



Browse LNG Precinct



Browse Liquefied Natural Gas Precinct Strategic Assessment Report

(Draft for Public Review)
December 2010

Appendix B-5

Browse On-shore LNG Precinct Siting Study



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Browse Onshore LNG Precinct Siting Study

Site Visit Report

301012-00633

20-Nov-08

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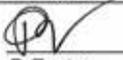
DEPARTMENT OF INDUSTRY AND RESOURCES
BROWSE ONSHORE LNG PRECINCT SITING STUDY
SITE VISIT REPORT

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PROJECT 301012-00633 - BROWSE ONSHORE LNG PRECINCT SITING STUDY

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1. INTRODUCTION

This report has been prepared to document the outcomes of phases one and two of the Browse Kimberly On-Shore LNG Precinct Study. The report documents the site assessment process undertaken by WorleyParsons, key findings from the analysis of background information, site visit and subsequent preliminary plant layouts.

It should be noted that the terms 'hub' and 'precinct' are used interchangeably throughout this report.

1.1 Purpose

Specifically, this report has been prepared to provide a record for each site satisfying the following requirements of the project brief:-

- *Identification and documentation of key opportunities and constraints associated with each site and proposed areas for further investigation to mitigate risks identified;*
- *Identification of the technically preferred configuration of the industrial site at each location;*
- *Identification of the technically preferred port location and configuration for each site;*
- *Identification of suitable locations for accommodation and airfields;*
- *Review the topography of the shoreline including the extent of any cliffs/escarpments, the presence of any low lying wetlands and associated identification of possible pipeline corridors connecting the plant to the shoreline; and*
- *Provide discussion on the likely constructability issues at each site.*

1.2 Locations

At the commencement of this study the Northern Development Taskforce (NDT) identified four potential locations for an LNG hub in the Kimberley. The four sites included:-

- Gourdon Bay;
- James Price Point;
- North Head (known to the traditional aboriginal land owners as "Map"); and



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- Anjo Peninsula.

1.3 Process

The study is broken into three stages as follows:-

1. Data Collection, Review and Consolidation

WorleyParsons reviewed a large amount of background information sourced from DoIR and other government departments. This information related primarily to a range of physical attributes for each site including:-

On-Shore

- Topography;
- Aerial Photography;
- Airports/Air Strips;
- Roads;
- Land Ownership/Tenure;
- Reserves;
- Department of Environment and Conservation controlled sites;
- Threatened/priority flora/fauna;
- Landforms of significance;
- Conservation areas;
- Townships;
- Native Title Claims / Department of Indigenous Affairs Sites
- European Heritage Sites; and
- Local Government Boundaries.

Off-Shore

- Bathymetry;
- Metocean data; and
- Marine conservation areas.



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Using this data a range of base maps were produced for each location. These maps identified various site attributes and areas of interest for the project team to investigate further whilst on site. They are included in Appendix 1.

Potential precinct proponents were approached by the DoIR and asked to provide a project definition document for their project. WorleyParsons then requested meetings with each of the proponents to discuss their project definition document and clarify any outstanding issues.

2. Site Visit and Technical Review

On the 4th of September WorleyParsons, accompanied by staff from DoIR, and Woodside (as observers), commenced a six day site visit to each of the four potential hub locations. Inpex provided an observer for the visit to the Anjo Peninsula. At each site the project team was accompanied by the Traditional Owners and representatives from the Kimberley Land Council (KLC).

During the site visit the project team was limited in its inspection by varying levels of access to the sites, however, inspected a representative area of each site with particular focus on the LNG process plant location, potential Jetty(s) locations and overall marine conditions. Each site was extensively photographed for low level aerial observations as well as ground level. As far as possible, GPS coordinates were recorded for later photograph identification. A selection of the photographic record is provided in Appendix 2.

3. Development of a Master Plan

This will occur for the preferred site and has not yet commenced.



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2. PROPONENT CONSULTATION

2.1 Browse Tenement Holders

The NDT wrote to all Browse Basin Tenement holders at the commencement of the siting study. The letter outlined the project process and asked potential precinct proponents to prepare a project definition document for their project. The letter also advised proponents that WorleyParsons would contact them in the future to discuss their project.

WorleyParsons contacted seven of the key tenement holders (as identified by the NDT) to request meetings and the project definition documents. Not all tenement holders were willing to meet with WorleyParsons or provide a project definition document.

The project definition documents structure was developed by the NDT to facilitate a standardised response from proponents. Information requested included:-

- A description of the proposal (built aspects and ongoing operations);
- A description of processing, inputs, products and discharges;
- Details of production design capacity and staging;
- The timeframe in which development is to occur;
- The proposed ultimate extent of areas required;
- Infrastructure to be developed or accessed in association with the proposal;
- Pipeline shore crossing details;
- Workforce numbers (construction/operation/maintenance), accommodation and transportation preferences;
- Bulk materials source/requirements;
- Waste storage/treatment or disposal;
- Emissions; and
- Domestic gas considerations.



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WorleyParsons met with three potential proponents some of who also provided project definition documents. Some of the information discussed in these meetings and provided in the project definition documents is confidential and WorleyParsons was required to sign confidentially agreements with some proponents. As such the details of the project definition documents and records of meetings have not been included in this document.

The main themes to come out of the project definition documents received and the meetings that were held include:-

- Proponents were generally unwilling to share infrastructure which is 'process critical'. This includes all infrastructure which may impact on plant performance, including:-
 - Power supply;
 - Jetties and wharfs
 - Storage; and
 - Any infrastructure that might bring production to a halt.
- Proponents did identify the opportunity to share some 'non process critical' infrastructure including:-
 - Access roads;
 - Accommodation;
 - Airfields; and
 - Fire and emergency services.

The willingness of proponents to share certain infrastructure elements but not others has influenced the land area required for the precinct. In some cases land savings can be achieved whilst in other no saving over a typical stand alone development is possible.

2.2 Other Consultation

In addition to consultation with potential proponents WorleyParsons also met with the Shire of Broome. The Shire identified a number of key issues for them including:-

- The potential impacts of increased truck movements to and from the Port of Broome;



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- The potential of the Shire to handle waste produced by the development;
- The potential to accommodate increased population in Broome; and
- The potential impacts of increases to population on local communities.

During the site inspections WorleyParsons was accompanied by various Traditional Land Owners. Whilst the purpose of the visit was not to officially consult with these groups, WorleyParsons did learn valuable information about prevailing weather, coastal processes and conditions at each site.

2.3 Alternative Non-Kimberley Sites

The development of on shore LNG facilities outside of the Kimberley Region has been considered by some proponents. Darwin and the Burrup Peninsula are options however in the main the additional length of subsea pipeline estimated at A\$4 million per kilometre would be expected to negate any potential benefit.

Depending on the particular Browse field the distance to Darwin is over 1000 kms and to the Burrup in excess of 850 kms. This compares to between 250 and 500 kms to the Kimberley coastline.

Long subsea pipelines will also require additional and more costly processing such as offshore platforms and compressors stations along the route. Condensate will also more likely be separated, stored and loaded offshore.

The Burrup Peninsula is the site of the Woodside operated Karratha Gas Plant (KGP) and currently runs five LNG processing trains, the fifth train having only been commissioned in September 2008. In addition an adjacent southern site on the Burrup houses the Pluto LNG project that is 100% owned and operated by Woodside and under construction at this time.

Apart from the additional length of subsea pipelines, the construction of a 6th processing train within the KGP to process Browse gas could have other downsides including:

- Space restrictions within lease boundaries
- LNG Berth availability
- Shipping channel restrictions
- Available space to align trunkline and shore crossings
- Complexity and safety in managing integration of an additional train into a 'brownfields' site.



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The Burrup and Darwin sites for onshore LNG facilities remain options for consideration, although are less attractive due to economic and other process and development issues.



3. STRATEGIC COMPARISON OF SITE CHARACTERISTICS

A site assessment matrix has been prepared to allow the comparison of various characteristics across each of the four locations. This matrix is supported by a more detailed set of site assessment notes in Section 4.



		POSSIBLE PRECINCT SITES					
		Anrjo Peninsula	North Head (MAP)	James Price A (North)	James Price B (Central)	James Price C (South)	Gourdon Bay
TRUNKLINE	Distance to Fields (Km) Woodside Torossa Inpex Ichthys	500 350	265 310	325 390	325 390	325 390	440 500
	Shore Crossing Availability	Yes	Yes	Yes	Yes	Yes	Yes
	Land Area Availability for LNG Precinct (Ha) <1000 1000 - 2000 >2000	2000+	1000 – 2000	2000+	2000+	2000+	1000 – 2000
ONSHORE PLANT SITE	Land Form Proposed (available) Plant Elevation (m AHD) Average Gradient	10-15m <1%	10-15m <1%	>15m <1%	>15m <1%	>15m <1%	approx 10m <1%
	Proximity to Coastline - Plant/Storage Tanks/Jetty (m)	Excellent	Constrained	Good	Good	Good	Constrained
	Available Coastline length for Jetty Access (m)	Unconstrained	Constrained	Unconstrained	Unconstrained	Unconstrained	Constrained
	Geology	Blocky sandstone rock mass with thin soil cover	Coastal sand & limestone grading to pindan soil	Pindan soil over siltstone & sandstone	Pindan soil over sandstone	Coastal sand & pindan soil over sandstone	Coastal sand, limestone & pindan soil over sandstone & mudstone
	Potential Geohazards	Loose blocks in cliffs at northern tip	Collapsible pindan. Unstable limestone cliff zone with ground subsidence.	Collapsible pindan Erodible cliffs in pindan soil. Deep pindan soil profile.	Collapsible pindan Erodible cliffs in pindan soil. Deep pindan soil profile.	Collapsible pindan	Collapsible pindan. Crumbling limestone cliffs.
	Modularisation Constraints (Haul Road)	Nil	Nil	Nil	Nil	Nil	Nil



POSSIBLE PRECINCT SITES						
	Anjo Peninsula	North Head (MAP)	James Price A (North)	James Price B (Central)	James Price C (South)	Gourdon Bay
Geology	Shoreline sandstone platform grading to submerged terraces with marine sediment cover	Shoreline limestone platform grading to submerged sandstone terraces with marine sediment cover	Shoreline sandstone platform grading to submerged terraces with marine sediment cover	Shoreline sandstone platform grading to submerged terraces with marine sediment cover	Shoreline sandstone platform grading to submerged terraces with marine sediment cover	Shoreline sandstone platform grading to submerged terraces with marine sediment cover
Potential Geohazards	Shallow rock close to shore; sandstone UCS<30-50MPa, quartzite UCS>50MPa Abrasive rocks Remote possibility of rocky shoals in basalt offshore	Shallow rock close to shore; limestone UCS<10-20MPa, sandstone UCS<30-50MPa Abrasive rocks	Shallow rock close to shore; sandstone UCS<30-50MPa, siltstone UCS<10MPa Abrasive rocks Rocky limestone shoals protruding above marine sediments in shallow to moderate waters	Shallow rock close to shore; beach conglomerate UCS<20-30MPa, sandstone UCS<30-50MPa Abrasive rocks Rocky limestone shoals protruding above marine sediments in shallow to moderate waters	Shallow rock close to shore; ferruginous conglomerate UCS<20-30MPa, sandstone UCS<30-50MPa, quartzite UCS>50MPa Abrasive rocks Rocky limestone shoals protruding above marine sediments in shallow waters	Shallow rock close to shore; limestone & mudstone UCS<10MPa, beach conglomerate <20-30MPa, sandstone UCS<30-50MPa Abrasive rocks Limestone patch reefs in deep water
Tidal Range HAT LAT	3.5m 0m	8.0m 0m	8.7m 0m	8.7m 0m	8.7m 0m	8.9m 0m
Surge Height (100yr)	3.3m	2.5m	2.7m	2.7m	2.7m	3.4m
Minimum Plant Height Elevation (est. 0.8MHWS + Storm surge + climate change + wave set up + wave run up + freeboard)	9.5 8.1	12.3 8.2	13.0 8.5	13.0 8.5	13.0 8.5	14.0 9.5
Datum LAT Datum AHD						

NEARSHORE FACILITIES



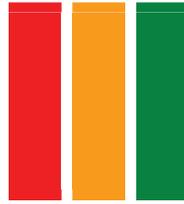
		POSSIBLE PRECINCT SITES						
		Anjo Peninsula	North Head (MAP)	James Price A (North)	James Price B (Central)	James Price C (South)	Gourdon Bay	
SUPPORT INFRASTRUCTURE	Coastal Protection Requirement (Against Maximum Surge)	No	No	No	No	No	Possibly	
	Distance to Navigable Water (14m)	2km	4.5km	9.5km	6.4km	5.2km	7.8km	
	Port Operability Annual Seasonal	>98%	<98%	<98%	<98%	<98%	<98%	
	Berth Availability Annual Seasonal	>98%	<98%	<98%	<98%	<98%	<98%	
	Requirement for Breakwater	No	Yes	Yes	Yes	Yes	Yes	
	Jetty Length	<1km	1.5-2km	3-4km	2.5km	1.5-2.0km	3-4km	
	Suitability for Multiple Jetties/berths	Yes	Limited	Yes	Yes	Yes	Limited	
	Materials Offload Facility (MOF) Access	Yes	Yes	Yes	Yes	Yes	Yes	
	Dredging Volumes	Low	Medium	High	Medium	High	High	
	Closest Major Population Centre	Kununurra	Broome	Broome	Broome	Broome	Broome	
	Distance to Population Centre (Straight Line) (Km)	310km	130km	60km	50km	40km	70km	
	Available Accommodation Area Construction Camp Permanent Housing/Camp	Near Site	Near Site	Near Site	Near Site	Near Site	Near Site	
	Road Access	Limited	Local Road	Local Road	Local Road	Local Road	Local Road	State Highway
Distance of required Road Upgrade (km)	569km	110km	16km sealed + 50km unsealed	16km sealed + 40km unsealed	16km sealed + 30km unsealed	16km sealed + 30km unsealed	20km access road	



		POSSIBLE PRECINCT SITES					
		Anjo Peninsula	North Head (MAP)	James Price A (North)	James Price B (Central)	James Price C (South)	Gourdon Bay
Wet Season Road Access		Closures even if sealed	Short closures, even if sealed	Short closures, even if sealed	Short closures, even if sealed	Short closures, even if sealed	Short closures, even if sealed
Airfield Availability and Distance from plantsite Runway Surface Length (m)		Truscott 5 km from site Sealed 1720m	Lombadina, sealed 70 km from site 1290m long Beagle Bay, unsealed 1000m	Broome 90 km from site Sealed 2458m	Broome 80km from site Sealed 2458m	Broome 70km from site Sealed 2458m	Broome 170 km from site Sealed 2458m Port Smith 5km to site unsealed 1000m
Power Supply		None	None	None	None	None	None
Water Supply Desalination Groundwater		Yes Low	Yes High	Yes Moderate	Yes High	Yes High	Yes Moderate
Waste Water/ Effluent Disposal		On Site	On Site	On Site	On Site	On Site	On Site
Fire & Emergency Service		None Available	None Available	None Available	None Available	None Available	None Available
Hospital and Medical Services		None Available	None Available	None Available	None Available	None Available	None Available
Construction Materials							
• Common Fill		Sand & rockfill	Sand/weathered rockfill	Sand/dredged fill	Sand/dredged fill	Sand/dredged fill	Sand/dredged fill
• Paving Material		Laterite gravel or CRB	Crushed limestone	Dredged spoil or import	Dredged spoil or import	Dredged spoil or import	Crushed limestone
• Concrete Aggregates		Crushed quartzite/basalt?	Import	Import	Import	Import	Import
• Armour Rock		Quartzite/ basalt quarry run	Concrete	Concrete	Concrete	Concrete	Concrete



POSSIBLE PRECINCT SITES						
	Anjo Peninsula	North Head (MAP)	James Price A (North)	James Price B (Central)	James Price C (South)	Gourdon Bay
	Seawater	Seawater	Seawater	Seawater	Seawater	Seawater
	Yes	Yes	Yes	Yes	Yes	Yes
<ul style="list-style-type: none"> Construction Water 	Remoteness, logistics Access in wet weather Constr downtime due to cyclones Dredge capability	Pindan soils, collapse potential Access in wet weather Constr downtime due to cyclones Dredge capability	Pindan soils, collapse potential Access in wet weather Constr downtime due to cyclones Dredge capability	Pindan soils, collapse potential Access in wet weather Constr downtime due to cyclones Dredge capability	Pindan soils, collapse potential Access in wet weather Constr downtime due to cyclones Dredge capability	Pindan soils, collapse potential Access in wet weather Constr downtime due to cyclones Dredge capability
<ul style="list-style-type: none"> Pioneering Works Required 						
<ul style="list-style-type: none"> Construction Risks Onshore Nearshore 						
CONSTRUCTABILITY						



Likely significant issue that may provide a serious impediment to choice of location.

Possible significant issue that may provide an impediment to choice of location.

No known issues of significance.



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4. DETAILED SITE ASSESSMENT NOTES

The following tables provide information on each of the sites in greater detail to the summary table provided in Section 2.

4.1 Anjo Peninsula

Characteristic	Anjo Peninsula Notes
TRUNKLINE	
Distance to Fields Woodside Torossa Inpex Ichthys	Direct distances are: Woodside 500km Inpex 350km Trunk line length may be greater than these distances due to shallow water depths and environmentally sensitive areas to the northwest of Anjo Peninsula.
Shore Crossing Availability	Approach is likely to be from the north west of the peninsula.
ONSHORE	
Land Area Availability <1000 ha 1000 - 2000 ha >2000 ha	Substantial areas of land available along the Peninsula for the development of single user/precinct with downstream processing if appropriate.
Land Form Proposed Plant Elevation (m) Average Gradient (%)	Peninsula and area to its south west are at elevations higher than any recorded storm surge or other seawater intrusions. Ground is generally flat with no apparent difficulties for a precinct.
Proximity to Coastline - Plant/Storage Tanks/Jetty (m)	No Geohazards are evident in proximity to the coastline with good access available on the eastern side of the peninsula where correspondingly deep water appears to be available.
Available Coastline length for	The eastern shoreline of the peninsula offers extensive



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Characteristic	Anjo Peninsula Notes
Jetty Access (m)	lengths of shoreline suitable for the location of jetties.
Geology and Geomorphology	King Leopold Sandstone bedrock with thin cover quartz sand soil. Exposed quartz sandstone is fractured and blocky with low relief. Minor tidal mud flats at coast. Carson Volcanics (basalt) lie to the south capped with laterite.
Potential Geohazards Unstable Cliff Zone Open Fissure Cavities Irregular Rockhead	There are no problematic soils present other than the localized coastal deposits within the mud flats. The sandstone is bedded with estimated rock strengths varying from medium to high. More massive quartzite layers display high to very high strength. Shallow sandstone bedrock forms good foundation material. Loose blocks in cliffs at northern tip.
Modularisation Constraints	There are no constraints that would impose limitations on the size or weight of modules for the construction of any plant or support infrastructure.
NEAR SHORE	
Geology and Geomorphology	Narrow beaches consisting of quartz sand pass into shoreline rock platforms developed in sandstone (exposed at low tide). The platform extends several hundred metres along the northern part of West Bay. Surrounding islands/reefs composed of same geological units as mainland. Away from the shoreline platform and islands, the sandstone bedrock is likely to step down as a series of submerged terraces covered by marine sediments (quartz/carbonate) increasing in thickness offshore. Nearest point on mainland to deep water is at base of Anjo Hill.
Potential Geohazards <ul style="list-style-type: none"> • High Strength rock (Dredgeability) • Irregular Rockhead • Sediment Transportation 	UCS strength for sandstone is likely to be less than 30 to 50MPa and quartzite greater than 50MPa. Bedded nature of sandstone may reduce rock strength. Sandstone will be very abrasive on dredging equipment. Rockhead is likely to step down as a series of terraces away from the coast. Delta discharge at southern part of West Bay has covered the shoreline rock platform with thin layers of sand and silt. Similar sediment fans are also developed along the main arm of the peninsula associated with seasonal outfall at the tidal flats. Longshore drift and tidal currents have re-deposited marine sediments around the offshore islands (deep water east of this chain of islands).
Tidal Range (HAT and LAT)	HAT 3.5m



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Characteristic	Anjo Peninsula Notes
	LAT 0
Surge Height (100yr)	3.3m
Coastal Protection Requirement (Against Maximum Surge)	Not required.
Distance to Navigable Water (14m)	2km
Dredging Requirements	Minimal dredging required. Deep water in the approaches removes the requirement for any significant dredging. May require some minor clean up adjacent to the berths or potential dredging to reduce the length of jetty required.
Port Operability <ul style="list-style-type: none"> • Annual • Seasonal 	>98% The port is a naturally sheltered harbour and full operability except for cyclone isolated wind or unusual events are expected.
Berth Availability <ul style="list-style-type: none"> • Annual • Seasonal 	>98% The tide range is relatively small and the water is naturally deep on the full approach.
Requirement for Breakwater	Breakwaters will not be required at this site.
Jetty Length	< 1km (depending on preferred dredging solution)
Suitability for Multiple Berths	Yes It will be possible to construct multiple berths within the harbour whilst achieving the require separations between them.
Materials Offload Facility (MOF) Access	Yes Multiple suitable locations exist in natural bays along



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Characteristic	Anjo Peninsula Notes
	the eastern shoreline of the peninsula.
SUPPORT INFRASTRUCTURE	
Closest Major Population Centre	Kununurra is the closest major population centre to the Peninsula. It has a population of approximately 3,500 people. The town includes a hospital, dentist, primary and high schools and recreation facilities.
Distance to Population Centre	<i>Distance as the crow flies:-</i> 310km <i>Distance by Road:-</i> Currently there is no direct road access from the peninsula to Kununurra. Sections of the Gibb River Kalumburu Road could however form part of an access road to the site in the future.
Available Accommodation Area <ul style="list-style-type: none">• Construction Camp• Permanent Housing/Camp	Both construction and permanent workforce accommodation could be provided close to the site. The closest existing town site is Kalumburu (approximately 40km from the peninsula as the crow flies). The distance by road would be significantly longer making it unlikely that personnel could be based here.
Road Access Standard <ul style="list-style-type: none">• Nil• Local Road Standard• State Highway Standard	Nil. Currently there is no road access to the peninsula. The Gibb River Kalumburu Road extends as far as Kalumburu, however this road is unsealed.
Distance of required Road Upgrade (km)	569km from site to Wyndham.
Airfield <ul style="list-style-type: none">• Availability and Distance from plant site• Runway Surface• Length	Mungalalu Truscott Airfield is located on the peninsula. The airbase is currently used by light aircraft and is a base for helicopters serving offshore oil and gas platforms. <ul style="list-style-type: none">• The airbase is approximately 5km from the plant site boundary.• The runway is sealed and includes lighting.• The runway is 1720m long and 30m wide.
Power Supply	There is currently no power supply of any significance to the peninsula.



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Characteristic	Anjo Peninsula Notes
Water Supply Desalination Groundwater	<p>There is currently no water supply of any significance to the peninsula.</p> <p>See Constructability</p>
Waste Water/ Effluent Disposal	<p>There is currently no waste water or effluent system of any significance on the peninsula.</p>
Fire & Emergency Service	<p>All fire and emergency services located on the peninsula are associated with the airbase.</p>
Hospital and Medical Services	<p>All medical services located on the peninsula are associated with the airbase.</p>
CONSTRUCTABILITY	
<p><i>Construction Materials</i></p> <ul style="list-style-type: none"> • <i>Bulk Fill</i> • <i>Paving Material</i> • <i>Concrete Aggregates</i> • <i>Armour Rock</i> • <i>Construction Water</i> 	<p>Construction materials likely to be available on-site include:</p> <ul style="list-style-type: none"> ○ Secondary armour (3-5t) for coastal protection works; ○ Various classes of rockfill; ○ Concrete & sealing aggregate (subject to ASR & PAFV verification testing); ○ Natural laterite gravel for road construction; ○ CRB (stabilize or blend to improve if necessary); and ○ Fine concrete aggregate won from quartz sand cover. <p>The majority of the above will require processing or manufacturing with minimal overburden removal. Basalt should be investigated for possible source of igneous aggregate. Alternatively high quality aggregates could be imported where necessary.</p> <p>Limited groundwater supplies likely to be available from bores constructed in fractured sandstone for pioneering works. Seawater to be used for site preparation & earthworks</p>
<p><i>Pioneering Works Required</i></p>	<p>Yes</p>
<p><i>Construction Risks</i></p>	<p>The remoteness of this site will result in logistics challenges exceeding that of the other sites. Construction downtime can be expected as a result of</p>



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Characteristic	Anjo Peninsula Notes
<ul style="list-style-type: none">• <i>Onshore</i>• <i>Nearshore</i>	cyclones. Access to the site will be impacted during the wet season, even if the access road is sealed. Dredge capacity will have to match the materials, rock is anticipated although volume low.



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4.2 North Head (Map)

Characteristic	North Head (Map) - Notes
TRUNKLINE	
Distance to Fields Woodside Torossa Inpex Icthis	Direct distances are: Woodside 265km Inpex 310km Trunk line length may be slightly larger than these distances to enable appropriate access direction near landfall.
Shore Crossing Availability	The pipeline approaches are limited and the traditional owners desire to maintain the reef outcrops along this section of the shoreline may drive a solution with approaches further along the shoreline. The instability of limestone cliffs along the shoreline does limit options for this activity. The area is exposed and installation will need to be timed with the most appropriate season. Large tides will offer some challenges to pipeline shore crossing installation.
ONSHORE	
Land Area Availability <1000 ha 1000 - 2000 ha >2000 ha	North Head (Map) has a limited area of land available in close proximity to the coast. Siting of a second LNG facility would result in additional run down and loading line distances between the plant/storage/loading facility for the second producer. Downstream processing and support facilities would need to be located further inland to the east of the main plant areas.
Land Form Proposed Plant Elevation (m) Average Gradient (%)	The available land area at North Head is at elevations higher than any recorded storm surge or other seawater intrusions. Ground is generally flat with no apparent difficulties for a precinct.



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Characteristic	North Head (Map) - Notes
Proximity to Coastline - Plant/Storage Tanks/Jetty (m)	Geo hazards associated with collapsing cliff areas will require the plant to be setback from the coast at least 200m.
Available Coastline length for Jetty Access (m)	North Head only provides a limited length of coastline for jetties, sufficient for a LNG hub/precinct, but likely to be seriously constrained for multiuser requirements for any downstream processing.
Geology and Geomorphology	Bossut Formation (coastal limestone) exposed as coastal headland extending offshore as wave cut platform, grading to submerged terraces in Broome/Emeriau Sandstone. Cliffs pass inland to calcareous sand dunes followed by pindan sand plain
Potential Geohazards Settlement Prone Pindan Sands Unstable Cliff Zone Open Fissure Cavities Irregular Rockhead	The limestone is bedded with low to medium rock strength. A distinctive jagged weathering surface is present. Other more significant karstic features observed include basal undercutting of cliffs, large block toppling/rockfalls, open fissure cavities and ground subsidence. There is evidence that this headland is subject to a high wave climate. Sand spit at entrance to Tappers Inlet passes into mangrove swamps and saline deposits. Surface exposures of Emeriau Sandstone 500m inland from the coast could indicate that the depth of pindan sand is not excessive. This type of sandstone is generally more susceptible to weathering than say the Broome Sandstone.
Modularisation Constraints	There are no constraints that would impose limitations on the size or weight of modules for the construction of any plant or support infrastructure.
NEAR SHORE	
Geology and Geomorphology	A significant feature observed was the presence of small breakers outside of the wave cut platform (approximately 250m from beach). These breakers would appear to reflect the presence of a submerged bedrock (possibly Broome Sandstone) terrace extending close to chart datum i.e. very shallow. Outside of the -10m contour (approximately 1km from shore) there does not appear to be any submerged reefs.
Potential Geohazards • High Strength rock	UCS for coastal limestone is likely to be less than 10 to 20MPa. In terms of the underlying bedrock the following UCS ranges are likely: • Emeriau Sandstone; <20 to 30MPa



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Characteristic	North Head (Map) - Notes
(Dredgeability) <ul style="list-style-type: none"> • Irregular Rockhead • Sediment Transportation 	<ul style="list-style-type: none"> • Broome Sandstone; <30 to 50MPa <p>All of the above rocks will contain abrasive quartz being more significant in the sandstones.</p> <p>Rock level likely to step down as a series of terraces draped with marine sediments (calcareous/quartz) increasing in thickness offshore.</p> <p>Longshore drift and tidal movements have led to the sand spit at Tappers Inlet. Shallow rock shoals noted within inlet appear to cover with sediment seasonally.</p>
Tidal Range (HAT and LAT)	HAT – 8.0m LAT – 0m
Surge Height (100yr)	2.5m
Coastal Protection Requirement (Against Maximum Surge)	Not required
Distance to Navigable Water (14m)	4.5km
Dredging Requirements	<p>Medium Requirement.</p> <p>Distance to deep water is approximately 4.5km requiring a long jetty. A possible jetty length of approximately 2km and some dredging is likely to be optimum balance.</p> <p>Materials to be dredged vary between medium difficulty and difficult.</p>
Port Operability <ul style="list-style-type: none"> • Annual • Seasonal 	<p><98%</p> <p>The site is exposed to the Indian Ocean swells, locally generated sea and high currents associated with the tidal range.</p> <p>It is expected that operability will be short of the above requirement. To achieve this benchmark a breakwater will be required.</p>
Berth Availability <ul style="list-style-type: none"> • Annual 	<p><98%</p> <p>The shallow water on the approaches requires a dredged channel to achieve full tidal access, which is likely to be undesirable.</p>



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Characteristic	North Head (Map) - Notes
<ul style="list-style-type: none"> Seasonal 	<p>The current regime is not understood for this site but will include some stages for the tide where current limitations will apply.</p> <p>The port users will require scheduling in spring tides to work with the available windows.</p>
Requirement for Breakwater	Yes
Jetty Length	1.5 – 2km
Suitability for Multiple Berths	Limited
Materials Offload Facility (MOF) Access	Yes, required. Area is available.
SUPPORT INFRASTRUCTURE	
Closest Major Population Centre	<p>Broome is the closest major population centre to North Head. It has a population of approximately 15,000 people which doubles to approximately 30,000 during the peak tourist season.</p> <p>The town includes commercial port facilities a hospital, schools, recreation facilities and international airport.</p>
Distance to Population Centre	<p><i>Distance as the crow flies:- 130km</i></p> <p><i>Distance by Road:- 165km</i></p>
Available Accommodation Area <ul style="list-style-type: none"> Construction Camp Permanent Housing/Camp 	<p>Both construction and permanent workforce accommodation could be provided close to the site.</p> <p>The town of Lombadina is located approximately 70km north of the North Head site (by road). However this is a small community with limited infrastructure. Distance from the plant site and the limited availability of infrastructure would make it difficult accommodate personnel here.</p>



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Characteristic	North Head (Map) - Notes
Road Access Standard <ul style="list-style-type: none"> • Nil • Local Road Standard • State Highway Standard 	<p>Local Road Standard.</p> <p>Sealed to State Highway standard to just south of Willie Creek (approximately 22km north of Broome). A short section is also sealed prior to entering the town site of Beagle Bay.</p>
Distance of required Road Upgrade (km)	<p>110km from site to Broome utilising Broome-Cape Leveque Road.</p>
Airfield <ul style="list-style-type: none"> • Availability and Distance from plant site • Runway Surface • Length 	<p>There is currently an airstrip at Lombadina however it has limited infrastructure and facilities:-</p> <ul style="list-style-type: none"> • Approximate 70km from site; • Sealed; and • 1290m long. <p>A 1000m unsealed airstrip also exists at Beagle Bay.</p> <p>Broome is the closest airfield of significance.</p> <p>It is likely that a new airfield would be required to service the hub development as both airports are a considerable distance from the site.</p>
Power Supply	<p>There is currently no power supply of any significance to the site.</p>
Water Supply Desalination Groundwater	<p>There is currently no water supply of any significance to the site.</p> <p>The Broome Sandstone is a known groundwater aquifer on the Dampier Peninsula. Several bores have utilised this resource at the Beagle Bay Community. High yields of fresh water can be expected in deeper bores located away from the coast.</p>
Waste Water/ Effluent Disposal	<p>There is currently no waste water or effluent system of any significance on the site.</p>
Fire & Emergency Service	<p>There are currently no fire and emergency services located on the site. Lombadina is the closest location of these.</p>
Hospital and Medical Services	<p>There are currently no medical services located on the site. Lombadina is the closest location of these.</p>



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Characteristic	North Head (Map) - Notes
CONSTRUCTABILITY	
<p>Construction Materials</p> <ul style="list-style-type: none"> • <i>Bulk Fill</i> • <i>Paving Material</i> • <i>Concrete Aggregates</i> • <i>Armour Rock</i> • <i>Construction Water</i> 	<p>Primary igneous armour is not available on the Dampier Peninsula. Consequently, any breakwater option will need to consider precast concrete blocks. Alternatively granite is available from the Goldsworthy area of the Pilbara Region but would require cartage over long distances (> 500km). Similarly high quality aggregates will need to be imported (e.g. sealing airstrip).</p> <p>The most likely source of on-site construction materials will be sand fill and sandstone/limestone rockfill won from bulk excavations. A mixture of these various materials would constitute common fill. Bossut Formation & Emeriau Sandstone would be suitable for core or road applications (if sufficient quantities). Given the lack of extensive surface outcrop on-site (particularly Broome and Melligo Sandstones) it is most likely that manufactured materials will have to be imported (nearest likely source rock occurs on plateau near One Arm Point on east coast). Alternatively source from commercial quarries. Seawater to be used for site preparation & earthworks.</p>
Pioneering Works Required	Yes
<p>Construction Risks</p> <ul style="list-style-type: none"> • <i>Onshore</i> • <i>Nearshore</i> 	<p>Based on work to date, constructability issues associated with potential collapsing pindan soils and karstic limestone are considered to have engineering solutions – preliminary subsurface information required as further input.</p> <p>Construction downtime can be expected as a result of cyclones. Access to the site will be impacted during the wet season, even if the access road is sealed.</p> <p>Dredge capacity will have to match the materials, could be materials, >30Mpa that will present difficulties.</p>



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4.3 James Price Point 'A' - North

Characteristic	James Price Point 'A' - (North) Notes
TRUNKLINE	
Distance to Fields Woodside Torossa Inpex Ichthis	Direct distances are:- Woodside 325km Inpex 390km
Shore Crossing Availability	Good Broad area of coastline is available with similar features and conditions for shore approach and extensive areas of sandy beach and flat onshore areas available for pipeline shore crossing installation. Area is exposed and installation will need to be timed with most appropriate season. Large tides will offer some challenges to pipeline shore crossing installation.
ONSHORE	
Land Area Availability <1000 ha 1000 - 2000 ha >2000 ha	This site has a large area of land available (2000Ha+) for the development of LNG and downstream industry in close proximity to the port facility.
Land Form Proposed Plant Elevation (m) Average Gradient (%)	The available land area at <i>James Price Point</i> is at elevations higher than any recorded storm surge or other seawater intrusions. Ground is generally flat with no apparent difficulties for a precinct.
Proximity to Coastline - Plant/Storage Tanks/Jetty (m)	The shoreline offers good potential for the location of plants, storage tanks and jetties with limited set backs required.
Available Coastline length for Jetty Access (m)	Multiple potential jetty launching locations are available at this site.



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Characteristic	James Price Point 'A' - (North) Notes
Geology and Geomorphology	Red silty to clayey sands associated with pindan soils forms moderate scarps along the coast, grading to calcareous sand beaches and wave cut platform developed in sandstone bedrock (Broome Sandstone). More extensive coastal dunes to the north where springs likely.
Potential Geohazards Settlement Prone Pindan Sands Unstable Cliff Zone Open Fissure Cavities Irregular Rockhead	Erosion scours & gullies evident in scarp faces. Based on height of scarp face it appears the pindan profile may be relatively deep inland. Headland represents raised terrace exposing interbedded ferruginous siltstone and sandstone capped with minor laterite deposits. Minor undercutting of cliff face. Siltstone has low to medium strength whereas sandstone is of high rock strength. A distinctive feature of the sandstone is the presence of angular quartz grains to 10mm with heavy mineral laminations.
Modularisation Constraints	There are no constraints that would impose limitations on the size or weight of modules.
NEAR SHORE	
Geology and Geomorphology	Shoreline rock platform extends some 500m from the beach. Distance to -10m CD contour is 8km and the -15m CD contour about 10km. Numerous rocky shoals in the shallow to moderate waters – clearly evident as being exposed above sea level during flyover.
Potential Geohazards • High Strength rock (Dredgeability) • Irregular Rockhead • Sediment Transportation	Shallow rock close to shore with UCS values ranging from: <ul style="list-style-type: none">• Sandstone; <30-50MPa• Siltstone:<10MPa The sandstone is likely to be very abrasive due to angularity and size of constituent quartz. Platform likely to step down as submerged terrace (containing shoals) that extends about 2km from shore
Tidal Range (HAT and LAT)	HAT - 8.7m LAT – 0m
Surge Height (100yr)	2.7m
Coastal Protection Requirement (Against Maximum Surge)	No



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Characteristic	James Price Point 'A' - (North) Notes
Distance to Navigable Water (14m)	10km
Dredging Requirements	<p>Very High</p> <p>Distance to deep water is approximately 9.5km requiring a long channel. The geology indicates sandstone surfaces in the benches of the wave cut platforms with predominantly dredgeable materials but the likelihood that hard materials will be encountered.</p> <p>Predominantly cuttable with LCSD cutter dredges with some limited drill and blast operations (likely to be less than 15%).</p>
Port Operability <ul style="list-style-type: none"> • Annual • Seasonal 	<p><98%</p> <p>The site is exposed to the Indian Ocean swells, locally generated sea and high currents associated the high tidal range.</p> <p>It is expected that operability will fall short of the above requirement and to achieve this benchmark a breakwater will be required.</p>
Berth Availability <ul style="list-style-type: none"> • Annual • Seasonal 	<p><98%</p> <p>The shallow water on the approaches requires a dredged channel to achieve full tidal access which is likely to be undesirable.</p> <p>The current regime is not understood for this site but will include some stages of the tide where current limitations will apply. The port users will require scheduling in spring tides to work within the available windows.</p>
Requirement for Breakwater	Yes
Jetty Length	3 -4km Estimated approximate optimum length of jetty versus dredging.
Suitability for Multiple Berths	Yes
Materials Offload Facility (MOF) Access	Yes



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Characteristic	James Price Point 'A' - (North) Notes
SUPPORT INFRASTRUCTURE	
Closest Major Population Centre	Broome is the closest major population centre to North Head. It has a population of approximately 15,000 people which doubles to 30,000 during the peak tourist season. The town includes commercial port facilities a hospital, schools, recreation facilities and international airport.
Distance to Population Centre	<i>Distance as the crow flies:-</i> 60km (approximate) <i>Distance by Road:-</i> 90km (approximate)
Available Accommodation Area <ul style="list-style-type: none"> • Construction Camp • Permanent Housing/Camp 	Both construction and permanent workforce accommodation could be provided close to the site. Broome is considered to be too far from the plant to accommodate any significant workforce although it is likely that some workforce may be accommodated there to support logistics operations.
Road Access Standard <ul style="list-style-type: none"> • Nil • Local Road Standard • State Highway Standard 	Sealed State Highway standard to south of Willie Creek (approximately 22km north of Broome). North of Willie Creek the road is unsealed and will require upgrade.
Distance of required Road Upgrade (km)	16 km sealed 50km unsealed
Airfield <ul style="list-style-type: none"> • Availability and Distance from plant site • Runway Surface • Length 	Broome is the closest airfield of significance. This is an international airport with significant passenger, freight and some maintenance facilities. <ul style="list-style-type: none"> • The airfield is approximately 90km from the plant site. • The airfield is sealed. • 2458m long, 45m wide



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Characteristic	James Price Point 'A' - (North) Notes
Power Supply	There is currently no power supply of any significance to the site.
Water Supply <ul style="list-style-type: none"> • Desalination • Groundwater 	There is currently no water supply of any significance to the site. Moderate supplies likely from bores targeting sandstone layers within Broome Sandstone
Waste Water/ Effluent Disposal	There is currently no waste water or effluent system of any significance on the site.
Fire & Emergency Service	There are currently no fire and emergency services located on the site.
Hospital and Medical Services	There are currently no medical services located on the site.
CONSTRUCTABILITY	
Construction Materials <ul style="list-style-type: none"> • Bulk Fill • Paving Material • Concrete Aggregates • Armour Rock • Construction Water 	Due to the current uncertainty associated using pindan soils for foundation materials, there are limited options for on-site supply of construction materials at this site. Further, the depth of sand overlying the bedrock inland is likely to preclude any economical quarry development. On this basis, it appears that the most viable option is to supplement pindan soils with dredged spoil. Manufactured material most likely to be imported. Seawater to be used for earthworks.
Pioneering Works Required	Not required, as could commute until established.
Construction Risks <ul style="list-style-type: none"> • Onshore • Nearshore 	Based on work to date, constructability issues associated with potential collapsing pindan soils and karstic limestone are considered to have engineering solutions – preliminary subsurface information required as further input. Construction downtime can be expected as a result of cyclones. Access to the site will be impacted during the wet season, even if the access road is sealed. Dredge capacity will have to match the materials, could be materials >30Mpa that will present difficulties.



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4.4 James Price Point 'B' (Central)

Characteristic	James Price Point 'B' - (Central) Notes
TRUNKLINE	
Distance to Fields Woodside Torossa Inpex Icthyus	Direct distances are:- Woodside - 325km Inpex - 390km
Shore Crossing Availability	Good Broad area of coastline is available with similar features and conditions for shore approach and extensive areas of sandy beach and flat onshore areas available for pipeline shore crossing installation. Area is exposed and installation will need to be timed with most appropriate season. Large tides will offer some challenges to pipeline shore crossing installation.
ONSHORE	
Land Area Availability <1000 ha 1000 - 2000 ha >2000 ha	This site has a large area of land available (2000Ha+) for the development of LNG and downstream industry in close proximity to the port facility.
Land Form Proposed Plant Elevation (m) Average Gradient (%)	The available land area at <i>James Price Point</i> is at elevations higher than any recorded storm surge or other seawater intrusions. Ground is generally flat with no apparent difficulties for a precinct.
Proximity to Coastline - Plant/Storage Tanks/Jetty (m)	The shoreline offers good potential for the location of plants, storage tanks and jetties with limited set backs required.
Available Coastline length for Jetty Access (m)	Multiple potential jetty launching locations are available at this site.
Geology and Geomorphology	Red silty to clayey sands associated with pindan soils forms moderate scarps along the coast, grading to calcareous sand beaches and wave cut platform developed in sandstone bedrock (Broome Sandstone). More extensive coastal dunes to the south.



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Characteristic	James Price Point 'B' - (Central) Notes
Potential Geohazards Settlement Prone Pindan Sands Unstable Cliff Zone Open Fissure Cavities Irregular Rockhead	Erosion gullies to 5m depth observed in scarp faces indicative of significant surface water runoff (likely to be attributed to increased radial drainage along this stretch of the peninsula. Pindan stands as subvertical cliffs at shoreline up to about 5m high (thickness will increase inland). No exposed rock at this headland other than well cemented beach conglomerate (1-2m) thick overlying bedrock. Both rocks display similar strength to those found elsewhere on the peninsula.
Modularisation Constraints	There are no constraints that would impose limitations on the size or weight of modules.
NEAR SHORE	
Geology and Geomorphology	Shoreline rock platform extends some 500m from the beach. Distance to -10m CD contour is 4.5km and the -15m CD contour about 6.5km. Numerous rocky shoals in the shallow to moderate waters – clearly evident as being exposed above sea level during flyover.
Potential Geohazards <ul style="list-style-type: none"> • High Strength rock (Dredgeability) • Irregular Rockhead • Sediment Transportation 	Shallow rock close to shore with UCS values ranging from: <ul style="list-style-type: none"> • Beach conglomerate; 20-30MPa • Sandstone; <30-50MPa Both of these rock types will be abrasive. Platform likely to step down as submerged terrace (containing shoals) that extends about 1km from the coast.
Tidal Range (HAT and LAT)	HAT – 8.7m LAT – 0m
Surge Height (100yr)	2.7m
Coastal Protection Requirement (Against Maximum Surge)	No
Distance to Navigable Water (14m)	6.5km
Dredging Requirements	Medium Distance to deep water is approximately 6.5km requiring a medium length channel. The geology



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Characteristic	James Price Point 'B' - (Central) Notes
	<p>indicates sandstone surfaces in the benches of the wave cut platforms with predominantly dredgeable materials but the likelihood that hard materials will be encountered.</p> <p>Predominantly cuttable with LCSD cutter dredges with some limited drill and blast operations (likely to be less than 15%).</p>
<p>Port Operability</p> <ul style="list-style-type: none"> • Annual • Seasonal 	<p><98%</p> <p>The site is exposed to the Indian Ocean swells, locally generated sea and high currents associated the high tidal range.</p> <p>It is expected that operability will fall short of the above requirement and to achieve this benchmark a breakwater will be required.</p>
<p>Berth Availability</p> <ul style="list-style-type: none"> • Annual • Seasonal 	<p><98%</p> <p>The shallow water on the approaches requires a dredged channel to achieve full tidal access which is likely to be undesirable.</p> <p>The current regime is not understood for this site but will include some stages of the tide where current limitations will apply. The port users will require scheduling in spring tides to work within the available windows.</p>
Requirement for Breakwater	Yes
Jetty Length	2.5km Estimated approximate optimum length of jetty versus dredging.
Suitability for Multiple Berths	Yes
Materials Offload Facility (MOF) Access	Yes, and area available.



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Characteristic	James Price Point 'B' - (Central) Notes
SUPPORT INFRASTRUCTURE	
Closest Major Population Centre	<p>Broome is the closest major population centre to North Head. It has a population of approximately 15,000 people which doubles to 30,000 during the peak tourist season.</p> <p>The town includes commercial port facilities a hospital, schools, recreation facilities and international airport.</p>
Distance to Population Centre	<p><i>Distance as the crow flies:- 50km (approximate)</i></p> <p><i>Distance by Road:- 80km (approximate)</i></p>
Available Accommodation Area	<p>Both construction and permanent workforce accommodation could be provided close to the site.</p> <p>Broome is considered to be too far from the plant to accommodate any significant workforce although it is likely that some workforce may be accommodated there to support logistics operations.</p>
Road Access Standard	<p>Sealed State Highway standard to south of Willie Creek (approximately 22km north of Broome).</p> <p>North of Willie Creek the road is unsealed and will require upgrade.</p>
<ul style="list-style-type: none"> • Nil • Local Road Standard • State Highway Standard 	
Distance of required Road Upgrade (km)	<p>16km Sealed</p> <p>40km Unsealed</p>
Airfield	<p>Broome is the closest airfield of significance. This is an international airport with significant passenger, freight and some maintenance facilities.</p>
<ul style="list-style-type: none"> • Availability and Distance from plant site • Runway Surface • Length 	<ul style="list-style-type: none"> • The airfield is approximately 80km from the plant site. • The airfield is sealed. • 2458m long, 45m wide



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Characteristic	James Price Point 'B' - (Central) Notes
Power Supply	There is currently no power supply of any significance to the site.
Water Supply	There is currently no water supply of any significance to the site.
<ul style="list-style-type: none"> • Desalination • Groundwater 	Good supplies are likely in 100m deep bores targeting the Broome Sandstone away from the coast. Saline intrusions can be expected within several kilometers of the shoreline.
Waste Water/ Effluent Disposal	There is currently no waste water or effluent system of any significance on the site.
Fire & Emergency Service	There are currently no fire and emergency services located on the site.
Hospital and Medical Services	There are currently no medical services located on the site.
CONSTRUCTABILITY	
Construction Materials <ul style="list-style-type: none"> • Bulk Fill • Paving Material • Concrete Aggregates • Armour Rock • Construction Water 	<p>Due to the current uncertainty associated with using pindan soils for foundation materials, there are limited options for on-site supply of construction materials at this site. Further, the depth of sand overlying the bedrock inland is likely to preclude any economical quarry development. On this basis, it appears that the most viable option is to supplement pindan soils with dredged spoil.</p> <p>Manufactured material most likely to be imported.</p> <p>Seawater to be used for earthworks</p>
Pioneering Works Required	Not necessary as could commute until established.
Construction Risks <ul style="list-style-type: none"> • Onshore • Nearshore 	<p>Based on work to date, constructability issues associated with potential collapsing pindan soils and karstic limestone are considered to have engineering solutions – preliminary subsurface information required as further input.</p> <p>Construction downtime can be expected as a result of cyclones. Access to the site will be impacted during the wet season, even if the access road is sealed.</p> <p>Dredge capacity will have to match the materials, could be materials, >30Mpa that will present difficulties.</p>



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4.5 James Price Point 'C' (South)

Characteristic	James Price Point 'C' (South) - Notes
TRUNKLINE	
Distance to Fields Woodside Torossa Inpex Icthyx	Direct distances are:- 325km 390km
Shore Crossing Availability	Good Broad area of coastline is available with similar features and conditions for shore approach and extensive areas of sandy beach and flat onshore areas available for pipeline shore crossing installation. Area is exposed and installation will need to be timed with most appropriate season. Large tides will offer some challenges to pipeline shore crossing installation.
ONSHORE	
Land Area Availability <1000 ha 1000 - 2000 ha >2000 ha	This site has a large area of land available (2000Ha+) for the development of LNG and downstream industry in close proximity to the port facility.
Land Form Proposed Plant Elevation (m) Average Gradient (%)	The available land area at James Price Point is at elevations higher than any recorded storm surge or other seawater intrusions. Ground is generally flat with no apparent difficulties for a precinct.
Proximity to Coastline - Plant/Storage Tanks/Jetty (m)	The shoreline offers good potential for the location of plants, storage tanks and jetties with limited set backs required.
Available Coastline length for Jetty Access (m)	Multiple potential jetty launching locations are available at this site.
Geology and Geomorphology	Dunes of pindan soil and calcareous sand overlie exposures of sandstone bedrock (Broome Sandstone).
Potential Geohazards Settlement Prone Pindan Sands	Bedrock at this site comprises quartz sandstone with subangular grains, high strength and moderate to wide joint spacings. Block shape is tabular reflecting flat bedding planes. A 1-2m thick layer of ferruginous



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Characteristic	James Price Point 'C' (South) - Notes
Unstable Cliff Zone Open Fissure Cavities Irregular Rockhead	conglomerate (derived from erosion of the underlying bedrock surface) is present to the north. The bedrock at this site is the most competent observed, primarily due to partial silicification (secondary cementation) making it more resistant to weathering.
Modularisation Constraints	There are no constraints that would impose limitations on the size or weight of modules.
NEAR SHORE	
Geology and Geomorphology	Shoreline rock platform extends some 500m from the beach. Distance to -10m CD contour is 2km and the -15m CD contour about 4km. Numerous rocky shoals in the shallow waters – clearly evident as being exposed above sea level during flyover.
Potential Geohazards <ul style="list-style-type: none"> • High Strength rock (Dredgeability) • Irregular Rockhead • Sediment Transportation 	Shallow rock close to shore with UCS values ranging from: <ul style="list-style-type: none"> • Ferruginous conglomerate; 20-30MPa • Sandstone; <30-50MPa • Quartzite; >50MPa All of these rock types will be abrasive. Platform likely to step down as submerged terrace (containing shoals) that extends about 1km from the coast.
Tidal Range (HAT and LAT)	HAT – 8.7m LAT – 0m
Surge Height (100yr)	2.7m
Coastal Protection Requirement (Against Maximum Surge)	No
Distance to Navigable Water (14m)	4km
Dredging Requirements	Medium This site does have desirable deep water penetration closer to the shoreline with the 10m contour shifting closer to the shore. This will result in the most desirable dredge scenario of the three potential James Price Point sites, particularly with partial use of tides for



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Characteristic	James Price Point 'C' (South) - Notes
	<p>access.</p> <p>Seabed materials as described herein indicate it is likely that sandstone of varying strength will be encountered. Predominantly cuttable with LCSD cutter dredges with some limited drill and blast operations (likely to be less than 15%) where quartzite was observed in beach outcrops.</p>
<p>Port Operability</p> <ul style="list-style-type: none"> • Annual • Seasonal 	<p><98%</p> <p>The site is exposed to the Indian Ocean swells, locally generated sea and high currents associated the high tidal range.</p> <p>It is expected that operability will fall short of the above requirement and to achieve this benchmark a breakwater will be required.</p>
<p>Berth Availability</p> <ul style="list-style-type: none"> • Annual • Seasonal 	<p><98%</p> <p>The shallow water on the approaches requires a dredged channel to achieve full tidal access which is likely to be undesirable.</p> <p>The current regime is not understood for this site but will include some stages of the tide where current limitations will apply.</p> <p>This southern site does however show the lowest tidal current conditions and shortest distance to deep water making it less susceptible to these conditions. The port users will require scheduling in spring tides to work within the available windows.</p>
Requirement for Breakwater	Yes
Jetty Length	<p>1.5 – 2km</p> <p>Estimated approximate optimum length of jetty versus dredging.</p>
Suitability for Multiple Berths	Yes
Materials Offload Facility (MOF) Access	Yes



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Characteristic	James Price Point 'C' (South) - Notes
SUPPORT INFRASTRUCTURE	
Closest Major Population Centre	<p>Broome is the closest major population centre to James Price Point. It has a population of approximately 15,000 people which doubles to 30,000 during the peak tourist season.</p> <p>The town includes commercial port facilities a hospital, schools, recreation facilities and international airport.</p>
Distance to Population Centre	<p><i>Distance as the crow flies:- 40km (approximate)</i></p> <p><i>Distance by Road:- 70km (approximate)</i></p>
Available Accommodation Area	<p>Both construction and permanent workforce accommodation could be provided close to the site.</p> <p>Broome is considered to be too far from the plant to accommodate any significant workforce although it is likely that some workforce may be accommodated there to support logistics operations.</p>
Road Access Standard	<p>Sealed State Highway standard to south of Willie Creek (approximately 22km north of Broome).</p> <p>North of Willie Creek the road is unsealed and will require upgrade.</p>
<ul style="list-style-type: none"> • Nil • Local Road Standard • State Highway Standard 	
Distance of required Road Upgrade (km)	<p>16km Sealed</p> <p>30km Un-sealed</p>
Airfield	<p>Broome is the closest airfield of significance. This is an international airport with significant passenger, freight and some maintenance facilities.</p>
<ul style="list-style-type: none"> • Availability and Distance from plant site • Runway Surface • Length 	<ul style="list-style-type: none"> • The airfield is approximately 80km from the plant site. • The airfield is sealed. • 2458m long, 45m wide



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Characteristic	James Price Point 'C' (South) - Notes
Power Supply	There is currently no power supply of any significance to the site.
Water Supply	There is currently no water supply of any significance to the site.
<ul style="list-style-type: none"> • Desalination • Groundwater 	Good supplies are likely in 100m deep bores targeting the Broome Sandstone away from the coast. Saline intrusions can be expected within several kilometers of the shoreline.
Waste Water/ Effluent Disposal	There is currently no waste water or effluent system of any significance on the site.
Fire & Emergency Service	There are currently no fire and emergency services located on the site.
Hospital and Medical Services	There are currently no medical services located on the site.
CONSTRUCTABILITY	
Construction Materials <ul style="list-style-type: none"> • Bulk Fill • Paving Material • Concrete Aggregates • Armour Rock • Construction Water 	<p>Due to the current uncertainty associated using pindan soils for foundation materials, there are limited options for on-site supply of construction materials at this site. Further, the depth of sand overlying the bedrock inland is likely to preclude any economical quarry development. On this basis, it appears that the most viable option is to supplement pindan soils with dredged spoil.</p> <p>Manufactured material most likely to be imported. Seawater to be used for earthworks.</p> <p>Any consideration of developing a quarry below the sand to source sandstone for crushing and screening operations along this stretch of the coast should target the bedrock at this site. Note that sandstone typically produces low quality aggregates but it is generally acceptable for secondary armour, rockfill and paving materials</p>
Pioneering Works Required	Not required, as could commute.



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Characteristic	James Price Point 'C' (South) - Notes
<p><i>Construction Risks</i></p> <ul style="list-style-type: none">• <i>Onshore</i>• <i>Nearshore</i>	<p>Based on work to date, constructability issues associated with potential collapsing pindan soils and karstic limestone are considered to have engineering solutions – preliminary subsurface information required as further input.</p> <p>Construction downtime can be expected as a result of cyclones. Access to the site will be impacted during the wet season, even if the access road is sealed.</p> <p>Dredge capacity will have to match the materials, potentially materials, >30Mpa that will present difficulties.</p>



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4.6 Gourdon Bay

Characteristic	Gourdon Bay - Notes
TRUNKLINE	
Distance to Fields Woodside Torossa Inpex Icthyis	Direct distances are: Woodside 440km Inpex 500km
Shore Crossing Availability	Shore crossing locations are limited with Heritage areas located along the coast to the east of the proposed precinct. Limited access and the presence of jetty facilities and the shipping channel to the north of the precinct will also limit access in this location, making the most likely shore crossing to the south of La Grange Bay, increasing the length of Trunk lines from the Browse gas fields.
ONSHORE	
Land Area Availability <1000 ha 1000 - 2000 ha >2000 ha	The Gourdon Bay location is limited in terms of coastal access with only the area immediately to the north of the proposed precinct area being available. The area to the east is unlikely to be accessible due to the presence of Heritage sites which were clearly of concern to the Traditional Owners during the site visit. The coast to the west of the precinct, La Grange Bay, is inaccessible with Mangrove areas and a highly silted shoreline making the establishment of a port impractical and unworkable.
Land Form Proposed Plant Elevation (m) Average Gradient (%)	Based on the digital elevation data available, significant areas of the proposed precinct site are at elevations below 10m and as such are in danger of being inundated in the design storm event. Elevating the site would require the importation of substantial amounts of fill, which may well be Pindan sands, which in turn would require armouring against wave actions in such storms. Land gradients are generally flat and unlikely to have any adverse impact on the establishment of any facility.



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Characteristic	Gourdon Bay - Notes
Proximity to Coastline - Plant/Storage Tanks/Jetty (m)	Tankage can be located in close proximity to the coast line with no identified geohazards. Elevations are such that coastal protection may be required, leading to added costs and risks to operators.
Available Coastline length for Jetty Access (m)	Gourdon Bay only provides a limited length of coastline for jetties, sufficient for a LNG hub/precinct, but likely to be seriously constrained for multiuser requirements for any downstream processing.
Geology and Geomorphology	Site characterized by dune fields ranging from pindan soils to coastal sands over Bossut Formation at the coast. Limestone cliffs pass into narrow beaches and a wave cut platform developed in sandstone bedrock (Frezier Sandstone). At Cape Du Boulay the bedrock includes mudstone. Minor laterite present below pindan. Port Smith inlet includes mangrove swamps.
Potential Geohazards Settlement Prone Pindan Sands Unstable Cliff Zone Open Fissure Cavities Irregular Rockhead	Limestone is friable, cross bedded with low rock strength. Localised cavities & crumbling cliff faces are present due to marine erosion with the larger blocks being detached at the cape. Thin beach conglomerate (Bossut Formation) with medium to high strength overlies sandstone bedrock (high strength). Frezier Sandstone consists mainly of ferruginous quartz sandstone with angular grains and a conglomeratic texture. Lesser interbedded mudstone has low strength. Bedrock likely to be flat lying with limestone extending 1 to 2km inland. Minor erosion rills noted in pindan soil at Cape Du Boulay.
Modularisation Constraints	There are no issues evident which would prevent the adoption of modular construction at this site.
NEAR SHORE	
Geology and Geomorphology	Shoreline rock platform in sandstone extends about 1km offshore and is likely to contain thin cover of marine sediments. Distance to -10m CD contour is 2km and -15m CD contour about 7.5km. These contours represent old shorelines developed parallel to the coast. Numerous limestone shoals apparent in deeper water.
Potential Geohazards • High Strength rock (Dredgeability)	UCS for coastal limestone & mudstone is likely to be less than 10MPa. In terms of the underlying rocks the following UCS range is likely: <ul style="list-style-type: none"> • Beach conglomerate; <20-30MPa • Sandstone; <30-50Ma



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Characteristic	Gourdon Bay - Notes
<ul style="list-style-type: none"> Irregular Rockhead Sediment Transportation 	<p>All of the above rocks will contain abrasive quartz being more significant in sandstone. Rock level likely to step down as series of terraces draped with marine sediments (thickness increasing offshore).</p> <p>Seasonal sediment movement likely associated with discharge and tidal currents from Port Smith inlet.</p>
Tidal Range (HAT and LAT)	<p>HAT – 8.9m</p> <p>LAT – 0m</p>
Surge Height (100yr)	3.4m
Coastal Protection Requirement (Against Maximum Surge)	Possibly
Distance to Navigable Water (14m)	8km
Dredging Requirements	<p>High</p> <p>Distance to deep water is approximately 8km. There are some very definitive wave cut platforms with limestone patch reefs evident in the bathymetry.</p> <p>Material is expected to be predominantly dredgeable materials but the likelihood that hard materials will be encountered.</p> <p>Predominantly cuttable with LCSD cutter dredges with some limited drill and blast operations (likely to be less than 15%).</p>
Port Operability <ul style="list-style-type: none"> Annual Seasonal 	<p><98%</p> <p>The site is exposed to the Indian Ocean swells, locally generated sea and high currents associated with the high tidal range. It is expected that operability will be short of the above requirement and to achieve this a breakwater will be required.</p>



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Characteristic	Gourdon Bay - Notes
Berth Availability <ul style="list-style-type: none"> • Annual • Seasonal 	<p><98%</p> <p>The shallow water on the approaches requires a dredged channel to achieve full tidal access, which is likely to be undesirable.</p> <p>The current regime is not understood for this site but will include some stages of the tide where current limitations apply.</p> <p>The port users will require scheduling in spring tides to work within the available windows.</p>
Requirement for Breakwater	Yes
Jetty Length	3 – 4km Estimated approximate optimum length of jetty versus dredging.
Suitability for Multiple Berths	Limited
Materials Offload Facility (MOF) Access	Yes
SUPPORT INFRASTRUCTURE	
Closest Major Population Centre	<p>Broome is the closest major population centre to <i>Gourdon Bay</i>. It has a population of approximately 15,000 people which doubles to 30,000 during the peak tourist season.</p> <p>The town includes commercial port facilities a hospital, schools, recreation facilities and international airport.</p>
Distance to Population Centre	<p><i>Distance as the crow flies:-</i> 70km (approximate)</p> <p><i>Distance by Road:-</i> 170km (approximate)</p>
Available Accommodation Area <ul style="list-style-type: none"> • Construction Camp • Permanent Housing/Camp 	<p>Both construction and permanent workforce accommodation could be provided close to the site.</p> <p>Broome is considered to be too far from the plant to accommodate any significant workforce although it is likely that some workforce may be accommodated there to support logistics operations.</p>



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Characteristic	Gourdon Bay - Notes
Road Access Standard <ul style="list-style-type: none"> • Nil • Local Road Standard • State Highway Standard 	Sealed State Highway standard to Port Smith Road (approximately 140km south of Broome). Port Smith Road is unsealed.
Distance of required Road Upgrade (km)	20km (approximately)
Airfield <ul style="list-style-type: none"> • Availability and Distance from plant site • Runway Surface • Length 	Broome is the closest airfield of significance. This is an international airport with significant passenger, freight and some maintenance facilities. <ul style="list-style-type: none"> • The airfield is approximately 170km from the plant site. • The airfield is sealed. • 2458m long, 45m wide A small unsealed airstrip exists at Port Smith.
Power Supply	There is currently no power supply of any significance to the site.
Water Supply <ul style="list-style-type: none"> • Desalination • Groundwater 	There is currently no water supply of any significance to the site. Moderate supplies likely from bores targeting Broome Sandstone aquifer underlying Frezier Sandstone. Mudstone main form local aquiclude.
Waste Water/ Effluent Disposal	There is currently no waste water or effluent system of any significance on the site.
Fire & Emergency Service	There are currently no fire and emergency services located on the site.
Hospital and Medical Services	There are currently no medical services located on the site.
CONSTRUCTABILITY	
Construction Materials <ul style="list-style-type: none"> • Bulk Fill 	Away from coastal sand, limestone and pindan sand on-site supply of construction materials appear lacking. Dredged fill likely to be necessary to supplement limited amounts of sand fill and crushed limestone. Depth of



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Characteristic	Gourdon Bay - Notes
<ul style="list-style-type: none">• <i>Paving Material</i>• <i>Concrete Aggregates</i>• <i>Armour Rock</i>• <i>Construction Water</i>	sand likely to make on-site quarry for sandstone uneconomical. Manufactured material most likely to be imported. Seawater to be used for earthworks.
<i>Pioneering Works Required</i>	Yes, camp, construction offices, laydown etc
<i>Construction Risks</i> <ul style="list-style-type: none">• <i>Onshore</i>• <i>Nearshore</i>	<p>Based on work to date, constructability issues associated with potential collapsing pindan soils and karstic limestone are considered to have engineering solutions – preliminary subsurface information required as further input.</p> <p>Construction downtime can be expected as a result of cyclones. Access to the site will be impacted during the wet season, even if the access road is sealed.</p> <p>Dredge capacity will have to match the materials, could be materials, >30Mpa that will present difficulties.</p>



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5. PRELIMINARY SITE LAYOUTS

To assist in our investigations, WorleyParsons has developed a preliminary site layout for each of the four potential sites. These layouts are at a strategic level only indicating three key elements of the sites overall layout (shipping zone, jetty zone and plant zone). The intention of these layouts is to identify a preferred location within each site for these activities and broadly how each site will be oriented. Layouts are included in Appendix 3.

For each preliminary site layout the following will be discussed:-

- Near Shore (Jetties, Materials Offloading Facility (MOF), Channels and Basins);
- On Shore;
 - LNG Layout;
 - Down Stream Industry;
 - Airport;
 - Road Access; and
 - Accommodation.

5.1 Site Layout Principles and Requirements

In developing each of the site layouts WorleyParsons utilised some broad guiding principles for each of the key elements. These are summarised in the following sections:-

5.1.1 Near Shore

- 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.



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- A 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).
- A common shipping channel to deep water could be shared by all site users.

The requirement for a breakwater at the three southern sites of Gourdon Bay, James Price Point and North Head has not been determined. This will depend on the outcome of future berth operability studies which require further numerical analysis and where possible more refined bathymetric and metocean measurements prior to finalising the estimates of port efficiency.

Where the port efficiency which is demonstrated by the level of operability cannot achieve the target values of 98% or greater, a breakwater structure may be required or the operations will be severely compromised (and possibly result in non-viable operations). The cost of a breakwater where it is required is very dependent on available sources of rock materials and the cost of artificial concrete armour units for the severe tropical cyclone design conditions.

It is evident that on the Dampier Peninsula hard rock for any armour or construction requirements is not available. The manufacture of concrete 'X blocks' or the cartage of hard rock from a Pilbara source will also be costly and preliminary estimates for breakwater construction indicate that for a 2 berth port facility the order of cost of a breakwater will be up to \$500M per kilometre or \$800Million for the port. It is also important to note that many of the sites do not provide for a safe and protected natural harbour for the MOF and tug pen facilities. As for the shipping berths, these facilities will also have significant cost penalties for any breakwater protection and this needs to also be factored in any capital estimates.

It is worthy of note that the technical viability and constructability of a breakwater in this area does require some significant further work before the viability can be confirmed. In fact, such a breakwater would be very unique internationally with the design conditions and constructability issues which would need to be addressed. A more detailed assessment of viability is therefore recommended for the sites where port operability is not verified without such a structure and also where no natural harbour sites can be identified for the MOF and tug pen facilities.

5.1.2 On Shore

- An accommodation site/complex/camp could be shared by all user of the precinct.
- An airstrip could be shared by all users of the precinct.



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- 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.
- At least one infrastructure corridor must be provided between downstream industry and the jetties.

5.1.3 Land Requirements and Plant Separation

An important aspect in identifying the suitability of each site is the availability of a suitably sized area of land with the potential to achieve the required separation distances between plants.

The 2008 GCA report prepared for the DoIR indicates that a land area of approximately 300-360Ha is required by each LNG operator. This area increases where more than one operator locates to a single site due to the required separation distances between critical plant components.

WorleyParsons experience with similar plants and industrial complexes suggests the following:-

- A single LNG plant will occupy approximately 500Ha
- Locating multiple LNG plants will increase the total area required for both plants in order to achieve separation distances between each plant;
- Additional land area will also be required to accommodate downstream industry. The total land area required for this will vary depending on the type of industry;
- It maybe possible to reduce the separation distances between LNG plants, however this would need to be agreed by the proponents of each plant;
- A total site area of approximately 1000Ha is required to accommodate up to two LNG operators.

5.1.4 Buffer Zones and Public Access

Public access around each plant will be restricted. There are two exclusion zones to consider in the case the precinct:-



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1. Urban development buffer zone. A buffer zone of approximately 3km to urban development will be required around the precinct. The size and shape of this zone will be determined by prevailing winds and other climatic conditions as well as the types of industry that locate within the precinct.
2. An exclusion zone for the general public of between 200m and 500m will be required. This will be delineated by a fence on land.

5.2 Anjo Peninsula

5.2.1 General

This site is located in close proximity to the northern Browse Basin Oil and Gas fields. It is 500km from Woodside's Torossa field and 350km from Inpex's Icthyus field. This site could also potentially receive gas from fields within the Bonaparte Basin.

5.2.2 Near Shore

Deep water is available relatively close to the eastern shore of the peninsula at many locations resulting in limited need and in some cases no requirement for dredging of approach channels and turning basins. The peninsula provides good shelter to the Mackenzie Anchorage and will allow for high berth operability levels. In fact, the site can be described as a model for a natural harbour in the region.

Due to the shelter offered by the peninsula the jetty zone (areas where jetties can be located) extends from West Bay to the northern tip of the peninsula. Within this zone multiple berths are possible with limited need for dredging depending on the length of jetty utilised. Further, this site is subject to significantly smaller tide range than the remaining Kimberley Region resulting in increased operability

Tug Pens and MOF's could potentially be constructed within the jetty zone along the eastern shore of peninsula in a number of locations utilising natural bays. There is likely to be no need for further protection of these facilities through the construction of breakwaters.

Overall the Anjo Peninsula site offers the opportunity of a sheltered port facility with high levels of operability and limited need for dredging.

5.2.3 On Shore

There is a significant area of land available for development on the peninsula with direct access to the Mackenzie Anchorage. Due to the significant land area available and generally favourable topography of the site, there is good opportunity to achieve optimal layouts for multiple LNG operators industrial



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uses. The area of land available also provides the opportunity for future expansion of the hub beyond the capacity assumed as part of this study (two LNG operators) to include other operators of downstream industry.

To serve the site with an airfield the existing airstrip at Truscott would require upgrading. This airfield is currently used primarily by fixed wing aircraft and helicopters supporting off shore oil and gas operations and includes some maintenance and basic support facilities.

No road access to the site is currently available beyond Kalumbaru. Significant upgrades, including bridging over creek and river crossings, to existing Kalumbaru roads would be required to provide access from the site to the Gibb River Road which will also require upgrading. The cost of this upgrade would be dependent on the level of access required and route selected and is estimated at over \$1B.

Kununurra and Kalumburu are the two closest towns to the peninsula however it is likely that accommodation would be provided on site (both construction and permanent workforce camps) within 5-10km from the plants rather than as part of these existing communities.

5.3 North Head (Map)

5.3.1 General

This site is located approximately 265km from Woodside's Torossa field and 310km from Inpex's Icthyus field.

5.3.2 Near Shore

At North Head a jetty zone approximately 4km from the headland has been identified where deep water is available approximately 4.5km off shore. The precinct will require significant jetty structures from a common location on the shoreline (Layouts must ensure adequate clearances can be achieved at the jetty heads).

Dredging will be required for the entrance channel, turning basins and berth pockets and will be significant, however, it will have the lowest quantity of dredging of the Dampier Peninsula sites. It is likely that a single common breakwater will be required to achieve the target berth operability levels. Tug pens located at this port site will also require dredging and protection by breakwaters, however, operators may elect to minimise this significant cost by utilising Beagle Bay. The acceptability of this to the traditional owners and local community requires further exploration.

The site is subject to large tides and cyclonic conditions, making the breakwater requirement very onerous for these projects and as such requires detailed consideration in site selection.



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5.3.3 On Shore

Access to the port site is constrained due to the landform of the headland. There is limited land available for storage tanks and infrastructure corridors at this location and a significant coastal set back is required due to the presence of unstable limestone cliffs along the coast here.

The plant zone extends inland and south east from the port site in order to achieve enough land area for the LNG plants and downstream industry. The shape of the site is likely to result in the sub-optimal layout of LNG plants as access to the port is limited and plant layouts will need to be arranged to ensure that tanks are located close to the coast whilst trains are aligned to the prevailing winds. The sites shape also makes it difficult to accommodate more than two LNG operators.

Should planning for this site be progressed to a more detailed master plan level it will be important to identify and delineate clearly, the use of critical land adjacent to the shoreline. It is likely that the tendency of the first developer to operate on the site will be occupy all of the available land in close proximity to the shore jetty abutments. The master plan must ensure that this does not occur in order to ensure that the site retains its precinct potential.

Existing airstrips at Lombadina and Beagle Bay would require upgrade in order to accommodate larger aircraft associated with the hubs operations. Whilst accommodation could potentially be incorporated into nearby communities it is likely that a village for both construction and permanent workforces would be most appropriate.

Road access to the site is available however significant upgrades would be required to for both the Broome Cape Leveque Road and local access to the site.

5.4 James Price Point

This section discusses the three potential James Price Point sites collectively rather than individually. Individual differences of a technical nature can be found in the Sections 2 and 3.

5.4.1 General

This site is located approximately 325km from Woodside's Torossa field and 390km from Inpex's Icthis field.

5.4.2 Near Shore

Three potential port sites have been located within the James Price Point location for which the distance to deep water increases between the most southern site and the most northern site, 5.2km, 6.4km and 9.5km respectively. This is a key distinguishing feature of these sites.



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Breakwaters are likely to be required at each of these port sites however further investigations are required to determine the location, size and orientation of these to meet the established target for operability on which this study is based.

Significant dredging will be required at all three port locations however due to the distance to deep water, dredging requirements increase progressively between the southern most and northern most sites. Tug pens located at this port site will also require dredging and breakwaters, making this facility a significant contributor to capital expenditure for these sites.

As for all exposed sites in the Kimberly, this site subject to large tides and cyclonic conditions making the breakwater requirements onerous for the projects and as such requiring detailed consideration in the site selection.

5.4.3 On Shore

Large areas of land are available onshore behind each of the three potential port locations. The landform allows for a relatively uniform shape of these areas and it is therefore likely that optimal layouts can be achieved for the LNG plants. The desire to allow shared use of dredge channels and possible breakwaters, will drive potential configurations and connections near the shoreline. Sufficient land is also available to accommodate additional future LNG operators or downstream industry should this be required.

Whilst Broome is relatively close to these sites (particularly the southern most) it may still be considered prudent to locate construction and permanent workforce accommodation closer to the site on safety grounds. This is an issue that requires further investigation in consultation with the Shire of Broome and needs to be considered in the context of their existing infrastructure, its capacity and the potential for upgrade. Should the decision be made to provide accommodation on site, sufficient land is available.

Road access to all of the sites will require significant upgrade, however the distance to be upgraded increases between the southern and northern most sites. The upgrade would require the southern portion of the Broome – Cape Leveque Road to be sealed and access from this road to each of the sites to be completed.

The closest airfield to the site is Broome International Airport, however it may be considered necessary to construct a new airfield closer to site to minimise transport distances for personnel and freight. If this option is selected sufficient land is available in the vicinity of the site to accommodate this. Alternatively upgrades may be required to Broome Airport in order to accommodate increase passenger and flight numbers. It is noted there is a current proposal to relocate the Broome Airport to a site 12km north east of Broome near the junction with the Cape Leveque Road. The relocation which would include a capacity upgrade is subject to agreement with the traditional owners and is anticipated to be some 10 – 15 years away.



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5.5 Gourdon Bay

5.5.1 General

This site is located approximately 440km from Woodside's Torossa field and 500km from Inpex's Ichthys field.

5.5.2 Near Shore

The port zone for this site is located on the headland immediately south of Gourdon Bay itself. This location offers the shortest distance to deep water (7.8km). Significant dredging and jetty structures will be required to provide vessel access. It is also likely that breakwaters will also be required to achieve the target operability levels at the port. Tug pens located at this port site will require breakwaters and dredging.

In addition the offshore bathymetry is unfavourable in regard to the location of the trunkline approach to Gourdon Bay. This, coupled with exposure to SW swells south of the Lecepedes Islands adds significant length to the trunkline route alignment.

5.5.3 On Shore

Due to the landform in this location access to the port site is constrained. It will be difficult to achieve optimal layouts for the LNG plants at this location due to the competing needs of infrastructure in close proximity to the jetties. If master planning is further progressed for this site, careful consideration will need to be given to ensure development of the site is managed to ensure that the first developer on the site maintains its integrity as a multi-user precinct.

Inland from the port zone a significant area of land is available for downstream and support industry should this be required. Due to the shape of the site (similar to that at North Head) it would be difficult to accommodate more than two LNG operators at this location. The site is located approximately 20km from the Great Northern Highway with access currently via an unsealed track that will require upgrade to facilitate the development.

Accommodation could be provided on site or in Broome although the distance to Broome may be considered too great for daily commuting. If this is the case sufficient land is available for the location of both construction and permanent accommodation villages in close proximity to the site.

The existing airstrip at Port Smith is not currently sealed and would require upgrade if it is to be utilised or an alternative location could be found in close proximity to the site. A third alternative would be to utilise Broome International Airport, however this facility may also require upgrade to cater for the expected increase in passenger and freight volumes.



6. FURTHER INVESTIGATIONS

6.1 Introduction

Following site selection further studies and investigations are required by the proponent in order to refine and further develop engineering concepts. For the purposes of this report, studies are defined as those additional specialist works required to provide key input data for further engineering. The purpose of further studies is to reduce the uncertainties behind the early concept work.

Future studies can be summarised into the following key areas:

- Geotechnical
- Aerial surveys for bathymetry and topography
- Geophysical (near shore) survey
- Meteorological
- Coastal and Oceanographic
- Port design and supply chain modelling

6.2 Geotechnical Surveys

Both onshore and nearshore geotechnical investigations will be required in order to verify assumptions made in regard to foundation conditions, construction materials, jetty substructures, pipeline shore crossings and dredging requirements.

In response to a request from the Department of Industry and Resources, WorleyParsons has developed a scope to undertake preliminary geotechnical investigations at North Head (Map).

6.2.1 North Head (Map) Geotechnical Investigations

OBJECTIVE

The objective of these investigations is to develop a better understanding of the geotechnical conditions at the North Head site. Site investigations identified that the North Head site was relatively unique when compared to the other sites and warranted further investigations to ensure that the implications of prevalent geotechnical conditions are understood.



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The purpose of the site investigation is to develop a geological map of the area and to confirm the extent of potentially collapsible Pindan soils.

SCOPE

The key task of this assessment is to prepare a geological map of the site which will identify geo-hazards such as:

- karstic features along the shoreline in coastal limestone;
- erosion gullies/local depressions in Pindan areas; and
- wave cut platforms and rock shoals.

Solid auger drilling will be undertaken to prove bedrock (sandstone) level and pindan thickness. This will involve utilising existing tracks to drill 40 boreholes, with an anticipated average refusal depth of 10 metres along the tracks. Disturbed drillings are to be logged.

Hand augers will be used to collect 10 disturbed samples to a maximum depth of 3 metres, for the purpose of Classification Testing. Penetration Testing (PSP/DCP) using hand equipment on existing tracks to a depth of 3 metres is also to be carried out. Testing sites are to coincide with hand auger locations.

6.3 Aerial Survey

Detailed bathymetric and topographical data is required to reduce the uncertainties in bulk quantities for earthworks and dredging. This can be achieved through the use of laser technologies, usually LADAR/LIDAR.

6.4 Geophysical (Nearshore) Survey

One of the key areas of uncertainty that has a substantial impact on the length, location and alignment of the LNG jetties, MOF wharf location, the extent of dredging required and port operability is seabed elevation and composition. A seismic refraction survey is required to determine the nearshore geological model and enable a more accurate evaluation of the likely dredging conditions.

6.5 Meteorological

Studies are currently based on meteorological data extrapolated from Broome and other data sets. To provide sufficient baseline data that is site specific a meteorological station should be established



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at the site to commence collection of data sets. At the time of publication, it is understood that some measuring stations, including 'wave rider buoys' have been installed.

6.6 Coastal and Oceanographic

No physical measurements of the metocean processes are available at any of the proposed sites. To provide key input data for port operability, berth location and orientation studies oceanographic surveys are required.

Field measurements would include detailed directional wave, current and water level recordings at proposed berth locations. Sediment transport rates should also be measured at several locations, also in the vicinity of the proposed berths.

6.6.1 Coastal Process Study

Detailed hydrodynamic modelling in order to quantify astronomical tidal velocities and direction is required. This can occur following the completion of the bathymetric survey, nearshore geotechnical investigations, calibrated wave, current, water level and wind datasets. The study will form the basis of siltation, shoreline effects assessment and provide calibrated data to refine port operability estimates.

6.6.2 Wave Modelling

Nearshore wave modelling is required including detailed ambient wave assessment using spectral wave and Boussinesq techniques. The wave modelling output would form the basis for detailed port operability assessment and inputs to the sediment transport modelling.

Cyclone wave modelling is also recommended to quantify the extreme nearshore wave climate, and to incorporate this into a hydrodynamic assessment to assess extreme current velocities and storm surge at the site.

6.6.3 Siltation Modelling

A detailed study is required to assess the spatial movement of sediment. The study would define the potential effects to long shore sediment transport resulting from the port development and the rate of sedimentation in turning basins and entrance channels within each option.

6.6.4 Tsunami Review

A review of the potential impact from tsunamis on any development should be undertaken.



6.7 Port Design and Supply Chain Modelling

Specific additional office-based studies are required for refinement of the port design and operation of any facility, necessary for the next level of cost refinement. This would include:

- Detailed Under Keel Clearance (UKC) Study
- Dynamic Simulation
- Port Operability Assessment
- Channel Navigation Study
- Supply Chain Modelling

The UKC study is recommended to refine the extent and required depth of the entrance channel.

Dynamic Simulation would follow confirmation of berth layouts and include a mooring analysis to provide more refined berth operability envelopes for particular vessels.

Following completion of the field measurement programme, nearshore wave modelling and the dynamic simulation a detailed port operability assessment is required to refine the operability estimates.

A ship navigation study is recommended to assess the port operation procedures and identify potential restrictions during channel transit.

A supply chain model study is required to assess the operational effectiveness of the port that includes ship scheduling, hydrodynamic limits and port operability to optimise onsite storage and assess port availability and throughput. As part of this study an assessment of economies for tide constrained channels and impacts on port availability would be assessed.

6.8 Further Studies - Conclusions

A number of further studies are required to be undertaken by proponents so as to provide input data for the next level of cost refinement. More detailed scoping of these specific areas will be required prior to implementation.



Appendix 1 – Glossary

AHD	Australian Height Datum
CD	Chart Datum
DOIR	Department of Industry and Resources
HAT	Highest Astronomical Tide
KGP	Karratha Gas Plant
KLC	Kimberley Land Council
LAT	Lowest Astronomical Tide
LNG	Liquified Natural Gas
MOF	Material Offloading Facility
NDT	Northern Development Taskforce
UCS	Unconfined Compressive Strength



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Appendix 2 – Base Maps



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Appendix 3 – Site Photos



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Appendix 4 – Preliminary Site Layouts