dangerous goods (IMDG) code*. International Maritime Organization, London, United Kingdom.
- *Litter Act* (NT).

- *Marine Pollution Act* (NT).
- Marine Pollution Regulations (NT).
- National Environment Protection (Movement of Controlled Waste between States and Territories) Measure (as varied December 2004).
- National Environment Protection (Used Packaging Materials) Measure (as varied July 2005).
- National Transport Commission. 2008. *Australian code for the transport of dangerous goods by road and rail*. 7th ed. National Transport Commission, Melbourne, Victoria.
- *Protection of the Sea (Prevention of Pollution from Ships) Act 1983* (Cwlth).
- *Quarantine Act 1908* (Cwlth).
- Quarantine Regulations 2000 (Cwlth).
- Secretariat of the Basel Convention. 1992. *Basel convention on the control of transboundary movements of hazardous wastes and their disposal*. Secretariat of the Basel Convention, Geneva, Switzerland.
- *Waste Management and Pollution Control Act* (NT) and the associated "Compliance Guidelines" prepared by the Department of Natural Resources, Environment and the Arts (now the Department of Natural Resources, Environment, the Arts and Sport), Darwin, Northern Territory.
- Waste Management and Pollution Control (Administration) Regulations (NT).

8 REFERENCES

DECC—*see* Department of Environment and Climate Change.

DECCW—see Department of Environment, Climate Change and Water.

Department of Environment and Climate Change. 2008. *Waste classification guidelines: Part 2—Immobilisation of waste*. Environment Protection Authority, Department of Environment and Climate Change, Sydney, New South Wales. Viewed online on 1 March 2010 at <http://www.environment.nsw.gov.au/resources/waste/08203immobilisationwaste.pdf>.

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DITR—*see* Department of Industry, Tourism and Resources.

Environment Protection Authority. 2009. *Waste definitions*. EPA Guideline 842/09. Environment Protection Authority, Adelaide, South Australia. Viewed online on 1 March 2010 at <http://www.epa.sa.gov.au/xstd_files/Waste/Guideline/guide_waste_definitions.pdf>.

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IMO—*see* International Maritime Organization.

International Maritime Organization. 1978. *International convention for the prevention of pollution from ships, 1973, as modified by the protocol of 1978 relating thereto (MARPOL 73/78)*. Viewed online on 1 March 2010 at <http://www.imo.org/Conventions/mainframe.asp?topic_id=258&doc_id=678>.

Appendix A: Listed wastes (from Schedule 2 of the Waste Management and Pollution Control (Administration) Regulations (NT))

Listed wastes
Acidic solutions or acids in solid form
Animal effluent or residues (including abattoir effluent, poultry and fish processing waste)
Antimony; antimony compounds
Arsenic; arsenic compounds
Asbestos
Barium compounds other than barium sulfate
Basic solutions or bases in solid form
Beryllium; beryllium compounds
Boron compounds
Cadmium; cadmium compounds
Ceramic-based fibres with physico-chemical characteristics similar to those of asbestos
Chlorates
Chromium compounds that are hexavalent or trivalent
Clinical and related wastes
Cobalt compounds
Containers that are contaminated with residues of a listed waste
Copper compounds
Cyanides (inorganic)
Cyanides (organic)
Encapsulated, chemically fixed, solidified, or polymerised wastes
Ethers
Filter cake
Fire debris and fire washwaters
Fly ash
Grease-trap waste
Halogenated organic solvents
Highly odorous organic chemicals (including mercaptans and acrylates)
Inorganic fluorine compounds excluding calcium fluoride
Inorganic sulfides
Isocyanate compounds
Lead; lead compounds
Mercury; mercury compounds
Metal carbonyls
Nickel compounds
Non-toxic salts
Organic phosphorus compounds
Organic solvents excluding halogenated solvents
Organohalogen compounds that are not otherwise specified in this Schedule
Perchlorates
Phenols; phenol compounds including chlorophenols
Phosphorus compounds other than mineral phosphates
Polychlorinated dibenzo-furan (any congener)
Polychlorinated dibenzo-p-dioxin (any congener)
Residue from industrial waste treatment or disposal operations

Appendix A: Listed wastes (from Schedule 2 of the Waste Management and Pollution Control (Administration) Regulations (NT))(continued)

Listed wastes
Selenium; selenium compounds
Sewerage sludge and residues including nightsoil and septic tank sludge
Soils contaminated with a listed waste
Surface active agents (surfactants) that contain principally organic constituents and that may contain metals and inorganic materials
Tannery wastes (including leather dust, ash, sludge and flours)
Tellurium; tellurium compounds
Thallium; thallium compounds
Triethylamine catalysts for setting foundry sands
Tyres
Vanadium compounds
Waste chemical substances arising from research and development or teaching activities, including those substances which are not identified and/or are new and the effects of which on human health and/or the environment are not known
Wastes containing peroxides other than hydrogen peroxide
Waste, containing cyanides, from heat treatment and tempering operations
Waste from the manufacture, formulation, and use of wood-preserving chemicals
Waste from the production, formulation and use of biocides and phytopharmaceuticals
Waste from the production, formulation and use of inks, dyes, pigments, paints, lacquers and varnish
Waste from the production, formulation and use of organic solvents
Waste from the production, formulation and use of photographic chemicals and processing materials
Waste from the production, formulation and use of resins, latex, plasticisers, glues and adhesives
Waste from the production and preparation of pharmaceutical products
Waste mineral oils unfit for their original intended use
Waste mixtures, or waste emulsions, of oil and water or hydrocarbon and water
Waste pharmaceuticals, waste drugs and waste medicines
Waste resulting from surface treatment of metals and plastics
Waste tarry residues arising from refining, distillation and any pyrolytic treatment
Waste substances and articles containing or contaminated by polychlorinated biphenyls (PCBs), polychlorinated naphthalenes (PCNs), polychlorinated terphenyls (PCTs) and/or polybrominated biphenyls (PBBs)
Wastes of an explosive nature not subject to the Dangerous Goods Act (NT)
Wool scouring waste
Zinc compounds

12 Commitments Register

12 COMMITMENTS REGISTER

12.1 Introduction

INPEX is committed to adopting management controls which will protect the environmental values of the areas in which the Ichthys Gas Field Development Project (the Project) will operate. These management controls are described and discussed in the various chapters of this draft environmental impact statement (Draft EIS), in particular in Chapter 7 *Marine impacts and management*, Chapter 8 *Terrestrial impacts and management*, Chapter 9 *Greenhouse gas management* and Chapter 10 *Socio-economic impacts and management*. They are also discussed in the provisional environmental management plans included as annexes to Chapter 11 *Environmental management program*.

To assist regulatory agencies, stakeholders and INPEX employees and contractors, Table 12-1 of this chapter provides a list of the Project's key environmental commitments. The commitments are listed by the following areas of focus:

1 general
2 receiving environment monitoring
3 alteration of marine habitats
4 drilling discharges
5 accidental marine hydrocarbon spills
6 naturally occurring radioactive materials (NORMs)
7 underwater noise and blast emissions
8 marine pests
9 marine megafauna
10 dredging, trenching and associated earthworks
11 soil erosion
12 acid sulfate soils
13 alteration to surface water and groundwater
14 vegetation clearing
15 alteration of terrestrial habitats
16 creation of breeding habitat for biting insects
17 introduced species
18 bushfire prevention
19 dust emissions
20 greenhouse gas and air emissions
21 onshore spills and leaks
22 wastes
23 liquid discharges
24 social integration
25 housing, social infrastructure and services
26 onshore traffic
27 marine traffic
28 heritage
29 airborne noise
30 visual amenity
31 commercial fishing
32 public safety
33 business opportunities, employment and training
34 decommissioning.

For the purposes of describing the environment in which the Project will operate, the development area can be divided into three main components:

- the offshore development area—this consists of the Ichthys Field in the Browse Basin off the north-west coast of Western Australia and its associated infrastructure, together with the gas export pipeline route from the field to the mouth of Darwin Harbour
- the nearshore development area—this consists of the gas export pipeline route from the mouth of Darwin Harbour south through the Harbour to the pipeline shore crossing on the west side of Middle Arm Peninsula; the waters around Blaydin Point in the East Arm where the product loading jetty, the module offloading facility, and the navigation channel will be constructed; and the dredge spoil disposal ground approximately 15 km north of Darwin Harbour
- the onshore development area—this consists of the onshore processing plant at Blaydin Point, the associated administration area and the onshore pipeline corridor from Blaydin Point to the pipeline shore crossing on the west side of Middle Arm Peninsula.

The phases of the Project described for each commitment are indicated in the register. These are design, construction, production drilling, precommissioning, commissioning, operations and decommissioning. In some cases the commitment will be relevant to "all phases" of the Project.

12.2 Key environmental commitments

Table 12-1 presents the key commitments for the Ichthys Gas Field Development Project.

Table 12-1: Key commitments for the Ichthys Gas Field Development Project

No.	Commitment (Action)	Phase(s)	Area	Reference
1	**General**			
1.1	The Ichthys Project's Health, Safety and Environmental Management Process will align with the requirements of *AS/NZS ISO 14001:2004, Environmental management systems—Requirements with guidance for use* and *AS/NZS 4801:2001 Occupational health and safety management systems—Specification with guidance for use.*	All phases	All areas	Chapter 11, Section 11.2
2	**Receiving environment monitoring**			
2.1	Wastewater discharge monitoring will be undertaken in the nearshore environment to confirm modelling predictions for wastewater dispersion.	Operations	Nearshore	Chapter 7, Section 7.3.4 Chapter 11, Section 11.4; Annexe 10, Section 4
2.2	A Darwin Harbour water quality monitoring program will be developed and implemented to determine if Project wastewater discharges are adversely impacting on water quality in the Harbour.	Operations	Nearshore	Chapter 7, Section 7.3.4 Chapter 11, Section 11.4; Annexe 10, Section 4
2.3	A marine sediments and bio-indicators monitoring program will be developed to determine if construction activities undertaken in acid sulfate soils have resulted in changes in pH and in the bio-availability of heavy metals in adjacent marine sediments.	Construction	Nearshore Onshore	Chapter 7, Section 7.3.2 Chapter 8, sections 8.2.2 and 8.6 Chapter 11, Section 11.4; Annexe 6, Section 4; Annexe 10, Section 4; Annexe 11, Section 4
2.4	Dredge-plume monitoring will be undertaken within Darwin Harbour and in the waters around the offshore dredge spoil disposal location.	Construction	Nearshore	Chapter 11, Section 11.4; Annexe 6, Section 4
2.5	A Reactive Coral Monitoring Program will be developed for the monitoring of the Channel Island coral community during dredging activities.	Construction	Nearshore	Chapter 7, Section 7.3.2 Chapter 11, Section 11.4; Annexe 6, Section 4
2.6	A coral monitoring program will be developed to document the effect of increased turbidity and sedimentation on corals due to dredging activities.	Construction	Nearshore	Chapter 7, Section 7.3.2 Chapter 11, Section 11.4; Annexe 6, Section 4
2.7	A soft-bottom benthos monitoring program for the offshore spoil disposal ground will be developed to determine the effects of dredge spoil disposal on soft-bottom benthos.	Construction	Nearshore	Chapter 7, Section 7.3.3 Chapter 11, Section 11.4; Annexe 6, Section 4
2.8	A soft-bottom benthos monitoring program will be developed to document the effects of increased suspended sediment loads and sedimentation on soft-bottom benthos communities in zones that could potentially be affected by dredging.	Construction	Nearshore	Chapter 7, Section 7.3.2 Chapter 11, Section 11.4; Annexe 6, Section 4
2.9	An intertidal sedimentation monitoring program will be developed to assess the effects on intertidal ecosystems of sedimentation from dredging.	Prior to construction Construction	Nearshore	Chapter 7, Section 7.3.2 Chapter 11, Section 11.4; Annexe 6, Section 4
2.10	A groundwater quality monitoring program will be developed to determine if activities in the onshore development area adversely impact on groundwater quality.	Operations	Onshore	Chapter 8, sections 8.2.3 and 8.6 Chapter 11, Section 11.4; Annexe 10, Section 4; Annexe 11, Section 4
2.11	Work will be undertaken in collaboration with the SERPENT[1] project to determine the impacts of production drilling discharges on epibenthic macrofauna in the offshore area.	Production drilling	Offshore	Chapter 11, Section 11.4; Annexe 10, Section 4
2.12	Air-quality monitoring will be undertaken to confirm modelling predictions.	Operations	Onshore	Chapter 8, Section 8.4.3 Chapter 11, Section 11.4

Table 12-1: Key commitments for the Ichthys Gas Field Development Project (continued)

No.	Commitment (Action)	Phase(s)	Area	Reference
2.13	Airborne noise monitoring will be undertaken to confirm modelling predictions.	Construction Operations	Onshore	Chapter 10, Section 10.3.10 Chapter 11, Section 11.4
2.14	A Marine Pests Monitoring Program will be developed for the nearshore development area. This will be developed in consultation with the relevant agencies.	Construction Operations	Nearshore	Chapter 7, Section 7.3.9 Chapter 11, Section 11.4; Annexe 13, Section 4
2.15	A Weed Monitoring Program will be developed to monitor the distribution and abundance of listed weeds species in the onshore development area.	Construction Operations	Onshore	Chapter 8, Section 8.3.4 Chapter 11, Section 11.4; Annexe 15, Section 4
2.16	A Vegetation Rehabilitation Monitoring Program will be developed and periodic surveys of rehabilitated areas will be undertaken to determine the level of success of rehabilitation programs.	Construction Operations	Onshore	Chapter 8, Section 8.3.1 Chapter 11, Section 11.4; Annexe 15, Section 4
2.17	A Mangrove Health Monitoring Program will be developed to assess the potential effects of Project activities on mangrove health.	Construction Operations	Nearshore Onshore	Chapter 8, Section 8.2.3 Chapter 11, Section 11.4; Annexe 10, Section 4
3	**Alteration of marine habitats**			
3.1	Flowlines and the gas export pipeline will be laid directly on to the seabed, without trenching in most areas, to minimise the disturbance of seabed habitats.	Construction	Offshore	Chapter 7, Section 7.2.1
3.2	Concrete weight coating will be used on the gas export pipeline to reduce the need for rock dumping or trenching in deep offshore waters, and to minimise the disturbance of seabed habitats.	Construction	Offshore	Chapter 7, Section 7.2.1
3.3	Antifouling paints used on offshore and nearshore infrastructure will be selected in accordance with regulatory-authority requirements.	Construction Operations	Offshore Nearshore	Chapter 7, sections 7.2.1, 7.2.3 and 7.3.4
3.4	Anchoring plans and procedures for construction vessels involved in dredging and pipelay activities will be developed to avoid sensitive seabed habitats, in consultation with the Darwin Port Corporation (DPC) and the harbourmaster.	Construction	Nearshore	Chapter 7, Section 7.3.1 Chapter 10, sections 10.3.8 and 10.3.9 Chapter 11, Annexe 6, Section 3.1.2; Annexe 9, sections 3.3 and 4.2
3.5	The dredging vessels will be equipped with appropriate global positioning system (GPS) equipment and other navigational aids to ensure that dredging will occur only in the specified dredge footprint.	Construction	Nearshore	Chapter 7, Section 7.3.1 Chapter 11, Annexe 6, Section 3.1.2
3.6	The central processing facility (CPF) and the floating production, storage and offtake (FPSO) facility will be removed from the infield location at decommissioning.	Decommis-sioning	Offshore	Chapter 7, Section 7.2.1 Chapter 11, Annexe 5, Section 3.1
4	**Drilling discharges**			
4.1	Procedural controls for preventing the accidental release of synthetic-based muds (SBMs) will be developed and implemented as part of a separate assessment under the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009 (Cwlth).	Prior to commence-ment of production drilling	Offshore	Chapter 7, Section 7.2.2 Chapter 11, Annexe 10, Section 3.4
4.2	Water-based muds (WBMs) will be used instead of SBMs in the upper-hole sections of production wells.	Production drilling	Offshore	Chapter 7, Section 7.2.2 Chapter 11, Annexe 10, Section 3.4
4.3	SBMs will be recovered after use and returned onshore for reuse or disposal.	Production drilling	Offshore	Chapter 7, Section 7.2.2 Chapter 11, Annexe 10, Section 3.4
4.4	The percentage by dry weight of SBMs released on drill cuttings will be restricted to 10% or less per well.	Production drilling	Offshore	Chapter 7, Section 7.2.2 Chapter 11, Annexe 10, Section 3.4

Table 12-1: Key commitments for the Ichthys Gas Field Development Project (continued)

No.	Commitment (Action)	Phase(s)	Area	Reference
4.5	The use of cuttings driers or other management options will be investigated to reduce SBMs on cuttings.	Production drilling	Offshore	Chapter 7, Section 7.2.2 Chapter 11, Annexe 10, Section 3.4
5	**Accidental marine hydrocarbon spills**			
5.1	The Project oil spill contingency plan (OSCP) will be revised prior to the commencement of construction and will be periodically reviewed (and updated as required) through the life of the Project.	All phases	Offshore Nearshore	Chapter 7, sections 7.2.4 and 7.3.5
5.2	As part of its OSCP, INPEX will have the capability to initiate real-time oil-spill fate and trajectory modelling so that any spill can be monitored and responses optimised.	All phases	Offshore Nearshore	Chapter 7, sections 7.2.4 and 7.3.5
5.3	Each component of the infrastructure in the offshore development area, including the gas export pipeline, will be designed to meet the oceanic, climatic and seismic conditions of the area.	Design	Offshore Nearshore	Chapter 7, sections 7.2.4 and 7.3.5
5.4	The FPSO will be constructed with a double-sided hull.	Design	Offshore	Chapter 7, Section 7.2.4
5.5	The design of the CPF and the FPSO will include engineering controls to prevent spills during refuelling, for example by using level devices and locating overflows from tanks and drainage systems appropriately.	Design	Offshore	Chapter 7, Section 7.2.4
5.6	Subsea equipment will be reviewed for potential snagging and dropped-object damage and appropriate measures will be taken as required to reduce risk to as low as reasonably practicable (ALARP).	Design	Offshore	Chapter 7, Section 7.2.4
5.7	In accordance with industry standards, blow-out preventers will be in place for each production well during drilling. They will be capable of withstanding pressures higher than those likely to be encountered.	Production drilling	Offshore	Chapter 7, Section 7.2.4
5.8	Measurement-while-drilling techniques will be in place during drilling operations to measure well paths, true vertical depth, bottom-hole location and orientation of directional drilling systems, and to transmit information to the surface for real-time pore-pressure monitoring.	Production drilling	Offshore	Chapter 7, Section 7.2.4
5.9	A well control manual will be maintained, providing guidance on the response required in the unlikely event of a subsea well failure.	Production drilling	Offshore	Chapter 7, Section 7.2.4
5.10	Stability and protection of the gas export pipeline will be achieved by the most appropriate construction technique, such as the addition of concrete coating, burial of the pipeline below the seabed and, where necessary, the placement of rock berms or armouring over the pipeline.	Design Construction	Offshore Nearshore	Chapter 7, sections 7.2.4 and 7.3.5
5.11	Hydrostatic testing of the gas export pipeline will be undertaken prior to the introduction of hydrocarbons.	Precommis-sioning	Offshore Nearshore	Chapter 7, Section 7.2.4
5.12	A precautionary zone will be defined and implemented for the gas export pipeline. This will be done in consultation with the regulatory authorities. The zone will be identified on marine navigation charts.	Operations	Offshore Nearshore	Chapter 7, sections 7.2.4 and 7.3.5
5.13	Periodic internal inspections of the gas export pipeline will be undertaken to assess its integrity.	Operations	Offshore Nearshore	Chapter 7, sections 7.2.4 and 7.3.5
5.14	Trading tankers will be subject to vetting procedures that will review the technical, operational and maintenance practices on each tanker prior to it being chartered.	Operations	Offshore Nearshore	Chapter 7, sections 7.2.4 and 7.3.5
5.15	Offloading operations will be monitored by a terminal representative on board the trading tanker.	Operations	Offshore Nearshore	Chapter 7, sections 7.2.4 and 7.3.5

Table 12-1: Key commitments for the Ichthys Gas Field Development Project (continued)

No.	Commitment (Action)	Phase(s)	Area	Reference
5.16	All valves and transfer lines will be checked for integrity before use, and offloading operations will be continuously monitored.	Operations	Offshore	Chapter 7, Section 7.2.4
5.17	A collision detection system will be in place for the CPF and FPSO.	Operations	Offshore	Chapter 7, Section 7.2.4
5.18	Appropriate spill response equipment will be available on the CPF, the FPSO, and the supply and pipelay vessels as well as at the onshore and nearshore facilities. Regular pollution response exercises will be undertaken.	Construction Operations	Offshore Nearshore Onshore	Chapter 7, sections 7.2.4 and 7.3.5
5.19	Visual monitoring of hoses, couplings and the sea surface will be undertaken during refuelling operations.	Construction Operations	Offshore Nearshore	Chapter 7, sections 7.2.4 and 7.3.5
5.20	Radio contact will be maintained between refuelling vessels and the offshore facilities or other vessels when refuelling activities are being undertaken.	Construction Operations	Offshore	Chapter 7, Section 7.2.4
5.21	During product loading, radio contact will be maintained between the support vessel and the jetty, and collision prevention procedures will be implemented.	Operations	Nearshore	Chapter 7, Section 7.3.5
5.22	Dry-break, breakaway couplings or similar technology will be installed and used where practicable during refuelling operations.	Construction Operations	Offshore	Chapter 7, sections 7.2.4
5.23	Maintenance, integrity testing and inspection programs will be undertaken on flowlines and condensate loading hoses.	Operations	Offshore	Chapter 7, Section 7.2.4
5.24	A maintenance and inspection program will be in place for product loading arms.	Operations	Nearshore	Chapter 7, Section 7.3.5
5.25	An emergency shutdown interface will be in place between vessels and the onshore gas plant.	Design Operations	Nearshore Onshore	Chapter 7, Section 7.3.5
5.26	The jetty structure is being designed according to Australian Standard *AS 4997:2005, Guidelines for the design of maritime structures* (taking cyclones into account). The jetty loading arms will be designed to allow them to be tied down in the event of a cyclone.	Design Operations	Nearshore	Chapter 7, Section 7.3.5
5.27	Approach speeds to the berth will be monitored by a speed-of-approach laser system and the data will be transmitted to the vessel pilot.	Design Operations	Nearshore	Chapter 7, Section 7.3.5
5.28	Sections of the subsea pipeline in Darwin Harbour will be trenched and impact-protected by rock dumping over the trench, to mitigate risks from anchor damage and ship grounding. The extent of the trenching and rock dumping will be dependent on the outcomes of the final quantitative risk assessment (QRA).	Design Construction	Nearshore	Chapter 7, Section 7.3.5 Chapter 10, Section 10.3.14
6	**Naturally occurring radioactive materials (NORMs)**			
6.1	Process equipment will be designed to restrict the potential for scale formation and scale-inhibition chemicals will be used if required.	Design Operations	Offshore	Chapter 7, Section 7.2.5 Chapter 11, Annexe 16, Section 3.4
6.2	Should scale be found to contain NORMs, a procedure will be developed for their storage and handling requirements. NORMs disposal will be determined on a case-by-case basis and will be discussed with the relevant regulatory authorities. The selected disposal method will minimise the potential for environmental impact.	Operations	Offshore	Chapter 7, Section 7.2.5 Chapter 11, Annexe 16, Section 3.4
7	**Underwater noise and blast emissions**			
7.1	A cetacean management plan and supporting documentation will be developed and their prescriptions will be implemented.	All phases	Offshore Nearshore	Chapter 7, sections 7.2.6, 7.2.9 and 7.3.10 Chapter 11, Section 11.3; Annexe 4, Section 3

Table 12-1: Key commitments for the Ichthys Gas Field Development Project (continued)

No.	Commitment (Action)	Phase(s)	Area	Reference
7.2	A piledriving and blasting management plan and supporting documentation will be produced and their prescriptions will be implemented.	Construction	Nearshore	Chapter 7, sections 7.3.1 and 7.3.7 Chapter 10, sections 10.3.10 and 10.3.14 Chapter 11, Section 11.3; Annexe 12, Section 3
7.3	Fauna "observation zones" will be designated for areas where vertical seismic profiling (VSP) activities are to be carried out. Procedures for cetacean observation will be developed to ensure that seismic profiling will not be carried out if cetaceans are observed within the observation zones.	Production drilling	Offshore	Chapter 7, Section 7.2.6 Chapter 11, Annexe 4, Section 3.1.1
7.4	A "soft-start" procedure will be implemented for VSP activities, to afford whales or other sensitive marine fauna the opportunity to leave the area before being exposed to the full intensity of underwater noise. This procedure requires the VSP acoustic source to commence at the lowest power setting, gradually increasing in power over a 20-minute period.	Production drilling	Offshore	Chapter 7, Section 7.2.6 Chapter 11, Annexe 4, Section 3.1.1
7.5	Confined blasting methods will be used, with micro-delays between charges to reduce peak pressure levels of each blast in the surrounding waters.	Construction	Nearshore	Chapter 7, Section 7.3.7 Chapter 11, Annexe 12, Section 3.1
7.6	Only the minimum required charge will be used for nearshore blasting operations.	Construction	Nearshore	Chapter 7, Section 7.3.7 Chapter 11, Annexe 12, Section 3.1
7.7	Fauna protection zones will be developed for nearshore blasting. The extent of these zones will be determined once detailed geotechnical investigations have been completed and further information from drill-and-blast contractors has become available.	Construction	Nearshore	Chapter 7, Section 7.3.7 Chapter 11, Annexe 12, Section 3.1
7.8	Trained marine fauna observers on board small vessels will survey fauna protection zones prior to the commencement of blasting. Blasting activities will be suspended if marine megafauna (e.g. cetaceans, dugongs, turtles or crocodiles) are observed to enter the fauna protection zone. Detonations will only occur if the fauna protection zone is observed to be free of marine megafauna for a period of at least 20 minutes.	Construction	Nearshore	Chapter 7, Section 7.3.7 Chapter 11, Annexe 12, Section 3.1
7.9	Marine blasting activities will only be undertaken in daylight hours in benign sea conditions. This will enable observers to detect marine traffic, recreational water-users or large marine animals within the safety exclusion zone and will make it easier to identify the animals.	Construction	Nearshore	Chapter 7, Section 7.3.7 Chapter 10, Section 10.3.14 Chapter 11, Annexe 12, Section 3.1
7.10	The possibility of using passive or active acoustic monitoring to identify submerged marine animals within marine-blasting fauna protection zones will be evaluated. If practicable, these methods are likely to be used to complement vessel-based surveys prior to the commencement of blasting activities.	Construction	Nearshore	Chapter 7, Section 7.3.7 Chapter 11, Annexe 12, Section 3.1
7.11	Should fish be killed as a result of blasting activities and float to the surface of the water, they will be retrieved in order to minimise the possibility of scavenging seabirds and other predators being injured by subsequent blasts	Construction	Nearshore	Chapter 7, Section 7.3.7 Chapter 11, Annexe 12, Section 3.1
7.12	Piledriving activities are planned to be undertaken during daylight hours only. Night-time piledriving would only be required if Project construction activities were to fall significantly behind schedule.	Construction	Nearshore	Chapter 7, Section 7.3.7 Chapter 10, Section 10.3.10 Chapter 11, Annexe 12 Section 3.2

Table 12-1: Key commitments for the Ichthys Gas Field Development Project (continued)

No.	Commitment (Action)	Phase(s)	Area	Reference
7.13	An observation zone with a radius of 100 m will be designated at the commencement of piledriving activities. This area will need to be confirmed as being clear of cetaceans, dugongs, turtles and crocodiles for 10 minutes prior to the start of operations.	Construction	Nearshore	Chapter 7, Section 7.3.7 Chapter 11, Annexe 12 Section 3.2
7.14	Piledriving will commence with a "soft-start" procedure, where activities are gradually scaled up over a 5-minute period. This will provide an opportunity for any sensitive marine fauna to leave the area before being exposed to the full intensity of underwater noise.	Construction	Nearshore	Chapter 7, Section 7.3.7 Chapter 11, Annexe 12 Section 3.2
7.15	A permit-to-work (or similar) system will be implemented to ensure that areas where blasting and piledriving activities are occurring, or will occur, are clearly identified and that management measures are in place prior to work commencing.	Construction	Nearshore	Chapter 7, Section 7.3.7 Chapter 11, Annexe 12, sections 3.1 and 3.2
8	**Marine pests**			
8.1	Quarantine management plans and supporting documentation will be developed and their prescriptions will be implemented in accordance with the requirements of the Australian Quarantine and Inspection Service (AQIS), the Northern Territory's Department of Regional Development, Primary Industry, Fisheries and Resources (DRDPIFR), and the DPC.	Construction Operations	Offshore Nearshore Onshore	Chapter 7, sections 7.2.8 and 7.3.9 Chapter 8, Section 8.3.4 Chapter 11, Section 11.3; Annexe 13, Section 3
8.2	INPEX will ensure that vessels engaged in Project activities comply with the biofouling requirements of the regulatory authorities.	Construction Operations	Offshore Nearshore	Chapter 7, sections 7.2.8 and 7.3.9 Chapter 11, Annexe 13, Section 3.2
8.3	Vessels engaged in Project work will be subjected to a biofouling risk assessment which may result in hull inspections or cleaning.	Construction Operations	Offshore Nearshore	Chapter 7, sections 7.2.8 and 7.3.9 Chapter 11, Annexe 13, Section 3.2
8.4	Relevant Project vessels will be required to maintain satisfactory records of antifouling management, hull-cleaning actions and ballast-water exchange.	Construction Operations	Offshore Nearshore	Chapter 7, sections 7.2.8 and 7.3.9 Chapter 11, Annexe 13, Section 5.1
8.5	Opportunistic inspections using remotely operated vehicle (ROV) film footage will be undertaken of submerged surfaces of offshore infrastructure to search for the presence of introduced species.	Operations	Offshore	Chapter 7, Section 7.2.8 Chapter 11, Annexe 13, Section 4
9	**Marine megafauna**			
9.1	A cetacean management plan and supporting documentation will be developed and their prescriptions will be implemented.	All phases	Offshore Nearshore	Chapter 7, sections 7.2.6, 7.2.9 and 7.3.10 Chapter 11, Section 11.3; Annexe 4, Section 3
9.2	Procedures for avoiding interactions between cetaceans and vessels or helicopters will be developed and implemented.	All phases	Offshore Nearshore	Chapter 7, sections 7.2.6, 7.2.9 and 7.3.10 Chapter 11, Annexe 4, Section 3.1.2
9.3	A range of options for reducing the risks of marine fauna entrainment by trailing suction hopper dredgers will be explored in consultation with the dredging contractor. Practicable options that could be effective in reducing risks will be incorporated as management controls into the final dredging management plan.	Construction	Nearshore	Chapter 7, section 7.3.10 Chapter 11, Annexe 6, Section 3.1.1
10	**Dredging, trenching and associated earthworks**			
10.1	A dredging and dredge spoil disposal management plan and supporting documentation will be developed and their prescriptions will be implemented.	Construction	Nearshore	Chapter 7, sections 7.3.1, 7.3.2 and 7.3.3 Chapter 11, Section 11.3; Annexe 6, Section 3

Table 12-1: Key commitments for the Ichthys Gas Field Development Project (continued)

No.	Commitment (Action)	Phase(s)	Area	Reference
10.2	If mangrove tree deaths result because of sedimentation from the dredging program (and are not attributable to natural causes or activities external to the Project), rehabilitation of the affected areas will be undertaken after the completion of dredging activities through a combination of natural recruitment, facilitated natural recruitment and active planting.	Construction	Nearshore	Chapter 7, Section 7.3.2 Chapter 11, Annexe 6, Section 4.3.2
10.3	Periodic inspections will be conducted in East Arm, where sediment accumulation could potentially impact upon the operability of infrastructure such as the East Arm Wharf berths, the Hudson Creek export facilities, and the East Arm boat ramp. Any unacceptable levels of sediment accumulation that occur in these areas will be removed at the end of the dredging program, or earlier if the operability of these facilities is affected.	Construction	Nearshore	Chapter 10, Section 10.3.5 Chapter 11, Annexe 6, Section 4.2.2
10.4	INPEX will undertake periodic bathymetric surveys of the spoil disposal ground outside Darwin Harbour to confirm sediment deposition depths and patterns.	Construction	Nearshore	Chapter 7, Section 7.3.3 Chapter 10, Section 10.3.5 Chapter 11, Annexe 6, Section 4.2.1
10.5	The final dredging program will be designed so that any changes to the current dredging methodology will not result in significant changes to the predicted environmental and social impacts described in this Draft EIS.	Design Construction	Nearshore	Chapter 4, Section 4.4.3
11	**Soil erosion**			
11.1	A vegetation clearing, earthworks and rehabilitation management plan and supporting documentation will be produced and their prescriptions will be implemented.	Construction Operations	Onshore	Chapter 8, sections 8.2.1, 8.3.1, 8.3.2 and 8.3.4 Chapter 11, Section 11.3; Annexe 15, Section 3
11.2	A liquid discharges, surface water runoff and drainage management plan and supporting documentation will be produced and their prescriptions will be implemented.	Construction Operations	Offshore Onshore	Chapter 8, sections 8.2.1 and 8.2.3 Chapter 11, Section 11.3; Annexe 10, Section 3
11.3	Surface-water drains and discharge points throughout the onshore development area will be designed to minimise erosion.	Design	Onshore	Chapter 8, Section 8.2.1 Chapter 11, Annexe 10, Section 3.1
11.4	Erosion protection infrastructure (e.g. silt fencing, contouring, and sediment ponds) will be installed to ensure that sediment is contained within the onshore development area as far as is practicable.	Construction	Onshore	Chapter 8, Section 8.2.1 Chapter 11, Annexe 10, Section 3.5
11.5	If soil erosion is evident, exposed surfaces at the affected area will be stabilised with mulched vegetation, dust suppressants or slope-stabilisation products.	Construction	Onshore	Chapter 8, Section 8.2.1 Chapter 11, Annexe 10, Section 3.5
11.6	Large-scale vegetation clearing and earthworks will preferentially be undertaken in dry-season conditions. Should clearing and earthworks be required to be undertaken during the wet season, adequate erosion and sedimentation control measures will be implemented to avoid any possible impacts.	Construction	Onshore Nearshore	Chapter 8, Section 8.2.1 Chapter 11, Annexe 10, Section 3.5; Annexe 15, Section 3.3
12	**Acid sulfate soils**			
12.1	An acid sulfate soil (ASS) management plan and supporting documentation will be developed and their prescriptions will be implemented.	Construction	Onshore Nearshore	Chapter 8, Section 8.2.2 Chapter 11, Section 11.3; Annexe 1, Section 3
12.2	Onshore facilities will be designed to minimise excavation of ASSs.	Design	Onshore Nearshore	Chapter 8, Section 8.2.2 Chapter 11, Annexe 1, Section 3.1

Table 12-1: Key commitments for the Ichthys Gas Field Development Project (continued)

No.	Commitment (Action)	Phase(s)	Area	Reference
12.3	If excavation of ASS is unavoidable, further testing to determine management and disposal options will be undertaken. Disposal options for ASSs include dumping at an offshore disposal ground; treatment of the ASSs with neutralising agents and reuse of the treated ASS as fill material; or treatment of the ASSs with neutralising agents followed by disposal of the treated ASS material off site.	Design Construction	Onshore Nearshore	Chapter 8, Section 8.2.2 Chapter 11, Annexe 1, Section 3.2
13	**Alteration to surface water and groundwater**			
13.1	A liquid discharges, surface water runoff and drainage management plan and supporting documentation will be produced and their prescriptions will be implemented.	Construction Operations	Onshore	Chapter 8, sections 8.2.1 and 8.2.3 Chapter 11, Section 11.3; Annexe 10, Section 3
13.2	Culverts will be installed to maintain natural tidal flows underneath the causeway between Blaydin Point and Middle Arm Peninsula.	Construction Operations	Onshore	Chapter 8, Section 8.2.3 Chapter 11, Annexe 10, Section 3.1
13.3	Numerous surface water drains will be constructed around the perimeter of the onshore development area, which, where applicable, will distribute fresh water to mangrove areas.	Design Construction Operations	Onshore	Chapter 8, Section 8.2.3 Chapter 11, Annexe 10, Section 3.1
13.4	Some areas on Blaydin Point will remain uncleared or unsealed, which will allow for some groundwater recharge by rainfall.	Design Construction Operations	Onshore	Chapter 8, Section 8.2.3 Chapter 11, Annexe 10, Section 3.1
14	**Vegetation clearing**			
14.1	A vegetation clearing, earthworks and rehabilitation management plan and supporting documentation will be produced and their prescriptions will be implemented.	Construction Operations	Onshore	Chapter 8, sections 8.2.1, 8.3.1, 8.3.2 and 8.3.4 Chapter 11, Section 11.3; Annexe 15, Section 3
14.2	Areas to be cleared will be clearly identified prior to work commencing. Clearing boundaries will be marked in the field and on site plans, and a register of clearing activities will be maintained.	Construction	Onshore	Chapter 8, Section 8.3.1 Chapter 11, Annexe 15, sections 3.3 and 5.2
14.3	The vegetation-clearing footprint for the onshore development area will be minimised during the design of the onshore facilities, subject to constructibility and safety operating requirements.	Design	Onshore	Chapter 8, Section 8.3.1 Chapter 11, Annexe 15, Section 3.1
14.4	All disturbance, including personnel and vehicle movement, will be contained within the designated onshore development area to avoid impacts to surrounding vegetation. Some additional clearances may be required around the perimeter of the site to allow for appropriate firebreaks.	Construction Operations	Onshore	Chapter 8, Section 8.3.1 Chapter 11, Annexe 15, Section 3.3
14.5	Temporarily disturbed areas such as those in the vicinity of the pipeline shore crossing and the onshore pipeline corridor, as well as areas around the plant that do not need to remain cleared, will be rehabilitated following the completion of construction activities.	Construction Operations	Onshore	Chapter 8, Section 8.3.1 Chapter 11, Annexe 15, Section 3.3
14.6	Some topsoil will be stockpiled from cleared areas for future use in rehabilitation.	Construction	Onshore	Chapter 8, Section 8.3.1 Chapter 11, Annexe 15, Section 3.3
14.7	Cleared vegetation will be mulched and stockpiled on site boundaries. Where possible, the mulch will be used both for rehabilitation and for soil stabilisation to prevent erosion. Cleared vegetation that cannot be reused will be disposed of off site. No stockpiled vegetation will be burned.	Construction	Onshore	Chapter 8, Section 8.3.1 Chapter 11, Annexe 15, Section 3.3

Table 12-1: Key commitments for the Ichthys Gas Field Development Project (continued)

No.	Commitment (Action)	Phase(s)	Area	Reference
15	**Alteration of terrestrial habitats**			
15.1	A vegetation clearing, earthworks and rehabilitation management plan and supporting documentation will be produced and their prescriptions will be implemented.	Construction Operations	Onshore	Chapter 8, sections 8.2.1, 8.3.1, 8.3.2 and 8.3.4 Chapter 11, Section 11.3; Annexe 15, Section 3
15.2	Major clearing activities will be undertaken in such a manner as to allow animals to move into remaining surrounding vegetation.	Construction	Onshore	Chapter 8, Section 8.3.2 Chapter 11, Annexe 15, Section 3.3
15.3	"High-risk" entrapment areas (e.g. deep trenches or pits) will be constructed with sloping egress ramps to allow trapped animals to escape. Targeted inspections will be undertaken of these areas and any animals which have been unable to escape will be removed and released.	Construction	Onshore	Chapter 8, Section 8.3.2 Chapter 11, Annexe 15, Section 3.3
16	**Creation of breeding habitat for biting insects**			
16.1	Natural drainage will be maintained around roads by installing drains and/or culverts, particularly in intertidal areas such as the causeway between Blaydin Point and Middle Arm Peninsula.	Design Construction Operations	Onshore	Chapter 8, Section 8.3.3 Chapter 11, Annexe 10, Section 3.1
16.2	Surface water drainage channels throughout the onshore development area will be designed to minimise the creation of breeding habitat for biting insects. Drains will be kept free of vegetation.	Design Construction Operations	Onshore	Chapter 8, Section 8.3.3 Chapter 11, Annexe 10, sections 3.1 and 3.7
16.3	Regular inspections will be carried out for mosquito larvae in high-risk areas and controls will be implemented as required.	Construction Operations	Onshore	Chapter 8, Section 8.3.3 Chapter 11, Annexe 10, Section 4
16.4	Temporary sedimentation systems will be designed to minimise their potential to become breeding habitat for biting insects.	Design Construction	Onshore	Chapter 8, Section 8.3.3 Chapter 11, Annexe 10, Section 3.1
17	**Introduced species**			
17.1	Quarantine management plans and supporting documentation will be developed and their prescriptions will be implemented in accordance with AQIS, DRDPIFR and DPC requirements.	Construction Operations	Offshore Nearshore Onshore	Chapter 7, sections 7.2.8 and 7.3.9 Chapter 8, Section 8.3.4 Chapter 11, Section 11.3; Annexe 13, Section 3
17.2	A vegetation clearing, earthworks and rehabilitation management plan and supporting documentation will be produced and their prescriptions will be implemented.	Construction Operations	Onshore	Chapter 8, sections 8.2.1, 8.3.1, 8.3.2 and 8.3.4 Chapter 11, Section 11.3; Annexe 15, Section 3
17.3	Topsoil containing high densities of weed seeds will not be used in rehabilitation.	Construction	Onshore	Chapter 8, Section 8.3.4 Chapter 11, Annexe 15, Section 3.3
17.4	Infestations of listed weeds will be controlled in the onshore development area and along the access road from Wickham Point Road.	Construction Operations	Onshore	Chapter 8, Section 8.3.4 Chapter 11, Annexe 15, Section 3.2
17.5	Machinery used for earthmoving and vegetation-clearing will be cleaned and inspected prior to commencement of work at the onshore development area to identify any attached material that should be removed for quarantine reasons.	Construction	Onshore	Chapter 8, Section 8.3.4 Chapter 11, Annexe 13, Section 3.3
17.6	A temporary washdown area for earthmoving and vegetation-clearing vehicles will be built for the construction phase.	Construction	Onshore	Chapter 8, Section 8.3.4 Chapter 11, Annexe 13, Section 3.1

Table 12-1: Key commitments for the Ichthys Gas Field Development Project (continued)

No.	Commitment (Action)	Phase(s)	Area	Reference
17.7	A temporary dedicated "quarantine-approved premises" (QAP) area will be provided for on Blaydin Point during the construction phase. The QAP will be designed to meet AQIS requirements.	Construction	Onshore	Chapter 8, Section 8.3.4 Chapter 11, Annexe 13, sections 3.1 and 3.3
17.8	Inspections of incoming vessels and modules will be undertaken in accordance with AQIS standards.	Construction Operations	Onshore	Chapter 8, Section 8.3.4 Chapter 11, Annexe 13, Section 3.2
18	**Bushfire prevention**			
18.1	A bushfire prevention management plan and supporting documentation will be produced and their prescriptions will be implemented.	Construction Operations	Onshore	Chapter 8, Section 8.3.5 Chapter 11, Section 11.3; Annexe 3, Section 3
18.2	Firebreaks will be established around Project infrastructure which borders woodlands. Advice will be sought from the Northern Territory's Bushfires Council on firebreak requirements for Blaydin Point.	Construction Operations	Onshore	Chapter 8, Section 8.3.5 Chapter 11, Annexe 3, Section 3.2
18.3	A firefighting capability will be available and strategically located firefighting stations will be established at the onshore Project site.	Construction Operations	Onshore	Chapter 8, Section 8.3.5 Chapter 10, Section 10.3.3 Chapter 11, Annexe 3, Section 3.2
18.4	Firefighting equipment will be available on site at all times, along with accessible supplies of water.	Construction Operations	Onshore	Chapter 8, Section 8.3.5 Chapter 11, Annexe 3, sections 3.1, 3.2 and 3.3
18.5	Grassy vegetation in the onshore development footprint will be controlled to reduce available fuel loads and prevent wildfire. Control methods may include slashing and spraying.	Construction Operations	Onshore	Chapter 8, Section 8.3.5 Chapter 11, Annexe 3, Section 3.2
18.6	Cleared vegetation will be stockpiled in designated areas, away from potential ignition sources.	Construction	Onshore	Chapter 8, Section 8.3.5 Chapter 11, Annexe 3, Section 3.3
18.7	An internal "hot work" permit system will be implemented for cutting, welding and any other work considered to have a high potential to start a fire.	Construction Operations	Onshore	Chapter 8, Section 8.3.5 Chapter 11, Annexe 3, Section 3.2
18.8	Designated smoking areas will be established for all phases of the Project and receptacles for cigarette butts will be provided.	All phases	Onshore	Chapter 8, Section 8.3.5 Chapter 11, Annexe 3, Section 3.2
19	**Dust emissions**			
19.1	A dust management plan and supporting documentation will be produced and their prescriptions will be implemented.	Construction	Onshore	Chapter 8, Section 8.4.2 Chapter 11, Section 11.3; Annexe 7, Section 3
19.2	Monitoring of dust generation and the effectiveness of management controls will be regularly undertaken.	Construction	Onshore	Chapter 8, Section 8.4.2 Chapter 11, Annexe 7, Section 4
19.3	Dust suppression techniques will be applied where necessary to protect vegetation health, worker health and amenity. This may include spraying from water trucks, irrigation, or stabilisation and revegetation of cleared areas that are no longer needed as soon as practicable during construction.	Construction Operations	Onshore	Chapter 8, Section 8.4.2 Chapter 10, Section 10.3.11 Chapter 11, Annexe 7, Section 3.2
19.4	On-site roads required for the operations phase will be sealed during the construction phase.	Construction	Onshore	Chapter 8, Section 8.4.2 Chapter 10, Section 10.3.11 Chapter 11, Annexe 7, Section 3.1

Table 12-1: Key commitments for the Ichthys Gas Field Development Project (continued)

No.	Commitment (Action)	Phase(s)	Area	Reference
19.5	Multiple handling of soil or rock materials will be minimised.	Construction	Onshore	Chapter 8, Section 8.4.2 Chapter 11, Annexe 7, Section 3.2
19.6	Loads in all trucks transporting soil, aggregate or other dust-generating materials to and from the onshore development area will be wetted down to reduce dust.	Construction	Onshore	Chapter 8, Section 8.4.2 Chapter 11, Annexe 7, Section 3.2
20	**Greenhouse gas and air emissions**			
20.1	An air emissions management plan and supporting documentation will be produced and their prescriptions will be implemented.	Operations	Onshore	Chapter 8, Section 8.4.3 Chapter 11, Section 11.3; Annexe 2, Section 3
20.2	A detailed greenhouse gas management plan and supporting documentation will be produced and their prescriptions will be implemented prior to commissioning.	Commis-sioning Operations	Onshore Offshore	Chapter 9, Section 9.5 Chapter 11, Annexe 8, Section 3
20.3	A commissioning plan will be developed to minimise and manage flaring during the commissioning phase.	Precommis-sioning	Onshore Offshore	Chapter 8, Section 8.4.3 Chapter 11, Annexe 2, Section 3.2
20.4	Greenhouse gas management offset targets will be defined once there is greater certainty in the legal and legislative framework around the Commonwealth Government's Carbon Pollution Reduction Scheme and once the technical and economic risks associated with offset options are assessed.	Prior to commis-sioning	Onshore Offshore	Chapter 11, Annexe 8, Section 2
20.5	Open-cycle gas turbines will be designed to achieve a low-NO_x (low nitrogen oxides) outcome.	Design	Onshore	Chapter 8, Section 8.4.3 Chapter 11, Annexe 2, Section 3.1
20.6	Residual hydrocarbons and hydrogen sulfide (H_2S) will be removed from the emission stream by acid gas removal unit (AGRU) incinerators. In the unlikely event that the AGRU incinerators are shut down, exhaust gases (including H_2S and residual hydrocarbons) will be hot-vented through gas turbine exhaust stacks to facilitate the safe dispersion of gases.	Design	Onshore	Chapter 8, Section 8.4.3 Chapter 11, Annexe 2, Section 3.1
20.7	Easily accessible sampling points will be provided on major emission points such as turbines and AGRU exhausts.	Design	Onshore	Chapter 8, Section 8.4.3 Chapter 11, Annexe 2, Section 3.1
20.8	Valves will be installed in the process system to allow for inventory isolation.	Design	Onshore Offshore	Chapter 8, Section 8.4.3 Chapter 11, Annexe 2, Section 3.1
20.9	Process monitoring systems and alarms will be installed to monitor flaring events and process upsets.	Design	Onshore Offshore	Chapter 8, Section 8.4.3 Chapter 9, Section 9.9.1 Chapter 11, Annexe 2, Section 3.1; Annexe 8, Section 3.1
20.10	Dry gas seals will be used on the main refrigerant compressors.	Design	Onshore Offshore	Chapter 8, Section 8.4.3 Chapter 11, Annexe 2, Section 3.1; Annexe 8, Section 3.1
20.11	Waste-heat recovery units or heat-recovery steam generators will be installed wherever waste heat can be economically utilised.	Design	Onshore Offshore	Chapter 8, Section 8.4.3 Chapter 9, Section 9.9.1 Chapter 11, Annexe 2, Section 3.1; Annexe 8, Section 3.1

Table 12-1: Key commitments for the Ichthys Gas Field Development Project (continued)

No.	Commitment (Action)	Phase(s)	Area	Reference
20.12	Boil-off gas from liquefied natural gas (LNG) storage tanks and LNG offtake tanker loading operations will be recovered by boil-off gas recompression systems and directed to the fuel-gas supply.	Design	Onshore	Chapter 8, Section 8.4.3 Chapter 9, Section 9.8.1 Chapter 11, Annexe 2, Section 3.1
20.13	Boil-off gas from butane and propane storage tanks will be recovered by butane and propane recovery systems.	Design	Onshore	Chapter 8, Section 8.4.3 Chapter 11, Annexe 2, Section 3.1
20.14	The ground and tankage flares will be designed to minimise the generation of particulates (smoke).	Design	Onshore	Chapter 8, Section 8.4.3 Chapter 10, Section 10.3.11 Chapter 11, Annexe 2, Section 3.1
20.15	The condensate storage tanks will be fitted with floating roofs.	Design	Onshore	Chapter 8, Section 8.4.3 Chapter 11, Annexe 2, Section 3.1
20.16	Consideration will be given to installing flare-gas recovery on all offshore flare systems.	Design	Offshore	Chapter 9, Section 9.9.1 Chapter 11, Annexe 8, Section 3.1
20.17	Selection of turbines will be based both on the Project's power requirements and on their operating efficiencies in high ambient temperatures.	Design	Onshore Offshore	Chapter 9, Section 9.9.1 Chapter 11, Annexe 8, Section 3.1
20.18	Combined-cycle gas turbines will be investigated as an alternative to open-cycle gas turbines for power generation.	Design	Onshore	Chapter 9, Section 9.9.1 Chapter 11, Annexe 8, Section 3.1
20.19	The base case is to use aeroderivative turbines for all offshore applications.	Design	Offshore	Chapter 9, Section 9.9.1 Chapter 11, Annexe 8, Section 3.1
20.20	Recovery of cargo tank vapours is being considered.	Design	Offshore	Chapter 9, Section 9.9.1 Chapter 11, Annexe 8, Section 3.1
21	**Onshore spills and leaks**			
21.1	An onshore spill prevention and response management plan and supporting documentation will be produced and their prescriptions will be implemented.	Construction Operations	Onshore	Chapter 8, Section 8.6 Chapter 11, Section 11.3; Annexe 11, Section 3
21.2	Onshore facilities will be designed and constructed in such a way that spills and leaks can be constrained or isolated, particularly in areas where there is an elevated risk of spill.	Design Operations	Onshore	Chapter 8, Section 8.6 Chapter 11, Annexe 11, Section 3.1
21.3	Material safety data sheets (MSDSs) will be available on the facilities to aid in the identification of appropriate spill clean-up and disposal methods.	Construction Operations	Onshore	Chapter 8, Section 8.6 Chapter 11, Annexe 11, Section 3.2; Annexe 16, Section 3.2
21.4	Chemicals and hazardous substances used during all phases of the Project will be selected and managed to minimise the potential adverse environmental impact associated with their transport, transfer, storage, use and disposal.	Construction Operations	Onshore	Chapter 7, sections 7.2.5 and 7.3.6 Chapter 8, sections 8.5.2 and 8.6 Chapter 11, Annexe 11, Section 3.2; Annexe 16, Section 3.2
21.5	Spill response materials and equipment (including personal protective equipment) will be available during all phases and will contain equipment to combat both chemical and hydrocarbon spills.	Construction Operations	Onshore	Chapter 8, Section 8.6 Chapter 11, Annexe 11, Section 3.2

Table 12-1: Key commitments for the Ichthys Gas Field Development Project (continued)

No.	Commitment (Action)	Phase(s)	Area	Reference
21.6	Personnel who routinely handle hazardous materials or wastes (e.g. refuelling personnel, pump operators, mechanics, and stores personnel) will receive training in handling, transporting and storing hazardous materials or wastes; in reporting and documentation requirements; and in spill clean-up techniques and practices.	Construction Operations	Onshore	Chapter 8, Section 8.6 Chapter 11, Annexe 11, Section 3.2
21.7	During construction of the onshore facilities, appropriate temporary containment facilities will be utilised for the storage of chemicals, fuel and hazardous waste until permanent infrastructure is in place.	Construction	Onshore	Chapter 8, Section 8.6 Chapter 11, Annexe 11, Section 3.3
22	Wastes			
22.1	A waste management plan and supporting documentation will be developed and their prescriptions will be implemented.	All phases	Offshore Nearshore Onshore	Chapter 7, sections 7.2.5 and 7.3.6 Chapter 8, sections 8.5.1 and 8.5.2 Chapter 11, Section 11.3; Annexe 16, Section 3
22.2	Waste minimisation will be included in the tendering and contracting process.	Construction	Offshore Nearshore Onshore	Chapter 7, sections 7.2.5 and 7.3.6 Chapter 8, Section 8.5.1 Chapter 11, Annexe 16, Section 3.2
22.3	Sufficient space will be provided on the FPSO and CPF and at the onshore facility to allow for the segregation and storage of wastes.	Design	Offshore Onshore	Chapter 7, Section 7.2.5 Chapter 8, Section 8.5.1 Chapter 11, Annexe 16, Section 3.1
22.4	Chemicals and hazardous substances used during all phases of the Project will be selected and managed to minimise the potential adverse environmental impact associated with their disposal.	All phases	Offshore Nearshore Onshore	Chapter 7, sections 7.2.5 and 7.3.6 Chapter 8, sections 8.5.2 and 8.6 Chapter 11, Annexe 11, Section 3.2; Annexe 16, Section 3.2
22.5	During the early construction phase, appropriate temporary containment facilities will be available for storing waste until permanent infrastructure is in place.	Construction	Onshore	Chapter 8, Section 8.5.1 Chapter 11, Annexe 16, Section 3.3
22.6	All solid-waste receptacles (e.g. skips and bins) will have covers and be fit for purpose and in good condition. This will prevent scavenging animals from gaining access to putrescible wastes.	Construction Commis-sioning Operations	Onshore	Chapter 8, sections 8.3.2, 8.3.4 and 8.5.1 Chapter 11, Annexe 16, Section 3.2
22.7	All hazardous liquid wastes will be stored over a bund in leakproof sealed containers.	All phases	Onshore	Chapter 8, Section 8.5.2 Chapter 11, Annexe 16, Section 3.2
22.8	Only approved and licensed waste contractors will be engaged for waste disposal.	All phases	Onshore	Chapter 7, sections 7.2.5 and 7.3.6 Chapter 8, Section 8.5.1 Chapter 11, Annexe 16, Section 3.2
22.9	Waste will be stored in the designated waste stations and appropriately segregated into hazardous waste and non-hazardous waste, and, where possible, into recyclable or reusable hazardous waste and recyclable or reusable non-hazardous waste. In the event of the discovery of any unidentified wastes, these will be treated as hazardous waste and stored accordingly.	All phases	Onshore Offshore	Chapter 7, Section 7.2.5 Chapter 11, Annexe 16, Section 3.2

Table 12-1: Key commitments for the Ichthys Gas Field Development Project (continued)

No.	Commitment (Action)	Phase(s)	Area	Reference
22.10	A baseline calculation of annual waste volumes will be undertaken in the first year of full steady operations (both LNG trains) and total waste reduction targets will be identified for subsequent years.	Operations	Offshore Onshore	Chapter 11, Annexe 16, Section 2
22.11	Non-hazardous solid wastes (with the exception of food scraps) and hazardous wastes will be retained on board vessels and offshore facilities, and transported to the mainland for disposal.	All phases	Offshore	Chapter 7, Section 7.2.5 Chapter 11, Annexe 16, Section 3.2
22.12	In the offshore environment, food scraps from construction, supply and supporting vessels will be disposed of in accordance with the requirements of the *Protection of the Sea (Prevention of Pollution from Ships) Act 1983* (Cwlth).	All phases	Offshore	Chapter 7, Section 7.2.5 Chapter 11, Annexe 16, Section 3.2
22.13	The amount of sands and sludge disposed of overboard will be kept to a minimum and will only be so disposed of with the approval of the relevant regulatory authorities.	Operations	Offshore	Chapter 7, Section 7.2.5 Chapter 11, Annexe 16, Section 3.4
22.14	In the offshore environment, food scraps from the FPSO and CPF will be disposed of in accordance with the requirements of Clause 222 of the Petroleum (Submerged Lands) Acts Schedule: Specific Requirements as to Offshore Petroleum Exploration and Production (2005).	Operations	Offshore	Chapter 7, Section 7.2.5 Chapter 11, Annexe 16, Section 3.2
22.15	All hazardous and non-hazardous solid wastes generated in the nearshore development area, including food scraps, will be retained on board vessels and transported to onshore facilities for disposal in accordance with the *Marine Pollution Act* (NT).	All phases	Nearshore	Chapter 7, Section 7.3.6 Chapter 11, Annexe 16, Section 3.2
23	Liquid discharges			
23.1	A liquid discharges, surface water runoff and drainage management plan and supporting documentation will be produced and their prescriptions will be implemented.	All phases	Nearshore Onshore	Chapter 7, sections 7.2.3 and 7.3.4 Chapter 8, Section 8.6 Chapter 11, Section 11.3; Annexe 10, Section 3
23.2	Liquid discharge monitoring of the combined outfall on the product loading jetty will be undertaken to confirm modelling predictions and to periodically monitor levels of pollutants in the combined outfall.	Commis-sioning Operations	Nearshore Onshore	Chapter 11, Annexe 10, Section 4
23.3	Hydrodynamic modelling of hydrotest water plumes from the gas export pipeline will be undertaken prior to the commissioning phase, to predict the dispersion of pollutants into the offshore marine environment.	Precommis-sioning	Offshore	Chapter 7, Section 7.2.3 Chapter 11, Annexe 10, Section 3.6
23.4	Hydrotest management plans and supporting documentation will be developed prior to precommissioning for approval under the relevant legislation.	Precommis-sioning	Offshore Nearshore	Chapter 7, sections 7.2.3 and 7.3.4 Chapter 11, Annexe 10, Section 3.6
23.5	A chemical selection process will be developed and will include consideration of the potential for ecotoxicity.	All phases	Offshore Nearshore Onshore	Chapter 7, sections 7.2.3 and 7.3.4 Chapter 11, Annexe 10, Section 3.6
23.6	Process modules will be precommissioned off site, if practicable, to minimise the discharge of hydrotest water.	Precommis-sioning	Offshore Nearshore	Chapter 7, sections 7.2.3 and 7.3.4 Chapter 11, Annexe 10, Section 3.6
23.7	During dewatering of the gas export pipeline, treated water will be discharged at the offshore facility.	Precommis-sioning	Offshore	Chapter 7, Section 7.2.3 Chapter 11, Annexe 10, Section 3.6

Table 12-1: Key commitments for the Ichthys Gas Field Development Project (continued)

No.	Commitment (Action)	Phase(s)	Area	Reference
23.8	Wellhead valves will be designed to minimise the volumes of subsea control fluids released.	Design	Offshore	Chapter 7, Section 7.2.3 Chapter 11, Annexe 10, Section 3.1
23.9	Water-soluble, low-toxicity hydraulic fluids will be selected to control open-loop subsea control valves.	Commis-sioning Operations	Offshore	Chapter 7, Section 7.2.3 Chapter 11, Annexe 10, Section 3.2
23.10	Sewage wastes will be macerated to diameters less than 25 mm prior to discharge from the CPF and FPSO in accordance with Clause 222 of the Petroleum (Submerged Lands) Acts Schedule: Specific Requirements as to Offshore Petroleum Exploration and Production (2005). The discharge will take place through submerged caissons.	Commis-sioning Operations	Offshore	Chapter 7, Section 7.2.3 Chapter 11, Annexe 10, Section 3.2
23.11	Construction vessels, supply vessels and the mobile offshore drilling unit (MODU) will adhere to the following prescriptions laid down by the *Protection of the Sea (Prevention of Pollution from Ships) Act 1983* (Cwlth) and the *Marine Pollution Act* (NT): • Sewage will not be discharged within three nautical miles of land. • Only treated sewage (macerated to fragment diameters less than 25 mm) will be discharged between three and twelve nautical miles of land. • Untreated sewage may be discharged beyond 12 nautical miles of land.	All phases	Offshore Nearshore	Chapter 7, sections 7.2.3 and 7.3.4 Chapter 11, Annexe 10, Section 3.3
23.12	Antifouling paints containing tributyltin compounds (TBTs) will not be used on any Project vessels or equipment in accordance with the prescriptions of the International Maritime Organization's International Convention on the Control of Harmful Anti-fouling Systems on Ships and the *Protection of the Sea (Harmful Anti-fouling Systems) Act 2006* (Cwlth).	All phases	Offshore Nearshore	Chapter 7, sections 7.2.1, 7.2.3 and 7.3.4
23.13	Oil-in-water concentrations of produced water will meet the regulatory requirements of less than 30 mg/L during each period of 24 hours as prescribed by Clause 29 of the Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009 (Cwlth). This will be monitored continuously by an online analyser to ensure compliance.	Commis-sioning Operations	Offshore	Chapter 7, sections 7.2.3 and 7.2.4 Chapter 11, Annexe 10, Section 3.2
23.14	Oil-in-water concentrations from the bilge discharges of construction and supply vessels, including the MODU, will meet the regulatory requirements of <15 mg/L in accordance with Annex I of the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto (MARPOL 73/78) and the Marine Pollution Regulations (NT).	All phases	Offshore Nearshore	Chapter 7, Section 7.2.4 Chapter 11, Annexe 10, Section 3.3
23.15	Vetting procedures for condensate tankers will be developed and implemented, ensuring that ballast-water tanks are segregated from fuel and product tanks.	All phases	Offshore Nearshore	Chapter 7, Section 7.2.3 Chapter 11, Annexe 10, Section 3.7
23.16	The wastewater outfall diffuser will be designed to optimise near-field dispersion of the discharged wastewater.	Design	Nearshore	Chapter 7, Section 7.3.4 Chapter 11, Annexe 10, Section 3.1
23.17	Drainage at the onshore development area will be designed to isolate areas that could be exposed to hydrocarbon contamination. Wastewater from these areas will be directed to an oily-water treatment system.	Design Operations	Nearshore Onshore	Chapter 7, Section 7.3.4 Chapter 11, Annexe 10, Section 3.1

Table 12-1: Key commitments for the Ichthys Gas Field Development Project (continued)

No.	Commitment (Action)	Phase(s)	Area	Reference
23.18	An on-site treatment facility will be used to treat sewage from the onshore development area during the operations phase, and will produce high-quality wastewater.	Operations	Onshore	Chapter 7, Section 7.3.4 Chapter 11, Annexe 10, Section 3.1
23.19	Wastewater streams will be sampled at appropriate frequencies and selected water quality parameters will be documented.	Operations	Onshore	Chapter 7, Section 7.3.4 Chapter 11, Annexe 10, Section 4
23.20	Maintenance practices during the operations phase (e.g. drainage of hydrocarbons from tanks and equipment) will avoid discharge of hydrocarbons to the oily-water treatment system.	Operations	Onshore	Chapter 7, Section 7.3.4 Chapter 11, Annexe 10, Section 3.2
24	**Social integration**			
24.1	INPEX personnel representing the Project will be expected to exhibit professional behaviour standards as required by INPEX's Code of Conduct. Through the Project induction, all Project personnel will be informed of the expectation that they will respect the Darwin community at all times and behave accordingly.	Construction Operations	Onshore Offshore Nearshore	Chapter 10, Section 10.3.1
24.2	Project personnel will be subject to random drug and alcohol testing.	Construction Operations	Onshore Offshore Nearshore	Chapter 10, Section 10.3.1
24.3	The accommodation village will include a number of restaurants, licensed premises and a range of social and recreational facilities for the benefit of the residents.	Construction	Onshore	Chapter 10, Section 10.3.1
24.4	A code of conduct for the accommodation village residents will be developed and implemented.	Construction	Onshore	Chapter 10, Section 10.3.1
24.5	An ongoing Stakeholder Communication Plan has been developed; this will create an avenue where the broader community can raise Project-related social issues and other matters.	Construction	Onshore	Chapter 2, Section 2.2 Chapter 10, Section 10.3.1
25	**Housing, social infrastructure and services**			
25.1	An accommodation village will be constructed to house the greater part of the construction workforce.	Construction	Onshore	Chapter 10, Section 10.3.2
25.2	An accommodation strategy is being developed to address accommodation solutions for short-term visitors during the construction phase and for managers and other personnel during the operations phase. This will include the requirements for periodic maintenance campaigns.	Construction Operations	Onshore	Chapter 10, Section 10.3.2
25.3	A first-aid capability will be available at the onshore facility during both the construction and the operations phases. In addition, a similar first-aid capability will be available at the accommodation village during the construction phase.	Construction Operations	Onshore	Chapter 10, Section 10.3.3
25.4	INPEX will work in conjunction with the Northern Territory Police, Fire and Emergency Services in order to plan effectively for any major emergencies.	Construction Operations	Onshore	Chapter 10, Section 10.3.3
25.5	A firefighting capability will be available and strategically located firefighting stations will be established at the onshore Project site.	Construction Operations	Onshore	Chapter 8, Section 8.3.5 Chapter 10, Section 10.3.3 Chapter 11, Annexe 3, Section 3.2
25.6	Fire-protection systems at the onshore Project site for the operations phase will be designed to enable INPEX personnel to handle fires capably until external help arrives.	Construction Operations	Onshore	Chapter 10, Section 10.3.3

Table 12-1: Key commitments for the Ichthys Gas Field Development Project (continued)

No.	Commitment (Action)	Phase(s)	Area	Reference
25.7	Appropriate quantities of water will be stored and made available for firefighting purposes during both the construction and operations phases at the onshore Project site.	Construction Operations	Onshore	Chapter 10, Section 10.3.3
25.8	An emergency response plan will be developed and emergency response teams will be established at the onshore Project site for both the construction and the operations phases of the Project.	Construction Operations	Onshore	Chapter 10, Section 10.3.3
25.9	The onshore facilities will be self-sufficient in meeting their power generation requirements during operations.	Operations	Onshore	Chapter 10, Section 10.3.3
25.10	Temporary ablution blocks and sewage systems will be in place at the onshore Project site to meet sewage management requirements during the construction phase.	Construction	Onshore	Chapter 10, Section 10.3.3
25.11	Permanent sewage treatment facilities will be installed at the onshore Project site for the operations phase of the Project.	Operations	Onshore	Chapter 10, Section 10.3.3
25.12	Waste-disposal facility capabilities for the construction and operations phases at the onshore Project site will be addressed during the detailed-design phase of the Project; this will be done in consultation with relevant local government authorities.	Design	Onshore Offshore	Chapter 10, Section 10.3.3
25.13	Ongoing consultation will be undertaken with local government, the Department of Planning and Infrastructure (DPI) and the Power and Water Corporation (PWC) in order to plan effectively for the provision of scheme water for Project requirements at the onshore Project site.	Design	Onshore	Chapter 10, Section 10.3.3
25.14	Development of the accommodation village will be undertaken in consultation with local government, the DPI and PWC in order to plan effectively for the provision of the required power, water, sewerage infrastructure and waste management facilities and avoid burdening existing infrastructure.	Construction	Onshore	Chapter 10, Section 10.3.3
26	**Onshore traffic**			
26.1	A traffic management plan and supporting documentation will be produced and their prescriptions will be implemented.	Construction	Onshore	Chapter 10, sections 10.3.4 and 10.3.10 Chapter 11, Section 11.3; Annexe 14, Section 3
26.2	The Project will work in conjunction with the DPI to identify any proposed road projects that may need to be brought forward or upgrades that may need to be undertaken to assist in reducing potential pressure on existing road systems.	Prior to Construction	Onshore	Chapter 10, Section 10.3.4 Chapter 11, Annexe 14, Section 3.2
26.3	Bus transport from the accommodation village or designated pick-up areas will be provided for the majority of the construction personnel.	Construction	Onshore	Chapter 10, Section 10.3.4 Chapter 11, Annexe 14, Section 3.2
26.4	Designated routes for travel from quarries, the accommodation village, the Darwin central business district, airport and East Arm Wharf will be set for the Project. The selection process for the routes will give consideration to minimising disturbance to local traffic and will be communicated to all relevant personnel.	Construction	Onshore	Chapter 10, Section 10.3.4 Chapter 11, Annexe 14, Section 3.2

Table 12-1: Key commitments for the Ichthys Gas Field Development Project (continued)

No.	Commitment (Action)	Phase(s)	Area	Reference
27	**Marine traffic**			
27.1	INPEX will undertake periodic bathymetric surveys of the dredge spoil disposal ground outside Darwin Harbour to confirm sediment deposition depths and patterns.	Construction	Nearshore	Chapter 7, Section 7.3.3 Chapter 10, Section 10.3.5 Chapter 11, Annexe 6, Section 4.2.1
27.2	An application will be made to the relevant government and regulatory agencies to implement safety exclusion zones and restricted navigation zones for the offshore and nearshore facilities. These zones will be gazetted on navigation charts.	Operations	Offshore Nearshore	Chapter 10, Section 10.3.5
27.3	An application will be made to the relevant government and regulatory agencies to send out a "Notice to Mariners" on the location of offshore infrastructure and the gas export pipeline. These notices will be promulgated through the Australian Maritime Safety Authority.	All phases	Offshore Nearshore	Chapter 10, Section 10.3.5
27.4	Shipping traffic schedules during the construction and operations phases will be developed in consultation with the DPC to minimise the impacts of marine traffic on Darwin Harbour.	Construction Operations	Nearshore	Chapter 10, Section 10.3.5
27.5	An application will be made to the relevant government and regulatory agencies to implement safety exclusion zones and restricted navigation zones around LNG, LPG and condensate tankers, and around selected construction vessels such as dredging and pipelay vessels.	Construction Operations	Offshore Nearshore	Chapter 10, Section 10.3.5
28	**Heritage**			
28.1	Heritage management plans and supporting documentation will be produced and their prescriptions will be implemented.	All phases	Onshore Nearshore	Chapter 10, sections 10.3.8 and 10.3.9 Chapter 11, Section 11.3; Annexe 9, sections 3 and 4
28.2	A Larrakia Heritage Management Committee (LHMC) will be established. It will be made up of representatives of the Larrakia people and INPEX and will have a standing agenda.	Prior to construction Construction Operations	Onshore	Chapter 10, Section 10.3.8 Chapter 11, Annexe 9, Section 3.1
28.3	Prior to commencement of construction, Aboriginal sites in the onshore development area will be divided into two categories: those which will receive full protection from disturbance and those which may need to be removed.	Prior to construction	Onshore	Chapter 10, Section 10.3.8 Chapter 11, Annexe 9, Section 3.2
28.4	In the case of an Aboriginal heritage site which may have to be moved, INPEX will request permission to do so from both the LHMC and the Heritage Branch of the Northern Territory's Department of Natural Resources, Environment, the Arts and Sport (NRETAS). If permission is granted to remove the site, advice will be sought from the traditional custodians on the correct procedures to be adopted for its removal.	Prior to construction Construction	Onshore	Chapter 10, Section 10.3.8 Chapter 11, Annexe 9, Section 3.2
28.5	Where the external boundary of an Aboriginal heritage site is 10 m or closer to any proposed construction activity, flagging, temporary fencing or similar will be erected 5 m from the site boundary and appropriate signage will be put in place if required by the Larrakia people. The boundary demarcation will be removed when the risk of disturbance no longer exists.	Construction	Onshore	Chapter 10, Section 10.3.8 Chapter 11, Annexe 9, Section 3.3

Table 12-1: Key commitments for the Ichthys Gas Field Development Project (continued)

No.	Commitment (Action)	Phase(s)	Area	Reference
28.6	Daily toolbox meetings, job hazard analyses, permit systems or similar will be implemented on site prior to the commencement of vegetation-clearing or construction activities. These will be undertaken to ensure that work areas are clearly identified before operations commence to avoid accidental disturbance to heritage sites either inside or outside the heritage site boundaries.	Construction	Onshore	Chapter 10, Section 10.3.8 Chapter 11, Annexe 9, Section 3.3
28.7	Anchor management plans will be developed to allow the safe anchoring of vessels undertaking pipelay, dredging and piledriving activities in the vicinity of any nearshore heritage or sacred sites.	Construction	Nearshore	Chapter 7, Section 7.3.1 Chapter 10, sections 10.3.8 and 10.3.9 Chapter 11, Annexe 6, Section 3.1.2; Annexe 9, sections 3.3 and 4.2
28.8	Monitoring will be undertaken for Aboriginal heritage sites. This will involve inspections by Larrakia representatives prior to and during the construction phase and during the commissioning and operations phases. Photographic records will be maintained for each of the sites.	All phases	Onshore	Chapter 10, Section 10.3.8 Chapter 11, Annexe 9, Section 5
28.9	To minimise disturbance, a 100-m-radius controlled zone will be established around all known Catalina flying-boat wrecks.	Construction	Nearshore	Chapter 10, Section 10.3.9 Chapter 11, Annexe 9, Section 4.2
28.10	To minimise disturbance, a 100-m-radius controlled zone for the wreck of the SS *Ellengowan* will apply (based on the intersection of latitude 12°32'16.3"S and longitude 130°52'06.3"E on the Port of Darwin 1:50 000 map sheet AUS 26).	Construction	Nearshore	Chapter 10, Section 10.3.9 Chapter 11, Annexe 9, Section 4.2
28.11	To minimise disturbance, a 100-m-radius controlled zone for the wreck of the coal hulk *Kelat* will apply (based on the intersection of the lines of latitude 12°29'55.4"S and longitude 130°52'40.2"E on the Port of Darwin 1:50 000 map sheet AUS 26).	Construction	Nearshore	Chapter 10, Section 10.3.9 Chapter 11, Annexe 9, Section 4.2
28.12	Accurate differential GPS (dGPS) locations of all wrecks near the nearshore development area will be obtained prior to the commencement of construction.	Construction	Nearshore	Chapter 10, Section 10.3.9 Chapter 11, Annexe 9, Section 4.2
28.13	Before dredging commences, Catalina flying-boat wrecks will be inspected to determine the current levels of sedimentation; records of these inspections will be kept.	Construction	Nearshore	Chapter 10, Section 10.3.9 Chapter 11, Annexe 9, Section 5
28.14	During the construction and operations phases, INPEX will periodically assess sediment conditions of Catalina wrecks near to the shipping channel and in consultation with NRETAS determine whether any remedial action is required to address impacts should they arise.	Operations	Nearshore	Chapter 10, Section 10.3.9
28.15	The World War II historical sites located on Blaydin Point are not listed and do not require approval to disturb; however INPEX will consult with the Heritage Branch of NRETAS before disturbing the sites, and all sites will be surveyed and recorded.	Prior to construction	Onshore	Chapter 10, Section 10.3.9 Chapter 11, Annexe 9, Section 4.2
29	**Airborne noise**			
29.1	A piledriving and blasting management plan and supporting documentation will be produced and their prescriptions will be implemented.	Construction	Nearshore Onshore	Chapter 7, sections 7.3.1 and 7.3.7 Chapter 10, sections 10.3.10 and 10.3.14 Chapter 11, Section 11.3; Annexe 12, Section 3

Table 12-1: Key commitments for the Ichthys Gas Field Development Project (continued)

No.	Commitment (Action)	Phase(s)	Area	Reference
29.2	Blasting operations will only be undertaken during daylight hours and adequate notice will be provided to communities which could be affected by the sound or activities (e.g. Darwin Harbour users, the City of Palmerston, and the Darwin Liquefied Natural Gas plant at Wickham Point).	Construction	Nearshore Onshore	Chapter 10, sections 10.3.10 and 10.3.14 Chapter 11, Annexe 12, Section 3.1
29.3	Smaller staggered blasts will be used for onshore blasting to minimise ground vibration and noise levels.	Construction	Onshore	Chapter 10, Section 10.3.10 Chapter 11, Annexe 12, Section 3.1
29.4	Piledriving activities are planned to be undertaken during daylight hours only. Night-time piledriving would only be required if Project construction activities were to fall significantly behind schedule.	Construction	Nearshore Onshore	Chapter 7, Section 7.3.7 Chapter 10, Section 10.3.10 Chapter 11, Annexe 12, Section 3.2
29.5	Buses will be utilised for transporting the majority of workers to and from site to reduce the total number of vehicles on the roads and therefore noise emissions.	Construction	Onshore	Chapter 10, Section 10.3.10 Chapter 11, Annexe 14, Section 3.2
29.6	Noise mitigation measures will be incorporated into the design and construction of the ground flare to reduce noise emissions.	Design	Onshore	Chapter 10, Section 10.3.10
30	**Visual amenity**			
30.1	The lighting design for the onshore and nearshore infrastructure will be selected with consideration of the visual impact to the community while meeting personnel safety requirements.	Design	Nearshore Onshore	Chapter 10, Section 10.3.11
30.2	The ground flares will be shielded to reduce light emissions.	Design	Onshore	Chapter 10, Section 10.3.11
30.3	The ground and tankage flares will be designed to minimise the generation of particulates (smoke).	Design	Onshore	Chapter 8, Section 8.4.3 Chapter 10, Section 10.3.11 Chapter 11, Annexe 2, Section 3.1
30.4	Dust suppression techniques will be employed where necessary to protect vegetation health, worker health and amenity. This may include spraying from water trucks or irrigation; it may also include stabilisation and revegetation of cleared areas that are no longer needed as soon as practicable during the construction phase.	Construction	Onshore	Chapter 8, Section 8.4.2 Chapter 10, Section 10.3.11 Chapter 11, Annexe 7, Section 3.2
31	**Commercial fishing**			
31.1	An application will be made to the relevant government and regulatory authorities to implement a safety exclusion zone with a radius of 500 m around surface and subsurface equipment in the offshore development area. This safety zone will be gazetted under the *Offshore Petroleum and Greenhouse Gas Storage Act 2006* (Cwlth), and will appear on Australian navigation charts.	All phases	Offshore	Chapter 10, Section 10.3.12
31.2	An application will be made to the relevant government and regulatory authorities to implement a precautionary zone around the offshore pipeline in consultation with the relevant regulatory authorities. The locations of the offshore infrastructure and pipeline will be gazetted on navigation charts.	Construction Operations	Offshore	Chapter 10, Section 10.3.12

Table 12-1: Key commitments for the Ichthys Gas Field Development Project (continued)

No.	Commitment (Action)	Phase(s)	Area	Reference
31.3	A precautionary zone will be applied within 200 m of the gas export pipeline in the nearshore development area, prohibiting dropping or dragging an anchor, or performing an action that could damage the pipeline (according to Section 66(5) of the *Energy Pipelines Act* (NT)).	Construction Operations	Nearshore	Chapter 10, Section 10.3.12
32	Public safety			
32.1	A safety exclusion zone for marine traffic and other recreational water users will be established and enforced during nearshore blasting activities. Public notices will be issued prior to blasting, to inform recreational water-users in any blasting area. INPEX will advise the community of the date, time and duration of the blasting activities and the boundaries of the safety exclusion zone.	Construction	Nearshore	Chapter 10, Section 10.3.14 Chapter 11, Annexe 12, Section 3.1
32.2	Notice will be given to the Northern Territory's Department of Lands and Planning and the Darwin Port Corporation advising vessel operators of any change to marine traffic conditions because of marine blasting activities.	Construction	Nearshore	Chapter 10, Section 10.3.14 Chapter 11, Annexe 12, Section 3.1
32.3	Blasting operations will only be undertaken during daylight hours and adequate notice will be provided to communities which could be affected by the sound or activities (e.g. Darwin Harbour users, the City of Palmerston, and the Darwin Liquefied Natural Gas plant at Wickham Point).	Construction	Nearshore	Chapter 10, sections 10.3.10 and 10.3.14 Chapter 11, Annexe 12, Section 3.1
32.4	Public access to the onshore development area will be restricted during construction.	Construction	Onshore	Chapter 10, Section 10.3.14 Chapter 11, Annexe 12, Section 3.1
32.5	Smaller staggered blasts will be carried out to minimise vibration and noise levels. The correct "maximum instantaneous charge" and blast-hole sizes will be used to minimise flyrock generation.	Construction	Onshore	Chapter 10, sections 10.3.10 and 10.3.14 Chapter 11, Annexe 12, Section 3.1
32.6	Public risk will be managed in accordance with the *National standard for the control of major hazard facilities* (2002) and the *National code of practice for the control of major hazard facilities* (1996) prepared by the National Occupational Health and Safety Commission and issued by Safe Work Australia.	Operations	Onshore	Chapter 10, Section 10.3.14
32.7	Marine exclusion zones will be established around the jetty and product tankers. The extent of the marine exclusion zones will be established in consultation with the DPC.	Operations	Nearshore	Chapter 10, sections 10.3.5 and 10.3.14
33	Business opportunities, employment and training			
33.1	INPEX will develop a communication engagement plan to support the key principles of the supplier relationship program and the Industry Participation Plan objectives.	All phases	Onshore	Chapter 10, Section 10.4.2
33.2	INPEX will support targeted training programs to further develop a local skilled construction labour force. This will include specific Aboriginal programs in the region.	Construction	Onshore	Chapter 10, Section 10.4.3
33.3	INPEX will explore and make use of successful training and development programs, infrastructure and initiatives to build the general labour capability with LNG skills in the region.	Construction Operations	Onshore	Chapter 10, Section 10.4.3
33.4	When sourcing additional Project resources, contract employers will give preference to suitable local applicants with the relevant skills, qualifications and work history.	Construction	Onshore	Chapter 10, Section 10.4.3

Table 12-1: Key commitments for the Ichthys Gas Field Development Project (continued)

No.	Commitment (Action)	Phase(s)	Area	Reference
34	**Decommissioning**			
34.1	Decommissioning plans and supporting documentation will be produced and their prescriptions will be implemented in consultation with the Commonwealth and Northern Territory governments.	Prior to decommissioning	Offshore Nearshore Onshore	Chapter 7, Section 7.2.1 Chapter 11, Section 11.3; Annexe 5, Section 3
34.2	When the Ichthys Field has reached the end of its useful life, the reservoirs will be permanently isolated, necessary well equipment will be removed, and the wells will be plugged and abandoned in accordance with Clause 514 of the Petroleum (Submerged Lands) Acts Schedule: Specific Requirements as to Offshore Petroleum Exploration and Production (2005).	Decommissioning	Offshore	Chapter 11, Annexe 5, Section 3.2
34.3	The CPF and the FPSO will be removed at the end of the useful life of the Ichthys Field.	Decommissioning	Offshore	Chapter 11, Annexe 5, Section 3.2

1 The SERPENT (Scientific and Environmental ROV Partnership using Existing iNdustrial Technology) project is a global collaborative project hosted by the DEEPSEAS group of the Ocean Biogeochemistry and Ecosystems Group at the National Oceanography Centre in Southampton, UK.

Glossary

AAPA	See **Aboriginal Areas Protection Authority** below.
AASS(s)	See **actual acid sulfate soil(s)** below.
abiotic	Non-living; devoid of life.
Aboriginal Areas Protection Authority	Abbreviated as **AAPA**. A statutory authority established under the *Northern Territory Aboriginal Sacred Sites Act* (NT) to administer sacred-site protection in the Northern Territory. The Administrator of the Northern Territory appoints members to the Authority, which administers the Act at arm's length from the day-to-day operations of the Northern Territory Government.
Aboriginal cultural heritage	The unique and irreplaceable legacy of the ancient, diverse and complex cultures of the original inhabitants of continental Australia. It encompasses cultural heritage as commonly understood but is particularly notable for its emphasis on the particular affinity that Aboriginal people have with the land, and the importance they place on social values and traditions, customs and practices, aesthetic and spiritual beliefs, artistic expression and language.
acid gas removal unit	Abbreviated as **AGRU**. Before raw natural gas can be processed and liquefied it has to be cleansed of impurities. Two of these are the "acid" gases carbon dioxide (CO_2) and hydrogen sulfide (H_2S). The CO_2 has to be removed from the gas stream to prevent it from freezing in the liquefaction process and blocking the main cryogenic heat exchanger and other equipment. The H_2S is removed from the gas stream to meet buyers' specifications for the final gas products. The Ichthys Project's AGRU removes the acid gases from the hydrocarbon gas stream using activated methyldiethanolamine. See **activated methyldiethanolamine** below.
acid sulfate soil(s)	Abbreviated as **ASS(s)**. Naturally occurring soft sediments and soils containing sulfides of iron, principally iron disulfide (FeS_2) but also iron monosulfide (FeS). The exposure of the sulfides in such soils to oxygen by drainage or excavation leads to their oxidation and to the generation of sulfuric acid. This in its turn reacts with other soil constituents to liberate naturally occurring heavy metals, such as aluminium, manganese, copper and arsenic, into soil and drainage waters. These substances are toxic in varying degrees to plants, fish, etc. See **actual acid sulfate soil(s)** and **potential acid sulfate soil(s)** below.
activated methyldiethanolamine	Abbreviated as **aMDEA**. An aqueous solution of methyldiethanolamine (MDEA) to which an activator has been added to accelerate the rate of absorption of carbon dioxide (CO_2) by the MDEA. The activator may be any of several organic compounds. See **MDEA** and **methyldiethanolamine** below.
actual acid sulfate soil(s)	Abbreviated as **AASS(s)**. Acid sulfate soils which have been subjected to disturbance and exposed to air. This exposure has therefore already resulted in the oxidation of some of the sulfides and the generation of liquid and leachable sulfuric acid. This acid moving through the soil has the potential to liberate naturally occurring heavy metals such as aluminium, manganese, copper and arsenic, which can cause secondary contamination of soils and water. These substances are toxic in varying degrees to plants, fish, etc. See **acid sulfate soil(s)** above and **potential acid sulfate soil(s)** below.

adsorption	The adhesion of molecules of a gas, liquid or dissolved substance as an ultrathin layer on the surface of (usually) solids.
aeolianite	A sedimentary rock formed from windblown sand that has been cemented by carbonates. See **calcarenite** below.
AGRU	See **acid gas removal unit** above.
airgun	A source of energy used to acquire seismic data in the marine environment. The airgun releases highly compressed air to produce an explosive blast into the water surrounding the gun. The shock waves are reflected and refracted by the subsurface layers of sediments and rocks and the returning signals are received by hydrophones.
airshed	A definable geographical area within which the movement of air containing gaseous emissions from industry, agriculture, bushfires, etc., takes place. An airshed will often be separated from other airsheds by local topographical and sometimes meteorological constraints.
ALARP	An acronym for the words "**as l**ow **a**s **r**easonably **p**racticable". This is a term used in the field of risk management and describes a process where the benefits of taking an action to minimise risk are evaluated with consideration of the practicality and costs of taking (or not taking) that action.
alkane	Any of a series of saturated hydrocarbons having the general formula C_nH_{2n+2}. The first five alkanes in the series are methane (CH_4), ethane (C_2H_6), propane (C_3H_8), butane (C_4H_{10}) and pentane (C_5H_{12}).
aMDEA	See **activated methyldiethanolamine** above.
anastomosing	Branching and recombining in a reticulated pattern, as in the channels in river deltas, the reticulation of veins in a leaf, or the cross-connections of arteries.
anoxic	Lacking (or deficient in) oxygen.
anthropogenic	Created or caused by man, or originating from human activity.
aspect	See **environmental aspect** below.
asphaltene	Asphaltenes constitute the heaviest component of crude oil. They are characterised by high molecular weight, often exist in solid form at room temperature, and are relatively non-volatile. Condensates contain very low levels of asphaltenes. See **condensate** below.
ASS(s)	See **acid sulfate soil(s)** above.
Australian emissions unit	The term used in Australian climate-change legislation to refer to a carbon pollution permit. See **carbon pollution permit** below.
avifauna	All of the bird species of a given region, taken collectively.
barotropic	Of tidal currents, flows induced by the horizontal forces resulting from a slope in the water surface.

bathymetry	The measurement of the depth of water in oceans and other large waterbodies.
benthic zone	The lowest levels in a body of water such as a sea or a lake, including the upper subsurface layers of the sediment. See **littoral zone**, **sublittoral zone** and **supralittoral zone** below.
benthos	The organisms attached to, or living on, in or near the seabed (or riverbed or lake floor).
billion	A thousand million (10^9 or 1 000 000 000). In the International System of Units (the SI) the prefix "giga-" (symbol G) indicates the value 10^9.
bioaccumulation	The increase in concentration of a usually toxic substance (e.g. a heavy metal such as lead or mercury or a pesticide such as DDT) in the tissues of a plant or an animal at a particular level in a biological food chain. Such toxins accumulate because they are absorbed at a faster rate than they can be excreted or broken down. Compare with **biomagnification** below.
bioavailability	In ecology, this term is used to describe the degree to which a substance existing or released into a particular environment is actually available for uptake by a living organism or organisms, for example a toxic metal or chemical in an aquatic ecosystem. Potentially toxic elements or substances may be unavailable for biological uptake because they are present in a form that organisms cannot absorb.
biochemical oxygen demand	Abbreviated as **BOD**. A measure of water pollution representing the content of biochemically degradable organic substances in water or effluent. It is typically measured as the mass of oxygen in milligrams per litre of water absorbed by a sample kept at 20 °C for five days. The oxygen is used by micro-organisms which break down organic materials into carbon dioxide and water.
bioclastic	Descriptive of sediments composed of broken fragments of organic skeletal matter, for example bioclastic limestones composed of shell fragments.
bioconcentration	The accumulation of waterborne chemicals by aquatic animals through non-dietary routes. By contrast, "bioaccumulation" is the accumulation of chemicals (by aquatic and other animals) through any route of exposure.
biodiversity	This term was defined by the United Nations Earth Summit in Rio de Janeiro in 1992 as "the variability among living organisms from all sources, including … terrestrial, marine, and other aquatic ecosystems, and the ecological complexes of which they are part: this includes diversity within species, between species and of ecosystems".
biofouling	The unwanted build-up of organisms on man-made structures. In the marine environment this occurs especially on the submerged portions of ships' hulls, oil and gas platforms, jetties, etc. It also applies to similar growths on filters, inside pipelines, and on other items of equipment used, for example, in the wastewater treatment industry.
biogenic	Produced by living organisms or biological processes.
biohermic	Descriptive of a moundlike mass of rock built by sedentary organisms such as colonial corals or calcareous algae.

biomagnification	The name given to the increase in concentration of a usually toxic substance (such as a heavy metal like lead or mercury or a pesticide like DDT) in the tissues of animals at higher levels in the biological food chain. The predators at the top of the food chain (e.g. man, dolphins and eagles) ingest and store in their tissues the bioaccumulated toxins of all the levels below them. Compare with **bioaccumulation** above.
bioregion	A biogeographical region characterised by a distinctive fauna and flora and made up of a group of interacting and related ecosystems. Terrestrial bioregions are defined in terms of their climate, geology, landforms and vegetation; marine bioregions are defined in terms of their plants, animals and ocean conditions.
biosequestration	The process of converting a chemical compound through biological processes to a chemically or physically isolated or inert form. The term is most commonly used to refer to the "locking", through photosynthesis, of the carbon in atmospheric carbon dioxide (CO_2) into plant biomass (usually trees) to offset the effect of the CO_2 and other greenhouse gases released by such activities as the development of natural gas fields, the burning of fossil fuels, etc.
biota	The collective term for the animal and plant life of a given region.
biotic	Relating to life or to living things.
biotone	An ecological term for a transition zone between two or more bioregions where the assemblages of species and communities are mixtures of those from the contributing bioregions.
bioturbation	In oceanography, the mixing of benthic sediments by the burrowing, feeding or other activity of living organisms such as annelid worms or bivalves.
BOD	See **biochemical oxygen demand** above.
bombora	An Australian word (from an Aboriginal language) for a coral reef or rock just under the sea's surface over which waves swell (in calm conditions) or break (in rough conditions).
BP	The letters meaning "before present" used by geologists, archaeologists, palaeontologists, etc., in association with an approximate year to specify when an event occurred in the distant past (usually in the order of thousands of years before the present, e.g. "8500 BP"). Because the "present" time changes, the year AD 1950 has been arbitrarily chosen as being the "present" for the purposes of the time scale.
British thermal unit	This unit (symbol **Btu**) is a measure of the energy required to raise the temperature of one pound of water by one degree Fahrenheit. Although no longer officially used in Britain or Australia, the British thermal unit is still widely used in the USA, as well as in the oil & gas industry worldwide where it appears along with its SI equivalent unit, the joule. (1 British thermal unit = 1.055×10^3 joules.) See **quad** below.

BTEX	The acronym (pronounced "bee-tex") for the low-boiling-point aromatic hydrocarbon compounds benzene (C_6H_6), toluene ($C_6H_5CH_3$), ethylbenzene ($C_6H_5CH_2CH_3$), and xylenes ($C_6H_4(CH_3)_2$). (The word "xylenes" is plural as there are three xylene isomers.) The BTEX compounds form a subset of the chemicals called "volatile organic compounds" (VOCs). They are some of the most commonly encountered VOCs and are, for example, normal components of petrol. The BTEX hydrocarbons are lumped together because they have similar properties and are toxic to humans and to the environment in general, particularly when they contaminate soil and groundwater. See **volatile organic compound(s)** below.
Btu	See **British thermal unit** above.
butane	An alkane hydrocarbon with the chemical formula C_4H_{10}. It is a major constituent (with propane) of liquefied petroleum gas. See **ethane**, **isopentane**, **liquefied petroleum gas**, **methane**, **pentane** and **propane** below.
bycatch	The non-target species caught incidental to commercial fishing operations, including both saleable and non-saleable fish and other animals.
calcarenite	A sedimentary rock formed from sand, shell fragments and other carbonate material. See **aeolianite** above.
carbon (dioxide) capture and storage	Abbreviated as **CCS**. An approach to carbon dioxide (CO_2) abatement in which the greenhouse gas CO_2 is captured from industrial processes (such as power generation and gas-field development projects) and injected deep underground for long-term storage in secure geological formations. The process is also called "geosequestration". See **geosequestration** below.
carbon dioxide equivalent	Abbreviated as **CO_2-e**. A measure, using carbon dioxide (CO_2) as the standard, used to compare the global warming potentials of the different greenhouse gases. For example, if the global warming potential for methane over 100 years is taken as 21, this means that the emission of 1 Mt of methane may be expressed as the emission of 21 Mt of carbon dioxide equivalents. See **methane** below.
carbon footprint	A measure of the total amount of greenhouse gas emissions (measured in carbon dioxide equivalents) that is directly and indirectly caused by an activity or is accumulated over the lifespan of a product.
carbon intensive	Descriptive of fuels, industries, economies, etc., whose emissions of greenhouse gases (measured in carbon dioxide equivalents) are relatively high in comparison with those of other fuels, industries, or economies.
carbon pollution permit	Australia's proposed domestic unit of compliance with an emissions trading scheme. It has been proposed that each permit should correspond to one tonne of carbon dioxide equivalent. In proposed Australian legislation a "carbon pollution permit" is referred to as an "Australian emissions unit". See **carbon dioxide equivalent** above.

Carbon Pollution Reduction Scheme	Abbreviated as **CPRS**. The name used for the Australian Government's emissions trading scheme (or ETS), proposed to be established as part of a framework for meeting the climate-change challenge. See **emissions trading scheme** below.
carbon sink	Any natural or man-made system that takes up and stores large quantities of carbon dioxide from the atmosphere, especially forests and the oceans.
carbon tax	A tax imposed by a government on industry-generated emissions of carbon dioxide (CO_2) and possibly other greenhouse gases. Its intention is to discourage the use of fossil fuels and thereby reduce CO_2 emissions which are believed to contribute to the phenomenon of global warming.
cay	A small low-lying island or island-like bank or reef of sand, coral, etc.
CCS	See **carbon (dioxide) capture and storage** above.
cetacean	Any whale, dolphin or porpoise of the largely marine order Cetacea.
cfu	See **colony-forming unit** below.
"charismatic megafauna"	Large well-known animals, such as whales, tigers, elephants and eagles, which possess wide popular appeal and can therefore be used by environmentalists in publicity campaigns to raise conservation awareness and funds. As these "charismatic" species are generally key or apex species, any conservation gains made for them are likely to cascade down to all of the plants and animals of the ecosystems in which they live.
chenier	A sandy or shelly beach ridge on a mudflat area, caused by wave-induced sorting of the mudflat sediments to concentrate coarser material in ridges.
chlorophyll-*a*	The primary photosynthetic pigment in all plants that carry out photosynthesis.
colluvium	Unsorted and unconsolidated rock etc. material at the base of a cliff or slope, deposited there by gravity. The adjective is "colluvial".
colony-forming unit	Abbreviated as **cfu**. A unit used in microbiology as a measure of the viable micro-organisms (typically bacteria) present in a water sample and commonly used to gauge the level of contamination of water. It is typically measured as the number of colony-forming units present in one hundred millilitres of water (cfu/100 mL).
combustion greenhouse gas	"Combustion greenhouse gases", as opposed to "reservoir greenhouse gas" in the context of liquefied natural gas (LNG) production, are the greenhouse gases created by burning any type of carbon-containing fuel in the LNG production process. They are produced, for example, by the gas turbines used for compression and power generation, as well as by incinerators, hot-oil furnaces, and flares.
condensate	In the oil & gas industry, condensate is the name given to the mixture of heavier hydrocarbons which is present in hydrocarbon-containing reservoirs. Condensate is ultimately marketed, after fractionation, in liquid form at normal atmospheric temperature and pressure.

contingent gas resources	In the resources industry, contingent gas resources are those which are potentially recoverable from known accumulations, but only if a number of contingent circumstances are overcome; these may be economic, legal, environmental, political, and regulatory matters, or a lack of markets.
coralgal	Descriptive of a marine reef substrate consisting of fragments of coral and other calcareous organisms bound together with algal growths.
coralline algae	Coralline algae are red algae of the marine order Corallinales, characterised by having calcareous deposits within their cell walls. They are typically encrusting and rocklike and play an important role in the ecology of coral reefs.
corymbose	Descriptive of corals, especially of the genus *Acropora*, which have horizontal branches and short-to-medium vertical branchlets that terminate in a flat top.
CO_2	The chemical formula for carbon dioxide.
CO_2-e	See **carbon dioxide equivalent** above.
CPRS	See **Carbon Pollution Reduction Scheme** above.
cryogenic	Of or relating to very low temperatures.
cuirasse	In geology, the name sometimes given to the weathered rock "crust" or "iron crust" on the surface of a soil in tropical regions. It is also called a "lateritic duricrust". See **duricrust** below.
cultural heritage	The cultural legacy of a group or society that is inherited from past generations, nurtured in the present and held in trust for the benefit of future generations. Its tangible components include both movable and immovable objects of archaeological, architectural, artistic, environmental, ethnographic, geological, historical and palaeontological importance. Its intangible components include social values and traditions, customs and practices, aesthetic and spiritual beliefs, artistic expression, language and other aspects of human activity.
Darwin Coastal Bioregion	One of the 85 terrestrial bioregions (= biogeographical regions) into which Australia has been divided. It covers an area of 28 000 km^2 and includes most of the western coastline of the Northern Territory. The major population centres in the bioregion are Darwin and Palmerston and it extends from Wadeye in the south through Peppimenarti to Oenpelli and Murganella in the north.
Darwin Harbour region	The "Darwin Harbour region" was defined by the Darwin Harbour Advisory Committee in 2003 for its *Darwin Harbour regional plan of management* as an area covering Port Darwin, Shoal Bay and their catchments. It covers 3227 km^2 and extends from Charles Point to Gunn Point, including the estuarine areas and tributaries of Woods Inlet, West Arm, Middle Arm, East Arm, the Howard River and all of the land that drains into these waterways. The total area of land within the Darwin Harbour region as thus defined is 2417 km^2. Six local governments are contained within the region: Darwin City Council, Palmerston City Council, Litchfield Council, Cox Peninsula Community Government Council, Belyuen Community Government Council, and Coomalie Community Government Council.

dB(A)

The symbol used in acoustics for the decibel (using the "A" weighting), a measure of perceived loudness.

Statistical sound level descriptors, such as $L_{A\,1}$, $L_{A\,10}$, and $L_{A\,90}$ are used to represent noise levels in A-weighted decibels that are exceeded 1%, 10% and 90% of the time.

See $\mathbf{L_{A\,10}}$ and $\mathbf{L_{A\,90}}$ below.

decibel

See **dB(A)** above.

delphinid

Any member of the dolphin family Delphinidae, including dolphins, pilot whales, killer whales and the melon-headed whale.

demersal

Descriptive of a fish etc. living near the sea bottom.

depauperate

Descriptive of a fauna, flora or ecosystem, especially on islands, which is lacking the species richness of similar environments or habitats elsewhere. The term is commonly applied to "islands" of natural vegetation in an agricultural landscape as these will inevitably decline in species richness over time.

detailed design

In engineering, the process of refining and expanding the preliminary design of a structure or component of a structure to the extent that the design is sufficiently complete to allow construction etc. to commence.

detritivore

An animal that subsists entirely or predominantly on dead organic material, especially plant detritus.

differential global positioning system

Abbreviated as **dGPS**. An enhanced global positioning system whose accuracy has been improved through the use of a network of fixed, ground-based reference stations with precisely known locations. Each station calculates its location based on the GPS satellite signals and compares this location with its true position. Any difference (that is, any inaccuracy contained in the signal from the global navigation satellite system) is broadcast to the dGPS user to correct the information received from the satellite system.

See **global positioning system** below.

digitate

Of corals, having short unbranched branches like the fingers of a hand.

dolphin

For the man-made mooring dolphins used in ports and marine terminals, see **mooring dolphin** below.

dry season (Darwin)

Darwin's climate is influenced by the tropical monsoon and thus has two distinct seasons—a wet season and a dry season. The dry season extends from May until October and the wet season from November until April. The dry season is mostly rain-free and day temperatures range from 16 to 32 °C (averaging about 25 °C).

See **wet season (Darwin)** below.

duricrust

In geology, the weathered hard rock "crust" formed on the surface of a soil or in the upper horizons of a soil in a semi-arid climate. The duricrust is "cemented" by the precipitation of minerals such as iron oxides and oxyhydroxides by the evaporation of groundwater saturated with dissolved salts etc.

See **cuirasse** above.

EC_{10}	The notation EC_{10} stands for "effect concentration 10%" or the concentration of a substance that results in 10% less growth, fecundity, germination, etc., in a population. In ecology it is used as a measure of a substance's ecotoxicity but, unlike the LC_{10} which measures lethality, the EC_{10} value measures sublethality—it demonstrates the adverse effects of a substance on a test organism, such as changes in its behaviour or physiology. See **EC_{50}**, **IC_{50}**, **LC_{50}** and **LD_{50}** below.
EC_{50}	The notation EC_{50} stands for "effect concentration 50%". See **EC_{10}** above and **IC_{50}**, **LC_{50}** and **LD_{50}** below.
ecotourism	In the strict sense ecotourism is a specialised form of tourism aimed at ecologically and environmentally aware people. It usually has a strong educational focus and often involves travel to wilderness areas or areas with special environmental or wildlife values with a view to drawing attention to their fragility. The term has been watered down, however, and now includes any commercial tourism operations in wilderness and semi-wilderness areas.
ecotoxicology	The study of the adverse effects of chemical or physical agents on ecosystems and on all or any of the animal and plant species living in them. These adverse effects may be lethal (causing death) or sublethal (having negative effects on growth, development, fertility, genetic constitution, etc.). Ecotoxicity tests may be carried out at the request of regulatory authorities, typically using well-studied "indicator" species.
EEZ	See **exclusive economic zone** below.
effect concentration 10%	See **EC_{10}** above.
EIS	See **environmental impact statement** below.
emissions trading scheme	Abbreviated as **ETS**. The name applied to a government approach to reducing pollutant production, especially of greenhouse gases but also of pollutants such as sulfur dioxide, through which economic incentives to achieve reductions are offered to industry. In Australia, the Commonwealth Government's ETS, the Carbon Pollution Reduction Scheme, proposes to achieve CO_2-e reduction through a "cap and trade" process whereby the government sets a limit or "cap" on the total emissions allowable from the activities or sectors covered under the scheme by setting a limit on the number of permits it releases. An industry needs to produce a "credit" or "permit" or "offset" for every tonne of gas it emits. This creates a market where some industries that cannot avoid reducing their CO_2-e production to below the cap are allowed to buy or trade "carbon credits" from another business that is emitting below its own cap. See **carbon dioxide equivalent**, **Carbon Pollution Reduction Scheme** and **CO_2-e** above.
endemic	Of plants or animals, native to and restricted to a specified geographical region.
endemicity	In biodiversity science, a measure of the extent to which the plants or animals (or both) of a particular region are endemic to it. It may be applied to the whole fauna or flora of the region or to a specified taxonomic group. It is often expressed as a percentage.

enhanced greenhouse effect	The name given to the imbalance created in the natural greenhouse effect—the historical equilibrium between incoming solar radiation and outgoing emissions of heat energy from the earth—by the increase in greenhouse gas emissions from human actions such as burning fossil fuels, intensive agriculture and land clearing. The “enhanced greenhouse effect” is believed to be the cause of global warming. See **greenhouse effect** below.
ENVID	This is the acronym for “environmental (impact) identification”. An ENVID process is a risk assessment process that investigates the likelihood of an accidental or unplanned event which could cause adverse impacts to air, land, water or living organisms in the natural (or urban etc.) environment.
environment	The Northern Territory Government defines the term “environment” in the *Environmental Assessment Act* (NT) as follows: “environment” means all aspects of the surroundings of man including the physical, biological, economic, cultural and social aspects The Commonwealth Government defines the term “environment” in the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth) as follows: ***environment*** includes: (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). These definitions are adhered to in the *Ichthys Gas Field Development Project: draft environmental impact statement*.
environmental aspect	In environmental management in Australia an “environmental aspect” is an element or activity of a project or operation that may result in an impact upon the environment, for example gas emissions, light emissions, the production of waste material, and vegetation clearing.
environmental impact	In environmental management in Australia an “environmental impact” is any change to the environment, whether adverse or beneficial, wholly or partly resulting from an organisation’s environmental aspects. See **environmental aspect** above.
environmental (impact) identification	See **ENVID** above.
environmental impact statement	Abbreviated as **EIS**. An environmental impact statement is a comprehensive report, based on detailed studies, that discloses the possible, probable and certain environmental consequences of a proposed development or project and outlines the measures that would be implemented to mitigate them. It is required by law and is prepared by or for a project proponent for submission to government as part of a formal review process. The EIS is also made available to the general public for comment. The final EIS forms the basis for a decision by the regulatory authorities as to whether a project may proceed and, if so, under what conditions.

environmental indicator	A significant physical, chemical, biological, social or economic variable which can be measured in a defined way for environmental management purposes.
environmental risk analysis	The systematic process undertaken to understand the nature of and deduce the level of environmental risk.
environmental risk assessment	The overall process of environmental risk identification, analysis and evaluation.
environmental risk evaluation	The process of comparing the level of risk against a set of risk criteria.
environmental risk identification	The process of determining what might happen to have an impact on the environment as the result of the implementation of a project etc., and where, when, why and how this could happen.
epibenthic	Of an organism, living at the surface of a seabed or lake floor.
epibenthos	The community of plant and animal organisms living at the surface of a seabed or lake floor.
ethane	An alkane hydrocarbon with the chemical formula C_2H_6. It is present in liquefied natural gas at anything from 1% to 10% by volume (methane being the main constituent at 83% to 99%) and is a valuable feedstock for the petrochemical industry. See **butane** above and **isopentane**, **liquefied natural gas**, **methane**, **pentane** and **propane** below.
ETS	See **emissions trading scheme** above.
exclusive economic zone	Abbreviated as **EEZ**. Australia's exclusive economic zone was declared in relation to Australia and its external territories under the *Seas and Submerged Lands Act 1973* (Cwlth). It commences at the outer limit of the territorial sea (12 nautical miles from the territorial sea baselines established under the Act) and extends generally to 200 nautical miles from the baselines. In its exclusive economic zone, Australia has sovereign rights to explore and exploit, conserve and manage the natural resources of the waters, seabed and subsoil.
fauna	All of the animals of a given region, taken collectively.
FEED	See **front-end engineering design** below.
ferruginous	Containing iron or iron compounds.
FID	See **final investment decision** below.
final investment decision	Abbreviated as **FID**. The commitment by a company, a joint venture, etc., to make funds available to proceed with the execution phase of a project based on a robust concept definition and a budget developed during the front-end engineering design phase.
flaring	The controlled burning off of hydrocarbon streams through flare stacks at an oil or gas facility such as an offshore processing facility or an LNG or LPG processing plant. Flaring is primarily carried out for safety reasons. The hydrocarbon streams flared will typically consist largely of natural gas but may also include higher alkanes.

floating production, storage and offtake (facility or vessel)	Abbreviated as **FPSO**. A converted tanker or barge or specially designed fixed facility in the ocean. Its purpose is to receive hydrocarbons from an oil or gas platform, to carry out a degree of processing, and to act as a storage vessel for liquid hydrocarbons before these products are offloaded into export tankers. The FPSO planned for the Ichthys Project will store condensate and monoethylene glycol (MEG) and will have a condensate storage capacity of more than 1 000 000 barrels. See **monoethylene glycol** below.
foliose	Of corals, having a flattened, leaflike growth form that may be folded and convoluted, often forming whorls.
formation water	Saline water trapped under natural gas and oil deposits and the surrounding rock formations. See **produced formation water** and **produced water** below.
4-D seismic technology	Time-lapse or 4-D seismic technology involves the acquisition, processing and interpretation of seismic data obtained from seismic surveys repeated at intervals over a producing oil or gas field. The technique analyses differences in successive data sets in order to determine the changes occurring in the reservoir as a result of hydrocarbon abstraction or the injection of water or gas into the reservoir.
FPSO	The abbreviation used for a "floating production, storage and offtake" facility or vessel. See **floating production, storage and offtake (facility or vessel)** above.
front-end engineering design	Abbreviated as **FEED**. The phase of an industrial plant construction project etc. where a single concept is defined in sufficient detail to allow a company to make its final investment decision (FID) prior to the project entering the execution phase. It entails undertaking a number of studies to provide a robust design where risks are well understood and the potential for (expensive) change following FID is minimised. These include technical studies; health, safety and environment studies; and operability, maintainability and availability studies.
frugivore	An animal that subsists entirely or predominantly on fruit.
frugivorous	Feeding on fruit.
fuel oil	Heavy distillates obtained from the refining of petroleum, used as fuels for engines to produce power or in boilers to produce heat. They have different grades from No. 1 to No. 6. Fuel oil graded No. 2, for example, with alkanes in the C_{14}–C_{20} carbon-chain range, is the diesel that trucks and some cars use and it is also used as heating oil. The heavy and viscous so-called "bunker oil" used to power ships is usually taken as being No. 6 and has carbon-chain lengths in the range C_{20}–C_{70}.
fugitive emissions	In the oil & gas industry, the term used to describe all gaseous emissions that result from leaks, including those from pump seals, pipe flanges and valve stems, and from accidents and equipment failures such as pipeline breaks.
gabbro	A dark volcanic rock of crystalline structure.
geographic information system	Abbreviated as **GIS**. A suite of computer applications widely used by planners to create multi-layered maps which permit the manipulation, analysis, and modelling of a wide range of spatially referenced data.

geosequestration	The process of capturing carbon dioxide, one of the most important greenhouse gases, from natural gas reservoirs and industrial sources such as power stations, and injecting it deep underground for long-term storage in secure geological formations. The technique is also called "carbon (dioxide) capture and storage". See **carbon (dioxide) capture and storage** above.
GHG(s)	See **greenhouse gas(es)** below.
GHG intensive	Descriptive of fuels, materials, processes, techniques, etc., with a direct or indirect capacity to produce undesirable quantities of greenhouse gases (GHGs).
GIS	See **geographic information system** above.
global positioning system	Abbreviated as **GPS**. Any worldwide navigational and surveying system based on radio signals transmitted from an array of orbiting satellites to hand-held or vehicle-mounted receivers. See **differential global positioning system** above.
global warming	The gradual increase in the earth's surface temperature caused by the enhanced greenhouse effect. See **enhanced greenhouse effect** above and **greenhouse effect** below.
global warming potential	Abbreviated as **GWP**. A measure of how much a given mass of a greenhouse gas is estimated to contribute to global warming. It is a relative scale which compares the global warming potential of the gas in question with that of an equivalent mass of carbon dioxide (which has been assigned the point-of-reference global warming potential of 1). See **methane** and **nitrous oxide** below.
GPS	See **global positioning system** above.
gravid	Pregnant. The term is usually used in relation to non-human animals, particularly reptiles and arthropods.
greenhouse effect	The natural warming process of the earth caused by the trapping of solar energy in the lower levels of the earth's atmosphere by greenhouse gases, principally carbon dioxide, methane and water vapour. In recent years, however, the necessary equilibrium between incoming solar radiation and outgoing emissions of heat energy from the earth has been affected by the increase in greenhouse gas emissions from human actions such as burning fossil fuels, intensive agriculture and land clearing. This is called the "enhanced greenhouse effect" and is believed to be the cause of global warming. See **enhanced greenhouse effect** above.
greenhouse gas(es)	Abbreviated as **GHG(s)**. Any of a number of gases found in the atmosphere which contribute to the greenhouse effect. The gases principally responsible for the greenhouse effect are defined in the *National Greenhouse and Energy Reporting Act 2007* (Cwlth) as carbon dioxide, methane, nitrous oxide and sulfur hexafluoride, together with certain specified hydrofluorocarbons and perfluorocarbons. See **carbon dioxide equivalent** and **greenhouse effect** above.

grey water	Non-industrial wastewater resulting from domestic activities in kitchens, showers, baths and laundries.
GWP	See **global warming potential** above.
HAT	See **Highest Astronomical Tide** below.
hazard	In industry, a hazard is any operation that could possibly cause a release of toxic, flammable or explosive chemicals or any action or situation that could result in injury to personnel or harm to the environment.
hazard and operability (analysis)	See **HAZOP** below.
hazard identification	See **HAZID** below.
HAZID	Acronym for "hazard identification". A HAZID process is a high-level process of hazard identification that addresses the overall project, not only the process equipment.
HAZOP	Acronym for "hazard and operability" (analysis). A HAZOP analysis is a systematic methodology used to examine facilities or processes to identify actual or potentially hazardous operations and procedures with a view to eliminating or mitigating them.
herpetofauna	All of the reptile and amphibian species of a given region, taken collectively.
Highest Astronomical Tide	Abbreviated as **HAT**. Highest Astronomical Tide is the highest level to which sea level can be predicted to rise under normal meteorological conditions.
hub	See **LNG hub** below.
hydrocarbon	Any compound consisting of hydrogen and carbon. The light hydrocarbons with low molecular weights are gases under room temperature and pressure (e.g. methane (CH_4)) and the heavy hydrocarbons with higher molecular weights are liquids (e.g. pentane (C_5H_{12}) and benzene (C_6H_6)) or solids (e.g. eicosane ($C_{20}H_{42}$), a constituent of candle wax). See **methane** and **pentane** below.
hydrogeology	The branch of geology that deals with the occurrence, distribution, movements and effects of groundwater.
hypothermia	The condition of having an abnormally low body temperature.
ichthyofauna	All of the fish species of a given region, taken collectively.
Ichthys Field	The Ichthys Field is the name given to the gas and condensate field discovered by INPEX in petroleum exploration area WA-285-P in the Brewster Member and the Plover Formation in the Browse Basin. *Ichthys* is the classical Greek word for "fish"—the modern word is *psari*. The Latin equivalent is *piscis*. It appears as an element in the (compound) scientific names of many fish. Examples include several fossil fish genera of the class Placodermi which flourished in the Late Devonian period some 360 to 400 million years ago. Three such genera are *Dinichthys*, *Gorgonichthys* and *Titanichthys*, after which three of the Ichthys Field's wells are named. The names for the wells were chosen by Shinsuke Ban (then the General Manager of INPEX's Perth office) in 2000 because of his interest in fossils, in particular those of the Devonian placoderms.

	The name "Ichthys" was chosen for the gas field because it was the common element in the names *Dinichthys*, *Titanichthys*, and *Gorgonichthys*.
igneous	In geology, descriptive of rock that has been solidified from molten rock material (magma) generated deep within the earth. It may solidify on the surface of the earth by volcanic action or under the surface of the earth by magmatic action. See **metamorphic** and **sedimentary** below.
IC_{50}	The notation IC_{50} stands for "inhibition concentration 50%". The IC_{50} value is the concentration of a substance that causes an inhibition of growth of 50% in a population of a target species when compared with controls. See **EC_{10}** and **EC_{50}** above and **LC_{50}** and **LD_{50}** below.
Indonesian Throughflow	A major ocean current which transports warm low-salinity water from the western Pacific into the high-salinity waters of the eastern Indian Ocean through the Indonesian archipelago. Flowing between the southern extremity of the Asian mainland and Australia, the Throughflow is one of the primary links or "choke points" in the global exchange of water and heat between the major ocean basins.
infauna	The animal life inhabiting the sediments of a river, lake, sea, or ocean, usually in burrows or in the interstices between the sediment particles.
infraspecific taxon	Any taxon below species level. In botany there are five ranks (taxa) below species level (subspecies, variety, subvariety, form and subform) while in zoology there is only the subspecies.
inhibition concentration 50%	See **IC_{50}** above.
inter-nesting period	Of marine turtle nesting, the period of time that elapses between the laying of the first and the laying of the last clutch of eggs by a female in one nesting season.
inter-nesting area	Of marine turtle nesting, the seas adjacent to a nesting beach where a gravid female will spend the time between the laying of successive clutches in one breeding season.
intertidal zone	See **littoral zone** below.
introduced species	An animal, plant or other organism present (either established or not) in any given ecosystem, which is not native to that ecosystem and has arrived there usually as a result of human activities.
invasive species	Defined by the International Union for Conservation of Nature and Natural Resources (IUCN) as "organisms (usually transported by humans) which successfully establish themselves in, and then overcome, otherwise intact pre-existing native ecosystems".
isobath	A contour line on a map connecting points of the same depth below the surface of a waterbody.
isopentane	Pentane (C_5H_{12}) has three isomers: the straight-chain isomer "pentane"; the single-branched isomer "isopentane"; and the double-branched isomer "neopentane". See **pentane** below.

JHA	See **job hazard analysis** below.
job hazard analysis	Abbreviated as **JHA**. A routine workplace requirement to assess the hazards and potential hazards associated with a job, and which identifies the measures to be taken to eliminate or mitigate causes of such hazards before the job is carried out. It is sometimes called “job safety analysis” (JSA).
Kjeldahl nitrogen	See **total Kjeldahl nitrogen** below.
Kyoto Protocol	An agreement made under the United Nations Framework Convention on Climate Change (UNFCCC). Countries that ratify the protocol commit to reduce their emissions of CO_2 and other GHGs or to engage in activities such as emissions trading if they maintain or increase emissions of these gases. The protocol was adopted in Kyoto, Japan on 11 December 1997 and entered into force on 16 February 2005. As of November 2009, 187 states had signed and ratified the protocol.
landform	A naturally formed feature of the earth’s surface such as a hill, a plateau or a cliff.
L_{AE}	The symbol for "sound exposure level". See **sound exposure level** below.
$L_{A\ max}$	The maximum noise level in A-weighted decibels (dB(A)), measured as an $L_{A\ Slow}$ value.
$L_{A\ Slow}$	The reading in decibels (dB) obtained using the “A” frequency-weighting characteristic and the “S” (Slow) time-weighting characteristic as specified in Australian Standard *AS 1259.1:1990, Sound level meters. Part 1: Non-integrating*.
LA_{10}	The noise level in A-weighted decibels (dB(A)) which, measured as an $L_{A\ Slow}$ value, is exceeded for more than 10% of a specified period.
LA_{90}	The noise level in A-weighted decibels (dB(A)) which, measured as an $L_{A\ Slow}$ value, is exceeded for more than 90% of a specified period.
LAT	See **Lowest Astronomical Tide** below.
laterite	Laterite is a residual rock or hard claylike crust formed in hot and wet tropical and subtropical areas by the weathering of pre-existing rocks through the action of rainwater. It is characteristically enriched in iron and aluminium compounds as they are less soluble in water than the sodium, potassium, calcium and magnesium minerals, which are leached out.
LC_{50}	The notation LC_{50} stands for “lethal concentration 50%”. It is the concentration of a chemical in air or water that will kill 50% of a group of a specific test animal species exposed to it in a given time, for example 4 hours or 24 hours. The LC_{50} is a measure of the short-term poisoning potential of a substance. See **EC_{10}**, **EC_{50}** and **IC_{50}** above and **LD_{50}** below.
LD_{50}	The notation LD_{50} stands for “lethal dose 50%” and is the amount of a material, given all at once, which will kill 50% of a group of test animals (typically laboratory mice or rats) in a given time. The LD_{50} is a measure of the short-term poisoning potential of a substance. See **EC_{10}**, **EC_{50}**, **IC_{50}** and **LC_{50}** above.

lenticel

A blister-like or lens-shaped pore on the stem of a woody plant containing loosely aggregated cells which provide a pathway for the exchange of gases between the plant and the surrounding air.

See **pneumatophore** below.

lethal concentration 50%

See **LC_{50}** above.

lethal dose 50%

See **LD_{50}** above.

liquefied natural gas

Natural gas is natural gas that has been converted to liquid form by cooling to under –160 °C. It contains only the lightest gaseous hydrocarbons of the alkane series, predominantly methane (CH_4), but also ethane (C_2H_6), a small amount of propane (C_3H_8), and a very small amount of butane (C_4H_{10}).

See **liquefied petroleum gas** below.

liquefied petroleum gas

Abbreviated as **LPG**. The generic name for mixtures of the gaseous hydrocarbons of the alkane series, slightly heavier than LNG hydrocarbons, which are converted to liquid form by slight cooling and/or compression. LPG is usually predominantly propane (C_3H_8) and butane (C_4H_{10}), but may contain small quantities of pentane (C_5H_{12}) and other hydrocarbons.

See **butane** and **liquefied natural gas** above and **pentane** and **propane** below.

littoral zone

In marine biology the littoral zone is taken as extending from the high-water mark of the seashore to the low-water mark. It is also called the intertidal zone.

See **benthic zone** above and **sublittoral zone** and **supralittoral zone** below.

LNG

See **liquefied natural gas** above.

LNG hub

As more natural gas (and condensate) fields are discovered off the Australian coast, particularly in Western Australia and the Northern Territory, there is a risk that there may be an unnecessary proliferation of project-specific onshore gas-processing plants. This could lead to unnecessary duplication of infrastructure and unnecessary damage to environmental, cultural and scenic values. This has led to governments developing the "hub" concept, whereby several gas-processing plants would be brought together at one location to minimise the overall level of environmental, cultural and scenic impact.

LNG train

An LNG train is the processing unit that carries out the purifying and liquefying of natural gas for transport to domestic and international markets. The facility is popularly known as a "train", as on an engineer's process flow diagram the major steps in the liquefaction process are represented by rectangular blocks coupled in a row, fancifully resembling a series of railway carriages. A train typically consists of a mercury removal unit; an acid gas removal unit (to remove carbon dioxide and hydrogen sulfide which are dangerous to the liquefaction process); a dehydration unit; a liquefied petroleum gas recovery unit; and a gas liquefaction unit with its associated refrigerant compressors, gas turbines, etc.

LOEC

See **lowest-observable-effect concentration** below.

London Convention	The Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972. This was drafted in London and is known as the "London Convention" for short. It is one of the first global conventions to protect the marine environment from human activities and it has been in force since 1975. In 1996 a special meeting of the contracting parties adopted the "1996 Protocol" to further modernise the 1972 Convention and eventually replace it. The Protocol entered into force on 24 March 2006 and had 36 State Parties as of November 2008. The London Convention is still in force and has 85 State Parties. The purpose of the London Convention 1972 is to control all sources of marine pollution and to prevent pollution of the sea through regulation of the dumping of waste materials into the sea. See **MARPOL 73/78** below.
low-carbon economy	An economy which produces low quantities of greenhouse gases (especially carbon dioxide) either naturally or because of a conscious political and social effort to use technologies that produce and use energy and materials with minimal emissions of greenhouse gases. The economic viability of such an economy may depend on legislative enforcement through the imposition of a "carbon tax" or an "emissions trading scheme". See **carbon tax** and **emissions trading scheme** above.
Lowest Astronomical Tide	Abbreviated as **LAT**. Lowest Astronomical Tide is the lowest level to which sea level can be predicted to fall under normal meteorological conditions. It is the datum used on Australia's hydrographic charts and is the zero value from which all tides and depths are measured.
lowest-observable-effect concentration	Abbreviated as **LOEC**. The lowest concentration used in a toxicity test on a test sample of a species that causes an effect significantly different from that observed in the control sample. See **no-observable-effect concentration** below.
LPG	See **liquefied petroleum gas** above.
lunate	Crescent-shaped.
macroalga	Any seaweed visible to the naked eye.
macrophyte	A plant large enough to be seen by the naked eye. Most marine macrophytes are macroalgae, but the term also includes seagrasses which are flowering plants and not algae.
macrotidal	Descriptive of a sea or estuary experiencing large tidal ranges, usually taken to be 4 metres and above. Compare with **mesotidal** and **microtidal** below.
mangal	See **mangrove** below.

mangrove	An intertidal salt-marsh community in the tropics and subtropics dominated by specialised trees and shrubs which have developed physiological adaptations to withstand fluctuating salinity levels and water levels together with a lack of oxygen in the mud substrate. The word may be used to describe individual species or groups of species, or it may be taken as a collective noun describing the mangrove community or ecosystem. The name "mangal" is sometimes applied to the mangrove forest community.
marine pests	Marine pests in Australia are marine plants or animals that are not native to Australia and which have been translocated to Australian waters by various vectors. Commercial vessels, for example, may discharge ballast water containing pest species from foreign waters; the biofouling organisms growing on the hulls and piping systems of commercial and recreational vessels may include pest species; commercial aquaculture operations may lead to the accidental introduction of pest species; and the aquarium industry may unknowingly or carelessly import pest species. Marine pests may have a significant impact on human health, fisheries and aquaculture, shipping and ports, tourism, environmental values, biodiversity and ecosystem health. They can be very expensive to eradicate.
MARPOL 73/78	The abbreviated name of the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto. It entered into force on 2 October 1983. "MARPOL" is short for "marine pollution" and 73/78 denotes the years 1973 and 1978. The Convention covers all the technical aspects of pollution from ships, except the dumping of wastes by ships and pollution arising from exploration and exploitation of seabed mineral resources. The dumping of wastes by ships is covered by the London Convention. See **London Convention** above.
matters of national environmental significance	Eight "matters of national environmental significance" are specially protected under national environment law and are listed in the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth). They are as follows: • listed threatened species and ecological communities • migratory species protected under international agreements • Ramsar wetlands of international importance • the Commonwealth marine environment • World Heritage properties • National Heritage places • the Great Barrier Reef Marine Park • nuclear actions. See **Ramsar wetland** below.
MDEA	See **methyldiethanolamine** below.
MEG	See **monoethylene glycol** below.
megafauna	Large animals. In a marine context the term includes animals such as whales and dolphins, dugongs and whale sharks. See **charismatic megafauna** above.

megaripples

High, ripple-like sand waves formed on the seabed, ranging in height from tens of centimetres to several metres.

See **sand wave** below.

meiofauna

Small invertebrate animals that can pass through a 1-mm mesh but are retained by a 0.1-mm mesh.

mesocosm

In the context of toxicological studies of marine organisms, a mesocosm is an enclosed experimental ecosystem in which the fate and effects of, for example, oil on individual organisms or populations can be studied and evaluated.

meso-scale bioregion

The Integrated Marine and Coastal Regionalisation of Australia (IMCRA) framework for classifying Australia's marine environment has defined 41 "provincial" bioregions and 60 "meso-scale" bioregions. The meso-scale (= intermediate scale) bioregions may be hundreds to one or two thousand kilometres wide. The IMCRA program operates under the auspices of the Commonwealth's Department of the Environment, Water, Heritage and the Arts.

mesotidal

Descriptive of a sea or estuary experiencing a moderate tidal range, usually taken to be between 2 and 4 metres.

Compare with **macrotidal** above and **microtidal** below.

metamorphic

In geology, descriptive of rock that has undergone partial or complete recrystallisation by natural agencies such as heat and pressure.

See **igneous** above and **sedimentary** below.

methane

A colourless, odourless gas with the chemical formula CH_4. It is the simplest alkane and the principal component of natural gas. It is the main constituent of liquefied natural gas, at usually 83–99% by volume.

According to the Second Assessment Report of the United Nations Intergovernmental Panel on Climate Change (1995), whose figures have been adopted by the Commonwealth Government's Department of Climate Change, weight for weight methane has the capacity to cause 21 times more global warming than carbon dioxide (CO_2), calculated over a time horizon of 100 years. Not including water vapour, after carbon dioxide it is the second-largest greenhouse gas contributor to global warming both by volume and on a carbon-dioxide-equivalent basis.

See **butane**, **carbon dioxide equivalent**, **ethane**, **isopentane** and **liquefied natural gas** above and **pentane** and **propane** below.

methyldiethanolamine

Abbreviated as **MDEA**. A compound which absorbs the acid gases carbon dioxide (CO_2) and hydrogen sulfide (H_2S) at lower temperatures and releases them at higher temperatures. It is used to separate CO_2 and H_2S from natural gas streams in the form of activated methyldiethanolamine (aMDEA).

See **activated methyldiethanolamine** above.

metocean conditions

Meteorological and oceanographic conditions. The word "metocean" is a compressed adjective derived from the first syllables of "**met**eorological" and "**ocean**ographic".

microtidal — Descriptive of a sea or estuary experiencing a low mean tidal range, usually taken to be less than 2 metres.

Compare with **macrotidal** and **mesotidal** above.

monoethylene glycol — Abbreviated as **MEG**. Monoethylene glycol is used to prevent hydrate formation in subsea pipelines. Gas produced at the wellhead contains water which, under conditions of high pressure and low temperatures, can react with methane or ethane to form solid methane or ethane hydrate. This material can block pipelines and its formation must therefore be prevented to allow gas to flow.

The MEG will be injected into the reservoir fluids flowing out of the Ichthys Field wellheads. After the reservoir fluids have been separated into liquid and gas streams on the central processing facility, the MEG will pass in the liquid stream of condensate and water to a regeneration unit where it will be recovered and returned to the wellheads for reuse.

See **triethylene glycol** below.

Montreal Protocol — The Montreal Protocol on Substances that Deplete the Ozone Layer is an international agreement signed in 1987 and subsequently amended on several occasions, most recently in 1999. It establishes in participating countries a schedule for phasing out release to the earth's atmosphere of chlorofluorocarbons and other substances with ozone-depleting potential.

mooring dolphin — An independent maritime structure at a port or maritime terminal that is not connected to the shore. It is fixed to the seabed and extends above water level as a platform or similar structure to provide a mooring point for ships. It permits tying mooring lines at favourable angles without having to extend an entire pier or wharf structure. Adjacent mooring dolphins are generally connected by pedestrian walkways.

native species — In the context of the Ichthys Project, a species (or subspecies etc.) that is considered to be indigenous to the offshore, nearshore or onshore Project areas.

natural gas — A mixture of hydrocarbon gases formed underground by the decomposition of organic materials from the decay of plants and animals. It commonly occurs in association with crude oil, but many gas (or gas and condensate) reservoirs have little or no oil. The main component of natural gas is methane, but there will also be other alkanes such as ethane, propane, butane and pentane as well as a range of heavier hydrocarbons. Possible contaminants include water, carbon dioxide, hydrogen sulfide, nitrogen and mercury.

naturally occurring radioactive material(s) — Abbreviated as **NORM(s)**. Naturally occurring radioactive materials occur in trace amounts in most of the earth's crust and all humans are exposed to low levels of radiation from this source. Certain minerals and other resources such as natural gas reservoirs contain radioactive substances and these may be concentrated in scale deposits in pipelines, processing vessels, etc., if not managed properly.

neap tide — The tide with the least difference between high and low water, occurring just after the first and third quarters of the moon.

See **spring tide** below.

nephelometric turbidity unit — Abbreviated as **NTU**. A unit used to measure the degree of turbidity in water. It is measured by an instrument, a nephelometer (from Greek *nephelē*"cloud" + English *meter* = "measuring device"), which quantifies how much light is scattered by suspended particles.

nitrogen oxides — Any of six gaseous oxides of nitrogen, three of which (N_2O_3, N_2O_4 and N_2O_5) are rare and unstable and may be discounted here. The two mononitrogen oxides, nitrogen monoxide (nitric oxide) (NO) and nitrogen dioxide (NO_2), are produced during combustion, especially at high temperatures. They are environmental pollutants which are harmful to human health. They are together known as NO_x and are not greenhouse gases.

Nitrous oxide (N_2O) is a dinitrogen oxide and is an important greenhouse gas. It is not a NO_x.

See **NO_x** below.

nitrous oxide — Nitrous oxide (N_2O) is a colourless non-flammable gas. It is the third-largest greenhouse gas contributor to global warming. According to the Second Assessment Report of the United Nations Intergovernmental Panel on Climate Change (1995), whose figures have been adopted by the Commonwealth Government's Department of Climate Change, weight for weight nitrous oxide has the capacity to cause 310 times more global warming than carbon dioxide (CO_2), calculated over a time horizon of 100 years.

NOEC — See **no-observable-effect concentration** below.

no-observable-effect concentration — Abbreviated as **NOEC**. "No-observable-effect concentration" is the highest concentration of a substance used in a toxicity test on a sample of a particular test species that causes an effect that is not significantly different from that observed in the control sample.

See **lowest-observable-effect concentration** above.

NORM(s) — See **naturally occurring radioactive material(s)** above.

normal cubic metre — A normal cubic metre (symbol Nm^3) is a quantity of any gas that, under "normal" conditions of temperature and pressure, occupies a volume of one cubic metre. The "normal" (or "standard") conditions must be defined, however, as there are a number of different measures in common use. It is usually defined as being measured at 0 °C and 1 atmosphere of pressure.

NO_x — The generic symbol or formula for the two mononitrogen oxides, NO (nitric oxide) and NO_2 (nitrogen dioxide). (By convention, the "x" is subscripted and italicised.)

See **nitrogen oxides** above.

NTU — See **nephelometric turbidity unit** above.

octanol–water partition coefficient — Abbreviated as **P_{ow}**. This coefficient is the ratio of the concentration of a chemical in octanol and in water at equilibrium and at a specified temperature. Octanol is an organic solvent that is used as a surrogate for natural organic matter. this coefficient is used in many environmental studies to help determine the fate of chemicals in the environment, for example in predicting the extent to which a contaminant will bioaccumulate in fish.

odontocete	Any (usually) marine mammal of the suborder Odontoceti, the toothed whales. Odontocetes include dolphins, the orca or “killer whale”, porpoises, beaked whales, pilot whales, bottlenose whales and the sperm whale. Most species live in the marine environment but several live in fresh water. The baleen whales such as the humpback and southern right whales make up the suborder Mysticeti.
Operator	INPEX Browse, Ltd. and Total E&P Australia are in joint venture for the development of the Ichthys gas and condensate field in the Browse Basin. INPEX Browse, Ltd., however, is the Joint Venturer designated as the Operator of the Ichthys Gas Field Development Project and, as such, is responsible for managing the operation for and on behalf of the Joint Venturers in accordance with the terms of the two companies’ joint operating agreement.
organotin	Compounds containing at least one bond between tin and carbon. They are often highly poisonous, especially to marine life. See **tributyltin** below.
PAH(s)	See **polycyclic aromatic hydrocarbon(s)** below.
palaeodrainage	Drainage systems of past geological ages, whose direction and structure can be inferred from geological analysis.
parasite	Any organism which is intimately associated with another organism (the host) and metabolically dependent upon the host for the completion of the whole, or part, of its life cycle. The activities of the parasite are typically detrimental to the host to a greater or lesser degree.
particulate matter	Abbreviated as **PM**. A term used to describe a complex group of air pollutants that are collectively regarded as a health hazard. These pollutants are a mixture of fine airborne solid particles and liquid droplets (aerosols) and include, for example, smoke, soot, dust particles, pollen, and a variety of chemical compounds. Particulate matter is usually categorised as PM_{10} and $PM_{2.5}$. The fraction of suspended particles whose diameter is less than 10 micrometres (10 µm or 10 millionths of a metre) is PM_{10}; these particles can enter the main passages in the lungs. Smaller particles, designated $PM_{2.5}$ (less than 2.5 µm in diameter), can enter the fine tubules deep in the lungs.
PASS(s)	See **potential acid sulfate soil(s)** below.
pathway	In biological quarantine terminology, a pathway is a means, method or route that can provide an alien organism with the opportunity to move across a declared quarantine border.
pelagic	Relating to the open sea. Of fish and other organisms, living and feeding in the open sea but not in close association with the seabed.
peneplain	An extensive area of land that has been levelled to a flat or gently undulating plain by long-term erosion.
pentane	An alkane hydrocarbon with the chemical formula C_5H_{12}. It is a liquid at normal temperature and pressure and is a minor constituent of liquefied petroleum gas (LPG) and a more significant constituent of condensate. See **butane**, **ethane**, **isopentane**, **liquefied petroleum gas** and **methane** above, and **propane** below.

permanent threshold shift	Abbreviated as **PTS**. In acoustics, the irreversible hearing loss that results from exposure to intense impulse or continuous sound, as opposed to the reversible "temporary threshold shift" that also results from somewhat or significantly less exposure.
P_{50} resources	In the terminology of the oil & gas industry, P_{50} resources (often called "proved plus probable") are a median estimate of the resources expected to be extracted from a hydrocarbon field. A P_{50} estimate refers to a value which has a 50% probability of being exceeded.
pH	The standard measure of acidity and alkalinity (from German *Potenz* = power, and H, the symbol for hydrogen). It is a logarithmic index for the hydrogen ion concentration in an aqueous solution.
photic zone	The upper layer of the ocean water column penetrated by light.
phytoplankton	The plant-life component of plankton. See **plankton** and **zooplankton** below.
pig	In the oil & gas industry, a pig is a device sent through an active pipeline either to inspect the condition of the interior of the pipe or to scrape off rust or other foreign matter. It is propelled by the pressure of the fluid behind it.
plankton	The mostly microscopic plants and animals which drift in the upper layers of seas, lakes, and other waterbodies. Although some species can propel themselves feebly, they are moved more or less passively by currents, wind or waves. See **phytoplankton** above and **zooplankton** below.
PM	See **particulate matter** above.
PM_{10}	Particulate matter smaller than 10 micrometres (10 μm) in diameter. See **particulate matter** above.
$PM_{2.5}$	Particulate matter smaller than 2.5 micrometres (2.5 μm) in diameter. See **particulate matter** above.
pneumatophore	Pneumatophores are specialised aerial roots developed by many of the mangrove species which inhabit tidal swamps and estuarine mudbanks. The subterranean roots grow in waterlogged, saline, anaerobic soils and cannot obtain enough oxygen to function. The pneumatophores allow atmospheric oxygen to enter through their lenticels and reach the submerged roots by diffusion. See **lenticel** above.
polycyclic aromatic hydrocarbon(s)	Abbreviated as **PAH(s)**. Polycyclic aromatic hydrocarbons (also called polynuclear aromatic hydrocarbons) are a complex class of hydrocarbon compounds with two or more fused benzene rings. They can be released into the atmosphere through incomplete combustion of organic matter and are environmental contaminants. Some are known to be carcinogens.
P_{ow}	See **octanol–water partition coefficient** above.

potential acid sulfate soil(s)	Abbreviated as **PASS(s)**. Potential acid sulfate soils are soils which contain iron sulfides or sulfidic materials which are in an anaerobic environment and have therefore not been exposed to air and oxidised. The pH of such a soil in its undisturbed state can be 4 or higher and may even be neutral (pH 7) or slightly alkaline. However, if disturbed, exposed to air and oxidised, PASSs pose a considerable environmental risk as they will become acidic ("actual acid sulfate soils") and leach sulfuric acid. Disturbances that can result in the oxidisation of PASSs include the lowering of natural water tables and the excavation of soils that were previously below natural groundwater levels. See **acid sulfate soil(s)** and **actual acid sulfate soil(s)** above.
ppmv	Parts per million by volume. In atmospheric chemistry, the unit "ppmv" is a measure of the volume of a gaseous component per million volumes of total gas.
ppt	The abbreviation for both parts per thousand and parts per trillion. It is used in the *Ichthys Gas Field Development Project: draft environmental impact statement* in the meaning "parts per thousand" in salinity measurements.
produced formation water	The saline formation water produced during the extraction and processing of oil and gas from underground reservoirs. See **formation water** above and **produced water** below.
produced water	Water is always produced during the extraction and processing of gas from a natural gas field. It has two sources: one is the saline "produced formation water" found as a liquid in the geological formation below the gas, and the other is the water vapour commingled with the gas which is condensed out during the processing phase. "Produced water" is the combination of produced formation water and the condensed water. The produced water that is normally discharged from offshore oil and gas facilities contains dissolved compounds from the geological formation (such as organic acids, salts and hydrocarbons of low molecular weight) and finely dispersed oils and production chemicals. See **formation water** and **produced formation water** above.
propane	An alkane hydrocarbon with the chemical formula C_3H_8. Propane and butane are the major constituents of liquefied petroleum gas. See **butane**, **ethane**, **isopentane**, **methane**, **liquefied natural gas** and **pentane** above.
PTS	See **permanent threshold shift** above.
pulverulent	In soil studies, descriptive of soils composed of fine particles which are powdery and dusty when dry and disturbed.

quad	A unit used in discussing large amounts of energy, equal to a quadrillion (10^{15}) British thermal units (symbol Btu). In the International System of Units (SI), energy is measured in joules (symbol J). The United States, however, uses the Btu and the US Department of Energy employs the term "quad" in calculating and reporting national and international energy budgets. For convenience, large-scale energy use is therefore measured in quadrillions (or quads) of Btu. A quad is equal to 1.055×10^{18} joules or 1.055 exajoules (1.055 EJ). See **British thermal unit** above.
quadrillion	One thousand million million (10^{15} or 1 000 000 000 000 000). In the International System of Units (the SI) the prefix "peta-" (symbol P) indicates the value 10^{15}. See **quad** above.
quarantine	A system of regulatory measures put in place by governments to prevent or control the introduction, establishment or spread of plants and animals, or of pathogenic fungi, viruses, bacteria or protozoa, that could cause damage to natural ecosystems, agriculture, human health, etc. In the context of the Ichthys Project, the quarantine measures put in place are to prevent or control the introduction of any living organism not native to any part of the terrestrial or marine environment in which the Project operates.
quarantine waste	In the context of the Ichthys Project, quarantine waste means materials or goods of quarantine concern as determined by the Australian Quarantine and Inspection Service (AQIS) and which are subject to and/or identified under the *Quarantine Act 1908* (Cwlth) and associated legislative instruments. It includes material used to pack and stabilise imported goods; galley food and other waste from overseas vessels; human, animal or plant waste brought into Australia; refuse or sweepings from the hold of an overseas vessel; and any other waste or other material that has come into contact with the quarantine wastes listed above.
Ramsar wetland	A wetland (or site) designated for inclusion on the Ramsar List of Wetlands of International Importance. The Ramsar Convention (the "Convention on Wetlands of International Importance, especially as Waterfowl Habitat") was signed in Ramsar in Iran in 1971 and came into force in 1975. It is an intergovernmental treaty which provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources. There are presently 159 contracting parties to the convention. Australia signed the convention in 1971. Wetlands included in the list acquire a new status at the national level and are recognised by the international community as being of significant value for humanity as a whole. Contracting parties are committed to ensuring the maintenance of the ecological character of each Ramsar site under their control.
receptor	In environmental management and ecology, receptors are living organisms, the habitats or ecosystems which support such organisms, or natural resources which could be adversely affected by any form of environmental contamination (e.g. toxins, sewage, dust, light or noise).

relevé	A simple quantitative sampling technique in which a visual description is made of the vegetation of an area, including characteristics such as species found, cover, density, etc. It allows large areas to be classified and mapped in a limited amount of time. The name is also applied to the sampling site itself.
reservoir CO2	A term used in the oil & gas industry to describe the carbon dioxide (CO_2) naturally present in a natural gas formation and which is typically vented to the atmosphere when the gas is extracted from the reservoir and processed. It is also called "native CO_2".
residual (environmental) risk	In environmental risk management, the level of risk remaining after the implementation of risk-control strategies.
rhizobenthic	Descriptive of seaweeds etc. which are rooted in the substrate of the seabed.
ria	A drowned river valley, usually long and narrow, formed as a result of a rise in sea level relative to the land, either by an actual rise in global sea level or by the land sinking. A "ria coast" is a deeply indented coastline with numerous rias.
salp	A free-swimming marine invertebrate with a transparent barrel-shaped body. Salps are tunicates related to the sea squirts.
sand wave	The term used for wave-like bed forms in sand on the seabed. These can vary in height from a few centimetres (sand ripples) to several metres (megaripples). See **megaripple** above.
SBM	See **synthetic-based mud** below.
sedimentary	In geology, descriptive of rock that has been formed by the consolidation of sediment carried by water, ice or wind and deposited on land or under water, for example sandstone. See **igneous** and **metamorphic** above.
SEL	See **sound exposure level** below.
semidiurnal	Descriptive of tides having cycles of approximately 12 hours. The predominant type of tide throughout the world is semidiurnal, with two high waters and two low waters each day.
semi-hispidose	Literally "half-bristly". Of corals, having numerous short side branchlets projecting outwards from the main branch.
septage	The liquid, sludge and solid material pumped from a septic tank, cesspool, or other primary treatment source.
sheetflow	Water flow that occurs overland in places where there are no defined channels. The floodwater may spread out over a large area at a relatively uniform depth.
SI	The international abbreviation for the French words *Système International* from *Le Système International d'Unités*, known in English as the International System of Units. The SI is the internationally recognised system of measurement.

slug catcher	A large vessel placed at the outlet of a gas pipeline before the gas enters the processing facilities at an off- or onshore hydrocarbon processing plant. A "slug" is a mass of liquid (condensate, water, etc.) travelling through the pipeline along with the gas. The slugs (along with any other liquids arriving continuously at the onshore processing plant through the pipeline) are captured in the slug catcher and removed before they can overload the downstream receiving equipment at the plant. The slug catcher essentially acts as a large gas–liquid separator ahead of facilities that will separately process the gas and the liquids.
sound exposure level	Abbreviated as **SEL**. The total noise energy produced from a single noise event. Its symbol is L_{AE}.
sound pressure level	Abbreviated as **SPL**. In acoustics, a logarithmic measure of the root mean square sound pressure of a sound relative to a reference value.
SO_x	The generic symbol for the oxides of sulfur. (By convention, the "x" is subscripted and italicised.) See **sulfur oxides** below.
SPL	See **sound pressure level** above.
spring tide	The tide with the greatest difference between high and low water, occurring just after the new moon and full moon. See **neap tide** above.
stakeholder	Any organisation, government agency, group or person that has an interest in, or may be affected by, a project or by the activities or decisions of an organisation.
"step back 5 × 5"	A workplace safety mantra which encourages workers to figuratively step back five paces and pause for five minutes to reflect upon likely hazards before embarking on an activity.
stochastic	Occurring in a random pattern.
subarborescent	Of corals, tending to be treelike in form.
sublittoral zone	The area of shallow water on a seashore immediately below the littoral (or intertidal) zone. It is permanently under water. See **benthic zone** and **littoral zone** above and **supralittoral zone** below.
Suezmax	A naval architecture term for the largest ships capable of passing through the Suez Canal fully loaded. It is almost exclusively used in reference to tankers.
sulfur oxides	Abbreviated as **SO_x**. Gaseous sulfur oxides are produced by the combustion of coal, oil, gas and metal-containing ores. Sulfur oxide emissions consist principally of the stable sulfur dioxide (SO_2), but include the unstable or short-lived sulfur monoxide (SO) and sulfur trioxide (SO_3). Anthropogenic emissions are caused by fossil-fuel combustion, smelting, etc. Sulfur oxides in the atmosphere are harmful to human health when in high concentrations and are considered to be environmental pollutants.

supralittoral zone	The area of a seashore immediately above the level of a spring high tide that is subject to splash by sea water but is not submerged. See **benthic zone**, **littoral zone** and **sublittoral zone** above.
supratidal	Of or relating to the coastal zone (often salt flats or sand dunes) above the high-tide mark.
synthetic-based mud	Abbreviated as **SBM**. A fluid used to facilitate the drilling of boreholes into rock. The mud is formulated using a variety of synthetic organic base fluids and has most of the performance properties of oil-based muds but without the adverse environmental effects caused by the use of diesel and mineral-oil muds. Synthetic-based muds are generally used deeper in the wells than the water-based muds in formations where the material being drilled swells if water-based muds are used. See **WBM** and **water-based mud** below.
tabular	Of corals, having a tiered, table-like growth form consisting of horizontal flattened plates.
TBT	See **tributyltin** below.
TEG	See **triethylene glycol** below.
temporary threshold shift	Abbreviated as **TTS**. In acoustics, the reversible hearing loss that results from exposure to intense impulse or continuous sound, as opposed to the irreversible "permanent threshold shift" that may result from more intense exposure.
terrigenous	Descriptive of marine rock material, sediments, etc., derived from the land. (From Latin *terrigenus* "earth-born".)
thermocline	A temperature gradient, especially an abrupt one in a body of water.
tidal excursion	The net horizontal distance covered by a water molecule or particle during one complete tidal cycle of flood and ebb.
Tiwi Islands	The Tiwi Islands are approximately 80 km north of Darwin at the junction of the Arafura Sea and the Timor Sea. There are three islands in the group—Melville Island, Bathurst Island and Buchanan Island. The first two are large, with a total area of 8320 km^2, while Buchanan Island in Shoal Bay in the south is only 170 ha in extent.
TKN	See **total Kjeldahl nitrogen** below.
Top End	The colloquial expression "the Top End" is used to distinguish the tropical and monsoonal northern quarter of the Northern Territory from the semi-arid and arid southern three-quarters. No southern boundary line has been officially defined for the Top End. For the purposes of the environmental impact statement for the Ichthys Gas Field Development Project, the Top End may be taken as being the whole of the Darwin – Arnhem Land peninsula south to a line joining the points where the eastern border of Western Australia and the western border of Queensland meet the sea in the Joseph Bonaparte Gulf and the Gulf of Carpentaria respectively.

total Kjeldahl nitrogen	Abbreviated as **TKN**. A quantification of total organic nitrogen and ammonia nitrogen present in water, used in environmental science in particular to determine the level of nitrogen pollution. It differs from the measure of total nitrogen (TN) in that it does not include the oxidised forms of nitrogen existing as nitrates and nitrites.
train	In the oil & gas industry a "train" is a "gas liquefaction train" or "liquefied natural gas train". See **LNG train** above.
tributyltin	Abbreviated as **TBT**. Tributyltin compounds are biocides and were used especially in marine antifouling paints to protect the hulls of boats and ships against the growth of marine organisms. They are now recognised as environmental pollutants and as of 1 January 2008 there is a complete prohibition on the presence of TBT paints on ships worldwide.
triethylene glycol	Abbreviated as **TEG**. Triethylene glycol has a strong affinity for water and is used in the oil & gas industry to dehydrate natural gas. It will be used on the central processing facility at the Ichthys Field to remove the water from the gas stream before the gas is sent through the gas export pipeline to the LNG plant in Darwin. See **monoethylene glycol** above.
trillion	A million million (10^{12} or 1 000 000 000 000). In the International System of Units (the SI) the prefix "tera-" (symbol T) indicates the value 10^{12}.
TTS	See **temporary threshold shift** above.
tubicolous	Living in tubes. Descriptive, for example, of those species of polychaete worm which construct "cemented" tubular burrows in seabed sediments.
tunicate	Any of various small marine animals of the subphylum Tunicata usually having a cylindrical or globular body enclosed in a tough outer covering. The adults are often colonial and affixed to rocks etc., but some are free-swimming. See **salp** above.
turbidity	The cloudiness in a liquid caused by the presence of finely divided suspended particles.
ultraviolet A	Abbreviated as **UV-A**. Ultraviolet radiation in the 320–400 nm band.
umbilical	In the oil & gas industry an umbilical is an assembly of hydraulic hoses which can also include electrical cables or optic fibres, used to control subsea structures from a platform or a vessel.
UV-A	See **ultraviolet A** above.
vacant Crown land	In the Northern Territory the expression "vacant Crown land" is the name used for Crown land currently not being used and not reserved for any specific future purpose.
viewshed	The area of a landscape that is visible from a given vantage point. The viewshed concept is used in urban and industrial planning and landscape architecture to assist planners to mitigate the impacts of developments.
VOCs	See **volatile organic compound(s)** below.

volatile organic compound(s)	Abbreviated as **VOC(s)**. Volatile organic compounds are organic chemical compounds that have a high enough vapour pressure under normal conditions to significantly vaporise and enter the atmosphere. It may contain hydrogen, oxygen, nitrogen and other elements. Methane (CH_4) is not generally included as a VOC. Volatile organic compounds react with nitrogen oxides in sunlight to form ground-level ozone and thus contribute to smog. Some VOCs, such as benzene (C_6H_6), have been identified as potential carcinogens. See **BTEX** above.
vug	A small hollow or cavity in rock, often lined with crystals whose mineral composition is different from that of the surrounding rock.
water-based mud	Abbreviated as **WBM**. A fluid used to facilitate the drilling of boreholes into rock. It consists of a blend of water with clay (bentonite) and other additives. The water-based muds are generally used higher in the wells than the synthetic-based muds. See **SBM** and **synthetic-based mud** above.
WBM	See **water-based mud** above.
wet season (Darwin)	Darwin's climate is influenced by the tropical monsoon and thus has two distinct seasons—a wet season and a dry season. The dry season extends from May until October and the wet season from November until April. Most rain falls in the period from December to March and "the Wet" is characterised by high humidity and high-intensity electrical storms. Wet-season temperatures range from 25 to 36 °C and the average annual rainfall is over 1700 mm (*c*.67 inches). See **dry season (Darwin)** above.
zone of visual influence	Abbreviated as **ZVI**. The zone within which a human can both see and define an object. The term is used by landscape architects and environmental planners especially in the preparation of visual impact assessments made as part of the approvals process for industrial developments. The ZVI has been defined to demonstrate what a person sees without assistance and is subject to factors such as air quality, illumination and light reflectivity.
zooplankton	The animal-life component of plankton. See **phytoplankton** and **plankton** above.
ZVI	See **zone of visual influence** above.

Abbreviations and Units of Measurement

Abbreviations and acronyms

AAPA	Aboriginal Areas Protection Authority (see *Glossary*)
AASS	actual acid sulfate soil (see *Glossary*)
ABARE	Australian Bureau of Agricultural and Resource Economics
ABS	Australian Bureau of Statistics
ACC	American Chemistry Council
ADCP	acoustic Doppler current profiler
ADF	Australian Defence Force
ADWG	Australian Drinking Water Guidelines
AER	Australian Energy Regulator
AFANT	Amateur Fishermen's Association of the Northern Territory
AFMA	Australian Fisheries Management Authority
AGL	above ground level
AGM	annual general meeting
AGRU	acid gas removal unit (see *Glossary*)
AHD	Australian Height Datum
AIMS	Australian Institute of Marine Science
ALARP	as low as reasonably practicable (see *Glossary*)
aMDEA	activated methyldiethanolamine (see *Glossary*)
AMSA	Australian Maritime Safety Authority
ANRA	Australian Natural Resources Atlas
ANZECC	Australian and New Zealand Environment and Conservation Council
APASA	Asia-Pacific Applied Science Associates, Australian-based representatives of the international ASA group, specialist providers of marine modelling services for environmental and engineering assessment
API	American Petroleum Institute
APIN	Army Presence in the North (Project)
APPEA	Australian Petroleum Production & Exploration Association Limited
AQIS	Australian Quarantine and Inspection Service
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
AS/NZS	(joint) Australian and New Zealand standard
AS/NZS ISO	(joint) Australian, New Zealand and International Organization for Standardization standard
ASS	acid sulfate soil (see *Glossary*)
BCF	bioconcentration factor
BHD	backhoe dredger
BMSL	below mean sea level
BOD	biochemical oxygen demand
BOG	boil-off gas
BOM	Bureau of Meteorology
BOP	blow-out preventer
BP	before present (see *Glossary*)
BTEX	benzene, toluene, ethylbenzene and xylenes (see *Glossary*)
c.	*circa* (Latin = "about", "approximately")
CASA	Civil Aviation Safety Authority
CBD	central business district
CCGT	combined-cycle gas turbine
CCS	carbon (dioxide) capture and storage (see *Glossary*)
CDM	clean development mechanism
CD-ROM	compact disc read-only memory
CDU	Charles Darwin University

CEMP	construction environmental management plan
CEO	chief executive officer
CER	certified emission reduction
cfu	colony-forming unit (see *Glossary*)
CF_x	perfluorocarbons
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CMS	Convention on the Conservation of Migratory Species of Wild Animals (signed at Bonn in Germany in 1979 and also known as the "Bonn Convention")
CO2CRC	Cooperative Research Centre for Greenhouse Gas Technologies
CPF	central processing facility
CPRS	Carbon Pollution Reduction Scheme (see *Glossary*)
CRC	Cooperative Research Centre
CSD	cutter-suction dredger
CSIRO	Commonwealth Scientific and Industrial Research Organisation
Cwlth	Commonwealth
CWR	Centre for Whale Research (Western Australia) Inc.
DAFF	(Commonwealth) Department of Agriculture, Fisheries and Forestry
DBE	(Northern Territory) Department of Business and Employment, formerly the Department of Business, Economic and Regional Development
DBERD	(Northern Territory) Department of Business, Economic and Regional Development, now the Department of Business and Employment
DCC	(Commonwealth) Department of Climate Change
DCM	(Northern Territory) Department of the Chief Minister
DEC	(Western Australia) Department of Environment and Conservation
DECC	(New South Wales) Department of Environment and Climate Change
DEET	(Northern Territory) Department of Employment, Education and Training, now the Department of Education and Training
DEFRA	(United Kingdom) Department for Environment, Food and Rural Affairs
DEH	(Commonwealth) Department of the Environment and Heritage, now the Department of the Environment, Water, Heritage and the Arts
DET	(Northern Territory) Department of Education and Training, formerly the Department of Employment, Education and Training
DEW	(Commonwealth) Department of the Environment and Water Resources, now the Department of the Environment, Water, Heritage and the Arts
DEWHA	(Commonwealth) Department of the Environment, Water, Heritage and the Arts, formerly the Department of the Environment and Heritage and the Department of the Environment and Water Resources
dGPS	differential global positioning system
DHA	Defence Housing Australia
DHAC	Darwin Harbour Advisory Committee
DHCS	(Northern Territory) Department of Health and Community Services, now the Department of Health and Families
DHF	(Northern Territory) Department of Health and Families, formerly the Department of Health and Community Services
DIPE	(Northern Territory) Department of Infrastructure, Planning and Environment, now (for environmental matters) the Department of Natural Resources, Environment, the Arts and Sport
DITR	(Commonwealth) Department of Industry, Tourism and Resources, now (for resources matters) the Department of Resources, Energy and Tourism
DLP	(Northern Territory) Department of Lands and Planning
DNA	deoxyribonucleic acid

DoR	(Northern Territory) Department of Resources, formerly the Department of Regional Development, Primary Industry, Fisheries and Resources
DoS	degree of saturation
DPC	Darwin Port Corporation
DPI	(Northern Territory) Department of Planning and Infrastructure, now the Department of Lands and Planning and the Department of Construction and Infrastructure
DRDPIFR	(Northern Territory) Department of Regional Development, Primary Industry, Fisheries and Resources, now the Department of Resources
DRET	(Commonwealth) Department of Resources, Energy and Tourism
DVD	digital video (or versatile) disc
EA Act	*Environment Assessment Act* (NT)
EC_{10}	effect concentration 10% (see *Glossary*)
EC_{50}	effect concentration 50% (see *Glossary*)
ECNT	Environment Centre Northern Territory
EEZ	exclusive economic zone (see *Glossary*)
EGS	Earth Sciences and Surveying, an international group of companies engaged, *inter alia*, in providing earth science and oceanographic services
EHA Division	Environment, Heritage and the Arts Division (of the Northern Territory's Department of Natural Resources, Environment, the Arts and Sport)
EIS	environmental impact statement (see *Glossary*)
EITE	emissions-intensive trade-exposed
EMP	environmental management plan
ENSO	El Niño Southern Oscillation
ENVID	environmental (impact) identification (see *Glossary*)
EPA	(Northern Territory) Environment Protection Authority
EPA (US)	(United States) Environmental Protection Agency
EPA	(Western Australia) Environmental Protection Authority
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999* (Cwlth)
ERMP	environmental review and management program
ERS	Environmental Risk Solutions Pty Ltd, an Australian health, safety and environmental consulting and training firm
ERU	emission reduction unit
ETS	emissions trading scheme (see *Glossary*)
EUA	European Union allowance
EU ETS II	European Union Emissions Trading Scheme Phase II
FEED	front-end engineering design (see *Glossary*)
FID	final investment decision (see *Glossary*)
FPSO	floating production, storage and offtake (vessel or facility) (see *Glossary*)
GBRMPA	Great Barrier Reef Marine Park Authority
GD	grab dredger
GDP	gross domestic product
GE	General Electric
GHD	an international professional services company, GHD Pty Ltd (formerly known as Gutteridge Haskins & Davey Pty Ltd)
GHG	greenhouse gas (see *Glossary*)
GIS	geographic information system (see *Glossary*)
GPS	global positioning system (see *Glossary*)
GSP	gross state product
GVA	gross value added
GWP	global warming potential (see *Glossary*)
HAT	Highest Astronomical Tide (see *Glossary*)
HAZID	hazard identification (see *Glossary*)

HAZOP	hazard and operability (analysis) (see *Glossary*)
HB	hopper barge
HFC(s)	hydrofluorocarbon(s)
HOCNF	Harmonised Offshore Chemical Notification Format
HSE	health, safety and environment
IC_{50}	inhibition concentration 50% (see *Glossary*)
ICN	Industry Capability Network
IMCRA	Integrated Marine and Coastal Regionalisation of Australia (IMCRA v. 4.0, 2006)
IMCRA	Interim Marine and Coastal Regionalisation of Australia (IMCRA v. 3.3, 1998)
IMDG Code	International Maritime Dangerous Goods Code
IMO	International Maritime Organization
IMS	Integrated Managed Services Pty Ltd, a Western Australian company offering people management services to heavy engineering construction projects
IO	internal olefin
IPCC	Intergovernmental Panel on Climate Change
IPCS	International Programme on Chemical Safety
IPP	Industry Participation Plan
ISO	International Organization for Standardization
ISQG(s)	interim sediment quality guideline(s)
IUCN	International Union for Conservation of Nature and Natural Resources
JHA	job hazard analysis (see *Glossary*)
JI	joint implementation
JPDA	Joint Petroleum Development Area
KP	kilometre point (measures in kilometres along the gas export pipeline, starting at the Ichthys Field and ending at the pipeline shore crossing on Middle Arm Peninsula in Darwin Harbour)
KPI	key performance indicator
$L_{A\,10}$	An $L_{A\,10}$ noise level is the noise level in A-weighted decibels (dB(A)) which, measured as an $L_{A\,Slow}$ value, is exceeded for more than 10% of a specified period.
$L_{A\,90}$	An $L_{A\,90}$ noise level is the noise level in A-weighted decibels (dB(A)) which, measured as an $L_{A\,Slow}$ value, is exceeded for more than 90% of a specified period
LAC	light attenuation coefficient
LAT	Lowest Astronomical Tide (see *Glossary*)
LC_{50}	lethal concentration 50% (see *Glossary*)
LD_{50}	lethal dose 50% (see *Glossary*)
LDC	Larrakia Development Corporation
LHMC	Larrakia Heritage Management Committee
LLR	lower limits of reporting
LNG	liquefied natural gas (see *Glossary*)
LOEC	lowest-observable-effect concentration (see *Glossary*)
LPG(s)	liquefied petroleum gas(es) (see *Glossary*)
MARPOL 73/78	International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto (MARPOL 73/78)
MCMPR	Ministerial Council on Mineral and Petroleum Resources
MEG	monoethylene glycol (see *Glossary*)
MMPE	Monterey–Miami Parabolic Equation (a modelling program for underwater acoustics)
MMRF	Monash Multi-Regional Forecasting (a modelling program for simulating the regional and national economic impacts of an Australian project etc.)
MODU	mobile offshore drilling unit
M_s	the notation for values of surface-wave magnitude (a magnitude scale for earthquakes)
MSDS	material safety data sheet
MW	molecular weight

n.a.	not applicable; not available
NAXA	Northern Australia Exercise Area
NEPC	National Environment Protection Council
NEPM(s)	national environment protection measure(s)
NGERS	National Greenhouse and Energy Reporting System
NHMRC	National Health and Medical Research Council
NIMPCG	National Introduced Marine Pests Coordination Group
NLC	Northern Land Council
NODGDM	National Ocean Disposal Guidelines for Dredged Material
NOEC	no-observable-effect concentration (see *Glossary*)
NOI	notice of intent
NORM(s)	naturally occurring radioactive material(s) (see *Glossary*)
NPV	net present value
NRETA	(Northern Territory) Department of Natural Resources, Environment and the Arts, now the Department of Natural Resources, Environment, the Arts and Sport
NRETAS	(Northern Territory) Department of Natural Resources, Environment, the Arts and Sport, formerly the Department of Natural Resources, Environment and the Arts
NRMMC	Natural Resource Management Ministerial Council
NT	Northern Territory
NTICN	Northern Territory Industry Capability Network
NTU	nephelometric turbidity unit (see *Glossary*)
OEMP	operations environmental management plan
OPGGS(Environment) Regulations	Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations 2009 (Cwlth)
OSCP	oil spill contingency plan
OSPAR	Oslo and Paris (Commission or Convention)
PAH	polycyclic aromatic hydrocarbon
PAR	photosynthetically active radiation
PASS	potential acid sulfate soil (see *Glossary*)
PBB	polybrominated biphenyl
PCB	polychlorinated biphenyl
PCN	polychlorinated naphthalene
PCT	polychlorinated terphenyl
PDA	Project Development Agreement
PFC(s)	perfluorocarbon(s)
pH	logarithmic index for the hydrogen ion concentration in an aqueous solution as a measure of acidity or alkalinity (see *Glossary*)
PLan	Planning Action Network Inc.
PM	particulate matter (see *Glossary*)
PM_{10}	(air-polluting) particulate matter with diameters less than 10 µm
$PM_{2.5}$	(air-polluting) particulate matter with diameters less than 2.5 µm
PMBH	polyhexamethylene biguanide hydrochloride
P_{ow}	octanol–water partition coefficient (see *Glossary*)
ppb	parts per billion
ppm	parts per million
ppmv	parts per million by volume
ppt	parts per thousand (see *Glossary*)
psi	pound(s) per square inch
P(SL)(MoE) Regulations	Petroleum (Submerged Lands) (Management of Environment) Regulations 1999 (Cwlth)
PTS	permanent threshold shift
PVC	polyvinyl chloride

PWC	Power and Water Corporation (of the Northern Territory)
PWSNT	Parks and Wildlife Service of the Northern Territory
QAP	quarantine-approved premises
QRA	quantitative risk assessment
rms	root mean square
RMU	removal unit
RO	reverse osmosis
ROV	remotely operated vehicle
RPS	an international consultancy providing, *inter alia*, environmental management services
SBM	synthetic-based mud (see *Glossary*)
SD	statistical division (of the Australian Bureau of Statistics)
SDP	self-elevating drilling platform
SERPENT (project)	"Scientific and Environmental ROV Partnership using Existing iNdustrial Technology" (project)
SKM	Sinclair Knight Merz Pty Limited, an international engineering, sciences and project delivery company
sp.	species (singular)
SPOCAS	suspension peroxide oxidation combined acidity and sulfate
spp.	species (plural)
SSD	statistical subdivision (of the Australian Bureau of Statistics)
SVT	SVT Engineering Consultants, a Perth-based consultancy specialising in acoustics, vibration and corrosion
TAPM	The Air Pollution Model (a CSIRO modelling program for the prediction of air quality)
TBM	tunnel-boring machine
TBT	tributyltin (see *Glossary*)
TDS	total dissolved solids
TEG	triethylene glycol (see *Glossary*)
TKN	total Kjeldahl nitrogen (see *Glossary*)
TOC	total organic carbon
TOPROC	Top End Regional Organisation of Councils
TPH(s)	total petroleum hydrocarbon(s)
TPWC Act	*Territory Parks and Wildlife Conservation Act* (NT)
TSHD	trailing suction hopper dredger
TSS	total suspended solids
TTS	temporary threshold shift (see *Glossary*)
UCL	upper confidence level
UNCLOS	United Nations Convention on the Law of the Sea
UNFCCC	United Nations Framework Convention on Climate Change
URS	URS Australia Pty Ltd, the Australian arm of an international multidisciplinary engineering design and environmental services consultancy, and formerly known in Australia as Dames & Moore
US EPA	(United States) Environmental Protection Agency
VER	voluntary emission reduction
VET	vocational education and training
VOC(s)	volatile organic compound(s) (see *Glossary*)
VSP	vertical seismic profiling
WBM	water-based mud (see *Glossary*)
WHO	World Health Organization
w/w	weight per weight
WWTP	wastewater treatment plant
YMCA	Young Men's Christian Association

Chemical symbols and formulae

$BaSO_4$	barium sulfate (barite)
C_5 (etc.)	(in carbon chain notation) a carbon compound with five carbon atoms, usually in a chain
$CaCO_3$	calcium carbonate
CH_4	methane
C_2H_6	ethane
C_3H_8	propane
$(C_4H_9)_3Sn$ group	the chemical group forming the basis of tributyltin compounds (TBTs)
C_4H_{10}	butane
C_5H_{12}	pentane
$C_{11}H_{19}N_5S$	Irgarol® 1051 (a triazine)
Co	cobalt
CO	carbon monoxide
CO_2	carbon dioxide
CO_2-e	carbon dioxide equivalent (see *Glossary*)
Cu	copper
Cu^{2+}	copper(II) cation
Fe	iron
Fe_2O_3	iron(III) oxide (haematite)
FeS	iron monosulfide (ferrous sulfide)
FeS_2	iron disulfide (ferric sulfide)
Hg	mercury
HNO_3	nitric acid
H_2S	hydrogen sulfide
H_2SO_4	sulfuric acid
Mn	manganese
N	nitrogen
NH_4^+	ammonium (ion)
NO	nitric oxide
N_2O	nitrous oxide
NO_2	nitrogen dioxide
NO_3^-	nitrate (ion)
NO_2^-	nitrite (ion)
NO_x	nitrogen oxides (see *Glossary*)
O_3	ozone
PO_4^{3-}	orthophosphate (ion)
SF_6	sulfur hexafluoride
Sn	tin
SO_2	sulfur dioxide
SO_x	sulfur oxides (see *Glossary*)
$SrSO_4$	strontium sulfate

Abbreviations and symbols for units of measurement

The units of measurement used in the *Ichthys Gas Field Development Project: draft environmental impact statement* are, in the main, those recommended by the International System of Units (SI). They also, however, include the following:

- non-SI units that are based on the SI and are retained because of their practical importance (e.g. hectare, litre and tonne)
- non-SI units that are recognised as having to be retained because of their practical importance (e.g. day, hour, minute and degree Celsius)
- various other non-SI units or specialist units in combination with SI units (e.g. decibel and parts per million)
- non-SI units widely used in the oil & gas industry (e.g. British thermal unit and million barrels).

a	year (from Latin *annus* = year)
bbl	barrel(s)
bbl/d	barrel(s) per day
Bq	becquerel(s)
Bq/L	becquerel(s) per litre
Btu	British thermal unit (see *Glossary*)
c	centi- (SI prefix = 0.01, or 10^{-2}, or one-hundredth)
°C	degree(s) Celsius
cfu/100 mL	colony-forming unit(s) per 100 millilitres (see *Glossary*)
cm	centimetre(s)
cP	centipoise
d	day
dB	decibel
dB(A)	decibel (“A” weighting) (see *Glossary*)
dB re 1 μPa	sound pressure level with reference to one micropascal
dB re 1 μPa at 1 m	sound pressure level with reference to one micropascal at the standard reference distance of one metre from the acoustic centre of the source
dB re 1 μPa rms	sound pressure level with reference to one micropascal root mean square
G	giga- (SI prefix = 1 000 000 000, or 10^9, or one thousand million)
GL	gigalitre(s)
GL/s	gigalitre(s) per second
Gm^3	cubic gigametre(s) (or thousand million cubic metres)
GW	gigawatt(s)
GW·h	gigawatt hour(s)
GW·h/a	gigawatt hour(s) per annum
g	gram(s)
g/L	gram(s) per litre
g/m^2	gram(s) per square metre
h	hour(s)
ha	hectare(s)
hp	horsepower
Hz	hertz
k (prefix)	kilo- (SI prefix = 1000, or 10^3, or one thousand)
kg	kilogram(s)
kg/d	kilogram(s) per day
$kg/ha{\cdot}a^{-1}$	kilogram(s) per hectare per annum
kg/m^3	kilogram(s) per cubic metre
kg/t	kilogram(s) per tonne
kHz	kilohertz
km	kilometre(s)

km/h	kilometre(s) per hour
km^2	square kilometre(s)
L	litre(s)
lm	lumen(s)
lm/m^2	lumen(s) per square metre
lx	lux
M (prefix)	mega- (SI prefix = 1 000 000, or 10^6, or one million)
ML	megalitre(s)
ML/a	megalitre(s) per annum
Mm^3	cubic megametre(s) (or million cubic metres)
Mt	megatonne(s)
Mt/a	megatonne(s) per annum
MW	megawatt(s)
m	metre(s)
m^2	square metre(s)
m^3	cubic metre(s)
m^3/a	cubic metre(s) per annum
m^3/d	cubic metre(s) per day
m^3/h	cubic metre(s) per hour
m/s	metre(s) per second
m^3/s	cubic metre(s) per second
m (prefix)	milli- (SI prefix = 0.001, or 10^{-3}, or one-thousandth)
mg	milligram(s)
mg/cm^2·d^{-1}	milligram(s) per square centimetre per day
mg/g	milligram(s) per gram
mg/kg	milligram(s) per kilogram
mg/L	milligram(s) per litre
mg/m^2	milligram(s) per square metre
mg/Nm^3	milligram(s) per normal cubic metre
mL	millilitre(s)
mm	millimetre(s)
mm/a	millimetre(s) per annum
mm/h	millimetre(s) per hour
mol	mole
μ	micro- (SI prefix = 0.000 001, or 10^{-6}, or one-millionth)
μg	microgram(s)
μg/cm^2·d^{-1}	microgram(s) per square centimetre per day
μg/L	microgram(s) per litre
μg/m^3	microgram(s) per cubic metre
μg/Nm^3	microgram(s) per normal cubic metre
μm	micrometre(s)
μPa	micropascal(s)
MMbbl	million barrels
MMscfd	million standard cubic feet per day
mol	mole(s)
n	nano- (SI prefix = 0.000 001, or 10^{-9}, or one thousand-millionth)
ng	nanogram(s)
ng/g	nanogram(s) per gram
nm	nanometre(s)
Nm^3	normal cubic metre (the volume of gas under standard conditions)

NTU	nephelometric turbidity unit (see *Glossary*)
P	peta – (SI prefix = 1 000 000 000 000 000, or 10^{15}, or one thousand million million)
PJ	petajoule(s)
Pa	pascal(s)
ppb	parts per billion
ppm	parts per million
ppmv	parts per million by volume
ppt	parts per thousand (see *Glossary*)
psi	pound(s) per square inch
s	second(s)
t	tonne(s)
t/a	tonne(s) per annum
tcf	trillion cubic feet

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