G3 Groundwater

Report

Dredge Material Placement Facility
Hydrogeological Study

NOVEMBER 2009

Prepared for

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Abbreviations

Abbreviation	Description
AHD	Australian Height Datum
ASS	acid sulfate soil
BoM	Bureau of Meteorology
CSD	Cutter Suction Dredger
DERM	Department of Environment and Resource Management
DMPF	Dredge Material Placement Facility
DI	Deionised
EIS	Environmental Impact Statement
EPP (Water)	Environmental Protection (Water) Policy 2009
GLNG	Gladstone Liquefied Natural Gas
GPC	Gladstone Ports Corporation
K	Hydraulic conductivity (m/day)
km	kilometres
L	litres
LNG	Liquefied Natural Gas
LTV	Long-term trigger values
m^3	Cubic metre, 1,000 L
MAP	Mean annual precipitation
mbgl	metres below ground level
MODHMS	An integrated groundwater and surface water software code
PASS	potential acid sulfate soil
STV	Short-term trigger values
uPVC	Unplasticised Polyvinyl Chloride
URS	URS Australia Pty Ltd
WASP	Waste – Aquifer Separation Principle

Executive Summary

In order to assess the possible impacts of seepage and artificial recharge from the proposed DMPF on the limited groundwater resources at Laird Point, URS conducted a fieldwork program and numerical modelling to simulate possible seepage.

Baseline groundwater and aquifer assessments were conducted based on site specific data obtained from the drilling and testing of monitoring bores, drive spears, and hand auger holes within the proposed DMPF footprint.

Hydrochemical data was obtained through the sampling of the new bores, where possible, and the existing licensed bore, RN91326. These data indicated that the groundwater is of poor quality due to the underlying geology and that the groundwater has limited suitability for use.

Aquifer assessments indicate that unaltered sediments have negligible groundwater resource potential. The potential is, however, enhanced due to secondary processes resulting in discrete secondary aquifers. The bores are low yielding and receive limited rainfall recharge. Groundwater resources associated with the mudflats are negligible due to very low permeability and are hypersaline. The results of the fieldwork confirm that the groundwater has limited environmental value and is not suitable for sustainable extraction.

The dredge material comprises mainly of uncontaminated sand, which has limited acid generating potential. Thus the seepage threat is not dependent on the dredge material composition. A preliminary evaluation of the quality of possible elutriate and long term seepage resulting from the transport water indicates that the seepage could potentially add additional dissolved solids to the already poor quality groundwater within the low beneficial use aquifers.

An integrated surface water and groundwater numerical model, suitable for evaluating variable saturation conditions, was constructed to simulate the potential seepage from the proposed DMPF. The model simulated seepage volumes, based on water and sediment build up on the DMPF, over a 48.8 week (capital dredge) time period. This allowed for the assessment of impacts during the highest probability of seepage occurring from the DMPF. Seepage is recognised to decrease over time due to reduced leakage through the dredge sediment. The average seepage rate was estimated at 340 m^3/day during the 342 day capital dredge deposition period.

Seepage modelling indicates that the seepage will have limited impacts on the groundwater gradients and flow patterns as only changes (rises) in groundwater levels of between 0.2 and 0.6 m are predicted below the DMPF. Groundwater levels down gradient and immediately adjacent to the DMPF will raise by only ~ 0.2 m, which will not result in decant or waterlogged areas as groundwater is > 4 m below surface in the weathered and fractured rock aquifers.

Increases in dissolved solids in groundwater, due to seepage from the DMPF, can occur. Estimates using chloride values, in a steady state scenario, indicate limited increase in chloride concentrations in the groundwater, < 5 % of the initial concentrations due to the capital dredge deposition.

Modelling simulations indicate that the envisaged seepage will not have any marked impacts on the limited poor quality groundwater resources on and adjacent to the DMPF site. Based on the model simulations no active mitigation plans, such as scavenger well systems, are required. A monitoring network and program is recommended to obtain additional information, which can be utilised to validate the model predictions.

1

Introduction

The proposed DMPF will cover an area of approximately 120 ha, and have a capacity of 10.1 million m^3 of consolidated dredged material. The DMPF will also provide some capacity for ongoing maintenance dredging.

External embankments will be constructed to a height of 22 m AHD (in four stages) which, combined with the natural contours of the land, will contain the dredge material. The dredge material will be pumped from the dredger combined with transport water, in the form of seawater, into the DMPF. The dredge material will be separated from the seawater through a series of settling ponds separated by internal bunds with adjustable weirs to allow the seawater to flow from one pond to the next. The dredged material will pass slowly through these structures, allowing the solid material (sand, silt etc) to settle out of the seawater. Following a period of controlled settlement and monitoring, the seawater will be discharged back into the marine environment.

The DMPF will be designed and managed to ensure that the quality of discharge water complies with the relevant environmental authority approval conditions.

1.1 Study methodology

A high level evaluation of the Laird Point proposed site to determine the suitability of disposing marine dredge material from a groundwater perspective, was conducted in early 2009 (URS 2009a).

The preliminary hydrogeology assessment was based on limited site specific data, utilising the Waste – Aquifer Separation Principle (WASP) methodology. The initial impact assessment included an assessment of:

- The potential hazard posed by the DMPF;
- The barrier between the base of the DMPF and the groundwater; and
- The groundwater resource(s).

The initial assessment of the Laird Point dredge spoil placement facility indicated that the site was suitable for dredge material disposal, from a groundwater perspective, within the intertidal zone, however, there may have been a need for the inclusion of groundwater protection measures, such as including compacted clay bases, in the final disposal site design to reduce potential risks to the groundwater regime associated with the discrete weathered and fractured bedrock aquifers associated with the Wandilla Formation.

To further assess the risks and evaluate the potential seepage impacts of the proposed DMPF URS conducted a field work program, which included drilling, aquifer testing, and hydrochemical sampling. The fieldwork allowed for the collection of site specific data. This data was utilised to construct and calibrate a groundwater model, using MODHMS modelling software, to evaluate the potential seepage / artificial recharge risk associated with the DMPF.

The evaluation of the potential seepage, quality and quantity, from the proposed DMPF and the assessment of the environmental values of the groundwater resources (through the collection of site specific data) allowed for the evaluation of potential impacts and the development of mitigation measures, from a groundwater perspective.

Project Description

Dredging operations are envisaged as part of the GLNG Project. A plan specific to the GLNG Project has been prepared to manage the project’s dredge material should it be required. The on-shore disposal of marine dredgings is proposed on an undeveloped site at Laird Point on Curtis Island. The Laird Point site is indicated on Figure 2-1, a locality plan.

The on-shore disposal at the Laird Point site will be achieved by pumping material directly to the disposal site. The intention is to create a bunded area, covering an area of ~120 ha, have a capacity of 10.1 million m^3 of consolidated dredged material. Total volumes of capital dredge spoil to be placed within the on-shore enclosure are estimated at ~ 7 million m^3. The DMPF will have some capacity for ongoing maintenance dredging.

The current design for the Laird Point site, compiled by URS, includes a main embankment which will close off the inter-tidal zone and is to be constructed to a final height of 22 m AHD. Saddle dams are to be designed and constructed on the landward side. The reception lagoons will not be lined due to the low permeable nature of the underlying mudflats and geology. Dredge material will be deposited over the main embankment, allowing for deposition of coarse material at the embankment. This material will then be utilised by the dredge contractor to construct internal bunds, settlement ponds, and water detention areas. The dredge material will flow through a series of internal ponds separated by the internal bunds, with strategically located weirs, to allow the transport (sea) water to flow from one pond to the next. The dredge material will pass slowly through these structures, allowing the solid material (sand, silt, etc.) to settle. Following a period of controlled settlement and monitoring, the water will be discharged back into the marine environment when the water is of suitable quality for disposal.

2.1 Dredge method

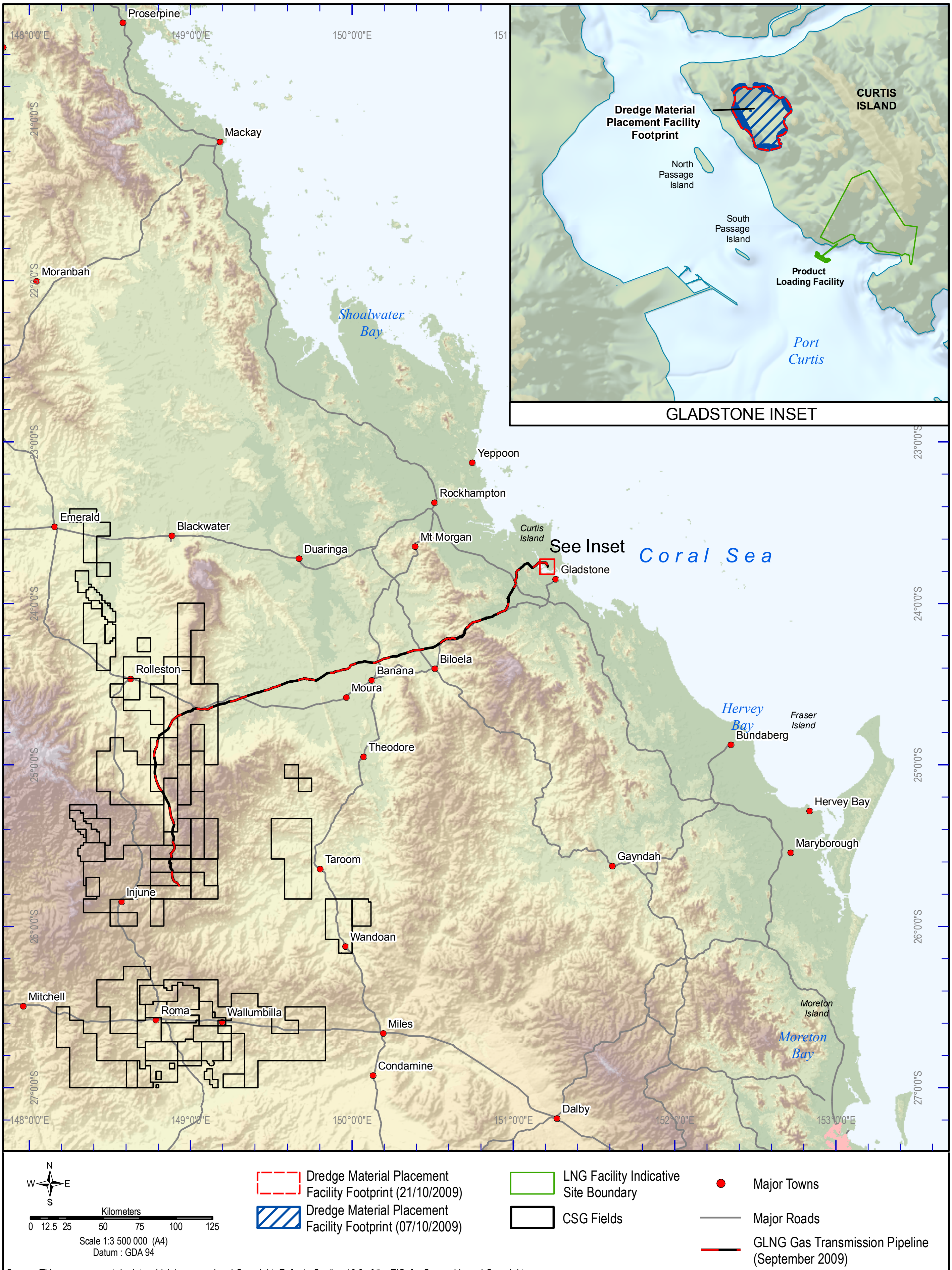
As the areas to be dredged are generally in sheltered waters Santos proposes to use a cutter suction dredger (CSD).

A cutter-suction dredger's suction tube has a cutter head at the suction inlet, to loosen the earth and transport it to the suction mouth. The cutter can also be used for hard surface materials like gravel or rock. The dredged soil is sucked up by a wear-resistant centrifugal pump and discharged through a pipe line. The CSD, with more powerful cutters, can excavate harder rock without blasting.

The dredging methodology involves using a CSD to cut and pump all the material 6 to 7 km to the Laird Point placement facility, based on the following:

- Discharge pipeline with a diameter of 800 mm;
- Dredging will be conducted for an average 140 hours per week;
- The weekly production (silty sand) will be ~ 150 000 m^3/week; and
- The weekly production of rock will be ~ 42 000 m^3/week.

The CSD method was utilised for assessing potential impacts, from a groundwater perspective, during the groundwater study.



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Client

Project

GLADSTONE LNG PROJECT
FOR THE SUPPLEMENTARY
ENVIRONMENTAL IMPACT STATEMENT
DREDGE MATERIAL PLACEMENT FACILITY
HYDROGEOLOGICAL STUDY

Title

REGIONAL LOCATION

Drawn: MG
Approved: MS
Date: 27-10-2009
Job No: **4262 6444** /6220
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Figure: **2-1**
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2.2 Placement

It is proposed that the dredge material will be deposited behind the main embankment to be constructed on the intertidal foreshore. The intention is to enclose the site, with dams created within saddles, to lagoon the dredged material. The dredge material will be pumped, via a pipeline either across land or in the sea, using at least one booster pump. Dredge material will be transported hydraulically, such that a mixture of water and solids will be pumped into the bunded facility. The mixture of water and solids will be pumped directly from the CSD through a pipeline into the containment area at Laird Point.

Based on an envisaged percentage of solid and water (14 % to 86 %) during the course of a week, when dredging silty sand, ~ 140 000 m^3/week of solids and some 856 000 m^3/week of water will be deposited. Data from the Draft Dredge Management Plan (HR Wallingford 2009) indicates the following volumes of material to be dredged and deposited on the proposed site (Table 2-1).

Table 2-1 Dredge volumes utilised in study

Dredge Area	Dredge Volumes (m^3)		Total Volume (m^3)
	Sandy Silt	Rock	
GLNG Basin	5 482 000	193 000	5 675 000
North China Bay approach channel	1 079 000	0	1 079 000
Total volume (m^3)	6 561 000	193 000	6 754 000

The internal design of the DMPF will depend on the rate of settlement and the need to reduce the velocity of the mixture as it flows through the site. The construction of internal bunds, using dredge material, will ensure the detention time required to ensure the settlement of fines. The water can then be discharged back into the ocean once the discharge requirements are met. It is envisaged that the ~ 120 ha Laird Point site is sufficiently large to allow settlement and containment of solids.

2.3 Landward side saddle dams

The preliminary design for the Laird Point site provides some details of the retaining main embankment and saddle dams. Detailed designs have not been developed, especially for the landward side area in the saddles between the surrounding hills, which form the boundaries of the proposed DMPF site. The designs are assumed to include measures to protect against seepage from the dredge material under and through the retaining saddle dams. Thus any potential seepage migration of water could occur below the saddle dams. This seepage can potentially allow migration of poor quality (hypersaline) water off site.

The possible seepage associated with the proposed DMPF footprint has been modelled, assuming the landward saddle dams are of low permeability (1×10^{-5} m/day). The set-up and results of the seepage model are detailed in Section 6.

DMPF Site Description

3.1 Climate

An assessment of the available meteorological data from the three weather stations within the study area was conducted. It is surmised that the area has a sub-tropical climate with three main seasons:

- Cool and dry: April to August;
- Warm and dry: August to November; and
- Hot and wet: November to April.

A brief description of the temperature and rainfall is given below.

3.1.1 Temperature

Long-term information was obtained from the Australian Bureau of Meteorology (BoM) for the weather stations at Gladstone Post Office, Gladstone Radar, and Gladstone Airport. The information is recognised to represent the climate at the project study area.

The mean maximum and minimum temperatures for the three weather stations are summarised in Table 3-1. From the table it can be seen that the average temperature data indicates a limited difference in temperatures, < 10°C difference between the coldest and warmest months.

Table 3-1 Temperature data

Month	Gladstone Post office (1872 - 1958)		Gladstone Radar (1957 -)		Gladstone Airport (1993 -)	
	Min	Max	Min	Max	Min	Max
Jan	22.2	29.9	22.5	31.2	23.0	30.7
Feb	22.1	29.7	22.4	30.9	23.0	30.5
Mar	21.0	29.1	21.5	30.2	21.6	29.8
Apr	18.2	27.8	19.6	28.4	19.0	28.0
May	15.0	25.1	17.0	25.7	15.6	25.7
Jun	12.6	22.8	14.3	23.2	13.3	23.4
Jul	11.4	22.2	13.4	22.8	11.7	22.9
Aug	12.2	23.1	14.2	24.0	12.6	23.6
Sep	15.0	24.8	16.4	26.4	15.5	25.8
Oct	17.9	26.7	18.7	28.4	18.7	27.5
Nov	20.1	28.3	20.5	29.9	20.4	28.7
Dec	21.6	29.6	21.9	31.0	22.1	30.0
Annual	17.4	26.6	18.5	27.7	18.0	27.2

3.1.2 Rainfall

The total annual rainfall records for the study area are variable, as seen in Table 3-2. Long term historical rainfall records from Gladstone Post Office (1872 - 1958) indicates that the study area received a mean annual precipitation (MAP) volume of 1,020 mm, while the shorter more recent records have mean annual rainfall volumes below 1,000 mm. For the seepage assessment modelling the mean annual value for the Gladstone Radar record was used, as this dataset includes recent drought conditions.

Table 3-2 Rainfall data

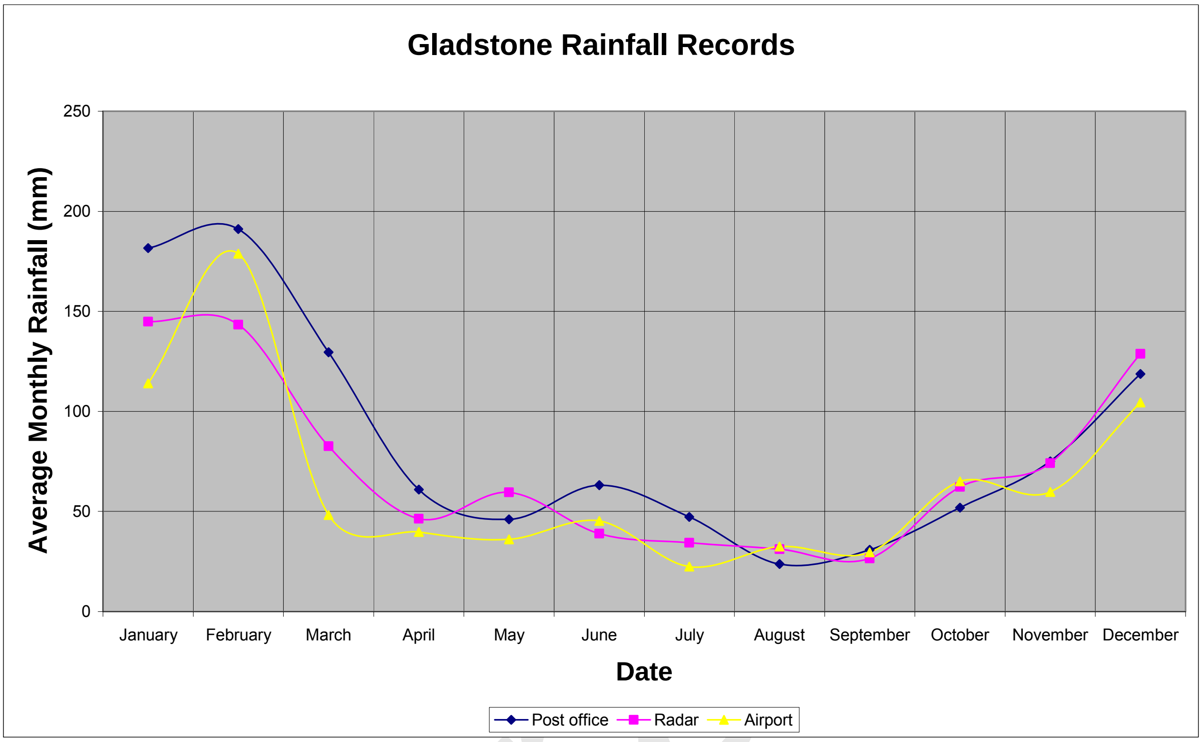
Month	Gladstone Post Office (1872 - 1958)	Gladstone Radar (1957 -)	Gladstone Airport (1993 -)
	Mean	Mean	Mean
Jan	181.6	144.9	114.0
Feb	191.1	143.4	178.8
Mar	129.6	82.6	48.3
Apr	61.0	46.4	39.7
May	46.1	59.6	36.0
Jun	63.1	38.9	45.3
Jul	47.3	34.4	22.4
Aug	23.7	31.2	32.5
Sep	30.9	26.5	29.6
Oct	51.9	62.3	65.0
Nov	75.1	74.2	59.8
Dec	118.7	128.8	104.4
Annual	1 020.8	873.2	771.0

The majority of these falls occur during the summer months (up to 60 %), with January and February receiving the highest total rainfall. Winter has generally had the lowest total rainfalls across the study area.

Figure 3-1 presents the average monthly rainfall data. The distribution and intensity of rainfall, based on these data, is similar across the entire study area.

3 DMPF Site Description

Figure 3-1 Average monthly rainfall data



3.1.3 Evaporation

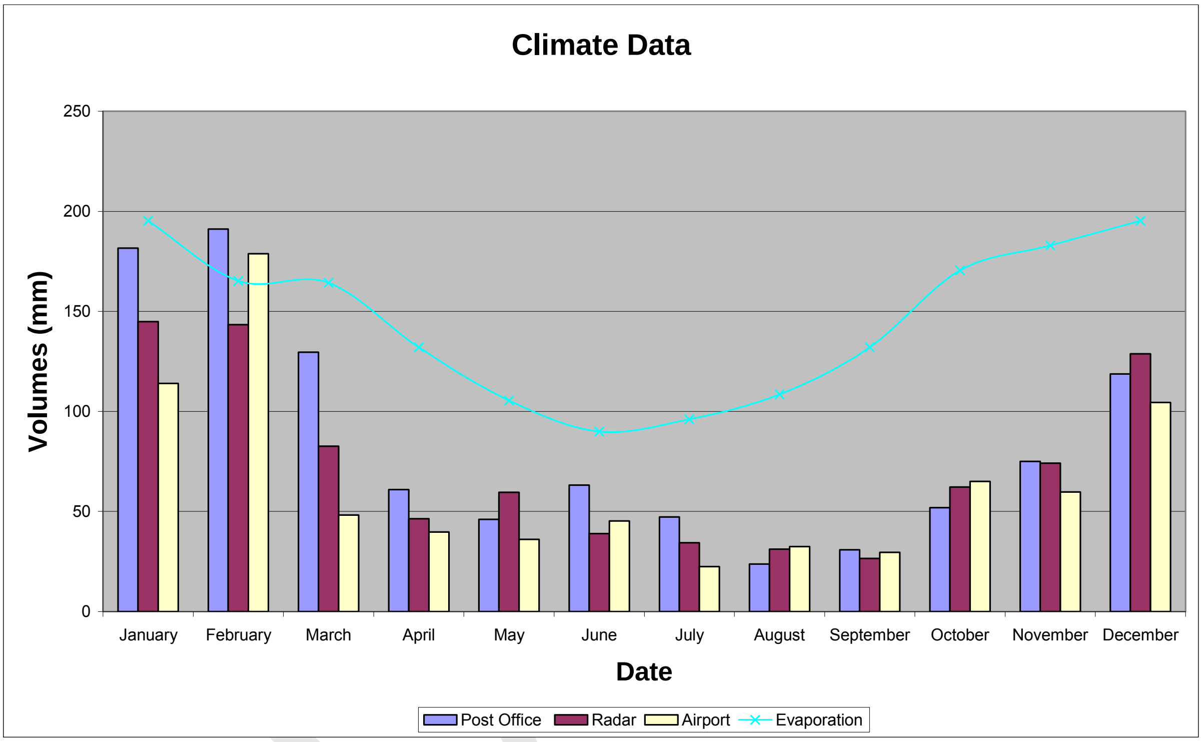
Limited evaporation data is available for the Gladstone study area. BoM data is only available for the Gladstone Radar weather station for the period 1957 onwards. Table 3-3 presents the mean daily evaporation data (in mm) and the calculated average monthly evaporation.

Table 3-3 Gladstone Radar evaporation data

Month	Gladstone Radar (1957 -)	
	Mean daily evaporation	Calculated monthly evaporation
Jan	6.3	195.3
Feb	5.9	165.2
Mar	5.3	164.3
Apr	4.4	132.0
May	3.4	105.4
Jun	3.0	90.0
Jul	3.1	96.1
Aug	3.5	108.5
Sep	4.4	132.0
Oct	5.5	170.5
Nov	6.1	183.0
Dec	6.3	195.3
Annual	4.8	144.8

Evaporation rates (~ 1,752 mm/year) are higher than rainfall, a negative water balance, for the study area. Monthly rainfall and evaporation data mimic each other with the highest rates of evaporation occurring during the summer wet season. Figure 3-2 illustrates the relationship.

Figure 3-2 Evaporation and rainfall data



Evaporation is recognised to exceed rainfall for all months of the year except for February. A mean annual value for evaporation of 1,750 mm/year was used in the seepage modelling.

3.2 Topography

The dredge material placement facility is proposed to be located in a broad, low lying valley area of mudflats, with elevated areas to the north and east. Soils in the area are characterised by deep soft saline clays, silt and muddy sands on the estuarine flats, deep uniform clay and silt loamy surface duplex soils on the alluvial flats, and gravelly loamy surface duplex soils and gravelly clay soils on the lower hill slopes.

A review of topographical maps of the study area indicate that water features at the site are limited to minor drainage features comprising ephemeral watercourses such that the smaller upper catchments will result in water flow only occurring during and immediately after rain events. Downstream of the proposed dredge material placement facility are the intertidal vegetation communities of saltflats and mangroves.

3.3 Regional Geology

The majority of Curtis Island is underlain by the Devonian – Carboniferous aged Curtis Island Group, which consists of a conformable sequence of three formations; the Doonside, Wandilla, and Shoalwater formations. The Curtis Island Group has undergone a regional metamorphic event of upper greenschist to lower amphibolite grade, with the grade decreasing from east to west. The regional structural trend is toward the northwest at 330°.

The metamorphism is associated with the complex structural geology within the study area, which relates to the New England orogeny (folding, faulting, and uplift) and faulting associated with the Narrows Graben structure. The Narrows Graben, a block faulted basin, was formed during a period of crustal extension which occurred throughout eastern Queensland during the Late Cretaceous period. The tectonic activity reactivated northwest trending basement faulting, resulting in subsidence in the region of the Narrows. The Narrows Graben, a block faulted continental basin some 40 km long and 5 km wide, was formed. The southern end of The Narrows Graben forms the Narrows Passage between the mainland and Curtis Island.

The proposed site is underlain by the Wandilla Formation. Structural deformation has produced steeply dipping foliations in the Wandilla Formation. Vertical foliations are also present. These result in north-northwest trending ridges of more competent arenite and greywacke and flatter areas of mudstone. The thickness of the unit is uncertain due to internal folding and faulting. The unit consists mainly of mudstone and arenite, with subordinate chert and minor limestone. The mudstone is characteristically dark grey and is commonly indurated. Lenticular and discontinuous cream sandy laminae are common, with locally developed phyllitic, micaceous sheen developed on cleavage surfaces. Thin quartz veins penetrate the rocks parallel to the major foliation.

The tectonic activities are recognised in the mineralisation of the Wandilla Formation, which contains minor gold, silver, turquoise, and manganese mineralisation on the islands in Port Curtis and on the mainland around Gladstone.

The Laird Point site is underlain by coastal tidal flats, mangrove flats, supratidal flats and grasslands, which comprise mud, sandy mud, muddy sand, and minor gravel. The Holocene sediments comprising tidal flats and surficial alluvial material occur on the western margin of the site and colluvial deposits, comprising silt, sand, and gravel, overlie the Wandilla Formation units. The colluvial deposits and Holocence sediments are between 0.5 and 1.5 m thick on the high-lying ridges and 3 to 5 m thick on the flat areas. Thicker alluvium has been deposited along the drainage lines draining the island. Mud, sand, and gravel estuarine deposits flank the shores in many places. The lithology logged during drilling in the Wandilla Formation included mudstone, sand, gravel, and weathered greywacke. The sediments within the alluvium and estuarine deposits comprise clay, sandy clay, sand, and gravel.

No geological structures (faults, intrusive dykes) have been mapped within the Laird Point site (1: 100 000 Geological Series map Gladstone Special).

3.4 Regional Hydrogeology

The groundwater potential of the Wandilla Formation sediments, in its unaltered state, is limited due to low primary permeability and storage. The groundwater resources can be enhanced through secondary processes, such as faulting and fracturing. Based on the complex regional structural geology and existing bore it is recognised that discrete zones of increased permeability occur within the Wandilla Formation units on site.

Based on a review of the geological data and drilling results from the GLNG EIS study (for the LNG facility on Curtis Island) aquifers were identified within several different units, including:

- Unconsolidated alluvial deposits along the drainage lines;
- The transition zone between weathered and competent bedrock;
- Fractures within the bedrock directly below the transition zone; and
- Zones of deeper weathering.

3.4.1 Regional groundwater resources

The main activities on Curtis Island are recreational use based around the small settlement of South End and a few grazing and forestry enterprises. The northern portion of Curtis Island is a National Park, which extends along the east coast. No resorts or developments have been constructed on the island. As such the main water supply for potable water on the island is rain harvesting.

No significant groundwater usage has been registered on the Department of Environment and Resource Management (DERM) groundwater database within the study area. Only two boreholes have been registered on the entire Curtis Island (578 km^2), located within the south-western portion of the island. The available information for these bores is summarised in Table 3-4.

Table 3-4 Registered groundwater bores

Bore	Depth	SWL	Yield	Aquifer	Comment
RN91326	30 m	10.6 mbgl	0.52 L/s	Fractured mudstone	No hydrochemical data recorded on database, possibly brackish quality
RN91325	27.3 m	10.6 mbgl	3.0 L/s	Fractured mudstone	EC = 12 000 µS/cm, used for stock watering

Bore RN91326 is located within the proposed footprint of the Laird Point site.

Monitoring bores were constructed at the proposed GLNG LNG facility on Curtis Island during the compilation of the GLNG EIS. These bores were drilled into the same geological units and aquifers / aquitards as those identified within the DMPF site. These bores were, therefore, utilised to provide additional hydrogeological data for the study. Three shallow (< 8 m) bores were drilled into the alluvial deposits and five deeper (~ 25 m) bores were drilled to intersect fractures within the bedrock. Table 3-2 presents a summary of the drilling results. The location of these bores is shown on Figure 3-3. Bore RN91326 is presented on Figure 5-1.

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Project

GLADSTONE LNG PROJECT
FOR THE SUPPLEMENTARY
ENVIRONMENTAL IMPACT STATEMENT
DREDGE MATERIAL PLACEMENT FACILITY
HYDROGEOLOGICAL STUDY

Title

GROUNDWATER
MONITORING BORES
LNG FACILITY

Drawn: MG
Approved: MS
Date: 27-10-2009
Job No: **4262 6444** /6220
File: 42626440-g-2062.mxd

Figure: **3-3**

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Table 3-5 GLNG LNG Facility monitoring bores

Monitoring Bore ID	Hole depth (m)	Static groundwater level (mbgl)	Static groundwater level (m AHD)	Aquifer / Aquitard Material	Hydraulic Conductivity (m/day)
Alluvial Deposits					
GW4S	7.7	4.4	-1.2	Clay and Sandy Clay	0.004
GW5	3	1.6	1.6	Clay and Sandy Clay	0.06
GW6	5	4.6	1.8	Clay with trace sand	0.003
Wandilla Formation					
GW1	22.2	9.8	1.7	Fractured greywacke	1.2
GW2S	6	Dry	Dry	Silty, Sandy Clay and Mudstone	NAD
GW2D	24	22.5	1.7	Weathered greywacke	0.02
GW3	6	2.4	0.01	Fractured greywacke	NAD
GW4D	27	5.6	-0.11	Sand and Gravel greywacke	1

NAD - Not Able to be Determined: bore was dry or the recovery was very slow.

Drilling intersected shallow (< 8 m) unconfined aquifers, which comprise poor quality brine groundwater. The shallow aquifers are associated mainly with alluvium material deposited along drainage lines. These aquifers have low permeability (Table 3-5), 0.003 to 0.06 m/day, and receive limited rainfall recharge. The alluvium material has limited saturated thickness, thus the shallow groundwater has limited abstraction potential or use. The shallow groundwater resources within the study area are considered to have limited environmental value.

Zones of secondary alteration, weathering and fracturing, were recorded in the bore logs indicating secondary permeability, which is recognised in the hydraulic conductivity calculations for the deeper bores (> 20 m). The deeper groundwater resources are brackish. The drilling results indicate discrete zones of secondary alteration.

The limited DERM information and the results of the monitoring bore drilling indicate that areas of enhanced groundwater resources are located within discrete alteration zones, which can include fracturing, faulting, and deeper weathering. The aquifer potential of the unaltered sediments is negligible.

Marine Dredge Material

The threat posed by the DMPF on the groundwater resources has been considered. The DMPF has the potential to act as a source of artificial recharge, due to the transport water volumes, which could be enriched with dissolved solids. This can occur as the process of dredging often dislodges elements residing in benthic substrates and injects them into the water column.

The threat posed is considered proportional to the volumes and quality of seepage produced. The threat is, therefore, seen as a factor of the size of the site and the amount of dredge material to be deposited. The footprint of the proposed site is ~ 120 ha with a final height of 22 m AHD. The proposed large footprint and recognised seepage potential indicates that the proposed DMPF could pose a potential threat to the groundwater resources.

Sampling of the dredge material to determine the contamination status of the material was conducted during the GLNG EIS (refer to the Coastal Environment Study and the Sediment Study of the EIS for in depth description of the marine sediments (URS 2009b)). The marine dredge material consists predominantly of sand with clay and silt (grain size between 63 µm and 2 mm). Minor amounts of gravel were recorded in the sediment samples, which were taken offshore in a linear band running parallel with the south western coast of Curtis Island.

The sediment samples were analysed to determine the contamination status, as marine contamination may have occurred in the study area. Potential contaminant sources include sewer outflow, fuel spills, municipal and industrial disposal, runoff, and atmospheric deposition.

The sample results were compared to the following guidelines:

- The Queensland Environmental Protection Agency 1998 Environmental Investigation Levels;
- The National Environmental Protection Council 1999 Health-based Investigation Levels; and
- The Environment Australia 2002 National Ocean Disposal Guidelines (NODG) for Dredged Materials.

Studies in the GLNG EIS indicate that the results from the offshore acid sulfate soil (ASS) assessment revealed that while shallow, near shore accreted silt/clay sediments retained a high potential acid sulfate soil (PASS), the seabed sequence within the main marine passage where dredging is proposed revealed a negative Net Acidity, i.e. has excess buffering capacity. The ASS results, thus, indicate the dredge material may have excess buffering capacity.

The dredge material is recognised to comprise uncontaminated sand, which has limited acid generating potential (limited potential to mobilise metals). Thus the seepage threat is not dependent on the dredge material composition.

During deposition of the marine dredge sediments at the DMPF it is accepted that seawater removed with the sediments could percolate vertically to interact with shallow groundwater at the site. Marine sediments have been collected off-shore and subjected to elutriate and deionised water leaching tests to profile the chemical and physical characteristics of the seawater. This was done as the transport (sea) water associated with the dredge material can potentially become enriched with dissolved solids, which could cause an alteration of the already poor quality underlying groundwater resources. The potential seepage is associated with the transport water quality. In order to evaluate the potential threat an assessment of the following was conducted:

- The elutriate (mixture of sea water and sediment after transport), which represents the initial seepage.

- Leach water from adding deionised (DI) water to the sediment, to represent ongoing seepage due to rainfall infiltration over time.

PLEASE NOTE: The transport and sediment leach information is discussed in detail in the URS surface water study (Attachment G4). The information presented here is based on the preliminary results and provides an initial indication of potential seepage quality as queries have been raised regarding the differences between sediment composition and potential leach concentrations.

Table 4-1 presents the typical composition of sea water and the initial laboratory results to allow for an initial assessment of the potential seepage quality.

Table 4-1 Sea water, elutriate, and leach composition data (in mg/L)

Analytes	Shallow[1] groundwater (mean / (range))	Deep groundwater (mean / (range))	Typical Seawater Composition[2]	Elutriate leach (mean / (range))	DI water leach (mean / (range))
pH	6.1 (6.1 – 6.1)	5.8 (5.3 – 6.2)	7.5 – 8.4		
EC (µS/cm)	13 240	30 900 (1 300 – 60 000)	48 000		
Major anions and cations					
Sulfate	415 (342 – 487)	1 400 (49 – 3 140)	905 (as S)		
Chloride	4 210 (3 370 – 5 050)	12 675 (447 – 27 400)	19 500		
Calcium	176 (29 – 322)	1 219 (28 – 2 050)	412		
Magnesium	364 (170 – 557)	1 355 (30 – 2 630)	1 290		
Sodium	2 195 (2 190 – 2 200)	5 140 (232 – 11 800)	10 770		
Potassium	4 (4 – 5)	16 (3 – 26)	380		
Selected metals					
Aluminium	4.09	0.19 (0.02 – 0.52)	0.0004	0.073 (0.01 – 0.26)	4 .576 (0.24 – 8.27)
Antimony	<0.001	<0.001	0.00024	0.0035 (0.0006 – 0.0059)	0.002 (0 – 0.004)
Arsenic	0.006	0.008 (0.005 – 0.011)	0.0037	0.0043 (0.0008 – 0.0144)	0.01 (0 – 0.024)
Cadmium	0.0003	0.009 (0.0015 – 0.0172)	0.0001	0.0008	0.231 (0 – 1.64)

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[1] Groundwater quality data discussed in Section 5

[2] Source: Ozreef

4 Marine Dredge Material

Analytes	Shallow[1] groundwater (mean / (range))	Deep groundwater (mean / (range))	Typical Seawater Composition[2]	Elutriate leach (mean / (range))	DI water leach (mean / (range))
Chromium	0.002	<0.001	0.0003	0.0006	0.009 (0 – 0.029)
Copper	0.0135 (0.002 – 0.025)	0.005	0.0001	0.0022 (0.001 – 0.004)	0.011 (0 – 0.022)
Iron	4.33 (0.15 – 8.51)	0.85 (0.05 – 1.7)	0.00055	0.163 (0.006 – 0.688)	6.67 (0.44 – 36.8)
Lead	0.090	0.008	0.000002	-	0.005 (0 – 0.012)
Manganese	0.73 (0.516 – 0.943)	10.8 (0.74 – 32.3)	0.0001	1.3 (0.06 – 5.7)	0.073 (0.008 – 0.296)
Mercury	< 0.0001	< 0.0001	0.000001	-	-
Nickel	0.019 (0.006 – 0.032)	0.075 (0.001 – 0.22)	0.00048	0.0019 (0.0005 – 0.0049)	0.005 (0 – 0.015)
Silver	-	-	0.000002	0.0003	< 0.001
Cyanide	-	-	-	-	< 0.004
Zinc	0.098 (0.021 – 0.175)	0.19 (0.012 – 0.658)	0.0005	0.013 (0.006 – 0.022)	0.124 (0.015 – 0.526)

The size of the footprint and the saturated nature of the dredge material indicate that the marine disposal facility has the potential to generate seepage. The resultant seepage could potentially cause an alteration of the groundwater quality, as the possible leachate can potentially be enriched with dissolved solids based on limited initial leach data (Table 4-1).

The seepage, after the placement of the capital dredge material, is envisaged to continue. The quality, as estimated in the DI leach results, will improve with time as the leaching and mobilisation of metals will not continue at the same rate (worst case results indicated in Table 4-1).

An assessment of seepage impacts on the ambient groundwater quality has been conducted in Section 6 based on the seepage model results.

Site Evaluation

5.1 Geology

5.1.1 Bores

Monitoring bores were drilled and constructed adjacent to the proposed DMPF in order to obtain site specific geological and hydrogeological information and to act as long term groundwater monitoring points. The bore locations were selected based on the proposed footprint, which was being considered in August 2009 (URS drawing g-268, dated 11 August 2009). Modifications to the final drill locations were required as the footprint of the DMPF was changed during the field work program[3]. The drill targets were positioned adjacent to the landward saddle dams. These dams have been proposed within the topographic lows (saddles). The monitoring bores were located to obtain ambient groundwater data and could be utilised to monitor potential seepage of groundwater under the saddle dams. The bore construction allowed URS to profile the lithologies under the saddle dams for construction purposes, while providing aquifer characteristics relating to permeability and transmissivity at each of the locations.

Six monitoring bores were drilled at three locations, allowing for a shallow (~ 10 m) and a deep (~ 30 m) bore at each location. This system of nested bores allowed for the evaluation of shallow groundwater occurrence and movement, and the hydrogeology associated with the deeper fractured rock aquifers.

A review of DERM data indicated the presence of an existing registered bore within the Laird Point site. This bore was located and is a privately owned stock watering bore (RN91326 Table 3-4). This bore was included as part of the field sampling scope in order to obtain additional baseline hydrogeological data. Bore RN91326 was equipped and no access to measure bore depth or groundwater level was available (URS did not want to remove the pump in case of damage). Permission from the owner was obtained to sample the bore. All bores within and adjacent to the Laird Point site are presented as Figure 5-1.

Site Geology

The bores were drilled using core and mud rotary drilling. The geology intersected during drilling was logged at 1 m intervals, the resultant bore logs are presented in Appendix A.

The geology intersected comprised clay, siltstone, and mudstone. Groundwater was intersected at varying depths in five of the monitoring bores as monitoring bore GW/BH1A (10 m) was dry. The bores were drilled at a diameter of 100 mm using solid-flight auger and polymer water-boring through soft units and cored using a 75 mm drill-bit through unweathered rock. On completion of the drilling, monitoring bores were constructed using 50 mm diameter uPVC class 18 casing and slotted 0.4 mm screens. The deep bores (30 m) were fitted with 6 metres of screen and the shallow bores with 3 metres of screen. A washed gravel filter pack was installed around the slotted casing to at least 1 m above the screen and a bentonite clay seal was then installed above the filter pack to seal off the screen.

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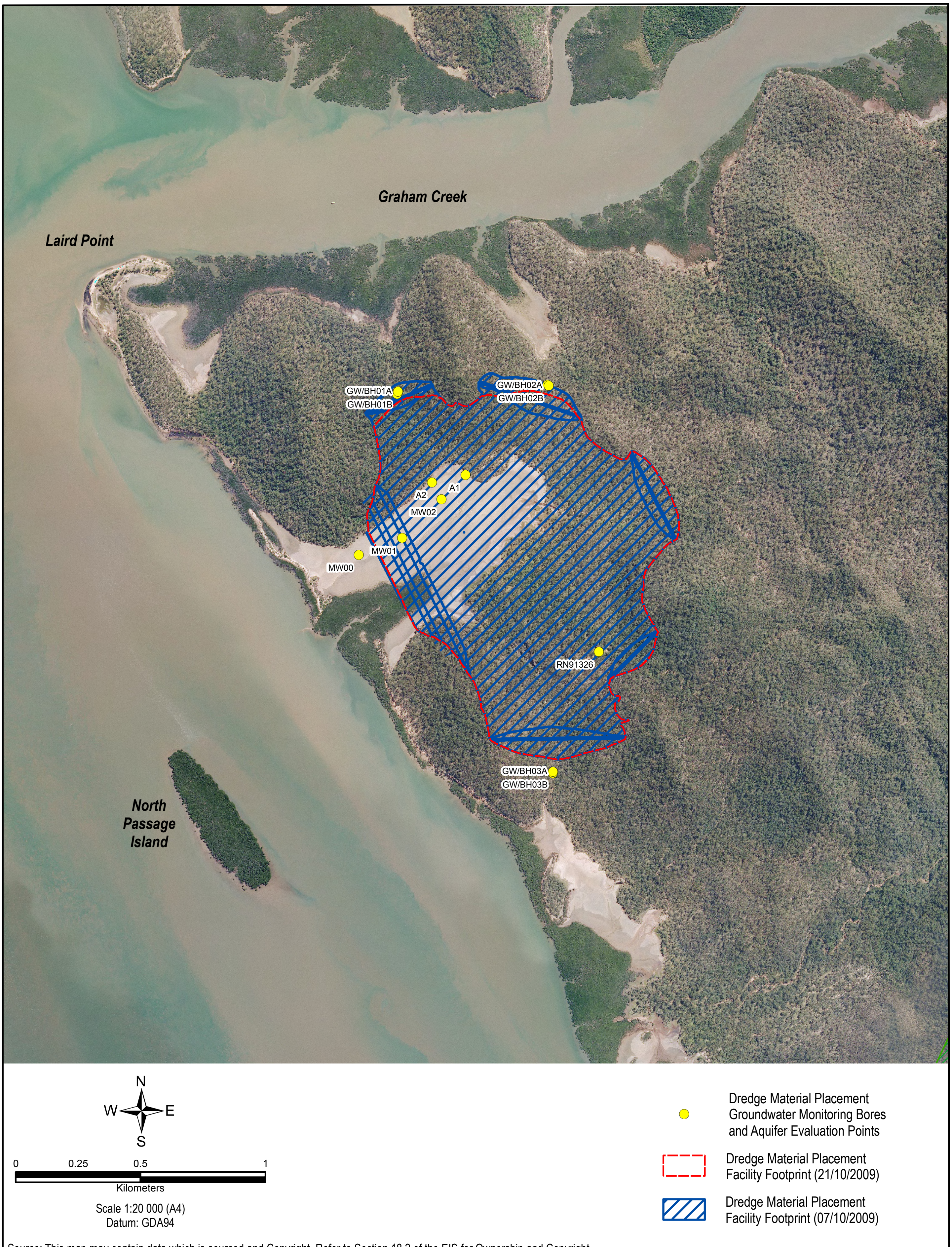
[3] The final footprint changed again due to site restrictions, the revised footprint (07/10/2009) was utilised in the seepage model (section 6). Please note that the final footprint only became available on 21/10/2009 after the completion of the hydrogeological study. The Figures and Appendix D include the latest footprint to indicate the slight variation compared to the footprint utilised for modelling. The slight modification and reduction in footprint is not deemed to alter the model predictions.



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Client

Project

GLADSTONE LNG PROJECT
FOR THE SUPPLEMENTARY
ENVIRONMENTAL IMPACT STATEMENT
DREDGE MATERIAL PLACEMENT FACILITY
HYDROGEOLOGICAL STUDY

Title

GROUNDWATER POINTS
DREDGE MATERIAL
PLACEMENT FACILITY

Drawn: MG
Approved: MS
Date: 27-10-2009

Job No: **4262 6444** /6220
File: 42626440-g-2063.mxd

Figure: **5-1**

Rev.B

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In the deep wells, drill cuttings were used as back-fill between the bentonite and the cement grout at ground-surface, where sufficient drill chips were available. The deep wells were back-filled with cuttings and grout to approximately 1 mbgl, where a cement seal was installed to ground level to prevent possible surface contamination entering the bores. The shallow wells were filled with cement grout from the bentonite plug to ground level.

A pad-locked steel protective monument has been placed over the monitoring bores in concrete to protect the piezometers from damage. The designs and construction adhere to the Minimum Construction Requirements for Water Bores in Australia (QDNR, 2003). A summary of the drilling results is presented in Table 5-1.

Table 5-1 Drilling results

Borehole	Depth (m)	Date	Lithology
GW/BH1A	10	05/08/2009	Clay
GW/BH1B	30	07/08/2009	Clay, Argillite
GW/BH2A	10	07/08/2009	Clay
GW/BH2B	30.0	09/08/2009	Siltstone
GW/BH3A	10.4	10/08/2009	Mudstone, Siltstone
GW/BH3B	30.5	12/08/2009	Clay, Mudstone

Drive Spears

Due to the soft nature of the mudflats within the proposed DMPF no drilling could safely be undertaken using the core or mud rotary drill. Drive spears, comprising stainless steel wedge-wire screen, were manually driven into the mudflats in order to obtain groundwater data. The drive spears were constructed to a length of 1.27 m with an internal diameter of 0.38 m. Constructed of two 600 mm stainless steel sections with a screw joint in the middle, the lower half of the drive spear is stainless steel screen with a 0.4 mm slot width.

The spears were installed, using a weighted hammer, into the mudflats at six different locations on the mudflats. The spears were initially installed across the mudflats and allowed to stabilise. Due to the very low permeability little or no water entered these points. The spears were then removed and installed in three alternative locations. The spears were left in the mudflats to allow access to the shallow groundwater. Water level measurements, variations due to tidal changes, and water quality/geochemistry sampling were undertaken, where possible.

The use of spears did not allow for the logging of geology within the mudflats. Test pits constructed during the URS geotechnical study on site indicate that the mudflats comprise moist stiff silt, clay with gravel, and very stiff clay.

5.2 Groundwater levels

On completion of the groundwater monitoring bores manual groundwater levels readings were compiled to determine the piezometeric levels associated with the shallow and deep bores. The water levels took several days to stabilise as indicated in Table 5-2.

5 Site Evaluation

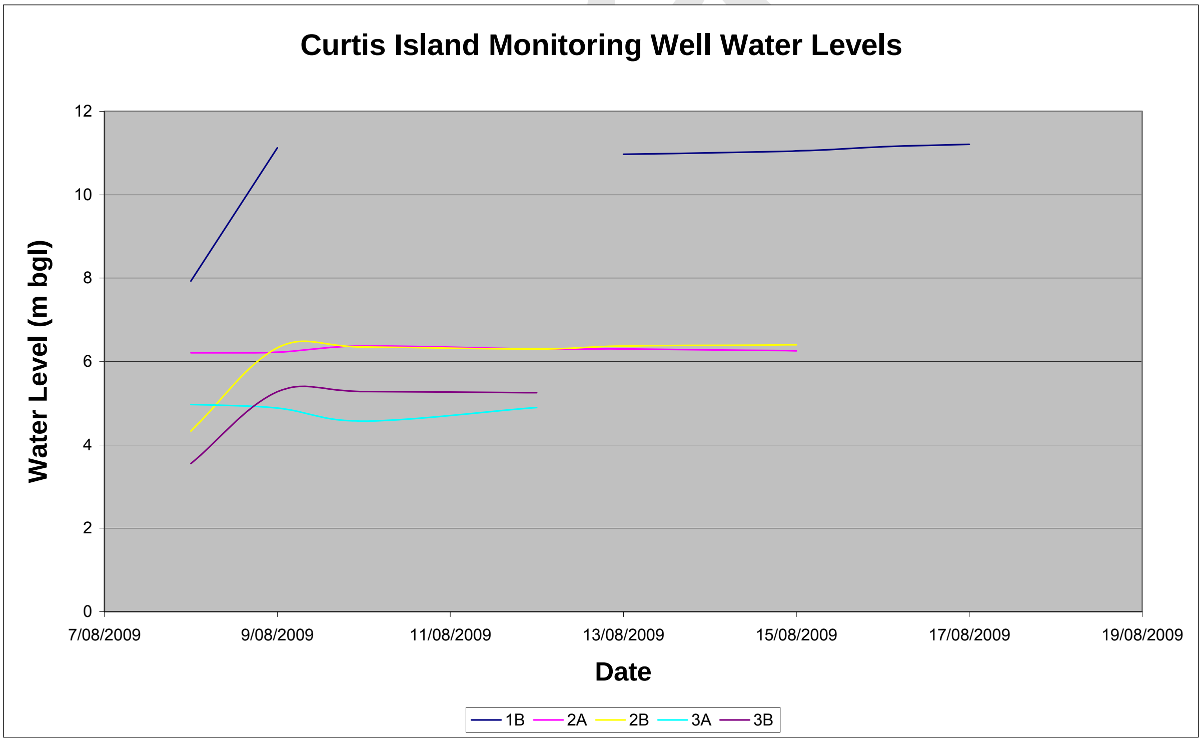
Table 5-2 Manual groundwater level readings

	Well*					
Date	GW/BH1A	GW/BH1B	GW/BH2A	GW/BH2B	GW/BH3A	GW/BH3B
8/08/2009	6.1	7.93				
9/08/2009	DRY	11.13				
10/08/2009			6.21	4.33		
12/08/2009			6.225	6.33		
13/08/2009		10.97	6.37	6.35	4.97	3.55
15/08/2009		11.05	6.3	6.3	4.885	5.275
16/08/2009		11.15	6.3	6.37	4.57	5.28
17/08/2009	DRY	11.21	6.255	6.4	4.895	5.25

🟨 Measurement taken following installation just before sampling (polymer affected)

* All water levels are in metres below ground level

Figure 5-2 Manual water level data



Once stabilised the groundwater levels were measured to metres above Australian Height Datum (m AHD). These data were then used to construct groundwater contours to determine groundwater flow patterns and gradients prior to any DMPF activities. These data were used as the initial heads for the groundwater seepage model in Appendix D (Figure D4). Table 5-3 presents the groundwater level data utilised to determine initial heads.

Table 5-3 Corrected groundwater level data

Bore	Groundwater level (mbgl)	Elevation (m AHD)[4]	Groundwater level (m AHD)
Shallow			
GW/BH1A	Dry	12.4	-
GW/BH2A	6.255	6.95	0.695
GW/BH3A	4.895	5.12	0.225
Deep			
GW/BH1B	11.21	12.2	0.99
GW/BH2B	6.4	7	0.6
GW/BH3B	5.25	5.29	0.04

Groundwater flow patterns (Figure D4), based on the deep groundwater levels measured in bores GW/BH1B, GW/BH2B, and GW/BH3B, is from north to south across the site at an average gradient of 1:1 430 (a 0.7 m drop every 1 km).

5.3 Aquifer tests

The monitoring bores that were drilled and constructed were subjected to variable head (rising and falling) tests to determine site-specific aquifer hydraulic characteristics, which assisted in describing the ambient hydrogeology.

The rising head aquifer testing involved the following:

- An electronic data logging pressure transducer was set to take water level measurements at 1 second intervals;
- The transducer was installed inside the monitoring point below the water level;
- The depths to water were measured in the monitoring well from top of casing;
- A disposable plastic bailer was lowered down the monitoring well and allowed to fill with water;
- The bailer was removed from the monitoring point to produce an instantaneous change in head and a stop watch was started to measure time;
- The monitoring point was allowed to recover to at least 80 % of the initial standing water level;
- The transducer was retrieved and the data was downloaded; and
- The data was analysed graphically using the methods of Hvorslev (1951) to determine estimates of the aquifer hydraulic conductivity.

Bore GW/BH1A, which was a dry bore, was subjected to a falling head test. Ten litres of water was injected into the bore and the water level decline (falling head) was monitored using a pressure transducer data logger. The results of the aquifer tests are presented in Appendix B and are summarised in Table 5-4.

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[4] Please note the elevation data was obtained from aerial photography as the bores have not yet been surveyed.

5 Site Evaluation

Table 5-4 Aquifer hydraulic parameter data

Monitoring Bore	Lithology Screened	Duration (hrs)	Transmissivity (m^2/day)	Hydraulic conductivity (m/day)	Method of Analysis
Shallow					
GW/BH1A	Clay	18	-	0.00002	Falling head
GW/BH2A[5]	Clay	-	-	-	-
GW/BH3A	Mudstone, Siltstone	18	0.02	0.006	Hvorslev
Deep					
GW/BH1B	Clay, Argillite	15.5	0.35	0.06	Hvorslev
GW/BH2B	Siltstone	18	0.01	0.03	Hvorslev
GW/BH3B	Clay, Mudstone	18	0.26	0.04	Hvorslev

The results indicate poor groundwater resources within the bores drilled on site. The drilling and aquifer test data indicates that the majority of the surficial geology within the proposed DMPF site has little or no groundwater potential in its unaltered state. The DERM data indicates the occurrence of low to moderate yielding bores, indicating discrete zones of increased groundwater potential due to secondary processes. It is, therefore, envisaged that discrete zones of alteration, with increased groundwater potential, can occur within the DMPF site.

Bore RN91326 was reported (DERM database) to have had a blow-out yield of ~ 0.5 L/s during drilling. Unfortunately the bore was equipped with a submersible pump, which did not allow URS to access the bore to obtain groundwater level data. The bore could, therefore, not be utilised for aquifer testing.

As no significant groundwater was intersected during drilling the aquifer data compiled during the field testing was utilised to set-up the numerical groundwater model, in order to assess potential seepage.

Drive Spears

Falling (variable) head tests were undertaken at three sites, MW0, MW1, and MW2, (Figure 5-1) to investigate the hydraulic conductivity of the marine silt and mud. Tests were undertaken over approximately a 24-hour period with the fall in head monitored using pressure transducer data loggers. Due to a programming error, only data from MW1 and MW2 was available for analysis. The results of the falling-head tests are presented in Appendix B and are summarised in Table 5-5.

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[5] Automated pressure transducer logger incorrectly programmed resulting in insufficient data for accurate evaluation

Table 5-5 Hydraulic conductivity data for the mudflats

Drive Spear	Lithology Screened	Permeability (m/day)	Method of Analysis
MW1	Marine silt and mud	0.2	Hvorslev
MW2		0.003	Hvorslev

In order to further assess the aquifer parameters associated with the mudflats, automated pressure transducer data loggers were installed to measure the change in groundwater levels due to tidal influences. For drive spears MW0 (closest to the sea) and MW2 (furthest from the sea) the variation in water levels between high and low tides was 10.5 and 7.5 cm, respectively. This damping of the tidal difference within the mudflats indicates sediments with lower hydraulic conductivity values. This corresponds to the low K value recorded within MW2 (Table 5-5).

For MW1 the variation in the water level over time, due to tidal influence, was ~ 80 cm (poor data was collected during this test). This larger response indicates high K values, which corresponds to the falling head test results for MW1 (Table 5-5).

A review of the aerial photographs indicates that the drive spears MW0 and MW2 were installed in damp / wet silty marine mud. This material has high porosity but very low permeability, thus the material remains wet, i.e. does not drain readily. The drive spear MW1 was installed in a dry section of the mudflats, which has higher permeability and drains more readily, which indicates limited effective storage.

Two zones, a wet and a dry, were recognised across the site and thus two zones of K were included in the seepage model for the mudflats.

Hand auger holes

Two hand auger holes were constructed within the unsaturated zone at the base of the hills. These auger holes were utilised for falling head tests in order to obtain site specific data for the unsaturated zone.

The auger holes, A1 and A2 (Figure 5-1), were constructed on the edge of the mudflats. The auger holes intersected fine grained clay and mud, which contained organic material (roots). The material, where moist, had moderate to good plasticity. Falling head tests (Appendix B) indicated that the unsaturated soil cover had high to moderate permeability, 0.5 to 3.1 m/day for A2 and A1, respectively. The higher K data is as a result of cracks forming within the dry clay.

The higher K of the unsaturated clay material on surface facilitates infiltration of rainfall runoff as evident when considering the surface water drainage patterns across the site. Drainage lines are recognised through the saddles, which facilitate the ephemeral flows. These flows are deemed to fan out and seep below the mudflats as limited well defined drainage lines are evident from the saddles across the mudflats.

The results of the evaluation for the unsaturated zone were included in the seepage modelling. The model allowed for a variation in saturation with time to allow for the change in leakage through the unsaturated zone below the site.

5.4 Hydrochemistry

Monitoring Bores

Representative groundwater samples were collected from all monitoring boreholes, except GW/BH1A which was dry. A sample was also collected from a privately owned stock watering bore (RN91326) for comparative reasons.

The bores were purged and samples were stabilised / preserved on site and delivered to an accredited analytical laboratory. The field measurement and purge volume details are summarised in Table 5-6.

Table 5-6 Field measurements

Bore	Dissolved oxygen (mg/L)	pH (pH units)	Electrical conductivity (µS/cm)	Temperature (ºC)	Redox potential (Eh)
GW/BH1B					
1 volume	2.30	5.35	40 300	26.4	101 mV
2 volume	1.70	5.26	43 100	26.5	103 mV
3 volume	1.76	5.19	44 000	26.9	124 mV
GW/BH2A					
1 volume	2.96	6.19	12 680	25.7	116 mV
2 volume	2.76	6.21	13 700	25.1	104 mV
3 volume	3.02	6.31	13 910	25.1	68 mV
GW/BH2B					
1 volume	2.50	5.99	18 290	25.3	-24 mV
2 volume	2.40	6.18	20 400	25.2	-10 mV
3 volume	2.70	6.25	20 950	25.1	13 mV
GW/BH3A					
1 volume	2.04	6.10	2 850	26.0	108 mV
2 volume	Dry	Dry	Dry	Dry	Dry
GW/BH3B					
1 volume	0.92	5.85	21 470	25.8	55 mV
2 volume	1.80	5.96	57 600	25.5	32 mV
3 volume	1.53	5.92	60 100	25.8	53 mV
RN91326					
1 volume	2.08	5.95	1 910	25.0	-116 mV
2 volume	1.40	5.90	1 590	25.3	-114 mV
3 volume	1.36	5.91	1 150	25.4	-101 mV
4 volume	2.10	5.92	1 280	25.4	-72 mV
5 volume	1.94	5.95	1 290	24.4	-73 mV

The volume of groundwater within each bore was calculated based on borehole depth, static water level, and bore diameter data. Representative groundwater samples were collected on the removal (purging) of three times the bore volume, where possible. Estimates of bore volumes (using the data in Table 3-4 from the DERM database) were made for bore RN91326 due to lack of access to groundwater level and bore depth. Five times the bore volume was purged from RN91326 to ensure a representative sample was collected. Bore GW/BH3A ran dry during purging, so it was allowed to recover and then grab sampled 24 hours later.

The field measurements indicate variable salinity across the site. Electrical conductivity (EC) values indicate a mix of freshwater (RN91326), brackish water (GB/BH2A) and brine groundwater in the monitoring bores (GW/BH3B). The groundwater quality is slightly acidic, even though EC values suggest the presence of seawater. The pH of seawater is normally limited to a range of 7.5 to 8.4. The groundwater environment is best described as a reducing environment with moderate to poor oxygenation.

Groundwater samples were collected using low-flow pumps or disposable bailers and stabilised / preserved according to recognised protocols (APHA, 1992) prior to delivery to a NATA accredited analytical laboratory. The groundwater samples from the monitoring bores were analysed for major ions, nutrients and select dissolved metals. A summary of the analytical results is provided in Appendix C.

The environmental values of the water have been assessed according to the values identified in the EPP Water (2009). The two environmental values of relevance to the groundwater at the site are biological integrity (maintaining the water quality so the plants and animals living in the waterways can survive); and suitability for primary industry (livestock) use.

Groundwater samples were compared against guideline values for physical and chemical characteristics from the Queensland Water Quality Guidelines 2009 (QWQG) and the Australia New Zealand Environment and Conservation Council Guidelines for Fresh and Marine Water Quality 2000 (ANZECC). Where no guideline value for a parameter exists in the QWQG and a value has been set within the ANZECC, the ANZECC guideline value has been adopted. The investigation levels adopted to encompass the two defined environmental values and to provide a comparison of the groundwater analytical results include:

- The Trigger Levels for Freshwater Ecosystems – 95 % protection level of species;
- The Trigger Values for Long and Short-term irrigation use; and
- The Livestock Drinking Water Guidelines – Beef and Sheep.

Livestock Drinking Water

With the exception of monitoring bores GW/BH1B and 3B, groundwater is suitable for livestock drinking water. The concentration of calcium in bores GW/BH1B (1,820 mg/l Ca) and GW/BH3B (2,050 mg/L Ca) exceeds the ANZECC guideline of 1,000 mg/L Ca. Levels of sulphate in both bores also exceed the recommended ANZECC levels (1,880 mg/L and 3,140 mg/L SO_4). Adverse effects may occur at sulphate levels between 1,000 and 2,000 mg/L, especially in lactating animals or in hot, dry environments with elevated water intake. Effects can be temporary; however, the groundwater from these bores would require blending prior to use to ensure stock safety.

Freshwater Ecosystems

The concentrations of dissolved zinc in groundwater from all bores are above the ANZECC guidelines for freshwater aquatic environments (0.008 mg/L Zn). The concentration of dissolved cadmium in groundwater from five bores exceeds the ANZECC guidelines for freshwater aquatic environments (0.0002 mg/L Cd). The concentrations of dissolved iron from four bores are above the ANZECC guidelines for freshwater aquatic environments (0.3 mg/L Fe). Elevated concentrations of dissolved aluminium, beryllium, boron, chromium, cobalt, copper, lead, manganese, nickel, and selenium that are above the ANZECC guidelines for freshwater aquatic environments were identified in monitoring bores.

The groundwater, from both shallow (10 m) and deep (30 m) boreholes, is recognised as not suitable for discharge into the freshwater environments.

Irrigation Use

Long-term Trigger Values (LTV)

The concentrations of dissolved manganese in groundwater from six bores (including RN91326) are above the ANZECC trigger value guidelines for long-term irrigation (LTV) use (0.02 mg/L Mn). Four bores exceed the LTV for iron (0.2 mg/L Fe) while two bores exceed the LTV for cobalt (0.05 mg/L Co) and selenium (0.02 mg/L Se). The concentrations of dissolved cadmium, nickel, and boron from some bores are above the ANZECC guidelines for irrigation LTV's.

Short-term Trigger Values (STV)

The concentrations of dissolved cobalt in groundwater from 2 bores are above the ANZECC trigger value guidelines for short-term irrigation (STV) use (0.1 mg/L Co). The concentration of dissolved manganese in one bore exceeds ANZECC trigger value guidelines for short-term irrigation (STV) use (10.0 mg/L Mn).

Domestic use

Groundwater samples were compared against drinking water guideline values for physical and chemical characteristics from the Australian Drinking Water Guidelines 2004 (ADWG) and the Australia New Zealand Environment and Conservation Council Guidelines for Fresh and Marine Water Quality 2000. Where no guideline value for a parameter exists in the ADWG and a value has been set within the ANZECC 2000, the ANZECC guideline value has been adopted. The analytical hydrochemical data was compared to the guidelines to illustrate the elevated nature of the dissolved metal concentrations. Appendix C contains the comparison.

The hydrochemical data indicates elevated concentrations of a wide range of dissolved metals. All of the bores sampled on Laird Point site contain concentrations of chloride and manganese that are above guideline levels. Four bores contain levels of calcium, lead, and magnesium that are above guideline levels. Elevated concentrations of aluminium, cadmium, lead, nickel, selenium, sodium that are above guideline values were detected in at least two of the groundwater samples. An elevated concentration of arsenic was detected in bore GW/BH2B (0.011 mg/L As).

Groundwater samples collected from five of the six monitoring bores (GW/BH1A was drilled dry) indicated pH levels outside of the acceptable range set by the ADWG guidelines (6.5-8.5). Bore GW/BH1B was measured in the field to have the lowest pH level with 5.3.

These results indicate that naturally elevated concentrations, as a result of the host geology, occur both spatially across the site and vertically in the aquifers (both shallow and deep bores). The poor quality reduces the suitability for use and treatment of groundwater will be required before it could be utilised for domestic purposes.

Drive Spears

Due to the low permeabilities across the mudflats and a lack of water to fill sample bottles, groundwater quality sampling was not possible; however, hydrochemical field measurements were recorded at three locations (MW3, MW4, and MW5). These measurements are presented below as Table 5-7.

Table 5-7 Mudflats field data

Spear location	EC (µS/cm)	TDS (mg/L)	Temperature (ºC)	pH (pH units)	Redox (mV)	Dissolved oxygen (ppm)
MW0	112 000	62 720	21.2	6.04	155	1.50
MW1	110 000	61 600	22.4	6.31	189	1.66
MW2	107 000	59 920	22.2	6.3	149	1.55
MW3[6]	108 000	60 480	21.6	6.51	130	1.52
MW4	102 000	57 120	22.4	6.19	195	1.68
MW5	105 000	58 800	21.8	6.32	155	1.58

The total dissolved solids (TDS) concentrations of the groundwater associated with the mudflats was estimated based on the formula; TDS = EC x 0.56.

The field measurements indicate that the groundwater within the mudflats is hypersaline when compared to sea water, which typically has a TDS concentration of 30 000 mg/L (EC 54 000 µS/cm).

5.5 Groundwater resource evaluation

5.5.1 Aquifers

An evaluation of the groundwater resources indicates two separate groundwater regimes within the proposed DMPF footprint. These two regimes include:

- Shallow hypersaline groundwater resources within the intertidal zone, which is underlain by mudflats. The groundwater associated with the mudflats has limited environmental value and have no beneficial use. This portion of the site would not be markedly impacted by possible saline seepage from the dredge material placement facility.
- Discrete fractured and weathered aquifers within the competent Wandilla Formation. These aquifers contain limited sustainable yields with variable groundwater quality, which reduces the suitability for use.

5.5.2 Other groundwater resources

Based on the site geology, surficial cover, and underlying structures it is envisaged that additional groundwater resources could be associated with buried palaeovalleys, fresh water lenses, derived from overland flow, associated with the Ghyben-Hertzberg Relationship[7], and the intertidal mudflats.

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[6] MW3, MW4, and MW5 were the initial locations of the drive spears on the mudflats; these were removed and reinstalled at MW0, MW1, and MW2.

5 Site Evaluation

Palaeovalleys

Based on the structural geology of Curtis Island, it was envisaged that palaeovalleys may occur within the Laird Point site. The palaeovalleys are typically filled with permeable gravel and sand, which allows for increased storage and increased groundwater potential. These palaeovalleys are overlain by clay-rich estuarine deposits, forming confined aquifers. The aquifers, which can result in artesian flows, are envisaged to be limited in size (due to poor interconnectivity) and have little or no recharge.

The assessment of the mudflats, using drive spears, indicated heterogeneity with hydraulic conductivity variations across the mudflats. Drive spear MW1 intersected a zone of increased hydraulic conductivity, which may be related to sediment deposition. No well defined palaeovalley was delineated. Based on the marine deposition environment and the field measurements it was recognised the groundwater quality associated with the higher K area was hypersaline (Table 5-7) and thus has limited suitability for use. The limited groundwater potential and suitability for use reduces the environmental value of the groundwater associated with any possible palaeovalley deposits on the mudflats.

Fresh water resources

It is envisaged that regular rainfall allows for the recharge of shallow weathered aquifers with fresh water. Unconfined aquifers associated with the zones of deeper weathering, estuarine, alluvial, and colluvial deposits, which are recently recharged, can potentially contain fresh groundwater. Limited interaction or mixing of groundwater is expected as the fresh water remains on top of the more saline groundwater (identified during drilling). The stratification is governed by the Ghyben-Herzberg Relation, due to a physical relation based on the difference in densities of saline (sea) water and fresh water.

The volumes of fresh water will depend on the aquifer characteristics, namely the effective storage and permeability. A water balance for the entire Curtis Island indicates recharge (deep drainage) equates to only 1.3 % of rainfall. Based on the following figures:

- Area of Curtis Island: 578 km^2;
- Precipitation: 506,772 ML/year;
- Runoff: 70,367 ML/year (based on land use mapped across the island);
- Evapotranspiration: 429,753 ML (based on land cover); and
- Recharge / Deep drainage: 6,651 ML.

(Data source: Bureau of Meteorology).

The volume of fresh water recharge, which is recognised as the sustainable yield (groundwater harvest potential) of the aquifers, is calculated to be limited at 115 m^3/ha/year. The volumes of fresh groundwater are, thus, recognised to be limited.

This was verified during the drilling and groundwater sampling as only the groundwater sample collected from bore RN91326 had low to moderate salinity. This bore receives rainfall recharge and, as it is located within a drainage line, receives runoff recharge. This fresh water has reduced the salinity of the groundwater within this bore. The groundwater samples from the remaining bores had high salinity concentrations.

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[7] Aka the Ghyben-Herzberg Principal which states that where readily permeable aquifers exist in coastal zones, for every 1 m of water-table height above sea level, the fresh water – saltwater interface will be about 40 m below sea level. The principle reflects the fact that freshwater is 1/40 less dense than sea water.

Mudflats

The field measurements recorded within the drive spears indicate that the groundwater associated with these deposits is hypersaline (Section 5.4). This occurs as recharge is predominantly from sea water flooding the mudflats surface during spring tides. Evaporation of seawater pools left after flooding increases the salt concentration, with this hypersaline water recharging the mudflats.

The test pits constructed within the mudflats indicates that low permeability units (stiff clay) are located at depth (2 to 5 m) below the mudflats. These low permeability units restrict upward groundwater flow thus reducing dilution of the saline groundwater.

The saline groundwater reduces the suitability for use, thus the environmental value of the groundwater associated with mudflats is recognised to be limited.

5.6 Environmental value

The *Environmental Protection (Water) Policy 2009* (EPP (Water)) commenced on 28 August 2009 replacing the former *Environmental Protection (Water) Policy 1997* which was in force when the EIS was published. The purpose of the EPP (Water) is to achieve the object of the Environmental Protection Act in relation to Queensland waters, being the protection of Queensland's water environment while allowing for development that improves Queensland's total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends. Against the framework of achieving that objective, the EPP (Water) identifies the following environmental values of waters to be enhanced or protected:

- Biological integrity of ecosystems (which varies depending on the categorisation of the waters as either high ecological value, as slightly disturbed, as moderately disturbed or as highly disturbed);
- For waters to be used in primary industry or agriculture, suitability for agricultural use, aquacultural use or producing aquatic foods for human consumption;
- For waters to be used for recreation or aesthetic purposes, suitability for primary or secondary recreational use;
- For waters to be used for drinking water, suitability for supply as drinking water; and
- For waters to be used for industrial purposes, suitability for industrial use.

A review of available data and information gained from the field work on the DMPF allowed for an assessment of the groundwater resources present on the proposed site. The available information allowed for an evaluation of the groundwater resource environmental values based on site specific data, these include:

Biological integrity of ecosystems

The groundwater quality results for the majority of the groundwater samples collected from the monitoring bores (Section 5.4 and Appendix C) contain elevated dissolved solids and metal concentrations when compared to the Queensland Water Quality Guidelines (2009) and ANZEEC guidelines Trigger Levels for Freshwater and Marine Ecosystems (2000). Groundwater discharge, to the sea or as baseflow to the surface water, occurs at concentrations above these guidelines. The groundwater discharge is unaltered as it has not been impacted as the study area is undisturbed.

The groundwater contribution to baseflow and the assurance of the biological integrity by maintaining the water quality so the plants and animals living in the local waterways can survive is recognised to be limited compared to the surface runoff and tidal water. Thus the ecological values of groundwater discharge and baseflow to the biological integrity of the aquatic ecosystem is limited.

Suitability for use in primary industry or agriculture

The groundwater quality data indicates that the majority of the groundwater samples collected on site have elevated salinity concentrations, above the ranges recommended for irrigation of crops and stock watering. In addition, concentrations of certain metals and phosphorous are above the recommended levels for long and short term irrigation (Appendix C).

The groundwater sample collected from bore RN91326, has reduced concentrations of dissolved metals and solids due to mixing with surface water, thus it is more suitable for stock watering and irrigation purposes. Groundwater yields from this bore are, however, limited (~ 0.5 L/s).

On the whole the groundwater resources have limited potential use in terms of irrigation, depending on crop type, soil type, and irrigation regime.

Due to the saline nature of the groundwater it is assumed that only mariculture (aquaculture practiced in marine environments) could be considered. Algaculture (the production of kelp/seaweed and other algae), fish farming, shrimp farming, or oyster farming, depending on suitability of habitat may be possible. Aquaponics, which integrates fish farming and plant farming, could also be possible.

It is envisaged that these activities would require reliable and assured water supplies. The available information regarding usable aquifers and recharge indicates limited discrete groundwater resources. It is therefore considered that sea water would be utilised in preference to the limited groundwater.

Suitability for recreation or aesthetic purposes

This category of environmental values is considered extraneous in relation to groundwater.

Suitability for drinking water

All groundwater samples collected in and adjacent to the proposed DMPF site are recognised to not be suitable for drinking purposes and thus would require treatment to achieve recognised drinking water quality guidelines. This groundwater would require complex treatment, such as reverse osmosis, to achieve drinking water quality to satisfy the Australian Drinking Water Guidelines 2004.

Issues of salinity, elevated arsenic within the Wandilla Formation sediments, and the ease of obtaining a rainwater tank supply are factors which preclude the usage and potential for usage of the groundwater as a drinking water source.

Suitability for industrial use

The groundwater quality is generally suitable for a large number of industrial processes including; cooling water, process water, utility water, and wash water. As industrial processes require particular water quality, specific hydrochemical data would be required to evaluate suitability for use.

Limited opportunities for industrial use are currently available on Curtis Island. Industrial users tend to require large volumes of water which would be unsustainable for the groundwater resources identified within the DMPF study area.

Impact Assessment

The threats associated with the dredge material have been considered. The disposal of dredge material has the potential to produce seepage due to the transport water volumes. The seepage could potentially be enriched with dissolved solids as recognised in the initial elutriate and DI test results.

The threat posed is essentially proportional to the volumes and quality of seepage produced. In order to assess the seepage threat a groundwater model was constructed to simulate possible seepage. The model outputs were then considered to evaluate the potential impacts of seepage on the groundwater quality.

6.1 DMPF Seepage Modelling

The potential impacts of the proposed DMPF on the limited groundwater resources were identified as potential seepage, which could result in artificial recharge. This recharge could potentially result in the deterioration of groundwater quality and the formation of groundwater mounding, resulting in saline waterlogged areas adjacent to the DMPF.

In order to assess the potential impact seepage predictions were estimated using a numerical groundwater model. The model was constructed using the MODHMS groundwater modelling software package. The MODHMS finite difference model was selected as it allows the modelling of variable saturation conditions, allowing for unsaturated and saturated conditions.

6.1.1 Model set-up

In order to simulate possible seepage below the proposed DMPF, which will not be lined, a three layered model was constructed. The model grid comprised 70 Rows and 70 Columns (4,900 cells) with a cell size of 50 m x 50 m, active cells covering the proposed site covered an area of ~128 ha. Figure 6-1 presents the model grid and active cells.

The seepage conceptualisation assumed the entire DMPF footprint would produce seepage, i.e. the internal bund walls were ignored. This was done based on the assumption that the interior bund walls will be constructed using dredge material.

The following inputs were used to simulate dredging operations and settlement within the final containment facility:

- Total volume of dredge sediment ~ 7 million m^3 (Table 2-1);
- Inflow ratio of 16 % sediment and 84 % transport (sea)water;
- Water injected into centre of facility at rate of 122,282 m^3/day (856,000 m^3/week Section 2.2);
- Final capacity of approx 10.1 million m^3;
- Dredging operations run 20 hrs per day, 7 days per week for 342 days (48.8 weeks[8]);
- Water will pond in the facility at a variable height with time above sediment;
- After a water height of 10 m water will begin to be discharged (sufficient detention time envisaged); and
- After this time an equal flow rate will be discharged.

The dredging inflow rates utilised for modelling are summarised in Table 6-1 below:

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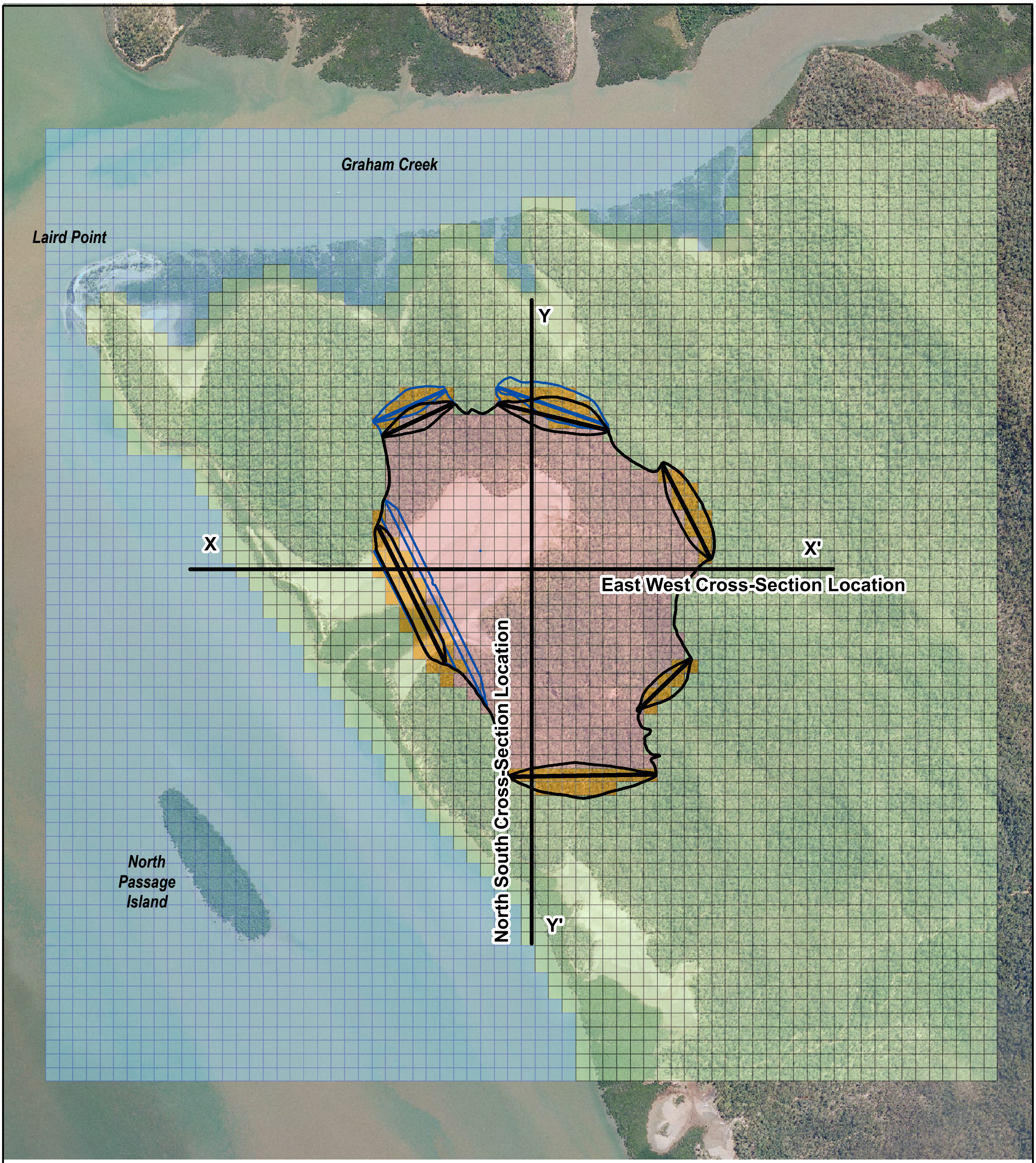
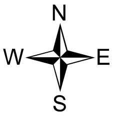
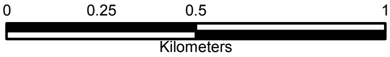
[8] The 48.8 week schedule is based on a scenario developed for the Dredge Management Plan. Dredging is estimated to take place over 43 to 58 week period depending on the final methodology chosen, but 48.8 weeks was used as a most likely scenario for modelling. Modelling results will not alter in any significant way for a longer or shorter dredge disposal period.







Scale 1:20 000 (A4)
Datum: GDA94

▭	Dredge Material Placement Facility Footprint (21/10/2009)
▭	Dredge Material Placement Facility Footprint (07/10/2009)

Model Grid

🟧	Bund
🟥	Disposal Facility
🟩	Land
🟦	Sea

Source: This map may contain data which is sourced and Copyright. Refer to Section 18.2 of the EIS for Ownership and Copyright.

Client

Project
GLADSTONE LNG PROJECT
FOR THE SUPPLEMENTARY
ENVIRONMENTAL IMPACT STATEMENT
DREDGE MATERIAL PLACEMENT FACILITY
HYDROGEOLOGICAL STUDY

Title
GROUNDWATER MODEL GRID

Drawn: MG | Approved: MS | Date: 27-10-2009

Job No: **4262 6444** /6220 | File: 42626440-g-2064.mxd

Figure: **6-1**

Rev.B

A4

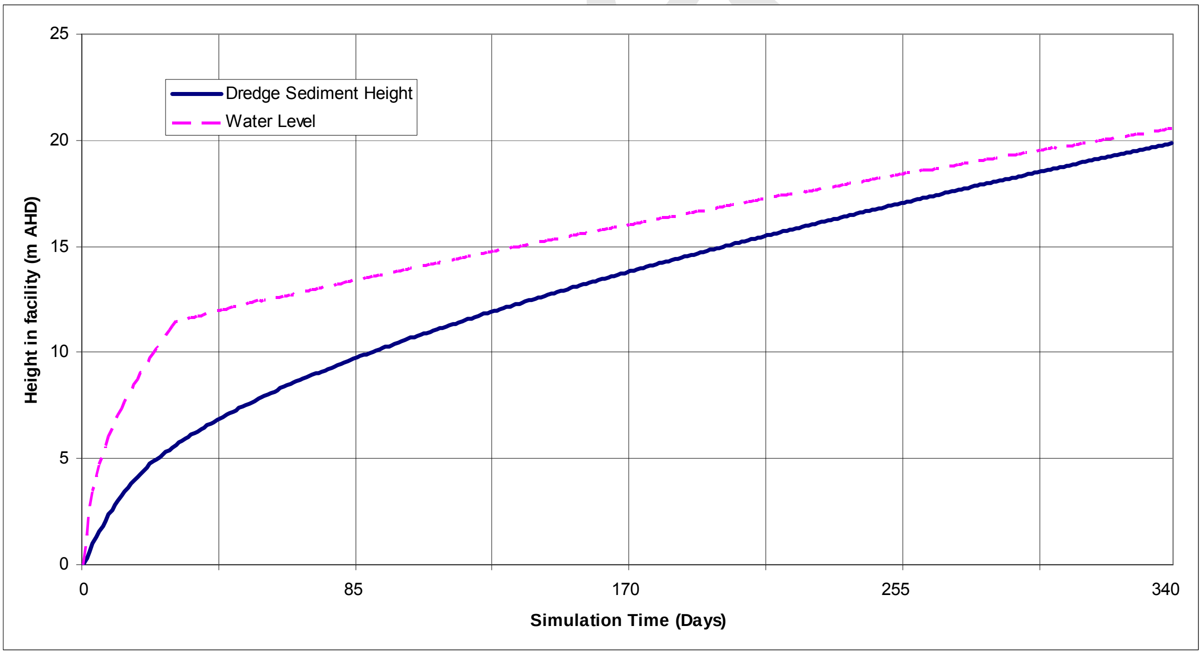
Table 6-1 Model input

Inflow	m^3/hr	m^3/day
Solid Inflow	995.3	19 906
Water Inflow	6114.1	122 282
Total	7109.4	142 188

6.1.2 DMPF head data

In order to determine realistic water level heights / heads for inclusion in the model an evaluation of dredge material placement was conducted. A bulking coefficient of 1.4 was used for sediment accumulation within the facility. The height of sediment accumulating and the water level within the facility over the dredging operations are displayed in Figure 6-2. This accumulation assumes that the dredging operations operate according to the 20 hr per day schedule over the 48.8 weeks (342 days) and that once the height of water reaches 10 m AHD, supernatant water begins to be discharged to the ocean. Using these parameters a final level of the sediment of ~ 20 m AHD, with 0.7 m water above it has been predicted.

Figure 6-2 Accumulation of sediment and water within facility



6.1.3 Climate input

The climate data, sourced from BoM and discussed in Section 3, used in the model is presented in Table 6-2.

Table 6-2 Climate data model input

Gladstone Radar Station (based on 51 years of data)	mm/day	m/day
Evaporation Average	4.800	0.004800
Rainfall Average	2.392	0.002392
Net Evaporation (Evaporation - Rainfall)	2.408	0.002408

6.2 Aquifer hydraulic parameters

The aquifer hydraulic parameters utilised to set up the three layered numerical groundwater model were identified from available aquifer tests (Tables 3-5, 5-4, and 5-5) and allocated to zones, which were based on site specific geology. The model conceptualisation, based on geology and horizontal hydraulic conductivity (K) values, allowed for three layers within the model:

- Layer 1: Includes bund areas and sedimentation within the facility;
- Layer 2: Includes the mudflats and the shallow (< 10 m) weathered aquifer unit; and
- Layer 3: Includes the deeper (~ 30 m) fractured rock aquifer unit.

These layers and spatial variation in K are shown in Figures D1 to D3 (Appendix D) for Layers 1, 2, and 3. A summary of the aquifer hydraulic parameters is presented in Table 6-3.

Table 6-3 Aquifer hydraulic parameters model input

Layer and K zone values	K (m/day)	Source
Layer 1		
Dredge material	0.001	Estimate for silty sand – literature value[9]
Bund	10^{-5}	Assumed impermeable[10]
Layer 2		
Average shallow weathered aquifer unit	0.007	URS Aquifer Tests
Average mudflats dry	0.2	URS Aquifer Tests
Average mudflats wet	0.003	URS Aquifer Tests
Layer 3		
Average deep fractured rock aquifer	0.04	URS Aquifer Tests

Vertical hydraulic conductivity (K_V) was, based on industry norms and literature (Domenico and Schwartz 1990), and estimated to be 10 % of the horizontal K presented in Table 6-3.

6.3 Groundwater head data

A spatial distribution for initial head was interpolated using groundwater level data measured on site (Section 5-2) and estimates of boundary conditions. Initial head distribution is shown in Figure D4 (Appendix D). This initial head distribution within the vicinity of the facility footprint shows higher head levels in the northwest, decreasing to the southeast parallel to the shoreline, with a head gradient of 7.39×10^{-4}.

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[9] Source: Freeze and Cherry, 1979

[10] A range of permeability was assessed for the bund K value; modelling results indicated that this was not a sensitive parameter.

Table 6-4 shows the head level values, for each of the three aquifer test locations (Figure 5-1 and D4 (Appendix D)), for the shallow upper weathered / alluvial aquifer (denoted A) and the deeper fractured rock aquifer (B).

Table 6-4 Groundwater level head data

Bores	GW/BH 1A	GW/BH 1B	GW/BH 2A	GW/BH 2B	GW/BH 3A	GW/BH 3B
Elevation (m AHD)	12.4	12.2	6.95	7	5.12	5.25
Static water level (mbgl)	DRY	11.21	6.255	6.4	4.895	5.29
Static water level (m AHD)	-	0.99	0.695	0.6	0.225	0.04

6.4 Model Simulation

The model aimed at simulating the deposition of dredge material over time. It was envisaged that the leakage from the DMPF would vary over time due to addition of sediment and the change in head across the DMPF, i.e. seepage rates were considered to vary from the initial seepage when dredge material is deposited onto bare ground to the end of deposition when thick dredge material has been deposited.

As the groundwater model is unable to represent the transport of sediments into the facility, i.e. the model cannot accommodate variable K with time, representation of the build up of the dredge sediments has been made though the use of four separate model phases (time steps) by approximating volumes / thickness of sediment for each phase. This allowed for the simulation of the reduction in hydraulic conductivity and the increase of head over time due to the sediment deposited on the DMPF.

The total deposition time of 342 days was divided equally allowing for four phases of approximately 85 days each. The equivalent sediment height of the phase was represented by the sediment height at the mid-point of each of the time steps, based on the accumulation of sediment and water within facility estimations, Figure 6-2. The equivalent sediment height, measured off Figure 6-2 at the mid point of each phase, was used to calculate the average leakage coefficient, using the thickness between the sediment (Z1) and the subsurface (Z2) and the K_V of layers 1 and 2 (Drawing 6-1). Table 6-5 presents the data utilised for each time step.

Drawing 6-1 Leakage coefficient

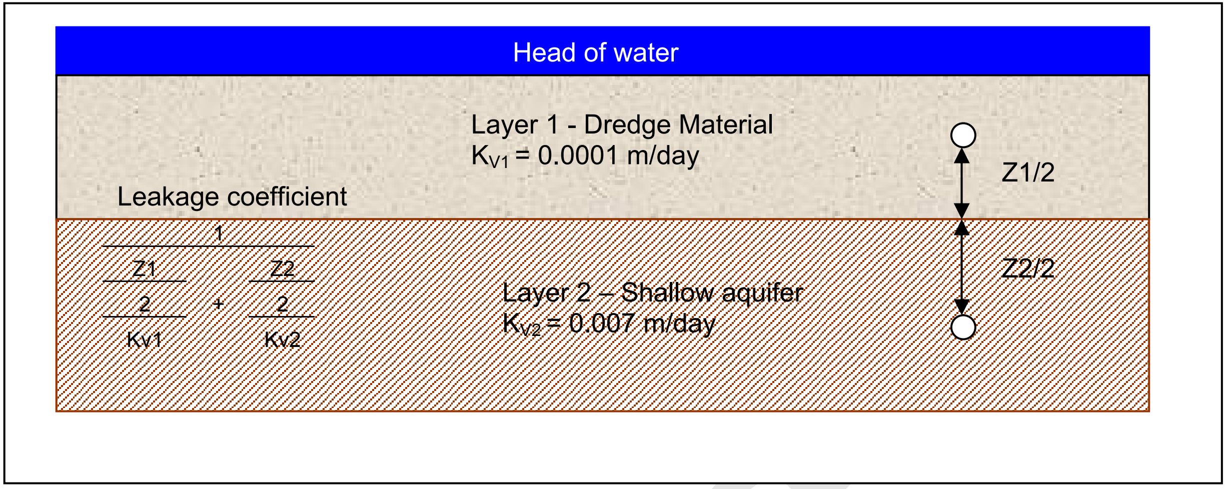


Table 6-5 Simulation of accumulation of sediment and water within the facility

	Mid-point of Phase (day)	Sediment Height (m AHD)	Average Leakage Coefficient (1/day)	Water Height (m AHD)	Height of Water Above Sediment (m)
First Phase (0-85 days)	43	6.81	4.2×10^{-5}	11.94	5.13
Second Phase (85-171 days)	128	11.91	2.4×10^{-5}	14.73	2.83
Third Phase (171-256 days)	214	15.44	1.8×10^{-5}	17.22	1.77
Fourth Phase (256 - 342 days)	299	18.46	1.5×10^{-5}	19.49	1.03

Surface elevation within the dredge area will change with time due to sediment build-up. The four models were run sequentially in order of time to simulate the changing leakage coefficient (dependent on sediment thickness) and the increasing water height in the facility. As the sediment builds up, the thickness and consolidation of the dredged sediments increases and the capacity for seepage (leakage coefficient) decreases. The model also includes for the height of water within the facility, which increases over time thus increasing the seepage driving head.

This approach allows for an under estimation of seepage for the first 43 days per time step and an over estimation for the last 43 days of the time step. The resultant total seepage volume is assumed to provide an accurate estimate of seepage per modelled phase.

6.4.1 Assumptions

The model aimed at evaluating the potential impacts of seepage from the proposed DMPF. In order to construct a suitable groundwater seepage model and achieve realistic simulations the following assumptions were made:

6 Impact Assessment

- Inflow rate from dredging operations is a constant inflow of ~ 140,000 m^3/week of solids and some 856,000 m^3/week of water (assumes the dredge is utilised 20 hours per day during the 342 day schedule);
- The solid to water ratio of 16:84 was assumed for the entire capital dredge life, this allowed for an estimate of sediment and water height with time;
- The model only looks at the impacts of the capital dredging as this is when the majority of seepage will occur, seepage post-dredging is expected to decrease markedly as all the transport water will be returned to the ocean and the negative climate balance (higher evaporation than rain) will remove ponding water from the top of the dredge pile;
- It was assumed that internal bunds will seep, i.e., seepage could occur across the entire 120 ha footprint;
- Initial groundwater levels, as generated in Figure D4, were assumed to be the same for the shallow weathered aquifer and the deep fractured rock aquifer, due to limited groundwater level data;
- The DMPF design, footprint and external embankment and saddle dam placements, dated 7 October 2009 was utilised in the model and was considered final. (The final footprint (21/10/2009) was generated after the seepage modelling had been conducted, based on the slight decrease in footprint it was deemed that the new footprint would not result in marked changes in the seepage predictions);
- A sediment bulking factor of 1.4 was assumed when considering sediment and water level heights during the capital dredge deposition;
- The height of sediment within the facility will increase gradually based on storage curves dated 15 September 2009 and pro-rated to final height of Sediment = 19.85 m AHD, Height of Water = 20.56 m AHD (DMPF design dated 7 October 2009);
- Water begins being discharged from the DMPF at rate equivalent to inflow once water in the DMPF reaches 10 m AHD. This is based on an estimate of detention time of ~ 410 hours, as discussed in a meeting with HR Wallingford on 21 September 2009;
- The ocean has been set as a constant head boundary, adjacent to the DMPF, at 0 m AHD;
- The sediment and water levels were modelled to increase in four separate phases. The levels were selected at the mid point time for each phase and read off Figure 6-2. The water and sediment levels selected are maintained over the entire phase. Therefore, water is not 'injected' as such in the model but instead it is set to be constant for each phase so as to simulate a continual head. The modelling approach to simulate variation with time using four phases allows a constant head for each phase, thus evaporation and rainfall inputs do not have any effect;
- The groundwater levels across the site decrease with time outside the footprint due to flow to the ocean, as no rainfall recharge has been added. The change in 342 days is assumed to be minor and does not affect the simulation of groundwater seepage;
- The external main embankment and saddle dams are assumed to be designed and constructed to have very low permeability, a range of hydraulic conductivity of the main embankment and saddle dams was considered. This parameter was not recognised to be sensitive such that the external embankments and dams were modelled to have a K of 1×10^{-5} m/day;
- The hydraulic conductivity of dredge sediment (the majority of the material is silty clay) was estimated to be 0.0014 m/day based on literature values;
- Vertical hydraulic conductivity (K_v) is assumed to be 10 % of the horizontal hydraulic conductivity;
- The surface leakage coefficient is assumed as the vertical conductivity divided by half the layer thickness, thus the leakage coefficient varied over the four phases as the sediment (Layer 1) thickness changed with time;

- The first model phase allows for an increase in relative permeability of Layer 2 over time as saturation increases in the vadose zone, assuming a linear relationship (pseudo-curve) between saturation and relative K;
- Layer 1 includes the main embankment, the saddle dams, and sediment within the facility and 1 m thickness at all other locations;
- Layer 2 has a uniform bottom elevation of - 3 m AHD, being an average of 4 m thick below the facility to 10 m thick at the external saddle dams;
- Layer 3 has a uniform thickness of 22 m; and
- The final height of the DMPF will be 22 m AHD.

6.5 Model Results

Based on the model parameter uncertainties and the assumptions detailed above a conservative approach were adopted when simulating the seepage from the proposed DMPF. This approach included:

- Seepage through the entire footprint;
- Transport water stored on site until the water reached a height of 10 m AHD before discharge;
- No compaction and reduction in dredge material permeability has been included in the model; and
- Constant water levels above the dredge material are simulated during the model steps.

6.5.1 Model Results

Seepage volume

The model conceptualisation is that infiltration will follow an exponential decay function due to saturation. The model, run sequentially with four phases, displayed decreasing seepage with time and resembles exponential decay. This can be attributed to the decreasing leakage coefficient, caused by the increasing height of the low K dredge sediments. This is a conservative approach as it does not take into consideration that K for the dredge material will decrease with time due to compaction. The model does, however, reduce the leakage from Layer 1 to Layer 2 over time based on the thickness of dredge material. The increased thickness (Z1 as shown in Drawing 6-1) reduces the leakage coefficient, which results in lower seepage with time. The seepage volumes and rates to the groundwater from the facility are displayed in Table 6-6. The decrease in seepage rate is presented in Figure 6-3. The seepage per square meter within the DMPF footprint has also been calculated using an approximate area of 120 ha.

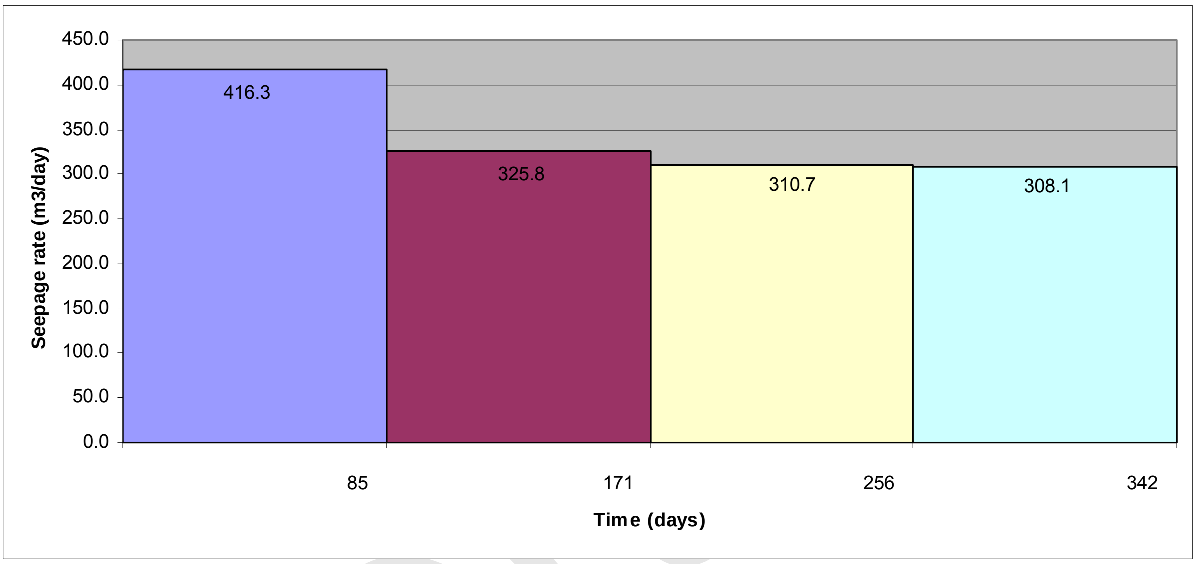
Table 6-6 Seepage to Groundwater

	Total seepage volume per phase (m^3)	Seepage rate per day (m^3/day)	Seepage rate over the 120 ha (L per m^2 per day)
First Phase (0-85 days)	35 388	416	0.35
Second Phase (85-171 days)	27 696	326	0.27
Third Phase (171-256 days)	26 407	311	0.26
Fourth Phase (256 - 342 days)	26 191	308	0.26

6 Impact Assessment

The water level height throughout the simulation increased with time, with the maximum height of water reaching 20.55 m AHD (Figure 6-2). Although the water level was increased (increasing the hydraulic head) the seepage rate does not increase due to the decreasing leakage coefficient. The dredge material is envisaged to become more impermeable with time due to compaction and the migration of fines to the bottom of the DMPF.

Figure 6-3 Seepage rate from facility to groundwater



The total volume of seepage over the 342 day (48.8 weeks) simulation period is approximately 115,500 m^3. This is comparable to dredging water inflow of only one day. The average seepage rate is approximately 340 m^3 per day.

The use of four model phases, using the central time for head and sediment thickness during each phase (Table 6-5), allows for an over and under estimation for end and start of each model phase. This allows for an accurate estimate of total seepage volume across the model phase.

Change in heads

The seepage from the proposed DMPF over the capital dredge period of 342 days has the potential to change groundwater gradients and cause a mounding of water beneath the DMPF. The seepage model was utilised to simulate the changes in groundwater levels, in the shallow and deep aquifers, based on the simulated seepage.

Figures D4, D5, and D6 (Appendix D) show the initial groundwater levels, the shallow groundwater levels after 342 days, and the deep groundwater levels after 342 days, respectively. The groundwater levels are predicted to increase between 0.2 and 0.6 m below the site. Groundwater gradients will increase slightly but as seepage occurs at a slower rate than groundwater through flow (within the aquifers) the impacts of mounding and changes in flow patterns are limited.

The groundwater level contours indicate that the groundwater levels in the two aquifers increase by ~ 0.2 m to the south of the DMPF. Groundwater levels in bores GW/BH3A and GW/BH3B in this area were measured to be some 5 m below surface (Table 5-3). A maximum increase (at the end of the capital dredge deposition) of ~ 0.2 m will not cause the groundwater to discharge on surface or cause waterlogged areas adjacent to the DMPF.

Consideration of the embankment and saddle dams' permeability was given and a range of K values (10^{-5} to 10^{-10}) was simulated in the model. Based on the limited mounding and limited variation in K between underlying units and the dredge material the model is not sensitive to K values used in the external main embankment and saddle dams.

Changes in groundwater quality

The impacts of seepage to groundwater will cause a plume that will follow the natural head gradient of the area, i.e. to the south east and towards the ocean. As discussed in Section 5.4 the groundwater beneath the facility is of poor quality. As the amount of seepage is of limited volume over a short period of time the seepage is not expected to increase the groundwater salinity markedly as demonstrated below when chloride concentration was evaluated.

In order to conduct a preliminary assessment of potential impacts of the modelled seepage from the DMPF an evaluation of groundwater quality changes was conducted using chloride (a relatively inert dissolved solid). The transport water comprises sea water, which may become enriched during the sediment dredging and transport (Section 4). As limited verified data is available a concentration of 20,000 mg/L chloride (typical for sea water Appendix C) was assumed for the seepage concentrations.

An average chloride concentration of 8,000 mg/L Cl was assumed for the ambient groundwater resources below the DMPF. An estimate of groundwater held in storage was calculated assuming steady state below the site;

- Volume of groundwater within a section of the aquifer below the site (115 ha x 20 m aquifer thickness x 15 % porosity) is estimated at ~ 3.6 x 10^6 m^3. The chloride mass is 2.88 x 10^{10} g Cl, using 8,000 mg/L Cl for groundwater;
- The volume of seepage over the 342 days of dredge disposal is ~ 116,280 m^3, based on an average seepage rate of 340 m^3/day. This results in a chloride mass of 2.3 x 10^9 g Cl, using 20,000 mg/L Cl for seawater seepage; and
- The combined volume of Cl equals 3.11 x 10^{10} Cl, which equates to a chloride contribution of ~ 8, 400 mg/L Cl.

The chloride concentrations in the groundwater increase from an average concentration of 8,000 mg/L to 8,400 mg/L, calculated based on the assumption of an average seepage rate of 340 m^3/day at a chloride concentration of 20,000 mg/L. This indicates that the potential seepage from the DMPF will result in a limited increase in dissolved solids, some 5 %.

The short seepage period, slow groundwater migration, and limited alteration in groundwater patterns indicates that the impact of seepage on the groundwater resources and ocean (once groundwater reaches the ocean) will be reduced due to long travel time, due to very low groundwater gradients and low K material, which will allow for dilution and attenuation.

Mitigation

Limited groundwater resources and limited seepage impacts, both quantity and quality, indicate that mitigation measures on site need to focus on verification of predictions. This will include developing a groundwater monitoring program which will assess changes to groundwater levels and quality over time. These data can then be utilised to re-run the seepage model and verify or update modelling predictions. Should monitoring indicate more marked impacts than envisaged then mitigation measures, such as phytoremediation (using halophytic plants to manage shallow saline groundwater / waterlogged areas) or an active scavenger system (comprising cut-off trenches, capture bores, and pumping), can be considered.

In order to validate the modelling an optimum monitoring network is required to allow:

- Additional groundwater level measurement points to facilitate more accurate groundwater flow patterns and contours;
- Groundwater monitoring points adjacent to all external embankments and saddle dams;
- Sampling points down gradient of the DMPF to evaluate groundwater quality leaving site; and
- Site specific leachate data from the DMPF, which would allow for contaminant transport modelling to be conducted using the existing MODHMS model.

Groundwater Monitoring Program

The existing groundwater monitoring bore network is to be increased by the installation of additional groundwater monitoring bores at strategic locations around the DMPF site. The location of these bores can be determined once the final design has been determined. The bores are envisaged adjacent to the saddle dams, thus it is suggested that geotechnical boreholes drilled prior to and during the construction phase could be converted to monitoring bores.

Based on the bores on site it is evident that secondary processes, such as faulting or fracturing, result in discrete zones of enhanced groundwater potential. These areas can also act as preferential flow paths for groundwater or contaminant transport. Seepage may, therefore, migrate from the DMPF along discrete fracture zones. Investigations will, therefore, be conducted to examine the type, depth, orientation and extent of fractures in the bedrock aquifer, as a precursor to any additional drilling and bore installation. An understanding of the fracture systems will aid in positioning monitoring bores in optimum locations to both examine baseline groundwater conditions and identify any potential seepage from the proposed DMPF.

The monitoring program, for groundwater levels, will be initiated prior to the operational phase and continued for the life of the DMPF. High frequency water level monitoring is to be conducted on a daily (every 12 hours) basis during the capital dredging.

Water quality monitoring, due to the limited changes in groundwater level predictions, will also be conducted at a high frequency to determine any possible alterations to groundwater through flow below the DMPF. The monitoring bores will be monitored for electrical conductivity (EC) readings. Multi-probe automated pressure transducer loggers, which can record groundwater level, temperature, and EC (LTC loggers) data, will provide EC readings at 12 hour intervals during the capital dredge operational phase of the DMPF.

Bi-annual sampling, to determine a full suite of analytes, will be conducted to evaluate potential impacts on groundwater quality.

7 Mitigation

A quarterly review of the monitoring program, during capital dredge operations, will allow for the re-running of the model and the evaluation of the simulation of seepage.

The objectives of the groundwater monitoring program are to:

- Detect potential groundwater impacts early, so that effective mitigation procedures can be developed and instigated.
- Determine the characteristics and trends of any contaminated groundwater flowing offsite.
- Identify whether any potential contaminants are varying in concentration or extent.

Analytes

The monitoring program will include the following minimum water quality parameters:

- pH, EC, and Total Dissolved Solids (TDS);
- Dissolved metals (NEPM 13 metal scan) plus iron (Fe); and
- Major anions and cations plus fluoride, nitrate, and bicarbonate.

Monitoring of groundwater levels and quality is to commence prior to construction of the DMPF to obtain additional long term baseline data at each monitoring location. These data will be used to determine the natural variability in the groundwater system. Evaluation of the baseline monitoring data allows for the establishment of trigger levels of key parameters which can be used as a quantitative method of determining whether unexpected impacts are occurring during construction or operation of the DMPF. In addition, an extensive baseline dataset will enable any seepage to be readily identified. Where monitoring results indicate levels in excess of the trigger values, an investigation appropriate for the situation will be conducted to assess the need to implement management/mitigation/remedial measures.

It should be noted that the DMPF has been designed to be self sealing with leakage decreasing as the volume and height of placed material increase. The results of the groundwater model support a decrease in leakage as the DMPF fills up. This will be verified through the collection of monitoring data.

Hydrocarbon and Chemical Contamination

Areas of hydrocarbon (fuel and oil) storage or contractor workshops are envisaged at the DMPF. These areas will have spill control measures and regular inspection regimes in order to prevent and monitor activities that could potentially lead to hydrocarbon contamination of groundwater. Spill control measures for hydrocarbon facilities include concrete slab bases that are bunded and include oil-water separators installed on all hydrocarbon above-ground storage, refuelling, and work shop areas. Bunded areas for hydrocarbon storage are provided with spill cleanup kits in accordance with the relevant Australian Standards. All transfers of fuels will be controlled and managed to prevent spillage outside bunded areas.

Potential for leaks and spills from operating equipment will be reduced by ensuring that all equipment is well maintained.

Installation and monitoring of the monitoring bore network on-site, including down-gradient of all potential contaminant sources, will enable early detection of any contaminated seepage. These monitoring bores are to be sampled for the analytes discussed above and Total Petroleum Hydrocarbon (TPH) fractions.

7 Mitigation

The low permeability of the alluvial and estuarine soils and weathered bedrock will enable isolation and remediation of potential spills. Any accidental spills will be assessed on a case by case basis and remediated in accordance with the requirements of the relevant authorities.

Conclusions

Initial assessments of the proposed DMPF site indicate possible impacts of seepage and artificial recharge on the limited poor quality aquifers within the vicinity of the site. Possible consequences include alterations to groundwater flow patterns due to mounding of water below the DMPF, changes in groundwater gradient, discharge of saline water adjacent to the site resulting in waterlogged areas and impacts on vegetation, and plume migration from the site.

Baseline groundwater data and aquifer assessments were conducted based on site specific data obtained from the drilling and testing of six monitoring bores across the site. Additional data was obtained from drive spears and hand auger holes within the proposed DMPF footprint.

Groundwater sampling of the new bores, were possible, and the existing licensed stock watering supply bore (RN91326) indicated that the groundwater is of poor quality due to the underlying geology. The groundwater was confirmed to have limited suitability for use.

Aquifer testing, using rising and falling head tests, indicates negligible groundwater resources within unaltered sediments on site. Groundwater potential is enhanced due to secondary processes resulting in discrete secondary aquifers. The bores are low yielding and receive limited rainfall recharge.

Groundwater resources associated with the mudflats are hypersaline due to remobilisation of salts left on surface due to high evaporation. The flushing of salts and recharge through sea water flooding the mudflats and low permeable units below the mudflats results in hypersaline groundwater.

The results of the fieldwork confirm that the groundwater has limited environmental value and are not suitable for sustainable extraction.

The dredge material is recognised to comprise mainly uncontaminated sand, which has limited acid generating potential. Thus the seepage threat is not dependent on the dredge material composition. A preliminary evaluation of the quality of possible elutriate and long term seepage resulting from the transport water indicates that the seepage could potentially cause an alteration of groundwater quality within the already poor quality groundwater resources below the DMPF site.

A groundwater model, suitable for evaluating variable saturation conditions, was constructed to assess the potential seepage from the proposed DMPF. The model simulated seepage, based on water and sediment build up on the DMPF, over a 48.8 week (capital dredge) time period. This allowed for the assessment of impacts during the highest probability of seepage occurring from the DMPF. Seepage is recognised to decrease over time due to reduced leakage through the dredge sediment. The average seepage was estimated at 340 m^3/day during the 342 day capital dredge deposition period.

Seepage modelling indicates that the seepage will have limited impacts on the groundwater flow patterns, with a change between 0.2 and 0.6 m in groundwater levels below the DMPF. Groundwater levels down gradient and adjacent to the DMPF will raise by ~ 0.2 m, which will not result in decant or waterlogged areas as groundwater is ~ 5 m below surface.

Increases in dissolved solids in groundwater, due to seepage from the DMPF, will occur. Estimates using chloride values, in a steady state scenario, indicate limited increase in chloride concentrations in the groundwater, < 5 % due to the capital dredge deposition.

No marked impacts are envisaged based on the model simulations, thus no active mitigation plans, such as scavenger well systems, are required. A monitoring network and program will be developed to obtain additional information, which will be utilised to validate the model predictions.

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9 References

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Limitations

10.1 Geotechnical & Hydro Geological Report

URS Australia Pty Ltd (URS) has prepared this report in accordance with the usual care and thoroughness of the consulting profession. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report. It is prepared in accordance with the scope of work and for the purpose outlined in the Proposal dated 15th July 2009.

The methodology adopted and sources of information used by URS are outlined in this report. URS has made no independent verification of this information beyond the agreed scope of works and URS assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to URS was false.

This report was prepared between August and October 2009 and is based on the conditions encountered and information reviewed at the time of preparation. URS disclaims responsibility for any changes that may have occurred after this time.

This report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose. This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

This report contains information obtained by inspection, sampling, testing or other means of investigation. This information is directly relevant only to the points in the ground where they were obtained at the time of the assessment. The borehole logs indicate the inferred ground conditions only at the specific locations tested. The precision with which conditions are indicated depends largely on the frequency and method of sampling, and the uniformity of conditions as constrained by the project budget limitations. The behaviour of groundwater and some aspects of contaminants in soil and groundwater are complex. Our conclusions are based upon the analytical data presented in this report and our experience. Future advances in regard to the understanding of chemicals and their behaviour, and changes in regulations affecting their management, could impact on our conclusions and recommendations regarding their potential presence on this site.

Where conditions encountered at the site are subsequently found to differ significantly from those anticipated in this report, URS must be notified of any such findings and be provided with an opportunity to review the recommendations of this report.

Whilst to the best of our knowledge information contained in this report is accurate at the date of issue, subsurface conditions, including groundwater levels can change in a limited time. Therefore this document and the information contained herein should only be regarded as valid at the time of the investigation unless otherwise explicitly stated in this report.

Appendix A Bore Logs

Sheet 1 of 1

URS Australia Pty Ltd

Monitoring Well GW/BH1A

URS Australia Pty. Ltd.
Level 16- 240 Queen Street Brisbane 4000
Phone 07-3243-2111
Fax 07-3243-2199

Drilling Contractor: **Drillsure**

Project No.: **42626444**

Project Reference: **GLNG Curtis Island Marine Dredge Disposal Facility**

Drill Method: **Auger, Wash boring**

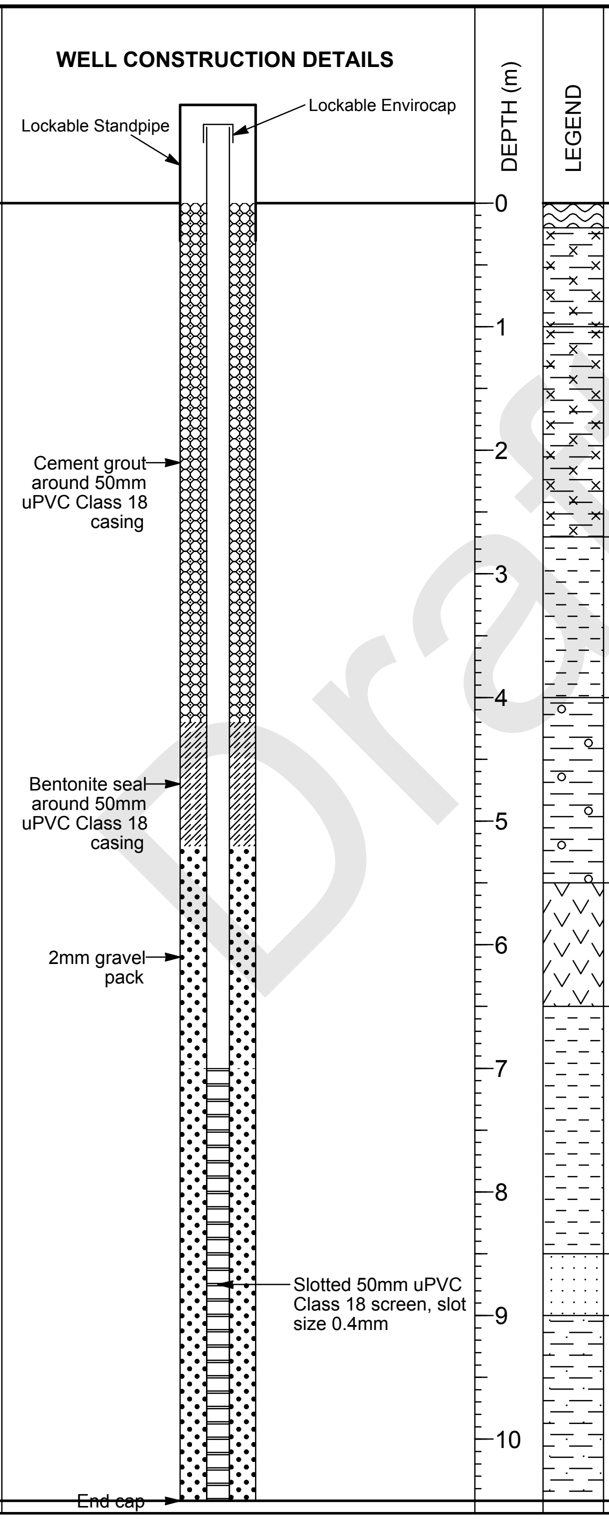
Logged By: **JPT**
Checked By: **SD**
Date Started: **5-8-09**
Date Finished: **5-8-09**

Relative Level: **12.400 mRL**
Coordinates: **7372480.000 mN**
314970.000 mE
Permit No: **N/A**

Client: **Santos Limited**

SAMPLE TYPE	SAMPLING and TESTING	PID (ppm)

WELL CONSTRUCTION DETAILS



DESCRIPTION OF STRATA	MOISTURE	CLASSIFICATION
Topsoil, roots and chert fragments		
silty CLAY with fine gravel, red, presence of hematite and jasper fragments		
silty CLAY with fine to medium gravel, red		
CLAY, red, interbedded with chert fragments		
CLAY with gravel, red to grey, some chert fragments		
CHERT, unweathered		
CLAY, red/grey/white, well indurated		
SANDSTONE, white, weathered, presence of clay		
sandy CLAY, white/grey		

REMARKS: DRY WELL
E.O.H = 10.5 m bgl

Sheet 1 of 2

URS Australia Pty Ltd

Monitoring Well GW/BH1B

URS Australia Pty. Ltd.
Level 16- 240 Queen Street Brisbane 4000
Phone 07-3243-2111
Fax 07-3243-2199

Drilling Contractor: **Drillsure**

Project No.: **42626444**

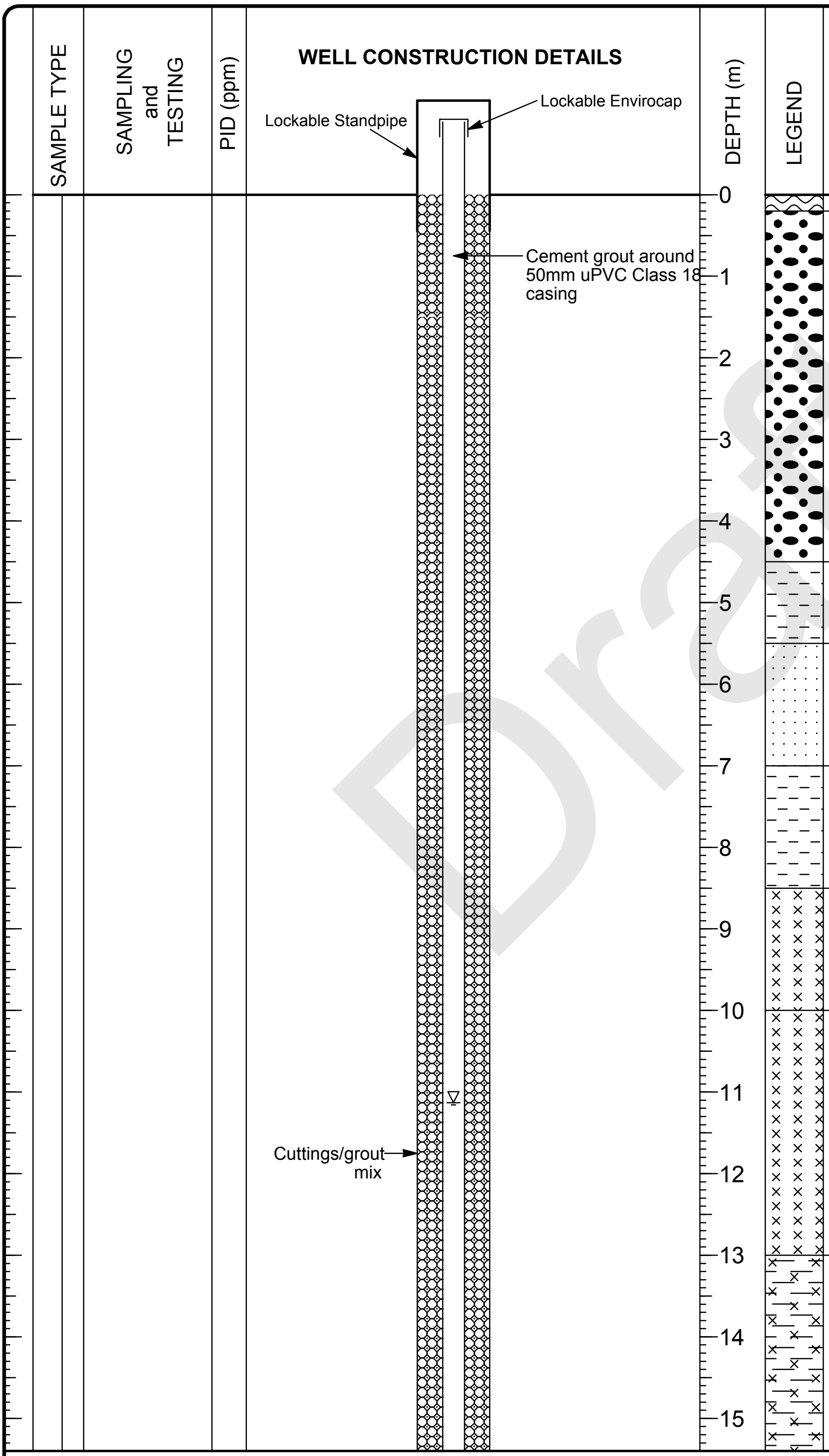
Project Reference: **GLNG Curtis Island Marine Dredge Disposal Facility**

Drill Method: **Auger, Wash boring**

Logged By: **JPT**
Checked By: **SD**
Date Started: **6-8-09**
Date Finished: **7-8-09**

Relative Level: **12.200 mRL**
Coordinates: **7372489.000 mN**
314973.000 mE
Permit No: **N/A**

Client: **Santos Limited**



DESCRIPTION OF STRATA	MOISTURE	CLASSIFICATION
Topsoil, roots, clay and high silica fragments		
COLLUVIUM (chert) with silty red clay		
CLAY, grey		
SANDSTONE with clay, grey/white/orange/red		
CLAYSTONE, orange, interbedded		
SILTSTONE, white/grey		
SILTSTONE with clay, yellow/white/grey, weathered		
silty CLAY, grey/orange		

REMARKS: Water Level = 11.13 m bgl (09/08/2009)

Sheet 2 of 2

URS Australia Pty Ltd

Monitoring Well GW/BH1B

URS Australia Pty. Ltd.
Level 16- 240 Queen Street Brisbane 4000
Phone 07-3243-2111
Fax 07-3243-2199

Drilling Contractor: **Drillsure**

Project No.: **42626444**

Project Reference: **GLNG Curtis Island Marine Dredge Disposal Facility**

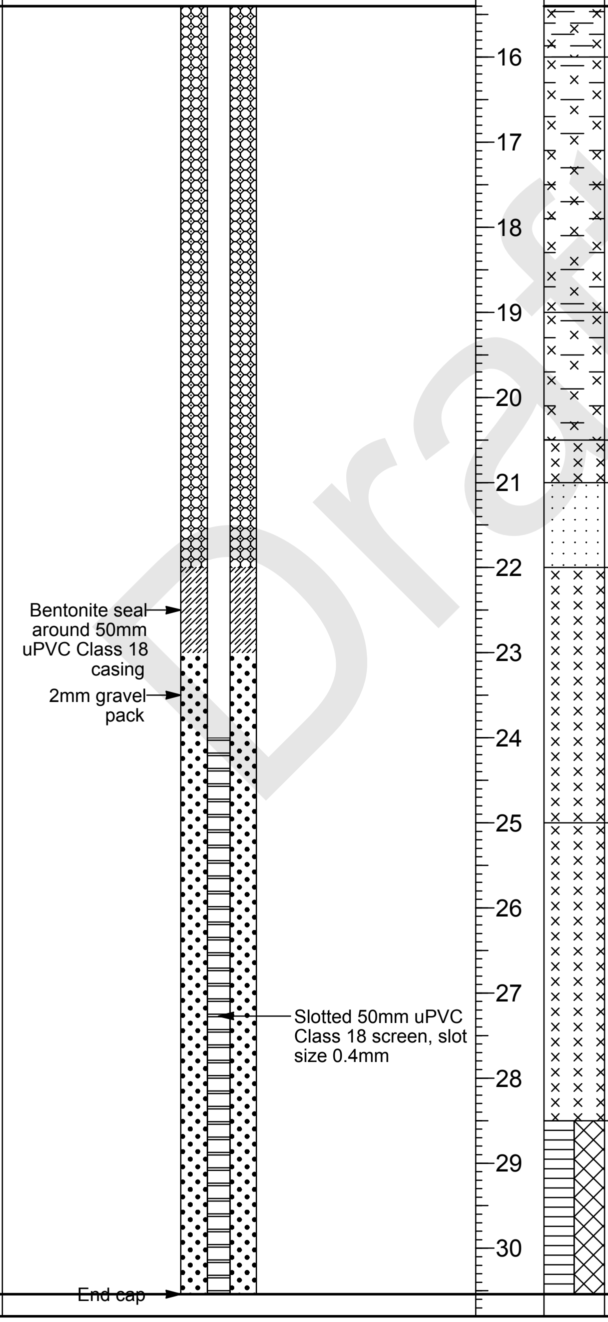
Drill Method: **Auger, Wash boring**

Logged By: **JPT**
Checked By: **SD**
Date Started: **6-8-09**
Date Finished: **7-8-09**

Relative Level: **12.200 mRL**
Coordinates: **7372489.000 mN**
314973.000 mE
Permit No: **N/A**

Client: **Santos Limited**

SAMPLE TYPE	SAMPLING and TESTING	PID (ppm)	WELL CONSTRUCTION DETAILS	DEPTH (m)	LEGEND	DESCRIPTION OF STRATA	MOISTURE	CLASSIFICATION



DESCRIPTION OF STRATA
clayey SILT, grey/orange/yellow, some siltstone fragments
silty CLAY, brown
SILTSTONE, orange/brown, well indurated
SANDSTONE, brown/red, well indurated
SILTSTONE with silt and sand, brown/orange, weathered
SILTSTONE, brown, weathered, fractured
SILTSTONE/MUDSTONE, interbedded, brown/red, weathered

REMARKS: E.O.H = 30.54 m bgl

Sheet 1 of 1

URS Australia Pty Ltd

Monitoring Well GW/BH2A

URS Australia Pty. Ltd.
Level 16- 240 Queen Street Brisbane 4000
Phone 07-3243-2111
Fax 07-3243-2199

Drilling Contractor: **Drillsure**

Project No.: **42626444**

Project Reference: **GLNG Curtis Island Marine Dredge Disposal Facility**

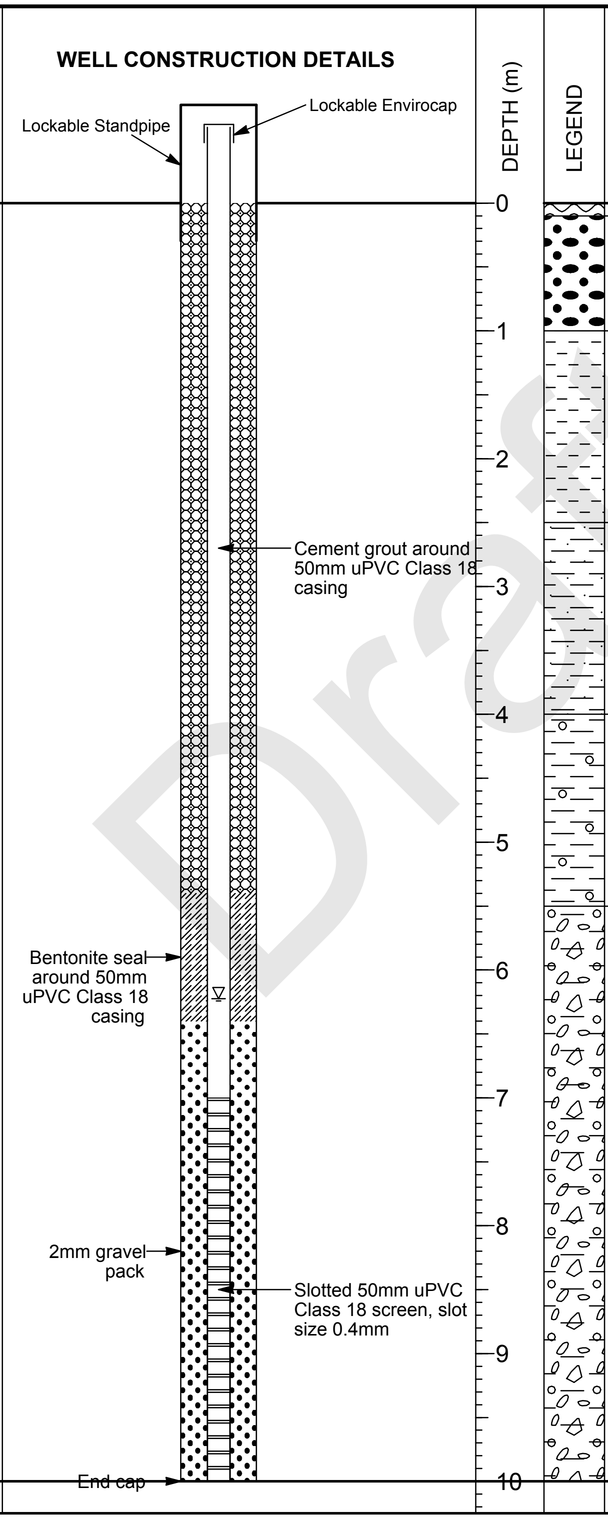
Drill Method: **Auger, Wash boring**

Logged By: **RJT**
Checked By: **SD**
Date Started: **7-8-09**
Date Finished: **7-8-09**

Relative Level: **6.950 mRL**
Coordinates: **7372516.000 mN**
315573.000 mE
Permit No: **N/A**

Client: **Santos Limited**

SAMPLE TYPE	SAMPLING and TESTING	PID (ppm)	WELL CONSTRUCTION DETAILS	DEPTH (m)	LEGEND	DESCRIPTION OF STRATA	MOISTURE	CLASSIFICATION



- Topsoil, roots
- COLLUVIUM (chert) with clay, grey/brown
- CLAY, brown/white
- sandy CLAY with gravel
- CLAY with gravel, grey/orange
- clayey GRAVEL, grey/brown, fine to medium sized gravel

REMARKS: Water Level = 6.225 m bgl (12/08/2009)
E.O.H = 10.0 m bgl

URS Australia Pty Ltd

Monitoring Well GW/BH2B

URS Australia Pty. Ltd.
Level 16- 240 Queen Street Brisbane 4000
Phone 07-3243-2111
Fax 07-3243-2199

Drilling Contractor: **Drillsure**

Project No.: **42626444**

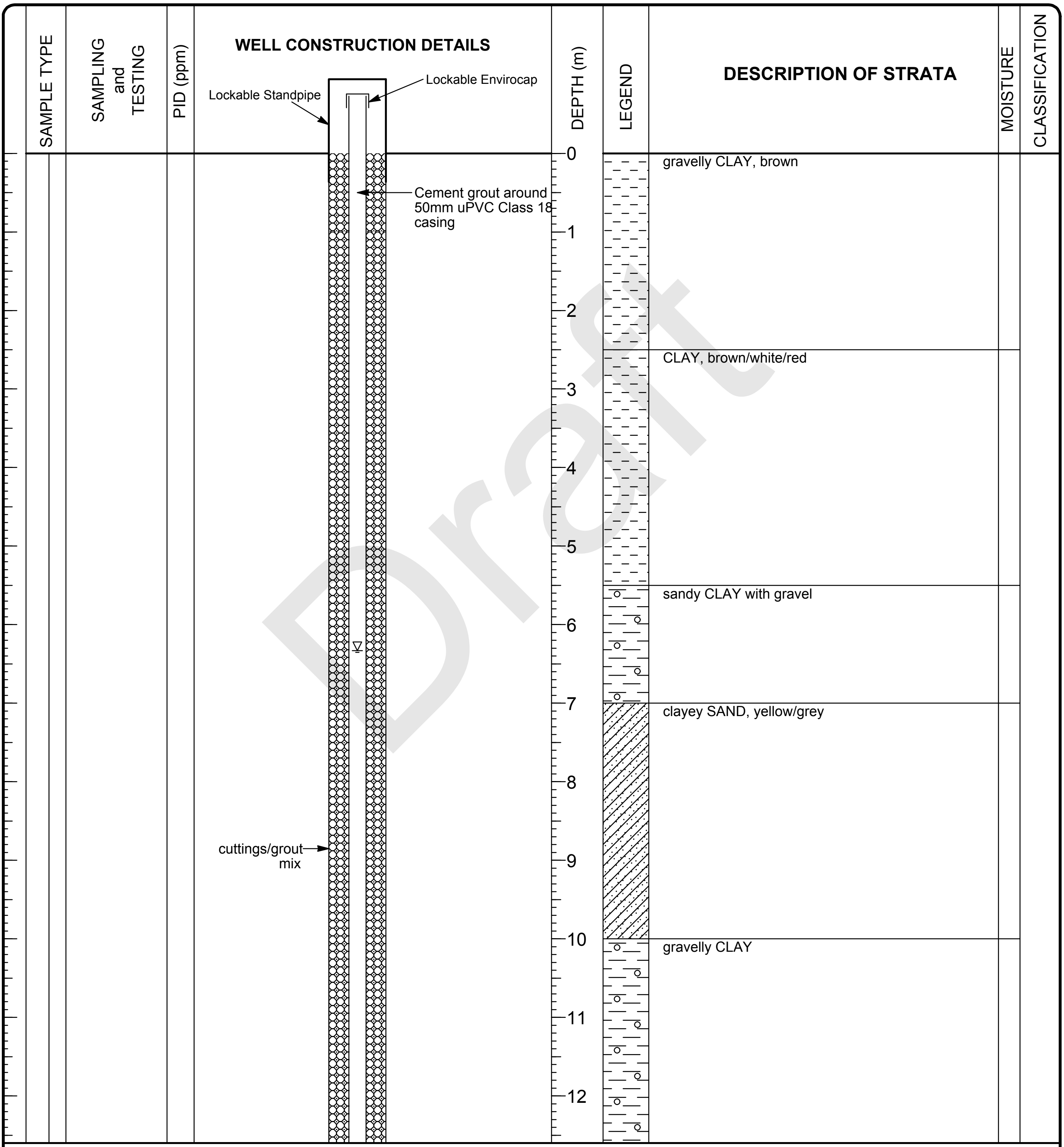
Project Reference: **GLNG Curtis Island Marine Dredge Disposal Facility**

Drill Method: **Auger, Wash boring**

Logged By: **RJT**
Checked By: **SD**
Date Started: **7-8-09**
Date Finished: **9-8-09**

Relative Level: **7.000 mRL**
Coordinates: **7372513.000 mN**
315578.000 mE
Permit No: **N/A**

Client: **Santos Limited**



REMARKS: Water Level = 6.33 m bgl (12/08/2009)

URS Australia Pty Ltd

Monitoring Well GW/BH2B

URS Australia Pty. Ltd.
Level 16- 240 Queen Street Brisbane 4000
Phone 07-3243-2111
Fax 07-3243-2199

Drilling Contractor: **Drillsure**

Project No.: **42626444**

Project Reference: **GLNG Curtis Island Marine Dredge Disposal Facility**

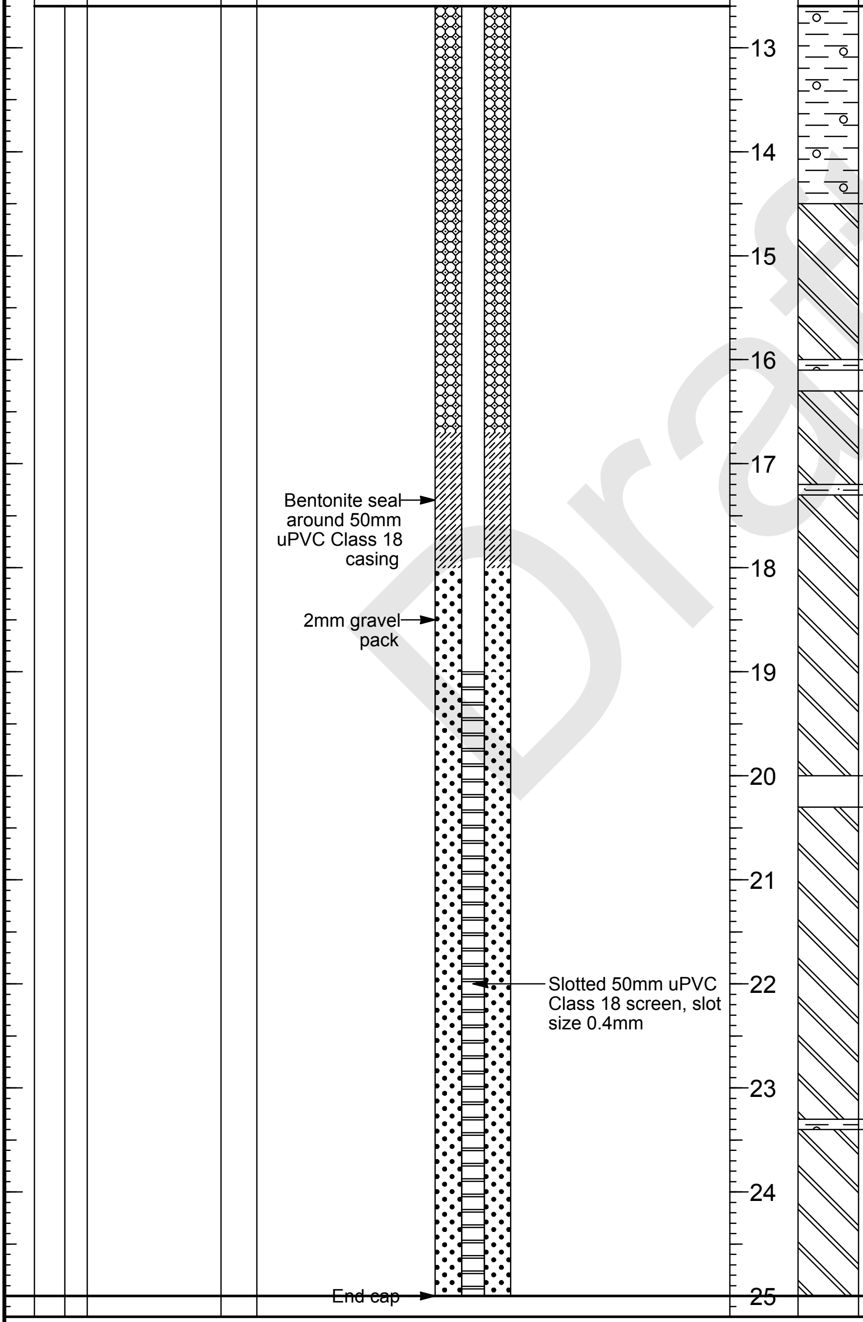
Drill Method: **Auger, Wash boring**

Logged By: **RJT**
Checked By: **SD**
Date Started: **7-8-09**
Date Finished: **9-8-09**

Relative Level: **7.000 mRL**
Coordinates: **7372513.000 mN**
315578.000 mE
Permit No: **N/A**

Client: **Santos Limited**

SAMPLE TYPE	SAMPLING and TESTING	PID (ppm)	WELL CONSTRUCTION DETAILS	DEPTH (m)	LEGEND	DESCRIPTION OF STRATA	MOISTURE	CLASSIFICATION



ARGILLITE, weathered

gravelly CLAY

Core Loss

ARGILLITE, grey, weathered

sandy CLAY with gravel

ARGILLITE, grey, weathered, fractured

Core Loss

ARGILLITE, grey, weathered, fractured

CLAY with small to large gravel

ARGILLITE, grey, weathered, fractured

REMARKS: E.O.H = 25.0 m bgl

Sheet 1 of 1

URS Australia Pty Ltd

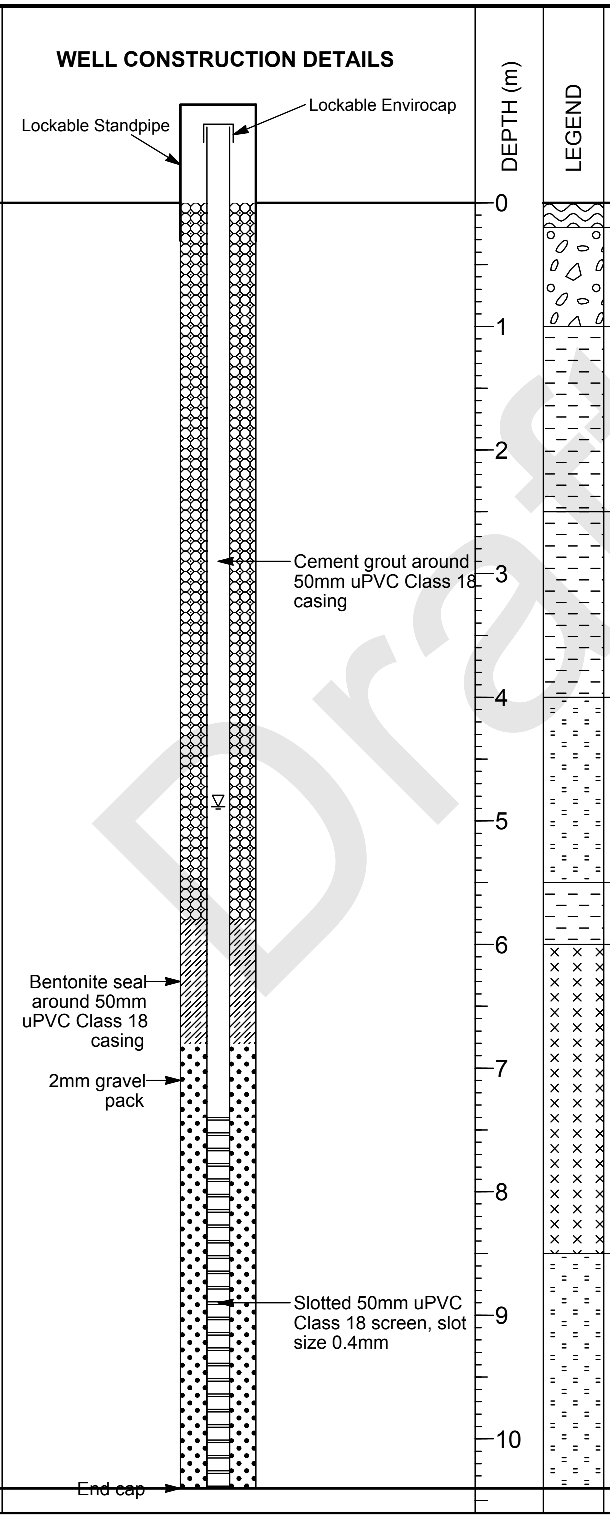
Monitoring Well GW/BH3A

URS Australia Pty. Ltd.
Level 16- 240 Queen Street Brisbane 4000
Phone 07-3243-2111
Fax 07-3243-2199

Drilling Contractor:	**Drillsure**
Project No.:	**42626444**
Project Reference:	**GLNG Curtis Island Marine Dredge Disposal Facility**
Drill Method:	**Auger, Wash boring**
Logged By:	**JPT**
Checked By:	**SD**
Date Started:	**10-8-09**
Date Finished:	**10-8-09**
Relative Level:	**5.120 mRL**
Coordinates:	**7370962.000 mN** **315594.000 mE**
Permit No:	**N/A**
Client:	**Santos Limited**

SAMPLE TYPE	SAMPLING and TESTING	PID (ppm)

WELL CONSTRUCTION DETAILS



DESCRIPTION OF STRATA	MOISTURE	CLASSIFICATION
Topsoil, roots		
GRAVEL with red/grey clay and silt, presence of jasper		
CLAY, red/grey		
CLAYSTONE with sandy silt, red/grey, weathered		
MUDSTONE, grey, weathered, clay-filled fractures, small presence of sand		
CLAY, red		
SILTSTONE, fine grained, interbedded with silty clay, weathered, highly fractured		
MUDSTONE with clay and fine to medium silts, red/orange, weathered		

REMARKS: Water Level = 4.885 m bgl (15/08/2009)
E.O.H = 10.4 m bgl

URS Australia Pty Ltd

Monitoring Well GW/BH3B

URS Australia Pty. Ltd.
Level 16- 240 Queen Street Brisbane 4000
Phone 07-3243-2111
Fax 07-3243-2199

Drilling Contractor: **Drillsure**

Project No.: **42626444**

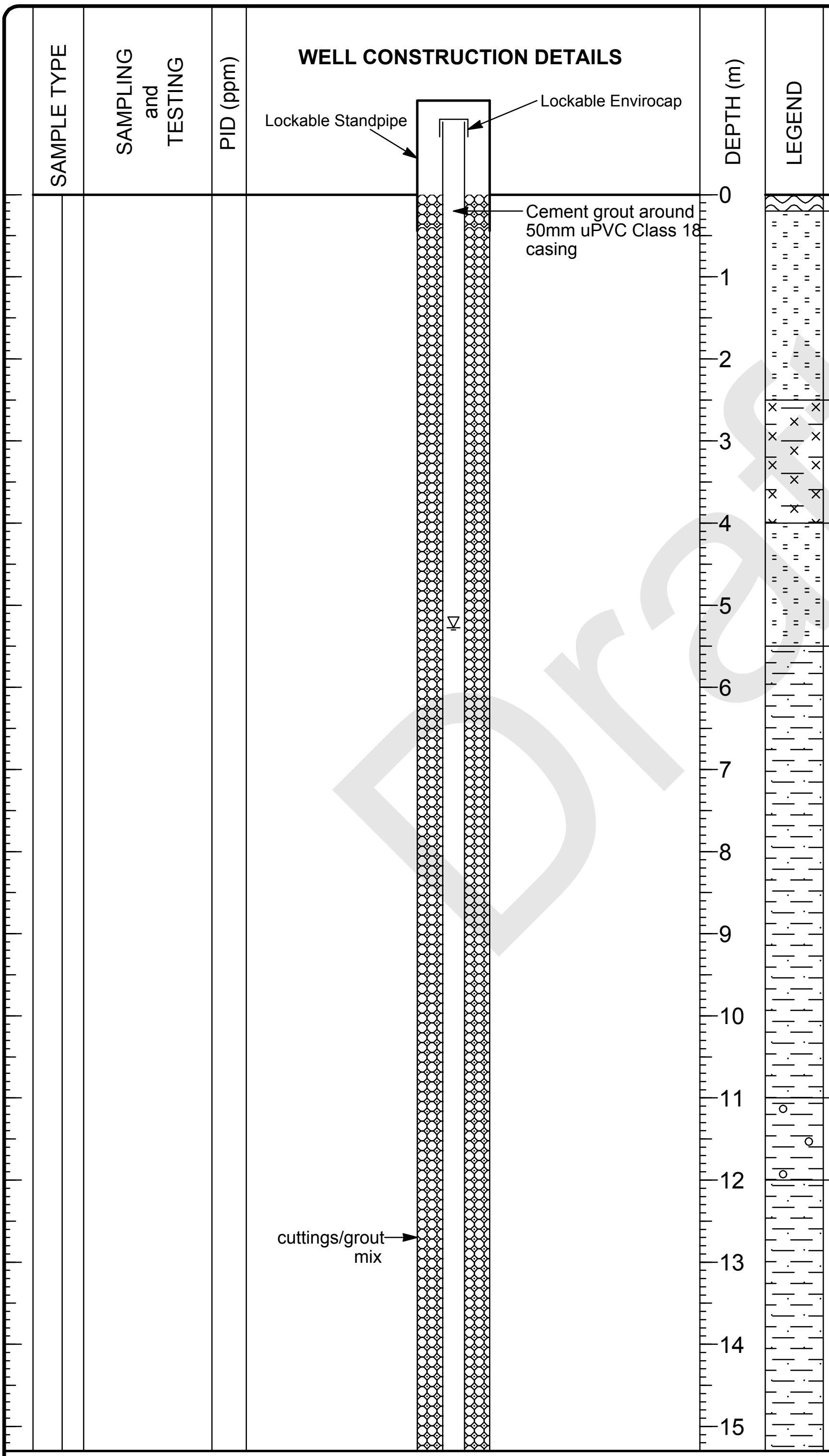
Project Reference: **GLNG Curtis Island Marine Dredge Disposal Facility**

Drill Method: **Auger, Wash boring**

Logged By: **RJT**
Checked By: **SD**
Date Started: **11-8-09**
Date Finished: **12-8-09**

Relative Level: **5.210 mRL**
Coordinates: **7370967.000 mN**
315595.000 mE
Permit No: **N/A**

Client: **Santos Limited**



DESCRIPTION OF STRATA

Topsoil, presence of roots, sub-angluar to sub-rounded gravel

carbonaceous MUDSTONE, interbedded, weathered, chert fragments

clayey SILT with mudstone fragments, jasper and chert, red/grey

MUDSTONE, red/orange, weathered with clay, silt and sand-filled fractures

sandy CLAY with some gravel, orange/grey, coarse sand

gravelly CLAY, yellow/brown

sandy CLAY, orange/grey, medium to coarse sand

REMARKS: Water level = 5.275 m bgl (15/08/2009)

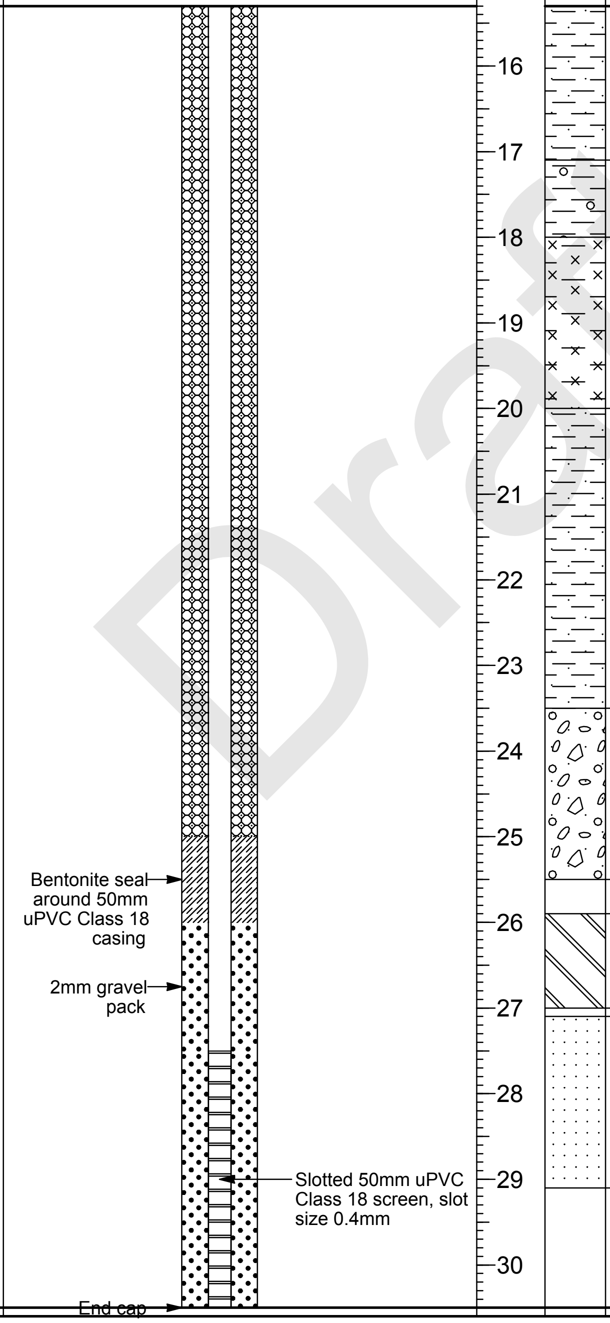
Sheet 2 of 2

URS Australia Pty Ltd

Monitoring Well GW/BH3B

URS Australia Pty. Ltd. Level 16- 240 Queen Street Brisbane 4000	Phone 07-3243-2111 Fax 07-3243-2199	Project No.: **42626444**	Project Reference: **GLNG Curtis Island Marine Dredge Disposal Facility**
Drilling Contractor: **Drillsure**			
Drill Method: **Auger, Wash boring**	Logged By: **RJT** Checked By: **SD** Date Started: **11-8-09** Date Finished: **12-8-09**	Relative Level: **5.210 mRL** Coordinates: **7370967.000 mN** **315595.000 mE** Permit No: **N/A**	Client: **Santos Limited**

SAMPLE TYPE	SAMPLING and TESTING	PID (ppm)	WELL CONSTRUCTION DETAILS	DEPTH (m)	LEGEND	DESCRIPTION OF STRATA	MOISTURE	CLASSIFICATION



gravelly CLAY, grey/brown

clayey SILT, brown, fragments of siltstone

sandy CLAY, brown/orange/grey, medium to coarse sand

GRAVEL with sand and clay

Core loss

ARGILLITE, dark grey

Core loss

SANDSTONE, dark grey, quartz veins

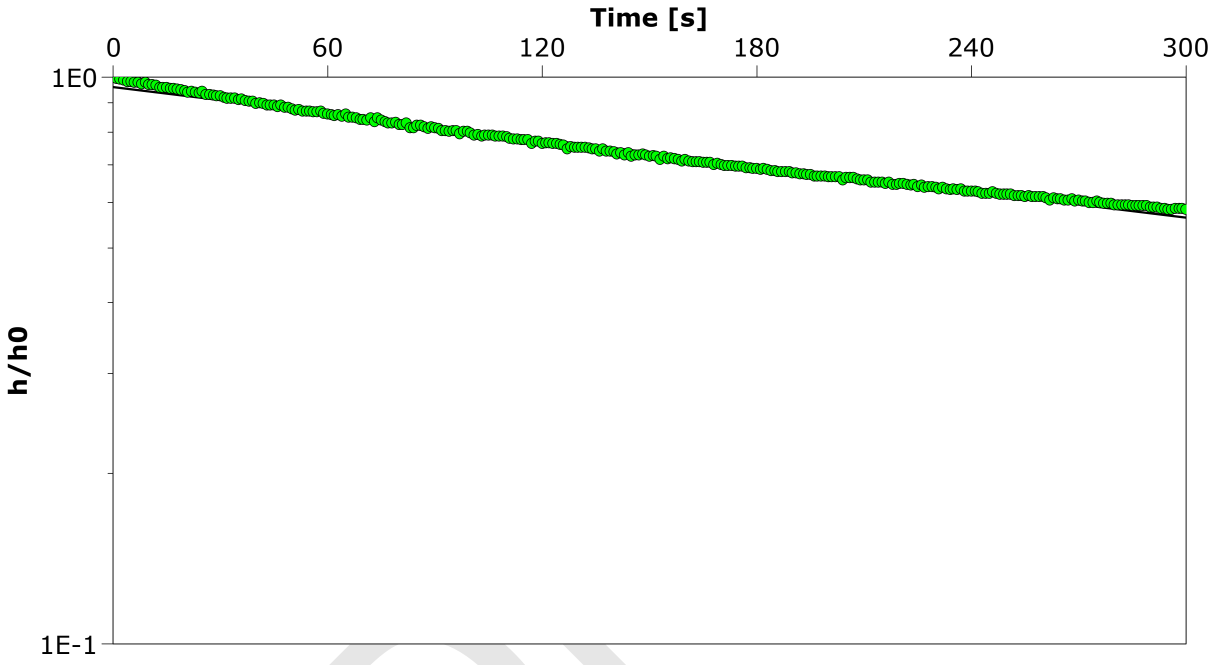
Core loss

REMARKS: E.O.H = 30.5 m bgl

Appendix B Aquifer Tests

URS Australia Pty Ltd Level 14, 240 Queen St Brisbane, QLD, 4000 Phone: +61 7 3243 2111	**Slug Test Analysis Report**	
	Project: GLNG EIS Supplement	
	Number: 42626444	
	Client: Santos Ltd	

Location: Curtis Island	Slug Test: MW1 Falling Head	Test Well: Well 1
Test conducted by: MS/JPT		Test date: 21/08/2009
Analysis performed by: MS	MW1 Falling Head Test	Date: 21/08/2009
Aquifer Thickness: 1.10 m		

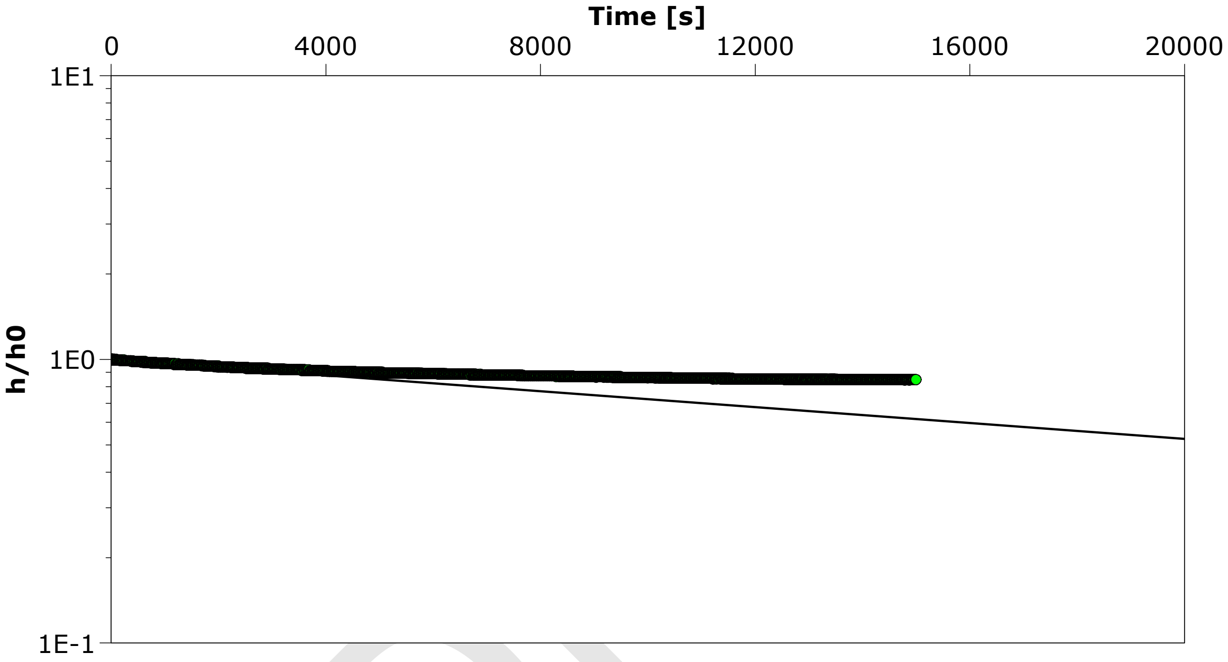


Calculation after Hvorslev

Observation well	K [m/d]
Well 1	1.89×10^{-1}

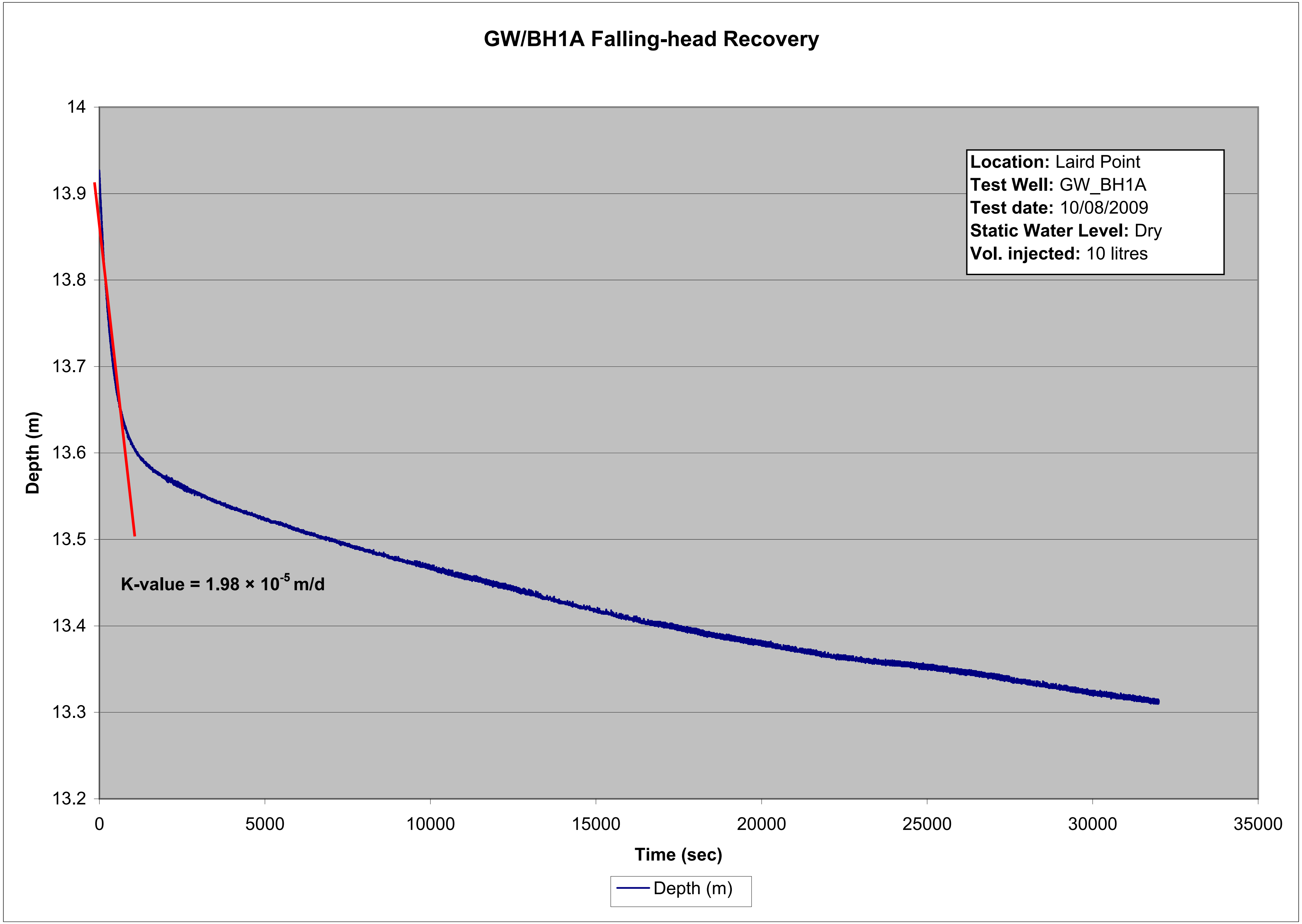
URS Australia Pty Ltd **Level 16, 240 Queen St** **Brisbane, QLD, 4000** **Phone: +61 7 3243 2111**	**Slug Test Analysis Report**
	Project: GLNG EIS Supplement
	Number: 42626444
	Client: Santos Ltd

Location: Curtis Island	Slug Test: MW2 Falling Head Test	Test Well: MW2
Test conducted by: MS/JPT		Test date: 21/08/2009
Analysis performed by: MS	MW2 Falling Head Test	Date: 21/08/2009
Aquifer Thickness: 1.10 m		



Calculation after Hvorslev

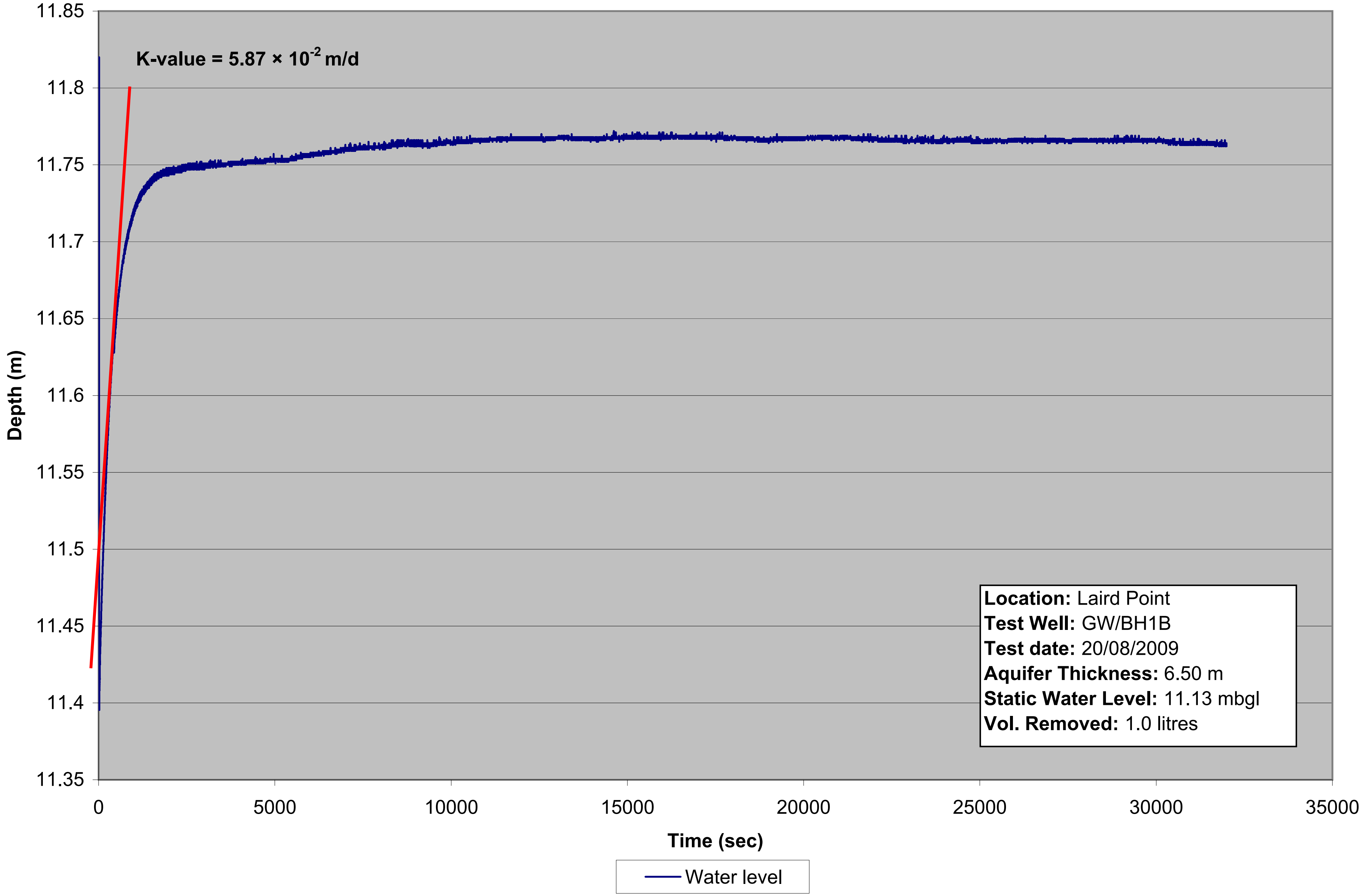
Observation well	K [m/d]	
MW2	3.42×10^{-3}	



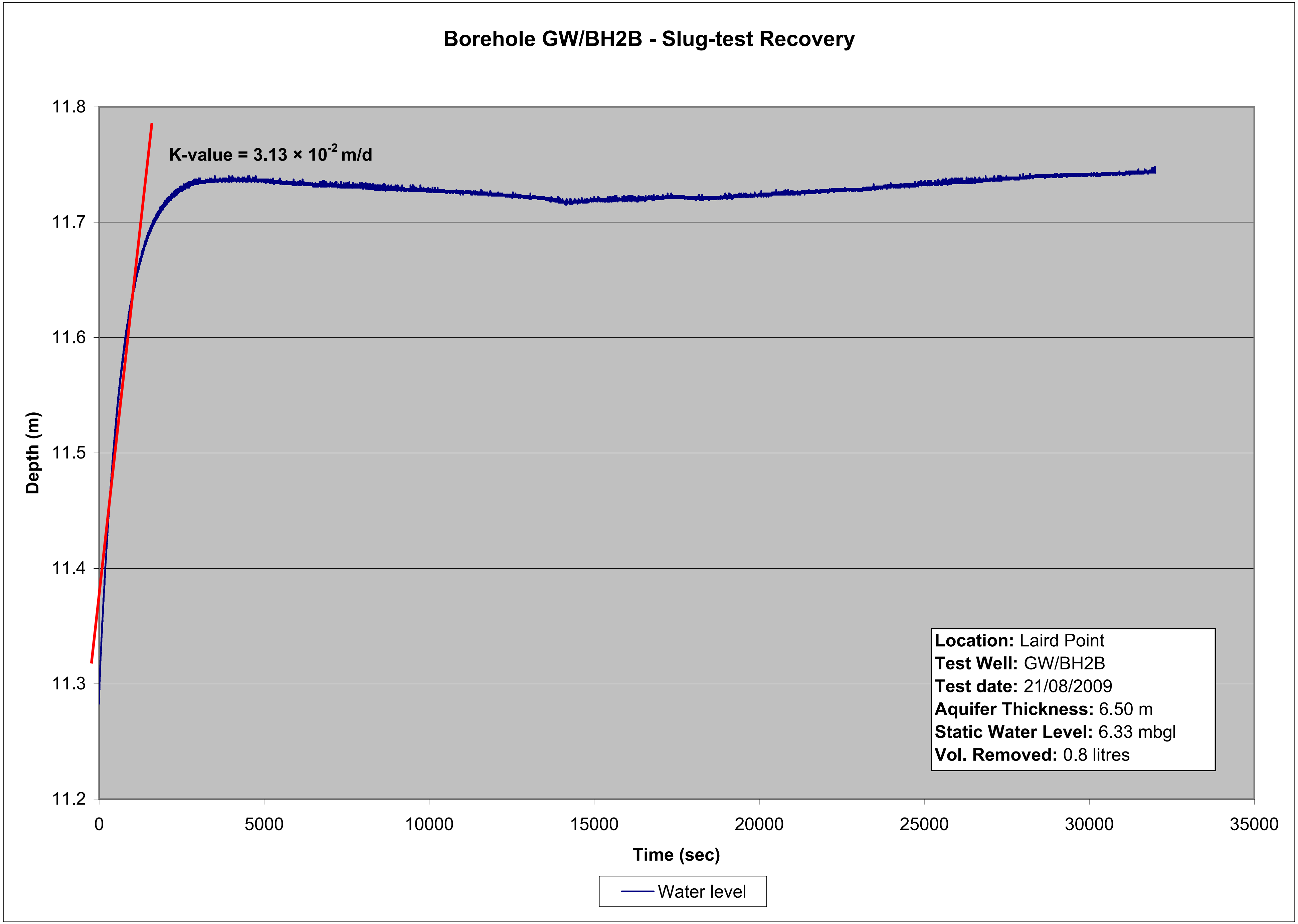
Location: Laird Point
Test Well: GW_BH1A
Test date: 10/08/2009
Static Water Level: Dry
Vol. injected: 10 litres

K-value = 1.98 × 10^{-5} m/d

Borehole GW/BH1B Slug-test Recovery



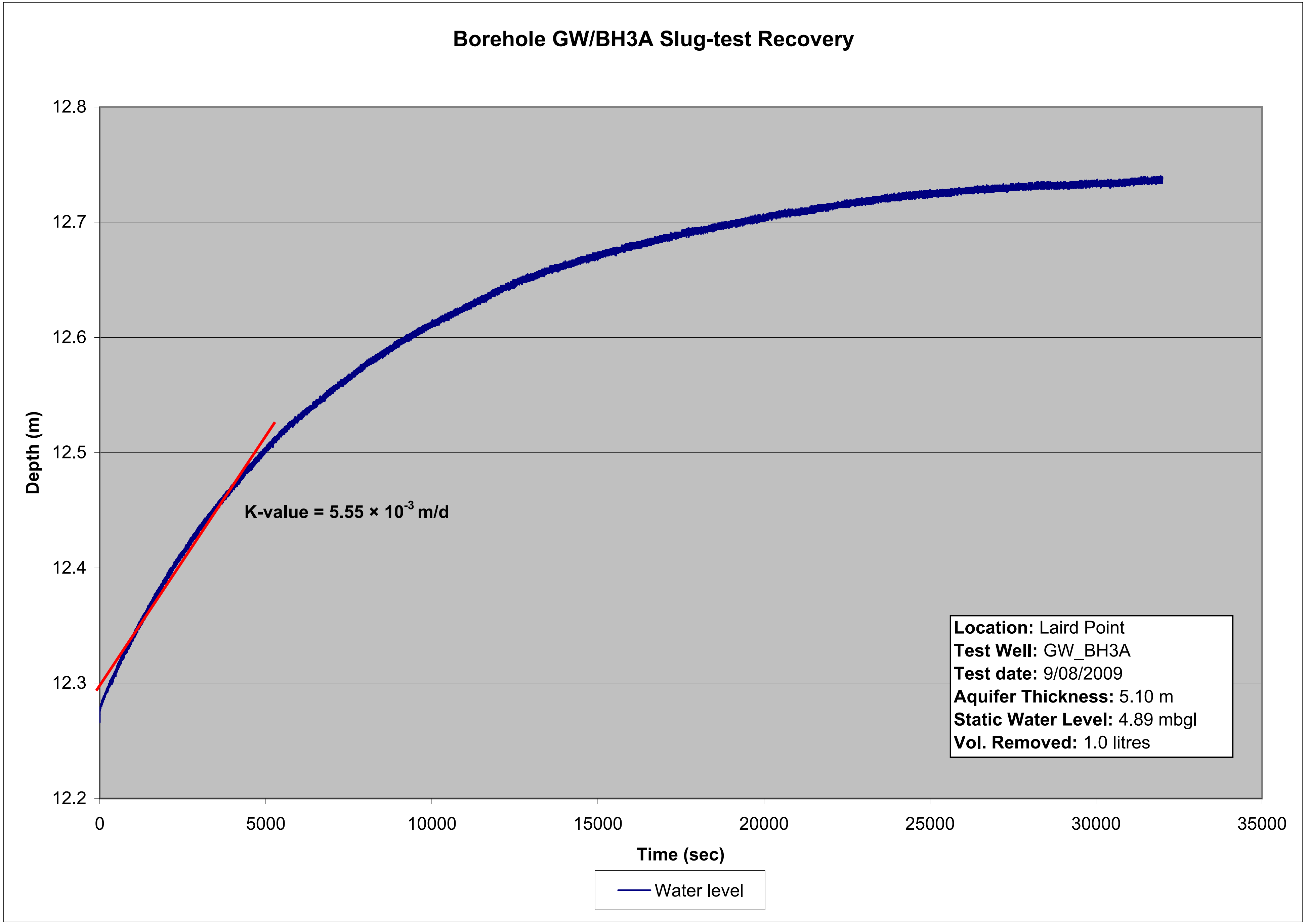
Location: Laird Point
Test Well: GW/BH1B
Test date: 20/08/2009
Aquifer Thickness: 6.50 m
Static Water Level: 11.13 mbgl
Vol. Removed: 1.0 litres



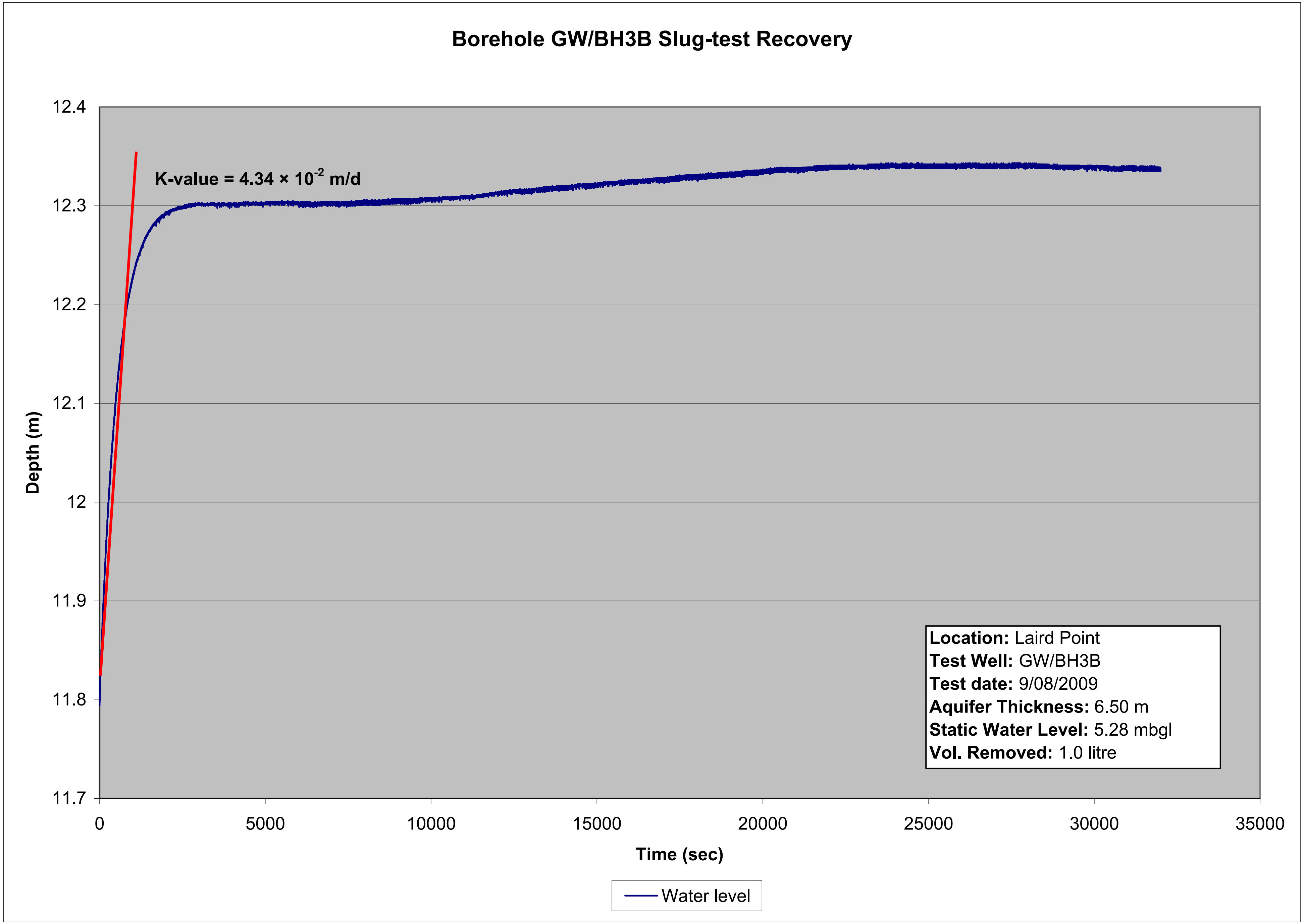
Borehole GW/BH2B - Slug-test Recovery

K-value = 3.13×10^{-2} m/d

Location: Laird Point
Test Well: GW/BH2B
Test date: 21/08/2009
Aquifer Thickness: 6.50 m
Static Water Level: 6.33 mbgl
Vol. Removed: 0.8 litres



Location: Laird Point
Test Well: GW_BH3A
Test date: 9/08/2009
Aquifer Thickness: 5.10 m
Static Water Level: 4.89 mbgl
Vol. Removed: 1.0 litres



Location: Laird Point
Test Well: GW/BH3B
Test date: 9/08/2009
Aquifer Thickness: 6.50 m
Static Water Level: 5.28 mbgl
Vol. Removed: 1.0 litre

URS Australia Pty Ltd
Level 14, 240 Queen St
Brisbane, QLD, 4000
Phone: +61 7 3243 2111

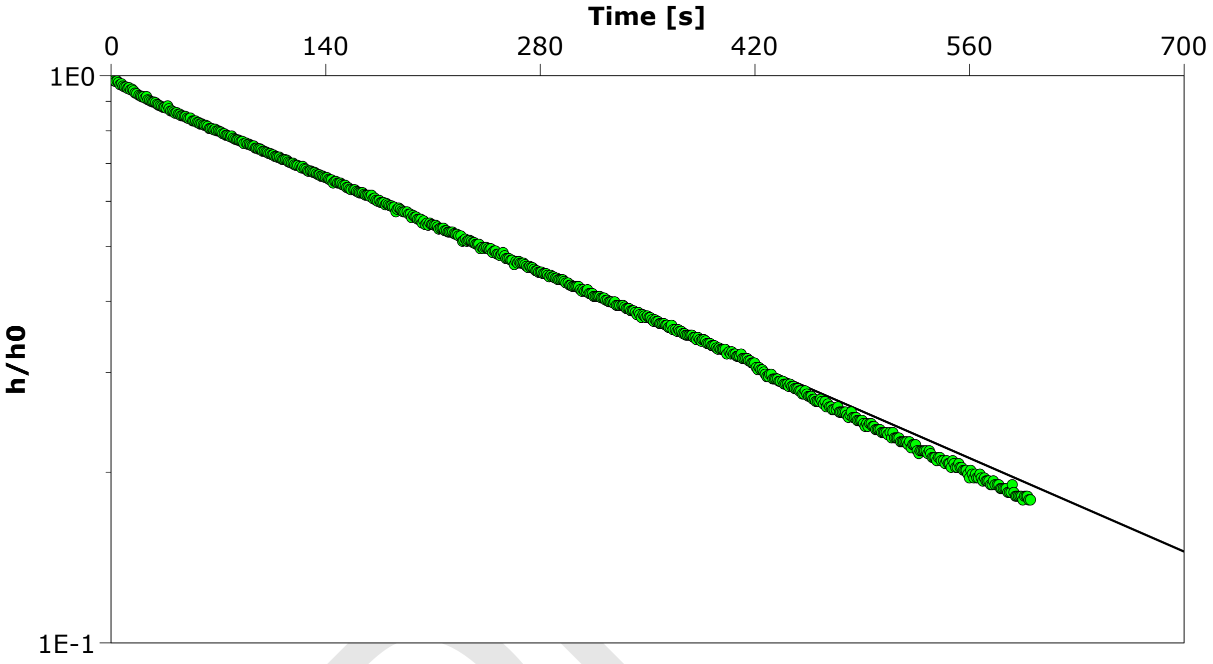
Slug Test Analysis Report

Project: GLNG EIS Supplement

Number: 42626444

Client: Santos Ltd

Location: Curtis Island	Slug Test: GW/BH1B	Test Well: GW/BH1B
Test conducted by:		Test date: 20/08/2009
Analysis performed by: MS	GW/BH1B	Date: 20/08/2009
Aquifer Thickness: 6.50 m		



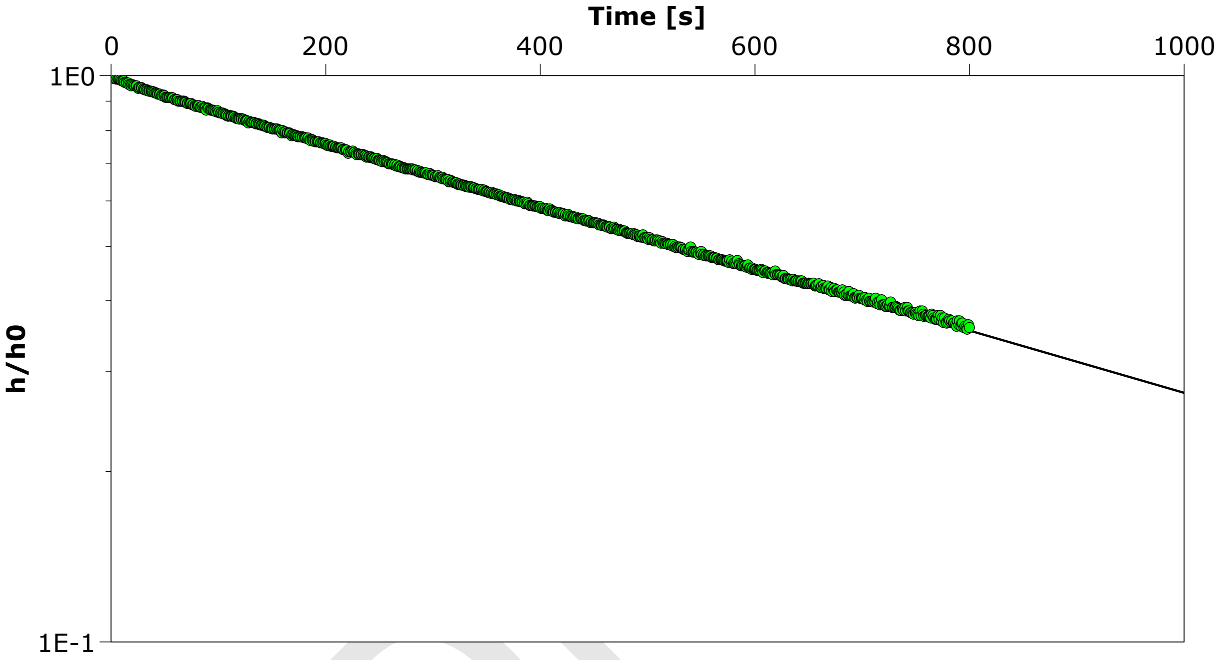
Calculation after Hvorslev

Observation well	K [m/d]
GW/BH1B	5.87×10^{-2}

URS Australia Pty Ltd
Level 14, 240 Queen St
Brisbane, QLD, 4000
Phone: +61 7 3243 2111

Slug Test Analysis Report
Project: GLNG EIS Supplement
Number: 42626444
Client: Santos Ltd

Location: Curtis Island	Slug Test: GW/BH2B	Test Well: GW/BH2B
Test conducted by: MS/JPT		Test date: 21/08/2009
Analysis performed by: MS	GW/BH2B Slug Test	Date: 21/08/2009
Aquifer Thickness: 6.50 m		



Calculation after Hvorslev

Observation well	K [m/d]	
GW/BH2B	3.13×10^{-2}	

URS Australia Pty Ltd
Level 16, 240 Queen St
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Phone: +61 7 3243 2111

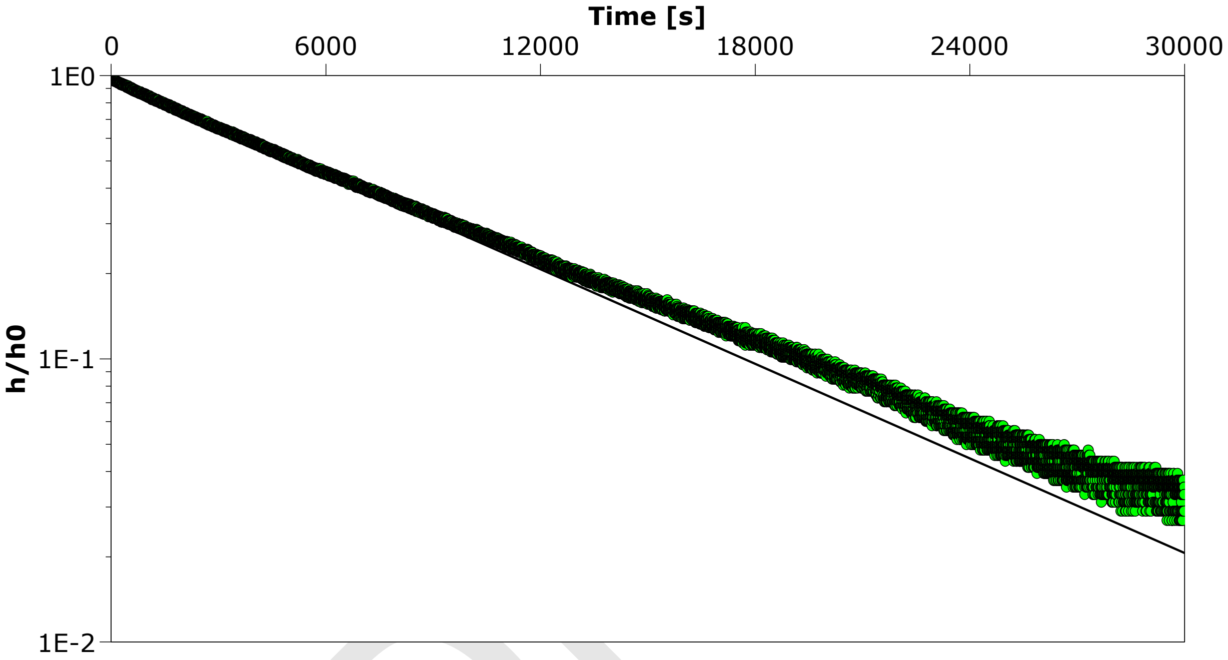
Slug Test Analysis Report

Project: GLNG EIS Supplement

Number: 42626444

Client: Santos Ltd

Location: Curtis Island	Slug Test: GW/BH3A	Test Well: GW_BH3A
Test conducted by: MS		Test date: 9/08/2009
Analysis performed by: MS	GW/BH3A	Date: 20/08/2009
Aquifer Thickness: 5.10 m		



Calculation after Hvorslev

Observation well	K [m/d]	
GW_BH3A	5.55×10^{-3}	

URS Australia Pty Ltd
Level 16, 240 Queen St
Brisbane, QLD, 4000
Phone: +61 7 3243 2111

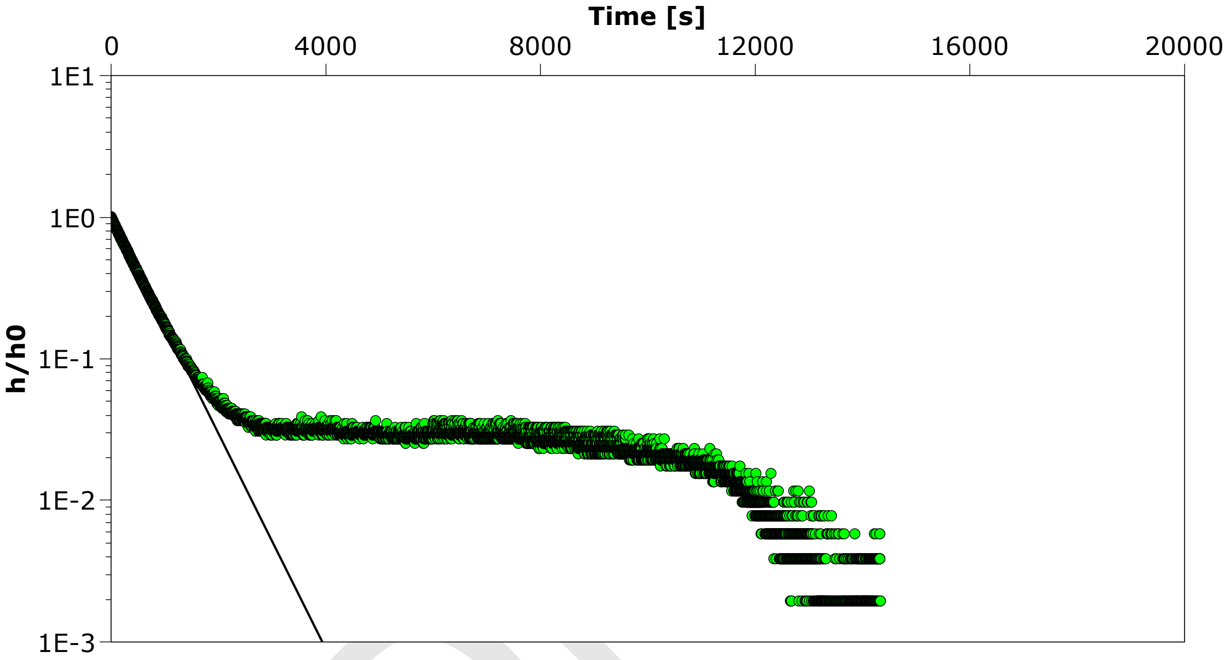
Slug Test Analysis Report

Project: GLNG EIS Supplement

Number: 42626444

Client: Santos Ltd

Location: Curtis Island	Slug Test: GW/BH3B	Test Well: GW/BH3B
Test conducted by: MS/JPT		Test date: 9/08/2009
Analysis performed by: MS	GW/BH3B	Date: 20/08/2009
Aquifer Thickness: 6.50 m		



Calculation after Hvorslev

Observation well	K [m/d]	
GW/BH3B	4.34×10^{-2}	

Hole no: **Auger Hole 1**
Project: **GLNG DMPF**

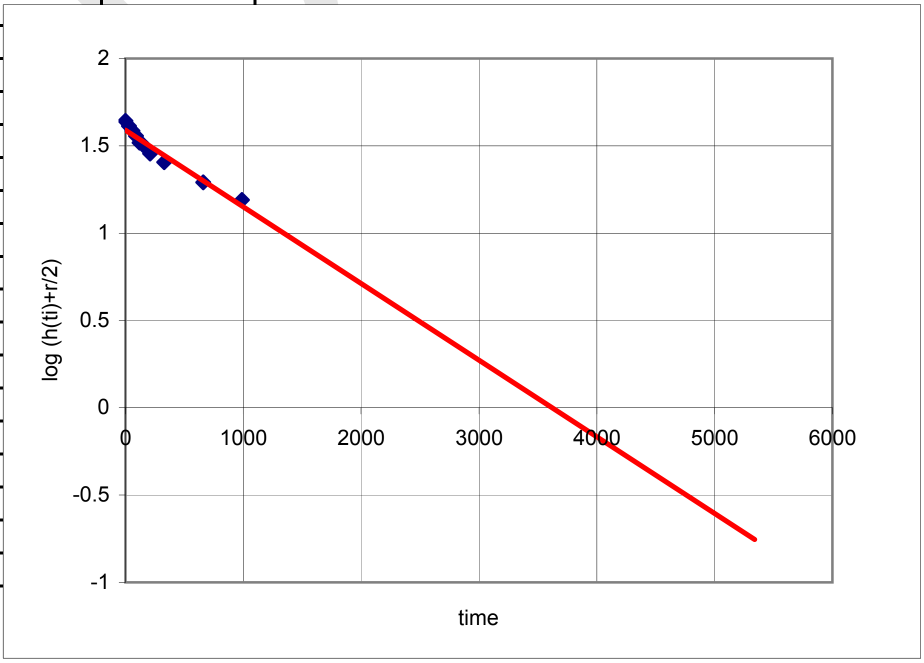
Diameter (cm): 8
Depth of Hole (cm): 40

Permeability:

K (cm/sec)
0.00368
K (m/day)
3.17952
K (m/s)
3.680E-05

Data:

Time (min)	Drawdown (cm)	Time (sec)
0.00	10.713	0
0.50	14.034	30
1.00	13.97	60
1.50	13.91	90
2.00	13.821	120
2.50	13.692	150
3.00	13.636	180
3.50	13.607	210
5.50	13.578	330
11.00	13.545	660
16.50	13.519	990
89.00	13.5	5340



Hole no: **Auger Hole 2**
Project: **GLNG DMPF**

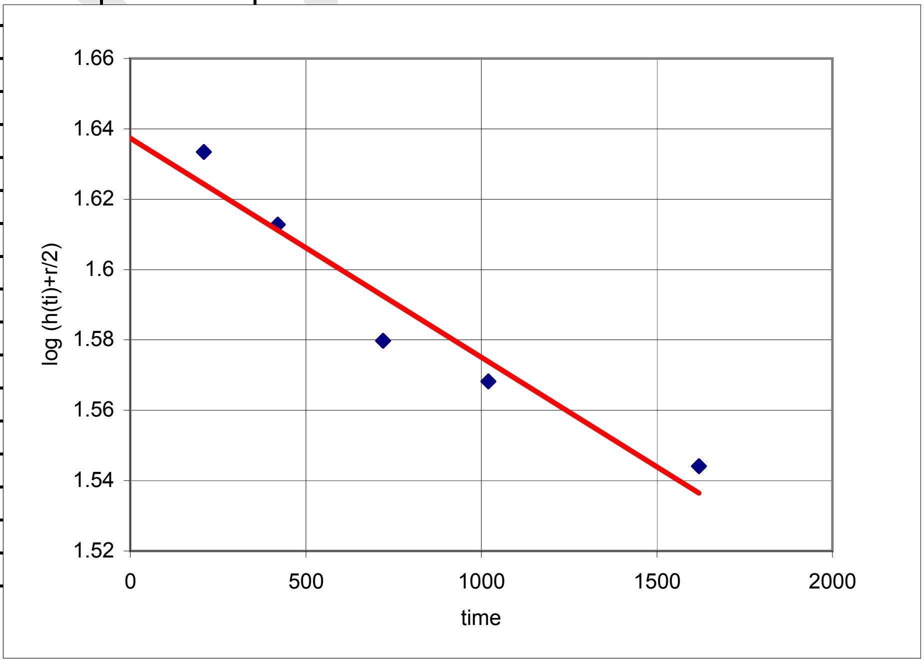
Diameter (cm): 8
Depth of Hole (cm): 50

Permeability:

K (cm/sec)
0.000552
K (m/day)
0.476928
K (m/s)
5.520E-06

Data:

Time (min)	Drawdown (cm)	Time (sec)
0.00	10.713	0
0.50	14.034	30
1.00	13.97	60
1.50	13.91	90
2.00	13.821	120
2.50	13.692	150
3.00	13.636	180
3.50	13.607	210
7.00	13.578	420
12.00	13.545	720
17.00	13.519	1020
27.00	13.5	1620



Hole no: **GW/BH1A**
Project: **GLNG DMPF**

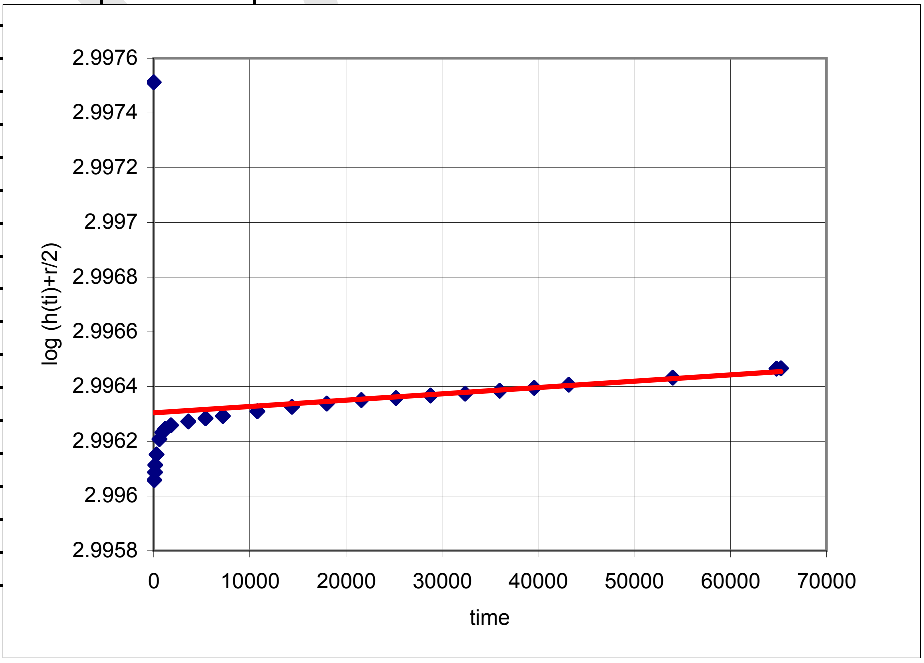
Diameter (cm): 10
Depth of Hole (cm): 1000

Permeability:

K (cm/sec)
0.000000023
K (m/day)
0.000019872
K (m/s)
2.300E-10

Data:

Time (min)	Drawdown (cm)	Time (sec)
0.00	10.713	0
1.00	14.034	60
2.00	13.97	120
3.00	13.91	180
5.00	13.821	300
10.00	13.692	600
15.00	13.636	900
20.00	13.607	1200
30.00	13.578	1800
60.00	13.545	3600
90.00	13.519	5400
120.00	13.5	7200
180.00	13.46	10800
240.00	13.424	14400
300.00	13.396	18000
360.00	13.368	21600
420.00	13.351	25200
480.00	13.331	28800
540.00	13.314	32400
600.00	13.289	36000
660.00	13.267	39600
720.00	13.239	43200
900.00	13.179	54000
1080.00	13.105	64800
1088.00	13.102	65280



Appendix C Hydrochemistry

Appendix C – Table A

Analytes	**Freshwater 95%[1]**	**Irrigation LTV[2]**	**Irrigation STV[3]**	**Livestock Beef[4]**	**Livestock Sheep[4]**	**Drinking Water[5]**	**BH1B**	**BH2A**	**BH2B**	**BH3B**
Field pH	*6.5 – 8.0*	6.0 - 8.5	6.0 - 8.5	n/e	n/e	*6.5 – 8.5*	5.3	6.1	6.2	5.9
Field EC (µS/cm)	*970*[$]	n/e	n/e	n/e	n/e	n/e	41 500	13 420	20 950	60 000
T. Alkalinity (mg/L $CaCO_3$)	n/e	n/e	n/e	n/e	n/e	n/e	38	194	233	176
Sulfate (mg/L)	n/e	n/e	n/e	1000[†]	1000[†]	*500*	1 880	342	528	3 140
Chloride (mg/L)	n/e	n/e	n/e	n/e	n/e	*250*	15 300	5 050	7 550	27 400
Calcium (mg/L)	n/e	n/e	n/e	1000	1000	*200**	1 820	322	978	2 050
Magnesium (mg/L)	n/e	n/e	n/e	n/e	n/e	*200**	1 770	557	988	2 630
Sodium (mg/L)	n/e	n/e	n/e	n/e	n/e	n/e	5 890	2 200	2 630	11 800
Potassium (mg/L)	n/e	n/e	n/e	n/e	n/e	n/e	24	4	11	26
Aluminium (mg/L)	0.055	5	20	5.6	5.1	0.2	0.52	<0.01	0.02	<0.50
Antimony (mg/L)	n/e	n/e	n/e	n/e	n/e	0.003	<0.005	<0.001	<0.001	<0.005
Arsenic (mg/L)	0.024 (III) 0.013 (V)	0.1	2	0.5	0.5	*0.007*	<0.050	0.006	0.011	<0.050
Beryllium (mg/L)	0.00013	0.1	0.5	n/e	n/e	n/e	0.010	<0.001	<0.001	<0.005
Barium (mg/L)	n/e	n/e	n/e	n/e	n/e	*0.7*	0.147	0.156	0.026	0.172
Cadmium (mg/L)	0.0002	0.01	0.05	0.01	0.01	*0.002*	0.0172	0.0003	0.0015	0.0094
Chromium (mg/L)	0.0013 (III) 0.0001 (VI)	0.1	1	1	1	*0.05 (VI)*	<0.005	<0.001	<0.001	<0.005
Cobalt (mg/L)	0.09	0.05	0.1	1	1	n/e	0.850	0.016	0.006	0.119
Copper (mg/L)	0.0014	0.2	5	1	0.5	2	<0.050	0.002	0.005	<0.050
Gallium (mg/L)	0.018	n/e	n/e	n/e	n/e	n/e	<0.005	<0.001	<0.001	<0.005
Lead (mg/L)	0.0034	2	5	0.1	0.1	0.001	0.008	<0.001	<0.001	<0.005
Lithium (mg/L)	n/e	2.5	2.5	n/e	n/e	n/e	0.556	0.230	0.300	0.635

Manganese (mg/L)	1.9	0.2	10	n/e	n/e	*0.5*	32.3	0.943	1.81	8.38
Molybdenum (mg/L)	0.34	0.01	0.05	0.15	0.15	0.05	<0.005	<0.001	0.001	<0.005
Nickel (mg/L)	0.011	0.2	2	1	1	*0.02*	0.220	0.006	0.001	<0.050
Selenium (mg/L)	0.011	0.02	0.05	0.02	0.02	0.01	<0.10	0.03	0.05	<0.10
Strontium (mg/L)	n/e	n/e	n/e	n/e	n/e	n/e	24.8	1.55	4.16	30.1
Thorium (mg/L)	n/e	n/e	n/e	n/e	n/e	n/e	<0.005	<0.001	<0.001	<0.005
Titanium (mg/L)	n/e	n/e	n/e	n/e	n/e	n/e	<0.05	<0.01	<0.01	<0.05
Uranium (mg/L)	n/e	0.01	0.1	0.2	0.2	0.02	<0.005	<0.001	<0.001	<0.005
Vanadium (mg/L)	n/e	0.1	0.5	n/e	n/e	n/e	<0.05	<0.01	<0.01	<0.05
Zinc (mg/L)	0.008	2	5	20	20	*3*	0.658	0.021	0.014	0.078
Boron (mg/L)	0.37	0.5	15^{+}	7	6.2	4	0.65	0.30	0.35	0.39
Iron (mg/L)	0.3	0.2	10	n/a	n/a	0.3	0.05	0.15	0.66	0.99
Mercury (mg/L)	0.0006	0.002	0.002	0.002	0.002	0.001	<0.0001	<0.0001	<0.0001	<0.0001
Hexavalent chromium (mg/L)	1.0	0.1	1.0	1.0	1.0	0.05	<0.010	<0.010	<0.010	<0.010
Nitrite + Nitrate as N (mg/L N)	*0.06*	n/e	n/e	n/e	n/e	n/e	0.10	0.10	0.08	0.13
Total Kjeldahl Nitrogen (mg/L N)	n/e	n/e	n/e	n/e	n/e	n/e	0.3	0.4	0.9	0.6
Total Nitrogen (mg/L N)	*0.5*	5^{+}	25^{+}	n/e	n/e	n/e	0.4	0.6	1.0	0.7
Total Phosphorus (mg/L P)	*0.05*	0.05^{+}	0.8-1.2^{+}	n/e	n/e	n/e	0.26	0.14	0.31	0.38

1- Regional guideline values for physio-chemical indicators- Central Coast region- Lowland streams, QWQG, 2009 denoted in *italics*. ANZECC 2000 Trigger Levels for Typical Slightly to Moderately Disturbed Freshwater Ecosystems, Chapter 3- Aquatic Ecosystems, in normal font.
2- LTV - Long-term Trigger Value, Chapter 4- Primary Industries, ANZECC 2000
3- STV - Short-term Trigger Value, Chapter 4- Primary Industries, ANZECC 2000
4- Trigger values for sheep and beef cattle watering, Chapter 4- Primary Industries, ANZECC 2000
5- Drinking water guideline values for physical and chemical characteristics, ADWG, 2004 denoted in *italics*. Where no trigger value exists for ADWG, ANZECC 2000 guideline values adopted.
n/e- not established
$^{\$}$- 75% percentile for Queensland Central Coast South, QWQS, 2004
*- total hardness as calcium carbonate (*calcium + magnesium*) in drinking water should not exceed 200 mg/L (ADWG, 2004)

[†-] No adverse effects expected ≤ 1000 mg/L, some adverse effects may occur at sulphate concentrations between 1000 and 2000 mg/L, levels of sulphate greater than 2000 mg/L may cause chronic or acute health problems in stock.

[+]- LTV and STV trigger values are site and crop dependant

[C]- Figure may not protect key test species from chronic toxicity (this refers to experimental chronic figures or geometric mean for species)

Appendix C – Table B

Analytes	**Freshwater 95%[1]**	**Irrigation LTV[2]**	**Irrigation STV[3]**	**Livestock Beef[4]**	**Livestock Sheep[4]**	**Drinking Water[5]**	**BH3A**	**RN91326**	**Duplicate** BH3A
Field pH	*6.5 – 8.0*	6.0 - 8.5	6.0 - 8.5	n/e	n/e	*6.5 – 8.5*	6.1	5.9	-
Field EC (µS/cm)	*970*[$]	n/e	n/e	n/e	n/e	n/e	(dry)	1 300	-
T. Alkalinity (mg/L $CaCO_3$)	n/e	n/e	n/e	n/e	n/e	n/e	<1	43	<1
Sulfate (mg/L)	n/e	n/e	n/e	1000[†]	1000[†]	*500*	487	49	518
Chloride (mg/L)	n/e	n/e	n/e	n/e	n/e	*250*	3 370	447	3 130
Calcium (mg/L)	n/e	n/e	n/e	1000	1000	200*	29	28	31
Magnesium (mg/L)	n/e	n/e	n/e	n/e	n/e	200*	170	30	182
Sodium (mg/L)	n/e	n/e	n/e	n/e	n/e	180	2 190	232	2 120
Potassium (mg/L)	n/e	n/e	n/e	n/e	n/e	n/e	5	3	6
Aluminium (mg/L)	0.055	5	20	5.6	5.1	0.2	4.09	0.03	4.05
Antimony (mg/L)	n/e	n/e	n/e	n/e	n/e	0.003	<0.001	<0.001	<0.001
Arsenic (mg/L)	0.024 (III) 0.013 (V)	0.1	2	0.5	0.5	*0.007*	<0.001	0.005	<0.001
Beryllium (mg/L)	0.00013	0.1	0.5	n/e	n/e	n/e	0.004	<0.001	0.003
Barium (mg/L)	n/e	n/e	n/e	n/e	n/e	*0.7*	0.133	0.046	0.134
Cadmium (mg/L)	0.0002	0.01	0.05	0.01	0.01	*0.002*	0.0003	<0.0001	0.0004
Chromium (mg/L)	0.0013 (III) 0.0001 (VI)	0.1	1	1	1	*0.05 (VI)*	0.002	<0.001	0.002
Cobalt (mg/L)	0.09	0.05	0.1	1	1	n/e	0.030	0.004	0.029
Copper (mg/L)	0.0014	0.2	5	1	0.5	*2*	0.025	<0.001	0.026
Gallium (mg/L)	0.018	n/e	n/e	n/e	n/e	n/e	<0.001	<0.001	<0.001
Lead (mg/L)	0.0034	2	5	0.1	0.1	*0.01*	0.090	<0.001	0.090
Lithium (mg/L)	n/e	2.5	2.5	n/e	n/e	n/e	0.066	0.026	0.066

Manganese (mg/L)	1.9	0.2	10	n/e	n/e	*0.5*	0.516	0.740	0.518
Molybdenum (mg/L)	0.34	0.01	0.05	0.15	0.15	0.05	<0.001	<0.001	<0.001
Nickel (mg/L)	0.011	0.2	2	1	1	*0.02*	0.032	0.004	0.033
Selenium (mg/L)	0.011	0.02	0.05	0.02	0.02	0.01	<0.01	<0.01	<0.01
Strontium (mg/L)	n/e	n/e	n/e	n/e	n/e	n/e	0.394	0.377	0.396
Thorium (mg/L)	n/e	n/e	n/e	n/e	n/e	n/e	<0.001	<0.001	<0.001
Titanium (mg/L)	n/e	n/e	n/e	n/e	n/e	n/e	<0.01	<0.01	<0.01
Uranium (mg/L)	n/e	0.01	0.1	0.2	0.2	0.02	<0.001	<0.001	<0.001
Vanadium (mg/L)	n/e	0.1	0.5	n/e	n/e	n/e	<0.01	<0.01	<0.01
Zinc (mg/L)	0.008	2	5	20	20	*3*	0.175	0.012	0.176
Boron (mg/L)	0.37	0.5	15^{+}	7	6.2	4	0.30	0.08	0.30
Iron (mg/L)	0.3	0.2	10	n/a	n/a	0.3	8.51	1.70	8.52
Mercury (mg/L)	0.0006	0.002	0.002	0.002	0.002	0.001	<0.0001	<0.0001	<0.0001
Hexavalent chromium (mg/L)	1.0	0.1	1.0	1.0	1.0	0.05	<0.010	<0.010	<0.010
Nitrite + Nitrate as N (mg/L N)	*0.06*	n/e	n/e	n/e	n/e	n/e	0.03	<0.01	<0.01
Total Kjeldahl Nitrogen (mg/L N)	n/e	n/e	n/e	n/e	n/e	n/e	0.4	0.6	0.4
Total Nitrogen (mg/L N)	*0.5*	5^{+}	25^{+}	n/e	n/e	n/e	0.5	0.6	0.4
Total Phosphorus (mg/L P)	*0.05*	0.05^{+}	0.8-1.2^{+}	n/e	n/e	n/e	0.04	0.36	0.02

1 - Regional guideline values for physio-chemical indicators- Central Coast region- Lowland streams, QWQG, 2009 denoted in *italics*. ANZECC 2000 Trigger Levels for Typical Slightly to Moderately Disturbed Freshwater Ecosystems, Chapter 3- Aquatic Ecosystems, in normal font.
2- LTV - Long-term Trigger Value, Chapter 4- Primary Industries, ANZECC 2000
3- STV - Short-term Trigger Value, Chapter 4- Primary Industries, ANZECC 2000
4- Trigger values for sheep and beef cattle watering, Chapter 4- Primary Industries, ANZECC 2000
5- Drinking water guideline values for physical and chemical characteristics, ADWG, 2004 denoted in *italics*. Where no trigger value exists for ADWG, ANZECC 2000 guideline values adopted.
n/e- not established
$^{\$}$- 75% percentile for Queensland Central Coast South, QWQS, 2004
*- total hardness as calcium carbonate (*calcium + magnesium*) in drinking water should not exceed 200 mg/L (ADWG, 2004)

[†] - No adverse effects expected ≤ 1000 mg/L, some adverse effects may occur at sulphate concentrations between 1000 and 2000 mg/L, levels of sulphate greater than 2000 mg/L may cause chronic or acute health problems in stock.

[+] - LTV and STV trigger values are site and crop dependant

[C] - Figure may not protect key test species from chronic toxicity (this refers to experimental chronic figures or geometric mean for species)

Appendix C – Table C

Analytes	Freshwater 95%[1]	Marine Water 95%[2]	Elutriate Leach Range	Elutriate Leach Average	DI Water Leach Range	DI Water Leach Average
Metals (Total)	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
Aluminium (mg/L)	0.040 (pH>6.5)	ne	0.01 – 0.26	0.073	0.24 - 8.27	4.576
Antimony (mg/L)	ne	ne	0.0006 - 0.006	0.0035	<0.001 - 0.004	0.002
Arsenic (mg/L)	0.012 (As V)	ne	0.0008 – 0.014	0.0043	<0.001 - 0.024	0.010
Cadmium (mg/L)	0.0002	0.0055	0.0008	0.0008	<0.0001 - 1.64	0.231
Chromium (mg/L)	0.001 (Cr VI)	0.0044 (Cr VI)	0.0006	0.0006	<0.001 - 0.029	0.009
Copper (mg/L)	0.0014	0.0014	0.001- 0.004	0.002	<0.001 - 0.022	0.011
Iron (mg/L)	ne	ne	0.006 – 0.688	0.163	0.44 - 36.8	6.666
Lead (mg/L)	0.0034	0.0044	ND	ND	<0.001 - 0.012	0.005
Manganese (mg/L)	0.33	ne	0.0633 – 5.69	1.295	0.008 - 0.296	0.073
Mercury (mg/L)	ne	ne	ND	ND	<0.0001	<0.0001
Nickel (mg/L)	0.011	0.12	0.0005 – 0.005	0.002	<0.001 - 0.015	0.005
Silver (mg/L)	0.00006	0.0014	0.0003	0.0003	<0.001	<0.001
Total Cyanide (mg/L)	ne	ne	ND	ND	<0.004	<0.004

Zinc (mg/L)	0.008	0.015	0.006 – 0.022	0.013	0.015 - 0.526	0.124

[1]ANZECC/ARMCANZ Trigger Values for Fresh Water Screening level (95% Level of Protection)
[2]ANZECC/ARMCANZ Trigger Values for Marine Water Screening level (95% Level of protection)
ND – Less than laboratory detection limits (Non-detect)

Analytes	**Typical Seawater Analysis**	**Elutriate Leach Range**	**Elutriate Leach Average**	**DI Water Leach Range**	**DI Water Leach Average**
Metals (Total)	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**
Aluminium (µg/L)	10.0	10 - 260	73.3	240 – 8 270	4 576
Antimony (µg/L)	0.5	0.6 - 5.9	3.5	< 1 - 4	2
Arsenic (µg/L)	3.0	0.8 - 14.4	4.3	< 1 - 24	10
Cadmium (µg/L)	0.1	0.8	0.8	< 1 – 1 640	231
Chromium (µg/L)	0.05	0.6	0.6	< 1 - 29	9
Copper (µg/L)	3.0	1- 4	2.2	< 1 - 22	11
Iron (µg/L)	10.0	6 - 688	162.5	440 – 36 800	6 666
Lead (µg/L)	3.0	ND	ND	< 1 - 12	5
Manganese (µg/L)	2.0	63.3 - 5690	1295.4	8 - 296	73
Mercury (µg/L)	0.03	ND	ND	< 0.1	< 0.1
Nickel (µg/L)	0.5	0.5 - 4.9	1.9	< 1 - 15	5
Silver (µg/L)	0.3	0.3	0.3	< 1	< 1
Total Cyanide (µg/L)	n/a	ND	ND	< 4	< 4
Zinc (µg/L)	10	6 - 22	12.7	15 - 526	124

CERTIFICATE OF ANALYSIS

Work Order : **EB0912894**

Client : **SANTOS LTD**
Contact : MR STEPHEN DENNER
Address : GPO BOX 302
BRISBANE QLD, AUSTRALIA 4000

E-mail : stephen_denner@urscorp.com
Telephone : +61 07 32432111
Facsimile : ----

Project : 42626444
Order number : A1335
C-O-C number : 134202
Sampler : Matt Smith
Site : Santos Ltd - Curtis Island

Quote number : BN/356/09

Page : 1 of 4

Laboratory : Environmental Division Brisbane
Contact : Tim Kilmister
Address : 32 Shand Street Stafford QLD Australia 4053

E-mail : Services.Brisbane@alsenviro.com
Telephone : +61-7-3243 7222
Facsimile : +61-7-3243 7218

QC Level : NEPM 1999 Schedule B(3) and ALS QCS3 requirement

Date Samples Received : 15-AUG-2009
Issue Date : 26-AUG-2009

No. of samples received : 4
No. of samples analysed : 4

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

WORLD RECOGNISED
ACCREDITATION

NATA Accredited Laboratory 825

This document is issued in accordance with NATA accreditation requirements.

Accredited for compliance with ISO/IEC 17025.

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Kim McCabe	Senior Inorganic Chemist	Inorganics

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insuffient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When date(s) and/or time(s) are shown bracketed, these have been assumed by the laboratory for processing purposes. If the sampling time is displayed as 0:00 the information was not provided by client.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

- **EG020A/B/D-F (Dissolved Metals) LORs for samples EB0912894-001(GW/BH1B) and EB0912894-004(GW/BH3B) have been raised due to saline sample matrix.**

Analytical Results

Sub-Matrix: **WATER**			*Client sample ID*	**GW/BH1B**	**GW/BH2A**	**GW/BH2B**	**GW/BH3B**	----
			Client sampling date / time	13-AUG-2009 15:00	13-AUG-2009 15:00	13-AUG-2009 15:00	13-AUG-2009 15:00	----
Compound	*CAS Number*	*LOR*	*Unit*	**EB0912894-001**	**EB0912894-002**	**EB0912894-003**	**EB0912894-004**	**----**
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	**38**	**194**	**233**	**176**	----
Total Alkalinity as CaCO3	----	1	mg/L	**38**	**194**	**233**	**176**	----
ED040F: Dissolved Major Anions								
Sulfate as SO4 2-	14808-79-8	1	mg/L	**1880**	**342**	**528**	**3140**	----
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	**15300**	**5050**	**7550**	**27400**	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	**1820**	**322**	**978**	**2050**	----
Magnesium	7439-95-4	1	mg/L	**1770**	**557**	**988**	**2630**	----
Sodium	7440-23-5	1	mg/L	**5890**	**2200**	**2630**	**11800**	----
Potassium	7440-09-7	1	mg/L	**24**	**4**	**11**	**26**	----
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	**0.52**	<0.01	**0.02**	<0.50	----
Antimony	7440-36-0	0.001	mg/L	<0.005	<0.001	<0.001	<0.005	----
Arsenic	7440-38-2	0.001	mg/L	<0.050	**0.006**	**0.011**	<0.050	----
Beryllium	7440-41-7	0.001	mg/L	**0.010**	<0.001	<0.001	<0.005	----
Barium	7440-39-3	0.001	mg/L	**0.147**	**0.156**	**0.026**	**0.172**	----
Cadmium	7440-43-9	0.0001	mg/L	**0.0172**	**0.0003**	**0.0015**	**0.0094**	----
Chromium	7440-47-3	0.001	mg/L	<0.005	<0.001	<0.001	<0.005	----
Cobalt	7440-48-4	0.001	mg/L	**0.850**	**0.016**	**0.006**	**0.119**	----
Copper	7440-50-8	0.001	mg/L	<0.050	**0.002**	**0.005**	<0.050	----
Gallium	7440-55-3	0.001	mg/L	<0.005	<0.001	<0.001	<0.005	----
Lead	7439-92-1	0.001	mg/L	**0.008**	<0.001	<0.001	<0.005	----
Lithium	7439-93-2	0.001	mg/L	**0.556**	**0.230**	**0.300**	**0.635**	----
Manganese	7439-96-5	0.001	mg/L	**32.3**	**0.943**	**1.81**	**8.38**	----
Molybdenum	7439-98-7	0.001	mg/L	<0.005	<0.001	**0.001**	<0.005	----
Nickel	7440-02-0	0.001	mg/L	**0.220**	**0.006**	**0.001**	<0.050	----
Selenium	7782-49-2	0.01	mg/L	<0.10	**0.03**	**0.05**	<0.10	----
Strontium	7440-24-6	0.001	mg/L	**24.8**	**1.55**	**4.16**	**30.1**	----
Thorium	7440-29-1	0.001	mg/L	<0.005	<0.001	<0.001	<0.005	----
Titanium	7440-32-6	0.01	mg/L	<0.05	<0.01	<0.01	<0.05	----
Uranium	7440-61-1	0.001	mg/L	<0.005	<0.001	**0.001**	<0.005	----
Vanadium	7440-62-2	0.01	mg/L	<0.05	<0.01	<0.01	<0.05	----
Zinc	7440-66-6	0.005	mg/L	**0.658**	**0.021**	**0.014**	**0.078**	----
Boron	7440-42-8	0.05	mg/L	**0.65**	**0.30**	**0.35**	**0.39**	----
Iron	7439-89-6	0.05	mg/L	**0.05**	**0.15**	**0.66**	**0.99**	----

Analytical Results

Sub-Matrix: **WATER**			*Client sample ID*	**GW/BH1B**	**GW/BH2A**	**GW/BH2B**	**GW/BH3B**	----
			Client sampling date / time	13-AUG-2009 15:00	13-AUG-2009 15:00	13-AUG-2009 15:00	13-AUG-2009 15:00	----
Compound	*CAS Number*	*LOR*	*Unit*	**EB0912894-001**	**EB0912894-002**	**EB0912894-003**	**EB0912894-004**	**----**
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	----
EG050F: Hexavalent Chromium - Filtered								
Hexavalent Chromium	18540-29-9	0.010	mg/L	<0.010	<0.010	<0.010	<0.010	----
EK059G: NOX as N by Discrete Analyser								
Nitrite + Nitrate as N	----	0.01	mg/L	**0.10**	**0.10**	**0.08**	**0.13**	----
EK061: Total Kjeldahl Nitrogen (TKN)								
Total Kjeldahl Nitrogen as N	----	0.1	mg/L	**0.3**	**0.4**	**0.9**	**0.6**	----
EK062: Total Nitrogen as N								
^ Total Nitrogen as N	----	0.1	mg/L	**0.4**	**0.6**	**1.0**	**0.7**	----
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	0.01	mg/L	**0.26**	**0.14**	**0.31**	**0.38**	----
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	**471**	**153**	**229**	**842**	----
^ Total Cations	----	0.01	meq/L	**493**	**158**	**245**	**832**	----
^ Ionic Balance	----	0.01	%	**2.24**	**1.38**	**3.45**	**0.60**	----

Environmental Division

CERTIFICATE OF ANALYSIS

Work Order	: **EB0913012**	Page	: 1 of 4
Client	: **SANTOS LTD**	Laboratory	: Environmental Division Brisbane
Contact	: MR STEPHEN DENNER	Contact	: Tim Kilmister
Address	: GPO BOX 302 BRISBANE QLD, AUSTRALIA 4000	Address	: 32 Shand Street Stafford QLD Australia 4053
E-mail	: stephen_denner@urscorp.com	E-mail	: Services.Brisbane@alsenviro.com
Telephone	: +61 07 32432111	Telephone	: +61-7-3243 7222
Facsimile	: ----	Facsimile	: +61-7-3243 7218
Project	: 426264444	QC Level	: NEPM 1999 Schedule B(3) and ALS QCS3 requirement
Order number	: A1335		
C-O-C number	: 134203	Date Samples Received	: 19-AUG-2009
Sampler	: Matt Smith	Issue Date	: 28-AUG-2009
Site	: Santos Curtis Island		
		No. of samples received	: 3
Quote number	: EN/039/09	No. of samples analysed	: 3

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. All pages of this report have been checked and approved for release.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA Accredited Laboratory 825

This document is issued in accordance with NATA accreditation requirements.

Accredited for compliance with ISO/IEC 17025.

WORLD RECOGNISED
ACCREDITATION

Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Kim McCabe	Senior Inorganic Chemist	Inorganics
Phillip Kennedy	2IC Environmental Laboratory	Inorganics
Stephen Hislop	Senior Inorganic Chemist	Inorganics

General Comments

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Where moisture determination has been performed, results are reported on a dry weight basis.

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Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When date(s) and/or time(s) are shown bracketed, these have been assumed by the laboratory for processing purposes. If the sampling time is displayed as 0:00 the information was not provided by client.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting

Analytical Results

Sub-Matrix: **WATER**

Compound	CAS Number	LOR	Unit	GW/BH3A	STW	QA01	----	----
			Client sample ID	GW/BH3A	STW	QA01	----	----
			Client sampling date / time	14-AUG-2009 11:00	15-AUG-2009 11:00	14-AUG-2009 11:00	----	----
				EB0913012-001	EB0913012-002	EB0913012-003	----	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	<1	43	<1	----	----
Total Alkalinity as CaCO3	----	1	mg/L	<1	43	<1	----	----
ED040F: Dissolved Major Anions								
Sulfate as SO4 2-	14808-79-8	1	mg/L	487	49	518	----	----
ED045G: Chloride Discrete analyser								
Chloride	16887-00-6	1	mg/L	3730	447	3130	----	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	29	28	31	----	----
Magnesium	7439-95-4	1	mg/L	170	30	182	----	----
Sodium	7440-23-5	1	mg/L	2190	232	2120	----	----
Potassium	7440-09-7	1	mg/L	5	3	6	----	----
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	4.09	0.03	4.05	----	----
Antimony	7440-36-0	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Arsenic	7440-38-2	0.001	mg/L	<0.001	0.005	<0.001	----	----
Beryllium	7440-41-7	0.001	mg/L	0.004	<0.001	0.003	----	----
Barium	7440-39-3	0.001	mg/L	0.133	0.046	0.134	----	----
Cadmium	7440-43-9	0.0001	mg/L	0.0003	<0.0001	0.0004	----	----
Chromium	7440-47-3	0.001	mg/L	0.002	<0.001	0.002	----	----
Cobalt	7440-48-4	0.001	mg/L	0.030	0.004	0.029	----	----
Copper	7440-50-8	0.001	mg/L	0.025	<0.001	0.026	----	----
Gallium	7440-55-3	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Lead	7439-92-1	0.001	mg/L	0.090	<0.001	0.090	----	----
Lithium	7439-93-2	0.001	mg/L	0.066	0.026	0.066	----	----
Manganese	7439-96-5	0.001	mg/L	0.516	0.740	0.518	----	----
Molybdenum	7439-98-7	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Nickel	7440-02-0	0.001	mg/L	0.032	0.004	0.033	----	----
Selenium	7782-49-2	0.01	mg/L	<0.01	<0.01	<0.01	----	----
Strontium	7440-24-6	0.001	mg/L	0.394	0.377	0.396	----	----
Thorium	7440-29-1	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Titanium	7440-32-6	0.01	mg/L	<0.01	<0.01	<0.01	----	----
Uranium	7440-61-1	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	<0.01	----	----
Zinc	7440-66-6	0.005	mg/L	0.175	0.012	0.176	----	----
Boron	7440-42-8	0.05	mg/L	0.30	0.08	0.30	----	----
Iron	7439-89-6	0.05	mg/L	8.51	1.70	8.52	----	----

Analytical Results

Sub-Matrix: **WATER**			*Client sample ID*	**GW/BH3A**	**STW**	**QA01**	----	----
			Client sampling date / time	14-AUG-2009 11:00	15-AUG-2009 11:00	14-AUG-2009 11:00	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**EB0913012-001**	**EB0913012-002**	**EB0913012-003**	**----**	**----**
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	----	----
EG050F: Hexavalent Chromium - Filtered								
Hexavalent Chromium	18540-29-9	0.010	mg/L	<0.010	<0.010	<0.010	----	----
EK059G: NOX as N by Discrete Analyser								
Nitrite + Nitrate as N	----	0.01	mg/L	**0.03**	<0.01	<0.01	----	----
EK061: Total Kjeldahl Nitrogen (TKN)								
Total Kjeldahl Nitrogen as N	----	0.1	mg/L	**0.4**	**0.6**	**0.4**	----	----
EK062: Total Nitrogen as N								
^ Total Nitrogen as N	----	0.1	mg/L	**0.5**	**0.6**	**0.4**	----	----
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	0.01	mg/L	**0.04**	**0.36**	**0.02**	----	----
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	**115**	**14.5**	**99.1**	----	----
^ Total Cations	----	0.01	meq/L	**111**	**14.0**	**109**	----	----
^ Ionic Balance	----	0.01	%	**2.06**	**1.64**	**4.71**	----	----

Appendix D Seepage Model

N
W E
S

0 0.25 0.5 1
Kilometers

Scale 1:20 000 (A4)
Datum: GDA94

▭	Dredge Material Placement Facility Footprint (21/10/2009)
▭	Dredge Material Placement Facility Footprint (07/10/2009)

Hydraulic Conductivity (m per day)

🟧	0.00001
🟦	0.00144

Source: This map may contain data which is sourced and Copyright. Refer to Section 18.2 of the EIS for Ownership and Copyright.

Client

URS

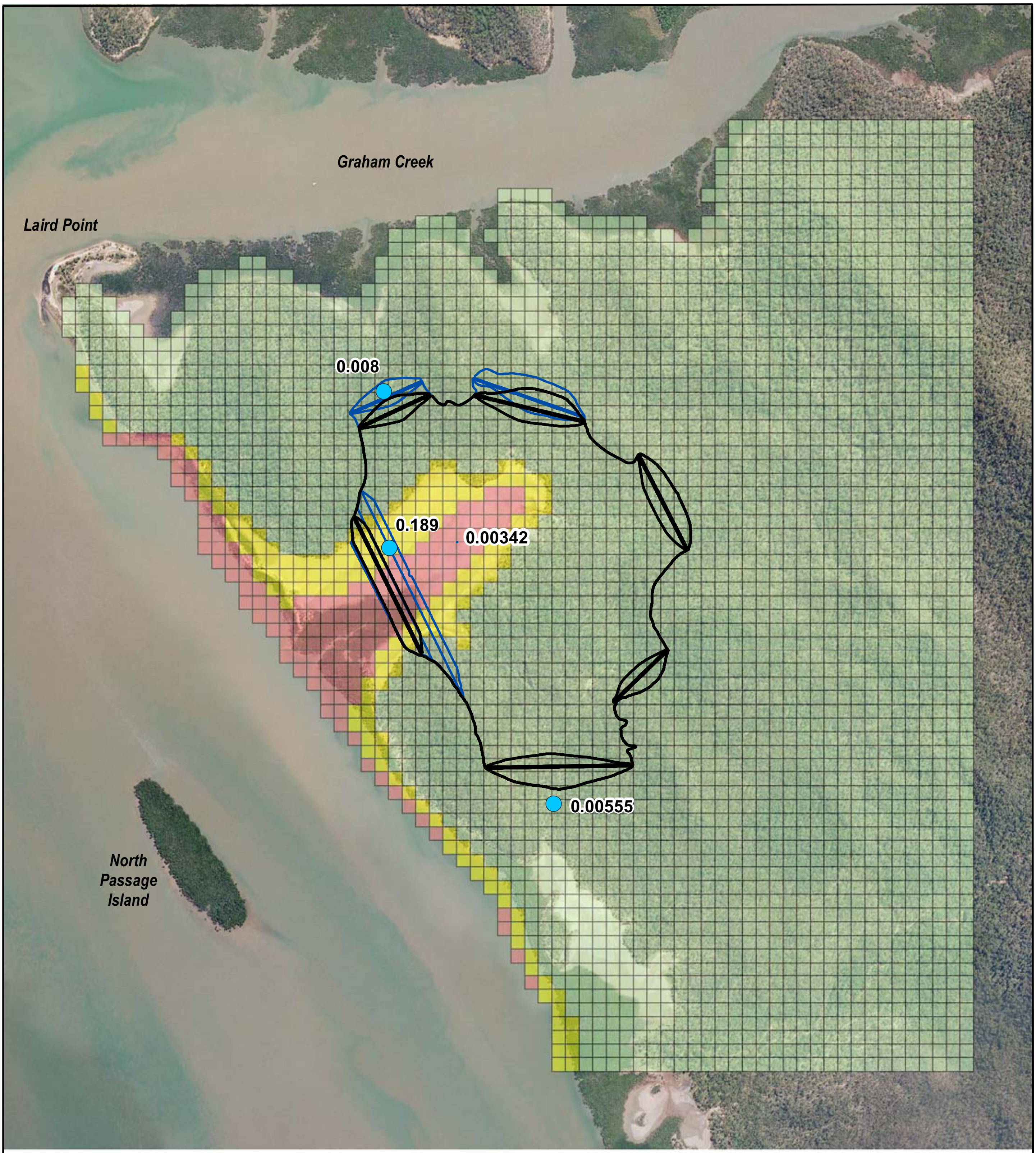
Project

GLADSTONE LNG PROJECT
FOR THE SUPPLEMENTARY
ENVIRONMENTAL IMPACT STATEMENT
DREDGE MATERIAL PLACEMENT FACILITY
HYDROGEOLOGICAL STUDY

Title

**GROUNDWATER
HYDRAULIC CONDUCTIVITY
- SURFACE
LAYER 1**

Drawn: MG
Approved: MS
Date: 27-10-2009
Job No: **4262 6444** /6220
File: 42626440-g-2065.mxd
Figure: **D1**
Rev.C
A4



Scale 1:20 000 (A4)
Datum: GDA94

● Groundwater Wells Hydraulic Conductivity

▭ Dredge Material Placement Facility Footprint (21/10/2009)

▭ Dredge Material Placement Facility Footprint (07/10/2009)

Hydraulic Conductivity (m per day)

🟨	0.0342
🟩	0.00677
🟥	0.20000

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Project

GLADSTONE LNG PROJECT
ENVIRONMENTAL IMPACT STATEMENT
SUPPLEMENT
DREDGE MATERIAL PLACEMENT FACILITY
HYDROGEOLOGICAL STUDY

Drawn: MG | Approved: MS | Date: 27-10-2009

Job No: **4262 6444** /6220 | File: 42626440-g-2066.mxd

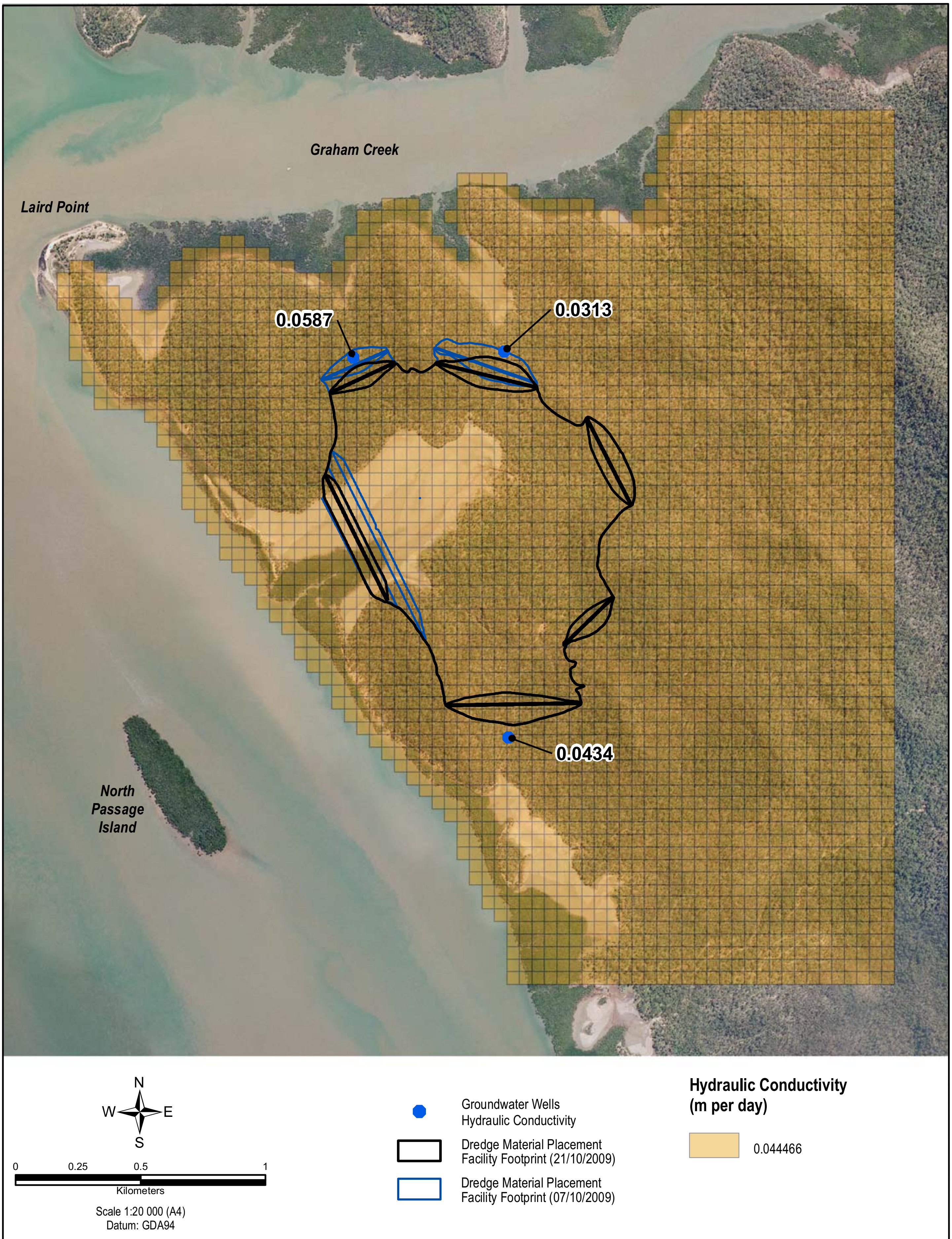
Title

GROUNDWATER HYDRAULIC CONDUCTIVITY - SHALLOW AQUIFER UNIT LAYER 2

Figure: **D2**

Rev.B

A4



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ENVIRONMENTAL IMPACT STATEMENT
DREDGE MATERIAL PLACEMENT FACILITY
HYDROGEOLOGICAL STUDY

Drawn: MG | Approved: MS | Date: 27-10-2009

Job No: **4262 6444** /6220 | File: 42626440-g-2067.mxd

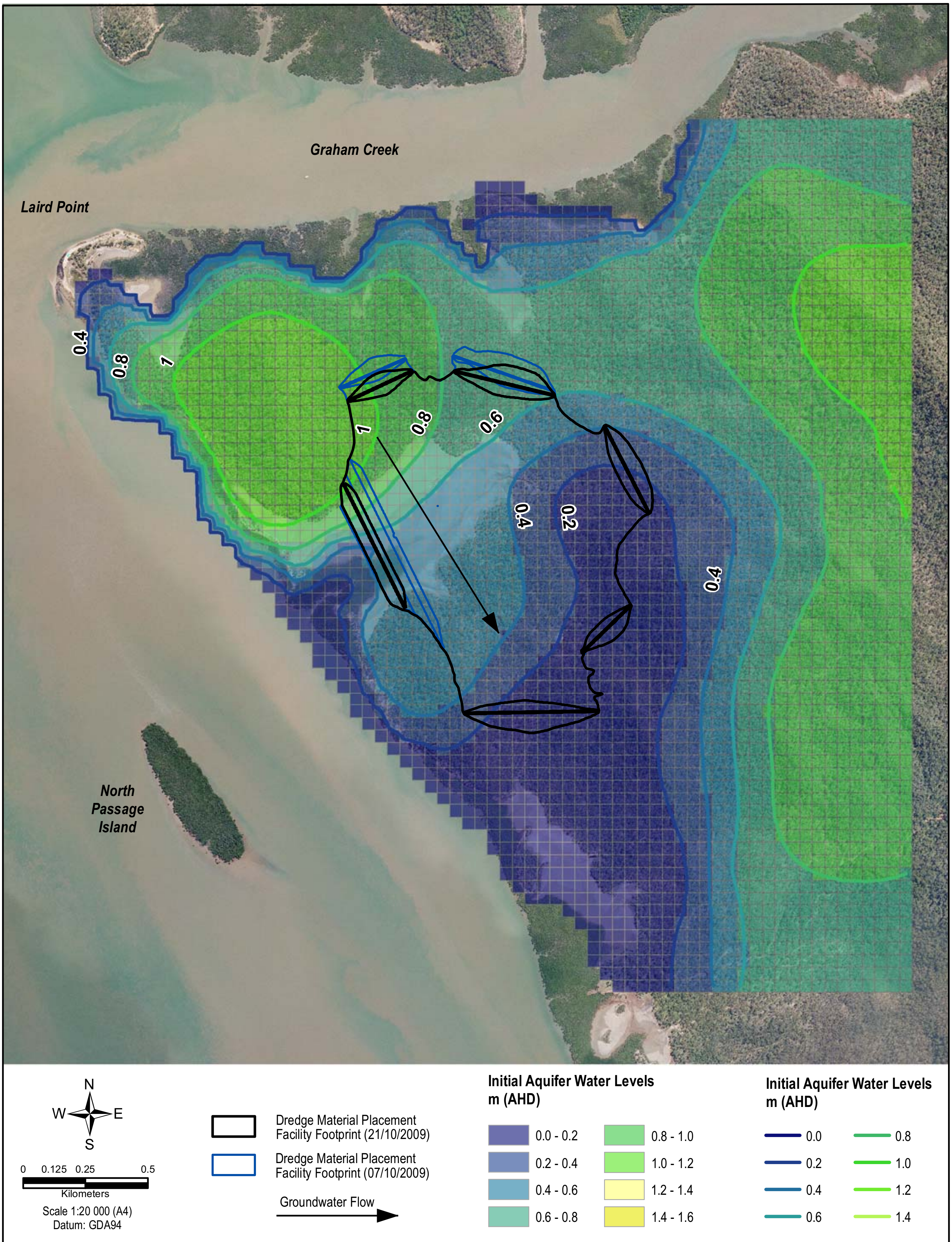
Title

GROUNDWATER
HYDRAULIC CONDUCTIVITY
- DEEP AQUIFER UNIT
LAYER 3

Figure: **D3**

Rev.B

A4



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GLADSTONE LNG PROJECT
FOR THE SUPPLEMENTARY
ENVIRONMENTAL IMPACT STATEMENT
DREDGE MATERIAL PLACEMENT FACILITY
HYDROGEOLOGICAL STUDY

Title

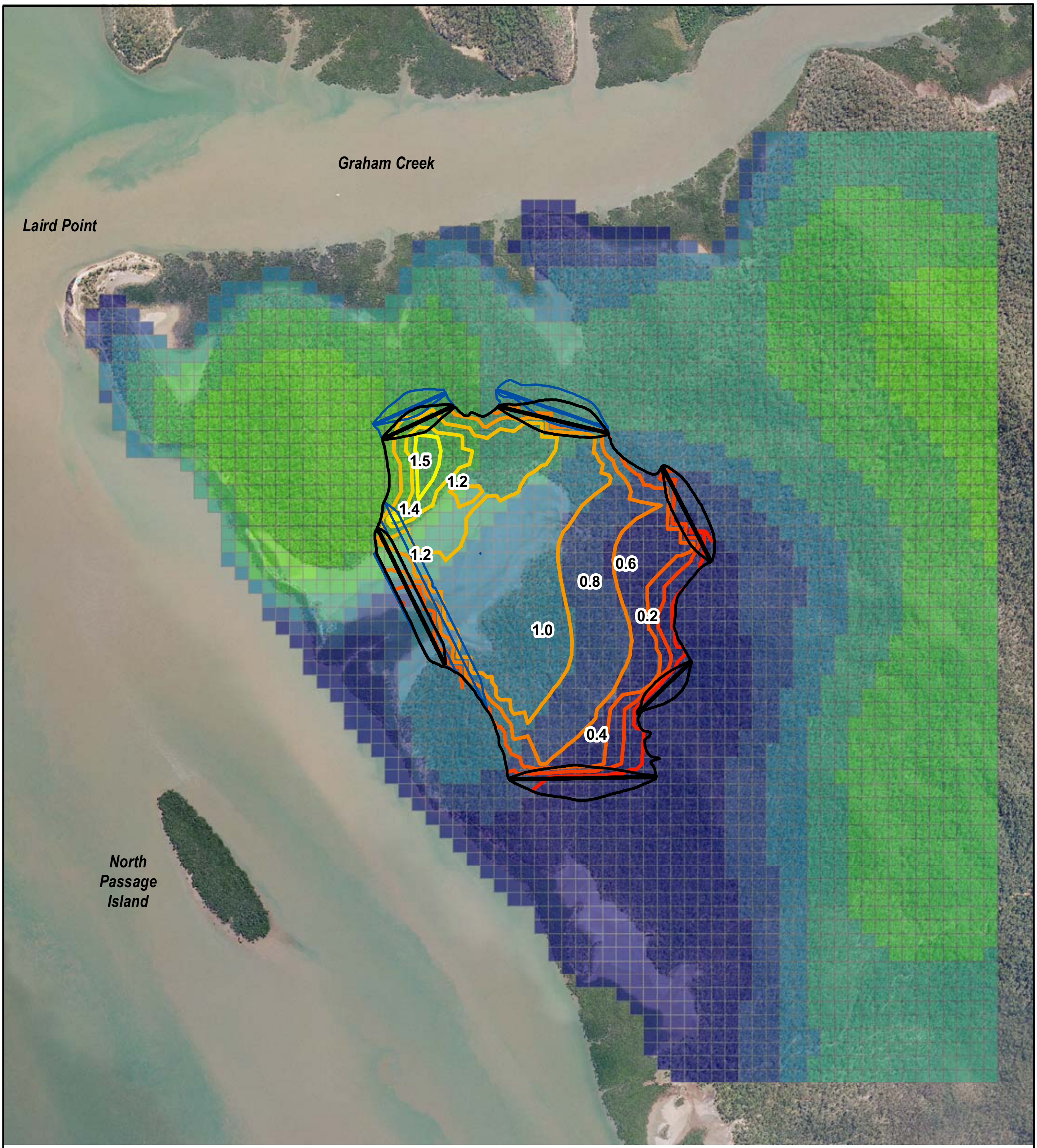
GROUNDWATER INITIAL HEAD VALUES

Drawn: MG
Approved: MS
Date: 27-10-2009
Job No: **4262 6444** /6220
File: 42626440-g-2068.mxd

Figure: **D4**

Rev.B

A4



Scale 1:20 000 (A4)
Datum: GDA94

▭ Dredge Material Placement Facility Footprint (21/10/2009)

▭ Dredge Material Placement Facility Footprint (07/10/2009)

Initial Aquifer Water Levels m (AHD)

🟦	0.0 - 0.2	🟩	0.8 - 1.0
🟦	0.2 - 0.4	🟩	1.0 - 1.2
🟦	0.4 - 0.6	🟨	1.2 - 1.4
🟩	0.6 - 0.8	🟨	1.4 - 1.6

End of Simulation - Shallow Unit Aquifer Water Levels m (AHD)

—	0.0	—	1.0
—	0.2	—	1.2
—	0.4	—	1.4
—	0.6	—	1.5
—	0.8		

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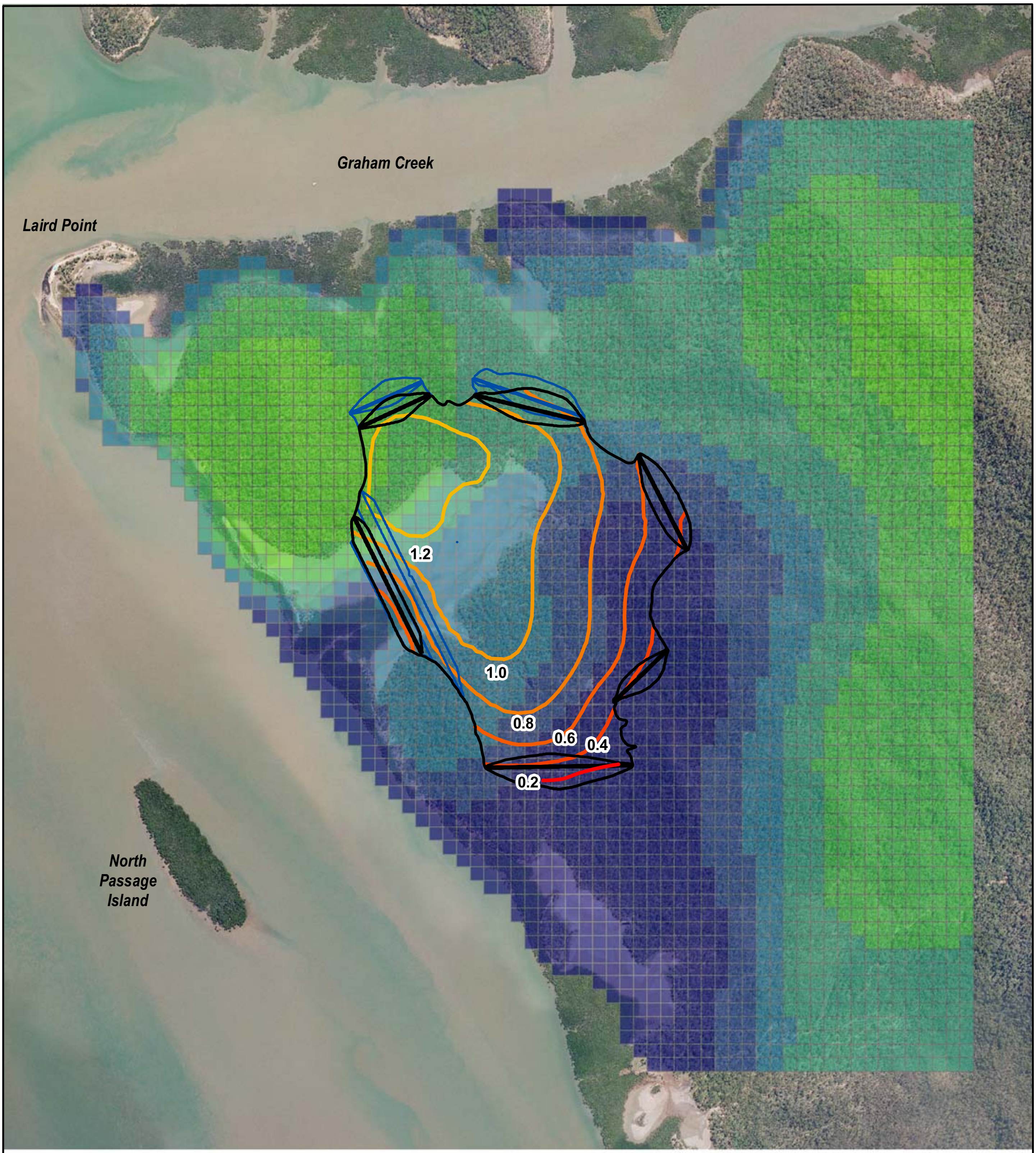
GLADSTONE LNG PROJECT
FOR THE SUPPLEMENTARY
ENVIRONMENTAL IMPACT STATEMENT
DREDGE MATERIAL PLACEMENT FACILITY
HYDROGEOLOGICAL STUDY

Title

GROUNDWATER END OF SIMULATION HEAD SHALLOW AQUIFER

Drawn: MG
Approved: MS
Date: 27-10-2009
Job No: **4262 6444** /6220
File: 42626440-g-2069.mxd
Figure: **D5**
Rev.C
A4



N
W E
S

0 0.125 0.25 0.5
Kilometers

Scale 1:20 000 (A4)
Datum: GDA94

▭ Dredge Material Placement Facility Footprint (21/10/2009)

▭ Dredge Material Placement Facility Footprint (07/10/2009)

Initial Aquifer Water Levels m (AHD)

🟦	0.0 - 0.2	🟩	0.8 - 1.0
🟦	0.2 - 0.4	🟩	1.0 - 1.2
🟦	0.4 - 0.6	🟨	1.2 - 1.4
🟩	0.6 - 0.8	🟨	1.4 - 1.6

End of Simulation - Deep Unit Aquifer Water Levels m (AHD)

—	0.2	—	0.8
—	0.4	—	1.0
—	0.6	—	1.2

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GLADSTONE LNG PROJECT
FOR THE SUPPLEMENTARY
ENVIRONMENTAL IMPACT STATEMENT
DREDGE MATERIAL PLACEMENT FACILITY
HYDROGEOLOGICAL STUDY

Title

GROUNDWATER
END OF SIMULATION HEAD
DEEP AQUIFER

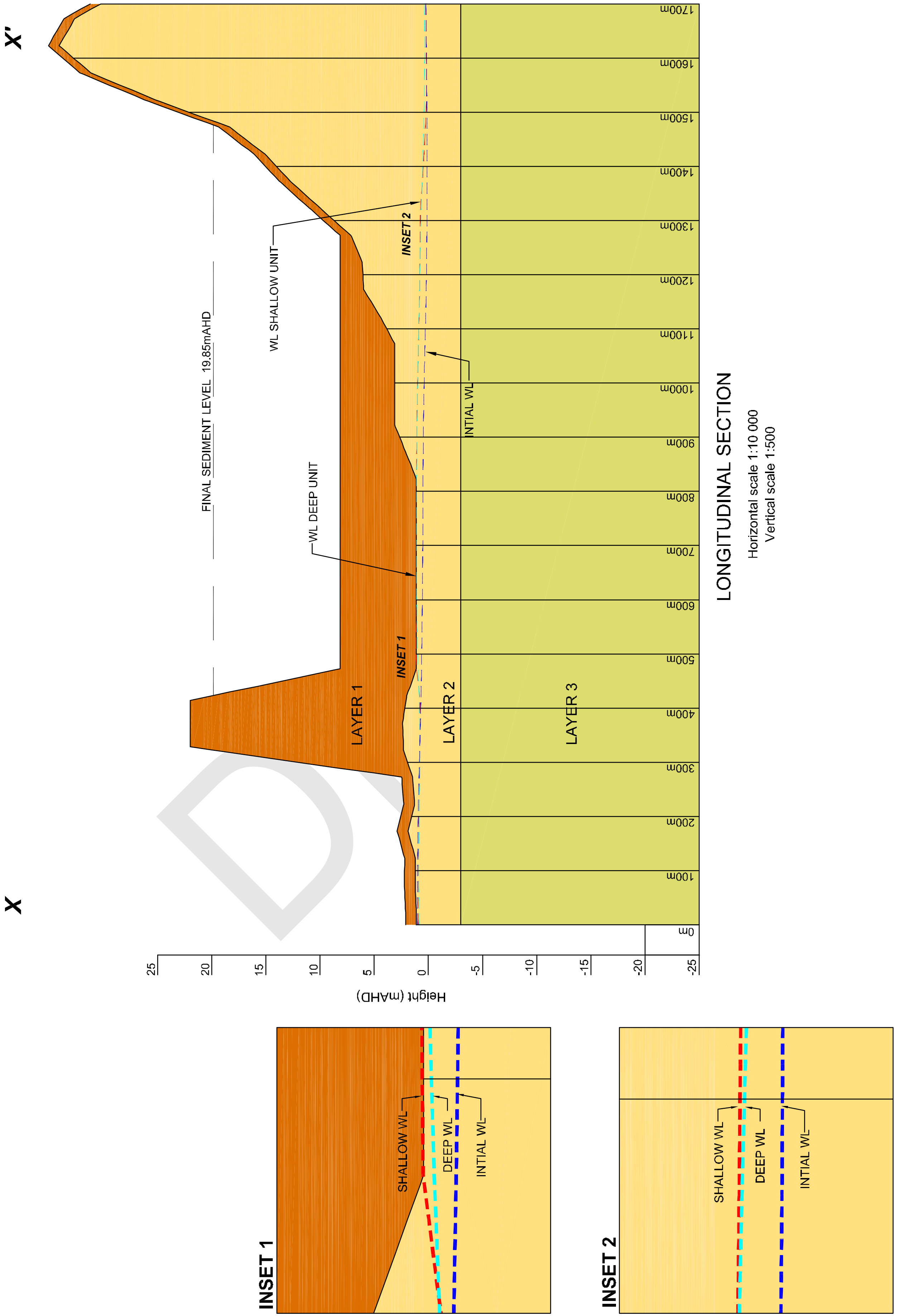
Drawn: MG | Approved: MS | Date: 27-10-2009

Job No: **4262 6444** /6220 | File: **42626440-g-2070.mxd**

Figure: **D6**

Rev.B

A4



Client

Project

GLADSTONE LNG PROJECT
ENVIRONMENTAL IMPACT STATEMENT SUPPLEMENT
DREDGE MATERIAL PLACEMENT FACILITY
HYDROGEOLOGICAL STUDY

Title

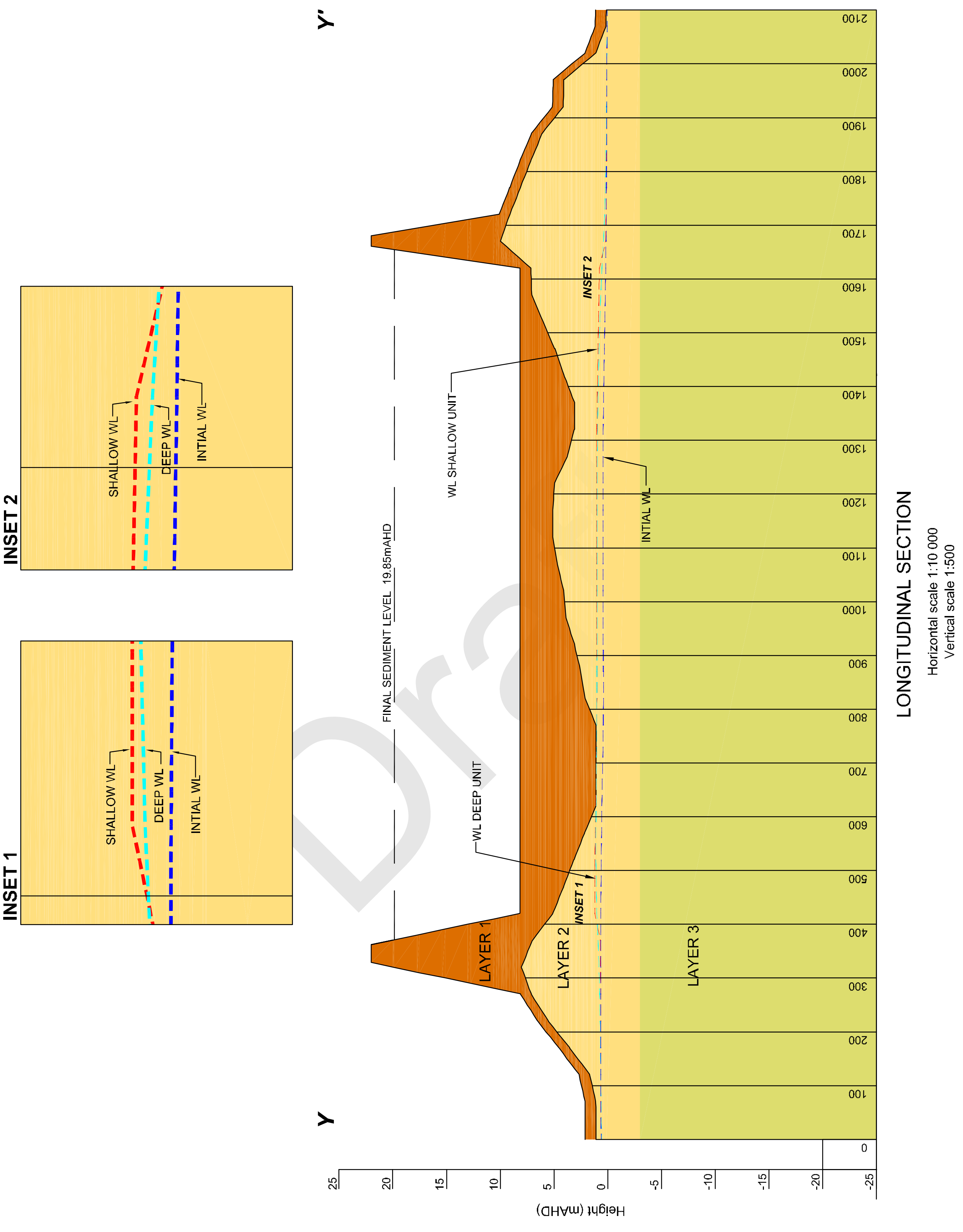
**EAST - WEST
CROSS SECTION**

Drawn: TA	Approved: JB	Date: 09-10-2009
Job No.: 42626440/6220	File No.: 42626440-g-2071.dwg	

Figure: **D7**

Rev. A

A4



Client	Project	Title
	GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT SUPPLEMENT DREDGE MATERIAL PLACEMENT FACILITY HYDROGEOLOGICAL STUDY	**NORTH SOUTH CROSS SECTION**

Drawn: TA	Approved: JB	Date: 09-10-2009
Job No.: 42626440/6220	File No.: 42626440-g-2072.dwg	

Figure: **D8**

Rev. A

A4

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