Australia Pacific LNG Project

Volume 4: LNG Facility

Chapter 5: Geology, Geomorphology, Soils and Land Contamination

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5. Land – geology, geomorphology, soil and land contamination

5.1 Introduction

5.1.1 Purpose

This chapter provides information on the existing values and characteristics of soils, geology, topography and geomorphology for the liquefied natural gas (LNG) facility study area as part of the Australia Pacific LNG Project (the Project). It also presents the findings of a preliminary site investigation on land contamination within the LNG facility study area in accordance with the terms of reference (TOR) for the Project's environmental impact statement (EIS). This assessment identifies those construction and operational activities that may result in significant impacts on the environment, along with suitable management and mitigation measures to ensure these are prevented, or at least reduce the risk to as low as reasonably practicable.

The study area includes the Australia Pacific LNG property boundary approximately 1km south of Laird Point, but also includes the Curtis Island Infrastructure Corridor located between the northern property boundary and Graham Creek to the north (refer Figure 5.1). The study area for this assessment totalled 453ha.

To obtain the information within this chapter, an assessment was carried out through desktop studies supplemented by field investigations within the LNG facility study area. The full technical reports for these studies are located in:

- Volume 5 Attachment 7 – Geology, topography, geomorphology and soils assessment
- Volume 5 Attachment 10 – Preliminary site investigation – land contamination report.

This chapter addresses the EIS TOR Sections 3.2.1 Topography, geomorphology and geology, 3.2.2 Soils and 3.2.5 Land contamination where they relate to the LNG facility (refer Volume 5 Attachment 1).

Australia Pacific LNG's sustainability principles will be applied to the planning, design, construction and operation of the LNG facility, to ensure the Project does not aversely impact people or the environment.

Of Australia Pacific LNG's 12 sustainability principles, key principles which relate to land for the LNG facility include:

- Minimising adverse environmental impacts and enhancing environmental benefits associated with Australia Pacific LNG's activities, products or services; conserving, protecting, and enhancing where the opportunity exists, the biodiversity values and water resources in its operational areas.
- Using resources efficiently, reducing the intensity of materials used and implementing programs for the reduction and re-use of waste.
- Identifying, assessing, managing, monitoring and reviewing risks to Australia Pacific LNG's workforce, its property, the environment and the communities affected by its activities.

Mitigation measures were developed in a number of ways to ensure no environmental harm or loss of beneficial land use or visual amenity will occur. By implementing water runoff diversion, erosion

prevention and sediment controls during construction and operation, off-site impacts can be minimised and the need for rehabilitation reduced. Pollution incidents can be avoided by controlling discharges to land and by undertaking monitoring programs consistent with Queensland legislation and national guidelines. Where pollution does occur, rehabilitation of land will endeavour to return the land to a pre-disturbed standard or better progressively over the course of the Project. This includes the potential for rehabilitation of previously disturbed land on an opportunistic basis.

These project sustainability principles have therefore been integral to the land assessment, and mitigation and management measures in this chapter.

5.1.2 Scope of work

The following scope of work was undertaken when assessing potential impacts on land based environmental values within the LNG facility study area:

- Describing existing conditions and environmental values
- Identifying potential impacts to both existing conditions and environmental values
- Considering relevant legislation and guidelines
- Proposing mitigation measures for these potential impacts
- Assessing residual risks with mitigation measures in effect.

5.1.3 Legislative framework

The assessment of land within the context of the proposed development is governed by a number of legal Acts, guidance documents and planning policies. These include:

- *Environmental Protection Act 1994* (EP Act)
- *Environmental Protection Regulation 2008*
- *Environmental Protection (Waste Management) Regulations 2000*
- *Environmental Protection (Water) Policy 2009*
- *Soil Conservation Act 1986*
- *Petroleum and Gas (Production and Safety) Act 2004*
- Guidelines for sampling and analysis of lowland acid sulfate soils in Queensland 1998
- National Environment Protection (Assessment of Site Contamination) Measure 1999 (NEPM)
- Queensland Department of Mines and Energy: Technical guidelines for environmental management of exploration and mining in Queensland (1995)
- State Planning Policy 1/92 Development and the conservation of agricultural land
- State Planning Policy 2/02 Planning and managing development involving acid sulfate soils.

The methodology of the assessments is guided by the above legislation, guidance documents and policies.

5.2 Methodology

5.2.1 Geology, topography, geomorphology and soils

The existing condition of the geology, topography, geomorphology and soil was assessed using a combination of desktop studies and field investigations.

The desktop study was completed using a number of national and State publications. These include geologic, topographic, acid sulfate soils (ASS), regional ecosystem (RE) and soils maps and reports. These are cited in the technical report in Volume 5 Attachment 7

This information was supplemented with direct observations of soils and terrain, and sampling of soils at selected locations (observations). The site observations comprised terrain assessments, including terrain type, slope, presence of drainage lines and existing infrastructure. These were, made at 27 locations within the study area. Figure 5.1 provides a plan of soil sampling locations.

All borehole locations were initially inspected by cultural heritage monitors in order to identify potentially significant artefacts, and relocate borehole locations if necessary. Due to the limited vehicular access, all but five of the 27 borehole locations were hand augered to a depth between 0.1m to 1.0m below ground level. This was considered an adequate sampling method and intensity for the field investigation. Five locations were drilled using a solid stem auger with the drill rig mounted on a four wheel drive vehicle. Drilled depths ranged from 3.0m to 4.0m below ground level.

Soil samples collected from 18 hand augered borehole locations were analysed for physical and agronomic parameters. Soil samples collected from eight borehole locations (five drilled, three hand augered) were analysed for ASS, physical and agronomic parameters. ASS sampling also involved field screening tests on 72 samples at 0.25m intervals.

Further detail regarding the field methodology, including soil sampling methods, soil descriptions, laboratory analysis, terrain and geological categorisation, is provided within the supporting technical documentation (refer to Volume 5 Attachment 7).

5.2.2 Contaminated land

The preliminary site investigation involved a desktop and field investigation. The desktop assessment was completed using the following information sources:

- Historical land titles, leases and aerial photographs provided by Department of Environment and Resource Management (DERM)
- Environmental management registers (EMR) and contaminated land registers (CLR) identifying notifiable activities as listed in Schedule 2 of the EP Act
- Interviews with previous land holders
- Former Department of Natural Resources and Mining (now DERM) groundwater bore data base and Groundwater Resource Map of Queensland.

The fieldwork component of the preliminary site investigation was conducted in general accordance with State and national standards cited within the Preliminary Site Investigation – Land Contamination Report (refer to Volume 5 Attachment 10.

Soil samples were collected from six hand augered borehole locations (described above) for analysis of heavy metals and pesticides (refer Figure 5.2). These samples were field screened for volatile organic compounds using a photoionisation detector. One groundwater sample was collected and

analysed for heavy metals, total petroleum hydrocarbons (TPH), benzene, toluene, ethylbenzene and total xylenes (BTEX).

The above approach conducted for the preliminary site investigation was also in general agreement with the following guiding documents:

- Department of Environment (now DERM) draft guidelines for the assessment and management of contaminated land in Queensland dated May 1998
- AS4482.1-2005 Guideline to the investigation and sampling of site with potentially contaminated soil Part 1: Non-volatile and semi-volatile compounds
- AS4482.2.2-1999 Guideline to the investigation and sampling of site with potentially contaminated soil Part 1: Volatile substances
- AS/NZS 5667.1:1998 Water quality – Sampling Part 1: Guidance on the design of sampling programs, sampling techniques and the preservation and handling of samples
- AS/NZS 5667.11:1998 Water quality – Sampling Part 11: Guidance on the sampling of groundwater.

5.3 Existing environment

5.3.1 Geology

General characteristics

Three geologic units occur within the general area of the LNG facility (i.e. the south-western portion of Curtis Island). These are the Palaeozoic-age Wandilla Formation (DCcw) of the Curtis Island group; Quaternary alluvium (Qa) and Holocene miscellaneous unconsolidated sediments (Qhe/m). These are illustrated in Figure 5.3. An inferred cross section is also provided in Figure 5.4.

Within the study area, the Holocene miscellaneous sediments (mudflats, salt pans or swamp deposits) overlie the Wandilla Formation bedrock in the flat central western area of the LNG facility and northern areas of the LNG pipeline corridor. The Wandilla Formation has been subjected to regional metamorphism and deformation (thrust faulting) and is comprised of mudstone, quartz greywacke, pale grey chert and lithic sandstone (locally containing silicified oolites), siltstone, jasper, chert and slate and local schist. This faulting and associated metamorphism accounts for the northwest trending ridges and areas of rock outcrop within the study area.

The Quaternary alluvium, located to the east and south of the study area is typically comprised of clay, silt, sand or gravel.

Holocene miscellaneous sediments make up the estuarine channels and banks, intertidal and supratidal flats and coastal grasslands. These sediments are typically mud, sandy mud, muddy sand and minor gravel. By nature, these materials are often potentially ASS and are located in the central to western portion of the study area.

Surface and near surface rock is likely to occur throughout the low round hills within the study area and make up the surface layer of the Wandilla Formation (refer Figure 5.3).

Seismic activity

A map of tectonic boundaries and earthquakes recorded since 1958 (refer Figure 5.5) indicates several faults (including concealed faults) occur north, east and adjacent to the study area. This figure

also illustrates previously recorded minor earthquakes (Richter magnitude >3) in the region. Not indicated on this figure, however, is the largest earthquake in Queensland. This was recorded as a Richter magnitude estimate of ML=6.3 135km off the Gladstone coast (ESSCC).

Data was obtained from Geoscience Australia Public Domain database, Geodata Topo 2.5M 2003 and presented in the desktop study completed by Fugro Consultants Inc. in February 2009. This data indicates that Curtis Island, and therefore the study area, occurs within an earthquake hazard risk of 0.05 to 0.10. A value of 0.05 indicates that, in any 50 year period, there is a 10% chance that the peak ground acceleration will exceed 0.05ms^{-2} (Fugro Consultants Inc. 2009).

Tsunami hazard

A literature review of the tsunami hazard along the northeast coast of Australia indicated the study area is located within a low level of tsunami hazard (WLA 2009). However, this is based on a qualitative assessment of relative tsunami hazard only, and further seismic potential analysis may need to be conducted as recommended by WLA (2009).

Extractive resources

The construction of the LNG facility will require extractive materials such as rock, sand and gravel for use as bedding, creation of hardstand areas, access tracks, fill, sediment and erosion control, landscaping and stabilisation (i.e. rock armouring for waterways). A number of existing quarries or borrow pits extract these materials and could potentially be used as sources for the construction of the LNG facility. These are listed in Table 5.1.

5.3.2 Topography and geomorphology

With reference to topographic contours (refer Figure 5.1) and digital slope analysis (refer Figure 5.6), the topography of Curtis Island is comprised of level to undulating terrain with intertidal mud flats and supratidal salt pans on the coast rising to steeply graded (>30% slope) low round hills. The study area, located in a small embayment on the south western corner of Curtis Island known as Laird Point, is surrounded by steeply sloping low round hills (commonly >20% slope) to the north, south and east, but the LNG facility site area is predominantly comprised of gently undulating flats (<2%). The western foreshore flats within the study area extend approximately 200 to 400m from the shore. Several small drainage lines traverse these flats.

The maximum elevation within the study area is 62m Australian height datum (AHD) which is located in the southeast corner. The lowest elevation is at the intertidal flats (located between low and high tide level) on the central to western portion of the study area. The intertidal flats merge into supratidal flats (located between high and spring tide level). Field assessments of the topography have generally confirmed the above broad terrain characteristics.

Using a classification system of terrain categories of low, medium and high, the majority of the observed areas are low; that is, flat and gently undulating terrain with slopes less than 10%.

Areas of medium to high terrain (i.e. areas with local relief ranging from less than 50m to 150m with slopes around 25%) were observed at the low round hills surrounding the study area.

Table 5.1 Existing extractive resource sites within 200km of the study area

Quarry name	Operator	Status	Production rate*	Local authority (based on pre-2008 boundaries)	Operation type	Descriptive locality
Avondale	R C Lawrie	Suspended	-	Banana	Hard rock	-
Callide Creek (Barnes)	G M & H J Barnes	Operating	Low	Banana	Sand & gravel	Callide Creek 73.8 to 74.5km 6km northeast of Biloela
Fairview Road	Moura Sand & Gravel Pty Ltd	Operating	Medium	Banana	Hard rock	-
Kianga	Kianga Quarries Pty Ltd	Suspended	-	Banana	Hard rock	20km south of Banana on Leichhardt Highway; 18km southeast of Moura
Boyne River	Blomfield Excavations	Operating	Medium	Calliope	Sand & gravel	Boyne River (at upper limit of tidal reaches)
Boyneglade	Grahame Allen & Sons Pty Ltd	Suspended	-	Calliope	Sand & gravel	1km west of intersection of Bruce Highway and Tannum Sands Road
Calliope River (Bruce)	Blomfield Excavations	Operating	Low	Calliope	Sand & gravel	North bank of Calliope River 3 to 4km upstream of Bruce Highway
H & R Quarry	H & R Quarrying Pty Ltd	Operating	Medium	Calliope	Hard rock	Quarry Road 1.5km west of Yarwun on a property owned by DJ Hall, PO Box 28 Yarwun
Hurcom	Rayment Excavations	Suspended	-	Calliope	Hard rock	Hurcom Road, Calliope
Tannum Sands	Grahame Allen & Sons Pty Ltd	Suspended	-	Calliope	Sand	1km north on Tannum Sands Road off Bruce Highway

Quarry name	Operator	Status	Production rate*	Local authority (based on pre-2008 boundaries)	Operation type	Descriptive locality
Taragoola	Unimin Australia Limited	Operating	High	Calliope	Hard rock	-
Yarwun (GPA)	Central Queensland Ports Authority	Operating	High	Calliope	Hard rock	On Gladstone - Mt Larcom Road
Bauhinia Downs	Park Equipment Pty Ltd	Suspended	Low	Duaringa	Hard rock	2km north of Bauhinia settlement
Bedford Weir	Whitsunday Crushers Pty Ltd	Operating	Medium	Duaringa	Hard rock	23km north of Blackwater
Blackhill	Department of Main Roads	Suspended	Low	Duaringa	Hard rock	5km northeast of Bluff
Mimosa Creek	Moura Sand & Gravel Pty Ltd	Operating	Low	Duaringa	Sand & gravel	Mimosa Creek 26.8 - 31.0 km 25km northwest of Moura
Hoare	Fitzroy Shire Council	Operating	Low	Fitzroy	Hard rock	-
James Bridge	Fitzroy Shire Council	Suspended	-	Fitzroy	Hard rock	-
Kraatz	Fitzroy Shire Council	Operating	Low	Fitzroy	Hard rock	-
McEvoy Road	G Halberstater	Operating	Medium	Fitzroy	Hard rock	McEvoy Road, SW of Gracemere
Moore	Fitzroy Shire Council	Suspended	-	Fitzroy	Hard rock	Gracemere Locality
Pink Lily Sands	Pink Lily Sands	Operating	Medium	Fitzroy	Sand & gravel	Fitzroy River 68.8 to 70km adopted middle tread distance (amtd), up stream of barrage at Pink Lilly Lagoon/Lotus Reserve

Quarry name	Operator	Status	Production rate*	Local authority (based on pre-2008 boundaries)	Operation type	Descriptive locality
Quarry at Midgee	Hopkins Bros	Operating	Medium	Fitzroy	Hard rock	Bruce Highway, Midgee
Ridgelands Gravel Pit	Fitzroy Shire Council	Operating	Low	Fitzroy	Hard rock	1km down Nicholson Road, 20km west of Rockhampton, along Ridgelands Road
Road Paddock	R C Lawrie	Suspended	-	Fitzroy	Hard rock	-
Wigginton	Fitzroy Shire Council	Suspended	-	Fitzroy	Hard rock	Gracemere
Kunwarara	Blomfield Excavations	Operating	Low	Livingstone	Hard rock	Bruce Highway approx 35km north of Yaamba
Nerimbera	Rinker Australia Pty Ltd	Operating	High	Livingstone	Hard rock	Emu Park - Rockhampton Road/Black Creek Road
Peak Hill	Earth Commodities Rockhampton	Operating	Low	Rockhampton	Hard rock	2km down Rockhampton - Yeppoon Road from Bruce Highway

Note: Extractive industry information obtained for the Australia Pacific LNG, LNG facility from the Department of Mines and Energy, QRock Database.
*low production (<80,000 tpa) medium production (80,000 – 200,000 tpa) high production (>200,000 tpa).

5.3.3 Soils

Soil types

A number of published government reports were reviewed to provide a background on soil types within the study area. These reports indicated the following main types:

- Hydrosols, commonly associated with ASS, are located within the intertidal and supratidal flats described above
- Vertosols and sodosols located within alluvial systems such as swamps, channels and flats
- Rudosols, tenosols, chromosols and some sodosols associated with the higher sloping areas of the study area.

As the published mapping only provides a very coarse representation of soil types, the field investigation was conducted to refine soil mapping and provide background data for identifying soil management constraints. A common soil group classification system was developed and is described in Volume 5 Attachment 7.

The field investigation indicated the main groups present in the study area are:

- Soils groups 1 and 2 occupy 24% of the study area. These are hydrosols derived from Holocene aged miscellaneous unconsolidated sediments with some deposits of quaternary alluvium material. These were mainly gravely ASS without topsoils located in the intertidal and supratidal flats
- Soil groups 3 and 4 occupy 31% of the study area. These are mainly sodosols (with some chromosols and kurosols) derived from the Wandilla Formation and comprising gravely texture contrast soils located mainly at the western low round hills
- Soil group 5 occupy 45% of the study area. These are mainly rudosols derived from the Wandilla Formation and comprising unconsolidated material located at the eastern low round hills and gently undulating flats.

These soils have been mapped and illustrated on Figure 5.7.

Topsoil thickness

The average topsoil thickness was calculated for soils encountered as 0.2m below ground level. Note that site sampling indicated an absence of topsoil in soil groups 1 and 2.

Sodicity and dispersion

Sodicity of a soil is the measure of exchangeable sodium in relation to other exchangeable ions. The sodicity of a soil correlates with its potential to disperse upon contact with water, so is one indicator of its susceptibility to erosion. It can also indicate the soil's potential to form a surface crust and its infiltration characteristics.

The majority of samples collected and tested within the study area were sodic to strongly sodic, but only soil from groups 3, 4 and 5 would be at a significant risk of dispersion as the extreme salinity and, in some cases, elevated organic content and acidic properties of soils at groups 1 and 2 limits dispersion. This indicates that soils from groups 1 and 2 should be kept separate from soils from groups 3, 4 and 5.

Erosion potential

The potential for erosion was assessed based upon the soil type, the local gradient (slope class) and the results of Emerson dispersion tests and other parameters. Accordingly, the field assessment indicated that, at the majority of the locations sampled, the soil has a low erosion potential in its natural state. However, most upland soils are considered to be susceptible to erosion when disturbed for development.

With reference to the soil types and the erosion potential rating, soils which have the highest susceptibility to erosion are groups 3, 4 and 5. These soils make up the majority of the study area. The study area erosion hazard has been illustrated on Figure 5.8.

Soil pH

Most soil samples collected and tested within soil group 1 and 2 were strongly acidic. This is the result of sulfidic materials derived from ASS. The pH of soils sampled collected and tested within soil group 3, 4 and 5 were slightly to strongly acidic, but still in the range considered acceptable to plant growth (pH 5 to 7). Acidic soils from group 3, 4 and 5 are unlikely to be ASS due to their origin and elevation in the landscape.

Salinity

Salinity is the presence of elevated levels of soluble salts in soils or on the soil surface. These are mainly sodium, but also potassium, calcium, magnesium, sulfates and chlorides. High salinity levels in soil may result in reduced plant productivity, including the elimination of native vegetation, and may increase susceptibility to erosion (Hazelton and Murphy 2007).

As expected, extremely saline samples were collected in the tidal flats within soil groups 1 and 2. The remaining samples, which are predominately non-saline, were collected within the non-tidally influenced soil groups 3, 4 and 5.

High concentrations of salinity help limit dispersion but also prohibit plant growth, except for species adapted to tidal and marine conditions. Non-saline soils (groups 3, 4 and 5) are predominately dispersive, but extremely saline soils from groups 1 and 2 are non-dispersive. As for sodicity, soils from groups 1 and 2 will be kept separate from soils from groups 3, 4 and 5.

Fertility

Soil fertility is a function of the soil's capacity to attract and release exchangeable ions and the presence of nutrients available for plant growth. In this assessment, cation exchange capacity (CEC), exchangeable ions and total Kjeldahl nitrogen (TKN) and phosphorus (P) were measured as indicators of soil fertility.

High to very high CEC ratings reported for soils within soil groups 1 and 2 are indicative of the silty clays encountered. However, this is attributed to the very high sodium concentrations and not fertility. CEC levels were variable in soil from groups 3, 4 and 5, but silty textured soils were found to be less fertile than clayey textured soils, so would be less likely to respond to changes in pH, nutrients and soil structure resulting from the addition of soil additives.

Analysis for TKN and P indicates that topsoils in the study area were primarily low to moderate fertility, so may require the addition of fertiliser to support plant growth during revegetation.

Dust

Bulldust is a term sometimes used to describe very fine dust generated from soils with high silt and fine sand content, as well as those with high calcium carbonate content. Bulldust can be an issue with intensive construction activity and for certain soil types (i.e. soil group 5). It can generate windblown dust and cause dry bogging of vehicles and equipment. If bulldust is generated, final rehabilitation and revegetation of the site may be difficult because the soil structure has been destroyed.

Bulldust was observed within the study area along vehicle access tracks. These tracks had been heavily used over recent months, due to the increase in development activity associated with LNG studies on Curtis Island. Bulldust development is likely to be mainly associated with the poorly structured surface soil layer within soil group 5.

This soil type makes up 45% (205ha) of the study area as defined in Section 5.1. So where topsoil is not removed, bulldust development will increase with further traffic and has the potential to contribute to dust generation and degradation of soils during construction.

Agricultural land capability

State planning policy 1/92 states that good quality agricultural land (GQAL) has a special importance. It should not be built on unless there is an overriding need for the development in terms of public benefit and no other site is suitable for the particular purpose.

As defined by Department of Primary Industries / Department of Housing, Local Government and Planning (DPI/DHLGP) Planning Guidelines: The Identification of Good Quality Agricultural Land (DPI/DHLGP 1993), GQAL is 'land which is capable of sustainable use for agriculture, with a reasonable level of inputs, and without causing degradation of land or other natural resources'.

DPI/DHLGP (1993) also define agricultural land as 'land used for crop or animal production, but excluding intensive animal uses such as feedlots, piggeries, poultry farms and plant nurseries based on either hydroponics or imported growth media'.

Agricultural land has been classified into four groups, as described within Volume Chapter 6 and briefly summarised in Table 5.2.

Table 5.2 Agricultural land classes

Class	Description
A	Crop land Land that is suitable for current and potential crops with limitations to production which range from none to moderate levels. There are two sub-classes of crop land: • A1 – crop land suitable for rain-fed cropping • A2 – crop land suitable for horticulture. All crop land is considered to be GQAL.
B	Limited crop land Land that is marginal for current and potential crops due to severe limitations; and suitable for pastures. Engineering and/or agronomic improvements may be required before the land is considered suitable for cropping. Land marginal for particular crops of local significance is considered to be GQAL.

Class	Description
C	Pasture land Land that is suitable only for improved or native pastures due to limitations which preclude continuous cultivation for crop production; but some areas may tolerate a short period of ground disturbance for pasture establishment. In areas where pastoral industries are the major primary industry, land suitable for improved or high quality native pastures may be considered to be GQAL. There are three sub-classes of pasture land: • C1 – land suitable for sown pastures with moderate limitations • C2 – land suitable for sown pastures with severe limitations • C3 – land suitable for light grazing for native pastures in inaccessible areas C1 may be considered to be GQAL, depending on the local authority planning provisions.
D	Non-agricultural land Land not suitable for agricultural uses due to extreme limitations. This may be undisturbed land with significant habitat, conservation and/or catchment values or land that may be unsuitable because of very steep slopes, shallow soils, rock outcrop or poor drainage. These limitations preclude any interference with land or biological resources for the production of agricultural goods.

There is no GQAL (i.e. classes A, B or C1) within the study area. Soil groups 1 and 2 have been classified as class D – non-agricultural land (i.e. lands with extreme limitations) while soil groups 3, 4 and 5 have been classified as class C3 – pasture land. Agricultural land classes within the study area are illustrated in Figure 5.9.

A summary of the existing soil constraints is provided in Table 5.3.

Table 5.3 Soil constraints in the study area

Soil group	Erosion potential	pH	Salinity	Topsoil fertility	Land capability
1 and 2	1 (low)	Strongly acid	Extremely saline	-	D
3 and 4	2 (moderate)	Slightly to strongly acidic	Non-saline	Low to moderate	C3
5	2 to 3 (moderate to high)				

5.3.4 Land contamination

Surrounding land use

The study area is situated within the south-western corner of Curtis Island and there are no developed areas surrounding the study area. The land surrounding the study area consists of the following land uses:

- North – Graham Creek
- East – native forest

- South – undeveloped land; includes the proposed location of the Queensland Curtis LNG facility. Environmental and geotechnical investigations were being conducted in this area at the time of the preliminary site investigation undertaken for this chapter
- West – Targinie Passage.

Hydrogeology

A search of the DERM groundwater data base produced a list of registered bores within a 5km radius of the study area. The search revealed one groundwater bore, No. 91326, located within the study area (Lot 3 on SP225924) and a second groundwater bore, No. 91325, located approximately 4km southeast (Lot 9 on DS220).

The details of these bores are summarised in Table 5.4. Both bores recorded a depth to groundwater of approximately 10m below ground level. The salinity of the groundwater from both bores was believed to be moderately saline based on one sample collected from bore No. 91325, which recorded an electrical conductivity of 12,000µS/cm, and bore No. 91326 being noted as salty.

Table 5.4 Registered bores

Bore #	Distance and direction from site	Use (refer to Section 4.3)	Comments
91325	4km south (Lot 9 DS220)	Not used	Date installed – 1993 Total bore depth – 27.3m Screened interval – 22.2m-27.3m Static water level – ~10m bgs (1993) Geologic formations encountered – Wandilla Formation Groundwater quality – 12,000µS/cm (1993) Groundwater yield – 3L/second (1993)
91326	Within study area (Lot 3 on SP225924)	Stock watering	Date installed – 1993 Total bore depth – 30.3m Screened interval – 15m-27.3m Static water level – ~10.6m bgs (1993) Geologic formation encountered – Wandilla Formation Groundwater quality – noted as salty (1993) Groundwater yield – 0.52L/second (1993)

The current and past use of cattle grazing should not have had an adverse impact on groundwater quality, so there would be a low risk for these registered bores to be contaminated from such activities.

Regional aquifer data

Reference to DERM groundwater resource map (Map 4, dated 1987, 1:250,000 series) indicated that the following aquifer characteristics could be encountered within the study area:

- Bore yield – <5L/second
- Salinity – 500 to 1,500mg/L
- Suitability – suitable for most purposes, and marginal for human consumption and low salt tolerant crops.

The aquifer yield information illustrated in the DERM groundwater resource map was in agreement with the data recorded from the surrounding registered bores (refer Table 5.4). However, the expected salinity of 500 to 1,500mg/L was much lower than the salinities recorded at these bores, which was approximately 12,000µS/cm (refer Table 5.4).

Soil analyses for contamination

Chemical analyses included heavy metals and organochlorine/organophosphate (OC/OP) pesticides, as these were considered a general screen for fill material. Petroleum hydrocarbons and related organic compounds were not investigated due to field screening results that indicated petroleum hydrocarbons were not likely to be present. A summary of the results are shown in Table 5.5. None of the analyses exceeded NEPM health-based investigation levels for Residential A settings, or DERM phyto-toxicity guidelines for copper and zinc. The combined guidelines are often used by DERM to determine if land is contaminated.

Table 5.5 Soil contamination analysis results summary

Analyte	Number of samples analysed	Exceedence of referenced guideline	Maximum concentrations reported (mg/kg)	Actions required
Heavy metals	6	None	Arsenic – 36 Cadmium – <1 Copper – 50 Chromium – 68 Lead – 9 Mercury – <0.1 Nickel – 25 Zinc – 39	No action
OC/OP pesticides	2	None	OC pesticides – <0.05 to <0.2 OP pesticides – <0.05 to <0.2	No action

Groundwater monitoring and analyses

One onsite groundwater monitoring bore contained a submersible pump which was used by a former lessee to pump groundwater for use as stock water. Water quality parameters recorded at the time of sampling are shown in Table 5.6.

Table 5.6 Groundwater monitoring results

pH	Electrical conductivity (µS/cm)	Temperature (ºC)	Redox (mV)	Dissolved oxygen (mg/L)	Total volume purged (L)
6.21	818	25	–63	1.43	156

Note: parameters measured at the time of sampling

These water quality parameters indicated:

- Groundwater was low salinity and had near neutral pH

- Dissolved oxygen concentrations were possibly affected by bailing, so could be higher than actual groundwater
- Groundwater was likely to be under reducing conditions based on redox of <200mV.

The groundwater analytical results for heavy metals (filtered) and TPH/BTEX are shown in tables Table 5.7 and Table 5.8.

Table 5.7 Groundwater analytical results (heavy metals filtered)

Sample #	Arsenic mg/L	Cadmium mg/L	Chromium mg/L	Copper mg/L	Lead mg/L	Nickel mg/L	Mercury mg/L	Zinc mg/L
GW LP	0.002	<0.0001	<0.001	0.004	<0.001	0.003	<0.0001	0.005
ANZECC/ARMCANZ 2000	NE	0.0055	0.0274	0.0013	0.0044	0.070	0.0004	0.015

Notes: ANZECC/ARMCANZ (2000) – Marine guidelines for 95% protection of species. NE = Not established.

The analytical results indicated there were no heavy metal concentrations detected above the ANZECC/ARMCANZ marine water guidelines, with the exception of copper. Given the low concentrations reported and lack of a contaminant source, the copper concentration was likely to be a natural occurrence.

Table 5.8 Groundwater analytical results for TPH and BTEX

Sample #	Benzene µg/L	Toluene µg/L	Ethyl benzene µg/L	Total xylenes µg/L	TPH C6-C9 µg/L	TPH C10-C14 µg/L	TPH C15-C28 µg/L	TPH C29-C36 µg/L
GW LP	<1	<2	<2	<2	<20	60	300	<50
ANZECC/ARMCANZ (2000)	700	NE	NE	NE	NE	NE	NE	NE
NZME (1999) Stock Water Screening Criteria	4,000	8,000	4,000	8,000	>S(1)	4,000	>S(2)	

Notes: NE – Not established. >S = Greater than the solubility limit. (1) Represents C_7-C_9. (2) Represents >C_{15}.

The analytical results indicated there was no benzene concentration detected above the ANZECC/ARMCANZ marine water guidelines or TPH detected above the New Zealand Ministry of Environment (NZME) stock water screening criteria.

The detection of TPH C10-C14 and C15-C28 compounds was not expected, given the historical land use. The TPH concentration was investigated further by the analytical laboratory. This indicated the TPH concentrations were a possible mix of substituted phenols (2.6 diisopropyl phenol), carbamates (ethyl N-benzyl carbamate) and fatty acids (hexadecanoic acid). The source of these potential compounds was not known.

Summary of land contamination

Based on the site history and soil analyses, the following findings of the existing environmental values were reported:

- No development has occurred within the study area
- No notifiable activities have been conducted within the study area
- The land use was primarily bushland with some cattle grazing
- Soil and groundwater investigations indicated that hazardous contaminants were not present.

Based on these findings, it was concluded that the study area was unlikely to be contaminated by existing and past land uses.

5.4 Potential impacts

5.4.1 General

Potential impacts to land resources will largely result from the construction phase of the LNG facility which will involve both onshore and offshore activities. These activities will also contribute to cumulative impacts resulting from other LNG projects in the region.

The onshore construction will mainly include building access roads, erosion control, vegetation clearing, earthworks and terrain levelling of the construction site, foundation excavations for main equipment and buildings, constructing the materials offloading facility, installing foundations, installing facility equipment, pile driving, fencing construction, commissioning and start-up activities.

The offshore construction will mainly include materials offloading facility construction, loading platform, mooring/breast dolphins and catwalk, rock dock construction, ferry embarkation point, jetty and trestle construction. Dredging activities will be undertaken by Gladstone Ports Corporation.

This section discusses the impacts on land associated with constructing the LNG facility – specifically existing geology, topography, and geomorphology and soil resources.

5.4.2 Geology

Effect of geology on excavation

Based upon the geological maps (refer Figure 5.3) and terrain models (refer Figure 5.6), an assessment was carried out to establish the potential excavation difficulties posed by each geology type. The assessment used a rating system that defines the potential excavation difficulty as low, medium or high.

A low rating is one in which, due to the nature and depth of soil cover associated with the geology type, few excavation problems are envisaged. A typical example would be generally soft and firm alluvial deposits that could easily be dug using a standard excavator.

A medium rating implies a stronger material such as a very dense gravely soil or weathered rock, in which progress with a standard excavator may be slow, so a larger machine would be required.

Finally, a high rating implies that the geology is of high strength and requires special methods such as ripping, hydraulic breaking or blasting to excavate. A good example of a high rating would be fresh, igneous rock or stiff sandstone.

The Wandilla Formation is expected to present a moderate to high excavation constraint due to the predominance of rock at depth. As a result, rock breaking and/or blasting may be required for rock removal. Holocene-age miscellaneous sediments (comprising intertidal and supratidal flats and

coastal grasslands) have a low excavation rating as they are soft, low strength and can be easily excavated using conventional plant. However, they may be unstable unless suitably retained.

A detailed geotechnical investigation will still be required to quantify the excavation constraints within the Wandilla Formation, but it can be expected that the environmental impact (in terms of noise, dust and vibration) would proportionally increase with excavation difficulty. Further detail is provided in Volume 4 Chapters 13 and Volume 4 Chapter 15.

The main environmental issue associated with excavation and/or filling of the Holocene-age miscellaneous sediments is the formation of sulfuric acid, releasing iron, aluminium, and other heavy metals. Rainwater or groundwater can transport these contaminants, which may lead to degradation of the receiving environment. This aspect is addressed in Section 5.4.4.

Seismic activity

A couple of minor (Richter magnitude >3) earthquakes have occurred in the Gladstone region. This is confirmed by the earthquake hazard risk classification of 0.05 to 0.10 given to Curtis Island. A number of faults also occur adjacent to the study area. Given the known seismic activity surrounding the study area, there is a certain risk of liquefaction which will depend on near surface soil types and density (Fugro Consultants Inc. 2009).

The study area has a low liquefaction potential, but the design of structures will need to consider the risk of earthquakes. Failure to appropriately design structures could result in some environmental risk, particularly where structures store dangerous goods or hazardous materials. This issue is discussed further in Volume 4 Chapter 22.

Should an earthquake occur during LNG facility construction, damage may occur. An indication of potential levels of public nuisance and damage is presented in Table 5.9.

Table 5.9 Indicative levels of damage from earthquakes

Modified Mercalli scale		Level of damage	Richter scale
1-4	Instrumental to moderate	No damage	</= 4.3
5	Rather strong	Damage negligible. Small, unstable objects displaced or upset; windows rattle, felt by some people	4.3 – 4.8
6	Strong	Damage slight. Windows, dishes, and glassware broken, door swing, felt by everyone	4.9 – 5.4
7	Very strong	Damage slight to buildings, with plaster cracking and brick falling	5.5 – 6.1
8	Destructive	Cause much building damage and houses move on foundations. Bridges twist, wall fracture, masonry building collapse. Most buildings collapse from 7.4 to 7.9. When greater than 8, total damage with waves seen on the ground surface and objects thrown in the air	6.2 – > 8

Source: Geoscience Australia (2010)

Information in Table 5.9 suggests structural damage would have the potential to occur during earthquakes of Richter 4.9 or higher. If so, damage to LNG infrastructure could result. A worst case

scenario would be that an earthquake was of significant magnitude or duration to rupture pipes and cause a release of contaminants into the ground and/or atmosphere. Whilst such an occurrence may be statistically remote, the potential seismic risks will be appropriately addressed during engineering design.

Induced seismicity impacts from rock blasting excavations are likely to be negligible.

Extractive resources

The construction of the LNG facility will require the supply of construction material such as cement, bentonite, lime, sand and rock aggregate. At this stage, detailed quantities required are unavailable, as is the required quality and type of materials, or where these will be used.

Material requirements will be determined during front end engineering and design (FEED) phase of the Project. However, an assessment of likely material sources (i.e. quarries) has been undertaken.

The quarry assessment identified numerous existing quarries on the mainland, and these are discussed in Section 5.3.1. Most quarries currently supply materials to local councils and communities for road construction, maintenance and building purposes.

This assessment did not identify the material reserves associated with existing quarries. Australia Pacific LNG does not plan to directly develop new quarries as part of the Project. However, new quarries and expansions to existing quarries (operated by others) may be required with LNG facility construction, and changes to land and road use would potentially occur as a result. To meet the demands of the Project, new quarries may be required to undergo an environmental assessment as part of gaining a separate development approval prior to commencing the activity.

Sterilisation of resources

No extractive industry or mineral resources are likely to be present within the LNG facility study area. This topic is discussed in Volume 2 Chapter 5 and Volume 3 Chapter 5.

5.4.3 Topography and geomorphology

The LNG facility is to be constructed in stages. It will extend over an area of approximately 156ha and oriented to minimise earthworks. However, this will still result in significant landform modification through stormwater diversion, vegetation clearing and earthworks, such as the filling the intertidal and supratidal flats to RL 6m AHD.

LNG facility construction will bring about a number of changes in local drainage flow, including stormwater diversion. Any unlined or un-vegetated channels would have the potential for erosion. During operation, stormwater will be diverted along the northern and southern boundaries of the study area. Onsite stormwater will be directed to sediment basins for reuse or, when overflow occurs, discharged into Port Curtis.

Landscape stability (i.e. landslip risk) can be an issue, where combinations of certain soil and subsoil profiles occur on slopes greater than 20% or where there is an increase in water infiltration and vegetation removal, such as during construction. There is no evidence of the landscape being prone to landslip in its natural state, but the assessment of erosion susceptibility (in relation to slope and vegetation removal) and potential impacts from LNG facility construction (Section 5.4.4) indicates some erosion risk. In addition, large volumes of excavated spoil produced during construction may not be suitable for reuse as backfill material due to the presence of ASS and owing to settlement (refer Section 5.4.2).

The potential for overall impact to terrain is significant, but the residual impact is likely to be medium when suitable engineering controls are implemented, including conservative batter slopes and strategic placement of other stabilisation works.

5.4.4 Soils

Topsoil

Careful management of the topsoil resource on site is critical for erosion control and important for effective revegetation and weed management. Erosion has the potential to result in scarring of the landscape, deepening or diversion of local drainage and adverse water quality impacts to Port Curtis.

The areas within the LNG study area that are likely to experience the greatest impact will be the areas of shallow gravely soils (rudosols), and texture contrast soils with sodic and dispersive subsoils (sodosols), particularly on steep slopes.

Activities that could contribute to erosion during site clearance and construction will be stripping topsoil and associated vegetation to create areas for the new infrastructure. In the long-term, it is anticipated that the infrastructure will be removed from some areas and the topsoil replaced. If not appropriately controlled, such activities can cause soil inversion, where the topsoil is placed below the subsoil. This can impact revegetation success.

Where rehabilitation work is proposed, a shortage of topsoil is inevitable in some areas. This is particularly the case in the shallow stony soils and shallow texture contrast soils most susceptible to erosion. To overcome the potential shortfall in these areas, additional topsoil may need to be sourced from zones with substantial topsoil depths.

Erosion

The area of greatest potential impact to soils associated with LNG facility construction will be the potential for significant soil erosion to occur. This could result from the vegetation clearing, poor drainage management (including concentration of flow), improper sediment and erosion controls, and inadequate earthworks contractor training and supervision.

Effects would include, but are not limited to, undermining structures, exposing pipelines, offsite sedimentation, decline in fertility through loss of soil structure, difficult vegetative rehabilitation, and increased dust generation. Therefore, it is important to implement mitigation measures to minimise the risk of erosion at the LNG facility.

The technical report in Volume 5 Attachment 7 has assessed the erosion potential for each of the soil groups (1 to 5) assigned for the study area (refer Figure 5.8). Based on the erosion ratings, soils which have the highest susceptibility to erosion are groups 3, 4 and 5. These soils make up most of the study area. Soil groups 1 and 2 have been rated with a low erosion potential due to salinity and landscape position and, in some instances, an elevated organic content, which helps bind soil particles and limit dispersion.

Where concentrated flows are likely, including stormwater diversion around construction areas, the greatest potential for erosion impact will occur in unprotected (un-vegetated) coarse textured soils and dispersive fine textured soils. This channelled runoff can lead to gully development and increased sedimentation.

There may be follow on effects where drainage lines are not reinstated to their original profile or protection works are not implemented. Where this occurs, the bed substrate may erode sufficiently to cause indirect effects such as bank collapse.

With the development and implementation of a sediment and erosion control plan, soil erosion impacts can be kept within acceptable levels during the construction phase. Given suitable controls and ongoing monitoring, soil erosion impacts during the operational and decommissioning phases are likely to be minor.

Salinity

The majority of subsoils located at groups 3, 4 and 5 were found to be non-saline. However, soils located at groups 1 and 2 were extremely saline and may be corrosive to civil structures, unless additional design measures are incorporated. Such precautions include undertaking geotechnical investigation of these soils to assess suitable corrosion protection requirements (refer Section 5.5.3).

Vegetation has a varying tolerance to salinity with only several species tolerating moderate to high salinity (electricity conductivity >8000μS/cm). Suitable handling will minimise potential blending between non-saline and highly saline soils and maintain soil fertility.

Soil acidification

The pH of soils within the study area ranged between strongly acid to slightly acid, with the most acidic soils located in soil groups 1 and 2. The low pH measured in these soil groups are attributed to sulfides associated with ASS.

If disturbed, these soils may oxidise and cause a lower pH. This has the potential to impact the aquatic and marine environment and affect civil structures through the mobilisation of acid. Acidic soils from group 3, 4 and 5 are not associated with ASS and as such these soils are unlikely to oxidise and impact the environment or the construction of the LNG facility.

The ASS management plan will describe the management strategies for the construction of the LNG facility (refer to Volume 5 Attachment 7). Implementing such a plan would ensure that potential impacts on the aquatic and marine environment will be minor.

Land capability

Assessment of site land capability (as per State Planning Policy 1/92) indicates that 76% and 24% of the study area has been classified as agricultural land class C3 and D, respectively. These categories are not considered to be GQAL. As the study area is of very limited value for agriculture, the LNG facility will have negligible impact in this regard.

Dust

Vehicular traffic can diminish soil structure and make soils prone to dust generation, as discussed in Section 5.3.3. The potential impact of this relates to elevated dust levels, which can be significant at the local scale during construction. Dust generation is expected to be negligible after construction has been completed.

5.4.5 Land contamination

Environmental receptors identified within and surrounding the study area included:

- The existing registered bore (No. 91326) within the study area, which is only used for stock watering and would likely be decommissioned during the construction of the proposed LNG facility, and therefore should not be considered a permanent receptor
- The registered bore (No. 91325) located approximately 4km south of the study area and is not used for any beneficial purpose
- The Targinie Passage (adjacent to the LNG facility), Graham Creek (1km from the LNG facility) and the marine environment which borders the northern and western boundaries of the study area.

Investigations outlined in Volume 5 Attachment 10 have indicated that existing land contamination, from existing and previous land use activities, is unlikely to be present within the LNG study area. Accordingly, potential impacts to the identified environmental receptors are likely to be negligible, and no further actions are considered to be necessary.

Potential land contamination issues and impacts associated with the construction and operation of the LNG facility do require consideration.

The assessment of potential impacts identified common issues applicable to each phase of LNG facility construction. These include:

- Leaks and overflow from the sediment ponds
- Spray irrigation of treated waters (effluent)
- Leaks and spills from process equipment
- Leaks and spills during refuelling of plant and vehicles
- Generation and handling of wastes
- Storage of dangerous goods
- Weed control.

Mitigation of potential impacts will involve implementing effective handling and management of potentially contaminating materials and wastes over the lifetime of the Project. These are addressed in Section 5.5.4. Adherence to these management strategies will avoid or minimise the potential for adverse impacts.

5.4.6 Cumulative impacts

The following section outlines the cumulative impacts to the environment external to the study area, resulting from the Project's land disturbance at the LNG facility. These impacts are also discussed in Volume 4 Chapter 25.

Geology

During construction, there may be an increased demand on existing or new local extractive material sources (quarries) external to the Project and operated by others. Material requirements have not been determined at this stage but will be determined during FEED phase of the Project. This assessment will need to account for demands from other projects. If additional material sources are required to be developed, follow on effects may include increased noise, dust and vibration levels, and changes to land and road use.

Soils

The destabilisation of soils (erosion) and sedimentation of Port Curtis is a potential cumulative impact during construction. This could come from vegetation clearing and earthworks at all project developments. This impact is expected to be low if appropriate mitigation measures are implemented.

Soil acidification and decline in downstream water quality (Port Curtis) is a potential cumulative impact during construction. This could come from the disturbance of soil groups 1 and 2 at all LNG developments. This impact is expected to be low once detailed ASS and geotechnical investigations are undertaken, and specific mitigation, management measures, and design criteria are outlined.

Land contamination

Potential impacts from the occurrence of contaminated land will be associated mostly with the construction and operation of all LNG facilities. Such impacts are likely to be caused by spills, leaks and storage of waste products and waste materials, which could cause localised areas of contamination.

Significant off-site migration of contamination via soil or groundwater is not likely from LNG facilities, given the design and construction of appropriate containment structures and effective ongoing management controls.

5.5 Mitigation and management measures

5.5.1 Geology

The following mitigation measures, related to geology and excavation, have been identified for the Project:

- During the FEED phase of the Project, a geotechnical assessment of the main areas requiring excavation will be required. This will include identifying the type of equipment required and assessing the associated environmental effects in relation to noise and dust issues
- If rock breaking and/or blasting is required, consideration will be given to any surrounding land use sensitive to vibration. This will be carried out in accordance with relevant guidelines, as discussed in Volume 4 Chapter 13 and Volume 4 Chapter 15
- Excavated material will be reused onsite, where practicable. A crusher may be engaged to render any excavated rock suitable for reuse on site, including use as rip-rap
- Where excavations in soil group 1 and 2 are proposed, detailed geotechnical investigations are to be conducted to assess design and construction techniques. A detailed ASS investigation will be performed in accordance with State Planning Policy 2/02, Planning and managing development involving ASS. Prior to construction an ASS and dewatering management plan will also be developed in accordance with Queensland guidelines.

Seismicity

A site-specific probabilistic seismic hazard analysis, including a ground motion and liquefaction study, will be conducted to assess the risk and guide the design of the LNG facility. The design of structures will therefore follow Australian Standard AS1170.4:2007. In addition, geotechnical and structural engineers will specifically consider the risk of settlement, slides, subsidence, liquefaction or faulting. Structures will be designed accordingly, or engineering measures will be put in place to protect the environment in the event of damage to property.

Extractive resources

Extractive industry operations that supply material to the Project would be expected to implement mitigation measures to ensure compliance with their operating licence conditions, and undertake rehabilitation of extraction areas when extraction is completed. The operation and management of these operations is outside the direct control of Australia Pacific LNG.

Australia Pacific LNG intends to work with industry to align with its sustainability principals (refer Volume 1 Chapter 3). It is expected that cut and fill for the development is largely on balance, with the exception of some civil materials that will be imported from existing commercial quarries on the mainland, such as those identified in Table 5.1.

To minimise impacts associated with extractive resources, proposed mitigation measures include:

- The FEED phase of the Project will quantify and qualify the necessary extractive materials prior to construction, as well as identifying the quality and type of materials required and the location at which it will be required
- Australia Pacific LNG has not planned to directly develop new quarries as part of the Project. Businesses which choose to meet the demand for extractive materials for the Project and other developments within the region would be required to follow an approvals process in accordance with applicable legislation
- Existing quarries will be used where required. However, these will be sufficiently assessed during the project FEED phase to determine the size and local demand for the resources. This will enable informed assessment on whether or not there are adequate resources to service the community and the requirements of the Project. The estimated future demands of other CSG projects will also be considered
- Mobile crushers will be considered for use on the Project, so excess excavated rock can be used to minimise the need to quarry materials
- Materials used during construction will be reused where feasible to reduce the need for quarried materials.

5.5.2 Topography and geomorphology

Site clearance and earthworks will have the greatest impact on existing landform through the re-profiling of local topography, altering drainage paths, and soil destabilisation. The general mitigation measures listed below will be addressed throughout the construction program to minimise potential soil erosion and associated impact on water quality of Port Curtis.

Mitigation measures to be adopted may include, but are not limited to:

- Setting of proposed site levels to reduce the need to create significant cut and fill areas
- Reusing construction materials to reduce the volume required from off-site sources
- Assessing slope stability in areas where clearing works are required on steep and very steep slopes.

5.5.3 Soils

Mitigation measures for soil resources will be largely applicable during construction and decommissioning. Although the footprint of the LNG facility will be cleared, levelled and remain occupied by infrastructure, some areas (e.g. temporary lay-down and accommodation areas, and

access tracks) will be stabilised and landscaped when no longer in use. General mitigation measures for implementation during construction and decommissioning are addressed below and detailed in Volume 5 Attachment 7.

Topsoil

Based on field classifications, topsoil varied in thickness but on average was 0.2m thick. This excludes soils at soil groups 1 and 2. As topsoil is generally removed down to the subsoil, site specific assessments will be undertaken prior to disturbance to determine the appropriate removal depth and handling/stockpiling arrangements.

Fertility of topsoils within the site is rated as low. As a result, additional nutrients (specifically nitrogen and phosphorus) or a soil conditioner will be required in some areas to improve topsoils, stabilise the subsoils and support vegetation regrowth during stockpiling and rehabilitation.

Where practicable, stripped topsoil will be diverted directly to areas where a similar soil type is required for landscaping and rocky materials removed. Where this is not practicable, the topsoil will be stockpiled and kept separate from vegetation and subsoils stockpiles. Sediment and erosion control measures will be implemented around stockpiles and weeds will be monitored. Where they occur in close proximity, soil groups 1 and 2 will be stockpiled separately from soil groups 3, 4 and 5. The height of the topsoil stockpiles will be limited to avoid loss in fertility.

Salinity

Geotechnical investigations will be required to assess suitable corrosion protection requirements. Soil will be managed to minimise potential blending between non-saline and highly saline soils.

Water diversion, sediment and erosion control

All soils which are to be disturbed will have sediment and erosion control measures adopted throughout construction and decommissioning. This is required for environmental, structural, land management and aesthetic reasons.

The following measures are proposed:

- Develop and implement a sediment and erosion control plan for the site
- Stabilise diversion structures with rip-rap or equivalent to minimise erosion risk
- Construct sediment fences on the downhill side of excavation areas and around stockpiles
- Where tracks go down slopes, use contour banks at appropriate intervals to produce sheet flow rather than concentrated flow, and direct these to discharge at multiple locations at low velocities and volumes
- Regularly inspect sediment and erosion control measures, replace where damaged and, if required, empty following rainfall events
- Create stable slopes and where appropriate, revegetate soon after disturbance.
- Use chemical surface stabilisers or physical alternatives (crushed rock) to treat stockpiles and/or exposed soil areas, such as unsealed access tracks, which are exposed for prolonged periods or have been identified as problem soils (erosive/dispersive)
- Install diversion sediment and erosion control devices before construction begins. These will remain in place at any landscaped areas until the area has been stabilised

- To capture sediment, construct sediment ponds onsite at appropriate locations, to protect the aquatic and marine environment associated with Port Curtis (refer to Volume 4 Chapter 11)
- Conduct routine water quality monitoring around site, of pH, electrical conductivity, dissolved oxygen, redox, temperature and turbidity.

An overview of the soil erosion control and monitoring plan, detailing the measures described above and additional measures is provided in the environmental management plan (refer to Volume 4 Chapter 24).

Drainage line management

A number of local drainage lines pass through the study area and currently dissect the existing access tracks. As dispersive soils are located in the study area, appropriate management of these soils around existing drainage lines and slopes is required to minimise sediment laden runoff and impact to Port Curtis. The following mitigation measures are proposed:

- Temporary earth banks/contour banks or diversion channels will be installed along the slope on approaches to drainage lines, at the boundary between soil groups 1 and 2 and soil groups 3, 4, 5 and adjacent to Port Curtis, immediately following vegetation clearing. Where earth banks are not appropriate, alternative controls will be implemented. These may include installing silt fences at the perimeter of the drainage line, down slope from disturbed areas, to prevent sediment from entering the drainage line and/or maintaining a buffer of vegetation adjacent to the drainage line, where practicable, until construction is imminent. If necessary, armouring will be incorporated to minimise soil erosion.
- Where access roads cross drainage lines, continuity of flow will be maintained using temporary culvert or pipes.
- Routine and event based (e.g. following rainfall) inspections of soils adjacent to drainage lines and Port Curtis will be conducted. These inspections will aim to visually monitor evidence of sediment laden runoff, and erosion immediately adjacent to the drainage lines and Port Curtis. Routine water quality monitoring of pH, electrical conductivity, dissolved oxygen and turbidity may also be conducted upstream and downstream of the crossing to identify trends and water quality degradation.

Acid sulfate soil management

Prior to construction, a detailed ASS investigation will be required, to assess the full extent of the ASS hazard, determine treatment techniques (generally liming) for disturbed ASS and geotechnical parameters. This will be undertaken in accordance with Queensland guidelines. This investigation would be used to prepare a detailed ASS management plan, which will outline management techniques, including any neutralisation requirements where alkaline materials (lime) are physically incorporated into the soil.

Dust control

Construction activities will need to be controlled to minimise dust generation, especially where soils may be susceptible to bulldust generation (i.e. soil group 5 which makes up 45% of the study area and along proposed onsite roads). Management strategies regarding soil protection and dust control will include:

- Carefully selecting onsite roads to minimise road length

- Surfacing onsite roads with stone and/or geotextile or using surface additives
- Seeding, mulching, wetting or covering stockpiles
- Wetting roads and site
- Potentially resurfacing onsite roads with crushed rock, diverting traffic and rehabilitating bulldust areas where it is necessary to maintain access
- Consider applying crushed rock and diverting traffic where soils occur that are likely to generate bulldust.

5.5.4 Land contamination

Management measures associated with mitigating the potential impacts identified in Section 5.4.5 can be achieved by incorporating the following strategies:

- Leaks and overflow from the sediment ponds can be minimised by reusing pond water, where practicable, to reduce the volume being contained and by conducting regular monitoring for leaks and erosion of embankments
- Spray irrigation of treated waters will be located away from sensitive receptors
- Leaks and spills from process equipment will have a minimal impact to the underlying soil and groundwater, as structures are to be located on concrete pads and bunded in accordance with AS 1940 and AS 3833 for storage of chemical and hazardous materials. Integrity monitoring schedules will be prepared for engineering controls and maintenance will include inspections of leak detection devices
- Leaks and spills during refuelling of plant and vehicles will have a minimal impact on the underlying soil and groundwater, as refuelling will only be done in designated areas away from sensitive receptors. Spill kits will be available throughout the site to allow prompt clean up of leaks and spills
- Generation and handling of wastes will be managed by identifying opportunities for waste minimisation, reuse and recycling over disposal, use of appropriate bins and designated areas for waste storage
- Dangerous goods management will be the responsibility of suitably trained personnel who will be knowledgeable of *Dangerous Goods Safety Management Act 2001*, AS 1940 Storage and handling of flammable and combustible liquids, AS 3833 Storage and handling of mixed classes of dangerous goods in packages and intermediate bulk containers and AS 3780 Storage and handling of corrosive substances
- Weed control will be performed by suitably trained contractors, and quality control inspections of herbicide use and storage will be performed to confirm adherence with agreed protocols.

Investigation procedure for contamination incidents

During construction, commissioning, operation and decommissioning, confirmed and potential contamination of land will be immediately reported to the LNG facility supervisor. The LNG facility supervisor will determine if further actions are needed in regard to fulfilling corporate and legislative responsibilities. Further actions may include, but not be limited to:

- An investigation into the cause(s) of the incident

- A qualitative assessment of the extent and severity of the incident and any impacts to environmental values
- Notification and cooperation with DERM in accordance the provisions of the EP Act
- Undertaking a detailed contamination investigation in accordance with relevant regulatory guidelines.

Where necessary, the detailed contamination investigation will determine the need for subsequent remediation and validation to retain the environmental values of the affected area.

Mitigation measures assessed by other studies

Mitigation measures relating to dredging and discharges of water streams to receiving waters (i.e. Targinie Passage and mangroves) are addressed by studies contained in other chapters of Volume 4. These mitigation measures have not been duplicated in this section, but are available in as follows:

- Dredging – Volume 4 Chapter 10 and Volume 4 Chapter 11
- Desalination brine discharge to sea – Volume 4 Chapter 10
- Stormwater discharges to sea – Volume 4 Chapter 11
- Sewage treatment plant wastes – Volume 4 Chapter 11
- Hydrotest water – Volume 4 Chapter 10 and Volume 4 Chapter 11
- Waste management – Volume 4 Chapter 16.

5.6 Conclusions

5.6.1 Assessment outcomes

A summary of the environmental values, sustainability principles, potential impacts, cause of the impacts and mitigation measures in relation to land issues (including soil and contamination management) is presented in Table 5.10.

In addition, Table 5.10 includes the residual risk levels for each factor. A risk assessment has been undertaken to identify potential risks, causes and consequences from gas pipeline activities. Mitigation measures to reduce the risk have been nominated and the residual risk has been calculated. Further details on the risk assessment methodology are provided in Volume 1 Chapter 4.

Table 5.10 Summary of environmental values, sustainability principles, potential impacts and mitigation measures

Environmental values	Sustainability principles	Potential impact	LNG facility phase affected	Possible cause(s)	Mitigation and management measures	Residual risk level
Existing finite resources to be sourced for construction material	Minimising adverse environmental impacts and enhancing environmental benefits associated with Australia Pacific LNG's activities, products or services; conserving, protecting, and enhancing where the opportunity exists, the biodiversity values and water resources in its operational areas Using resources efficiently, reducing the intensity of materials used and implementing programs for the reduction and re-use of waste Identifying, assessing, managing, monitoring and reviewing risks to	Alteration of topography, drainage, leaching of chemical/minerals, removal of vegetation, changes to road use and changed dust, noise and vibration levels	Construction	Demand on local resources for LNG facility development. Development of new and / or expansion of existing quarries	FEED phase of the LNG facility will quantify the need for extractive materials prior to construction, as well as identifying the quality, volume and type of materials required and the location at which it will be required FEED phases will identify size and local demand of existing extractive resources Re-use of materials onsite through use of mobile crushers to minimise need for quarry materials from external sources	Low

Environmental values	Sustainability principles	Potential impact	LNG facility phase affected	Possible cause(s)	Mitigation and management measures	Residual risk level
	Australia Pacific LNG's workforce, its property, the environment and the communities affected by its activities.					
Existing landform character and stability	As above	Change to drainage Destabilisation of soils Degraded water quality in Port Curtis Slope instability	Construction Commissioning Operation Decommissioning	Landform modification through stormwater diversion, vegetation clearing and earthworks (e.g. filling intertidal and supratidal flats to RL 6m AHD)	A sediment and erosion control plan will be implemented. Runoff will be managed to minimise concentrated flows and sediment runoff Construction materials will be reused where practicable Geotechnical slope analysis will be undertaken	Medium
As above	As above	Loss of topsoil quality and quantity	Construction Commissioning	Incorrect stripping, prolonged exposure and erosion Soil inversion (replacement of topsoils with subsoils) Poor rehabilitation and drainage management	Site-specific topsoils assessment Nutrients/conditioner or suitable seed stock applied to topsoil stockpiles where required Vegetation and soil groups stockpiled separately Additional stockpile storage accounted for Topsoils stockpile heights will	Low

Environmental values	Sustainability principles	Potential impact	LNG facility phase affected	Possible cause(s)	Mitigation and management measures	Residual risk level
					be limited Rocky material removed during stripping Implement sediment and erosion control plan Monitoring and eradication of weeds	
As above	As above	Soil erosion – soil destabilisation Undermining of structures (roads, buildings, fencing) where soil has been washed away through runoff Exposure of pipelines Excessive sediment discharge to Port Curtis Decline in soil fertility Poor rehabilitation and drainage management Increase dust generation	Construction Commissioning	Vegetation clearing Poor drainage management. Concentrated flow discharge Improper sediment and erosion controls Inadequate earthworks contractor training and supervision	A sediment and erosion control plan which includes redirection and management of runoff to minimise concentrated flows will be developed and implemented Rip-rap will be used to stabilise diversion structures where required Contour banks will be installed at appropriate intervals and between soil groups 1 and 2 and soil groups 3, 4 and 5 and adjacent to Port Curtis Runoff will be directed to silt fences where contour banks are inappropriate Slopes will be stabilised	Medium

Environmental values	Sustainability principles	Potential impact	LNG facility phase affected	Possible cause(s)	Mitigation and management measures	Residual risk level
					Vegetation buffers will be retained adjacent to drainage lines until construction imminent Sediment and erosion control measures will be regularly inspected and replaced if required Topsoil stockpiles will be seeded where required Erosive / dispersive areas which are exposed for extended periods will be stabilised Sediment and erosion control devices will be installed prior to construction and retained until the area is stabilised On site stormwater will be directed to sediment ponds to hold and settle out suspended particles Stormwater level in sediment ponds will be kept low where practicable by reusing water for dust suppression and other practical uses during	

Environmental values	Sustainability principles	Potential impact	LNG facility phase affected	Possible cause(s)	Mitigation and management measures	Residual risk level
					construction Routine and event based water quality monitoring will be undertaken	
As above	As above	Soil erosion and destabilisation Undermining structures (roads, buildings, fencing) where soil has been washed away through runoff Exposure of pipelines Excessive sediment discharge to Port Curtis Decline in soil fertility Poor rehabilitation and drainage management Increase dust generation	Operation	Poor drainage management Concentrated flow discharge Improper sediment and erosion controls	A sediment and erosion control plan which includes monitoring of rehabilitated areas will be developed and implemented Eroded areas will be stabilised. On site stormwater will be directed to sediment ponds to hold and settle out suspended particles Stormwater level in sediment ponds will be kept low where practicable by reusing water for dust suppression and other practical uses during operations Routine and event based water quality monitoring will be undertaken	Low
As above	As above	Increased salinity leading to poor rehabilitation and	Construction Decommissioning	Poor soil handling (removal, stockpiling and respreading)	A geotechnical investigation will be undertaken to assess suitable corrosion protection for	Low

Environmental values	Sustainability principles	Potential impact	LNG facility phase affected	Possible cause(s)	Mitigation and management measures	Residual risk level
		corrosion of civil structures		leading to soil inversion Blending of non-saline and highly saline soils Inadequate monitoring of rehabilitation	civil structures Suitable subsoil handling, minimising blending of non-saline and highly saline soils will be undertaken	
Minimise acid generation associated with potential exposure of ASS	As above	Soil acidification - oxidisation of potential ASS Degradation of environment and new civil structures from acidic run-off	Construction	Excavation and / or filling of soil groups 1 and 2	A geotechnical investigation will be undertaken pre-construction to assess design and construction techniques A detailed ASS investigation will be undertaken and an ASS management plan will be developed	Low
Existing qualities of the air environment, including the life, health and wellbeing of the community	As above	Degradation of soil structure and dust generation	Construction	Clearing of vegetation and increased traffic	Appropriate on-site traffic routes will be assessed Onsite roads will be surfaced with stone and/or geotextile or surface additives Stockpiles will be seeded, mulched, wetted or covered where required Consideration will be given to the application of crushed rock and diversion of traffic in order	Low

Environmental values	Sustainability principles	Potential impact	LNG facility phase affected	Possible cause(s)	Mitigation and management measures	Residual risk level
					to prevent the generation of bulldust	
Soil and associated surface and groundwater quality plus marine environment	As above	Localised soil contamination, potential impact to surface and groundwater Potential impact to the receiving waters (Targinie Passage)	All phases	Leakage from sediment ponds, over filling, erosion of walls Leaks and spills from treated effluent holding tank, corrugated plate interceptor, diffused aeration facility, chemical storage area, waste oil storage area and aboveground fuel tanks. Discharge of contaminated water to sea	Contained stormwater to be reused for dust suppression and other practical uses Groundwater monitoring wells installed near sediment pond for monitoring purposes Investigate contamination and where appropriate remediate or manage in accordance with relevant legislation and guidelines Structures on concrete pads and bunded in accordance with AS 1940 and AS 3833 Structures maintained and inspected Discharges to sea via concrete lined or earth lined with geotextile membrane channels	Low
Soil and groundwater quality	As above	Leaks and spills to ground causing localised soil contamination and	All phases	Onsite refuelling of plant and vehicles	Staff training in proper refuelling procedures Refuelling away from sensitive off-site receptors, on-site drains	Low

Environmental values	Sustainability principles	Potential impact	LNG facility phase affected	Possible cause(s)	Mitigation and management measures	Residual risk level
		potential impact to groundwater			and on-site storage of surface waters/ponds Spills kits will be visible located throughout the site Appropriate remediation of spills to ground, and further investigations where necessary	
Soil and groundwater quality and marine environment	As above	Leaks and spills to ground, causing localised soil contamination and potential impact to groundwater Potential impact to the receiving waters (Targinie Passage)	Commissioning Operations Decommissioning	Overflow of in-ground sump within custom holding and washdown area Discharge of contaminated water to sea	Structures to be located on a concrete pad and bunded. Structures maintained and inspected. Investigate contamination and where appropriate remediate or manage in accordance with relevant legislation and guidelines.	Low
Soil and groundwater quality	As above	Leaks and spills to ground causing localised soil contamination and potential impact to groundwater	Commissioning Operations Decommissioning	Leaks and spills from the wastewater storage tanks	The wastewater storage tank will be located on a concrete pad Structures maintained and inspected Leaks and spills contained in in-ground sump. Wastewater will be removed from site by a licensed operator for off-site	Low

Environmental values	Sustainability principles	Potential impact	LNG facility phase affected	Possible cause(s)	Mitigation and management measures	Residual risk level
					disposal	
Soil and groundwater quality and marine environment	As above	Localised soil contamination and potential impact to groundwater. Potential impact to marine environment.	Commissioning Operations Decommissioning	Leaks and spills to ground from the process area spill containment sump Discharge of contaminated water to sea	The floor of the process area will be concrete Stormwater and process water will be directed to a containment sump Contained water will be discharged to external environment based on first flush principals The first flush will also pass through a separator system to remove separate phase hydrocarbons	Low
Soil and groundwater quality	As above	Contamination of soil, groundwater and private groundwater bore	All phases	Spray irrigation of treated waters	Effluent treatment systems will be maintained and tested regularly for quality of effluent Spray irrigation located away from existing surface water bodies	Low
As above	As above	Release of contaminated water to land	Commissioning Decommissioning	Disposal of contaminated hydrotest water to external environment.	Hydrotest water to be held in a containment pond and tested prior to release. Investigation of soil and groundwater where significant releases to land	Low

Environmental values	Sustainability principles	Potential impact	LNG facility phase affected	Possible cause(s)	Mitigation and management measures	Residual risk level
					occurs	
As above	As above	Contamination of soil and groundwater during removal of plant, equipment and infrastructure	Operations Decommissioning	Removal of plant, equipment and infrastructure, sediment ponds	Investigate or manage contamination in accordance with relevant legislation and guidelines	Low
As above	As above	Localised contamination of soil and groundwater.	All phases	Dangerous goods management.	Dangerous goods will be management in accordance with: • *Dangerous Goods Safety Management Act 2001* • AS3833 Storage and handling of mixed classes of dangerous goods in packages and intermediate bulk containers • AS3833 Storage and handling of corrosive substances. MSDS onsite for all chemicals being stored.	Low
As above	As above	Contamination of soil and groundwater	All phases	Poor waste management practices	Implement reuse and recycling of materials over disposal	Low

Environmental values	Sustainability principles	Potential impact	LNG facility phase affected	Possible cause(s)	Mitigation and management measures	Residual risk level
					Use mobile roll-on-roll-off bins for waste storage Investigate contamination, where appropriate remediate or manage according to relevant legislation and guidelines Quality control inspections to ensure achievement of waste management plan objectives (refer to Volume 4 Chapter 16)	
As above	As above	Over use of herbicides.	All phases	Weed control	Investigate contamination and where appropriate remediate or manage in accordance with relevant legislation and guidelines Quality control inspections of herbicide use and storage to confirm adherence with agreed protocols	Low

5.6.2 Commitments

Australia Pacific LNG commits to the following for the construction, operation, and decommissioning of the LNG facility:

- Avoid areas of severe erosion potential where practicable
- Minimise erosion risk by refining construction techniques, and erosion and sediment control methods
- Complete an ASS investigation and develop an ASS management plan in accordance with the relevant Queensland guidelines
- Develop and implement procedures and monitoring programs to identify, investigate and conduct necessary remediation for potential site contamination.

5.7 References

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Figures

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Graham Creek

BH14 BH12 BH13 A04 BULLDUST002 BH16 BH11 A01 A02 A08 A06 BH01 BH02 BH17 BH18 A03 A05 BH03 BH04 BULLDUST001 SWAMP BH08 BH05 LPGW BH06 BH07 BH09B BH09 BH15 BH10 A07

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Loading Berth Option 1b

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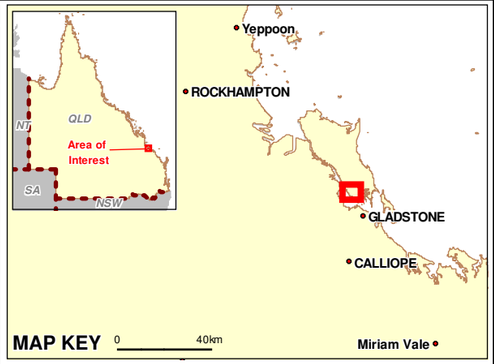
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Map Grid of Australia, Zone 56

Geocentric Datum of Australia 1994

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LEGEND

- Soil sampling sites
- Groundwater well
- Rocky outcrop
- 5m contours
- Riverine system (drainage lines)
- LNG facility study area
- Cadastral boundaries
- LNG facility development footprint

Source Information

Satellite imagery (GeoEye-1 on 24 March 2009)
AAM Hatch 2009
Indicative Plant Layout
Extracted from Bechtel. Drawing No. P1-000-20001 2009
Cadastre survey supplied data
Fredriksen, Maclean & Associates 2009
DEMs and derived contours
Department of Natural Resources and Water, Queensland 2009
Commonwealth of Australia (Geoscience Australia) 2009

AUSTRALIA PACIFIC LNG PROJECT

Volume 4 Chapter 5
Figure 5.1 Study Area Location Showing Topography

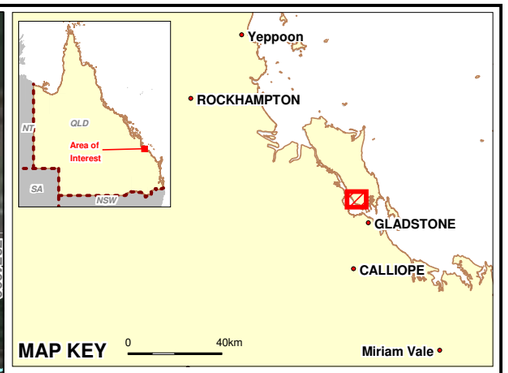
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BH12
BH16
BH01
Intertidal Flat
BH03
LP GW
BH07
BH10
ERM Dip Site



LEGEND

- Groundwater well
- Soil sampling sites
- ERM dip
- Riverine system (drainage lines)
- LNG facility study area

Source Information

Groundwater well sites
Collected by WorleyParsons, July 2009
Soil sampling sites
Collected by WorleyParsons, July 2009
Satellite imagery (GeoEye-1 on 24 March 2009)
AAM Hatch 2009

0 250 500m

SCALE - 1 : 20,000 (at A3)
Map Grid of Australia, Zone 56
Geocentric Datum of Australia 1994

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AUSTRALIA PACIFIC LNG PROJECT

Volume 4 Chapter 5
Figure 5.2 Borehole Locations

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7374000 7373000 7372000 7371000 7370000

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Loading Berth Option 1b

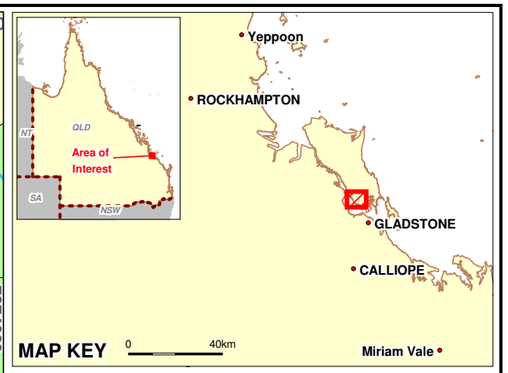
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Map Grid of Australia, Zone 56
Geocentric Datum of Australia 1994

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LEGEND

- Riverine system (drainage lines)
- LNG facility study area
- LNG facility soils study area
- LNG facility development footprint

Geology

- Soil sampling sites
- Groundwater well
- Rocky outcrop
- A A' Cross section (refer to Figure 3.2)
- Holocene Miscellaneous Unconolidated Sediments (Qhe/m-Yarrol/Scag). Mud, sandy mud, muddy sand and minor gravel: estuarine channels and banks, supratidal flats and coastal grasslands
- Wandilla Formation (DCCW). Mudstone, lithic sandstone (locally containing silicified oolites), siltstone, jasper, chert, slate; local schist
- Quaternary Alluvium (Qa). Clay, silt, sand, gravel; floodplain alluvium
- Ts-Yarrol/Scag. Semi-consolidated clayey sandstone and conglomerate, commonly associated with deep weathering profiles and local duricrusts
- Holocene Miscellaneous Unconolidated Sediments (Qhe/m-Yarrol/Scag). Mud, sandy mud, muddy sand and minor gravel: estuarine channels and banks, supratidal flats and coastal grasslands

Source Information

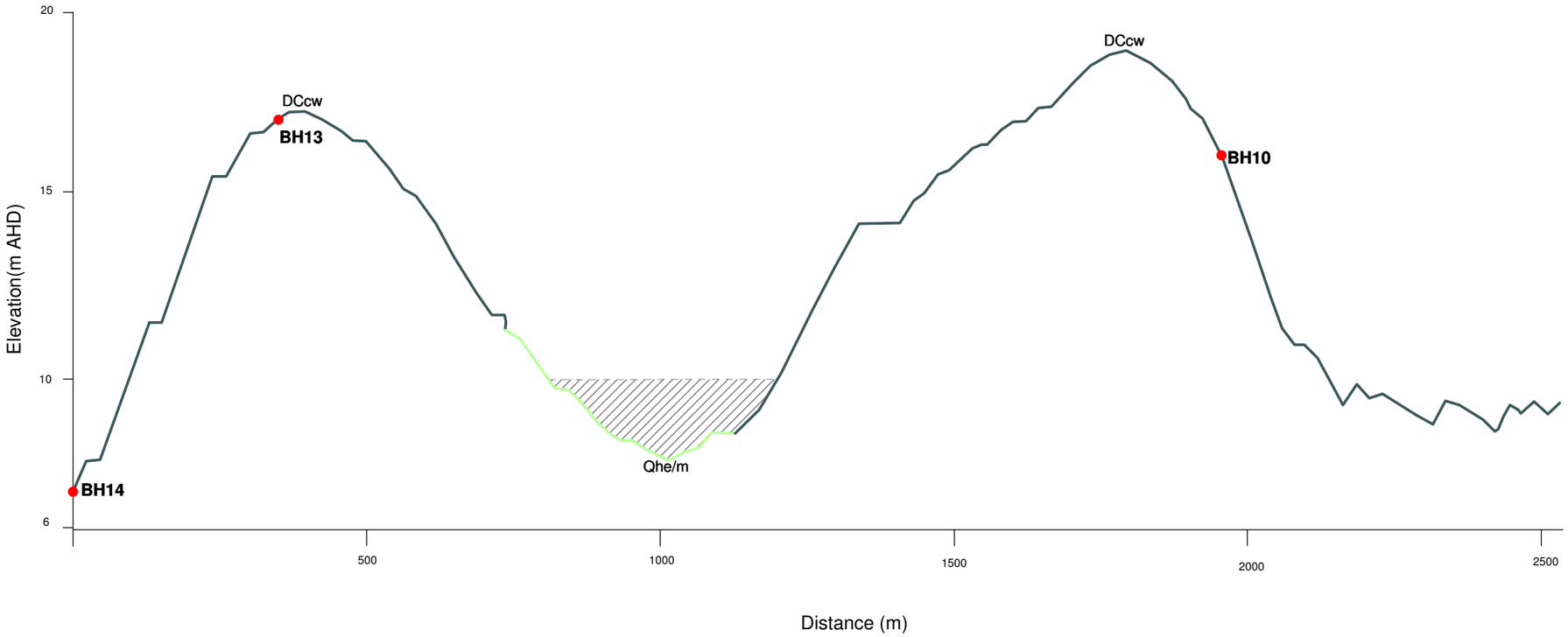
Riverine system (drainage lines)
Qld Water Bodies and Wetland Regional Ecosystems data, 2009
Indicative Plant Layout
Extracted from Bechtel. Drawing No. P1-000-20001 2009
Soil sampling sites
Collected by WorleyParsons, July 2009
Groundwater well
Collected by WorleyParsons, July 2009
Geology data
Sourced from 1:100,000 vector dataset purchased from Department of Mines & Energy. Data captured at 1:25 000 scale. The data set is sourced from the Department's Geoscience and Resources Database (GRDB), a component of the Mineral and Energy Resources Location and Information Network (MERLIN) corporate database.

AUSTRALIA PACIFIC LNG PROJECT

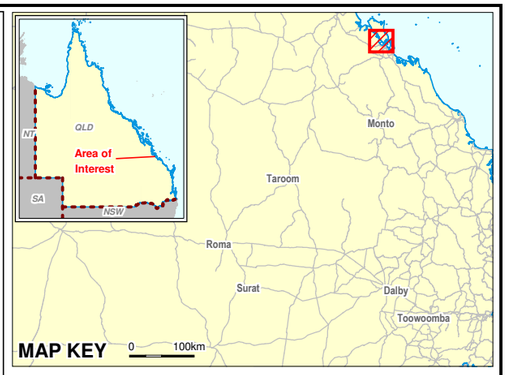
Volume 4 Chapter 5
Figure 5.3 Study Area Geology

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Elevations expressed in
Australian Height Datum (metres)



LEGEND

Sampling location

Late Devonian - Carboniferous

DCcw: Mudstone, lithic sandstone (locally containing silicified oolites), siltstone, jasper, chert, slate; local schist; Wandilla formation

Holocene

Qhe/m: Mud, sandy mud, muddy sand and minor gravel: estuarine channels and banks, supratidal flats and coastal grasslands; Qhe/m-YARROL/SCAG

Inferred Holocene and Quaternary sediments

Source Information

Geological cross section
Created by WorleyParsons based upon Department of Mines and Energy data

AUSTRALIA PACIFIC LNG PROJECT

Volume 4 Chapter 5
Figure 5.4 - Inferred Study Area GeologicalCross Section

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7440000 7420000 7400000 7380000 7360000 7340000 7320000

Curtis Island

Yarrol Fault

Ambrose Fault

Bracewell Fault

East End Anticline

Harper Fault

Alma Syncline

Queenslander Fault

Rhyolite Dyke or Vein

Andesite Dyke or Vein

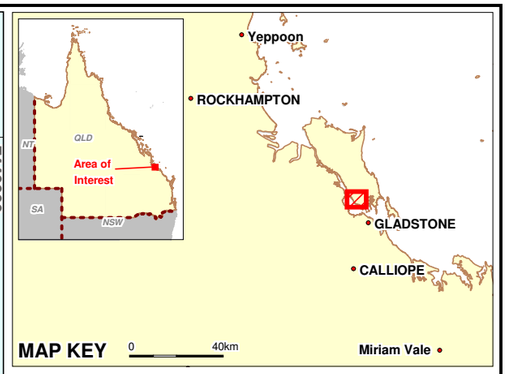
Rhyolite Dyke or Vein

ROVINCE

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SCALE - 1 : 500,000 (at A3)
Map Grid of Australia, Zone 56
Geocentric Datum of Australia 1994

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LEGEND

Earthquakes - Magnitude

- Earthquake Magnitude > 2
- Earthquake Magnitude > 3
- Earthquake Magnitude > 4
- Earthquake Magnitude > 5
- Faults Accurate
- Faults Approximate/Concealed/Inferred
- Anticlines Accurate
- Anticlines Approximate/Concealed/Inferred
- Synclines Accurate
- Synclines Approximate/Concealed/Inferred
- Dykes Veins
- LNG facility study area

Tectonic Provinces

- Gympie Province
- Unknown
- Wandilla Province
- Yarrol Province

Source Information

Tectonics
Data downloaded from the interactive Resource and Tenure Maps website of the Queensland Department of Mines and Energy

Earthquake data
Data downloaded from the U.S. Geological Survey website

AUSTRALIA PACIFIC LNG PROJECT

Volume 4 Chapter 5
Figure 5.5 Historical Earthquakes Since 1958 and Tectonic Boundaries

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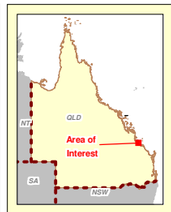
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Loading Berth Option 1b

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Map Grid of Australia, Zone 56
Geocentric Datum of Australia 1994

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MAP KEY 0 40km Miriam Vale

LEGEND

- Soil sampling sites
- Groundwater well
- Rocky outcrop
- Riverine system (drainage lines)
- LNG facility study area
- Cadastral boundaries
- LNG facility development footprint

Slope Grid

Derived from DNRW 25m DEM

50 40 30 20 10 0

Z-units: % Grade

Source Information

Indicative Plant Layout
Extracted from Bechtel. Drawing No. P1-000-20001 2009
Cadastre survey supplied data
Fredriksen, Maclean & Associates 2009
Slope
Created by WorleyParsons November 2009 from 25m DEM (Queensland Department of Natural Resources Mines and Water 2007).
Soil Sample sites
Collected by WorleyParsons, July 2009
Groundwater well
Collected by WorleyParsons, July 2009

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Figure 5.6 Study Area Digital Slope Analysis

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7374000 7373000 7372000 7371000 7370000 7369000

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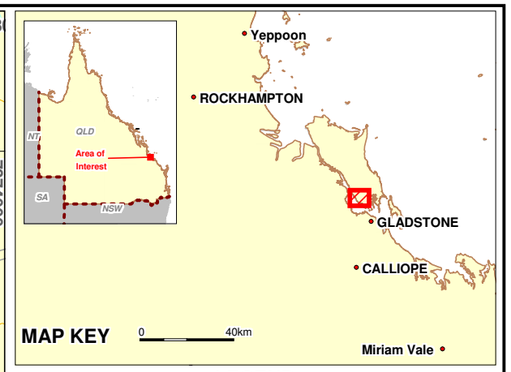
0 500m

SCALE - 1 : 20,000 (at A3)

Map Grid of Australia, Zone 56

Geocentric Datum of Australia 1994

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LEGEND

- Soil sampling sites
- Groundwater well
- Rocky outcrop
- Riverine system (drainage lines)
- 5m contour
- LNG facility study area
- Cadastral boundaries
- LNG facility development footprint

Soil Groups

- 1 - Intertidal HYDROSOLS
- 2 - Supratidal HYDROSOLS
- 3 - Gravely SODOSOLS (Some Chromosols + Kurosols)
- 4 - SODOSOLS
- 5 - RUDOSOLS

(refer Section 5.3.3)

Source Information

Soil sampling sites and soil types
Collected by Worley Parsons, July 2009
Groundwater well
Collected by Worley Parsons, July 2009
Riverine system (drainage lines)
Qld Water Bodies & Wetland Regional Ecosystems data
Indicative Plant Layout
Extracted from Bechtel. Drawing No. P1-000-20001 2009
Cadastre survey supplied data
Fredriksen, Maclean & Associates 2009
DEMs and derived contours
Department of Natural Resources and Water, Queensland 2009
Commonwealth of Australia (Geoscience Australia) 2009

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Figure 5.7 Study Area Soil Groups

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BH14 BH12 BH13 BULLDUST002 BH16 A04 BH11 A01 BH01 BH02 A06 A08 A02 BH17 A03 BH03 BH18 A05 BH04 BULLDUST001 LP GW BH06 SWAMP BH08 BH05 BH07 BH09 BH09B BH15 BH10 A07

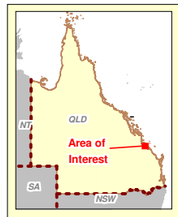
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0 500m

SCALE - 1 : 20,000 (at A3)
Map Grid of Australia, Zone 56
Geocentric Datum of Australia 1994

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MAP KEY 0 40km

LEGEND

- Soil sampling sites
- Groundwater well site
- Rocky outcrop
- Riverine system (drainage lines)
- 5m Contour
- LNG facility study area
- Cadastral boundaries
- LNG facility development footprint

Erosion Potential

- Low
- Medium
- High

Source Information

Soil sampling sites and soil types
Collected by WorleyParsons, July 2009
Groundwater well site
Collected by WorleyParsons, July 2009
Riverine system (drainage lines)
Qld Water Bodies & Wetland Regional Ecosystems data, 2009
Indicative plant layout
Extracted from Bechtel. Drawing No. P1-000-20001 2009
Cadastre survey supplied data
Fredriksen, Maclean & Associates 2009
Erosion potential
interpreted by WorleyParsons, October 2009

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Figure 5.8 Study Area Erosion Potential

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0 500m

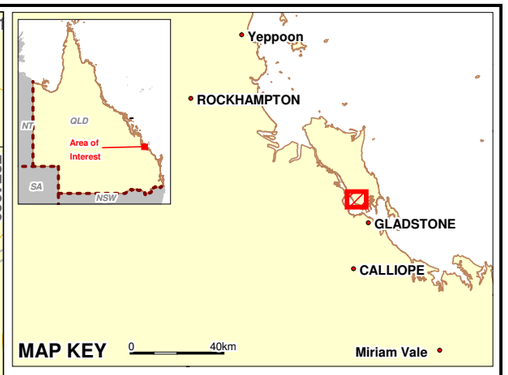
SCALE - 1 : 20,000 (at A3)

Map Grid of Australia, Zone 56

Geocentric Datum of Australia 1994

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LEGEND

- Soil sampling sites
- Groundwater well
- Rocky outcrop
- Riverine system (drainage lines)
- 5m contour
- LNG facility study area
- LNG facility development footprint
- Cadastral parcels

AGRICULTURAL LAND CLASS

- CLASS C3 - Land suitable for light grazing for native pastures in inaccessible areas
- CLASS D - Non-agricultural land - Land not suitable for agricultural uses due to extreme limitations

Source Information

DEMs and derived contours
Department of Natural Resources and Water, Queensland 2009
Commonwealth of Australia (Geoscience Australia) 2009
Soil sampling sites
Collected by WorleyParsons, July 2009
Groundwater well
Collected by WorleyParsons, July 2009
Riverine system (drainage lines)
Qld Water Bodies & Wetland Regional Ecosystems data, 2009
Indicative Plant Layout
Extracted from Bechtel. Drawing No. P1-000-20001 2009
Cadastre survey supplied data
Fredriksen, Maclean & Associates 2009
Good Quality Agricultural Lands
Department of Natural Resources and Water, Queensland 2009

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Figure 5.9 Study Area Agricultural Land Class

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