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Report

Amended LNG facility footprint - Soils and Terrain

NOVEMBER 2009

Prepared for

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Date: **November 2009**
Reference: 42626443/1/C
Status: FINAL

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Abbreviations

Abbreviation	Description
AHD	Australian Height Datum
ASS	Acid Sulfate Soils
D	Dispersive soils
EIS	Environmental Impact Statement
GSQ	Geological Survey Queensland
GTP	Gas transmission pipeline
ha	Hectares
km	Kilometre
MOF	Marine Offloading Facility
PLF	Product Loading Facility
R	Reactive soils
Sa	Saline soils
So	Sodic soils

Executive Summary

Subsequent to the submission of the GLNG final Environmental Impact Statement (EIS) document, and as a result of refinements in design, some changes have been made to the LNG facility structural layout as now shown in Figure 1. The changes have resulted in an increase in the previously proposed development area disturbance footprint. The areas of terrain units that occur within the current disturbance footprint as shown in Figure 2 have been re-assessed as outlined in the report. However whilst the areas of land impacted have changed to some extent, the land management and proposed mitigation measures to minimise environmental impact remain as stated in EIS Section 8.3 and in Technical Appendix L3.

1

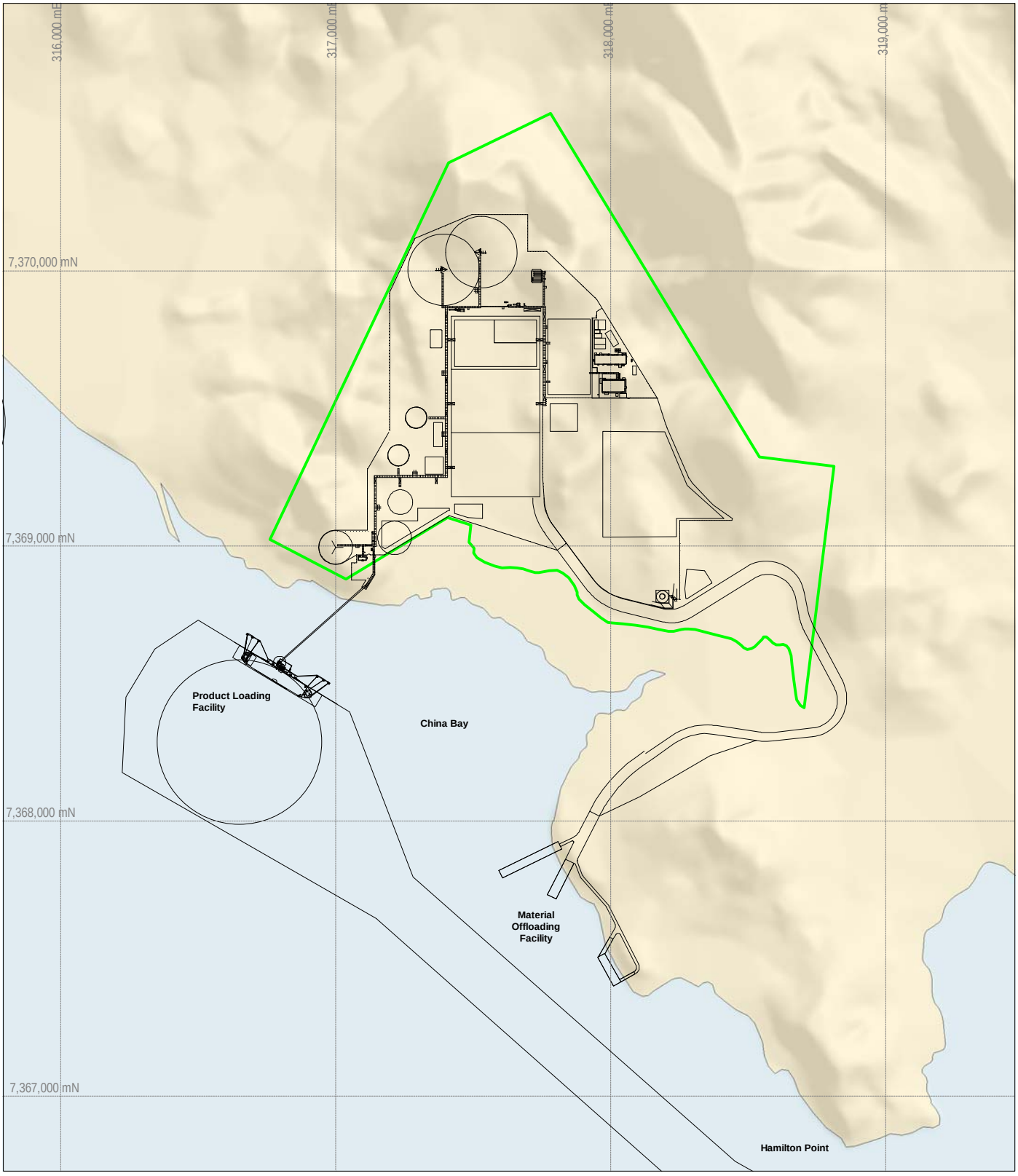
Introduction

Subsequent to the submission of the GLNG Environmental Impact Statement (EIS), and as a result of refinements in design, some changes and additions to the LNG facility site layout have been made which have resulted in an increase in the previously proposed development area disturbance footprint. That area has been re-assessed as outlined below, however whilst the areas of land impacted have changed to some extent, the land management and proposed mitigation measures to minimise environmental impact remain as stated in EIS Section 8.3.

The overall development proposed for the LNG facility site area includes a series of facility components. These include:

- The LNG facility site development area including the construction accommodation facility;
- The extension of the gas transmission pipeline corridor from the LNG facility site boundary to the LNG facility site area;
- The Marine Offloading Facility (MOF), haul road and quarantine area; and
- The Product Loading Facility (PLF).

The general layout of the LNG plant site and associated infrastructure is shown in Figure 1.



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LNG Facility Structures

LNG Facility Indicative Site Boundary

Source 2: With regard to Product Loading Facility and Material Offloading Facility - These layouts are subject to alteration during detailed design development and ongoing consultation with the Gladstone Ports Corporation and the Gladstone Regional Harbour Master to ensure issues of navigation safety are appropriately addressed.

Source 3: This map may contain data which is sourced and Copyright. Refer to Section 18.2 of the EIS for Ownership and Copyright.

Client: LNG	Project: GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT SUPPLEMENT SOILS ASSESSMENT	Title: **LNG FACILITY STRUCTURAL LAYOUT**
URS	Drawn: CA | Approved: JB | Date: 05-11-2009 Job No: **4262 6440** /6220 | File No: 42626440-g-2028.wor	Figure: **1** | Rev:A | **A4**

2

Methodology

2.1 Terrain Mapping

The methodology adopted for the identification of terrain mapping units (Terrain Units) included a baseline soils and terrain investigation and impact assessment study. The baseline investigation included:

- A desktop assessment, primarily based on interpretation of aerial photography;
- A site investigation including soil sampling; and
- Terrain unit and associated soil descriptions, soil characterisation and testing.

Reference should be made to the more detailed information provided in EIS Section 8.3 and in the EIS Appendix L3.

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Existing Environmental Values

The topography of the LNG facility comprises low rounded hilly, intermediate steep hilly and steep high hilly lands developed on Upper Carboniferous to Lower Devonian Wandilla Formation sedimentary rock types and meta-sediments comprising mudstone, lithic sandstone, quartz greywacke, siltstone, chert, slate and local schist. The hilly crestal areas vary from approximately RL 20 - 45 m Australian Height Datum (AHD) in the low hilly lands, to approximately RL 50 - 75 m AHD in the intermediate steep hilly areas, and up to approximately RL 120 - 175 m AHD in the high steep hilly lands. Hill and ridge slopes are mainly irregular planar to shallow concave on the lower slopes and vary from around 15 % on the lower hilly areas, increasing to 20 – 35 % in the steep hilly areas and approximately 25 – 45 %+ in the higher hilly lands. The hilly areas are separated by gently to moderately inclined (5 - 15 %) lower hill slopes and undulating lowlands with overall slopes mostly within a range of 3 – 7 %, which collectively form broad valley floors. Near flat to gently undulating alluvial plains with slopes mostly < 2 % occurs in the valley bottoms. In most cases these alluvial valley flats extend towards the coast and merge with estuarine supra-tidal flats which are mostly fringed by tidal mangrove flats along the coast line.

Descriptions of the geology, geomorphology, terrain units and soil types that occur in the LNG facility study area have been made and reference should be made to the more detailed information provided in EIS Section 8.3 and in EIS Appendix L3.

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Potential Impacts and Mitigation Measures

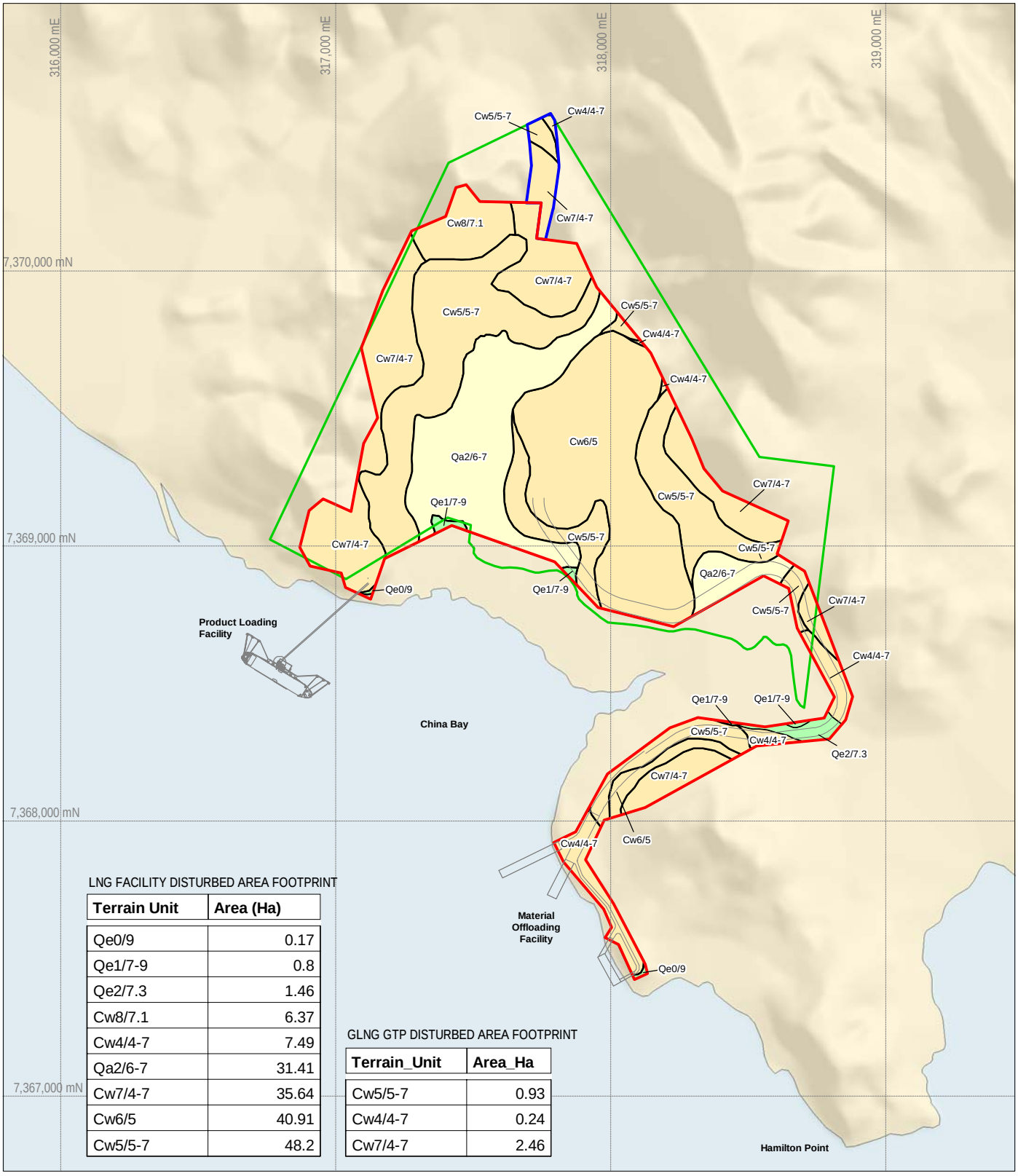
The combined disturbance footprint of the proposed facilities is shown in Figure 2, together with the terrain units encompassed within the overall disturbance footprint area. A key to the identification of terrain units is provided in Figure 3.

The disturbance footprint encompasses a land area of 176.1 hectares (ha). The cumulative areas of the terrain encompassed within the development area footprint, together with some important associated environmental attributes, are summarised in Table 4-1.

Table 4-1 Terrain Units & Engineering/Environmental Impacts

Terrain Units	Area (ha)	Erosion Potential *	Drainage Status *	Problem Soil Areas *	Pre-Disturbance Ag. Land Class
Qe0/9	0.2	L-M	F4	H - (Sa, So, ASS)	D
Qe1/7-9	0.8	M	F3	H - (Sa, So, D, ASS)	D
Qe2/7.3	1.5	M	F1	M - (Sa, So, D,ASS)	C3
Qa2/6-7	31.4	M-H	F1-F2	M - (So, D subsoils)	B
Cw4/4-7	7.7	L-M	W	L-M (D subsoils)	C1
Cw5/5-7	49.1	M-H	I	M - (So, D subsoils)	C2
Cw6/5	40.9	M-H	W-I	M - (So, D subsoils)	C3
Cw7/4-7	38.1	M-H	X	L-M (D subsoils)	C3
Cw8/7.1	6.4	M-H	X	L-M (D subsoils)	D
Total	**176.1**	-	-	-	-

* Refer to EIS Appendix L3 for the basis of the assessment of environmental attributes



LNG FACILITY DISTURBED AREA FOOTPRINT

Terrain Unit	Area (Ha)
Qe0/9	0.17
Qe1/7-9	0.8
Qe2/7.3	1.46
Cw8/7.1	6.37
Cw4/4-7	7.49
Qa2/6-7	31.41
Cw7/4-7	35.64
Cw6/5	40.91
Cw5/5-7	48.2

GLNG GTP DISTURBED AREA FOOTPRINT

Terrain_Unit	Area_Ha
Cw5/5-7	0.93
Cw4/4-7	0.24
Cw7/4-7	2.46

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Scale 1:20 000 (A4)
Datum : GDA94

Qe0/9 Terrain Unit Boundary

LNG Facility Disturbed Area Footprint

GLNG Gas Transmission Pipeline Disturbed Area Footprint

LNG Facility Indicative Site Boundary

Client

Project

GLADSTONE LNG PROJECT
ENVIRONMENTAL IMPACT STATEMENT
SUPPLEMENT
SOILS ASSESSMENT

Title

TERRAIN UNITS FOR LNG FACILITY DISTURBED AREA FOOTPRINT

Drawn: CA | Approved: JB | Date: 10-11-2009

Job No: **4262 6440** /6220 | File No: 42626440-g-2026.wor

Figure: **2**

Rev:B

A4

Client

Project

GLADSTONE LNG PROJECT
ENVIRONMENTAL IMPACT STATEMENT
SUPPLEMENT
SOILS ASSESSMENT

Title

TERRAIN UNITS
IDENTIFICATION KEY

Drawn: CA | Approved: JB | Date: 15-10-2009

Job No: **4262 6440** /6220 | File No: 4262 6440-g-2026.wor

Figure: **3**

Rev: A

A4

Generic Key to the Identification of Terrain Units

GEOLOGICAL REGIME		LANDFORM – TERRAIN TYPE		SOILS	
Symbol	Description	Type	Surface Form and Slope	Group	Soil Types [1]
Qe	Quaternary (Holocene) estuarine delta and coastal marine deposits; saline silty clays, clays, saline muds and sands	0	Channel floors, banks and active levees of major streams and waterways with irregular steep, and locally benched bank slopes and low flood terraces. Locally tidal mangrove and marine flats and tidal inlets with mangroves fringing.	0	Extensive areas of rock outcrop, locally with skeletal to shallow usually stony or gravelly soils.
Qa	Quaternary Alluvium on water courses, terraces and floodplains; clay, silt sand and gravel deposits	1	Floodplains alluvial flats, lower stream terraces and flat to broadly depressional backplains, slopes typically <1%; periodically floodprone and locally poorly drained areas. Locally comprising estuarine/marine plains, extratidal and supratidal flats subject to periodic tidal inundation; slopes mostly <0.5%.	1	Skeletal, rocky or gravelly soils (>60% coarse fragments) with sandy, sily, loamy or clayey soil matrix (K- Uc1, Um1, Gn1, Uf1)
Cw	Carboniferous Wandilla Formation; mudstone, lithic sandstone, siltstone, jasper, chert, slate and schist			2	Sand soils; shallow to deep uniform or weakly gradational profiles; includes stratified alluvial soils, residual sand soils, earthy sands (Ucl-Uc6) [2]; Rudosols or Tenosol Soil Orders [3]
		2	Flat to gently undulating or gently inclined intermediate to higher stream terraces, older alluvial plains or, floodplains and higher stream terraces, with slopes generally <2%;occasionally floodprone in lower-lying areas and along tributary drainage channels.	3	Coarse to medium-textured soils; uniform or gradational profiles; predominantly sandy earths silty or clayey sand profiles (Uc4-5, Uml-3); Tenosols or Podosol Soil Orders.
		3	Undulating plain and gently rolling to broadly rounded rises with gently inclined planar to concave intervening lower-lying broadly depressional areas; slopes mostly in the range 1- 3%	4	Medium-textured sandy, sandy loam or silt to clay loamy surface uniform or gradational profiles, often (siliceous or ferruginous) gravelly or stony soils; (Um4-7, Gn1-2); Tenosols, Kandosols or Ferrosol Soil Orders.
		4	Undulating to strongly undulating plains and rolling rises, locally flat to undulating upland plateau crests and undulating uplands; with slopes mostly in the range 3-7%	5	Sandy to loamy surface duplex soils with neutral to acidic, in places strongly acidic sandy clay to medium to heavy clay subsoils (Dr1-5, Dy1-5); Chromosol or Kurosol Soil Orders.
		5	Gently to moderately inclined planar to concave intermediate to lower hill and ridge slopes or convex planar dissection slope interfluves; slopes variable mostly within the range 5-12%	6	Fine sandy, silty or clay loamy surface duplex soils with neutral to alkaline often calcareous, sodic and locally saline medium to heavy clay or heavy clay subsoils; (Db-Dd-Dy1-5); Chromosols, Sodosols or Calcarosols Soil Orders.
		6	Isolated low rounded hills and rises and low hilly lands mostly with broadly rounded crestal areas and hill slopes in the range 12-25%;	7	Uniform fine-textured (non-cracking) clay soils or gradational clay loam or light clay surface soils with acidic or alkaline often sodic and/or saline medium to heavy clay subsoils – locally incipient cracking clays; (Uf5-6); Dermosol or Hydrosol Soil Orders.
		7	Steep hilly lands with mostly narrow rounded hill and ridge crests and steep irregular planar hill and ridge slopes mostly in the range 20 to 40%	8	Uniform fine-textured (cracking) clay soils, locally with thin self-mulching surficial soils with dark grey, brown or black mostly alkaline or alkaline over acidic heavy clay subsoils; (Ug5-Ug6); Vertosols Soil Order.
		8	Steep to very steep ridges and high hilly lands; mostly with narrow rounded ridge and spur crests, with slopes typically in the range 30-50%, with local subvertical rocky scarps and bluffs	9	Uniform, weakly gradational or weak duplex soils with highly organic silty to clay loamy surficial soils and seasonally or permanently saturated often gleyed and saline silty clay or medium to heavy clay subsoils; Um, Dd-Dy, Uf-Ug 5-6 profiles; Organosols, Hydrosols some Vertosol Soil Orders.
		9	Very steep high hilly to mountainous lands or very steep to locally sub-vertical or vertical escarpment slopes 35 ->100%		
			Example: **Terrain Unit Qa2/6-7** Qa (Geological Regime) 2 (Landform) 6-7 (Soils)		**Notes:-** (1) – Soil profile form and texture class (2) - Principal Profile Form (Northcote 1974) (3) - Australian Soil Classification (Isbell, 1996). Dual symbols eg (2-7) indicate both soil types may be present:

NOTE: This Figure 3 must be viewed with Figure 2

4 Potential Impacts and Mitigation Measures

4.1.1 Development Impacts – LNG Facility Site Development Area

The main potential impacts relating to the construction and development of the LNG facility site and related infrastructure include:

- Changes to agricultural land capability;
- Erosion potential of the development area lands when subject to clearing and earthworks;
- Potential for site flooding and/or tidal inundation;
- The occurrence and management of problem soil areas including saline (Sa), sodic (So) and/or dispersive (D) soils and/or acid sulfate soils (ASS);
- Excavation conditions; and
- Embankment construction or filling over soft ground potentially containing ASS.

Agricultural Land Capability

LNG facility site construction and development activities will result in changes to the pre-development land classes shown in **Table 4-1,** which will result in an overall increase of non-agricultural lands during the project life-span. On a terrain unit basis, this will result in:

- Changes to 31.4 ha of Class B land;
- Changes to 7.7 ha of Class C1 land;
- Changes to 49.1 ha of Class C2 land;
- Changes to 80.5 ha of Class C3 land; and
- Changes to 7.4 ha of Class D land.

The loss of or changes to agricultural land capability will be for the operational life of the LNG facility. Unless otherwise by agreement with the site regulatory authority, upon decommissioning of the project, structures and hard-stand areas will be removed and the land rehabilitated, using good quality local or imported topsoil in order to return the land to as near as practicable to its pre-development land use capability status, principally grazing lands (refer to EIS Section 8.16 for further details).

Erosion Potential

Approximately 165.9 ha (94.2 %) of the land in the LNG facility site disturbance footprint area has been rated as having moderate to high (M-H) erosion potential where the land is subject to clearing and earthworks for site development purposes. A further 2.3 ha (1.3 %) has been rated moderate (M) and 7.9 ha (4.5 %) has been rated as having low to moderate (L-M) erosion potential.

The steep hilly and higher hilly lands (Terrain units Cw8/7.1 and Cw7/4-7) have been rated as having medium to high (M-H) erosion potential if subject to disturbance and/or clearing of vegetation, primarily due to the overall steepness of the hill slopes. Although the overall slopes are less steep, terrain unit Cw6/5 is rated medium to high, mainly due to the sodic and dispersive nature of the sub-soils if they become exposed and remain unprotected. Terrain units Cw5/5-7 and Qa2/6-7 are also rated medium to high due to the topographic position in the landscape, whereby these areas may be subject to considerable surface water run-on due to run-off from the adjacent higher hill slopes. These areas also have moderately sodic and dispersive subsoils.

Terrain units Qe1/7-9 and Qe2/7.3 are susceptible to wind erosion due to the bare or sparse surface cover and the silty nature of the surface soils and have been rated as having moderate (M) erosion potential.

4 Potential Impacts and Mitigation Measures

Erosion potential in terrain unit Cw4/4-7 has been rated low to moderate (L-M) due to the overall, relatively gentle surface slopes and the gravelly nature of the surficial soils which permits rapid surface water infiltration and reduces the potential for surface run-off. In the lower-lying and generally flatter coastal lands and the transition to the alluvial valley floors, terrain unit Qe0/9 has been rated as having low to moderate erosion potential due to the permanently saturated, fine-textured and cohesive nature of the surficial soils.

In order to minimise erosion on disturbed areas, the recommended general erosion control measures outlined in EIS Section 8.3.1.5 will be adopted to help minimise erosion and reduce sediment loss from construction sites.

Tidal Inundation and Site Flooding Potential

Within the LNG facility site areas identified as terrain unit Qe0/9 comprise tidal mangrove flats which are prone to regular tidal inundation. Terrain unit Qe1/7-9, which comprises extra-tidal marine/ estuarine coastal flats is subject to less frequent tidal inundation due to extra high tide events. Both these terrain units occur as discontinuous small areas along the margins of the disturbance area footprint and together occupy an area of 1.0 ha. Terrain unit Qe2/7.3 also occurs as small slightly higher areas around the fringes of the estuarine flats and may be subject to tidal effects only on occasions. Collectively this terrain unit occupies an area of 1.5 ha along the haul road to the marine off-loading facilities.

Terrain units Qa2/6-7 comprise the broad alluvial valley floors which are infrequently flood prone but may be subject to local flash flooding in the immediate vicinity of the tributary streams and drainage ways. Together, these terrain units occupy a land area of 31.4 ha within the disturbance footprint and will be mostly subject to land filling in order to create the base-level for the LNG facility site construction platform at RL 16.0 m AHD.

Where necessary, existing drainage lines currently flowing through the development footprint area will be re-directed and modified to link with the internal site drainage network to control potential flooding within the site. Where the site development platform encroaches onto the estuarine tidal flats, rock armouring of the flood prevention levee embankments may be incorporated where necessary to protect the integrity of the embankment from tidal ingress or possible storm surge.

Problem Soil Areas

Reference to the description and assessment of terrain units in Appendix L3 of the GLNG EIS, and to Table 4-1 above, highlights the following:

- Terrain units Qe0/9, Qe1/7-9 and Qe 2/7.3 have associated soil types with moderate (M) and high (H) levels of soil salinity (Sa), sodicity (So) and/or dispersive (D) properties, as well as existing or potential acid sulfate soils (ASS). Collectively these soils occur over an area of 2.5 ha (1.5%) of the disturbance footprint area, mainly in local small pockets around the seaward margins.
- Terrain units Qa2/6-7, Cw5/5-7 and Cw6/5 have associated soil types exhibiting moderate (M) levels of sodic and/or dispersive clays and in parts moderately saline clays in the subsoil and deeper substrate materials. Combined, these soil types occur mainly in the central sector and occupy an area of 121.4 ha (68.9%) of the disturbance footprint area.
- Terrain units Cw4/4-7, Cw7/4-7 and Cw8/7.1 have associated soil types that in places may have low to moderate (L-M) levels of dispersion mainly in the subsoil layers. These soil types occur

4 Potential Impacts and Mitigation Measures

mainly along the higher hilly margins of the site and occupy a combined area of 52.2 ha (29.6 %) of the disturbance footprint area.

The finished base-level of the LNG facility site construction platform is proposed to be RL 16.0 m AHD. To achieve this level, following stripping and stockpiling of topsoil resources, the topographically higher outer margins of the area and central lower-lying parts of the site will be subject to cut and fill earthworks operations respectively. These earthworks operations may expose areas of saline, sodic and/or dispersive soil layers in the cut slopes and within the finished surface level of the construction platform or fill batters. Accordingly, prior to commencing construction works or re-spreading topsoil resources, site specific geotechnical soils investigations will be undertaken to identify any area specific problem soils areas, in particular where strongly acidic and/or saline soils may occur which could give rise to corrosion of buried steel or concrete structures (e.g. footings or foundations). Where suspected sodic and/or dispersive soils may be exposed as a result of earthworks, pre-construction investigations will include soil sampling and soil testing as appropriate to clearly define the extent of potential problem areas and to determine the appropriate engineering solutions or management strategies required to mitigate the impact. A dolomite or gypsum-based soil conditioner may also be considered for blending into the exposed surface soils to restore the ionic balance, and thus reduce levels of sodicity and dispersion effects in the soils prior to commencing construction or the placement of topsoil material.

Embankment Construction or Filling on the Coastal/Estuarine Tidal Flats

Construction of the materials offloading facility, haul road and the LNG loading dock may in part involve embankment construction or filling over areas of terrain units Qe0/9, Qe1/7-9 and Qe2/7.3, which combined occupy an area of approximately 2.5 ha of soft saturated soils and other soils potentially containing ASS. Site specific ASS investigations of these areas will be undertaken to determine if Actual ASS or Potential ASS materials are present. If found to occur, ASS management strategies to neutralise the existing or potential acidity levels will be undertaken in accordance with the Actual/Potential Acid Sulfate Soil Management provisions of the LNG Facility Environmental Management Plan (Attachment B3), as filling over Actual ASS (very strongly acidic) soils is prohibited unless the materials are treated. The high salinity levels also create a potentially highly corrosive environment for buried steel or concrete structures and any requirement for cathodic protection to mitigate corrosion effects will also be investigated.

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Conclusion

A terrain analysis was carried out to assess the engineering and/or environmental constraints with respect to the future development of the LNG facility site and associated infrastructure areas. A suite of terrain units were identified for the main geological regimes identified within the area, based on landform characteristics (surface form and slope) and associated soil types. Descriptions of the terrain units identified, together with an assessment of potential engineering and/or environmental constraints for site development have been determined. These data, by association, have been used to determine potential levels of environmental impacts for the LNG facility site development.

The potential areas of engineering or environmental impact identified above have been addressed and a range of engineering solutions or other management strategies have been recommended in order to successfully mitigate the potential environmental impacts identified. However in places where potentially high area-specific environmental impacts have been identified, more detailed geotechnical site investigations including acid sulfate soil investigations will be undertaken where necessary. These pre-construction investigations will include soil sampling and soil testing as appropriate to clearly define the extent of potential problem areas and to determine the appropriate engineering solutions or management strategies required to mitigate the impact.

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Limitations

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

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

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

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