



Browse LNG Precinct



Browse Liquefied Natural Gas Precinct Strategic Assessment Report

(Draft for Public Review)

December 2010

Appendix B-7

Comparative Analysis of the
Feasibility of Alternative Locations
for the Development of a
Liquefied Natural Gas Plant



CLIENTS | PEOPLE | PERFORMANCE

**Department of the
Environment, Water,
Heritage and the Arts**

**Comparative Analysis of the
Feasibility of Alternative
Locations for the Development
of a Liquefied Natural Gas
Precinct**

January 2009



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Executive Summary

In February 2008 the Australian and Western Australian (WA) Governments entered into an agreement under the Strategic Assessment provisions of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) for the selection and management of a site(s) for a common-user liquefied natural gas (LNG) precinct to service the Browse Basin gas reserves off the Western Australian Kimberley coast.

The Government of Western Australia established the WA Northern Development Taskforce (NDT) in July 2007. The initial purpose of the NDT is to manage across-government planning processes and stakeholder consultation in regard to selection and development of a suitable location or locations for the processing of Browse Basin gas reserves. The preliminary findings of the NDT were released in July 2008 and provide details of eleven potential sites based on an assessment of technical, environmental and heritage issues. Of these eleven precinct sites, four were shortlisted as being feasible. In December 2008 and following a public comment period, James Price Point was announced by the WA Government as their preferred site for the development of a LNG precinct in the Kimberley.

As stated in the Strategic Assessment agreement, the process for selection and assessment of the LNG precinct needs to consider feasible alternative locations outside of the Kimberley Region. In order to provide an assessment of alternative locations, the Australian Government Department of the Environment, Water, Heritage and the Arts (DEWHA) engaged GHD to prepare a comparative analysis of the feasibility of alternative locations for the development of a common-user LNG precinct outside of the Kimberley region.

The analysis was based on the identification of sites along the Western Australian Pilbara coast, Northern Territory coast and Northern Australian offshore floating platform locations. The analysis is not intended to be a comprehensive analysis of options, but rather an analysis based on existing information to help identify key issues.

Over fifty possible locations in Western Australia, three in the Northern Territory and three options for offshore structures were considered.

At first glance a significant number of sites along the Pilbara coast present themselves as having some potential as sites for an LNG precinct. However, this analysis indicates that it would be inappropriate to conclude that because of the presence of some industry on the Pilbara coast it represents lower environmental values than the Kimberley.

Economics dictate that any proposed site greater than 500 km from the gas field is prohibitively expensive to develop from a green field situation. This can guide selection of a precinct because any economic proposal either must be within 500 km or already have significant industrial infrastructure present. This infrastructure at the very least would include a dredged shipping channel in close proximity to the coastline.



Selection of brown field sites may, however be constrained by impacts on the local or regional airshed. Recent modelling of the Burrup Peninsula appears to suggest that approximately two thirds of the airshed capacity will be taken up when the Pluto LNG development comes on-line. An airshed capacity issue could exist even in a green field site if an industrial concentration significantly larger than that on the Burrup Peninsula is proposed.

Socially, an uncontrolled imposition of a large industrial precinct can present problems even if a town already exists. There are no large urbanised areas capable of absorbing the workforce from an LNG precinct anywhere along the North West Coast. A significant itinerant workforce can place considerable pressures on local facilities and services.

Most of the North West is subject to Native Title Claim and the position of Claimants in relation to industrial development is uncertain. Very little is known in relation to Aboriginal heritage sites, but landscape features such as promontories or near shore islands are often associated with significant sites. The absence of listed sites does not indicate that nothing exists in these areas; rather it usually indicates that no survey has taken place.

LNG precinct options are limited in the Northern Territory and all but one site is undeveloped with no significant infrastructure. The distance of these sites from the Browse Basin suggests that their development would be economically challenging.

Offshore LNG facilities offer some potential for processing close to the gas field. However, little actual development of these types of infrastructure has occurred. For development of this type, each company would be required to make individual investment with very little opportunity for synergy. It might be assumed that the environmental impacts of such developments are less, however the specifics of any proposal would need to be considered in detail before such a conclusion could be made with certainty.

1. Introduction

In February 2008 the Australian and Western Australian (WA) Governments entered into an agreement under the Strategic Assessment provisions of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) for the selection and management of a site(s) for a common-user liquefied natural gas (LNG) precinct to service the Browse Basin gas reserves off the Western Australian Kimberley coast.

The Government of Western Australia established the WA Northern Development Taskforce (NDT) in July 2007. The initial purpose of the NDT is to manage across-government planning processes and stakeholder consultation in regard to selection and development of a suitable location or locations for the processing of Browse Basin gas reserves. The preliminary findings of the NDT were released in July 2008 and provide details of eleven potential sites based on an assessment of technical, environmental and heritage issues. Of these eleven precinct sites, four were shortlisted as being feasible. In December 2008 and following a public comment period, James Price Point was announced by the WA Government as their preferred site for the development of a LNG precinct in the Kimberley.

As stated in the Strategic Assessment agreement the process for selection and assessment of the LNG precinct needs to consider feasible alternatives to locations of the precinct outside of the Kimberley Region. In order to provide an assessment of alternative locations, the Australian Government Department of the Environment, Water, Heritage and the Arts (DEWHA) engaged GHD to prepare a comparative analysis of the feasibility of alternative locations for the development of a common-user LNG precinct outside of the Kimberley region.

The analysis was based on the identification of sites along the Western Australian Pilbara coast, Northern Territory coast and Northern Australian offshore floating platform locations through consultation with key stakeholders and the review of relevant published and unpublished literature. The findings of the comparative analysis are outlined in this report. Figure 1 shows the location of these areas.

1.1 Precinct Requirements

There are many possible configurations for a common user LNG precinct. Gaffney Cline and Associates (2008) evaluated sites with a land area up to 950 hectares. However, Worley Parsons (2008) indicated that this might not be sufficient to accommodate up to 10 LNG trains unless separation distances between proponents was reduced.

Worley Parsons outline the requirements for a suitable precinct location as;

Marine:

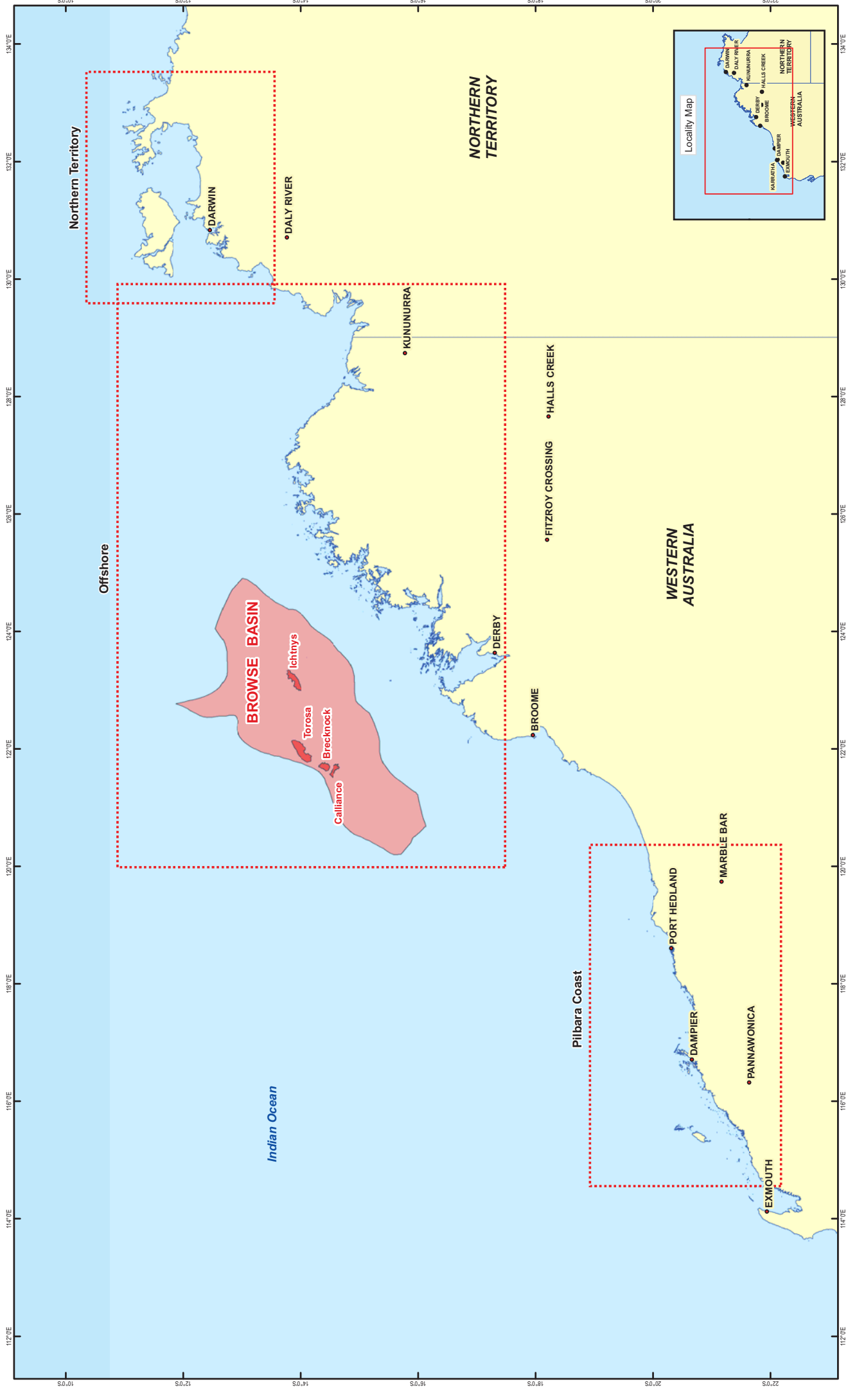
- ▶ Access to deep water is critical due to cost considerations. Achieving short channels and minimum dredging will therefore influence the location of on-shore facilities.



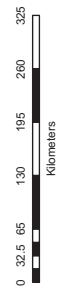
- ▶ Berth operability of 98% as a target is likely to be required for the operators to achieve the desired reliability. Breakwaters may be required where this cannot be achieved. All precinct users will need to comply with the same port drivers to allow an efficient solution to be developed.
- ▶ A Materials Offload Facility (MOF) and tug pens which could potentially be shared by different precinct users, therefore only one of these would be required at each site.
- ▶ LNG loading facilities (which we assume to be single user facilities due to high utilisation).
- ▶ Multiple downstream industries could be accommodated through a shared jetty with more than one berth required.
- ▶ A common shipping channel to deep water could be shared by all site users.

1.1.1 On Shore

- ▶ An accommodation site/complex/camp could be shared by all users of the precinct.
- ▶ An airstrip could be shared by all users of the precinct.
- ▶ LNG storage tanks must be located as close as practical to the jetty abutment location and the berth (Loading Arms) will be within 4km and preferably 3km of the storage tanks to cap costs of cryogenic loading lines.
- ▶ LNG trains must be located in line with prevailing winds across the site, as they will be air cooled.
- ▶ LNG trains must be located in close proximity to the LNG storage tanks, again to cap costs of cryogenic loading lines.
- ▶ Down stream industry can be located further from the jetties, but these facilities must have efficient corridor access to the proposed port site.
- ▶ At least one infrastructure corridor must be provided between downstream industry and the jetties.



1:6,500,000 (at A3)



Geographic Coordinate System
Horizontal Datum: Geocentric Datum of Australia 1994

LEGEND

- Browse Basin & Gas Fields - GHD - 20081127
- Browse Basin Gas Fields
- Browse Basin
- Mainland - GA - 2008



Townsville - GA - 20080422
Potential LNG Hub Locations - GHD - 20081204
Mainland - GA - 2008



Department of Environment, Water, Heritage and the Arts
Alternative Locations for LNG Hub
Job Number 61-23286
Revision 1
Date 12 JAN 2009

Location Map of Northern Territory, Offshore & Pilbara Coast

Figure 1

2. Study Methodology

A staged approach was employed in undertaking the comparative analysis of alternative precinct locations.

2.1 Research and Review

Alternative precinct sites along the Western Australian Pilbara coast, Northern Territory coast and Northern Australian offshore floating platform locations were identified through consultation with key stakeholders and a review of published and unpublished literature. Interviews were conducted with representatives from various WA State Government agencies, industry organisations and consultants.

Relevant studies and reports dating from 1986 were sourced and databases searched for information supporting the investigation of possible LNG precinct locations.

Each available study and report was reviewed to obtain:

- ▶ Information relevant to the assessment process, which was used to populate a site selection criteria matrix developed for the analysis; and
- ▶ Details and status of any approvals that are currently in process.

Where information was not available or not provided in the studies and reports, desktop information was obtained from the various environmental, heritage, regional development, tourism and planning databases and websites.

A bibliography including those databases and websites searched is provided in Appendix B. The availability of relevant studies and reports are noted.

2.2 Comparative Analysis

2.2.1 Site Consideration Matrix

A site consideration matrix was developed that sets out criteria across the four high-level categories of:

- ▶ Environment;
- ▶ Socio-economic, Community and Tourism;
- ▶ Industry and Site Technical Requirements; and
- ▶ Indigenous.

The criteria were based on the site selection criteria employed by the WA NDT in their short listing of the Kimberley region locations.

The site consideration matrix was populated with information relevant to the four categories for the Pilbara coast, Northern Territory coast and Northern Australian offshore floating platform locations.

A list of sites included in the analysis is included in Appendix C.



Several criteria in the site consideration matrix were unable to be addressed and populated with information as a result of information pertaining to that particular precinct site either not in existence or currently cannot be disclosed by a development proponent.

Due to the large area of the Pilbara coast and for ease in the analysis, the Pilbara was further divided into subregional groupings, including:

- ▶ *Onslow subregion* including Onslow surrounds and offshore islands;
- ▶ *Dampier/Karratha subregion* including the Burrup Peninsula, Maitland Estate, the Dampier Archipelago and offshore islands;
- ▶ *Cape Lambert subregion* including Point Samson, Wickham, Cossack, Cape Lambert Industrial Estate and Roebourne; and
- ▶ *Port Hedland subregion* including Port Hedland surrounds, South Hedland, Boodarie and offshore islands.

2.2.2 Analysis

Each alternative precinct site was considered against the following criteria wherever possible:

- ▶ Potential environment and heritage constraints and impacts;
- ▶ Technical constraints at the alternative locations;
- ▶ Potential social constraints and impacts; and
- ▶ Economic viability of the alternative locations.

The analysis is not intended to be a comprehensive analysis of options, but rather an analysis based on existing information to help identify key issues. No recommendations have been provided for alternative precinct location(s) for the development of LNG processing facilities outside of the Kimberley region.

3. Western Australian Pilbara Coast

3.1 Introduction

The Pilbara region is located in north-west Western Australia. The region extends from the eastern portion of the Exmouth Gulf to the western end of Eighty Mile Beach (east of Port Hedland).

The Pilbara coast has been divided into subregions for this study (Figure 2), specifically:

- ▶ *Onslow region* including Onslow surrounds and offshore islands;
- ▶ *Dampier/Karratha region* including the Burrup, Maitland Estate, the Dampier Archipelago and offshore islands;
- ▶ *Cape Lambert region* including Point Samson, Wickham, Cossack, Cape Lambert Industrial Estate and Roebourne; and
- ▶ *Port Hedland region* including Port Hedland surrounds, South Hedland, Boodarie and offshore islands.

3.1.1 Local Business

The mineral and petroleum industries are the two leading sectors in the Pilbara's economy, with a production value of \$20.6 billion in 2004/05 (DLGRD, 2006). These industries include oil and condensate (\$7.2 billion), iron ore (\$8 billion) and gas (\$4.8 billion). Other mining activities include salt, silver, gold, manganese and base metals (\$282 million in 2003/04).

There are several commercial activities supporting the mineral and energy sector including engineering, surveying, personnel and equipment hire services, with estimated turnover of \$345 million in 2004/05. Other industries in the region include manufacturing (\$309 million in 2001/02), tourism (\$226 million in 2004/05), and livestock disposal (\$45 million in 2003/04).

3.1.2 Indigenous Economic Development

A report by Taylor and Scambury (2005) found that the recent substantial economic development in the Pilbara region to date has provided negligible benefits to the indigenous population, with the employment rate remaining well below 50 per cent. Many potential indigenous employees are often ill-equipped for the labour force due to low literacy and numeracy skills, lack of qualifications and work experience, substance misuse and consequential lack of motivation. The links between poor employment status, low incomes and high welfare dependency are recognised as factors that need to be addressed to increase the workforce participation and social wellbeing of the indigenous population.

Employment within large resource companies alone is not the only solution, and the report suggests initiatives that favour a hybrid economy, including private, public and customary sector employment. The increasing access to traditional lands and the ties



to country are incentives to continue customary social and economic activities that provide alternative income streams, such as the arts industry and cultural education. The expanding working-age population in the Pilbara means that the structural impediments to participation need to be addressed so that the economic development of the indigenous residents can be achieved in a sustainable manner.

3.1.3 Cost of Living

The Department of Local Government and Regional Development (DLGRD) produced the 2007 Regional Price Index (RPI), which compared the price of a basket of goods and services which were weighted according to the frequency of purchase. Regional data was collected from specific town sites including Port Hedland and Karratha in the Pilbara region and Exmouth and Carnarvon in the Gascoyne region. A summary of the indices reported, compared to a base of 100 for the Perth region, is contained in Table 1.

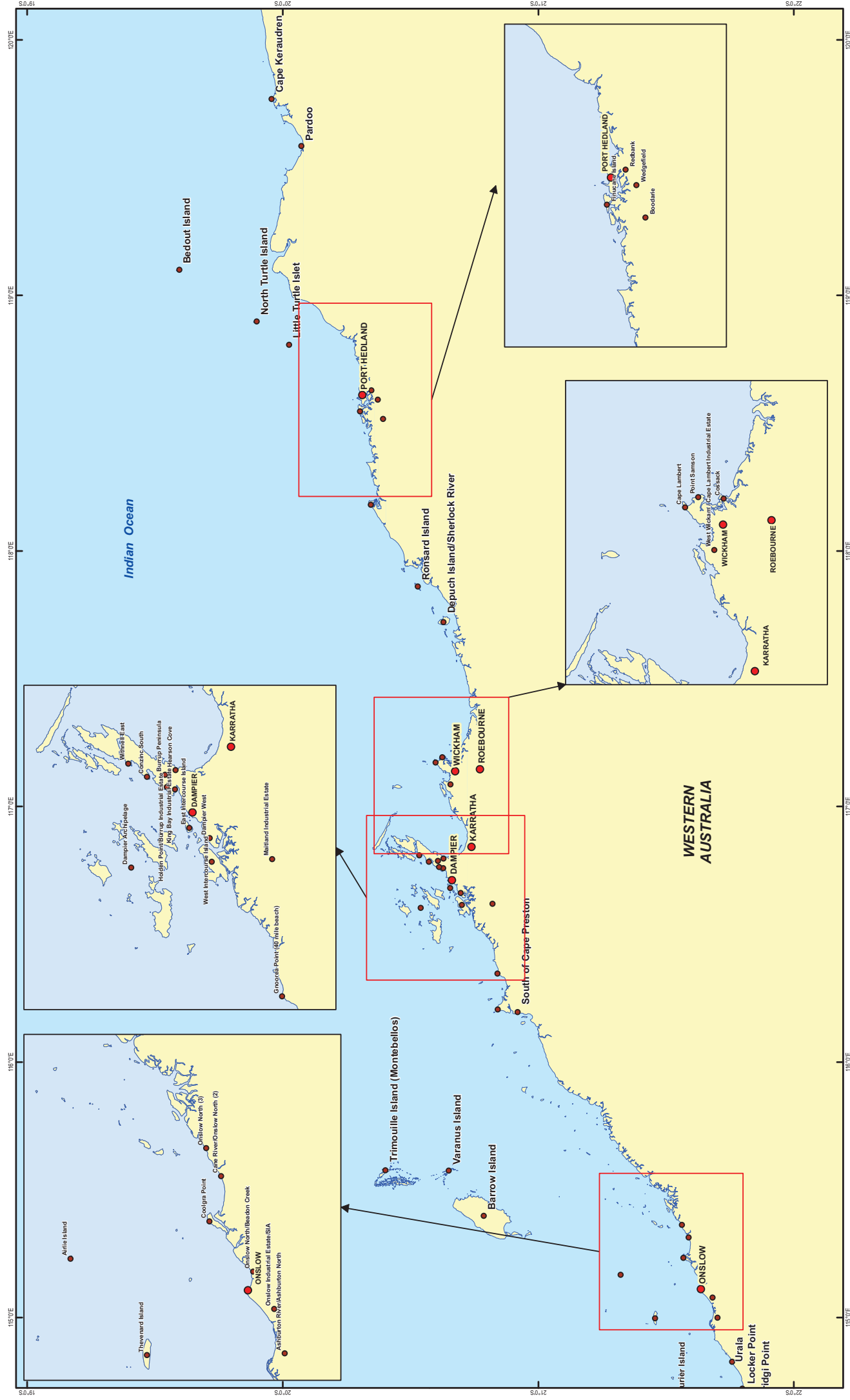
Table 1. Regional and town price indices 2007

| Indices | Region: Pilbara | Town: Karratha | Town: Port Hedland | Region: Gascoyne | Town: Exmouth |
|-----------------------------------|----------------------------|---------------------------|-----------------------------------|-----------------------------|--------------------------|
| Regional and town | 120.1 | 123.1 | 117.6 | 105.3 | 112.7 |
| Food commodities | 106.3 | 114.4 | 99.4 | 105.9 | 116.8 |
| Clothing commodities | 103.5 | 103.9 | 103.2 | 111.2 | 111.2 |
| Housing commodities | 149 | 155.1 | 143.8 | 92.9 | 99.2 |
| Household equipment and operation | 107 | 108 | 106.1 | 105.5 | 107.8 |
| Transportation | 101.8 | 101.6 | 102 | 101.4 | 102.2 |
| Cigarettes, tobacco and alcohol | 105.3 | 105.3 | 105.2 | 105.9 | 107.2 |
| Health and personal care | 103.8 | 104.9 | 102.7 | 98 | 98.6 |
| Recreation and education | 141.5 | 142.2 | 140.9 | 125.5 | 148.5 |

Source: adapted from DLGRD, Regional Prices Index November 2007

The Pilbara region was found to have the highest regional price index in WA of 120.1 which was expected to be due to the continuing impacts of the mining boom. The higher costs were mainly due to the cost of housing, recreation and education services. The cost of living in Karratha was consistently higher than in Port Hedland, apart from transportation which was similar. Exmouth had several relatively high indices, which is possibly due to its remoteness and small population which limits local market opportunities.

Forty-six potential alternative LNG precinct sites were identified along the Pilbara coast. Consideration of each of the subregions is given in the sections that follow.




LEGEND

- Place of Interest - GA - 20080422
- Townsite - GA - 20080422
- Islands and Mainlands - GA - 20081015



1:1,500,000 (at A3)



Kilometers

Geographic Coordinate System
Horizontal Datum: Geocentric Datum of Australia 1994



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| | | |
|--|------------|-------------|
| Department of Environment, Water, Heritage and the Arts | Job Number | 61-23286 |
| Alternative Locations for LNG Hub | Revision | 1 |
| | Date | 12 JAN 2009 |

Location Map of Pilbara Coast

Figure 2

GHD US 9308764-1 GHD® (US) Ltd
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Dataset names include published date where available.
Created by: S Imai, KDRALU, KORALU, seagat

GHD House, 239 Adelaide Terrace Perth WA 6004 T 61 8 6222 8222 F 61 8 6222 8555 E email@ghd.com.au W www.ghd.com.au

3.2 Onslow Region

The Onslow region and offshore islands have been subject to a number of site assessments in order to service petroleum interests in the North West Shelf and twelve sites were identified in the review. Investigations have been undertaken for Chevron, BHP and Woodside.

This area is distant from the Browse Basin fields and whilst offering possible locations, can only do so at the cost of significant infrastructure. This analysis identifies the following in regard to the Onslow Sites.

Environment and Heritage Constraints and Issues

- ▶ The mainland does not have reserve/national park status or marine parks in the adjacent coast.
- ▶ The two offshore islands (Serrurier and Thevenard) are nature reserves.
- ▶ The two islands are on the Register of the National Estate (RNE).
- ▶ No Aboriginal Heritage was identified from databases on the mainland except sites near coastal Onslow (Commonwealth land).
- ▶ The EPBC protected matters searches identified one vulnerable terrestrial species, the Pilbara leaf-nosed bat (*Rhinonicteris aurantia*).
- ▶ Marine endangered species identified from the EPBC search in the vicinity of the sites included;
 - Birds - Southern Giant-Peterel (*Macronectes giganteus*).
 - Mammals - Blue Whale (*Balaenoptera musculus*) and Southern Right Whale (*Eubalaena australis*).
 - Reptiles - Loggerhead Turtle (*Caretta caretta*).
- ▶ Vulnerable species identified from the EPBC search in the vicinity of the sites included;
 - Mammals - Humpback Whale (*Megaptera novaeangliae*).
 - Reptiles - Green Turtle (*Chelonia mydas*), Leathery Turtle (Leatherback Turtle) (*Dermochelys coriacea*), Hawksbill Turtle (*Eretmochelys imbricat*) and Flatback Turtle (*Natator depressus*).
 - Sharks - Whale Shark (*Rhincodon typus*).
- ▶ Migratory species identified from the EPBC search in the vicinity of site included;
 - Birds - White-bellied Sea-Eagle (*Haliaeetus leucogaster*), Barn Swallow (*Hirundo rustica*), Rainbow Bee-eater (*Merops ornatus*), Great Egret (White Egret) (*Ardea alba*), Cattle Egret (*Ardea ibis*), Oriental Plover (Oriental Dotterel) (*Charadrius veredus*), Oriental Pratincole (*Glariola maldivarum*), Little Curlew (Little Whimbrel) (*Numenius minutus*), Southern Giant-Petrel (*Macronectes giganteus*) and Fork-tailed Swift.

- Mammals - Bryde's Whale (*Balaenoptera edeni*), Dugong (*Dugong dugong*), Humpback Whale, Killer Whale (Orca) (*Orcinus orca*), Indo-Pacific Humpback Dolphin (*Sousa chinensis*) and Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) (*Tursiops aduncus*).
- Reptiles - Loggerhead Turtle, Green Turtle, Leathery Turtle, Hawksbill Turtle and Flatback Turtle.
- Sharks - Whale Shark (*Rhincodon typus*).
- ▶ No Critical Habitats, as defined in the EPBC protected matters search, were identified.
- ▶ The EPBC search showed that Serrurier and Thevenard Islands did not have any identified endangered or vulnerable species.
- ▶ Mangrove communities are in the vicinity of the majority of the mainland sites.
- ▶ Waters off Onslow are characteristically turbid and have a maximum spring tide of 2.5 m.

Due to the apparent commonality of environmental issues across the Pilbara (based on existing information) a discussion on potential impacts is provided in section 6.

Social Constraints and Issues

- ▶ Onslow is a small town hence it has limited ability to manage a substantial influx of personnel.
- ▶ Disruptions would initially be caused and services/infrastructure would require upgrading.
- ▶ There is limited available labour in Onslow, thus labour would need to be outsourced.
- ▶ There is some opportunity for employment from indigenous communities.
- ▶ Recreation includes fishing, camping and SCUBA. Increased shipping is likely to interfere with this.
- ▶ Possible industry conflicts may occur with fishing, pastoral and tourism industries.
- ▶ No historic non-indigenous sites were found.
- ▶ The sites range in zoning from Strategic Industry, Rural, and Conservation Recreation and Natural Landscape.
- ▶ Majority of sites have no registered aboriginal sites under the Aboriginal Heritage Act (1972).
- ▶ Native title extends over approximately half of the sites.

Technical Constraints

- ▶ Dredging is required for all sites.
- ▶ Flooding concerns noted for the majority of the sites.
- ▶ Limited shipping access due to:

- Distance to navigable waters
- Islands and reefs
- ▶ Majority of sites are located in areas lacking infrastructure and are isolated from Onslow.
- ▶ This area is approximately 1200 km from the Browse Basin.

Economic Viability

- ▶ Limited information available.
- ▶ Unlikely to be economically feasible for a stand alone green field LNG processing plant as it would be located at a considerable distance from existing industrial infrastructure.

3.3 Dampier/ Karratha Region

The Dampier/Karratha region has been the subject of ongoing oilfield activity since the 1970's. An LNG plant has been established on the Burrup Peninsula by Woodside and a further plant is currently under construction. Successive WA State Governments have sought to identify land and undertake assessment and approvals processes for industry on the Peninsula, offshore islands and at other areas around Karratha (e.g. the Maitland Estate).

Due to this interest and other primary resource activities in this location, the town sites of Karratha and Dampier are under considerable pressure to supply housing and other social services. Recent stakeholder meetings indicate that Shire, health, police, emergency and education services are under pressure due to the rapid growth of the population and the fly in/fly out nature of a significant percentage of the workforce. Eighteen discrete sites were found during this review which identified the following in regard to the Dampier/Karratha Region.

Environment and Heritage Constraints and Issues

- ▶ No conservation park/reserves identified around the mainland.
- ▶ The islands off Cape Preston are part of a nature reserve.
- ▶ All offshore islands are nature reserves or conservation parks.
- ▶ The Dampier Archipelago (including the Burrup Peninsula) is listed on the National Heritage List. This National Heritage place covers 241 square kilometres across the majority of the Burrup Peninsula, islands within the archipelago and parts of the Maitland industrial estate.
- ▶ Cape Preston area has one offshore site in the RNE.
- ▶ Offshore islands are all included in the RNE.
- ▶ Marine environment of Dampier- Archipelago has been impacted by recreation and commercial activities.

- ▶ The EPBC protected matters search showed that mainland sites in the vicinity of Burrup may have the Northern Quoll (*Dasyurus hallucatus*) in the area (an endangered species) and two vulnerable terrestrial species; the Pilbara leaf-nosed bat and the Olive Python (*Liasis olivaceus*).
- ▶ Marine endangered species identified from the EPBC searches included;
 - Birds - Southern Giant-Peterel.
 - Mammals - Blue Whale and Southern Right Whale.
 - Reptiles - Loggerhead Turtle.
- ▶ Vulnerable species identified from the EPBC search included;
 - Mammals - Humpback Whale
 - Reptiles - Green Turtle, Leathery Turtle (Leatherback Turtle), Hawksbill Turtle and Flatback Turtle.
 - Sharks - Whale Shark.
- ▶ Migratory species identified from the EPBC search included;
 - Birds - White-bellied Sea-Eagle, Barn Swallow, Rainbow Bee-eater, Ruddy Turnstone (*Arenaria interpres*), Common Greenshank (*Tringa nebularia*), Whimbrel (*Numenius phaeopus*), Great Egret (White Egret), Cattle Egret, Oriental Plover (Oriental Dotterel), Oriental Pratincole, Little Curlew (Little Whimbrel), Southern Giant-Petrel and Fork-tailed Swift.
 - Mammals - Bryde's Whale, Dugong, Humpback Whale, Killer Whale (Orca), Indo-Pacific Humpback Dolphin and Spotted Bottlenose Dolphin (Arafura/Timor Sea populations).
 - Reptiles - Loggerhead Turtle, Green Turtle, Leathery Turtle (Leatherback Turtle), Hawksbill Turtle and Flatback Turtle.
 - Sharks - Whale Shark.
- ▶ No Critical Habitats, as defined in the EPBC protected matters search, were identified.
- ▶ Burrup has rich and varied vegetation that is not replicated anywhere else in the Pilbara.
- ▶ Extensive mangroves are in the Cape Preston area.
- ▶ Maximum tides are 4.5 m.
- ▶ A rich diversity of coral reefs and fish species occur along the coast.
- ▶ Sensitive mangroves are also in the region.
- ▶ Beaches may be used as turtle breeding sites including for the EPBC listed species - the loggerhead turtle, Green Turtle, Leatherback Turtle, Hawksbill Turtle and Flatback Turtle.

Due to the apparent commonality of environmental issues across the Pilbara (based on existing information) a discussion on potential impacts is provided in section 6.

Social Constraints and Issues

- ▶ Dampier/Karratha have a larger population than Onslow, however the capacities of the towns are already stretched and may be challenged in accommodating increased workforce.
- ▶ Disruptions may occur and community services are likely to be strained.
- ▶ There is a sizable employment base in Karratha, however, shortfalls still expected and outsourcing likely.
- ▶ Recreation such as fishing and boating will be impacted. Some sites would impact upon swimming beaches.
- ▶ Increased shipping may conflict with other industries.
- ▶ Good infrastructure is nearby, however work is still required.
- ▶ Zoning ranges from Industry, Rural and Conservation Recreation and Natural Landscape.
- ▶ Tourism includes fishing, camping, boating and rock art.
- ▶ Native title over the majority of the area still to be negotiated.
- ▶ A Native title agreement has been established over certain parts of the Burrup and other industrial sites.
- ▶ Area has a large number of registered sites under the *Aboriginal Heritage Act (1972)* and several in the RNE.
- ▶ A National Heritage Area is established over a significant area to protect Indigenous heritage, including rock art.

Technical Constraints

- ▶ A range of dredging requirements for the sites.
- ▶ Sites near Dampier have good access to deep water; however the Port is heavily congested.
- ▶ Sites near Dampier are close to good regional infrastructure.
- ▶ The size of infrastructure may be an issue for Cape Preston and island sites as the land area available is constrained.
- ▶ Site slope varies across the area.

3.4 Cape Lambert

Very few investigations have been undertaken to the East of Karratha. However, some investigation was undertaken for the Cape Lambert area and there is a proclaimed industrial area at Point Wickham. Cape Lambert has an operating iron ore export jetty and therefore it appears possible that some of the criteria may be satisfied by further investigation of this area.

Consideration needs to be given to the established industry in this area and the availability or capacity to establish further industry and shipping in this location. Very little information is available from petrochemical site selection studies. Desktop studies undertaken for this review provide the majority of the information however an investigation of site selection studies for export options for iron ore might provide further details. This review identified the following in regard to Cape Lambert.

Environment and Heritage Constraints and Issues

- ▶ The EPBC protected matters searches showed that mainland sites in the vicinity may have the Northern Quoll in the area (an endangered species) and the vulnerable terrestrial species; the Pilbara leaf-nosed bat, the Mulgara (*Dasycercus cristicauda*) and the Olive Python.
- ▶ Marine endangered species identified in vicinity of site included;
 - Birds - Southern Giant-Peterel.
 - Mammals - Blue Whale and Southern Right Whale.
 - Reptiles - Loggerhead Turtle.
- ▶ Vulnerable species identified from the EPBC search in vicinity of site included;
 - Mammals - Humpback Whale.
 - Reptiles - Green Turtle, Leathery Turtle (Leatherback Turtle), Hawksbill Turtle and Flatback Turtle.
 - Sharks - Whale Shark.
- ▶ Migratory species identified from the EPBC search in the vicinity of site included;
 - Birds - White-bellied Sea-Eagle, Barn Swallow, Rainbow Bee-eater, Ruddy Turnstone, Common Greenshank, Whimbrel, Great Egret (White Egret), Cattle Egret, Oriental Plover (Oriental Dotterel), Oriental Pratincole, Little Curlew (Little Whimbrel), Southern Giant-Petrel and Fork-tailed Swift.
 - Mammals - Bryde's Whale, Dugong, Humpback Whale, Killer Whale (Orca), Indo-Pacific Humpback Dolphin and Spotted Bottlenose Dolphin (Arafura/Timor Sea populations).
 - Reptiles - Loggerhead Turtle, Green Turtle, Leathery Turtle (Leatherback Turtle), Hawksbill Turtle and Flatback Turtle.
 - Sharks - Whale Shark.
- ▶ No Critical Habitats, as defined in the EPBC protected matters search, were identified.
- ▶ No conservation/marine reserves identified in the region.
- ▶ One RNE (for Dixon Island) was identified for the West Wickham site.
- ▶ Mangrove habitat would be impacted if sufficient area to enable the development of an LNG precinct was to be made available.



Social Constraints and Issues

- ▶ Limited available information.
- ▶ European cultural sites identified at Cossack.
- ▶ Mainly zoned Rural and Strategic Industry.
- ▶ Smaller population centres would have limited capacity however there is a short commute time to Karratha.
- ▶ Native title is over all sites.
- ▶ Some sites registered under the Aboriginal Heritage Act (1972), though there are no RNE.

Technical Constraints

- ▶ Limited available information from Petrochemical Reviews.
- ▶ Only 135 ha available without impact on Mangroves.
- ▶ Existing shipping channel (16m deep) at the end of an approximately 2.6km long jetty used for Cape Lambert Operations.
- ▶ 10m deep water is located approximately 2.5km offshore with waters of 15m depth at 14km offshore.
- ▶ Approximately 965 km to the Browse Basin.

Economic Viability

- ▶ Limited information available.
- ▶ Unlikely to be economically feasible for a stand alone green field LNG processing plant as it would be located at a considerable distance from existing industrial infrastructure.

3.5 Port Hedland

There has been very little published consideration of Port Hedland as a site for a potential LNG precinct, as with Cape Lambert. However, there is a multi-user deepwater port in this location. The capacity of this port and channels to handle further shipping is uncertain at this stage, but likely to be limited. Eleven locations were considered in the general vicinity of Port Hedland. The analysis identified the following in regard to the Port Hedland region.

Environmental and Heritage Constraints and Issues

- ▶ No marine conservation parks adjacent to the mainland, though offshore islands are nature reserves.
- ▶ The EPBC protected matters searches showed that mainland sites in the vicinity may have the Northern Quoll in the area (an endangered species) and the vulnerable terrestrial species; the Pilbara leaf-nosed bat, the Mulgara and the Olive Python.

- ▶ Marine endangered species identified from the EPBC search in the vicinity of the sites included;
 - Birds - Southern Giant-Peterel.
 - Mammals - Blue Whale and Southern Right Whale.
 - Reptiles - Loggerhead Turtle.
- ▶ Vulnerable species identified from the EPBC search in vicinity of the site included;
 - Mammals - Humpback Whale.
 - Reptiles - Green Turtle, Leathery Turtle (Leatherback Turtle), Hawksbill Turtle and Flatback Turtle.
 - Sharks - Whale Shark.
- ▶ Migratory species identified from the EPBC search in vicinity of site included;
 - Birds - White-bellied Sea-Eagle, Barn Swallow, Rainbow Bee-eater, Ruddy Turnstone, Sharp-tailed Sandpiper (*Calidris acuminata*), Sanderling (*Calidris alba*), Red Knot (*Calidris canutus*), Curlew Sandpiper (*Calidris ferruginea*), Red-necked Stint (*Calidris ruficollis*), Great Knot (*Calidris tenuirostris*), Greater Sand Plover (Large Sand Plover) (*Charadrius leschenaultii*), Oriental Plover (Oriental Dotterel), Grey-tailed Tattler (*Heteroscelus brevipes*), Bar-tailed Godwit (*Limosa lapponica*), Eastern Curlew (*Numenius madagascariensis*), Pacific Golden Plover (*Pluvialis fulva*), Grey Plover (*Pluvialis squatarola*), Painted Snipe (*Rostratula benghalensis*), Marsh Sandpiper (Little Greenshank) (*Tringa stagnatilis*), Terek Sandpiper (*Xenus cinereus*), Fork-tailed Swift, Little Tern (*Sterna albifrons*), Common Greenshank, Whimbrel, Great Egret (White Egret), Cattle Egret, Oriental Plover (Oriental Dotterel), Oriental Pratincole, Little Curlew (Little Whimbrel) (*Numenius minutus*), Southern Giant-Petrel and Fork-tailed Swift.
 - Mammals - Bryde's Whale, Dugong, Humpback Whale, Killer Whale (Orca), Indo-Pacific Humpback Dolphin and Spotted Bottlenose Dolphin (Arafura/Timor Sea populations).
 - Reptiles - Loggerhead Turtle, Green Turtle, Leathery Turtle (Leatherback Turtle), Hawksbill Turtle and Flatback Turtle.
 - Sharks - Whale Shark.
- ▶ No Critical Habitats, as defined in the EPBC protected matters search, were identified.
- ▶ A transition in the natural environment occurs over the region with the Green Sawfish (*Pristis zijsron*) having been identified at Cape Keraudron. The Green Sawfish is listed as Vulnerable under the EPBC Act.
- ▶ Maximum tides are 6 m.

Social Constraints and Issues

- ▶ Limited available information.
- ▶ No European Heritage sites identified.

- ▶ The town has better capacity than the other regions to manage influx of personnel due to the presence of a large community and more services infrastructure.
- ▶ Native title over whole area.
- ▶ Offshore islands have no registered sites under the *Aboriginal Heritage Act 1972* (WA); on the mainland, they range from 2 to 155 sites in the Department of Indigenous Affairs (DIA) database.

Technical Constraints

- ▶ All sites are in excess of 800km from the Browse Basin.
- ▶ Land areas suitable for a precinct are available around Port Hedland.
- ▶ A dredged channel exists to Port Hedland, however, it is unclear how much spare capacity exists.

Economic Viability

- ▶ Limited information available.
- ▶ Unlikely to be economically feasible for a stand alone green field LNG processing plant as it would be located at a considerable distance from existing industrial infrastructure.

3.6 East of Port Hedland

The previous section addresses the coastline to a distance of 110km East of Port Hedland at Cape Keraudron. Further to the East is Eighty Mile Beach, which is technically part of the Kimberley but often associated with the Pilbara. These areas are very remote and appear to be transitional in nature between the ecologies of the Pilbara and the Kimberley. The Australian Heritage Database notes the following;

“Eighty Mile Beach is of exceptional international and national significance as a feeding and resting site for transcontinental migratory birds. The area is listed under the Ramsar convention and of the 60 species of shorebirds which regularly visit the site, 40 species are listed on the Japan-Australia Migratory Bird Agreement (JAMBA) and China-Australia Migratory Bird Agreement (CAMBA) treaties. Eighty Mile Beach is a significant link in the migratory path between the Northern Hemisphere and Australia for a large number of wader and shorebirds. In terms of numbers of birds, Eighty Mile Beach is the most important site in Australia as a migratory shorebird non-breeding area. Over 465,000 individuals were recorded on the beach in one survey alone; a number not exceeded anywhere in Australia. Population numbers closer to 750,000 are suspected, making it one of the top five sites in the world in terms of total numbers.

The place is important for the maintenance of the Australian populations of many shorebirds. It supports at least 1% of the international flyway populations of 16 species and at least 1% of the national population of a further three species. The populations of 14 of these species are ranked either first or second in terms of the highest known Australian counts. The beach is the site of many records of rare or uncommon shore



and waterbirds in Australia. The place has the highest non-breeding population of Great Knots in the world with 160,000 birds counted in 1998.

The place has a high diversity of benthic invertebrates in the region with over 112 taxa found in the intertidal areas.

The beach is an important nesting site for the nationally vulnerable flatback turtle in Western Australia. The nationally vulnerable green turtle has also been observed nesting on the beach.

The beach and hinterland is of biogeographical interest as a major ecological barrier to some birds which separates the Pilbara and the South West of Western Australia from the Kimberley and the northern half of Australia.

The isolated pockets of mangroves on Eighty Mile Beach and Mandora Marsh are evidence of more extensive mangrove communities in north western Australia in the recent past and of past climate change.

Birds Australia and other international research bodies have extensively surveyed Eighty Mile Beach for shorebirds since 1981 mainly through an ongoing research program of shorebird banding expeditions. More than 35,000 shorebirds have been banded at the site with recoveries and sightings from all countries throughout the flyway including China, Russia, India and Japan. The research data gathered from the place is important in the study of the biology and behaviour of many wader species."

From a technical perspective, Eighty Mile Beach offers little in terms of a LNG Precinct;

- ▶ There is very little infrastructure or access to this location;
- ▶ There are no settlements;
- ▶ Water depth is shallow for a considerable distance offshore requiring a significant dredged channel to navigable waters;
- ▶ The hinterland includes wetlands areas that are also listed as Ramsar Sites (Eighty Mile Beach); and
- ▶ There is a potential conflict with the pearling industry.

In view of this it is understandable that this area has never been given detailed consideration as a potential LNG precinct.

4. Northern Territory Coast

4.1 Introduction

The Northern Territory comprises 20% of Australia's land mass and only 1% of Australia's population. The Northern Territory ranges from deserts in Central Australia to the tropics in the Top End. The major population centres for the Northern Territory include Darwin and Palmerston in the Top End, Katherine, Tennant Creek, Alice Springs and smaller communities such as Nhulunbuy, Timber Creek and Borroloola. Darwin has a multicultural population of approximately 117 400.

Three sites were identified as having potential for an alternative LNG Precinct along the Northern Territory coast, as shown in Figure 3. The three sites include:

- ▶ Middle Arm Locality which is located within the Darwin Harbour;
- ▶ Glyde Point Locality which is located on the Gunn Peninsula to the east of Darwin; and
- ▶ Bynoe Harbour Locality which is located on the Cox Peninsula to the west of Darwin.

Overall data availability for these three sites is good, and hence a more detailed discussion is provided.

4.1.1 Local Business

The Northern Territory Government have stated that the Territory Gross State Product (GSP) for 2007/08 was \$13.4 billion. The key activities in the Northern Territory include mining, defence, alumina production, liquefied natural gas production and government services. Darwin is the capital of the Northern Territory and it is ideally located at the gateway to Asia. Darwin is serviced by a domestic and international airport, a port and a railway.

The largest employer in the Northern Territory is the Northern Territory Government. Government administration and defence is the largest contributor to GSP in the Northern Territory.

4.1.2 Indigenous Economic Development

A report by the Northern Territory Government (2005) Northern Territory Indigenous Economic Development Strategy highlighted that approximately 54% of the Northern Territory is granted or subject to claims by Indigenous Territorians and approximately 84% of the Northern Territory coastline is owned by Indigenous Territorians. Indigenous Territorians make up approximately 30% of the population of the Northern Territory.

The Report also highlighted that the Northern Territory Indigenous population suffers the highest levels of disadvantage across all social and economic indicators when compared to other States and Territories. This level of disadvantage seems to limit the

capacity of individuals, families, clan groups and communities to successfully engage in social and economic development opportunities.

These economic disadvantages cannot be solved through direct employment within large companies as over 75% of Indigenous Territorians live outside major regional centres. The Strategy recommends identifying and developing economic opportunities through a range of sectors including aquaculture, arts, forestry, mining and tourism.

4.1.3 Aboriginal Heritage

The Northern Territory contains a rich and diverse range of Aboriginal cultural places, many of which are highly significant to the Northern Territory Aboriginal people. The *Heritage Conservation Act* was established to conserve and protect these places.

All sacred sites in the Northern Territory are protected by the *Northern Territory Aboriginal Sacred Sites Act* whether they are registered or not. Any proposals to carry out works in the Northern Territory require an application to the Aboriginal Areas Protection Authority for an Authority Certificate to cover proposed activities.

Any proposal for the development of an LNG Precinct in the Northern Territory would require investigation into potential Aboriginal sacred sites and heritage places.

4.1.4 Cost of Living

A 1995 Report of the Committee on cost of living in Darwin compared the cost of living of Darwin against Perth and Sydney. The Report concluded that the cost of living in Darwin was 5.5% higher than in Perth and 2.7% than Sydney with higher costs for food, hospitality, motor vehicles and lower costs for clothing and footwear (Northern Territory Government, 2008).

The NT Treasury has updated this report in December 2007. The update suggests that the gap between Darwin and Perth has narrowed to 0.5% and that Darwin's cost of living is around 1.5% lower than Sydney's. Prices growth in Sydney and Perth relative to Darwin is higher for all categories of the CPI except for housing, clothing, footwear, tobacco and alcohol.

4.2 Middle Arm Locality

The locality of Middle Arm, as referred in this document, is the section of land between East Arm and Middle Arm channels in the Darwin Harbour, it has undergone extensive investigation for current and proposed industrial use. Middle Arm is currently zoned Development, Future Development and Conservation under the Northern Territory Planning Scheme. Industrial uses already exist on Middle Arm including the ConocoPhillips LNG Precinct at Wickham Point and a Power Station on Channel Island. Middle Arm has existing services and infrastructure including all weather access, power, water and rail. Middle Arm is surrounded by deep water with only minor dredging required. There is some capacity for a local workforce to be sought from Darwin and Palmerston however it is likely that the majority of workers would come from interstate.

While Middle Arm has the potential to be developed as an alternative precinct, the available land zoned for development is limited in size. Providing an area large enough to accommodate an LNG precinct would require rezoning and an amendment to the Northern Territory Planning Scheme.

Blaydin Point is located on Middle Arm and is the proposed site for the Inpex Gas development. Inpex are proposing to pipe natural gas/condensate from the Ichthys Field off the Western Australian coast to an onshore facility at Blaydin Point in Darwin Harbour. The onshore footprint would cover an approximate area of 300 ha. The pipeline from the Ichthys Field to Blaydin Point will range from 850-935 km in length depending on the route taken. Blaydin Point is located approximately 9 km directly from Darwin and 4 km directly from Palmerston. Blaydin Point and Middle Arm were considered as one site for the purpose of this analysis.

The following issues, constraints and impacts in regard to the Middle Arm locality have been identified.

Environment and Heritage Constraints and Impacts

- ▶ Middle Arm contains monsoon vine thicket and mangrove communities zoned for conservation. To clear areas containing monsoon vine thicket requires an application for clearing of native vegetation under Clause 10.3 of the Northern Territory Planning Scheme.
- ▶ The EPBC listed endangered fauna, the Northern Quoll, has been recorded at Middle Arm.
- ▶ The Northern Territory Fauna Atlas identifies the occurrence of the following reptiles which are listed as vulnerable under the Territory Parks and Wildlife Conservation Act (TPWC Act) - Merten's Water Monitor (*Varanus mertensi*) and Floodplain Monitor (*Varanus panoptes*).
- ▶ EPBC endangered *Typhonium taylori* and TPWC threatened *Cycas armstrongii* were identified through database searches as occurring within this vicinity
- ▶ Vulnerable species identified from the EPBC protected matters search in the vicinity of the site included:
 - Mammal -Humpback Whale.
 - Reptiles - Green Turtle, Leatherback Turtle, Hawksbill Turtle and Flatback Turtle.
 - Sharks - Whale Shark (not known to visit Darwin Harbour), Freshwater sawfish (*Pristis microdon*), Green sawfish.
- ▶ Migratory species identified from the EPBC protected matters search in the vicinity included:
 - Birds - Melville Cicadabird (*Coracina tenuirostris melvillensis*), White-bellied Sea Eagle, Little Tern, Ruff, Eastern Curlew, Rainbow Bee Eater, Common Sandpiper (*Actitis hypoleucos*) Ruddy Turnstone, Sanderling, Greater Sand Plover, Lesser Sand Plover, Bar-tailed Godwit, Black-tailed Godwit (*Limosa limosa*), Whimbrel, Grey Plover.

- Mammals – Dugong, Humpback Whale, Spotted Bottlenose Dolphin.
- Reptiles - Green Turtle, Hawksbill Turtle and Flatback Turtle, Saltwater Crocodile (*Crocodylus porosus*).
- ▶ The Humpback Whale was identified through the EPBC protected matters search as potentially occurring in the area. This species has only ever been recorded at the entrance to Darwin Harbour and not within the Harbour itself. Further investigation would be required to determine potential impacts on the Humpback Whale.
- ▶ The saltwater crocodile may be impacted through potential loss of habitat and disturbance.
- ▶ There is the potential for acid sulfate soils to occur.
- ▶ Northern Territory waters are regarded as being marginal for large bodied whales and they therefore qualify as data deficient under the TPWC Act (Northern Territory Government, 2007a).
- ▶ There are a number of archaeological sites located across Middle Arm. These include shell middens and historic sites from WWII and the remains from a leprosarium. Further investigation of potential archaeological sites would be required before any development could be permitted.

Social Constraints and Issues

- ▶ Middle Arm is located 25 km by road from Palmerston and approximately 45 km by road from Darwin.
- ▶ Both Darwin and Palmerston have some capacity to provide local labour and services.
- ▶ Infrastructure exists on Middle Arm including all weather access, power and rail.
- ▶ Areas on Middle Arm are zoned for Development however these sites are limited in size. Rezoning of land to accommodate the size of an LNG precinct would be required.
- ▶ In 1999 an agreement was reached with the various Native Title parties and the Northern Land Council to resolve Native Title and aboriginal land rights claims previously lodged for the Middle Arm area.

Technical Constraints

- ▶ Industrial uses already occur on Middle Arm including the ConocoPhillips LNG Precinct and Channel Island Power Station.
- ▶ The Middle Arm site would require the construction of a pipeline ranging in length from 850 – 930 km from the source.

Economic Viability

Whilst the distances are long for a sub sea pipeline the presence of existing infrastructure allows for some synergies in development that could make this site

economically viable. It is likely that the development of an LNG Precinct on Middle Arm would require a major upgrading of the existing infrastructure.

4.3 Glyde Point

Glyde Point is located on the Gunn Peninsula approximately 90 km by road from Darwin. In 2002 Glyde Point was zoned for development and was identified by the Northern Territory Government as the location for a major gas-related industrial estate. In 2007 the then Chief Minister, Claire Martin, rezoned Glyde Point to Public Open Space for the purpose of conservation and recreation, prohibiting industrial development. Current Northern Territory Government Policy precludes the development of Glyde Point as a future gas industry development.

The original proposed industrial estate was to cover an area of 4,212 ha of which approximately 1,572 ha would be reclaimed land. The industrial estate would include a port consisting of a 4.9 km long, 17 m deep access channel, a 875 m by 500 m, 17 m turning basin and a composite wharf.

To service and support this industrial estate it was also proposed to develop a residential estate and district centre at Murrumujuk which would house a population of approximately 16,000 people. At the present time it would be more feasible to develop a workers camp to support an LNG precinct.

The analysis identifies the following issues, constraints and impacts in regard to Glyde Point.

Environment and Heritage Constraints and Issues

- ▶ In the north western corner of Glyde Point is an environmentally sensitive area containing *Eucalyptus* and *Corymbia* woodlands, *Melaleuca* communities, hypersaline flats, mangrove communities and rainforest/monsoon vine thickets. The monsoon vine thicket contains *Freycinetia excelsa* which is listed as vulnerable under the TPWC Act. It would require a buffer and exclusion from development to minimize the effects of fragmentation and preserve the *Freycinetia excelsa*.
- ▶ EPBC and TPWC listed endangered flora includes *Ptychosperma bleeseri*.
- ▶ Flora species listed as vulnerable under the TPWC Act known to occur in the area includes *Cycas armstrongii*, *Utricularia dunstaniae*, *Malaxis marsupichila*.
- ▶ Flora listed as near threatened under the TPWC Act known to occur in the area include *Operculina turpethum*, *Pittosporum moluccanum* and *Utricularia hamiltonii*. The following flora which is listed as near threatened under the TPWC Act were identified through a database search as possibly occurring in the vicinity: *Acacia oligoneura*, *Chiloschista phyllorhiza*, *holtezi* and *triflora*, *Nymphoides subacuta*, *Citrus gracilis*.
- ▶ Fauna listed as endangered under EPBC and TPWC which were identified through database searches includes the Northern Quoll.
- ▶ Vulnerable fauna identified through database searches as possibly occurring in the vicinity includes:

- Mammals - Water Mouse (*Xeromys myoides*) (EPBC).
- Birds - Red Goshawk (*Erythrotriorchis radiatus*) (EPBC/ TPWC), Partridge Pigeon (*Geophaps smithii*) (EPBC).
- Amphibians - Howard Springs Toadlet (*Uperoleia daviesae*) (TPWC).
- ▶ Migratory species identified from the EPBC protected matters search in the vicinity included:
 - Sharks - Northern River Shark (*Glyphis* sp. C.), and Freshwater Sawfish.
 - Mammals - Humpback Whale.
 - Reptiles - Green Turtle, Hawksbill Turtle and Flatback Turtle, Saltwater Crocodile.
 - Birds- White-bellied Sea-Eagle, Rainbow Bee-eater, Common Sandpiper, Ruddy Turnstone, Sanderling, Great Knot, Greater Sand Plover, Lesser Sand Plover, Oriental Sand Plover, Oriental Pranticole, Bar-tailed Godwit, Little Curlew, Grey Plover, White-browed Robin (*Poecilodryas superciliosa cerviniventris*).
 - Mammals - Irrawaddy Dolphin (*Orcaella brevirostris*), Indo-Pacific Humpback Dolphin, Spotted Bottlenose Dolphin, Dugong.
- ▶ Arafura Fantail (*Rhipadura dryas*) is listed as a migratory species under the TPWC Act and has been recorded in the Glyde Point area.
- ▶ Northern Territory waters are regarded as being marginal for large bodied whales and they therefore qualify as data deficient under the TPWC Act (Northern Territory Government, 2007a).
- ▶ The Howard Springs Toadlet was recorded in the sand plains to the south of Glyde Point and within the proposed infrastructure corridor. The toadlet is listed as vulnerable under the TPWC Act.
- ▶ The sand plains area would require appropriate water management in order to protect the Howard Springs Toadlet.
- ▶ The saltwater crocodile may be impacted through potential loss of habitat.
- ▶ Based on available information, the Glyde Point area doesn't appear to be of major regional significance to whales or dolphins and minimal direct impacts are anticipated.
- ▶ There is the potential for acid sulfate soils to occur.
- ▶ The Northern Territory Government has proposed the creation of the Beagle Gulf Marine Park.
- ▶ Glyde Point includes a site known as Ginger Palmer's Camp which is registered on the NT Heritage Register.
- ▶ Native Title has not yet been resolved for Glyde Point. There are a number of native title claims and schedules currently before the Federal Court.
- ▶ 18 registered indigenous sacred sites and 9 recorded sites under the *Northern Territory Aboriginal Sacred Sites Act* occur in the Glyde Point area. The area would



require further investigation for Aboriginal sites of significance before any development could occur.

Social Constraints and Issues

- ▶ Glyde Point is located approximately 90km from Palmerston and the nearest community or services.
- ▶ Glyde Point is zoned Public Open Space and would require rezoning under the NT Planning Scheme.
- ▶ There is the possibility that WWII unexploded ordinances may occur at Glyde Point.

Technical Constraints

- ▶ There is no existing infrastructure or services at Glyde Point.
- ▶ There is deep water off Glyde Point however dredging would be required.
- ▶ The Glyde Point site would require the construction of a pipeline of over 900 km in length from the source.

Economic Viability

- ▶ Limited information available.
- ▶ Unlikely to be economically feasible for a stand alone green field LNG processing plant as it would be located at a considerable distance from existing industrial infrastructure.

4.4 Bynoe Harbour

Bynoe Harbour is located on the Cox Peninsula. The Northern Territory Government identified Bynoe Harbour in the Darwin Regional Land Use Structure Plan as a potential site for a port in 1990. There have been no intensive environmental surveys undertaken of Bynoe Harbour to investigate the suitability and feasibility of this location as either a port or alternative LNG precinct.

Bynoe Harbour is relatively remote from any major centre and has no existing services or infrastructure. The waters of Bynoe Harbour contain subtidal reefs and the only known large seagrass bed west of Darwin. These seagrass beds may be important to the Dugong which is listed as migratory and marine under the *EPBC Act*. The Bynoe Harbour area has been proposed as a Marine Park by the Northern Territory Government.

The following key points in regard to Bynoe Harbour were identified.

Environment and Heritage Constraints and Impacts

- ▶ Bynoe Harbour contains subtidal reefs and the largest known seagrass bed west of Darwin.

- ▶ Intensive surveying would be required to determine the environmental significance of the area.
- ▶ The NT Government has recommended the creation of a marine park in the Bynoe Harbour area.
- ▶ The only endangered mammal species listed under EPBC and TPWC identified within the vicinity includes the Northern Quoll.
- ▶ Vulnerable species identified from the EPBC protected matters search in the vicinity included:
 - Birds - Red Goshawk, Partridge Pigeon (eastern).
 - Mammals - Water Mouse.
- ▶ Vulnerable species identified from the EPBC protected matters search included:
 - Mammals - Humpback Whales.
 - Reptiles - Green Turtle, Hawksbill Turtle, Olive ridley (*Lepidochelys olivacea*) and Flatback Turtle.
 - Sharks - Freshwater Sawfish.
- ▶ Migratory species identified from the EPBC protected matters search included:
 - Birds -White-bellied Sea-Eagle, Rainbow Bee-eater, Common Sandpiper, Ruddy Turnstone, Sanderling, Great Knot, Great Sand Plover, Lesser Sand Plover, Oriental Sand Plover, Oriental Pranticole, Bar-tailed Godwit, Little Curlew, Grey Plover, Whimbrel, Derby White-browed Robin (*Poecilodryas superciliosa cerviniventris*).
 - Mammals - Irrawaddy Dolphin, Indo-Pacific Humpback Dolphin, Spotted Bottlenose Dolphin, Dugong, Indian Ocean Bottlenose Dolphin.
 - Reptiles - Saltwater Crocodile.
- ▶ Northern Territory waters are regarded as being marginal for large bodied whales and they therefore qualify as data deficient under the TPWC Act (Northern Territory Government, 2007a).
- ▶ Bynoe Harbour is located beside the Cox Peninsula which is under the Kenbi Land Claim.
- ▶ No registered indigenous sites under the *Northern Territory Aboriginal Sacred Sites Act* could be identified from database searches, however it appears likely that sites exist in this locality. The area would require investigation for Aboriginal sites of significance before any development could occur

Social Constraints and Issues

- ▶ There are no nearby communities to provide local labour or services.
- ▶ The Cox Peninsula is zoned Rural and would require rezoning under the NT Planning Scheme.

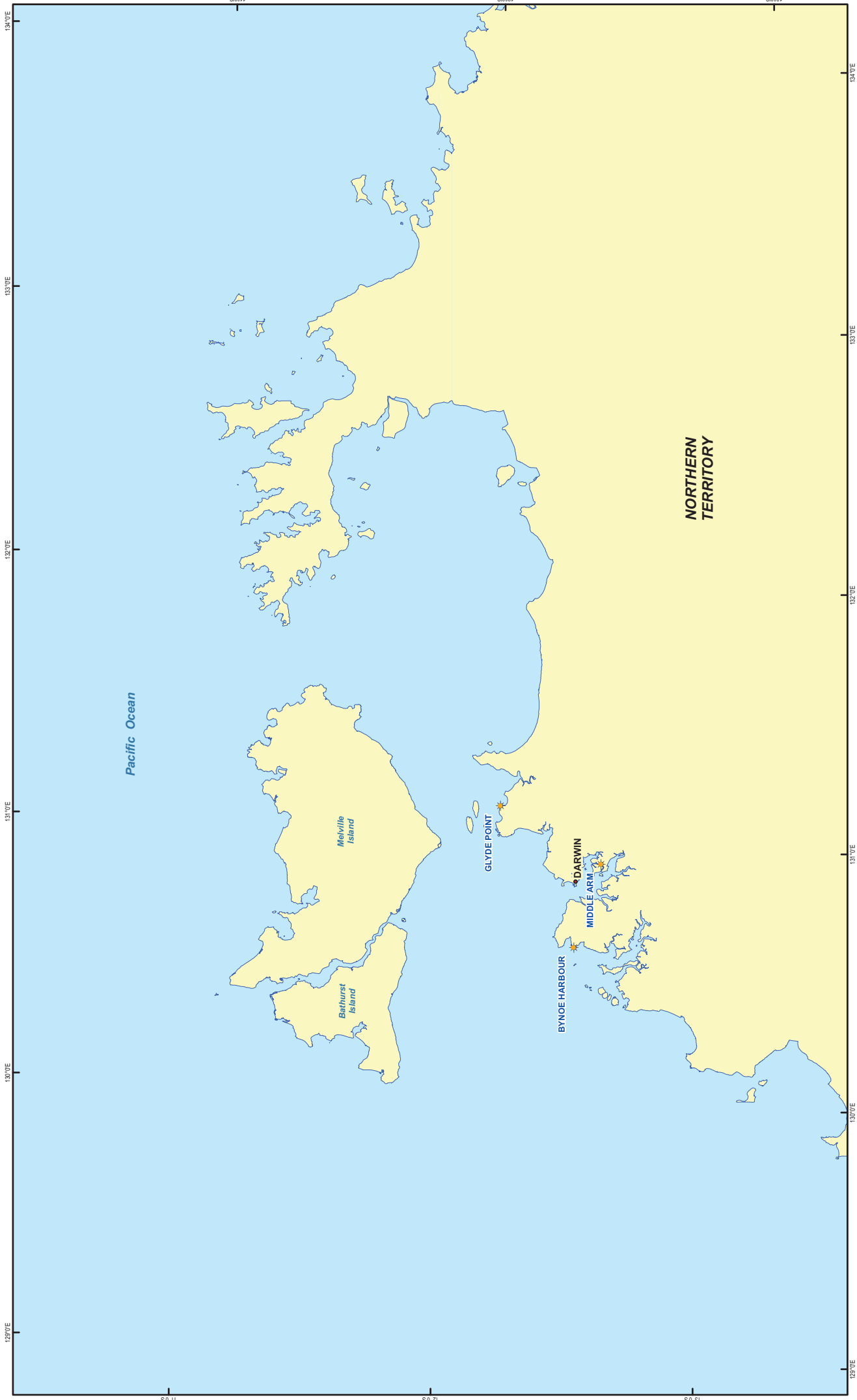


Technical Constraints

- ▶ There is the potential for a conflict of industries as a pearling farm already operates within Bynoe Harbour.
- ▶ There is no existing infrastructure or services.
- ▶ The Bynoe Harbour site would require construction of a pipeline over 800 km in length.
- ▶ There is a considerable dredge length to navigable waters.

Economic Viability

- ▶ Limited information available.
- ▶ Unlikely to be economically feasible for a stand alone green field LNG processing plant as it would be located at a considerable distance from existing industrial infrastructure.



1:1,500,000 (at A3)

0 10 20 40 60 80

Kilometres

Map Projection: Transverse Mercator
Horizontal datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 50

LEGEND

- Townsite - GA - 20080422
- Proposed Hub Locations - GHD - 20081204
- Island and Mainlands - GA - 20081015

GHD

CLIENTS | PEOPLE | PERFORMANCE

Department of Environment, Water, Heritage and the Arts

Alternative Locations for LNG Hub

Job Number
61-23286

Revision
1

Date
12 JAN 2009

Location Map of Northern Territory

G:\6123286\GIS\mxd\6123286_G005_Rev01.mxd
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Data set names include published data where available. Created by: S Irmali, KDIRALI, sheet2

5. Northern Australia Offshore Locations

5.1 Technological Development

Floating LNG (FLNG) concepts focus on offshore stranded gas reserves, representing a fast track option to capitalise on these reserves. These stranded reserves are held in more than 2,500 gas fields containing 0.1 to 5 tcf of natural gas. For this reason the FLNG capacity is smaller (1.0-5.0 mmtpa) in comparison to onshore plants (8.0 mmtpa).

In Western Australia, this option is considered to reduce cost, since a large quantity of the natural gas fields are located more than 300 km off the coast requiring very expensive large diameter pipelines to transport the gas to shore.

FLNG studies are more than 20 years old, with the most significant study performed by Mobil technology in 1997. This study focused on a world-scale FLNG facility designed for offshore North West Australia-type environments and 200 m water depths.

Floating offshore LNG production avoids the flaring or re-injection associated with crude production. Shell has developed the concepts such as FLNG and floating oil and natural gas (FONG) for processing natural gas and associated gas respectively, as illustrated in Figure 4.

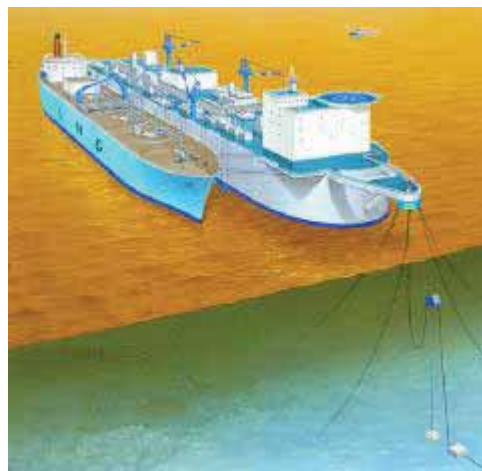


Figure 4. Shell's offshore FLNG concept

In recent media releases Shell indicated that they are evaluating FLNG for the Prelude Gas Field in Western Australia, located in 112 m of water (Searancke, 2008).

Statoil pursued possible designs for offshore LNG in Nigeria. The Statoil Snøhvit project involved the construction of an offshore subsea development combined with an onshore gas reception terminal and LNG plant. To date this is the only floating LNG facility that was partially operated (Bradbury, 2002).

There are three basic configurations of FLNG terminals:

- Gravity Based Structure (GBS) supported firmly on the sea bottom;

- ▶ Permanently moored floating facility; and
- ▶ Conventional fixed platform based facility, supported firmly on a jacket from the sea bottom (Denney, 2006).

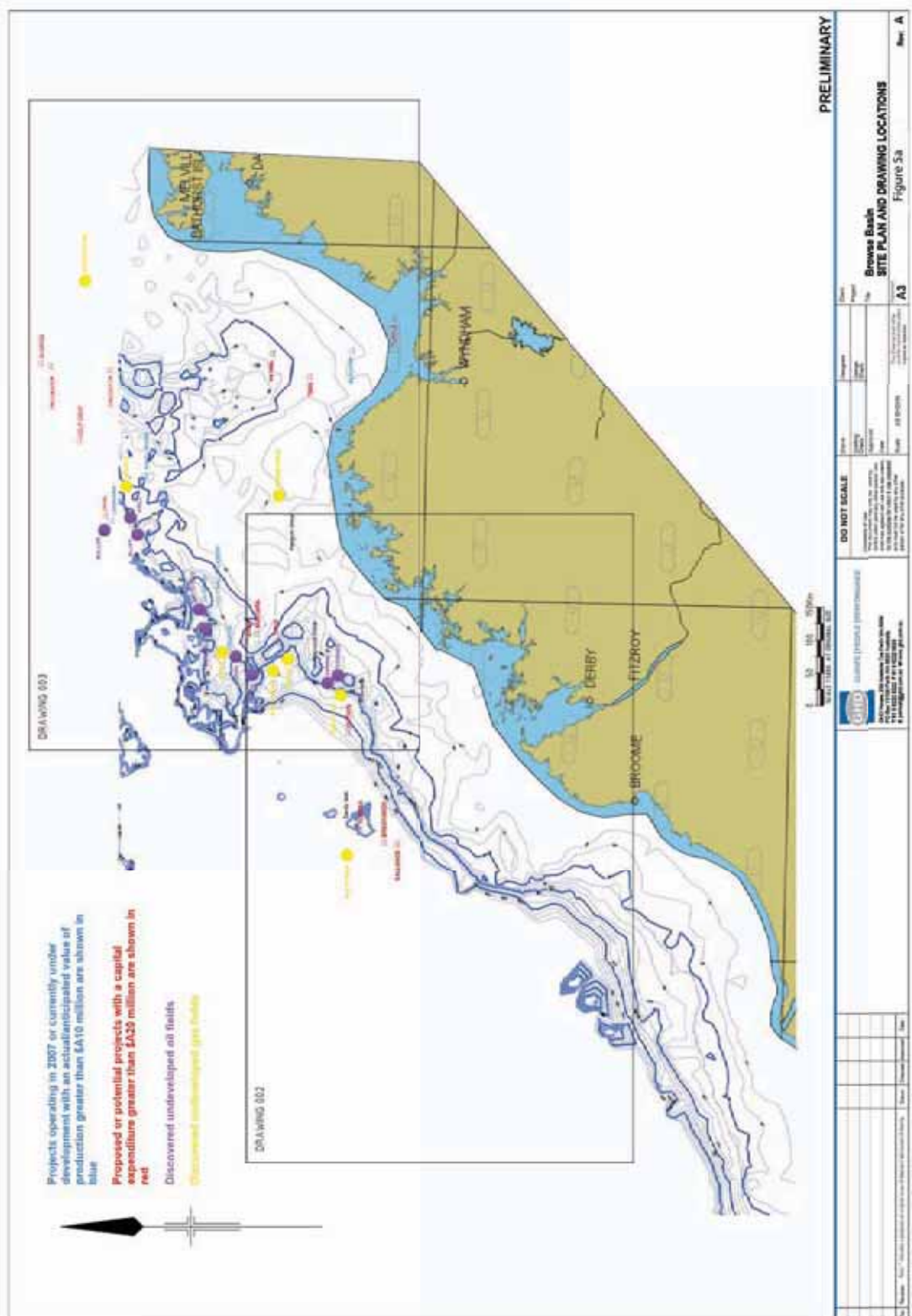
The ideal water depth for FLNG terminals are 45 – 100 m, providing reasonable flexibility (more than 45 m) for risers while using internal or external turret designs. There is no real limit as to how deep the water can be for a FLNG, except that deeper water depths requires additional cost and economic considerations for risers and mooring (Pepper *et al.* 2004).

The general limit for the design of fixed structure platforms can be as great as 300 m, but the suggested practical water depth limit is 20 – 100 m. The 20 m limit utilizes deepwater port advantages, while the 100 m limitation is based on cost of supporting the LNG storage.

5.2 Northern Australian Offshore Resources

Current and future offshore resources were reviewed to capture the water depth, as outlined in the Joint Petroleum Development Area (Figure 5 a-c). The site considerations were restricted to water depths of 20 - 100 m based on the FLNG and GBS water depth recommendations.

Ideally a FLNG facility would be located as close as possible to the well. The first consideration focussed on FLNG facilities located between the Bayu-Undan gas and Challis oil field in 40 – 70 m of water, more than 200 km from the Northern Australian coastline, close to identified resources to limit the subsea pipeline costs for future projects. The second and third site considerations focus on GBS structures located in 20 – 50 m of water located at the South of the Calliance or North of the Prometheus wells, respectively.



5.3 Floating LNG Facilities

There are numerous potential issues, constraints and benefits that are common for the different types of FLNG facilities. In particular, the social implications of a Fly In/Fly Out (FIFO) workforce can have both positive and negative impacts on local communities. The threat of these offshore facilities becoming desirable terrorist targets is also a possibility.

Offshore facilities have an increased operational cost (\$600-\$1500 per ton of annual LNG capacity). Offshore LNG production reliability is more affected by weather and environmental conditions than a land based LNG facility.

No commercially operated facility is currently in use, the first offshore LNG regasification facility is anticipated to open in 2009.

Environmental and Heritage Constraints and Impacts

- ▶ The specific environmental impacts of FLNG relate to moorings and subsea pipelines, although any listed marine species could potentially be impacted by these facilities.
- ▶ One endangered marine species was identified from the EPBC protected matters search in the vicinity, the Blue Whale (*Balaenoptera musculus*).
- ▶ Vulnerable marine species identified from the EPBC protected matters search included;
 - Mammals - Sei Whale (*Balaenoptera borealis*) Humpback Whale.
 - Reptiles - Green Turtle, Leathery Turtle (Leatherback Turtle), Flatback Turtle .
 - Sharks - Whale Shark.
- ▶ Migratory species identified from the EPBC protected matters search included;
 - Birds - Streaked Shearwater (*Calonectris leucomelas*), Streaked Shearwater (*Puffinus leucomelas*).
 - Mammals - Antarctic Minke Whale Dark-shoulder Minke, (*Balaenoptera bonaerensis*) Sei Whale, Bryde's Whale, Blue Whale, Humpback Whale, Killer Whale, Orca, Sperm Whale (*Physeter macrocephalus*).
 - Reptiles - Green Turtle, Leathery Turtle (Leatherback Turtle), Flatback Turtle.
 - Sharks - Whale Shark.
- ▶ The FLNG system could be located in the Joint Petroleum Development Area avoiding conservation areas completely.
- ▶ Sedimentation impact during construction phase activities on benthic reef habitats is anticipated to be short-term and recolonisation of impacted areas is most likely to occur upon completion of construction.
- ▶ The impact of fire is limited to the facility and is likely to have minimal impact on the marine ecology.

- ▶ A high equipment density approach to optimise deck space would limit the CO₂ capture potential.
- ▶ Stormwater management is limited.
- ▶ Loss of containment and resulting contamination of surrounding waters is a concern as pelagic organisms would encounter acute exposure to contaminants. This may impact on survival rates of organisms and trophic transfer of contaminants.

Social Constraints and Issues

- ▶ The influx of people constraining urban and medical services is mitigated through a Fly In/Fly Out (FIFO) operation providing that medical staff can also be flown in as part of the operation.
- ▶ Isolated FLNG could limit the impact of terrorist attacks by distributing assets.
- ▶ An upgrade of the marine and airport facilities in nearby towns may be required to support the FLNG from a central supply base as part of the FIFO operation
- ▶ The FLNG asset is more exposed to environmental conditions, such as cyclonic activity.
- ▶ Limited evacuation potential due to remote location. There is the potential for total facility loss in an explosion from gas leak or vessel collision. In addition, there are large volumes of refrigerants on board increasing the operational risk and there is no operational unit to give an indication of cyclone sensitivity.

Technical Constraints

- ▶ LNG storage quantities would be greatly reduced in FLNG concepts reducing the overall fire risk to the facility.
- ▶ Loss of containment, as significant damage to the storage tanks could result in a cryogenic liquid spill into the sea resulting in a rapid phase transition causing serious structural damage to the facility. The risk is greater since the revised partial filled tank designs are not yet commercially proven.
- ▶ Unproven technology. FLNG is a new developing technology, holding much potential, but at this stage not suitable for large gas resources such as the Browse Basin gas fields.
- ▶ Existing infrastructure utilised by a FLNG is limited to FIFO operation with no precinct requirement, and may require marine and airport upgrades in nearby towns.
- ▶ FLNG operation and mooring for offloading is affected by wind, waves and currents.
- ▶ The LNG capacity of a FLNG is about 50% smaller than land based units i.e. 3.5 mmtpa LNG versus 8.0 mmtpa LNG
- ▶ FLNG is constructed in shipyards reducing schedule and construction risks.

Economic Viability

- ▶ FLNG is located directly above the gas field reducing subsea pipelines costs and increasing gas use efficiency.
- ▶ The cryogenic pipe distance from the LNG facility to loading facility is reduced by using 'first of a kind' technology principles.
- ▶ Remote location could minimise the impact on other land and marine businesses already in operation.
- ▶ Offshore facilities have an increased operational cost (\$600 - \$1500 per ton of annual LNG capacity).
- ▶ Each company would be required to make individual investment with very little opportunity for synergy.

5.4 GBS-Prometheus and Calliance Site Facilities

A GBS facility could be located close to, but still outside of the Joint Petroleum Development Area due to the water depth recommendation, approximately 50 km offshore.

Constraints, benefits and potential issues of a GBS facility are illustrated using the Prometheus and Calliance offshore locations. A GBS LNG approach more resembles land based operation, yet the issues are similar to FLNG facilities.

Environmental and Heritage Constraints and Impacts

- ▶ One endangered marine species was identified from the EPBC protected matters search in the vicinity, the Blue Whale.
- ▶ Vulnerable marine species identified from the EPBC protected matters search included;
 - Mammals - Sei Whale, Humpback Whale.
 - Reptiles - Green Turtle, Leathery Turtle (Leatherback Turtle), Flatback Turtle.
 - Sharks - Whale Shark.
- ▶ Migratory species identified from the EPBC protected matters search in the vicinity included;
 - Birds - Streaked Shearwater (*Calonectris leucomelas*), Streaked Shearwater (*Puffinus leucomelas*).
 - Mammals - Antarctic Minke Whale Dark-shoulder Minke, Sei Whale, Bryde's Whale, Blue Whale, Humpback Whale, Killer Whale, Orca, Sperm Whale.
 - Reptiles - Green Turtle, Leathery Turtle (Leatherback Turtle), Flatback Turtle.
 - Sharks - Whale Shark.
- ▶ The environmental impact of a GBS is more severe than FLNG requiring an offshore marine plot space (1 km x 1 km) and subsea pipelines (Raine *et al.*, 2002).

- ▶ LNG tanks captured within the GBS adds additional protection to vessel coalitions and would limit vessel motion thereby reducing the sloshing in partially filled tanks, potentially one of the reasons it was considered by BHP Billiton at Bayu-Undan. This reduced vessel motion should reduce the loss of containment risk.
- ▶ The LNG facility is spread out over the GBS, making it possible to incorporate CO₂ capture with sequestration (depending on nearby oil/gas well geology).
- ▶ Sedimentation impact during construction phase activities on benthic reef habitats is anticipated to be short-term and recolonisation of impacted areas is likely to occur upon completion of construction phase.
- ▶ Smothering of the benthos may occur during construction and day-to-day operations. Degree of impact of day-to-day operations may be influenced by prevailing tidal movements. Colonisation of disturbed areas will occur if impacts are managed and mitigated.
- ▶ The impact of fire is limited to the facility and is likely to have minimal impact on the marine ecology.
- ▶ The shallower positioning of the structure may increase the occurrence of wave action but this is anticipated to be minimal.

Social Constraints and Issues

- ▶ Remote location would minimize the impact on other land and marine businesses already in operation within 50 km offshore.
- ▶ Constructing a graving dock in Australia, similar to the Wandoo project in 1996 would utilise local resources.

Technical Constraints

- ▶ Still impacted by cyclonic activity, but to a lesser extent than FLNG.
- ▶ The connection of a subsea pipeline is more reliable when coupled to a GBS or other fixed structure due to the rigid connection at the sea floor.
- ▶ GBS LNG technically resembles more aspects of commercialised land based technology.
- ▶ The cryogenic pipe distance from the LNG facility to the loading facility is reduced.
- ▶ GBS LNG can be constructed in graving docks reducing schedule and construction risks.
- ▶ The GBS provides a breakwater structure making the marine offloading operation more reliable.
- ▶ More than one LNG facility could be located on a GBS, making shared maintenance and utility services possible.
- ▶ Limited evacuation potential due to remote location.



Economic Viability

- ▶ GBS LNG is located offshore in less than 50m of water, increasing the subsea pipelines costs.
- ▶ A larger capital cost is expected for a GBS LNG facility compared to an FLNG, since the subsea pipeline benefit is reduced and large scale graving docks are limited (Alan, 2001).
- ▶ No commercially operated facility currently in use, the first offshore LNG regasification facility (less complicated facility) should come on-line in 2009.
- ▶ Each company would be required to make individual investment with very little opportunity for synergy.

6. Impacts

The following sections describe potential impacts associated with the construction and operation of an LNG precinct. With respect to impacts on fauna, the specific impact will relate to the specific habitat and biological cycle of the species. Examples of specific impacts are discussed in this section in order that the range of impacts can be considered, however, a full Environmental Impact Assessment would be required in order to address all of the possible impacts at each site.

6.1 Airshed Issues

Emissions from an LNG precinct will depend upon the number of industries proposed for the precinct location.

The most significant precinct in Western Australia at this time is the Burrup Peninsula, which was modeled prior to assessment of the Woodside Pluto Project by Sinclair Knight Mertz (SKM). This cumulative impact modelling included the Karratha Gas Plant, Dampier Power Station, Burrup Fertiliser Plant, proposed Pluto Plant, shipping, other area sources and biogenic sources. The modelling domain covered an area of 25 km x 25 km and revealed elevated levels of pollution (nitrogen dioxide and ozone) across this domain under normal operation, but no exceedance of concentrations established as per the standards set by the National Environmental Protection Measures (NEPM).

The modelling identified that under upset conditions there could be short term exceedance of these standards, but the location and duration of these were not considered important. Particulate Matter (PM10) was also considered and it was noted that levels might well exceed the NEPM standards, but the cause of this was not from the gas plants, but the iron ore processing that occurs in this area.

Consideration of these results suggests that at some point further significant emission sources might lead to levels in excess of the NEPM standards within this modelling domain under worst case scenario within normal operation. Therefore, if the proposed precinct were expected to contain significantly more emission sources than those found at Dampier it might be prudent to provide a reasonable 15-20 km separation from any significant community. It should also be recognised that ozone and nitrogen dioxide are oxidising substances that can have impacts upon the natural as well as human environment and a more thorough consideration of these pollutants using a detailed photochemical model may also be required if the surrounding environment is considered to be sensitive.

Middle Arm, located in the Darwin Harbour, has also been considered as a location for an LNG precinct. Air dispersion modelling conducted prior to the development of the ConocoPhillips Darwin LNG facility predicted ground level concentrations of nitrogen dioxide below NEPM standards. This modelling incorporated cumulative impacts by considering emissions from the Channel Island power station.



An air quality assessment will be conducted as part of preparation of an Environmental Impact Statement (EIS) for the Inpex gas development, including air dispersion modelling considering cumulative impacts from existing facilities (ConocoPhillips Darwin LNG and Channel Island power station).

In addition, terms of reference have been released for an environmental assessment for Middle Arm Development - Gas Based Industry by the NT Department of Planning and Infrastructure (DPI). These terms of reference include an air quality assessment to ensure future development does not adversely effect environmental values or health, welfare and amenity of people and land uses.

Existing air quality assessments indicate industries operating in the Middle Arm precinct are not leading to exceedances of the NEPM standards. Future development in the area will be informed by completion of air quality assessment for the Inpex gas development and as part of the environmental assessment for Middle Arm Development - Gas Based Industry by DPI.

6.1.1 Potential Impacts

Emissions that lead to the formation of excess levels of nitrogen dioxide and ozone can lead to significant impacts on human health and the natural environment. Acid deposition from nitrogen based chemistry is proportional to nitrogen dioxide concentrations.

6.2 Cetaceans

A number of whale species can be found in the waters of Western Australia's north-west. Section 3 to 5 give the results of protected matters searches for the areas under consideration.

The Humpback Whale is known for its regular migration from Antarctic feeding grounds to calving areas around Camden Sound (Appendix D). Construction and operational activities of any proposed LNG facility have the potential to disrupt communication between whales, however no specific occurrences have been recorded. General management activities include attempting to undertake construction activities outside of the known migration times and it can be expected that the mother and calf migration time would be the more sensitive of the two migration periods. In addition, support vessels are instructed not to approach within 300 m of any whales that are seen. It is understood that a number of oil companies are funding research by the Centre for Whale Research in an effort to improve the understanding of the whale migration and management protocols that can protect these species.

Other whale species are seen across the North of Australia, but little is really known about their migration pathways or if they actually migrate in the same manner as Humpback and Southern Right Whales. Some, such as the Orca and Pygmy Blue Whale are known to congregate when specific food sources are present, but little is known from their sporadic sightings in the waters of Northern Australia.



Dolphins and porpoises are generally considered to be more territorial and to have a much smaller range than the larger cetaceans.

6.2.1 Potential Impacts

None of the possible precincts are located within the calving area for humpback Whales around Camden Sound.

Impacts to large whales include;

- 1) Impacts of noise
- 2) Boat strikes
- 3) Increased Turbidity

Impacts to dolphins and porpoises could include;

- 1) Direct loss or changes to localized habitat;
- 2) Boat Strikes
- 3) Increased Turbidity
- 4) Potential for unacceptable increases in human interaction
- 5) Noise

6.3 Turtles

Turtles are most vulnerable during egg laying and hatching periods, and any sandy beach along the North-West coast could be a potentially suitable laying beach.

Construction activities have the potential to disrupt the laying-hatching cycle and should be restricted where possible to non-peak laying or hatching periods.

Operational activities can also have significant impacts such as from lighting, which has the potential to disorientate the turtles making it difficult for them to find suitable locations for laying.

6.3.1 Potential Impacts

Impacts to turtle species could include;

- 1) Direct Loss of Marine habitat
- 2) Direct Loss of Hatcheries
- 3) Boat Strike
- 4) Impacts of Light Spill on Hatcheries
- 5) Increased levels of disturbance both during construction and operation
- 6) Increased turbidity
- 7) Impacts due to pollution from floating plastic and other debris.

6.4 Dugongs

Dugongs are considered to be a transient species presumably moving from one area of seagrass to another for feeding purposes. Most of their life is spent in relatively shallow protected waters. Dugongs are relatively slow moving compared with other marine mammals.

6.4.1 Potential Impacts

Impacts to Dugongs could include;

- 1) Direct Loss of Marine habitat – especially seagrass meadows
- 2) Boat Strike – dugongs can be surprised by fast moving boats and the Western Australian Department of Environment and Conservation (DEC) requests that boats reduce speed to 8 knots when traveling over seagrass meadows around Shark Bay.
- 3) Increased levels of disturbance both during construction and operation
- 4) Increased turbidity

6.5 Other Marine Species

Other marine species include a range of sawfish, pipefish, sea snakes and the Saltwater Crocodile as well as the Whale Shark. The latter appears to be an occasional visitor to the area in much the same way as many of the larger cetaceans and impacts could be expected to be similar.

Sawfish appear to spend the majority of their time in relatively shallow water around mangroves and estuaries. They would be particularly susceptible to dredging and use of these area. In addition they are very vulnerable to fishing activities using nets. Development in a pristine area including the construction of roads has the potential to open the area up to fishermen.

The saltwater crocodile may be impacted through potential loss of habitat.

Pipefish inhabit shallow sheltered lagoons, coral reefs and seagrass beds and are therefore susceptible to localized direct impacts on shallow habitat areas.

Very little is known about the status of populations of sea snakes in Australian waters, or about the basic ecology, movement patterns, life history strategies, reproductive biology and population genetics of most species of sea snakes.

6.6 Terrestrial Species

Each of the terrestrial species listed in the protected matters search has a particular habitat preference. Activities conducted in or near these specific habitats has the potential to impact upon these species. Some examples are as follows;

Pilbara Leaf-nosed Bat – Loss of caves or mines where colonies might be established (highly unlikely).



Northern Quoll – Loss of Savannah or Eucalypt Forest areas due to terrestrial development.

Mulgara – Impacts on areas where the desert fringes the ocean.

Olive Python – Loss of Rocky areas where freshwater can be found.

6.7 Migratory Birds

A considerable number of the migratory bird species are wading birds that feed along the shorelines of Western Australia. Impacts on these species will be caused through direct development of the shoreline and possibly alteration of the local hydrographic regime. Many of these bird species are relatively shy and subject to impacts from regular disturbance. Pollution of the shoreline may cause a loss of food.



7. Economic Viability of LNG Facilities

It is important to consider that there are significant costs associated with the development of gas fields that affect the viability of development and limit the distance that key infrastructure can reach. These components include subsea gas pipelines, dredge channels and cryogenic export pipelines.

Subsea Pipelines

It is generally understood that a distance of approximately 500 km is the reasonable limit for subsea or gas pipelines without further boosting stations. The Bayu-Undan high pressure pipeline that leads to Darwin is approximately 500 km long. Woodside's second trunk pipeline at the Burrup is approximately 135 km long, 42 inches in diameter and is estimated to have an approx cost of \$US800 million. Much of the economics of the oilfield costs are very specific to the application and location. Factors to consider include the actual diameter and thickness of the pipeline, anchoring, sea depths and so on. Therefore, it is difficult to provide a simple answer to the cost of a subsea pipeline cost per kilometre.

In terms of green field developments, the costs of dredging and cryogenic export pipelines become increasingly important.

An internet literature search has not provided any parametrics with regard to evaluating the economic length of LNG pipelines. However, two recent instances have been found from which the cost of an LNG pipeline can be estimated. These two references are the Federal Energy Regulatory Commission's FERC's Final EIS report for the Elba III Project in Georgia, USA and the Phase 1 Grain LNG expansion. In addition, indicative cost for the LNG export line for the Sun LNG project in Gladstone was obtained and a rule of thumb was provided by an external source.

Cryogenic Export Pipelines

Case 1 – Elba III

The Final EIS report for the Elba III LNG import project (August 2007) includes an economic comparison of the proposed near shore terminal expansion against offshore terminal alternatives. A portion of this analysis included the cost of two LNG subsea pipelines from an offshore unloading terminal to the onshore storage facilities.

Details of the LNG pipelines evaluated are:

| | |
|--------------|-------------------|
| Type | Cryogenic, subsea |
| Number | 2 |
| Diameter | 42" OD |
| Length | 20 miles |
| Cost / mile | US\$ 34,000,000 |
| Cost / in-km | US\$ 253,000 |

Case 2 - Grain LNG

The reported cost for the Phase 1 Grain LNG project is £130 million.

Phase 1 involved the construction of a 1 km long jetty and a 4.5 km cryogenic pipeline system rated at an import rate of 5,000 tph. The cost included new compression and vaporisation equipment plus modification of the existing LNG storage tanks.

The LNG import pipeline system included 3 off 16" loading arms and 1 off 16" vapour return arm. One 36" import pipeline and one 14" recirculation pipeline were installed.

A breakdown of the £130 million project cost has not been published. However, if the cost of the DPA BLB (~600 m long) is used as a comparison (both built at about the same time), then a figure of say £50 million could be assumed for the jetty and associated equipment. An allowance of say another £10 million for the tank modifications, compressors and vaporisers could also appear reasonable. This would leave about £70 million for the pipeline.

Details of the LNG pipelines are:

- ▶ Type Cryogenic, above ground
- ▶ Number 2
- ▶ Diameter 1 x 36" OD & 1 x 14"
- ▶ Length 4.5 km
- ▶ Cost £ 70,000,000
- ▶ Exchange rate, assumed US\$ 2.00 = £ 1.00
- ▶ Cost / in-km US\$ 622,000

Case 3 - Sun LNG

The proposed Sun LNG export facility at Gladstone is designed to have an above ground export line capable of handling 8,000 tph. A liquid recirculation line and a vapour return line are also included. Total length of the pipelines is about 1.6 km. The cost for the pipelines is estimated at US\$10 million.

Details of the LNG export pipelines are:

- ▶ Type Cryogenic, above ground
- ▶ Number 3
- ▶ Diameter 1 x 30" & 2 x 8"
- ▶ Length 1.6 km
- ▶ Cost US\$ 10,000,000
- ▶ Cost / in-km US\$ 135,870

Case 4 – External Advice

Advice was obtained via an industry contact regarding the indicative cost of a 24" LNG pipeline. A figure of \$10,000/m was given. The pipe diameter for a pre-insulated pipe (pipe in pipe system as used in LNG service at Darwin LNG plant) is typically about 4"

to 6" greater than the main liquid carrying pipe. Assuming an OD of 30" yields an approximate unit cost of:

- Cost / in-km US\$ 333,300

Analysis

As would be expected and as illustrated by Cases 2 and 3 above, the economic length of an LNG import or export pipeline depends on the commercial aspects of the project. The Sun LNG project has a relatively small scale LNG liquefaction unit (0.5 Mtpa) and the export pipeline system is estimated to represent about 5% of the estimated cost to build the plant.

If this figure is used as a rule of thumb, then for the hypothetical future 5 Mtpa plant the cost of the export pipeline system would be in the order of US\$ 190 million. Assuming a pipeline system similar to that of the Sun LNG plant, an economic length would be about 16 km. Distances from the coast and from the 15m contour were considered in the analysis. The actual length of pipeline required would, of course, depend on the distance to and length of the export jetty. This distance can be reduced to some extent by dredging.

Dredging

The precise requirements for a dredge channel will depend on a number of factors that are not well understood at this stage. These include, but are not limited to the size of LNG ships to be used, the sea conditions that can be expected and the limitations that are acceptable in terms of shutdown weather conditions. It can be understood that the dredge channel requirements in sheltered waters, where pitch and roll of vessels is small, will be less than that required in an approach that is exposed to significant swells or tidal currents.

Typical examples for Dampier are as follows:

- 13 m maintained depth for dredge channel (actually 12.3 m at Dampier)
- Width of dredge channel 250 m
- Turning basin at jetty (with tugs) ~600 m
- Costs:
 - \$8M each way to mobilise and demobilise the dredger
 - \$20 (sand, soft substrate) to \$60 (hard granitic substrate) per m³ of dredged material, perhaps assuming \$40 per m³ for generic costing purposes.

Hence, a single kilometre of channel dredging would be expected to cost in the region of \$130 million. These figures are substantial and explain why a pipeline to a green field site beyond 500 km becomes challenging and prohibitive in some cases.

8. Conclusion

This study highlights the feasibility potential for numerous alternative precinct sites along the Western Australian Pilbara coast, Northern Territory coast and offshore locations in Northern Australian waters.

At first glance a significant number of sites along the Pilbara Coast present themselves as having some potential as sites for an LNG precinct. However, closer investigation reveals that extremely little on-the-ground information is available for these sites. It would be inappropriate to conclude that because of the presence of some industry on the Pilbara Coast that it represents lower environmental values than the Kimberley.

There are significant stretches of the Pilbara coast about which very little is known, and information presented for a number of sites is little more than inference or generalisation. References to threatened species east of Dampier often fall in this category, rendering any commentary impossible on numbers or management.

Economics dictate that any proposed site greater than 500 km from the gas field is prohibitively expensive to develop from a green field situation. This can guide selection of a precinct because any economic proposal either must be within 500 km or already have significant industrial infrastructure present. This infrastructure at the very least would include a dredged shipping channel in close proximity to the coastline.

Such brownfield sites include; The Burrup Peninsula, Port Hedland, Cape Lambert in the Pilbara and Middle Arm in the Northern Territory. There are no Greenfield sites in this study within 500km of the Browse Field.

Selection of brown field sites may, however be constrained by impacts on the local or regional airshed. LNG liquifaction trains emit significant quantities of nitrogen oxide and volatile organics, which in the presence of strong sunlight can lead to the generation of photochemical pollution. Recent modelling of the Burrup Peninsula appears to suggest that approximately two thirds of the airshed capacity will be taken up when the Pluto LNG development comes on-line. Further significant development, such as, an LNG train to liquify gas from the Browse Basin could effectively fill the airshed carrying capacity. More detailed photochemical modelling would be required to address the significant non-linearities in atmospheric photochemistry. Modelling for Pluto also indicated that pollution concentrations might exceed National Environmental Protection Measures during upset conditions. This was not considered to be significant due to the short time frame and location of elevated ground level concentrations at this site. This might not be the case elsewhere. An airshed capacity issue could exist even in a green field site if an industrial concentration significantly larger than that on the Burrup Peninsula is proposed.

Socially, an uncontrolled imposition of a large industrial precinct can present problems even if a town already exists. There are no large urbanised areas capable of absorbing the workforce from such a development anywhere along the North West Coast and a significant itinerant workforce can place considerable pressures on local facilities and services. Recent consultation has indicated significant stress in Karratha



due to the rapid increase in population caused by the primary resources boom. In the past it has been assumed that the presence of significant industry would contribute to local prosperity and employment but this can come at a significant cost.

Most of the North West is subject to Native Title Claim and the position of Claimants in relation to industrial development is uncertain. Very little is known in relation to Aboriginal heritage sites, but landscape features such as promontories or near shore islands are often associated with significant sites. The absence of listed sites does not indicate that nothing exists in these areas; rather it usually indicates that no survey has taken place. Disturbance of a site listed or otherwise, is an offence under the Western Australian Aboriginal Heritage Act (1972).

LNG precinct locations are limited in the Northern Territory and all but one site are undeveloped with no significant infrastructure. The distance of these sites from the Browse Basin suggests that their development would be cost prohibitive.

Offshore LNG facilities offer some potential for processing close to the gas field. However, little actual development of these types of infrastructure has occurred. For development of this type, each company would be required to make individual investment with very little opportunity for synergy. It might be assumed that the environmental impacts of such developments are less, however the specifics of any proposal would need to be considered in detail before such a conclusion could be made with certainty.



9. Acknowledgements

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- ▶ Mr Paul Frewer, Director, WA Chamber of Minerals and Energy
- ▶ Mr Rob Sippe, former Director, WA Department of Environment and Conservation and Coordinator of WA Environmental Protection Authority Services Unit
- ▶ Mr Arthur Ventham, WA Office of Development and Approvals Coordination
- ▶ Mr Brian O'Gallagher, NT Department of Chief Minister
- ▶ Ms Maria Billias, NT Department of Chief Minister
- ▶ Ms Juanita Croft, NT Environment Protection Authority
- ▶ Representatives from the NT Department of Regional Development, Primary Industries, Fisheries and Resources



Appendix A

Acronyms



| BHPB | BHP Billiton |
|---------------|---|
| CALM | Department of Conservation and Land Management (now DEC) |
| DEC | Department of Environment and Conservation |
| DEWHA | Department of the Environment, Water, Heritage and the Arts |
| DIA | Department of Indigenous Affairs |
| DIPE | Department of infrastructure, planning and environment |
| DLGRD | Department of Local Government and Regional Development |
| DMPR | Department of Mineral and Petroleum Resources |
| DoIR | Department of Industry and Resources |
| DoW | Department of Water |
| DPI | Department of Planning and infrastructure |
| DRD | Department of Resource Development |
| EPBC Act | Environment Protection and Biodiversity Conservation |
| FIFO | Fly-in Fly-out |
| FLNG | Floating LNG |
| GBS | Gravity Based Structure |
| LNG | Liquefied natural gas |
| NEPM | National Environmental Protection Measures |
| NOI | Notice of Intent |
| RNE | Register of the National Estate |
| RPI | Regional Price Index |
| TPWC Act (NT) | Territory Parks and Wildlife Conservation Act |
| WA EPA | Western Australian Environmental Protection Authority |
| WAPC | Western Australian Planning Commission |



Appendix B

Bibliography



- Asian Oil and Gas (2003). *Floating terminals back in fashion*. Available Online: <http://www.oilonline.com/news/features/aog/20030123.Floating.10542.asp>, [24/11/2008].
- Astron Environmental (2002). *The Maitland Heavy Industrial Estate: Assessment and Comparison with the Burrup Industrial Estate*. Prepared for the Shire of Roebourne [Publicly Available].
- Australian Bureau of statistics (2006). Census Data. Available Online: <http://www.abs.gov.au/websitedbs/D3310114.nsf/Home/Census+Data> [25 November 2008]. Australian Bureau of Statistics.
- Blackbourn, Luke (2008). *Gorgon Project Briefing Pilbara Dialogue*. Slideshow presentation from 25 July 2008. Gorgon project operated by Chevron Australia in joint venture with ExxonMobil. Available Online: <http://www.pdc.wa.gov.au/media/36558/chevrongorgon-luck%20blackbourn%20txt.pdf>, [12/11/2008].
- Bliault, Alan (2001). *Gas-To-Liquids Technology: Shell floating LNG plant, technology ready for project development*. Article in Offshore Volume 61, issue 5. Available Online: http://www.offshore-mag.com/display_article/100620/9/ARCHI/none/none/1/GAS-TO-LIQUIDS-TECHNOLOGY:-Shell-floating-LNG-plant,-technology-ready-for-project-development/ [24/11/2008].
- Bradbury, John (2002). *To LNG or not to LNG*, Offshore Report 3255, Available Online: <http://www.epmag.com/archives/offshoreReport/3255.htm> [24/11/2008].
- Chen-Hwa Chiu (2006). *Commercial and Technical considerations in the development of offshore Liquefaction Plant*. Presented at 23rd World Gas Conference. Available Online: <http://www.igu.org/html/wgc2006/pdf/paper/add11306.pdf> [27/11/2008].
- Chevron (2006) *Final Environmental Impact Statement / Response to Submissions on the Environmental Review and Management Programme for the Proposed Gorgon Development*. Chevron Australia Pty Ltd. Available Online: [http://www.gorgon.com.au/03moe_finaleis.html#frames\(content=03moe_finaleis_body.html\)](http://www.gorgon.com.au/03moe_finaleis.html#frames(content=03moe_finaleis_body.html)), [21/11/2008].
- Chevron Australia (2008). *Gorgon Gas Development Revised and Expanded Proposal: Public Environmental Review*. Gorgon project operated by Chevron Australia in joint venture with ExxonMobil. Available Online: http://www.gorgon.com.au/review/FromClient/Gorgon_Revised_Proposal_PER_Final_Main_Report_20080909.pdf, [21/11/2008].
- Churchward HM, McArthur WM (1980). *The Soil Pattern in Relation to Physiography and Geology in the Northern Pilbara Region, Western Australia*. Land Resources Management Technical Paper No. 6. Commonwealth Scientific and Industrial Research Organisation, Australia.
- Denney, Dennis (2006). *Natural Gas Technology/Monetization: Floating LNG Systems – Export and Import Terminals*. JPT online. Available Online: <http://www.spe.org/spe-site/spe/spe/jpt/2006/04/Synopsis17547.pdf> [26/11/2008].
- Department of Industry and Resources (2008). *Location Options*. Available Online: <http://www.doir.wa.gov.au/2630.aspx>. Government of Western Australia.
- Department of Planning and Infrastructure (2008). *Shire of Roebourne Town Planning Scheme No. 8*. Available Online: <http://www.wapc.wa.gov.au/Region+schemes/Local+planning+schemes/609.aspx>.



Department of Planning and Infrastructure (2008). *Town of Port Hedland Town Planning Scheme No. 5*. Available Online: <http://www.wapc.wa.gov.au/Region+schemes/Local+planning+schemes/565.aspx>.

Department of Planning and Infrastructure (2007). *Port and Related Infrastructure Requirements to Meet the Expected Increases in Iron Ore Exports from the Pilbara*. Abridged version of a report prepared by WorleyParsons Services Pty Ltd. Available Online:

http://www.dpi.wa.gov.au/mediaFiles/planning_pilbarareportsstudy_abridged070615.pdf [28 November 2008]. Department of Planning and Infrastructure.

Department of Planning and Infrastructure (2005). *Shire of Ashburton Town Planning Scheme No. 7*. Available Online: <http://www.wapc.wa.gov.au/Region+schemes/Local+planning+schemes/395.aspx>.

Department of Planning and Infrastructure (2005). *Shire of Exmouth Town Planning Scheme No. 3*. Available Online: <http://www.wapc.wa.gov.au/Region+schemes/Local+planning+schemes/485.aspx>.

Dixon, IR., Dixon, KW. and Barrett, M., (2000) *Eradication of Buffel Grass (Cenchrus ciliaris) on Airlie Island, Pilbara Coast, Western Australia*. Kings Park and Botanic Garden, West Perth, Western Australia.

DLGRD (2006) *Pilbara Economic Perspective*. Government of Western Australia. Available online: http://www.dlgrd.wa.gov.au/Publications/Docs/EconomicPerspectives_pilbara.pdf

DLGRD (2007) *Regional Prices Index November 2007*. Government of Western Australia. Available online: <http://www.dlgrd.wa.gov.au/Publications/Docs/RegionalPriceIndex2007.pdf>

Dunlop, JN., Long, P., Stejskal, I. and Surman, C., (2002). *Inter-annual Variations in Breeding Participation at Four Western Australian Colonies of the Wedge-Tailed Shearwater Puffinus Pacificus*. Marine Ornithology, Volume 30, No. 1: 13-18, 2002.

Fluor Daniel (1997). *Pilbara Petrochemical Complex: Site Comparative Cost Study*. Prepared for the Department of Resources Development, Government of Western Australia [Publicly Available].

Gaffney, Cline and Associates (2008). *Addendum to Report 1 of 3 LNG Plant Site Selection Validation, Browse Basin Gas Technical Report Development Options Study*. Prepared for the Department of Industry and Resources Northern Development Taskforce. Available Online: http://www.doir.wa.gov.au/documents/Appendix_1_Gaffney_Cline_and_Associates_-_Addendum_to_Report_1.pdf, [10/11/2008].

Gaffney, Cline and Associates (2008). *Report 1 of 3 LNG Plant Site Selection Validation, Browse Basin Gas Technical Report Development Options Study*. Prepared for the Department of Industry and Resources Northern Development Taskforce. Available Online: http://www.doir.wa.gov.au/documents/Appendix_1_Gaffney_Cline_and_Associates_-_Report_1.pdf, [10/11/2008].

Gaffney, Cline and Associates (2008). *Report 2 of 3 Development Concepts for Development of Browse Basin Gas, Browse Basin Gas Technical Report Development Options Study*, Prepared for the Department of Industry and Resources Northern Development Taskforce. Available Online: http://www.doir.wa.gov.au/documents/Appendix_1_Gaffney_Cline_and_Associates_-_Report_2.pdf, [10/11/2008].

Gaffney, Cline and Associates (2008). *Report 3 of 3 Onshore LNG Hub Development, Browse Basin Gas Technical Report Development Options Study*, Prepared for the Department of Industry and Resources Northern Development Taskforce. Available Online:



http://www.doir.wa.gov.au/documents/Appendix_1_Gaffney_Cline_and_Associates_-_Report_3.pdf, [10/11/2008].

Gorgon Australian Gas (2005) *Draft Environmental Impacts Statement / Environmental Review and Management Programme for the Proposed Gorgon Development*. Gorgon project operated by Chevron Australia in joint venture with ExxonMobil and Shell. Available Online:

[http://www.gorgon.com.au/03moe_eis.html#frames\(content=03moe_eis_body.html\)](http://www.gorgon.com.au/03moe_eis.html#frames(content=03moe_eis_body.html)), [21/11/2008].

Gurfinkel Mariano E. et al. (2007). *Novel offshore LNG terminals address some, not all issues*. Oil and Gas Journal Volume 4 issue 1. Available Online:

http://www.ogj.com/display_article/281181/94/ARTCL/none/none/Novel-offshore-LNG-terminals-address-some,-not-all-issues/ [24/11/2008].

Halpern Glick Maunsell (1994). *Cape Lambert / Dixon Island Heavy Industrial Siting Study – Preliminary Investigation*. Prepared for Department of Resource Development and Landcorp [Publicly Available].

Hydrocarbons Technology (2008). *North Adriatic LNG terminal, Italy*. Available Online:

<http://www.hydrocarbons-technology.com/projects/adriatic/> [24/11/2008].

Market Watch (2008). *Dresser-Rand Awarded the Industry's First Floating LNG Project*, Available Online:

<http://www.marketwatch.com/news/story/dresser-rand-awarded-industrys-first-floating/story.aspx?guid=%7B5E8C38C3-9AD4-4CFF-AACC-006B8FA781A4%7D> [24/11/2008].

MMR Reports (2007). *Results and Updates Gulf of Mexico Exploration and Development & Main Pass Energy Hub™ Activities*. Available Online: <http://www.mpeh.com/new/2008.htm> [27/11/2008].

Mokhatab, Saeid & Wood, David (2007). *Breaking the offshore LNG stalemate*. Article in World Oil Volume 228 Number 4. Available Online:

http://www.worldoil.com/Magazine/MAGAZINE_DETAIL.asp?ART_ID=3165&MONTH_YEAR=Apr-2007 [28/11/2008].

Northern Development Taskforce (2008a). *Northern Development Taskforce Site Evaluation Report, Part A*. Department of Industry and Resources. Available Online:

[http://www.doir.wa.gov.au/documents/Site_Evaluation_Report_Part_A_\(release_14_Oct_2008\)_2\).pdf](http://www.doir.wa.gov.au/documents/Site_Evaluation_Report_Part_A_(release_14_Oct_2008)_2).pdf), [10/11/2008].

Northern Development Taskforce (2008b). *Northern Development Taskforce Site Evaluation Report, Part B*. Department of Industry and Resources. Available Online:

[http://www.doir.wa.gov.au/documents/Site_Evaluation_Report_Part_B_\(release_14_Oct_2008\).pdf](http://www.doir.wa.gov.au/documents/Site_Evaluation_Report_Part_B_(release_14_Oct_2008).pdf), [10/11/2008].

Northern Territory Government (2007a), *Lost from our Landscape*.

Northern Territory Government (2007b), *Minerals and Energy, Crux*. Available Online:

http://www.nt.gov.au/d/Minerals_Energy/index.cfm?header=Crux [24/11/2008].

Northern Territory Government (2008), *Northern Territory 2008/09 Budget*.

Northern Territory Government (2005), *Northern Territory Indigenous Economic Development Strategy*.

Northern Territory Lands Group (2008), *Terms of Reference for Preparation of an Environmental Assessment to Support the Proposed Development of Industry on Middle Arm Peninsula*. Available Online: <http://www.nt.gov.au/lands/newsroom/2008/documents/toreamiddlearm200804.pdf>. Northern Territory Government.



- Northern Territory Lands Group (2007). *NT Planning Scheme*. Available Online: <http://www.nt.gov.au/lands/planning/scheme/index.shtml>. Northern Territory Government.
- Offshore magazine, Issue 61 (2001). *Gas to liquids technology: Shell Floating LNG plant, technology ready for project development*. Available Online: www.offshore-mag.com/articles_print_screen.cfm_ARTICLE_ID=100620 [24/11/2008].
- Pepper, Greg & Shah Kamal (2004). *Engineering Considerations in Siting and Design of Offshore LNG Terminals*, Presented by Aker Kvaerner at Prevention First 2004 Symposium. Available Online: http://www.slc.ca.gov/Division_Pages/MFD/Prevention_First/Documents/2004/Marine%20Terminal%20Engineering%20Issues/shah%20paper.pdf [24/11/2008].
- Pilbara Development Commission (2008). *Pilbara Projects Update*. Volume 1, Issue 1 – October, 2008. Available Online: <http://www.pdc.wa.gov.au/media/38058/pilbara%20projects%20update%20nov%202008.pdf>. Government of Western Australia.
- Power Planning and Management (1998) *Onslow Potential Development Sites for Processing Industry and Offshore Support*. Prepared for the Department of Resources Development [Publicly Available].
- Raine B., & Kaplan A. (2002). *Examining Nigerian built concrete substructures for floating or gravity based Liquefied gas production facilities*. Article drafted by Arup Energy and Foster Wheeler. Available online: http://209.85.173.132/search?q=cache:jckxQJx0OUQJ:www.fwc.com/publications/tech_papers/files/ALKAPLAN.pdf+ArupEnergy%2BExamining%2BNigerian%2Bfloating%2Bgravity%2Bbased&hl=en&ct=clnk&cd=1&gl=au [2/12/2008].
- Ryan, GR (1966) Roebourne Western Australia. Sheet SF/50-3 International Index, Geological Series Explanatory Notes. Bureau of Mineral Resources, Geology and Geophysics.
- Santos Limited (2008). Santos Ltd/Exploration (mineral, oil and gas – marine)/ Permit area WA-247-P, offshore Browse Basin/WA/BRSN08 3D marine Seismic Survey. Referral 11 Nov 2008, reference number 2008/4582. Available Online: http://www.environment.gov.au/cgi-bin/epbc/epbc_ap.pl?name=current_referral_detail&proposal_id=4582 [1 November 2008].
- Searancke Russell (2008). *Floating LNG on menu at Prelude*. Available Online: <http://www.upstreamonline.com/incoming/article151878.ece> [27/11/2008].
- Shell Gas & Power (2008). *Shell issues tender invitation for floating LNG facility*. Shell Media News release. Available Online: http://www.shell.com/home/content/shellgasandpower-en/news_and_library/press_releases/2008/floating_lng_030708.html [24/11/2008].
- Sinclair Knight Mertz (2002). *Strategic Assessment of Amenities at Hearson Cove Beach*. Prepared for the Department of Mineral and Petroleum Resources, Office of Major Projects [Publicly Available].
- SMEC (2004). *Pilbara Coast Petroleum and Minerals Study*. Prepared for the Department of Industry and Resources [Publicly Available].
- Taylor, J. and Scambury, B. (2005) *Indigenous People and the Pilbara mining boom: A baseline for regional participation*, Centre for Aboriginal Economic Policy Research, The Australian National University, Canberra. Available Online: <http://www.anu.edu.au/caepr/mono.php> [27/11/2008].



URS Australia Pty Ltd (2005) *Pilbara LNG Project: Site Selection Study*. Prepared for BHP Billiton. Available Online:

<http://www.bhpbilliton.com/bbContentRepository/docs/OurBusiness/Petroleum/PilbaraReport.pdf>, [11/11/2008].

Western Australian Planning Commission (2003). *Onslow Structure Plan, Final*. Available Online: <http://www.wapc.wa.gov.au/Publications/61.aspx> [1/12/2008]. State of Western Australia.

Wire Services (2008). *Inpex submits \$19.6bn floating LNG plan*. Article in Upstreamonline.com on 6 June 2008. Available Online: <http://www.upstreamonline.com/live/article156695.ece> [28/11/2008].

Woodside Energy Ltd (2006). *Pluto Fact Sheet: Why Burrup?* Woodside Energy Ltd. Available Online: <http://www.woodside.com.au/NR/rdonlyres/EB7E9626-935F-4173-8E0B-5590CD028B9C/0/PlutoFactsheetWhyBurrup.pdf>, [12/11/2008].

Woodside Energy Ltd (2007). *Pluto LNG Development Burrup LNG Park: Social Impact Study*. Woodside Energy Ltd. Available Online: <http://www.woodside.com.au/NR/rdonlyres/6A1824EB-3418-4E79-A968-E69410348A1B/0/PlutoLNGDevelopmentBurrupLNGParkSocialImpactStudyMarch2007.pdf>, [24/11/2008].

Worley Parsons resources and energy (2005). *Onslow Strategic Industrial Area Expansion Study*. Prepared for Department of Industry and Resources. Available Online: <http://www.doir.wa.gov.au/3738.aspx>, [12 November 2008].

Worley Parsons resources and energy (2008). *Wheatstone Development: Site Screening Study Report*. Report for Chevron Australia Pty Ltd [Not Publicly Available].



Desktop Searches

Australian Bureau of Statistics (2008). <http://www.abs.gov.au/>. Australian Government.

Department of the Environment, Water, Heritage and the Arts (2008). *Australian Heritage Database*. Available Online: <http://www.environment.gov.au/cgi-bin/ahdb/search.pl> [25/11/2008]. Australian Government.

Department of the Environment, Water, Heritage and the Arts (2008). *Australian Heritage Places Inventory*. Available Online: <http://www.heritage.gov.au/ahpi/> [28/11/2008]. Australian Government.

Department of Indigenous Affairs (2008). *Aboriginal Heritage Inquiry System*. Available Online: <http://www.dia.wa.gov.au/Heritage--Culture/Heritage-management/Register-of-Aboriginal-sites/Aboriginal-Heritage-Inquiry-System/>, [20/11/2008]. Government of Western Australia.

Department of Agriculture and Food (2008). *Declared Plant Search*. Available Online: http://agspsrv95.agric.wa.gov.au/dps/version02/01_plantsearch.asp [28/11/2008]. Government of Western Australia.

Department of the Environment, Water, Heritage and the Arts (2008). *EPBC - Protected Matters Search Tool*. Available Online: <http://www.environment.gov.au/erin/ert/epbc/index.html> [20/11/2008]. Australian Government.

Department of the Environment, Water, Heritage and the Arts (2008). *Australian Natural Resource Atlas*. Available Online: <http://www.anra.gov.au/>. Australian Government.

Department of Environment and Conservation (2008). *FloraBase*. Available Online: <http://florabase.calm.wa.gov.au/> [28/11/2008]. Government of Western Australia.

Department of Natural Resources, Environment, the Arts and Sport (2008). Available Online: <http://www.nt.gov.au/nreta/>. Northern Territory Government.

Department of Regional Development, Primary Industry, Fisheries and Resources (2008). <http://www.nt.gov.au/d/index.cfm>.

Department of Water (2008). *Geographic Data Atlas*. Available Online: <http://portal.water.wa.gov.au/portal/page/portal/MapsDataAtlases/GeographicDataAtlas> [24/11/2008]. Government of Western Australia.

Geological Survey of Western Australia (2001) *1:250,000 Dampier – Barrow Island Map Sheet – Sheet SF 50-2 and part of Sheet SF 50-1*.

Geological Survey of Western Australia (1983a) *1:250,000 Lagrange Map Sheet – Sheet SE 51-10*.

Geological Survey of Western Australia (1983b) *1:250,000 Pender Map Sheet – Sheet SE 51-2*.

Geological Survey of Western Australia (1981a) *1:250,000 Mandora Map Sheet – Sheet SE 50-13*.

Geological Survey of Western Australia (1981b) *1:250,000 Onslow Map Sheet – Sheet SF 50-5 and part of Sheet SF 49-8*.

Geological Survey of Western Australia (1981c) *1:250,000 Port Hedland – Bedout Island Map Sheet – Sheet SF 50-4 and part of Sheet SE 50-16*.

Geological Survey of Western Australia (1971) *1:250,000 Broome Map Sheet – Sheet SE 51-6*.



Geological Survey of Western Australia (1968) *1:250,000 Yarraloola Map Sheet – Sheet SF 50-6*.

Geological Survey of Western Australia (1965) *1:250,000 Roebourne Map Sheet – Sheet SF 50-3*.

Geoscience Australia (2008). *Online Mapping and Databases, Maps of Australia*. Available Online: <http://www.ga.gov.au/map/index.jsp> [27/11/2008]. Australian Government.

Geoscience Australia and Department of Climate Change (2008). *OzCoasts: Australian Online Coastal Information*. Available Online: <http://www.ozcoasts.org.au/> Australian Government.

Google Earth (2008). <http://earth.google.com/>.

Hydrographic Service Royal Australian Navy (1998). Australia – North West Coast Western Australia, *Exmouth Gulf and Approaches*, 1:150 000 Marine Chart. Based on 1984 hydrography.

Hydrographic Service Royal Australian Navy (1994). Australia – North West Coast Western Australia, *Rosemary Island to Barrow Island*, 1:150 000 Marine Chart. Based on 1992 hydrography.

Hydrographic Service Royal Australian Navy (1993). Australia – North West Coast Western Australia, *Barrow Island to Onslow*, 1:150 000 Marine Chart. Based on 1993 hydrography.

Hydrographic Service Royal Australian Navy (1986). Australia – North West Coast Western Australia, *Port Hedland to Port Walcott*, 1:150 000 Marine Chart. Based on 1985 hydrography.

Hydrographic Service Royal Australian Navy (1985). Australia – North West Coast Western Australia, *Approaches to Dampier Archipelago*, 1:150 000 Marine Chart.

Landgate (2008) *WA Atlas – Shared Land Information Platform* (2008). *WA Atlas*. Available Online: <https://www2.landgate.wa.gov.au/idelve/bmvf/app/waatlas/> [28/11/2008]. Landgate.

National Native Title Tribunal (2008). <http://www.nntt.gov.au/Pages/default.aspx>.

Northern Territory Land Information System (2008). <http://www.nt.gov.au/ntlis/>.



Appendix C

List of Sites Considered



Pilbara, Western Australia

| | |
|---------------------------------|---|
| Onslow Region | Onslow North |
| | Cane River – Onslow North |
| | Coolgra Point |
| | Onslow North – Beadon Creek |
| | Ashburton River / Ashburton North |
| | Onslow Industrial Estate - SIA |
| | Urala |
| | Locker Point |
| | Tubridgi Point |
| | Serrurier Island |
| | Thevenard Island |
| | Airlie Island |
| Dampier / Karratha Region | King Bay Industrial Estate |
| | Inland Burrup Peninsula |
| | Maitland Estate and West Intercourse Island |
| | Cape Preston |
| | South of Cape Preston |
| | Hearson Cove |
| | Dampier West |
| | Holden Point / Burrup Industrial Estate |
| | Gnoorea Point (40 Mile Beach) |
| | Conzinc South |
| | Withnell East |
| | Islands of the Dampier Archipelago |
| | West Intercourse Island |
| | East Intercourse Island |
| | Barrow Island |
| | Varanus Island |
| | Montebello's |



| | |
|---------------------------|--|
| | Trimouille Island (Montebello's) |
| Cape Lambert Region | Cape Lambert |
| | Point Sampson |
| | Cossack |
| | West Wickham with Dixon Island or Bougner Entrance Port Facilities |
| | Depuch Island (Sherlock River) |
| Port Hedland Region | Ronsard Island |
| | Cape Thouin |
| | Port Hedland / Nelson Point |
| | Finucane Island |
| | Wedgefield |
| | Redbank |
| | Pardoo |
| | Cape Keraudren |
| | Boodarie |
| | North and Turtle Islands |
| | Bedout Island |
| Northern Territory | |
| | Middle Arm |
| | Glyde Point |
| | Bynoe Harbour |
| Offshore | |
| | FLNG near Bayu-Undan |
| | GBS LNG near Prometheus |
| | GBS LNG south of Calliance |



Appendix D

Humpback Whale Activity

Humpback Whale Activity Map

LOCATION AND ESTIMATED PERIOD OF HUMPBACK WHALE ACTIVITY IN WA

0 100 200 300 400 KILOMETRES

ALBERS EQUAL AREA PROJECTION WITH STANDARD PARALLELS 17° 30' S AND 31° 30' S

This map has been compiled from various data sources received from a number of agencies. No responsibility is accepted for any error or omission.

30 APRIL 2003
Western Australia 2003

The periods for resting and calving shown are estimated peak migration periods. Actual timing of annual migration may vary by as much as 3 weeks from year to year due to food availability in the Antarctic.

The major calving ground identified is situated in the Kimberly region - Camden Sound.

Humpback whales can also be expected to be encountered outside the shown migratory paths which are representative only of the main migratory body during peak season at each area. (ref. Jenner et al 2001)

INDIAN OCEAN

INDIAN OCEAN

SOUTHERN OCEAN

| | May | June | July | Aug | Sept | Oct | Nov |
|-----------------------------|---|------|------|---------|--|-----|-----|
| Migration Route | Peak Northbound Migration The northern migration extends further offshore and lies within the 400m bathymetry. | | | Calving | Peak Southbound Migration The southbound migration is generally closer to shore, mostly within the 200m bathymetry. | | |
| Broome to Camden Sound | | | | ● | ● | ● | |
| Port Hedland to Broome | | | | ● | ● | ● | |
| NW Cape to Port Hedland | | | ● | ● | ● | ● | |
| Carnarvon to NW Cape | | | ● | ● | ● | ● | |
| Jurien Bay to Carnarvon | | | ● | ● | ● | ● | |
| Geographe Bay to Jurien Bay | | ● | ● | | ● | ● | ● |

- North Bound Peak
- South Bound Peak
- South Bound Cow/Calf Peak

Camden Sound - Resting/milling area/calving area
Exmouth Gulf - Resting area with calves
Shark Bay - Resting area with calves
Geographe Bay - Resting area with calves

(Megaptera novaeangliae) The most recognised great whale species. Notable for their long flippers, complex 'songs' and frequent aerial behaviours. Length 14-18 metres.



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