Appendix C-22

Assessment of Hydrogeology for LNG Precinct at James Price Point, West Kimberley, Western Australia
BROWSE LNG DEVELOPMENT
Desktop Assessment of Hydrogeology for Browse LNG Precinct

Document Cover Sheet

<table>
<thead>
<tr>
<th>Phase:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>WEL Document No:</td>
<td>JA0006RH0087</td>
</tr>
<tr>
<td>Contrat No:</td>
<td>PO # 4510085922</td>
</tr>
<tr>
<td>Equipment Tag No:</td>
<td></td>
</tr>
<tr>
<td>Vendor Document No:</td>
<td>368.09/0</td>
</tr>
<tr>
<td>Rev:</td>
<td>0</td>
</tr>
<tr>
<td>Total # of Pages: (incl Doc Cover Sheet)</td>
<td>26</td>
</tr>
<tr>
<td>Rev: (if applicable)</td>
<td></td>
</tr>
</tbody>
</table>

Vendor shall ensure that documents have been fully checked and approved prior to submitting to WEL

Prepared | Checked | Approved
Date | Date | Date

Notes: 

Supplier/Subcontractor Name, Address and Logo:

WOODSIDE REVIEW / STATUS INFORMATION

- 1. No Comments
- 2. Revise as noted see below
- 3. Revise & Resubmit for Review
- 4. Certified Final
- 5. Information Only
- 6. As Built

To be Returned at:
(INFO, CF, AB or N/A)

0 05/03/10 Issued for Information

Rev Date Description

Revisions to WEL Document No.

Signed: [Signature] Date 5/3/10

Craig Gouplent

Responsible Engineer Name:
WOODSIDE ENERGY LIMITED

DESKTOP ASSESSMENT OF HYDROGEOLOGY FOR BROWSE LIQUIFIED NATURAL GAS PRECINCT

DECEMBER 2009

REPORT FOR WOODSIDE ENERGY LIMITED

Woodside Energy Document J0000AG0006
(Report 368.0/09/01)
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>1.1</td>
</tr>
<tr>
<td>1.2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>3.1</td>
</tr>
<tr>
<td>3.2</td>
</tr>
<tr>
<td>3.2.1</td>
</tr>
<tr>
<td>3.2.2</td>
</tr>
<tr>
<td>3.2.3</td>
</tr>
<tr>
<td>7</td>
</tr>
<tr>
<td>7.1</td>
</tr>
<tr>
<td>7.2</td>
</tr>
<tr>
<td>7.2.1</td>
</tr>
<tr>
<td>7.2.2</td>
</tr>
<tr>
<td>7.2.3</td>
</tr>
<tr>
<td>7.2.4</td>
</tr>
<tr>
<td>9</td>
</tr>
<tr>
<td>9</td>
</tr>
<tr>
<td>11</td>
</tr>
</tbody>
</table>

## Tables

- **Table 1**: Average Rainfall at Broome Airport | 2
- **Table 2**: LNG Precinct Area Extrapolated Average Rainfall and Average Areal Potential Evapotranspiration | 2
- **Table 3**: Summary of Stratigraphy, Canning Basin, Broome 1:250,000 Sheet | 3
TABLE OF CONTENTS
(Continued)

Figures

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>General Location Map</td>
</tr>
<tr>
<td>2</td>
<td>Bore Locations and Licensed Groundwater Users Dampier Peninsula</td>
</tr>
<tr>
<td>3</td>
<td>James Price BLNG Precinct Topographic Contours</td>
</tr>
<tr>
<td>4</td>
<td>Base of the Broome Sandstone</td>
</tr>
<tr>
<td>5</td>
<td>Base of the Wallal Formation</td>
</tr>
<tr>
<td>6</td>
<td>Structure Contours Top of the Grant Group</td>
</tr>
<tr>
<td>7</td>
<td>Geological Cross Section Extrapolate from Oil Well Data</td>
</tr>
<tr>
<td>8</td>
<td>Geological Cross Section A-B Extrapolated from Seismic Survey of Grant Group</td>
</tr>
<tr>
<td>9</td>
<td>Water Level Contours Broome Sandstone</td>
</tr>
<tr>
<td>10</td>
<td>Acid Sulphate Soils Risk Map</td>
</tr>
</tbody>
</table>
INTRODUCTION

This desktop assessment of the local and regional hydrogeology in the vicinity of the proposed Browse Liquefied Natural Gas (BLNG) Precinct at James Price Point, 50 km north of Broome, has been undertaken by Rockwater for Woodside Energy Limited. It contains descriptions of the aquifers that might be utilised for the proposed BLNG Project’s water supplies, and estimates of the groundwater resources and potential effects of development.

At the present planning stage, Precinct Project Area is positioned as shown in Figure 1. It extends about 12 km along the coast and about 8 km inland; these dimensions may be changed in due course.

Hydrogeological information for the assessment has been drawn from field investigations by the Geological Survey of Western Australia (Laws, 1984 a and b, 1985, and 1991) and Rockwater (1985 and 1987), from existing water bores/wells (Department of Water database), and from petroleum exploration wells. Woodside Energy has provided several maps and data-sets used in the assessment.

PHYSICAL FEATURES

TOPOGRAPHY AND DRAINAGE

The precinct is located on the western coastline of the Dampier Peninsula (Fig. 1), which is about 150 km wide from the Fitzroy River estuary to James Price Point. Across the peninsula, ground elevation increases gradually to the maximum of 247 m AHD about 35 km east of James Price Point (Fig. 2). The drainage divide trends north-north-easterly, separating the drainage westerly to the Indian Ocean from that leading easterly to King sound or south-westerly to the Roebuck Plains.

Drainages on the peninsula are shallow, ephemeral, and general sandy. The most prominent westerly drainage is Bobby Creek, located about 80 km north-east of James Price Point, it drains into Beagle Bay.

The BLNG Project appears to be located on an old alluvial fan system (Google Earth, 2009). Two small remnant drainage lines of about 8 km and 20 km length (north and south of the point respectively) drain west-north-westwards to the coast (Fig. 3). The northern drainage line flows directly to the ocean through a steep-sided gorge, while the southern drainage line terminates at the sand dunes, with water most likely discharging into the interdunal swales. Several very small and localised drainage lines (less than 1 km in length) are also present on the site, with rainfall runoff flowing to the beach through well-defined ditches north of the point, or terminating near the coast with water dissipating in low lying areas and in the sand dunes south of the point.
2.2 CLIMATE; RAINFALL

The climate in the Broome area is hot, semi-arid, with mean maximum temperatures ranging from 29°C in June/July to 34°C in December, March and April (Broome airport data). Inland from the coast, the summer temperatures are slightly higher.

Monsoonal rainfall predominates from December to March (Table 1) in the "wet season", when 85 per cent of the annual rainfall of 602 mm is received, on average, at Broome. It is associated with thunderstorms and occasional tropical cyclones and shows considerable variation annually. The "dry season" produces very low rainfall, in the range 1 to 26 mm per month on average.

Annual rainfall apparently varies strongly over the Dampier Peninsula region, with values of 622 mm for Derby, 896 mm for Country Downs Station, and 752 mm for Beagle Bay. Some of the differences in these values are likely to be caused by differing lengths of records for the sites.

Table 1: Average Rainfall at Broome Airport

<table>
<thead>
<tr>
<th></th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sept</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Ann</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainfall (mm)</td>
<td>175.2</td>
<td>180.2</td>
<td>102.0</td>
<td>26.0</td>
<td>26.8</td>
<td>18.3</td>
<td>5.9</td>
<td>1.7</td>
<td>1.3</td>
<td>8.3</td>
<td>54.6</td>
<td>602.4</td>
<td></td>
</tr>
</tbody>
</table>

(Bureau of Meteorology Data; Station No. 3003; Years 1941-2009)

For comparison of average rainfall and average areal potential evapotranspiration at the BLNG precinct, data have been interpolated from the Broome Airport average rainfall multiplied by a factor of 1.17 and the Evapotranspiration Atlas published by the Bureau of Meteorology (2001). The values, listed in Table 2, indicate that on average, rainfall exceeds potential evapotranspiration only in February, and that potential evaporation is 2.7 times greater than the average rainfall.

Table 2: LNG Precinct Area Extrapolated Average Rainfall and Average Areal Potential Evapotranspiration

<table>
<thead>
<tr>
<th></th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sept</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Ann</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainfall (mm)</td>
<td>205</td>
<td>211</td>
<td>119</td>
<td>31</td>
<td>31</td>
<td>21</td>
<td>7</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>10</td>
<td>64</td>
<td>705</td>
</tr>
<tr>
<td>Areal Potential Evapotranspiration (mm)</td>
<td>207</td>
<td>185</td>
<td>191</td>
<td>139</td>
<td>110</td>
<td>88</td>
<td>95</td>
<td>114</td>
<td>149</td>
<td>193</td>
<td>209</td>
<td>220</td>
<td>1900</td>
</tr>
</tbody>
</table>
3 REGIONAL HYDROGEOLOGY

3.1 GEOLOGY

The project area lies within the Canning Basin, a major basin of sedimentary strata lying between the Kimberley and Pilbara blocks of older (Precambrian-age) rocks. The basin here is about 550 km wide in a north-easterly direction, extending from Pardoo Station to Cape Leveque. James Price Point lies about 150 km from its northern edge. To the north of Broome, the strata extend to about 10,000 m below sea level (Gibson, 1983).

A summary of the stratigraphic units in the basin on the Broome 1:250,000 sheet is presented in Table 3.

Table 3: Summary of Stratigraphy, Canning Basin, Broome 1:250,000 Sheet

<table>
<thead>
<tr>
<th>Age</th>
<th>Formation</th>
<th>Thickness Approximate m</th>
<th>Lithology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quaternary</td>
<td>Superficial deposits: eolian,</td>
<td>5-20</td>
<td>Sand, silt clay</td>
</tr>
<tr>
<td></td>
<td>alluvial, estuarine and beach</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>deposits (calcareous)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cainozoic</td>
<td>Superficial deposit: laterite</td>
<td>3</td>
<td>Pisolitic; some massive</td>
</tr>
<tr>
<td>Early Cretaceous</td>
<td>Emerian Sandstone</td>
<td>30</td>
<td>F.gr – c.gr.</td>
</tr>
<tr>
<td></td>
<td>Mellillo Sandstone</td>
<td>30</td>
<td>F.gr. – m.gr.</td>
</tr>
<tr>
<td></td>
<td>Broome Sandstone</td>
<td>280</td>
<td>F.gr. – v.c.gr.</td>
</tr>
<tr>
<td>Late Jurassic –</td>
<td>Jarlemai Siltstone</td>
<td>260</td>
<td>Siltstone, claystone and sandstone</td>
</tr>
<tr>
<td>Early Cretaceous</td>
<td>Late Jurassic</td>
<td>20</td>
<td>F.gr. – c.gr. Sandstone and mudstone</td>
</tr>
<tr>
<td></td>
<td>Alexander Formation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Early (?) to</td>
<td>Wallal Sandstone</td>
<td>360</td>
<td>F.gr. – f.gr. with minor siltstone and</td>
</tr>
<tr>
<td>Late Jurassic</td>
<td></td>
<td></td>
<td>conglomerate</td>
</tr>
<tr>
<td>Early Triassic</td>
<td>Blina Shale</td>
<td>60</td>
<td>Mudstone</td>
</tr>
<tr>
<td>Early to Late</td>
<td>Liveringa Group</td>
<td>200</td>
<td>Sandstone, mudstone, etc</td>
</tr>
<tr>
<td>Permian</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Early Permian</td>
<td>Noonkanbah Formation</td>
<td>200</td>
<td>Mudstone, fine sandstone, limestone</td>
</tr>
<tr>
<td></td>
<td>Poole Sandstone</td>
<td>50</td>
<td>V.f.gr. – f.gr.</td>
</tr>
<tr>
<td></td>
<td>Grant Group</td>
<td>800</td>
<td>F.gr. – c.gr.</td>
</tr>
<tr>
<td>Early Carboniferous</td>
<td>Anderson Formation</td>
<td>2,550</td>
<td>Sandstone, F.gr. – c.gr., siltstone</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>etc</td>
</tr>
<tr>
<td>Older Palaeozoic</td>
<td>Not defined</td>
<td>2,800</td>
<td>Dolomite, limestone, shale etc.</td>
</tr>
<tr>
<td>Devonian,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ordovician</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

F = fine  Vf = very fine  gr = grained  c = coarse

The strata with potential as large groundwater sources are the Broome Sandstone, Wallal Sandstone, and Grant Group. These are productive aquifers, up to several hundred metres thick, developed for water supplies in several parts of the Canning Basin. Permeable formations of lesser thickness - the Alexander Formation and Poole
Sandstone - are considered together with the thicker units beneath them (Wallal Sandstone and Grant Group, respectively).

Structure contours of the bases of the Broome Sandstone and Wallal Sandstone are presented in Figures 4 and 5 respectively, based on those presented by Laws (1991) – derived from seismic and drill-hole data. Structure contours on the top of the Grant Group are presented in Figure 6, based on seismic-derived plots provided by Woodside Energy for this assessment.

North of Broome the strata are folded into broad structures trending approximately east-west: the Fitzroy trough and the Baskerville and Barlee anticlines (designated Baskerville/Fraser River and Barlee/Yulleroo anticlines by some authors – Fig. 6). The gravity low of the Fitzroy trough (Gibson, 1983) extends westerly through the southern part of the BLNG precinct. The anticlines lie respectively to the north and south of the precinct (Fig. 6).

A regional east–west geological cross section is presented in Figure 7, based on the structure contour maps for the bases of the Broome and Wallal Sandstones, and deeper (pre-Jurassic) strata depths extracted from the logs of several oil wells (provided by A. Morey, GSWA). Data were extrapolated to the latitude of the BLNG precinct. Because of the extrapolations, the section is diagrammatic, and the depths are approximate only.

A more-specific geological cross section through the BLNG precinct (Fig. 8) shows the interpreted strata depths incorporating the structure contours of the top of the Grant Group (top) based on seismic-survey results (Fig.6).

The Broome Sandstone is 150 m thick at the coast, with its base at -150 m AHD. Inland (eastwards), the base rises to above sea level locally – notably at the Baskerville Anticline - but is generally below sea level (Fig.4).

The base of the Wallal Sandstone lies at -550 to -600 m AHD at the coast, and eastwards it increases in elevation by up to 150 m to -400 m AHD). With the Alexander Formation, it is overlain by 250 m of Jarlemai Siltstone, separating them from the Broome Sandstone.

The Grant Group (including Poole Sandstone) lies below -850 m AHD at the coast, and it deepens or shallows eastwards depending on the Latitude of the data points (oil wells). The Grant Group is 900 m thick at a distance of 15 km offshore (at Pearl 1), and generally 400 to 600 m thick inland, although it is locally absent as at Barlee 1 oil well (Fig. 7).

Folding of the Grant Group and other pre-Triassic strata has produced east-west trending structures, the Baskerville and Barlee anticlines, separated by the Fitzroy trough (Fig 6). The axis of the latter traverses the southern part of BLNG precinct. Over the tops of the anticlines, lying to the north and south of the precinct, the Noonkanbah Formation has been eroded away leaving eroded Grant Group directly underlying the Wallal Sandstone (Fig 8).
3.2 HYDROGEOLOGY

The investigation is directed towards the provision of water at high production rates, from the aquifers with the greatest potential: the Broome Sandstone, Wallal Sandstone and Grant Group. Thinner aquifers, such as the superficial deposits (e.g., Pindan sand), the Alexander Formation, and the Poole Sandstone are included with their underlying aquifers.

3.2.1 Broome Sandstone Aquifer

The Broome Sandstone is the uppermost, unconfined, aquifer over most of the region except for a lobe about 12 km wide on the crest of the Baskerville anticline where the base of the formation is above the groundwater level. In the vicinity of the BLNG precinct the formation has saturated thickness of 100 to 150 m. It is a layered, fine- to coarse-grained sandstone with minor conglomerate. In the vicinity of Broome it has moderate to high permeability, in the range 12 to 23 m/d (1.44 x 10^4 to 2.75 x 10^4 mD) and averaging 15 m/d (1.79 x 10^4 mD) as indicated by pumping tests on six bores constructed in this aquifer (Laws, 1985). In the Beagle Bay area, test-pumping indicated aquifer permeability of 11 to 29 m/d (1.32 x 10^4 to 3.47 x 10^4 mD) with an aquifer thickness of 250 m.

Groundwater levels in the Broome Sandstone are at about 2 m AHD near the coast, reflecting an unconfined aquifer with groundwater flow to the sea. Inland, the groundwater levels form a mound, up to 69 m AHD (Fig. 9), based on sparse data except near Broome township. The groundwater mound is the result of recharge by infiltration of rainwater and subsurface flow towards the coastlines.

Inland from the coast, water salinities in this aquifer are in the range 250 to 500 mg/L TDS (total dissolved solids). A wedge of salt water occupies the basal part of the aquifer around the coastline, generally reflecting a natural fresh/salt-water interface. In the Broome area, the salt water at the base of the Broome Sandstone is depicted as extending 10 to 13 km inland from the coast (Laws 1991). By extrapolation, the toe of the saltwater wedge at the BLNG precinct is estimated to lie about 6 km inland.

The hydraulic gradient in the Broome Sandstone aquifer at the Latitude of the precinct is 0.0014 westward from the mound, reducing to about 0.0004 near the coast. These values are based on widely-spaced data points. The lower gradient near the coast might be the result of the greater saturated aquifer thickness, and therefore higher aquifer transmissivity.

3.2.2 Wallal Sandstone Aquifer

The Wallal Sandstone is a substantial aquifer which is interpreted to lie between the elevations of -400 to -600 m AHD at the BLNG precinct. It has been tapped by a bore in the Broome township area: ACP No. 1 (Rockwater, 1987). Here, the aquifer top is at -470 m AHD and water levels are about 51 m AHD, giving rise to artesian flows.
The bore, with 36 m of screen, was test-pumped at 1200 m³/d (14 L/s) giving a calculated aquifer permeability of 44 m/d (5.26 x 10⁴ mD).

Generally, the Wallal Sandstone aquifer is confined or semi-confined by the Jarlemai Siltstone which forms an aquitard and separates it from the overlying Broome Sandstone. It may receive recharge by slow leakage through the siltstone, or from the Broome Sandstone if the siltstone is absent.

Hydraulic gradients in the Wallal Sandstone are unknown, because of the lack of water-level data points. The gradients are likely to be lower than those in the Broome Sandstone, given that water levels in the Wallal aquifer are about 50 m higher, at the coast, than those in the Broome Sandstone. Inland, beneath the groundwater mound of the Dampier Peninsula, the groundwater levels are likely to be lower in the Wallal aquifer than in the Broome Sandstone.

Groundwater in the Wallal Sandstone aquifer at Broome is brackish, with salinity of about 5,500 mg/L Total Dissolved Solids (TDS) at bore ACP1. Such values are probably widespread, but there are no data.

The Wallal Sandstone is potentially a source of large supplies of brackish water, with resources probably exceeding those of the Broome Sandstone. Although hydraulic gradients and groundwater recharge sources are undefined, the aquifer appears to have very high transmissivity.

### 3.2.3 Grant Group Aquifer

The Grant Group is a major aquifer of the Canning basin, producing substantial quantities of water at several locations including Ellendale, in the West Kimberley. In the Broome environs it is 500 to 800 m thick, with the top of the Group at about -900 m AHD at the BLNG precinct. Generally, this aquifer is confined by the Noonkanbah Formation, but over the Barlee and Baskerville anticlines it is locally overlain by the Wallal Sandstone. There is potential for groundwater flow between these aquifers, possibly downwards into the Grant Group from the Wallal Sandstone. The Grant Group is widespread in the Canning basin, but is (as interpreted) absent at oil well Barlee 1, where the Wallal Sandstone is underlain by the Carboniferous-age Anderson Formation.

Hydrogeological information on the Grant Group is available in detail from the Ellendale area, 300 km east of Broome. Here, the aquifer has saturated thickness of 110 to 250 m and permeability averaging 8 m/d (9.57 x 10³ mD). Production rates from individual bores are 600 to 2400 m³/d (7 to 28 L/s).

The groundwater in the Grant Group at Ellendale is fresh, with salinity in the range 250 to 400 mg/L total dissolved solids. Such low salinity results from the location of the borefield near the northern edge of the Canning Basin where the Grant Group is in faulted contact with the Devonian reef complexes of the Oscar Range. In the BLNG precinct the salinity in the Grant aquifer is not known. Because the groundwater is recharged via the Wallal
Sandstone on the anticlines, its salinity is likely to be similar to or higher than those in the Wallal, and therefore in excess of 5,000 mg/L TDS. This depends on areal salinity variations in the Wallal Sandstone; to the north, in the Dampier Peninsula, the salinities may differ from those measured near Broome in bore ACP 1.

Elevations of the groundwater levels in the Grant Group are not known, as there are no records of bores penetrating this aquifer on the Dampier Peninsula. Over the central part of the peninsula they are likely to be lower than those in the Broome and Wallal Sandstones, but near the coast they are likely to be higher than those in the Broome Sandstone.

4 POTENTIAL FOR ACID SULPHATE SOILS

4.1 BACKGROUND

Acid sulphate soils (ASS) include actual ASS (soils that have acidified) and potential ASS (soils that have the potential to generate acidity). Acid sulphate soils contain naturally occurring fine-grained metal sulphides, typically pyrite (FeS$_2$), formed under saturated anoxic, or reducing, conditions. They generally occur in Quaternary marine or estuarine sediments, and are predominantly confined to coastal low-lands (elevation less than 5 m AHD). Within these sediments, the soils most likely to pose an environmental risk are Holocene-aged (less than 10,000 years) muds. When oxidised, these materials commonly have a mottled appearance (orange and yellow discolouration) due to oxidation of iron minerals.

In Western Australia, ASS conditions have also been identified in other soil types such as leached sands and silts and the Department of Environment and Conservation (DEC) has identified tidal, intertidal and supratidal flats along the northern coastline in the Pilbara and Kimberley regions as areas of particular concern (DEC 2009). Specifically, areas of concern that may occur in the study area include: shallow tidal flats; shallow estuarine or marine deposits; coastal alluvial valleys; flood plains, and; scalded areas. Sediments containing acid sulphide minerals, such as former marine or estuarine shales, coal deposits and mineral sand deposits all have the potential to create ASS.

Under the Western Australian Planning Bulletin 64/2009 guidelines for development, identification and assessment of ASS is required where:

- Surface elevation is less than 5 m AHD and excavation of greater than 100 m$^3$ of soil is planned;
- Surface elevation is greater than 5 m AHD and excavation of greater than 100 m$^3$ of soil to more than 2 m depth is planned, and;
- Dewatering is required.

Accordingly, a preliminary desktop review has been undertaken to assess the potential for ASS at the development site, and recommendations for sampling and monitoring have been made.
4.2 RESULTS OF DESKTOP REVIEW

The study area for assessment of ASS covers 200 km$^2$, extending 10 km to the north, south and east of James Price Point.

4.2.1 Site Topography and Drainage

Most of the area proposed for development is above 10 m AHD. The site is located on gently sloping land (1:100), dipping to the south-west and north-west away from a broad west-north-westly trending anticlinal structure toward the coast, dropping away at coastal cliffs to the north of the Point, and across sand dunes to the south and further north of the Point (Fig. 3). Two small ephemeral streams flow west-north-west to the ocean, forming a steep-sided gully at the coast in the larger stream to the north, and dissipating into the swales of the sand dunes to the south.

A larger drainage system occurs about 15 km north of the study area, comprising a network of ephemeral creeks flowing north-west to an extensive coastal estuarine environment, between Cape Bertholet and Cape Baskerville at Carnot Bay, but they are outside of the planned development site.

Given the ephemeral nature of the surface drainage in the study area, and the absence of any significant permanent water logging, formation of ASS is unlikely, although some sulphides may be present in the sediments deposited into the swales to south of the Point during high rainfall events. A water-logged area is evident in photographic images from Google Earth, about 12 km north of James Price Point, but this falls outside the current area of investigation.

4.2.2 Vegetation

The study area is predominantly covered by medium density Pindan shrubland and open woodland/forest. There are no indications of mangroves, wetlands or salt tolerant vegetation (with the exception of the coastal vegetation), which would mark areas of concern with regard to ASS, although two small areas of drainage basin south of the point have been identified in a vegetation survey conducted by Biota on behalf of DSD.

4.2.3 Geology

The study area east of the coast is predominantly covered by Quaternary sands, comprising sand, silt and minor gravel of mixed alluvial and aeolian origin. The sands in this region are often referred to as “Pindan Sands”. Along most of the coast, more recently deposited sands form coastal dunes, with some low-energy sediments (silts and clays) laid down in the interdunal swales during stream flow events.
Broome Sandstone outcrops along the cliff face extending over a distance of about 4 km north of James Price Point. Broome Sandstone comprises predominantly fine to very coarse grained sand, but it also has minor siltstone and clay beds, and thin coal seams, which could provide a source of potential ASS if present at this location. Similarly, some sediments within the Broome Sandstone were deposited around formally more extensive tidal inlets and may therefore contain higher amounts of sulphide minerals; such areas are marked by higher groundwater salinity and elevated levels of dissolved magnesium and sulphate.

4.2.4 Acid Sulphate Soils Risk Map

A map of Acid Sulphate Soils Risk was accessed through the DEC web-site: http://www.environment.gov.au and the relevant section area been reproduced in Figure 10. The map shows no significant areas of known risk in the study area; although a narrow strip along the coast has been highlighted south of the Point in the coastal dunes, indicating further investigation may be required for dredging or development activities in this location.

4.3 ASS CONCLUSIONS AND RECOMMENDATIONS

A desktop investigation has been undertaken to ascertain potential risk of ASS at the development site.

The results indicate there is minimal risk of intercepting ASS at the site, with most of the investigation area being above 10 m AHD and few risk factors identified.

However, should dredging or excavation be required along the coast, in the interdunal swales of the sand dunes to the south of the point, or elsewhere to below the water table, then some sampling for ASS in the immediate vicinity of the proposed development should be conducted to confirm the absence of sulphides at that location: this could probably be included in the drilling programme, with samples collected at relevant sites just above and below the water table. Results of groundwater quality sampling from the Broome Sandstone aquifer could also be used to determine whether estuarine deposits are likely to be present in the sandstone at this site.

5 CONCLUSION

Rockwater has undertaken a desktop assessment of the local and regional hydrogeology of the BLNG Precinct at James Price Point on the Dampier Peninsula. The Peninsula is relatively flat and gently rises to an elevation of about 200 m towards the east of the Precinct. The area is typified with sandy medium-density scrubland with shallow ephemeral drainages leading to the Indian Ocean on the western side and to King Sound on the eastern side of the peninsula.
Rainfall ranges from about 602 mm at Broome, 50 km to the south of the Precinct, to 896 mm at Country Downs, about 50 km to the north east.

The Precinct lies within the Fitzroy Trough in Canning Basin. It comprises sedimentary strata which are characterised by two east-west trending structures; the Baskerville anticline to the north and the Barlee anticline to the south.

The stratigraphy of the Fitzroy Trough is summarised as:

- Quaternary superficial deposits (Pindan sand) 5 to 20 m thick;
- early Cretaceous age, Broome Sandstone, 280 m thick;
- late-Jurassic to early Cretaceous age, Jarlemai Siltstone, 260 m thick;
- late-Jurassic age, Alexander Formation, 20 m thick;
- early- to late-Jurassic age, Wallal Sandstone, 360 m thick;
- early-Permian age, Noonkanbah Formation, 200 m thick;
- early-Permian age, Poole Sandstone, 50 m thick; and
- early-Permian age Grant Group, 200 m thick.

At the top of the anticlines the Noonkanbah Formation has been eroded away, leaving the eroded Grant Group directly underlying the Wallal Sandstone.

The Broome Sandstone is unconfined and is the uppermost aquifer over most of the region, except for a lobe about 12 km wide on the crest of the Baskerville anticline where the base of the formation is above the groundwater level. The formation has saturated thickness of 100 to 150 m in the vicinity of the BLNG precinct.

Groundwater produced from the Broome Sandstone is likely to be fresh, about 500 mg/L TDS or less, if the production bores are located about 8 km inland from the coast.

Brackish to slightly saline groundwater should be available at high rates of production from the Wallal Sandstone. The aquifer is estimated to be about 200 m thick and to contain water with salinity of about 5,000 mg/L TDS. Bores designed to test this water source would be drilled to about 650 m depth, and fitted with screens about 100 m in length. High rates of supply from this aquifer are likely to be approved because of its salinity, the water is unlikely to be useful for town water supplies (unless desalination is undertaken), or for agriculture. Therefore, there is likely to be essentially no other demand for the water.

The Grant Group, aquifer which includes the Poole Sandstone, is probably more than 500 m thick in this area, and should be high-producing. In the south-eastern sector, its top should be at -1050 to -1100 m AHD. In the north-eastern sector, the top of the unit is not indicated by the seismic data but it is interpreted to have been eroded from the Baskerville Anticline at unstated depths, probably -950 to -1050 m AHD.

A desktop investigation has been undertaken to ascertain potential risk of ASS at the development site.
The results indicate there is minimal risk of intercepting ASS at the site, with most of the investigation area being above 10 m AHD and few risk factors identified.

Dated: 23 December 2009

Rockwater Pty Ltd

K Johnston
Senior Hydrogeologist

J R Passmore
Principal

G L Bolton
Principal

REFERENCES


FIGURES
FIGURE 6

CLIENT: Woodside Energy Ltd
PROJECT: BLNG Precinct Hydrogeological Study
DATE: December 2009
Dwg. No: 368.0/09/1-6 (JA0006RH0087)

STRUCTURE CONTOURS
TOP OF THE GRANT GROUP

- Fitzroy Unconformity
- Top Grant Subcrop
- Anticline
- Syncline
- 600 Elevation (mAHG)
FIGURE 9

WATER LEVEL CONTOURS BROOME SANDSTONE

From WIN Data and Laws (1991)

CLIENT: Woodside Energy Ltd
PROJECT: BLNG Precinct Hydrogeological Study
DATE: December 2009
Dwg. No: 368.0/09/1-9 (JA0006RH0087)

ROCKWATER PTY LTD

368.0/09/01
From Department of Environment and Conservation website, 2009.

CLIENT:          Woodside Energy Ltd
PROJECT:      BLNG Precinct Hydrogeological Study
DATE:             December 2009
Dwg. No:         368.0/09/1-10    (JA0006RH0087)

ACID SULPHATE SOILS
RISK MAP

Potentially pyritic sediment

CLIENT:          Woodside Energy Ltd
PROJECT:      BLNG Precinct Hydrogeological Study
DATE:             December 2009
Dwg. No:         368.0/09/1-10    (JA0006RH0087)