Australia Pacific LNG Project

Volume 5: Attachments

Attachment 6: Geology, Topography, Geomorphology and Soils Assessment - Pipeline

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Executive summary

An assessment was undertaken to identify the existing values and characteristics of soils, geology, topography and geomorphology within the area proposed for the Australia Pacific Liquefied Natural Gas (LNG) gas pipeline, which extends from the town of Miles to Curtis Island in the Gladstone State Development Area. At the time of this assessment, the route of the gas pipeline (approximately 444km in length) had not been finalised and was subject to minor alterations in response to local environmental values and constraints. Hence, for the purposes of this assessment, a 'study area' was adopted to provide spatial boundaries to accommodate possible route changes in the future. The gas pipeline study area encompasses an approximate 5km corridor on either side of the transmission pipeline (about 10km wide in total).

The purpose of this assessment was to identify potential impacts of the proposed Australia Pacific LNG gas pipeline development on land-based environmental values. Where appropriate, mitigation measures that would ameliorate potential impacts were identified.

The assessment was carried out through a desktop study supplemented by field investigations along the gas pipeline route involving terrain observations and intrusive soil sampling. The field assessment was followed by laboratory testing on soil samples retrieved.

Geology, topography and geomorphology

The geological review indicated that there is a likely probability of encountering surface rock which may require particular equipment and excavation methods for the development works. Investigations should be undertaken to quantify the environmental impact (such as potential for increased dust, noise and vibration) at site-specific excavations, These investigations would also include detailed assessment of Holocene-age miscellaneous sediments located at 'The Narrows' associated with intertidal and supratidal flats and coastal grasslands. These sediments are soft, low strength, occur in areas of high groundwater and are commonly associated with acid sulfate soils (ASS).

The geological review also indicated that the study area is located in an area of low earthquake risk. A 'worst case scenario' would be that an earthquake was of sufficient magnitude or duration to cause severe damage to the pipeline.

A review of extractive resources in the region indicated that most existing quarries have a low production output (generally <80,000tpa). Although this assessment did not identify the material reserves associated with existing quarries, expansion of these quarries and new quarries (both operated by others) may be required to meet the demands of this and other CSG projects. To meet the demand of the Australia Pacific LNG Project, any new quarry would be required to undergo an impact assessment as part of gaining a separate development approval prior to commencing the activity.

The topographical assessment indicated that the majority of the route traverses level to gently undulating plains and low hills with slopes less than 20%, although steeper areas occur from KP89-134, 165-225, 248-281, 308-313 and 346-348. In terms of environmental impact, landform classified as mountains and hills would be most affected through construction due to steepness of terrain (mainly earthworks resulting in temporary landform change during construction)

An assessment of waterways with a stream order greater than three indicated that the majority of crossings will occur through soils with a very high erosion rating, which are prone to scour during flood events. This was evident in the form of gully erosion and bank incision at a number of locations. A detailed scour assessment should be undertaken at each significant watercourse prior to construction.

To maintain existing landform functions, the capacity of drainage lines should be maintained through implementation of progressive construction techniques, water diversion, sediment and erosion control, and revegetation. Erosion protection measures should be implemented at vehicle and pipe crossings of watercourses to minimise damage to stream banks.

Soils

The soils assessment revealed a range of soil types within the study area. Predominant soils were identified as shallow texture contrast soils (Sodosols, Kurosols and Chromosols) and shallow skeletal soils (Rudosols). Only minor areas of deep, dark cracking and non-cracking clays (Vertosols and Dermosols) were identified. The shallow texture contrast soils are predominantly used for grazing on improved and native pastures while shallow soils with a predominance of stone are used for forestry activities or rough grazing on native pastures. The cracking and non-cracking clays (particularly of alluvial origin) are the most productive soils in the region and are used for dryland and irrigated cropping and improved pasture. The texture contrast soils, in particular, were identified as commonly having a highly sodic and dispersive subsoil.

A small area (approximately 11.6ha within the gas pipeline right of way [RoW]) of soils which occur within the study area comprise Hydrosols. These occur within The Narrows area and are associated with intertidal (commonly known as mudflats), supratidal (commonly known as saltpans) and extratidal marine plains (or flats). A key issue with these soils is the presence of ASS. As a result, detailed ASS and geotechnical investigations should be undertaken prior to construction to fully assess construction techniques required to minimise environmental risk.

Minimising erosion associated with gas pipeline construction will be a significant issue to be addressed further in planning and design, particularly where significant (stream order greater than three) watercourse crossings are required, where construction will occur within soils rated as very highly erosive and on slopes greater than 8%. This assessment has identified a high to severe erosion hazard along the majority of the gas pipeline corridor without application of mitigation measures. Intensive erosion control measures specified within sediment and erosion control plans should be implemented in these areas. On-going maintenance and monitoring of erosion levels and the effectiveness of erosion control measures should also be incorporated.

Due to the nature of soils within the study area, good topsoil[1] segregation and handling procedures should be implemented. Topsoil depth is highly variable and site-specific topsoil assessments should be undertaken. The high erosion hazard in many areas of the gas pipeline route reinforces the need for good water diversion, sediment and erosion control, as well as a thorough rehabilitation and revegetation.

Good quality agricultural land

Approximately 44% (773ha) of the pipeline route (encompassing the 40m gas pipeline RoW) has been identified as good quality agricultural land (GQAL). The best agricultural land (Class A) is mainly associated with the deep dark clay soils identified above and is located mainly on the alluvial plains. Loss of GQAL will have a temporary impact during construction, but will be reinstated to its original use during the operation phase of the Project. Implications of this aspect are addressed in the Land Use and Planning Chapter 6.

[1] In the context of this report, 'topsoil' refers to the surface profile of the soil that is darkened due to organic matter accumulation and/or with a structure generally conducive to use for vegetative rehabilitation (often termed the A1 horizon).

Proposed rehabilitation measures in GQAL areas should include reinstatement of the original landform and soil profile so as to minimise productivity losses and maintain cropping efficiency.

Dust

Dust has been identified as an issue in the study area, especially the potential generation of bulldust. Dust management will be required including construction of gravel access roads on the main haul routes, controls on vehicle speeds as well as dust suppression with water trucks or Dustmag on unsealed roads.

Overview

In summary, a significant potential adverse impact associated with the Australia Pacific LNG gas transmission pipeline development without mitigation measures would be excessive soil erosion. This has the potential to result in scarring of the landscape, gullying of local drainage lines and adverse water quality impacts in downstream areas. Land within the study area likely to experience the greatest impact would be the substantial areas of shallow texture contrast soils with sodic and dispersive subsoils (that is, Sodosol soil types), particularly where slopes exceed 3%. Areas where slopes exceed 8% would have very high to severe levels of erosion risk. The development, implementation and ongoing monitoring of sediment and erosion control plans will be critical to ensure that such impacts are minimised to acceptable levels.

There may also be issues with the source and availability of suitable extractive material sources for construction of the gas pipeline. Further assessment is required into the likely demands of the construction phase in this regard.

Moderate to high levels of excavation difficulty are envisaged. Detailed geotechnical investigations will be required to determine the most appropriate method of excavation. This includes investigation of Holocene-age miscellaneous sediments (intertidal and supratidal flats and coastal grasslands where Hydrosols are present), which are easily excavated but may be unstable during earthworks and release acidic runoff should ASS be present and poorly managed.

There are a number of faults (mostly inferred) which occur along the gas pipeline corridor, the majority of which occur in the northern portion. Limited data suggests these faults are not active. Earthquake data recorded since 1958 indicates only a few low magnitude earthquakes have occurred in the study area. Although the occurrence of an earthquake within the study area may be statistically low, the potential seismic risk should be appropriately addressed during design.

While the gas pipeline is likely to disturb a substantial area of GQAL, the area impacted is able to be reinstated to its original landform and agricultural values following rehabilitation after construction.

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1. Introduction

An assessment was undertaken to identify the existing values and characteristics of soils, geology, topography and geomorphology within the area proposed for the Australia Pacific Liquefied Natural Gas (Australia Pacific LNG) gas pipeline, which extends from near the town of Miles to Curtis Island in the Gladstone State Development Area.

At the time of this assessment, the route of the gas pipeline (approximately 444 km) had not been finalised and was subject to minor alterations in response to local environmental values and constraints. Hence, for the purposes of this assessment, a study area (refer Figure 1.1) was adopted to provide spatial boundaries. The gas pipeline study area encompasses an approximate 5km corridor on either side of the transmission pipeline (10km wide in total).

The purpose of this assessment is to identify potential impacts of the proposed Australia Pacific LNG gas pipeline development (refer Figure 1.1) on land-based environmental values. Existing geophysical conditions were investigated through collection and evaluation of local soil and terrain data pertaining to the study area. Based on this information, the potential environmental impacts of the proposed gas pipeline were assessed and land management strategies identified to mitigate these impacts, such as soil erosion. The assessment also identified potential constraints for the construction, operation and rehabilitation of the proposed pipeline.

1.1 Legislative framework

The following describes the main pieces of legislation application to the planning, approval, construction and operation of the pipeline in relation to landform, soils and soil management.

1.1.1 Environmental Protection Act 1994

The primary objectives of the EP Act is to protect environmental values and human health whilst allowing developments that improve the total quality of life both now and in the future in a way that maintains ecological processes. The requirements of the EP Act are administered by the Department of Environment and Resource Management (DERM); formerly the Environmental Protection Agency (EPA).

1.1.2 Petroleum and Gas (Production and Safety) Act 2004

The purpose of this Act is to facilitate and regulate the carrying out of responsible petroleum activities and the development of a safe, efficient and viable petroleum and fuel gas industry. It also has provisions to carry out activities on land within and outside the area of authority in order to allow access. This includes access to conduct environmental investigations such as soil sampling.

1.1.3 Soil Conservation Act 1986

The *Soil Conservation Act 1986* allows for the approval of soil conservation property plans to ensure the co-ordination of runoff to control erosion. Although there are no approvals required under the *Soil Conservation Act 1986*, the Project will need to comply with any Project Plans, Property Plans, run-off coordination notices and soil conservation notices that have been issued under the Act.

1.1.4 Environmental Protection (Water) Policy 2009

The *Environmental Protection (Water) Policy* 2009 aims to support the Environmental Protection Act 1994 with a range of water management guidelines. This policy develops a framework for identifying environmental values, developing water quality objectives, managing the intent for waters and developing management plans.

1.1.5 State Planning Policy 1/92

State Planning Policy 1/92 states that Good Quality Agricultural Land (GQAL) has a special importance and 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 (DPI/DHLGP 1992). As defined by *Planning Guidelines: The Identification of Good Quality Agricultural Land* (DPI, 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 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". GQAL classes for the study area are described in Section 5.3.

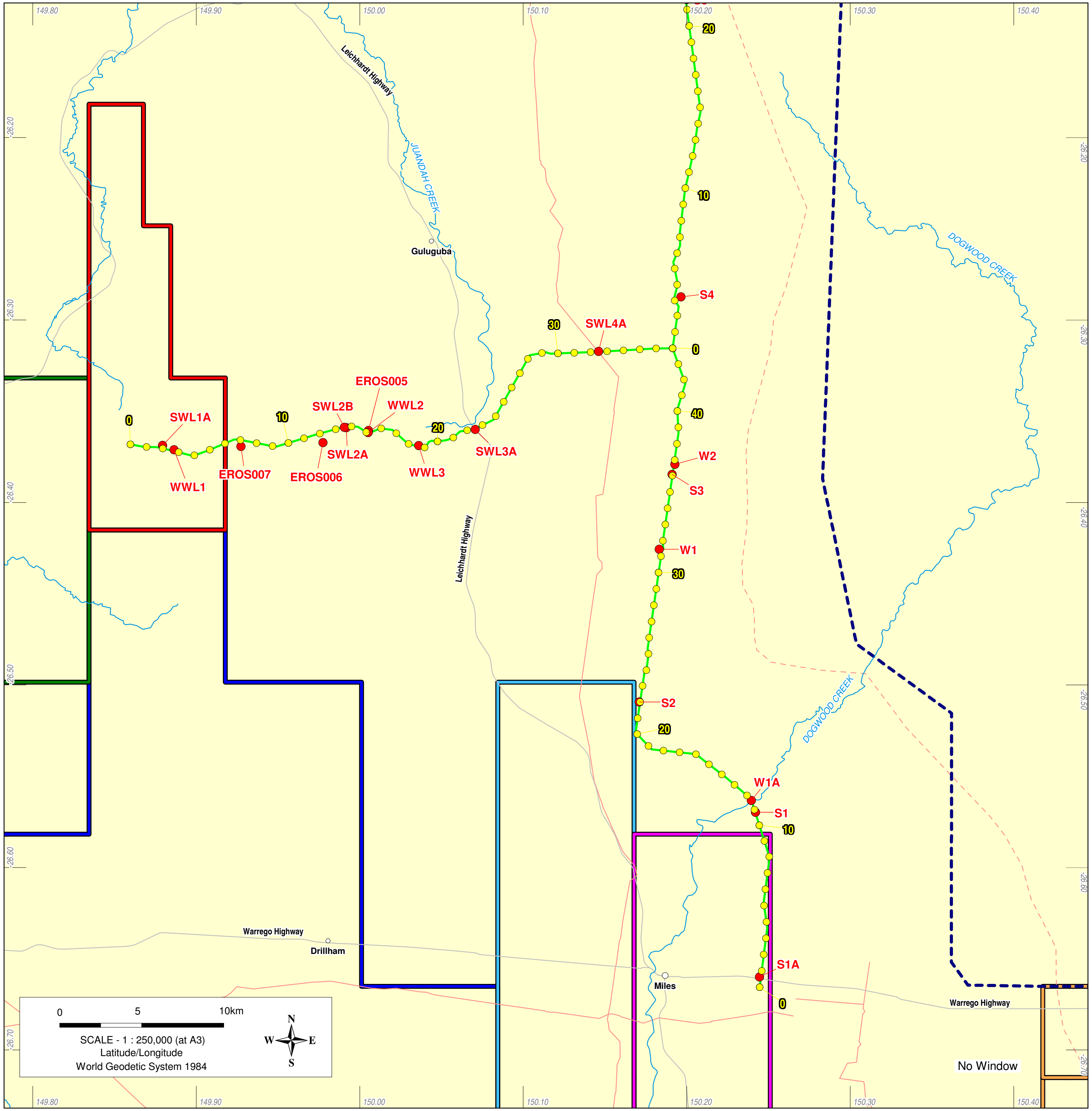
1.1.6 State Planning Policy 2/02

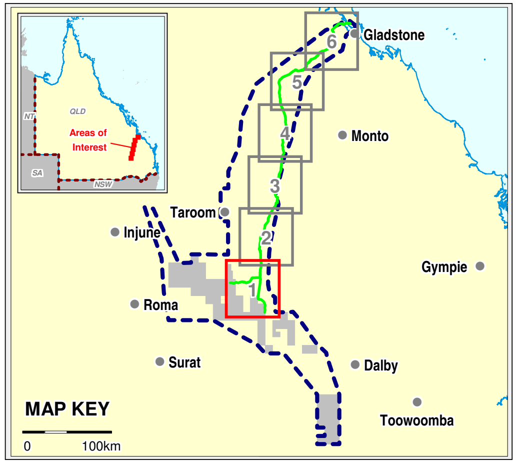
In Queensland, the State Planning Policy (SPP) 2/02 sets out the State's interest concerning development involving acid sulfate soils (ASS) in low-lying coastal areas. The SPP 2/02 has effect under the *Sustainable Planning Act 2009* (SPA) and applies to all land, soil and sediment at or below 5mAHD where the natural ground level is less than 20mAHD (Queensland Government 2002). Within this area, the SPP2/02 applies to all development involving excavating or removing 100m^3 or more of soil or sediment, or filling of land involving 500m^3 or more of material with an average depth of 0.5m or greater.

DERM (previously known as NR&M) has published comprehensive guidelines for ASS management, sampling and analysis. These guidelines also provide technical and procedural advice to avoid environmental harm and achieve best practice environmental management. They include:

- Guidelines for Sampling and Analysis of Lowland Acid Sulfate Soils (ASS) in Queensland 1998, version 4.0 (Ahern et al. 1998)
- Queensland Acid Sulfate Soil Technical Manual – Soil Management Guidelines, 2002, version 3.8 (Dear et al. 2002).

Methodology for this assessment is guided by the above policies and is presented in Section 2, below.





LEGEND

- Observation location
- Pipeline kilometre point
- Town
- Study area
- Preferred pipeline alignment
- Pipeline licence (Application)
- Pipeline licence (Granted)
- Major drainage

Walloons Gas Fields Development Areas

- Combabula / Ramyard
- Woleebee
- Carinya
- Condabri
- Talinga / Orana
- Dalwogan
- Kainama
- Gilbert Gully

Rev	Date	Revision Description	ORIG	CHK	ENG	APPD
1	09/03/2010	Re-issued for use	GSB	MZ		
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Figure 1.1 Study area and observation locations Map 1 of 6

Project No: 301001-00448 | Figure: 00448-00-EN-DAL-0288 | Rev: 1

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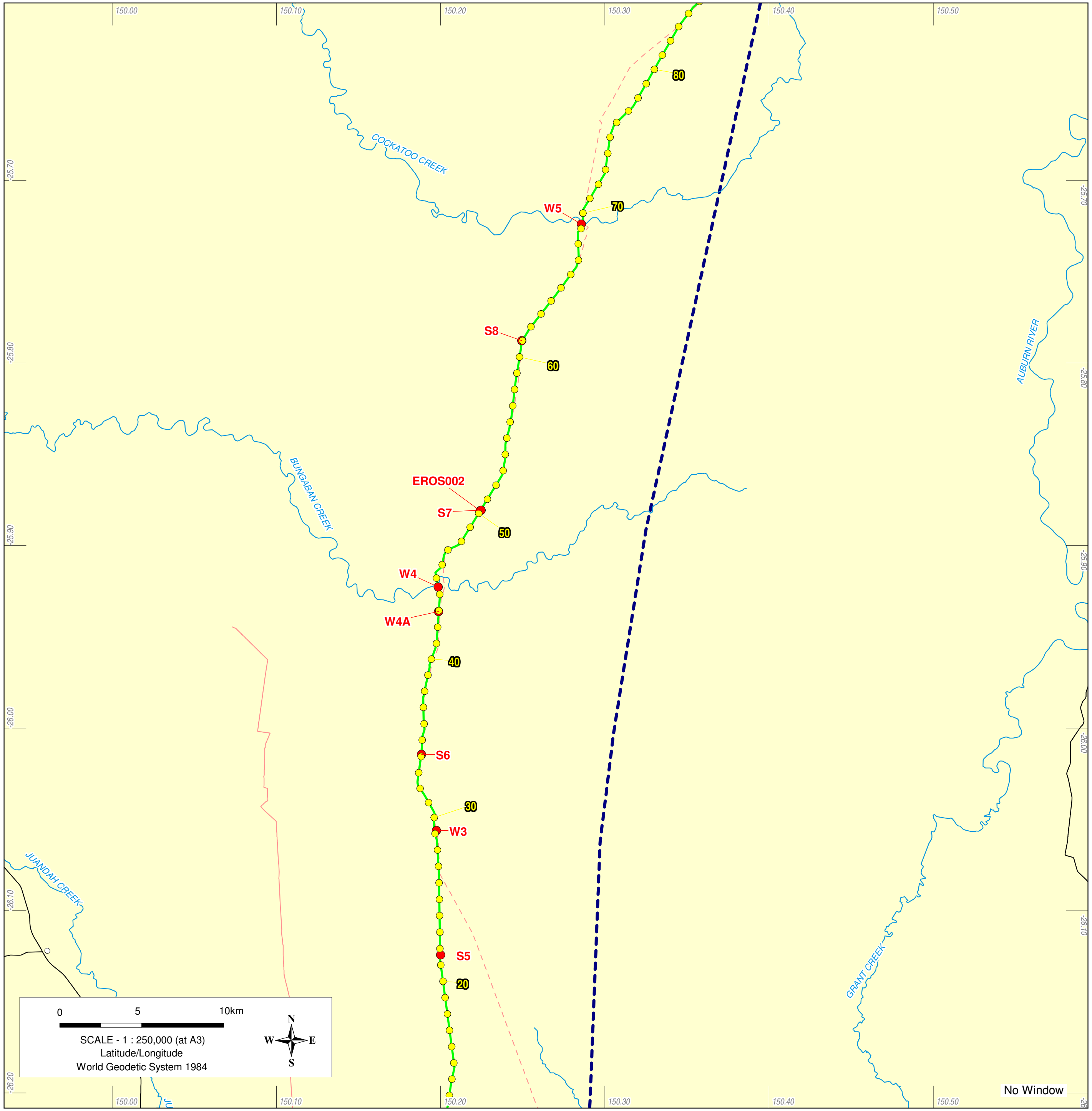

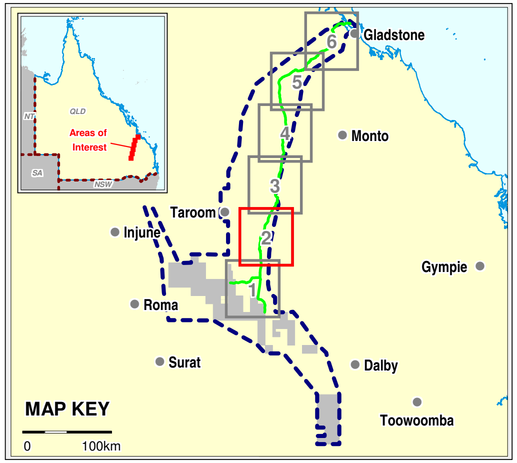

LEGEND

- Observation location
- Pipeline kilometre point
- Town
- Study area
- Preferred pipeline alignment
- Pipeline licence (Application)
- Pipeline licence (Granted)
- Major drainage

Walloons Gas Fields Development Areas

- Combabula / Ramyard
- Woleebee
- Carinya
- Condabri
- Talinga / Orana
- Dalwogan
- Kainama
- Gilbert Gully

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Figure 1.1 Study area and observation locations
Map 2 of 6

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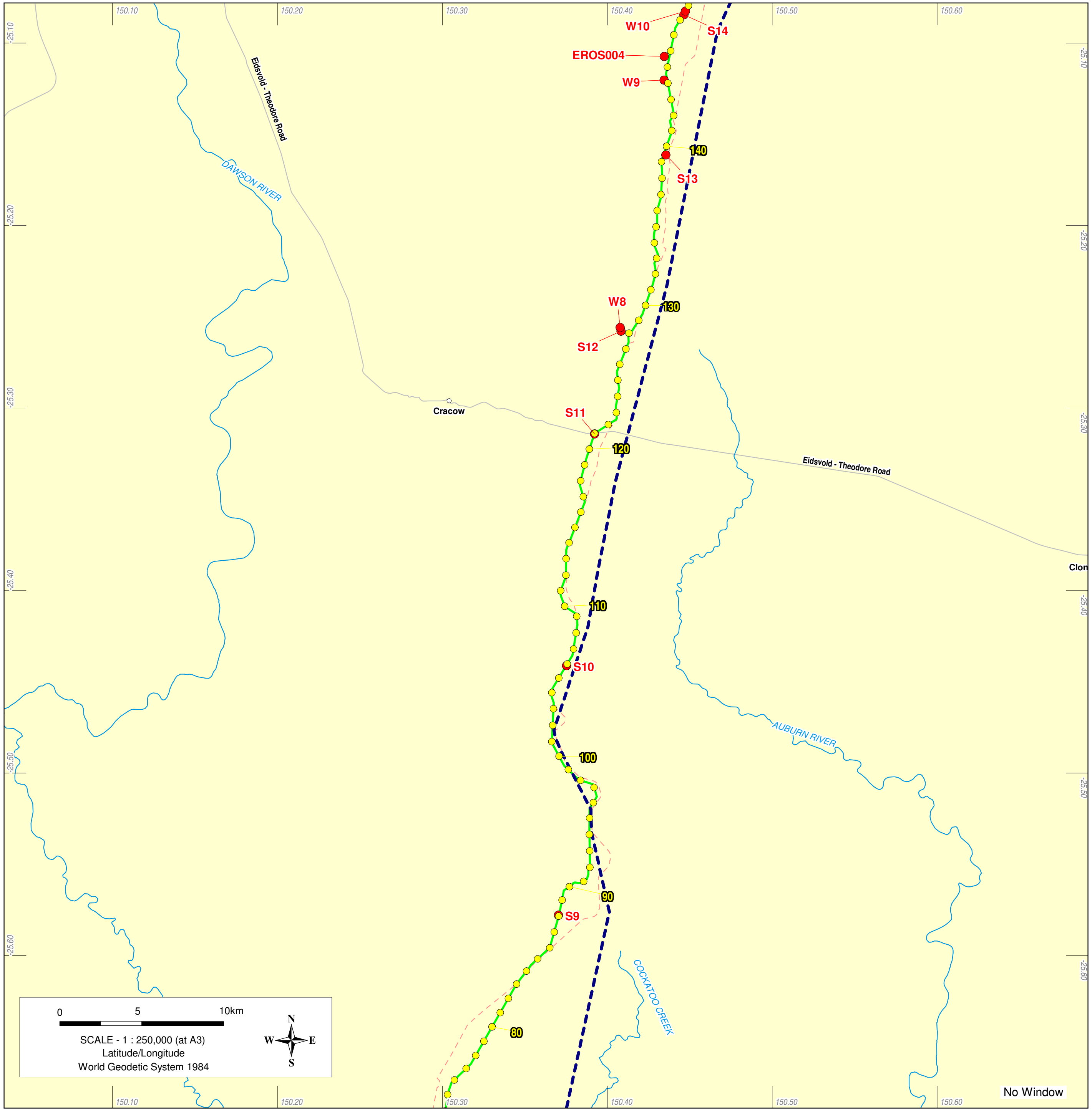

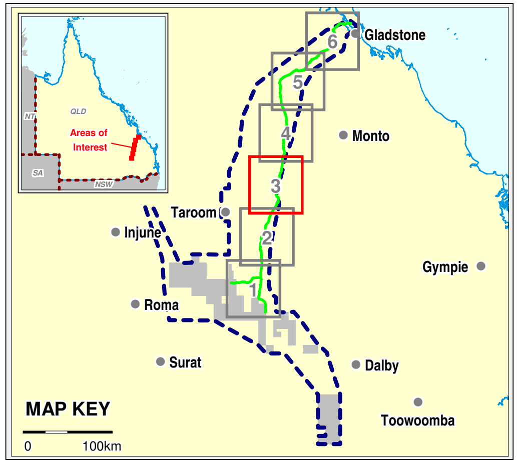

LEGEND

- Observation location
- Pipeline kilometre point
- Town
- Study area
- Preferred pipeline alignment
- Pipeline licence (Application)
- Pipeline licence (Granted)
- Major drainage

Walloons Gas Fields Development Areas

- Combabula / Ramyard
- Woleebee
- Carinya
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Figure 1.1 Study area and observation locations
Map 3 of 6

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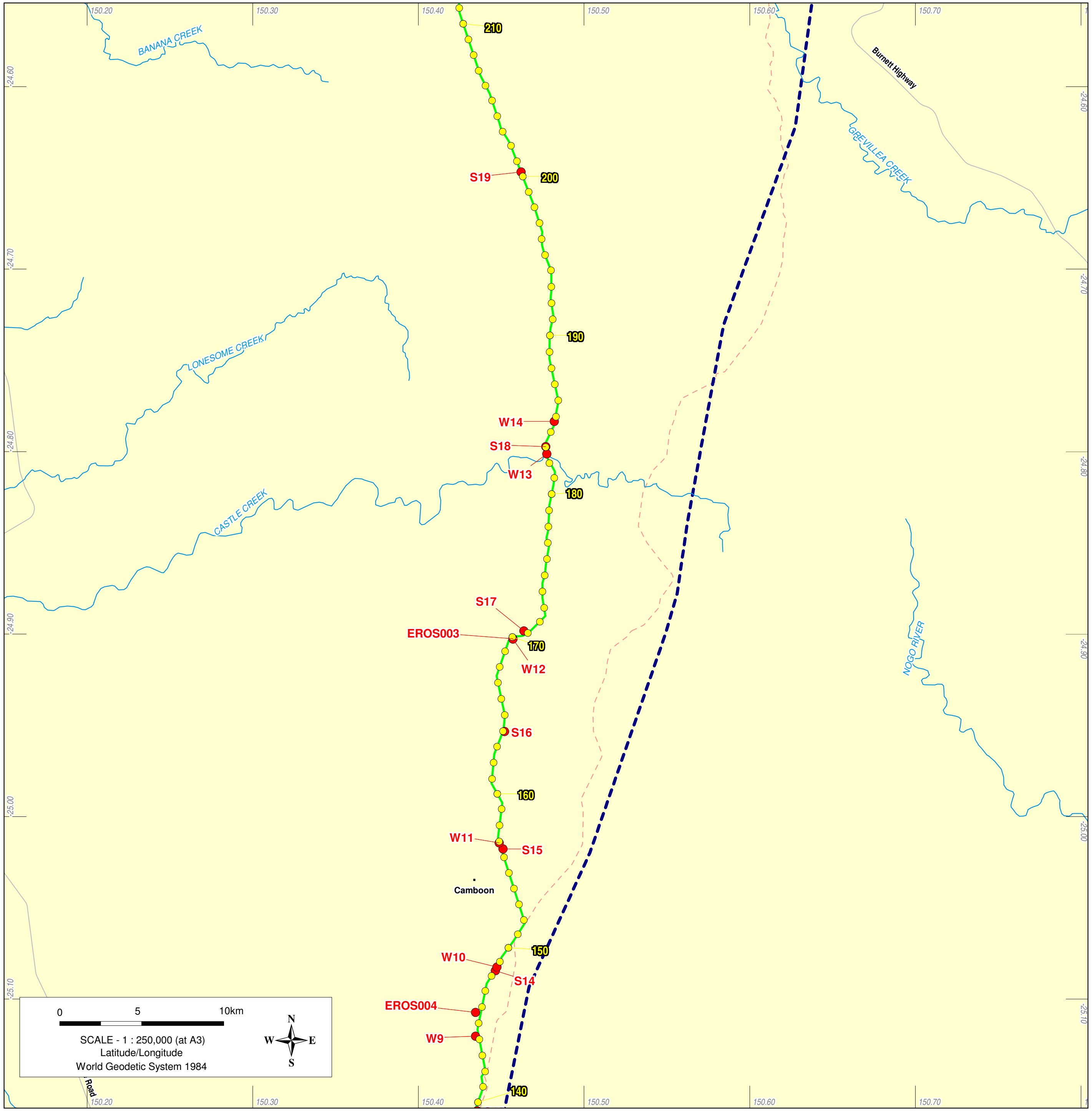

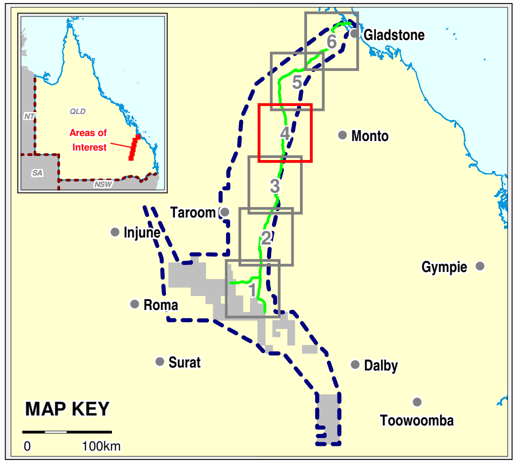

LEGEND

- Observation location
- Pipeline kilometre point
- Town
- Study area
- Preferred pipeline alignment
- Pipeline licence (Application)
- Pipeline licence (Granted)
- Major drainage

Walloons Gas Fields Development Areas

- Combabula / Ramyard
- Woleebee
- Carinya
- Condabri
- Talinga / Orana
- Dalwogan
- Kainama
- Gilbert Gully

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Figure 1.1 Study area and observation locations Map 4 of 6

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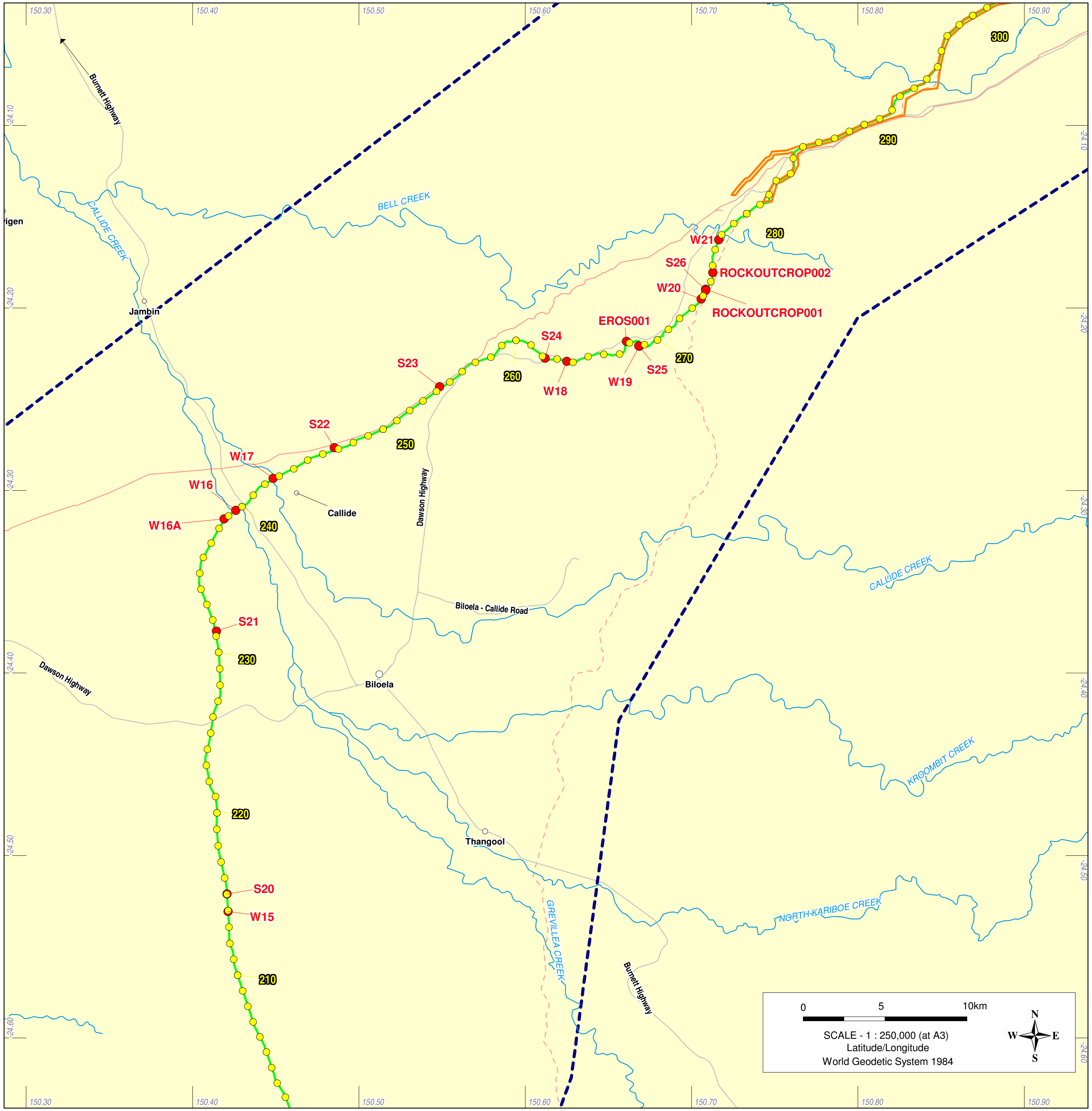

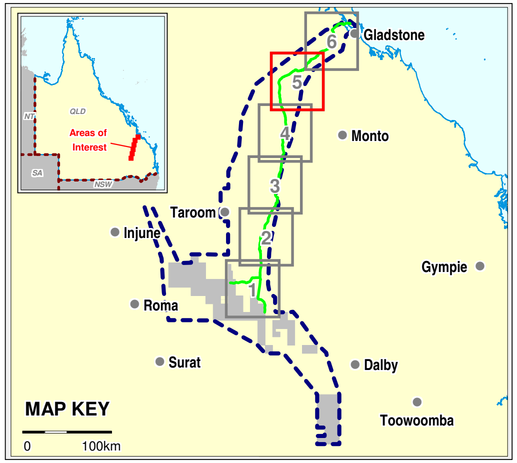

LEGEND

- Observation location
- Pipeline kilometre point
- Town
- Study area
- Preferred pipeline alignment
- Pipeline licence (Application)
- Pipeline licence (Granted)
- Major drainage
- Common infrastructure corridor (CIC)

Walloons Gas Fields Development Areas

- Combabula / Ramyard
- Woleebee
- Carinya
- Condabri
- Talinga / Orana
- Dalwogan
- Kainama
- Gilbert Gully

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Figure 1.1 Study area and observation locations Map 5 of 6

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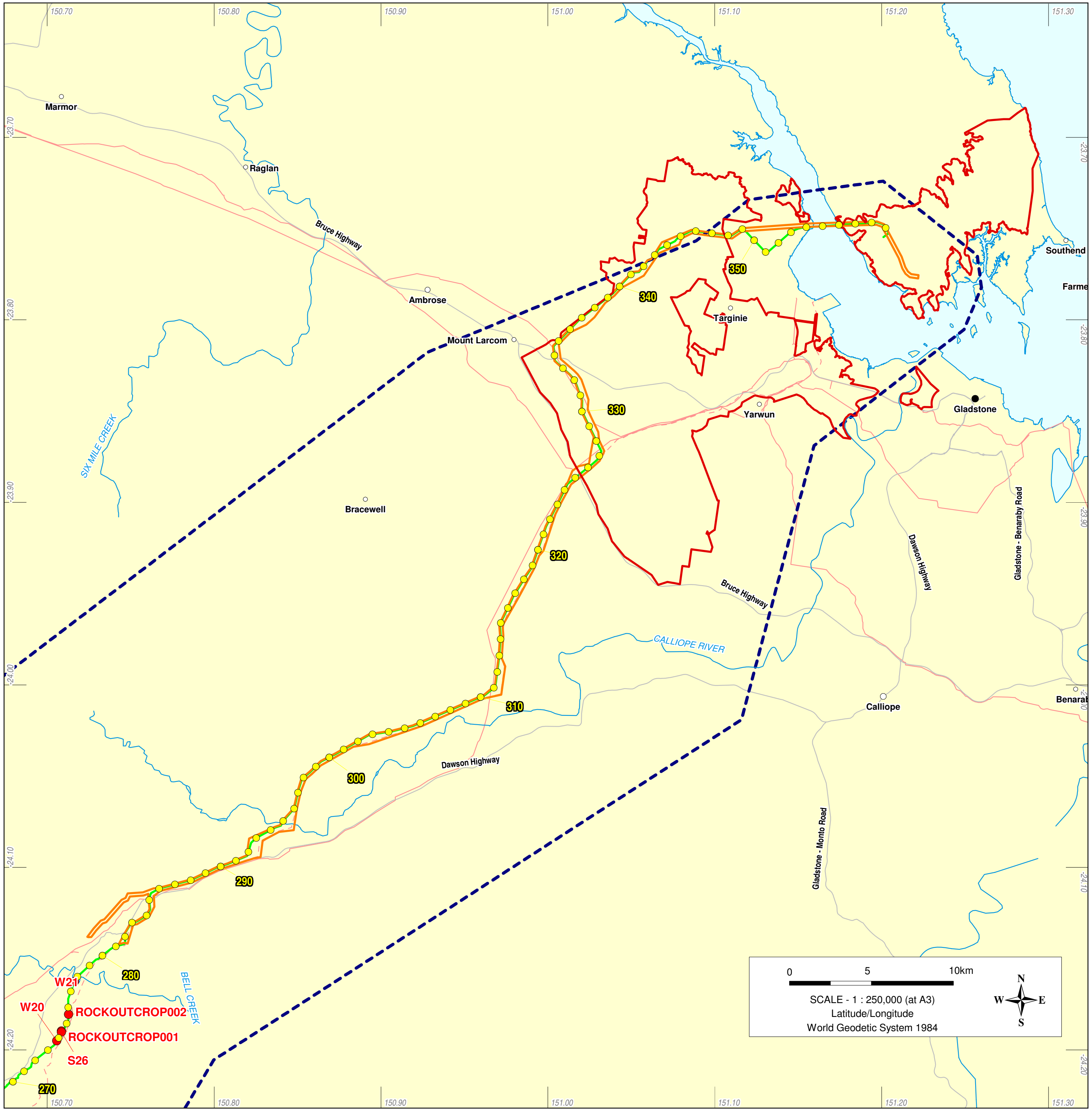

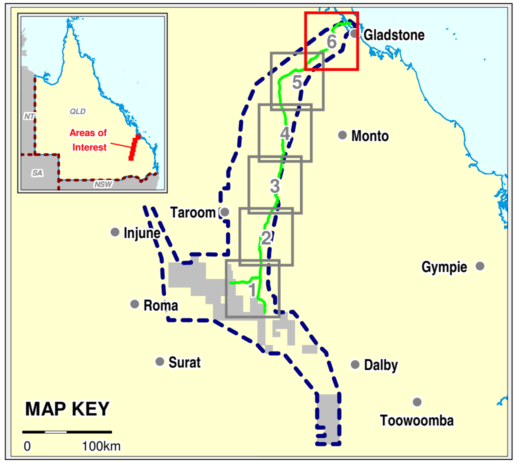

LEGEND

- Observation location
- Pipeline kilometre point
- Town
- Study area
- Preferred pipeline alignment
- Pipeline licence (Application)
- Pipeline licence (Granted)
- Major drainage
- Common Infrastructure Corridor
- Gladstone State Development Area

Walloons Gas Fields Development Areas

- Combabula / Ramyard
- Woleebee
- Carinya
- Condabri
- Talinga / Orana
- Dalwogan
- Kainama
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Figure 1.1 Study area and observation locations Map 6 of 6

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2. Methodology

2.1 Geology

The geology of the study area (refer Figure 3.1) was assessed using the following information sources:

a) Regional geological mapping derived from Geological Survey of Queensland (2006), 1:100,000 series geological mapping, including geoscience data sets of Gladstone, Banana, Biloela, Calliope, Scoria, Theodore, Cracow, Rawbelle, Bajool, Bungaban and 1:250,000 series geological mapping of Chinchilla and Roma

b) Queensland Department of Mines and Energy (2007) QRock Data Set.

Geology mapping has also been used in combination with topographic data provided in Section 4 to produce a geological profile of the study area. This is shown in Figure 3.2.

2.2 Topography and geomorphology

The assessment was undertaken in two parts:

a) Desktop review of major topographic features within the study area.
This was carried out using the 25m Digital Elevation Model (DEM) supplied by Natural Resources and Water (NRW) [2007] to assess slope class. This data was used in conjuction with the following land system mapping to identify and assess landform:

   i) Department of Primary Industries (DPI) 1995, Land Resource Areas – Murilla and Chinchilla Shires, 1: 250,000, DPI, Brisbane.

   ii) Commonwealth Scientific and Industrial Research Organisation (CSIRO) – Division of Land Research 1968 Land Systems – Dawson - Fitzroy Area, Queensland Australia, 1: 500,000, CSIRO.

   iii) Department of Primary Industries (DPI) 1995, Land Systems of the Capricornia Coast, map 3 Calliope Area, 1: 250,000, DPI, Brisbane.

   Digital data for the purposes of mapping land systems and soil types have been derived predominantly from the above datasets.

b) A field assessment across the study area classifying terrain and slope at each observation location.

2.3 Soils

The soils assessment was undertaken in two parts:

a) Desktop review of existing information pertaining to the study area such as land system, land resource and soils mapping (including a review of ASS) and

b) A field assessment including soil sampling and classification, and erosion categorisation.

2.3.1 Desktop studies

Land system and land resource maps provide useful soils and landform data across wide areas throughout Queensland. These have been developed from various sources such as geology and topographic mapping, local knowledge and experience and soil analytical data. A land system map generally presents areas of discrete landscape based on a combination of geology, landform, soils and natural vegetation characteristics. However, such maps should not be regarded as detailed soils maps. They indicate the general soil characteristics of an area at a sufficient level to enable management issues and constraints to be defined. They also provide reliable background data that would otherwise be impracticable to obtain through a comprehensive field survey.

The gas pipeline study area, incorporating the 10km corridor, covers approximately 1,687,000ha and is spread across three land system study areas, described in Section 2.2.

As the three reports describing these land systems use different classification techniques and nomenclature, a standardised key to soil types within the study area was prepared to ensure impact assessment and management recommendations were tied to a common base (refer to Figure 5.1 and Section 5.1).

Due to timing and access restrictions, a portion of the study area (KP 281 to KP 360) which passes through the Callide Common Infrastructure Corridor (CCIC) [KP 281 to KP 325] and the Gladstone State Development Area (GSDA) [KP 325 to KP 360] was assessed through desktop review only. A field investigation of this area is expected to be undertaken during the supplementary EIS preparation phase.

In addition to land system, land resource and soils mapping sources noted above, aerial photography, topographic contours and existing ASS reports were used for this desktop review. These additional information sources are listed below:

- Queensland Department of Natural Resources and Water (NRW) 2007, Fitzroy 25m DEM, Brisbane, Queensland.
- Ross, D. 2002, Acid Sulfate Soils -Tannum Sands to St Lawrence, Central Queensland Coast (QNRM02008), Department of Natural Resources and Mines Queensland, Rockhampton.
- Ross, D. 2005, Acid Sulfate Soils of the Narrows Area, Central Queensland Coast (QNRM05524), Department of Natural Resources and Mines Queensland, Rockhampton.

2.3.2 Field investigations

Field investigation of the study area was undertaken from 21 to 29 October 2009 and consisted of sampling and testing soils for physical and agronomic parameters at 31 observation locations (refer Figure 1.1) and inspecting 25 waterway crossings along the field-assessable portion of the pipeline route – Condabri (KP0 to 37) and Woleebee (KP0 to 44) laterals and the main transmission pipeline (KP0 to 281). This approximates a total of 363km of assessable pipeline length. All observation locations were initially reviewed by Australia Pacific LNG prior to field work commencing, and adjusted according to cultural heritage and land access restrictions. Significant attention has been given to proposed watercourse crossing points due to the potential impacts associated with disturbance and stabilisation requirements.

Soil observation locations were selected by focussing on areas that were readily accessible and gave a representative analysis of soils that predominated along the gas pipeline route. Water crossing observations were selected based on stream order classification as per the DERM stream order classification, which is based on Strahler, 1952. Observation locations were adjusted in the field based

on permissible land access, cultural heritage constraints and ongoing alterations to the proposed transmission pipeline route.

This methodology represents a sampling intensity of approximately one location (observation) every 47ha (31 locations across the approximate 1,452ha area of disturbance, based on the 40m wide RoW plus associated facilities. This was considered adequate to represent soils within the study area (in conjunction with existing published land resource information) and provide sufficient information to correlate encountered soils with published land system data.

Soil observations were hand augered to a depth of between 0.15m to 1.0m below ground level (BGL), depending on hardness of subsurface material and presence of coarse fragments. Soil characteristics were described at all 31 soil observation locations and photographed to show the soil profile and surrounding environmental setting (refer Section 2.3.3). Soil samples were collected for laboratory analysis of their physical and agronomic constituents.

2.3.3 Soil descriptions

Soils at each borehole location were described in accordance with the Australian Soil and Land Survey Field Handbook (McDonald et al. 1990) and the Australian Soil Classification (Isbell 1996). This included soil horizon and landscape information provided in Table 2.1, while a summary of field data is provided in Appendix B.

Table 2.1 Soil horizon and landscape information

Soil horizon descriptions	Landscape information
Subgroup classification	Terrain (slope class)
Horizon name	Predominant slope
Depth	Slope position
Colour (matched to the Munsell Colour Chart paint chip)	Existing erosion
Texture	Drainage
Structure	Aspect
Consistence	Approximate water table depth
Coarse fragments	Universal Transverse Mercator (UTM) coordinates of Zone 55
Mottles	Vegetation (canopy / understory)
Presence of carbonates and/or salts	Land use
Rooting description	

2.3.4 Soil sampling methodology

Field sampling procedures conformed to WorleyParsons Quality Assurance / Quality Control (QA/QC) protocols to minimise potential for cross contamination and preserve the sample integrity. The following sections provide a brief description of the testing methods used, while Table 2.2 provides a summary of the soil sampling activities.

Table 2.2 Soil sampling methods

Activity	Details
Borehole locations	Borehole locations were recorded using a Garmin 76 hand-held ground positioning system (GPS) unit which has an accuracy of ±4m.
Soil coring	Borehole coring was undertaken using an 82mm manual hand auger by WorleyParsons staff members and extended to a maximum depth of 1m BGL.
Abandonment	Boreholes were backfilled to the existing natural ground level using soil retrieved during soil coring.
Soil logging	Soil profiles were logged based on the subsoil brought to the surface.
Soil sampling	Soil samples were obtained directly from the auger or borehole using new disposable nitrile gloves. Samples to be tested for agronomic parameters were then placed into resealable plastic bags and stored in eskies for dispatch to the laboratory.
Labelling	Sample containers were labelled with the date, the abbreviated project title APLNG and the location / depth. For instance, a sample collected at S1a at a depth of 0.3 to 0.4mBGL was labelled as follows: APLNG 29/10/09 S1a/0.3-0.4
Dispatch	Samples were stored in eskies and transported to BioTrack for analytical testing following the completion of field works.

2.3.5 Soil sampling and laboratory analysis

Sampling for physical and agronomic parameters included the collection of discrete soil samples within the topsoil (typically surface to 0.2m) and subsoil horizons (typically 0.2m to 1.0m). A total of 30 topsoil and 33 subsoil samples were collected and analysed.

Soil samples were dispatched to BioTrack Laboratory in Brisbane for Emerson dispersion testing and analysis of pH, electrical conductivity (EC), available nutrients [Total Kjeldahl Nitrogen (TKN) and phosphorus (P)], cation exchange capacity (CEC) and exchangeable cations. The laboratory analysis plan is presented in Appendix C.

3. Existing geology

3.1 Regional tectonics

The proposed Australia Pacific LNG gas pipeline corridor traverses through regions which have been subject to extensive tectonic activity. The basement rocks of the southern section of the pipeline corridor form part of the Surat Basin and Bowen Basin, with the basement rocks for the northern and eastern section of the pipeline corridor forming part of the Yarrol Province, Connors-Auburn Province, Gogango Overfold Zone and Wandilla Province of the Northern New England Fold Belt.

The formations of the several distinct geological provinces and basins in which the gas pipeline corridor traverses are described below.

3.1.1 Bowen Basin stratigraphy

The Bowen Basin was formed during the Early Permian to Middle Triassic and occupies an area of around 160,000km^2. It is a north-south trending belt which extends from Townsville, Queensland, southwards into central northern New South Wales, near Moree. Deposition of the Bowen Basin was concentrated in two depocentres, the Taroom Trough on the eastern edge of the basin and the Denison Trough along its western edge. The deposition commenced in the Early Permian and extended through to the Middle Triassic.

Early phases of deposition in the Taroom Trough consisted of fluvial and lacustrine sediments and volcanics, while in the Denison Trough deposition consisted of a thick succession of coals and non-marine clastic sediments. Following rifting (pulling apart of Earth's crust), a subsidence phase extending from the Early to Late Permian allowed deposition of deltaic and shallow marine, predominately clastic sediments as well as extensive coal measures. A period of accelerated subsidence followed during the Late Permian, resulting in the deposition of a very thick succession of marine and fluvial clastics, consisting of Early to Middle Triassic fluvial and lacustrine clastic sediments and further coal. The deposition was terminated by the Middle to Late Triassic contraction of the surface.

3.1.2 Surat Basin stratigraphy

The Early Jurassic to Early Cretaceous Surat Basin overlies the southern half of the Bowen Basin, and extends from the southern part of central southern Queensland in the vicinity of the Expedition Range southward to central northern New South Wales, near the Warrumbungle Range.

Deposition in the Surat Basin commenced during the Early Jurassic, comprising mostly fluviolacustrine deposition. By the Middle Jurassic, coal swamp environments predominated over much of the basin, except in the north where fluvial sedimentation continued. By the end of the Middle Jurassic, fluvial deposition again predominated and continued until the Early Cretaceous when a period of marine transgression followed, depositing paralic and marine sediments. The subsequent regression caused a fairly abrupt return to fluvial, lacustrine and paludal environments before sedimentation ceased in the Early Cretaceous.

3.1.3 Connors and Auburn Province stratigraphy

The northern section of the Connors and Auburn Province of the northern New England Orogen consists mainly of a fore-arc basin sequence of Late Devonian to Carboniferous age overlaid by Early

Permian strata. It is located east of the Bowen Basin. The southern section of the province extends north to Banana and south to about Auburn.

The Late Devonian to Carboniferous sequence was not a typical continental margin arc as it contains primary marine volcanic rocks. During the Early Carboniferous, a convergent margin tectonic event commenced and continued through much of the period.

Early Permian strata that overlie the Late Devonian-Carboniferous fore-arc basin and accretionary wedge sequences are comprised of a series of extensional basins which developed at the same time as the Bowen Basin to the west. Lower Permian volcanic rocks along the western side of the Connors-Auburn Province are associated with the extensional event which formed the Bowen Basin. Late Permian deformation of the New England Orogen produced west-north-west directed thrusting and associated folding.

3.1.4 Gogango Overfolded Zone stratigraphy

The Gogango Overfolded Zone is a belt of strongly cleaved sandstone, mudstone and deformed mafic to felsic volcanic rocks that separates the Connors-Auburn Province into northern and southern sections. It extends north to St Lawrence and south to Auburn. The Gogango Overfolded Zone is essentially a section of the Bowen Basin that was more intensely deformed by thrusting.

3.1.5 Yarrol Province stratigraphy

The Yarrol province of the Northern New England Orogen consists mainly of a fore-arc basin sequence of Late Devonian to Carboniferous age located to the east of the Bowen Basin. It extends north to Bowen and south to about Kingaroy.

The basin mainly comprises volcaniclastic sedimentary rocks deposited on a marine shelf that became shallower towards the Bowen Basin to the west. The Lower Carboniferous part of the sequence is characterised by the widespread development of oolitic limestone beds. The fore-arc basin succession overlies the Middle Devonian and older rocks unconformably.

3.1.6 Wandilla Province stratigraphy

The Wandilla Province extends in a band from Shoalwater Bay to the north and south into northern New South Wales. The Wandilla Province comprises numerous deep water sedimentary and volcanic rocks which, in general, are steeply dipping, structurally complex, and sparsely fossiliferous. A gross regional stratigraphy is preserved, with an earlier western assemblage characterised by radiolarian jasper and chert, a central belt of volcaniclastic greywacke and argillite, and an enigmatic later eastern sequence of quartzose sandstone and argillite. Limited age control is provided by radiolarians and conodonts from chert, conodonts from sparse limestone lenses and, in the central belt, by the occurrence of a persistent horizon of greywacke beds containing ooliths which is likely to have been sourced from Lower Carboniferous limestones of the fore-arc basin to the west.

3.2 Study area geology

The regional geology within the proposed Australia Pacific LNG gas pipeline corridor has been mapped by the Geological Survey of Queensland (GSQ) in the Geoscience Datasets and geological 1:100,000 series mapping of Gladstone, Banana, Biloela, Calliope, Scoria, Theodore, Cracow, Rawbelle, Bajool, Bungaban, and the geological 1:250,000 series maps of Roma and Chinchilla.

The geology mapped within the southern region of the proposed pipeline corridor comprises predominantly Jurassic to Cretaceous mudrocks, arenites and other sedimentary rocks of the Surat Basin and southern Bowen Basin. Quaternary alluvium and soil occur in the lower lying areas and adjacent to waterways throughout the Surat and Bowen basins, and typically overlie earlier sediments.

Geology mapping describes the central region of the proposed pipeline corridor, in the vicinity of the Banana and Auburn ranges, as comprising predominantly Late Carboniferous to Early Triassic granites and other extrusive and intrusive volcanics of the Connors-Auburn Province. Early Tertiary mudrocks and other sedimentary rocks of the Biloela Formation and Triassic sedimentary rocks of the Callide Coal Measures underlie the Biloela region. Quaternary alluvium and soil occur in low-lying areas and adjacent to major waterways of this region.

Geology mapping describes the northern segment of the pipeline corridor, traversing through the Callide and Calliope ranges, as comprising predominately Permian to Triassic intrusive volcanics of the Yarrol Province.

The geology identified within the eastern section of the proposed pipeline corridor, in the vicinity of the Mount Larcom Range and Curtis Island, comprises predominately Late Devonian to Early Carboniferous Volcaniclastic sedimentary rocks of the Wandilla Province.

As mapped in the GSQ Geoscience Datasets, several of the geological mapping units identified have similar characteristics in terms of age, rock type and region. To simplify the mapping process, these mapping units have been combined and re-defined as ’geological units’. The geological units and map symbols that have been adopted as a basis for terrain mapping are summarised in Table 3.1. The colours presented correlate to those on Figure 3.1.

Table 3.1 Study area geologic unit summary

Description	Major geological unit	Age	Lithology summary	Dominant rock	Map symbol
Human-made deposits	Human-made deposits	Holocene	Gravel, sand and mud; human-made deposits associated with land-fill or mining	Human-made deposits (tailings, landfill, mine dumps etc)	Qmm
Quaternary (Holocene) Alluvium and estuarine sediments	Alluvium	Holocene	Mud, sandy mud, muddy sand and minor gravel forming estuarine channels and banks, supratidal flats and coastal grasslands	Miscellaneous unconsolidated sediments	Qa
	Alluvium	Quaternary	Sand, silt, mud, gravel from residual soils	Miscellaneous unconsolidated sediments	
	Alluvium	Quaternary – Pleistocene	Clay, silt, sand, gravel; floodplain alluvium	Alluvium	
Tertiary Alluvium	Alluvium	Late Tertiary – Quaternary	Locally red-brown mottled, poorly consolidated sand, silt, clay, minor gravel; high level alluvial deposits, generally dissected, and related to present stream valleys	Poorly consolidated sediments	Ta
	Poorly consolidated sediments	Tertiary	Semi consolidated clayey sandstone and conglomerate, associated with deep weathered profiles	Poorly consolidated sediments	
	Floodout and residual sand, soil and gravel	Late Cainozoic	Sand, soil and gravel	Miscellaneous unconsolidated sediments	

Description	Major geological unit	Age	Lithology summary	Dominant rock	Map symbol
Late Tertiary-Quaternary Colluvium	Colluvium	Late Tertiary – Quaternary	Clay, silt, sand, gravel and soil; colluvial and residual deposits	Colluvium	TQc
Tertiary Volcanics, mainly Basalt	Intrusive Volcanics	Early Tertiary	Olivine Basalt; plug	Basalt	Tv
	Volcanics	Tertiary	Olivine Basalt	Basalt	
Tertiary Sediments - Biloela Formation	Biloela Formation	Early Tertiary	Mudstone, siltstone, oil shale, carbonaceous mudstone and sandstone	Arenite-Mudrock	Ts
	Paleocene-Oligocene Sediments	Tertiary	Sandstone, mudstone, conglomerate	Sedimentary rock	
	Ferricrete	Tertiary	Duricrusted palaeosols at the top of deep weathering profiles, including ferricrete and silcrete	Ferricrete	
Cretaceous Volcanics - Double Mountain Volcanics, Peninsula Range Volcanics, Proserpine Volcanics, Whitsunday Volcanics	Double Mountain Volcanics, Peninsula Range Volcanics, Proserpine Volcanics, Whitsunday Volcanics, unnamed volcanics	Cretaceous	Dacitic crystal tuff, lithic, vitric and lapilli tuff, agglomerate, minor siltstone	Felsites (lavas, clastics and high level intrusives)	Kv
Cretaceous Sediments - Wallumbilla Formation	Wallumbilla Formation	Early Cretaceous	Mudstone and siltstone with calcareous concretions	Mudrock	Ku
Early to Middle Jurassic Sediments - Precipice Sandstone, Evergreen Formation, Hutton Sandstone	Precipice Sandstone	Early Jurassic	Poorly sorted thick bedded, cross bedded, fine to very coarse grained, pebbly quartzose sandstone	Arenite	Jp
	Evergreen Formation	Early Jurassic	Fine to medium grained, micaceous, labile to sublabile sandstone, carbonaceous mudstone, siltstone and	Arenite-Mudrock	

Description	Major geological unit	Age	Lithology summary	Dominant rock	Map symbol
			coal		
	Hutton Sandstone	Middle Jurassic	Medium grained, feldspathic sublabile sandstone overlaid by quartzose sandstone, minor carbonaceous siltstone, mudstone and rare pebbly conglomerate	Arenite	
Middle to Late Jurassic Sediments - Injune Creek Group, Mulguildie Coal Measures, Walloon Subgroup	Injune Creek Group, Mulgildie Coal Measures, Walloon Subgroup	Middle Jurassic – Late Jurassic	Calcareous lithic sandstone, siltstone, mudstone, coal, conglomerate	Sedimentary rock	Ji
Jurassic Sediments - Razorback beds	Razor Back Beds	Jurassic	Sandstone, mudstone, conglomerate	Arenite	Jr
Jurassic to Cretaceous Sediments - Bungil Formation, Gubberamunda Sandstone, Hooray Sandstone, Kumbarilla Beds, Longsight Sandstone, Moonga Sandstone, Orallo Formation, Southlands Formation	Bungil Formation, Gubberamunda Sandstone, Hooray Sandstone, Kumbarilla Beds, Longsight Sandstone, Moonga Sandstone, Orallo Formation, Southlands Formation	Jurassic – Cretaceous	Glauconitic, labile to quartzose, siltstone, mudstone, sandstone, minor conglomerate and coal	Arenite	JKb
Triassic to Jurassic Sediments - Bundamba Group, Landsborough Sandstone	Bundamba Group, Landsborough Sandstone	Triassic - Jurassic	Sandstone, siltstone, shale, conglomerate	Arenite - mudrock	RJs
Triassic Volcaniclastic Sediments - Callide Coal Measures	Volcaniclastic Sediments	Middle Triassic – Late Triassic	Polymictic, volcaniclastic, pebble to cobble conglomerate, volcaniclastic sandstone; trachytic to andesitic, lithic and crystal tuff; quartz-lithic sandstone	Mixed sedimentary rocks and felsites	Rc

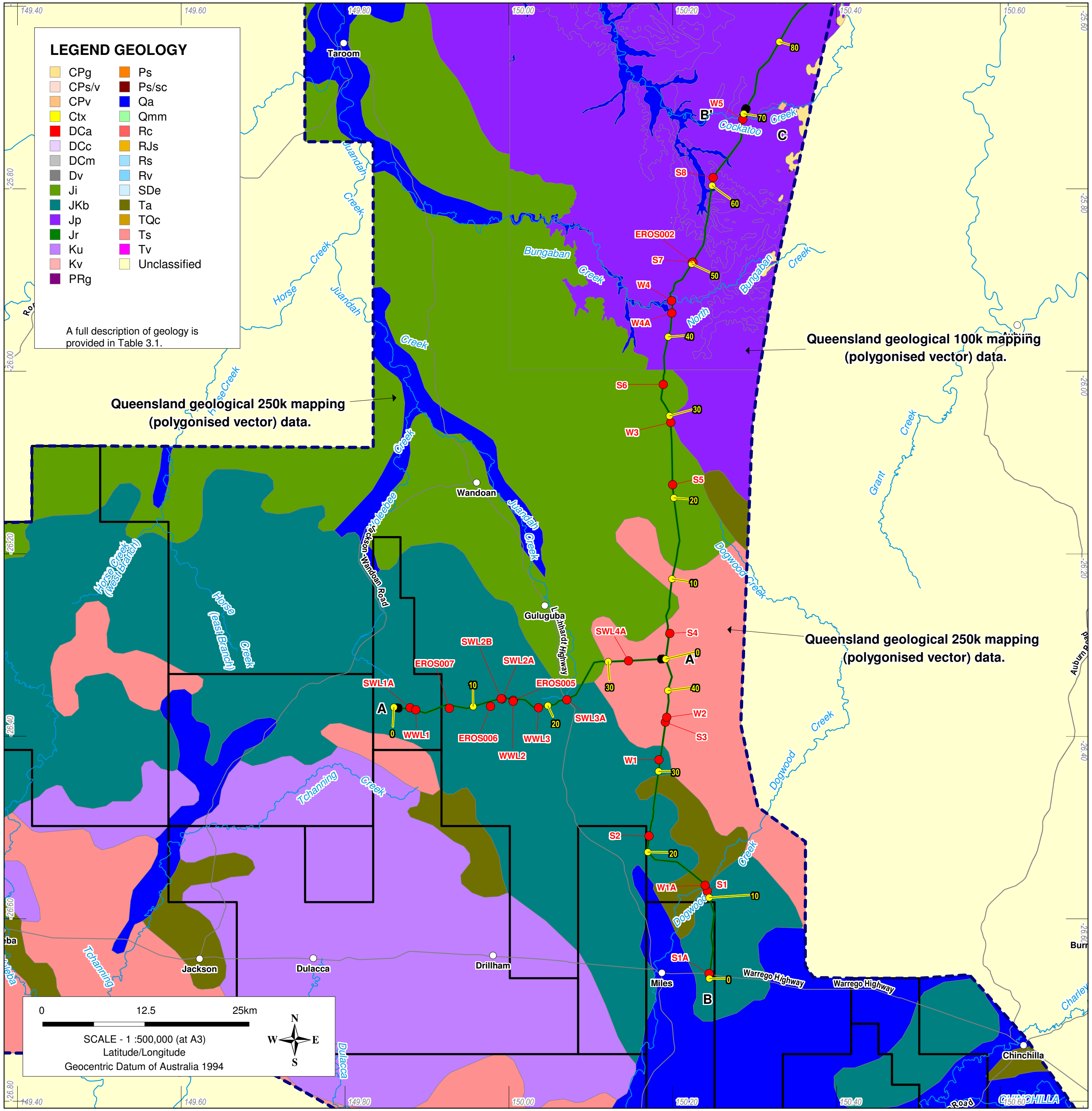
Description	Major geological unit	Age	Lithology summary	Dominant rock	Map symbol
			and siltstone; rare carbonaceous siltstone		
	Callide Coal Measures	Triassic	Poorly sorted polymictic pebble to boulder conglomerate, sandstone, siltstone, coal seams, and felsic tuff	Sedimentary rock	
Triassic Sediments - Moolayember Formation, Clematis Sandstone, Rewan Formation	Moolayember Formation, Clematis Sandstone, Rewan Formation	Triassic	Medium to coarse-grained quartzose to sublabile, micaceous sandstone, siltstone, mudstone and granule to pebble conglomerate	Arenite	Rs
Triassic Volcanics - Agnes Water Volcanics, Aranbanga Volcanic Group,Gayndah Formation, Ooramera Volcanics, Toogoolawah Group	Agnes Water Volcanics,Aranbanga Volcanic Group,Gayndah Formation,Ooramera Volcanics,Toogoolawah Group	Triassic	Rhyolitic, andesitic and trachytic volcanics, sandstone, shale	Mixed Mafites and Felsites (mainly volcanics)	Rv
Permian to Triassic Intrusive Volcanics, mainly Granite, Diorite and Gabbro	Intrusive Volcanics	Late Permian – Early Triassic	Hornblende diorite, biotite-horenblende quartz diorite, monzodiorite and monzonite, grey, fine to coarse – grained, equigranular to porphyritic gabbro	Diorite, Gabbro	PRg
	Ravenscraig Gabbro	Late Permian – Early Triassic	Fine to medium grained, porphyritic hornblende gabbro, with well developed igneous layering	Gabbroid	
	Bocoolima Granodiorite, Mannersley Granodiorite, Zig Zag Granodiorite, Rock Point Granodiorite, Redshirt Granite, Wyalla Granite, Targine	Late Permian – Early Triassic	Medium grained biotite hornblende granodiorite, quartz monzonite and hornblende-biotite tonalite, hornblende-biotite granite, biotite-	Granitoid	

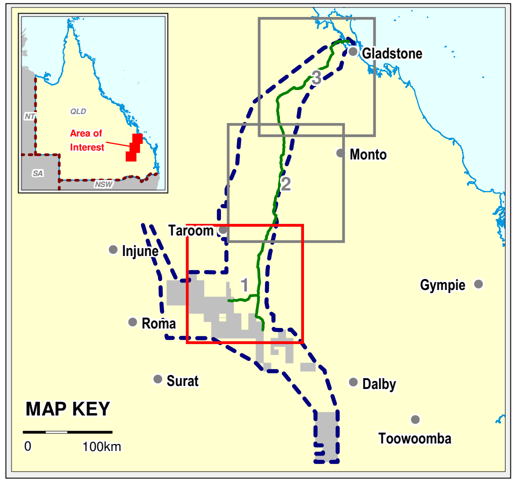
Description	Major geological unit	Age	Lithology summary	Dominant rock	Map symbol
	Quartz Monzonite, Dumgree Tonalite		hornblende toalite		
	Voewood Granite	Middle Triassic	Medium grained biotite granite, locally with pyrite along joint planes	Granitoid	
Permian Siliciclastic and Carbonate Rocks	Buffel Formation, Yarrol Formation	Early Permian	Massive to thick bedded, fossiliferous limestone that grades locally into white chert or silicified limestone; some volcanilithic sandstone, conglomerate, breccia and mudstone	Mixed siliciclastic/ carbonate rocks	Ps/sc
	Oxtrack Formation	Late Permian	Fossiliferous, flaggy, silty limestone grading into calcareous siltstone and mudstone, silicified limestone and coquinite	Mixed siliciclastic/ carbonate rocks	
Permian Sedimentary Rocks	Barfield Formation	Late Permian	Locally calcareous mudstone with local calcareous to phosphatic concretions and glendonites, lithic and feldspathic sandstone and minor conglomerate; minor lapilli tuff and volcanilithic pebble conglomerate; rare andesite	Sedimentary rock	Ps
	Lakes Creek Formation	Early Permian	Siltstone and lithic sandstone	Arenite-Mudrock	
Carboniferous to Perimian Extrustive & Intrusive Volcanics	Intrusive Volcanics	Late Carboniferous – Early Permian	Porphyritic, intrusive rhyolite with quartz and feldspar phenocrysts	Felsites (lava, clastics and high level intrusives)	CPv
	Elliott Rhyolite	Early Permian	Intrusive porphyritic rhyolite and dacite, possibly localised extrusive lava and breccia	Felsites (Lava, clastics & high level intrusives)	

Description	Major geological unit	Age	Lithology summary	Dominant rock	Map symbol
	Chalmers Formation,	Early Permian	Siltstone, lithic sandstone, rhyolitic to andesitic volcaniclastic breccia, rhyolitic and dacitic tuff, minor andesitic tuff	Mixed sedimentary rocks and felsites / Arenite-Mudrock	
	Camboon Volcanics	Late Carboniferous – Early Permian	Basaltic to andestic lava and equivalent volcaniclastic rocks	Mafites (lava, clastics and high level intrusives)	
	Torsdale Volcanics	Late Carboniferous	Dacitic, volcanic sandstone and conglomerate or breccia	Felsites (lava, clastics and high level intrusives)	
Carboniferous to Permian Intermediate Intrusive Volcanics, mainly Granite, Diorite and Gabbro	Glenhalvern Granite,Tindarra Granite, Shawlands Granite Complex, Glandore Granodiorite, Jonah Vale Granite, Hainault Granodiorite, Pinedale Granite, Dawson Granite, Kandoonan Granite, Moocoorooba Granite, Auburn Arch, Ten Mile Granite, JP Granite, Mugunal Granite, Rockdale Granite, Nine Mile Granite, Jan Mar Granite, Ross Granite	Late Carboniferous – Early Permian	Medium to coarse grained hornblende biotite granite to mononite, biotite hornblende granodiorite and diorite	Granitoid	Cpg
	Montour Gabbro	Late Carboniferous – Early Permian	Fine to medium grained gabbro	Gabbroid	
	Windmill Diorite, Okangal Quartz Monzodiorite, Glen View Quartz Monzodiorite	Late Carboniferous – Early Permian	Fine to medium grained, porphyritic biotite hornblende diorite to quartz diorite and biotite hornblende gabbro	Dioritoid	

Description	Major geological unit	Age	Lithology summary	Dominant rock	Map symbol
Carboniferous to Permian Sedimentary and Volcanic Units of the Yarrol and Campwyn Blocks	Rockhampton Group	Carboniferous-Permian	Mudstone, Siltstone, felsic volcaniclastic sandstone, ooid-bearing sandstone and conglomerate with mudstone rip-up clasts, minor limestone and rhyolitic ignimbrite; siltstone, sandstone, intrusive and extrusive domes, volcanic breccia.	Sedimentary rock	CPs/v
	Youlambie Conglomerate	Late Carboniferous – Early Permian	Granule to boulder polymictic comglomerate commonly with abundant granite and rhyolite clast, felsic volcaniclastic sandstone, tuffaceous and carbonaceous siltstone and mudstone, dacitic to rhyolitic ignimbrite, breccia, minor coal	Arenite-Rudite	
	Mount Bulgi Conglomerate Member	Late Carboniferous – Early Permian	Polymictic conglomerate and subordinate sandstone containing mainly felsic volcanic clasts and local granite clasts	Rudie	
	Three Moon Conglomerate	Late Devonian – Early Carboniferous	Granule to cobble andesitic to basaltic conglomerate, lithofeldspathic to feldspatholithic sandstone, siltstone, mudstone, andesite, minor felsic tuff, fossilferous limestone; rare basaltic pillow lava	Mixed volcanic and sedimentary rocks	
Carboniferous Sediments - Texas Beds	Texas Beds	Carboniferous	Greywacke, mudstone, slate, local phyllite; subordinate jasper, chert, conglomerate, limestone	Sedimentary rock	Ctx

Description	Major geological unit	Age	Lithology summary	Dominant rock	Map symbol
Devonian to Carboniferous Sediments -Curtis Island Group	Wandilla Formation	Late Devonian – Carboniferous	Mudstone, lithic sandstone (localised containing silicified ootlites), siltstone, jasper, chert, slate, localised schist	Arenite-Mudrock	DCc
	Doonside Formation	Devonian-Carboniferous	Chert, jasper, mudstone, siltstone, lithic sandstone, limestone and altered basalt	Arenite-Mudrock	
Devonian to Carboniferous Metamorphics - Maronghi Creek beds, Sugarloaf Metamorphics	Maronghi Creek Beds, Sugarloaf Metamorphics	Devonian - Carboniferous	Mudstone, slate, greywacke, chert, jasper, acid to basic metavolcanics	Mixed volcanic and sedimentary rocks	DCc
Devonian to Carboniferous Volcaniclastic Sediments - Mount Alma Formation	Mount Alma Formation	Late Devonian- Early Carboniferous	Thinly interbedded, fine grained sandstone and siltstone and thick beds of conglomerate with andesitic to dacitic clasts and siltstone rip-up clasts	Arenite-Mudrock	Dca
Devonian Volcanics - Mount Morgan Trondhjemite	Mount Morgan Trondhjemite	Middle Devonian	Biotite-hornblende tonalite, biotite granodiorite, hornblende quartz diorite	Granitoid	Dv
Silurian to Early Devonian Volcaniclastic Sediments – Erebus Beds	Erebus Beds	Silurian – Early Devonian	Dacitic to rhyolitic volcaniclastic sandstone and conglomerate, minor siltstone, fossiliferous limestone and marble	Sedimentary rock	Sde





LEGEND

- Observation location
- Pipeline kilometre point
- Town
- Road
- Major drainage
- Preferred pipeline alignment
- Cross-Section
- Reservoir
- Study area
- Common Infrastructure Corridor (CIC)
- Gladstone State Development Area (GSDA)
- Walloons gas fields development areas

Geology is a combination of Queensland geological 100k mapping (polygonised vector) data and Queensland geological 250k mapping (polygonised vector) data.

0	10/12/2009	Issued for use	JB	DH		
Rev	Date	Revision Description	ORIG	CHK	ENG	APPD

AUSTRALIA PACIFIC LNG PTY LIMITED

AUSTRALIA PACIFIC LNG PROJECT EIS
Figure 3.1a Study area geology and cross section profile locations - Map 1 of 3

Project No: 301001-00448	Figure: 00448-00-EN-DAL-0300	Rev: 0

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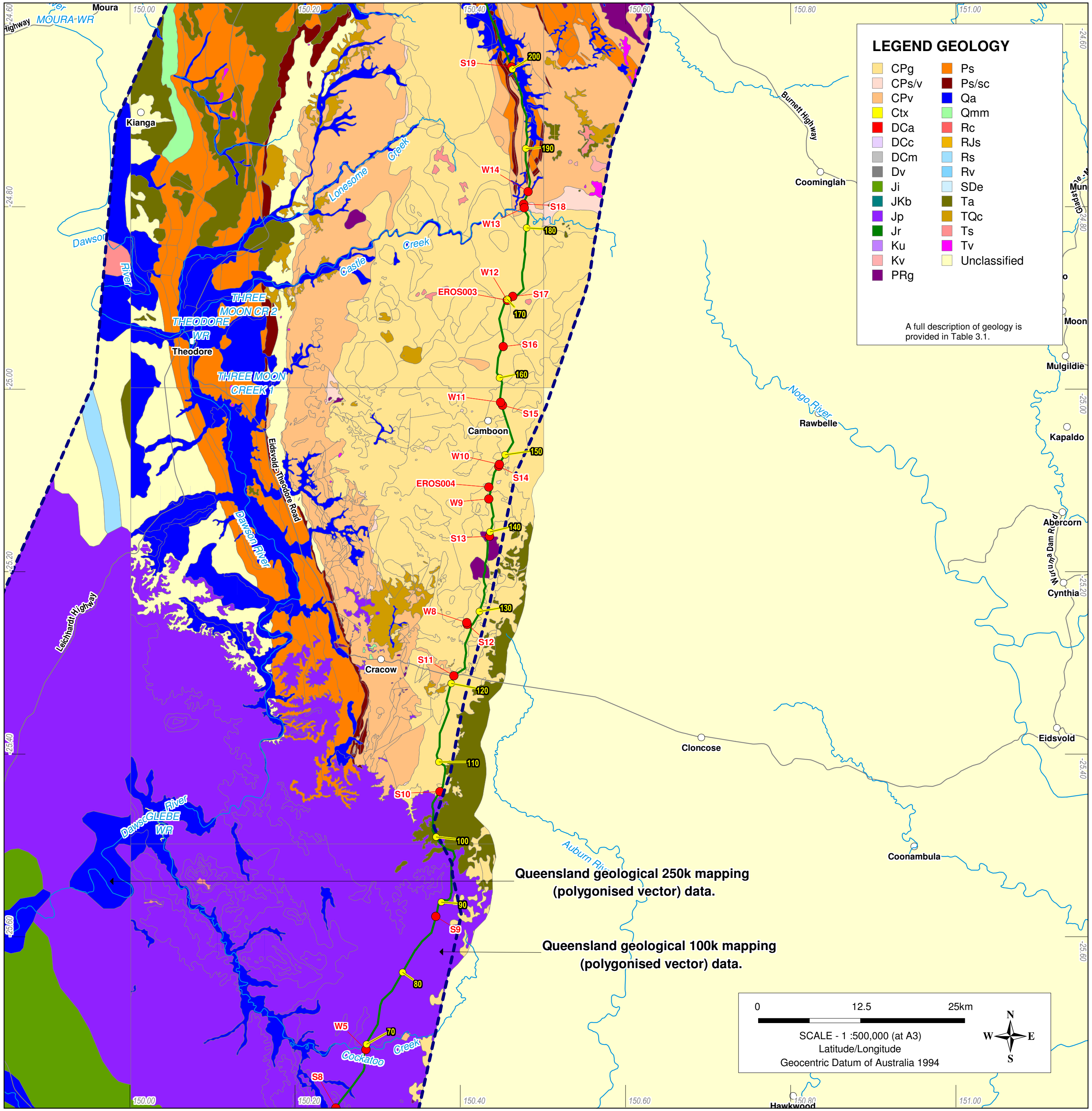

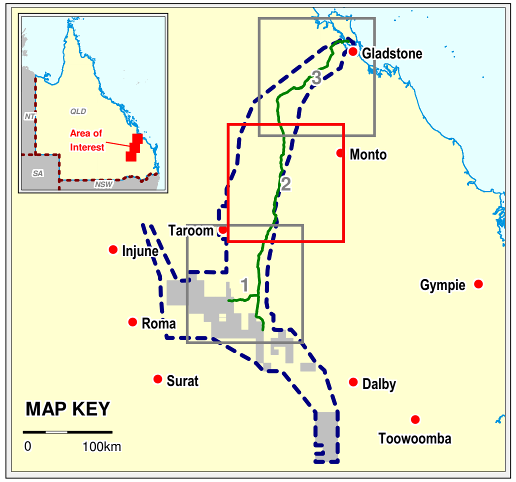

LEGEND

- Observation location
- Pipeline kilometre point
- Town
- Road
- Major drainage
- Preferred pipeline alignment
- Cross-Section (A – A')
- Reservoir
- Study area
- Common Infrastructure Corridor (CIC)
- Gladstone State Development Area (GSDA)
- Walloons gas fields development areas

Geology is a combination of Queensland geological 100k mapping (polygonised vector) data and Queensland geological 250k mapping (polygonised vector) data.

Rev	Date	Revision Description	ORIG	CHK	ENG	APPD
0	10/12/2009	Issued for use	JB	DH		
B	10/12/2009	Re-issued for squad check	JB	DH		

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AUSTRALIA PACIFIC LNG PROJECT EIS
Figure 3.1b Study area geology and cross section profile locations - Map 2 of 3

Project No: 301001-00448	Figure: 00448-00-EN-DAL-0301	Rev: 0

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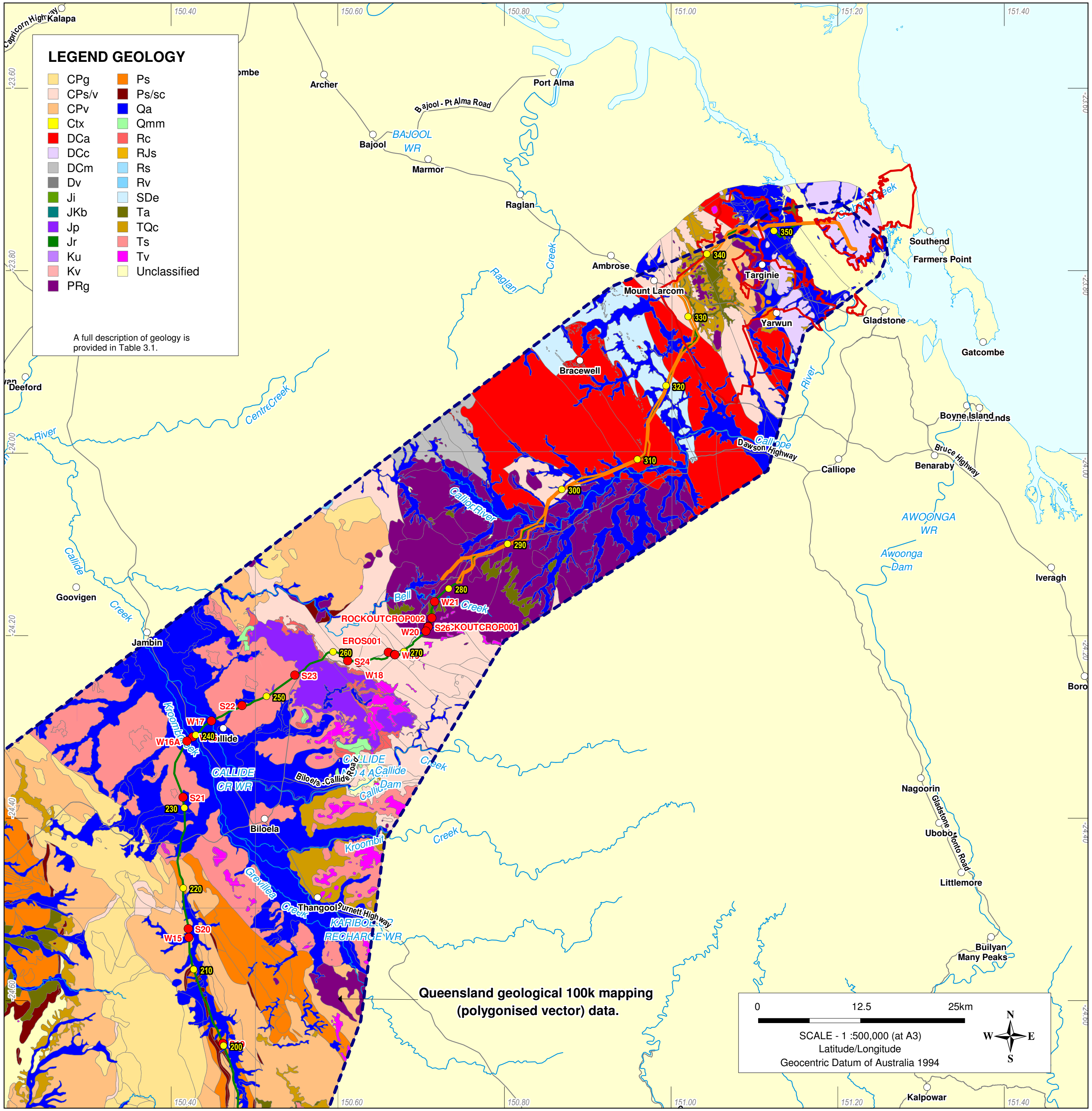

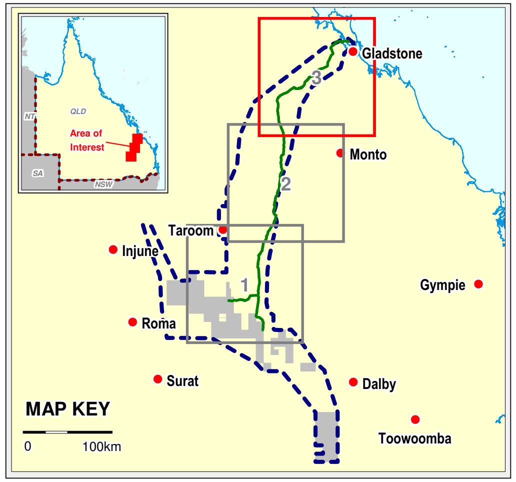

LEGEND

- Observation location
- Pipeline kilometre point
- Town
- Road
- Major drainage
- Preferred pipeline alignment
- Cross-Section (A – A')
- Reservoir
- Study area
- Common Infrastructure Corridor (CIC)
- Gladstone State Development Area (GSDA)
- Walloons gas fields development areas

Geology is a combination of Queensland geological 100k mapping (polygonised vector) data and Queensland geological 250k mapping (polygonised vector) data.

Rev	Date	Revision Description	ORIG	CHK	ENG	APPD
0	10/12/2009	Issued for use	JB	DH		
B	10/12/2009	Re-issued for squad check	JB	DH		

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AUSTRALIA PACIFIC LNG PROJECT EIS
Figure 3.1c Study area geology and cross section profile locations - Map 3 of 3

Project No: 301001-00448 | Figure: 00448-00-EN-DAL-0302 | Rev: 0

Compiled by BRISBANE INFRASTRUCTURE GIS SECTION

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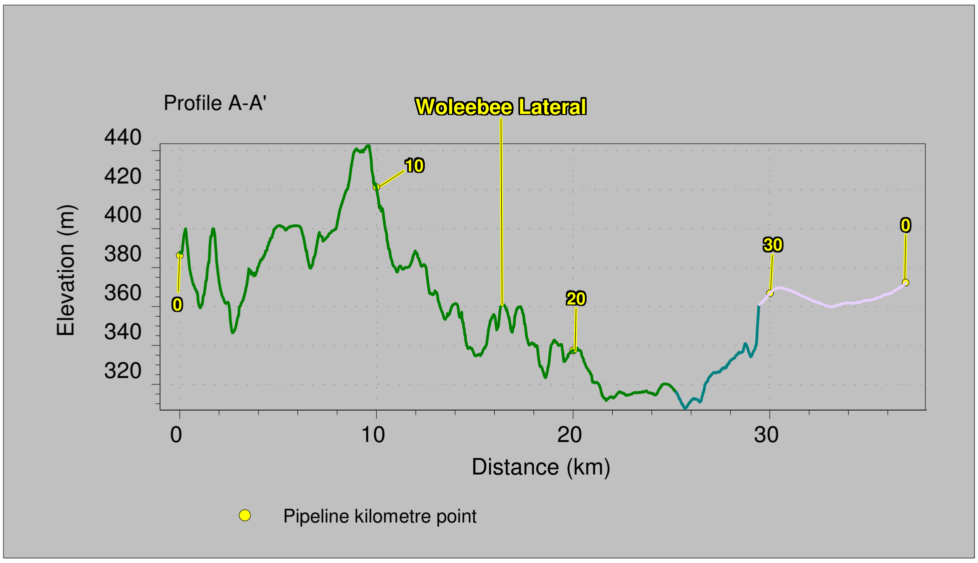

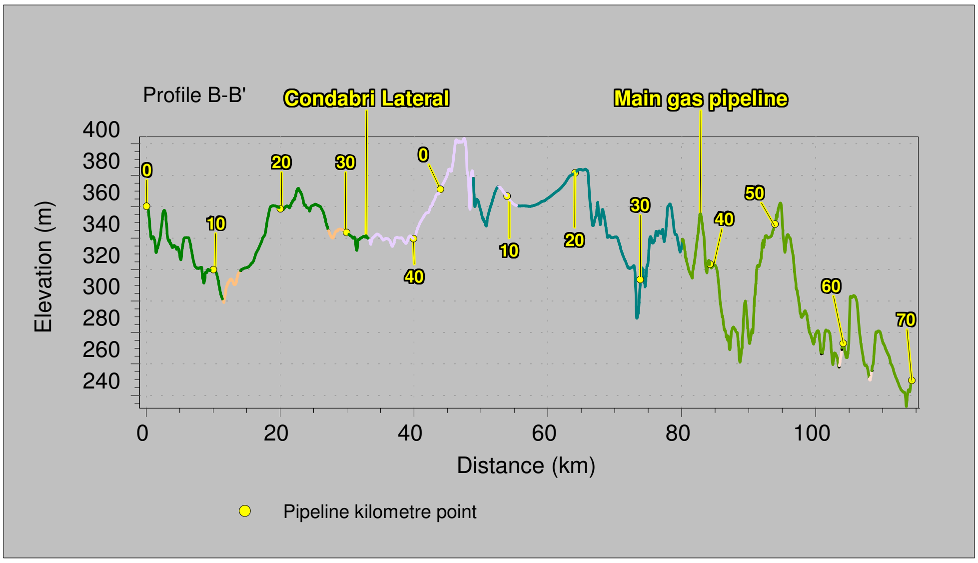

LEGEND GEOLOGY

CPg	Jp	RJs
CPs/v	Jr	Rs
CPv	Ku	Rv
Ctx	Kv	SDe
DCa	PRg	Ta
DCc	Ps	TQc
DCm	Ps/sc	Ts
Dv	Qa	Tv
Ji	Qmm	Unclassified
JKb	Rc	

A full description of geology is provided in Table 3.1.

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Figure 3.2a Study area geological cross sections - Map 1 of 2

Project No: 301001-00448 | Figure: 00448-00-EN-DAL-0303 | Rev: 0

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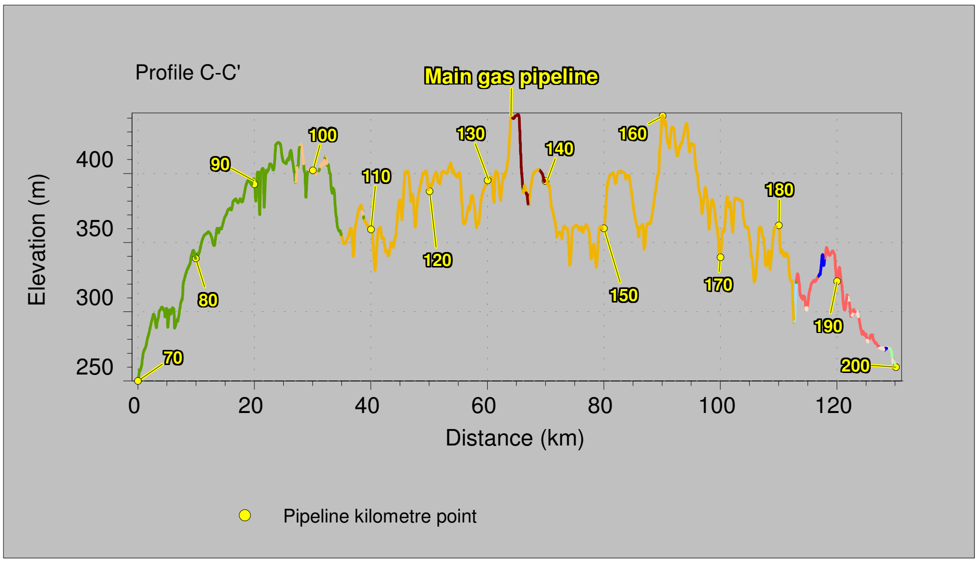

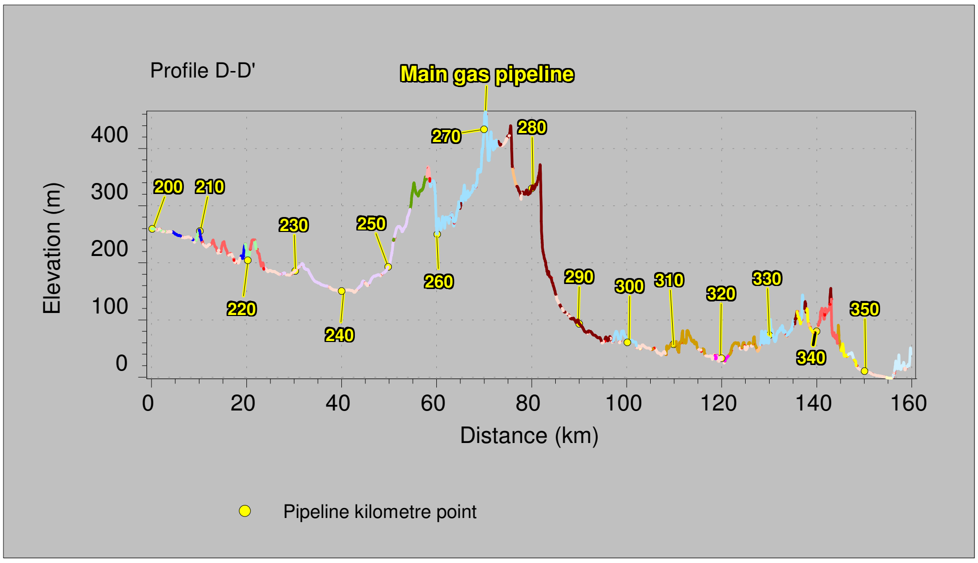

LEGEND GEOLOGY

CPg	Jp	RJs
CPs/v	Jr	Rs
CPv	Ku	Rv
Ctx	Kv	SDe
DCa	PRg	Ta
DCc	Ps	TQc
DCm	Ps/sc	Ts
Dv	Qa	Tv
Ji	Qmm	Unclassified
JKb	Rc	

A full description of geology is provided in Table 3.1.

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Figure 3.2b Study area geological cross sections - Map 2 of 2

Project No: 301001-00448 | Figure: 00448-00-EN-DAL-0407 | Rev: 0

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3.3 Geological structural features and faults

The Australia Pacific LNG gas pipeline corridor intersects or passes within close proximity to several identified faults, inferred faults (as indicated on mapping), folds and other geological structural features, which have been mapped by the Geological Survey of Queensland (GSQ). The geologic structural features and faults information were obtained from GSQ fault lines, that occur in close proximity to, or intersect the proposed Australia Pacific LNG gas transmission pipeline corridor, as well as other geological structural features have been mapped by the Geological Survey of Queensland and are illustrated on the 1:100,000 Series Geological Maps/Datasets series geological maps of Auburn (9046), Bajool (9050), Banana (8949), Biloela (9049), Bungaban (8946), Calliope (9149), Cracow (8947), Gladstone (9150), Rawbelle (9047), Scoria (9048) and Theodore (8948)), and on the 1:250,000 Series Geological Maps series geological maps of Chinchilla and Roma.

These structural features could potentially be zones of weakness in the upper crust that may be subject to differential movement during a significant seismic event in the region. The approximate locations of the major structural features and inferred faults that intersect or occur in the vicinity of the proposed pipeline are described in Table 3.2 below and illustrated in Figure 3.3. This figure also indicates recorded earthquakes since 1958.

Table 3.2 Major structure features and faults

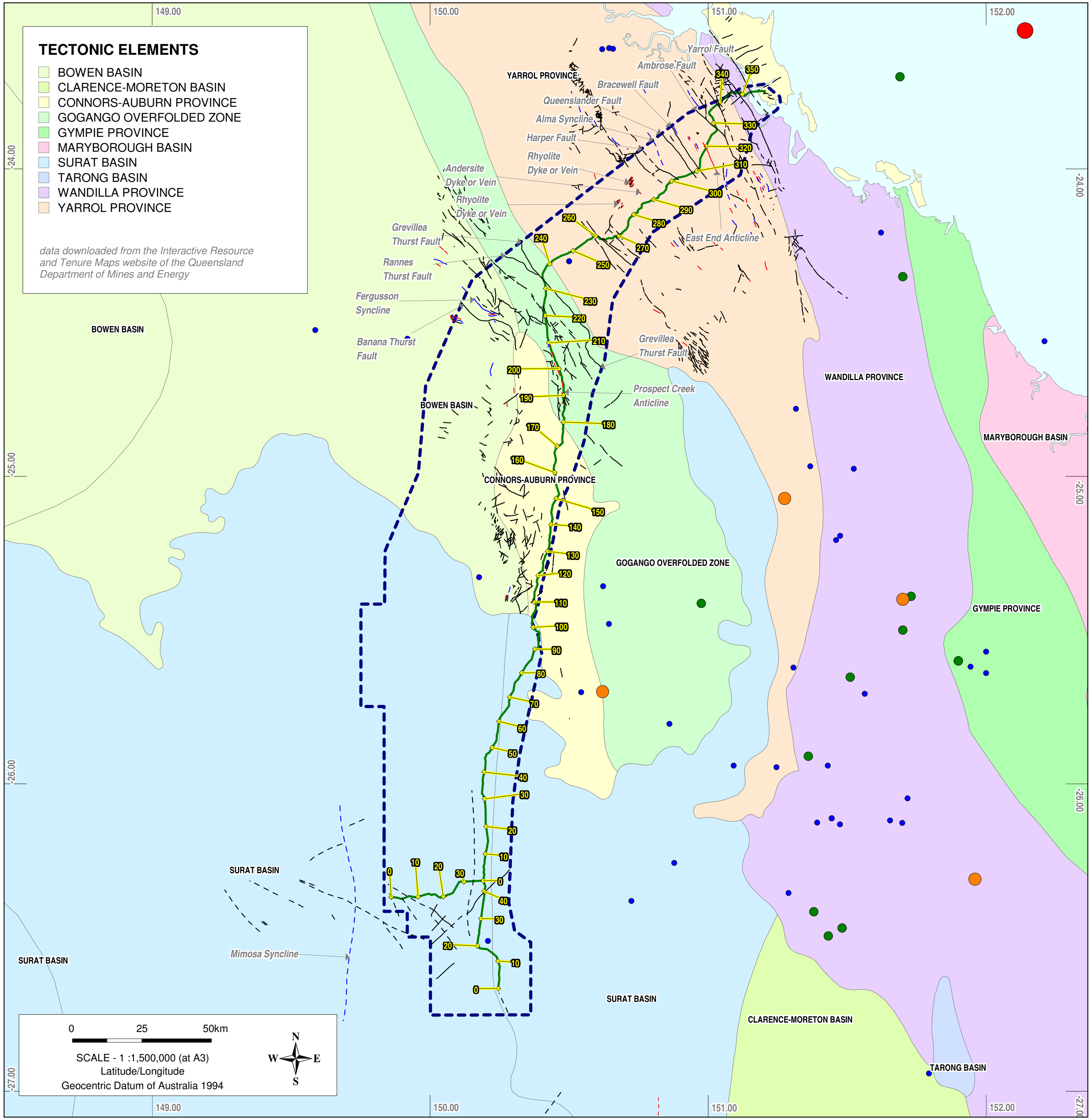
Feature	Description	Location
Mimosa Syncline	The north-south trending Mimosa Syncline is located approximately 10 km east of Jackson and extends north to Baralaba and south into northern New South Wales.	Vicinity of KP0
Inferred Fault	An east-west trending inferred fault extending along the Great Dividing Range, north west of Miles.	Vicinity of KP 6
Burunga Fault (Inferred)	An east-west trending inferred fault extending north to Wandoan and south to Miles.	Vicinity of KP33
Inferred Fault	North-east to south-west trending inferred fault and intersects the pipeline between Wandoan and Miles.	Vicinity of KP 40
Inferred Fault	North-east to south-west trending inferred fault extending along the Auburn Range, south east of Cracow.	Vicinity of KP 135
Inferred Fault	North-south trending inferred fault extending along the Auburn Range.	Vicinity of KP 130
Inferred Faults	North-east to south-west trending inferred faults extending along the north western side of the Auburn Range.	Vicinity of KP 111
Inferred Faults	North-south trending inferred faults extending along the western side of	Intersects KP 218

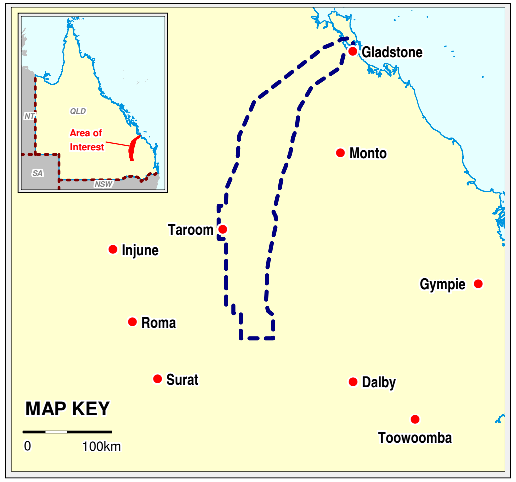
Feature	Description	Location
	Prospect Creek in the vicinity of Banana Range.	
Inferred Thrust Fault	North-south trending inferred thrust fault extending along the eastern side of Prospect Creek in the vicinity of Dawes Ranges. Direction of the fault dips typically towards the east.	Intersects KP220
Prospect Creek Anticline (Inferred)	North-south trending anticline extending along the Prospect Creek between Dawes and Banana Ranges.	Vicinity of KP 195
Prospect Creek Thrust Fault (Inferred)	North-south trending thrust fault extending along the east side of Prospect Creek between Dawes and Banana Ranges. Direction of the fault dips typically towards the east.	Intersect at KP 221
Drumberle Fault (Inferred)	North-west to south-east trending fault extending along the eastern side of the Prospect Creek.	Vicinity of KP 220
Mount Bertha Fault (Inferred)	North-west to south-east trending fault extending along the southeast of Mount Bertha.	Vicinity of KP 220
Barfield Fault (Inferred)	North-west to south-east trending fault extending along the Banana Range.	Vicinity of KP 220
Belmont Fault	North-west to south-east trending fault extending along the Banana Range.	Vicinity of KP 220
Fergusson Syncline	North-west to south-east trending syncline extending along the eastern side of the Banana Range.	Vicinity of KP 223
Banana Thrust Fault	North-west to south-east trending thrust fault extending along the western side of the Banana and Cooper Ranges. Direction of the fault dips typically towards the north-east.	Vicinity of KP 212
Rannes Thrust Fault (Inferred)	Typically north-west to south-east trending thrust fault extending along the Banana Range and north to Gogango and linking with Grevillia Thrust Fault to the south. Direction of the fault dips typically towards the north east.	Vicinity of KP 235
Grevillea Thrust Fault (Inferred)	Typically north-west to south-east trending thrust fault extending along the western	Intersects at KP 233

Feature	Description	Location
	side and parallel to Callide Creek. Direction of the fault dips typically towards the north east.	
Neville Creek Fault (Inferred)	North-east to south-west trending fault extending along Neville Creek, west of Biloela.	Vicinity of KP 233
Rainbow Creek Fault (Inferred)	North-west to south-east trending fault extending along the Callide Range, east of Biloela.	Vicinity of KP 259
Inferred Faults	Typically north-west to south-east trending inferred faults extending along the eastern side and parallel to Callide Range. Associated with the internal scarps within the Callide Range.	Vicinity of KP 263
Inferred Faults	Typically north-west to south-east trending inferred faults extending along the eastern side and parallel to Calliope Range. Associated with the internal scarps within the Calliope Range.	Vicinity of KP 290
Inferred Fault	North-west to south-east trending inferred fault extending along Alma Creek	Vicinity of KP294
Harper Fault (Inferred)	North-west to south-east trending fault extending along Harper Creek.	Vicinity of KP 302
Alma Syncline (Inferred)	North-South trending syncline extending north to Mount Bennett and south to Mount Alma.	Vicinity of KP 303
Queenslander Thrust Fault (Inferred)	North-west to south-east trending thrust fault extending along Kangaroo Creek and north to Bajool and south to Nagoorin. Direction of the fault dips typically towards the north east.	Vicinity of KP 308
Bracewell Thrust Fault (Inferred)	North-west to south-east trending thrust fault extending north to Bajool and south to Hazeldean, west of Calliope. Direction of the fault dips typically towards the north east.	Vicinity of KP 311
East End Anticline	North-west to south-east trending anticline extending along Larcom Creek and north to East End and south to the Dawson Highway near Calliope River.	Vicinity of KP 319
Ambrose Thrust Fault (Inferred)	North-west to south-east trending inferred	Vicinity of KP 328

Feature	Description	Location
	thrust fault extending north to Port Alma and south to Nagoorin. Direction of the fault dips typically towards the north east.	
Yarrol Fault (Inferred)	North-west to south-east trending Yarrol Fault located east of Mount Larcom Range and extending north to Yarwun and south to Lake Awoonga.	Vicinity of KP 346
Inferred Fault	North-south trending inferred fault extending parallel to the western shoreline of "The Narrows" channel in the vicinity of Friend Point, Kangaroo Island	Intercepts at KP 350
Inferred Faults	Typically east-west trending faults located on Curtis Island.	Vicinity of KP 359

The northern section gas pipeline corridor generally indicates a higher occurrence of major geologic structural features and faults typically in at the tectonic plate boundaries, within the Gogango Overfolded Zone and the eastern portion of the Yarrol Province. These structural features may potentially comprise zones of weakness in the upper crust that may be subject to differential movement during a significant seismic event in the region. Limited information is available regarding to the movement of the identified faults, however traditionally in Queensland, no active faults have been observed in recent times. In addition, as shown in the following figure, there have been only three earthquakes recorded in the study area since 1958, and all of these have been of a magnitude of 2.0 or less.





LEGEND

- Earthquake magnitude > 2
- Earthquake magnitude > 3
- Earthquake magnitude > 4
- Earthquake magnitude > 5
- Pipeline kilometre point
- Preferred pipeline alignment
- Faults accurate
- Faults approximate / concealed / inferred
- Anticlines accurate
- Anticlines approximate / concealed / inferred
- Synclines accurate
- Synclines approximate / concealed / inferred
- Dykes or veins
- Pipeline study area

Earthquake data courtesy of the U.S. Geological Survey

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Figure 3.3 - Historical earthquakes 1958 onwards and tectonic boundaries - Pipeline

Project No: 301001-00448 | Figure: 00448-00-EN-DAL-0400 | Rev: 0

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3.4 Location and quality of CSG resources

Information on the location and quality of CSG resources is discussed within the EIS, Volume 2, Chapter 5 – Geomorphology, geology soils and land contamination.

3.5 Extractive resources

The construction of the proposed Australia Pacific LNG gas pipeline 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 and rehabilitation (i.e rock armouring). Furthermore, a source of cement for concrete and bentonite for grouting is also likely to be required.

The quantities of extractive materials that would be required for the development of the proposed pipeline and other potential CSG related projects within the area have not been fully calculated; nor has the quality and type of materials required or the location where they will be required been determined. These calculations and factors are developed during FEED phases of a project and involve conceptualisation and feasibility of design.

As part of this assessment, a search for existing quarries around and within the study area was conducted and the results provided in Table 3.3. This search indicated that most existing quarries have a low production rate (generally <80,000tpa) and generally provide extractive materials exclusively to local councils and communities for road maintenance and upgrades and building construction. Although this assessment did not identify the material reserves associated with existing quarries, expansion of existing operations and new quarries may be required to meet demands of this and other CSG projects.

Table 3.3 Existing extractive resources sites within 200km of the study area

Quarry name	Operator	Status	Production rate(a)	Local authority (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 and gravel	Callide Creek 73.8 - 74.5km, 6km north-east of Biloela
Fairview Road	Moura Sand & Gravel Pty Ltd	Operating	med	BANANA	Hard rock	-
Kianga	Kianga Quarries Pty Ltd	Suspended	-	BANANA	Hard rock	20km south of Banana on Leichhardt Highway; 18km south=east of Moura
Yuleba	Yuleba Minerals Pty Ltd	Suspended	-	BENDEMERE	Sand and gravel	6km south of Yuleba on Yuleba-Surat Rd
Warrians	Boral Resources (Qld) Pty Ltd - Country	Operating	low	BUNGIL	Hard rock	35km up Roma - Taroom Rd
Boyne River	Blomfield Excavations	Operating	med	CALLIOPE	Sand and gravel	Boyne River (at upper limit of tidal reaches)
Boyneglade	Grahame Allen & Sons Pty Ltd	Suspended	-	CALLIOPE	Sand and gravel	1km west of intersection of Bruce H'way & Tannum Sands Rd
Calliope River (Bruce)	Blomfield Excavations	Operating	low	CALLIOPE	Sand and gravel	North bank of Calliope R. 3-4 km upstream of Bruce Highway

Quarry name	Operator	Status	Production rate(a)	Local authority (pre 2008 boundaries)	Operation type	Descriptive locality
H & R Quarry	H & R Quarrying Pty Ltd	Operating	med	CALLIOPE	Hard rock	Quarry Rd 1.5km west of Yarwun on property owned by DJ Hall PO Box 28 Yarwun
Hurcom	Rayment Excavations	Suspended	-	CALLIOPE	Hard rock	Hurcom Rd, Calliope
Tannum Sands	Grahame Allen & Sons Pty Ltd	Suspended	-	CALLIOPE	Sand	1km north on Tannum Sands Rd of Bruce Highway
Taragoola	Unimin Australia Limited	Operating	high	CALLIOPE	Hard rock	-
Yarwun (GPA)	Central Queensland Ports Authority	Operating	high	CALLIOPE	Hard rock	On Gladstone - Mt Larcom Rd
Blackswamp Pit	Chinchilla Shire Council	Operating	low	CHINCHILLA	Hard rock	cnr North Kogan/Warra Kogan Rds
Colls Pit	N & J Bobcat Hire	Operating	low	CHINCHILLA	Sand	Monmouth Bridge Rd (Redhill Rd) West Shire
Hunter Road pit	Neville Colls	Operating	low	CHINCHILLA	Sand	Hunter Road via Chinchilla, 'Monmouth Park'
Warra-Kogan	Chinchilla Shire Council	Operating	low	CHINCHILLA	Hard rock	Warra - Kogan Rd, Condamine South

Quarry name	Operator	Status	Production rate(a)	Local authority (pre 2008 boundaries)	Operation type	Descriptive locality
Bauhinia Downs	Park Equipment Pty Ltd	Suspended	low	DUARINGA	Hard rock	2km north of Bauhinia settlement
Bedford Weir	Whitsunday Crushers Pty Ltd	Operating	med	DUARINGA	Hard rock	23km north of Blackwater
Blackhill	Department of Main Roads	Suspended	low	DUARINGA	Hard rock	5km north-east of Bluff township
Mimosa Creek	Moura Sand & Gravel Pty Ltd	Operating	low	DUARINGA	Sand and gravel	Mimosa Creek 26.8 - 31.0km 25km north-west of Moura
Gales	Eidsvold Shire Council	Operating	low	EIDSVOLD	Hard rock	Kerwee Rd approx 40km north-west of Eidsvold
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	med	FITZROY	Hard rock	McEvoy Rd south-west of Gracemere
Moore	Fitzroy Shire Council	Suspended	-	FITZROY	Hard rock	Gracemere locality
Pink Lily Sands	Pink Lily Sands	Operating	med	FITZROY	Sand and gravel	Fitzroy River 68.8 to 70km, up stream of barrage at Pink Lilly Lagoon/Lotus Reserve

Quarry name	Operator	Status	Production rate(a)	Local authority (pre 2008 boundaries)	Operation type	Descriptive locality
Quarry at Midgee	Hopkins Bros	Operating	med	FITZROY	Hard rock	59793 Bruce Highway Midgee
Ridgelands Gravel Pit	Fitzroy Shire Council	Operating	low	FITZROY	Hard rock	1km down Nicholson Rd, 20km west of Rockhampton along Ridgelands Rd
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 Rd/Black Creek Rd
Hawkwood Rd	Eastern Stone & Minerals Pty Ltd	Suspended	-	MUNDUBBERA	Hard rock	3230 Hawkwood Road, 35km west of Mundubbera
Malu	Wagner Investments Pty Ltd	Operating	high	ROSALIE	Hard rock	Malu Siding off Warrego Highway, 4km west of Jondaryan
Noller's Pit	Rosalie Shire Council	Operating	low	ROSALIE	Hard rock	-
Peak Hill	Earth Commodities	Operating	low	ROCKHAMPTON	Hard rock	2km down Rocky -

Quarry name	Operator	Status	Production rate(a)	Local authority (pre 2008 boundaries)	Operation type	Descriptive locality
	Rockhampton					Yeppoon Rd from Bruce Highway
Juandah Creek	Richards Concrete	Suspended	-	TAROOM	Sand	Juandah Creek
Jimbour	Wambo Shire Council	Operating	high	WAMBO	Hard rock	About 20km along Dalby/Bell (Bunya Highway) road on left just after Jimbour Quarry Road T/O
Newton's	GCM Mining Pty Ltd	Operating	low	WAMBO	Hard rock	-
Cushnie	Wondai Shire Council	Operating	low	WONDAI	Hard rock	North-east of Boondooma Dam, west of Wondai approx. 10km

Note: Extractive industry information obtained for the Australia Pacific LNG gas fields from the Department of Mines and Energy, QRock database

Low production (<80,000tpa) Medium production (80,000 – 200,000tpa) High production (>200,000tpa)

4. Existing topography and geomorphology

Terrain characteristics of the study area have been assessed in terms of topography (surface form and slope) and geomorphology (landform).

4.1 Desktop topography review

Figure 4.1 illustrates study area terrain and slope (digital slope analysis). Figure 4.2 illustrates study area landform based on categories generated from the digital slope analysis (refer Figure 4.1) and landform descriptions provided in Table 5.1. These categories are as follows:

- Mountains and hills
- Dissected plateaus
- Plateaus
- Plateaus and low hills
- Low hills and rises
- Rises and undulating plains
- Level to gently undulating plains and low hills
- Level to gently undulating plains.

These figures indicate the study area is comprised of a variety of landforms ranging from level to gently undulating plains to mountains and hills (refer Figure 4.2), with slopes from flat to greater than 50% (refer Figure 4.1).

In terms of environmental impact, landforms classified as mountains and hills would be most affected during construction due to their steepness (earthworks in this terrain may result in permanent landform change). Other areas of concern include major waterways where crossings will be required, often through steep embankments.

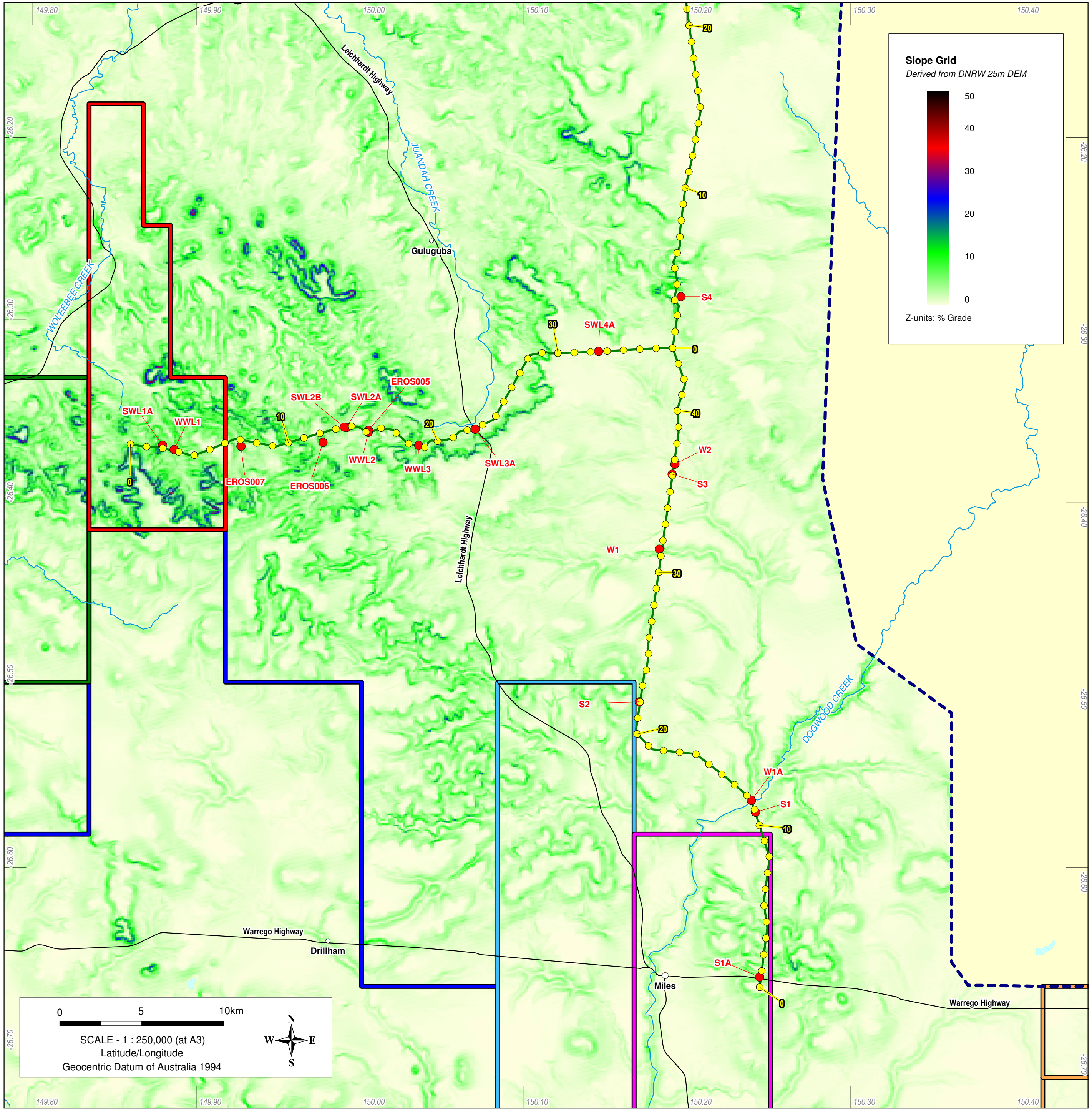
Landform categories are highlighted in Table 4.1 which outlines the generalised landform and slope within the study area in the context of the proposed pipeline route. As this table shows, the majority of the route traverses level to gently undulating plains and low hills with slopes less than 20%.

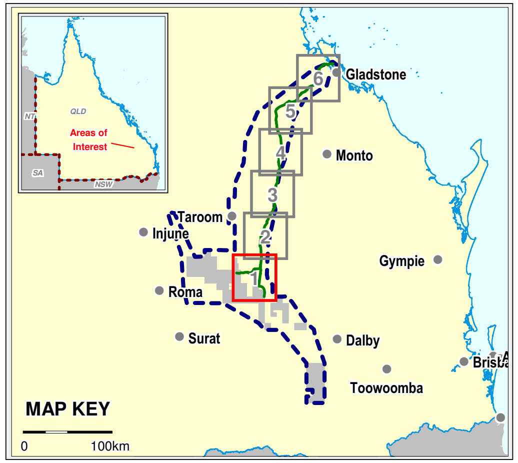
Table 4.1 Project area landform

Land tenement (refer Figure 1.1)	Land resource Project Area (refer Section 4)	Soil Grouping (refer Section 4.3)	Landform
Woleebee Lateral (KP 0-37)	Murilla and Chinchilla/Tara	1b 2b/2c/2d 5b(m)	Undulating plains on weathered, subhorizontal sandstone, plateaus and low sandstone hills to undulating plains and hills on flat lying Mesozoic sandstone. Lateritic scarps are also common. Landform is classified ranging from level to gently undulating plains and rises and plateaus and low hills. Slopes greater than 20% occur; however, the pipeline mainly traverses slopes less than 15%.
Condabri Lateral (KP 0-44)	Murilla and Chinchilla/Tara Dawson-Fitzroy: (northern section only)	1b 2b 5b(m)	Plateaus and low sandstone hills to undulating plains and lateritic scarps occur in this portion of the pipeline. Landform varies from level to gently undulating plains and rises and low hills. Slopes range from 0% to 10%. The pipeline traverses Dogwood Creek at approximately KP 12. Slopes less than 5% occur in this area.
Transmission pipeline (approximately KP0 to 62)	Murilla and Chinchilla/Tara Dawson-Fitzroy	1b 2c/2b/2d 4b 5b 5b(m)	Hills and dissected tablelands on flat-lying Jurassic rocks predominate along this portion of the pipeline. Low sandstone hills to undulating plains and lateritic scarps occur in the southern portion. Landform is classified as level to gently undulating plains with slopes generally up to 15%. Some isolated slopes (mainly scarps) of greater than 20% occur. The pipeline traverses Bungaban Creek at approximately KP 44.5.
Transmission pipeline (approximately KP62 to 89)	Dawson Fitzroy	4b 5b	Hills and dissected tablelands on flat-lying Jurassic shale and sandstone, as well as low hills and undulating plains on subhorizonal Mesozoic shale and sandstone, occur on this portion of the pipeline. Here, landform is classified as rises and undulating plains with slopes ranging from 0% to 15%. The pipeline traverses Cockatoo Creek at approximately KP 69.
Transmission pipeline (approximately KP89 to 134)	Dawson Fitzroy	1b/1c 2b/2c/2d 5b	Dissected tablelands of flat-lying Mesozoic sandstone with strongly undulating plains with low hills occur along this portion, classified as dissected plateaus with slopes from 0% to 15%.

Land tenement (refer Figure 1.1)	Land resource Project Area (refer Section 4)	Soil Grouping (refer Section 4.3)	Landform
Transmission pipeline (approximately KP134 to 165)	Dawson Fitzroy	1c 2c/2d 5b	Diverse landforms are encountered here, ranging from level to gently undulating plains with rises, plateaus and low hills and dissected plateaus. Slopes range from 0% to 15%.
Transmission pipeline (approximately KP165 to 225)	Dawson Fitzroy	2c 5b	Characterised by strongly undulating plains with low hills, this landform has been classified as dissected plateaus with slopes up to 10%. The proposed pipeline would traverse Castle Creek at approximately KP 182.
Transmission pipeline (approximately KP225 to 248)	Dawson Fitzroy	1b 2a/2b/2c 3a 4a/4b 5a/5b/5c	Landform in this portion of the pipeline consists of level to gently undulating plains and rises with slopes of 0% to 10%. This portion is mainly near flat plains. The proposed pipeline would traverse the Callide No4 Anabranch at approximately KP 243 and Kroombit Creek at approximately KP 239.
Transmission pipeline (approximately KP248 to 281)	Dawson Fitzroy	1c 2c	Terrain along this portion of the pipeline is mainly comprised of hills on dipping Upper Palaeozoic volcanics. The landform is mainly classified as plateaus and low hills. However, mountains and hills occur from approximately KP 256 to 258 and dissected plateaus occur at approximately KP 258 to 272. This area ranges in slope with the steepest slopes (>50%) occurring at the plateaus and low hills. Through this area the pipeline follows valleys with slopes generally less than 10%. The proposed pipeline would traverse Bell Creek at approximately KP 278.
Transmission pipeline (approximately KP281 to 285)	Capricornia Coast	1c	Steep to rolling hills and escarpments with slopes up to 50%. The landform is classified as mountains and hills.
Transmission pipeline (approximately KP285	Capricornia Coast	2a/2b/2c	This portion of the pipeline mainly traverses gently undulating rises and plains on granitic rocks. Here the landform is classified as rises and undulating plains with gentle slopes ranging from 0-10%. At

Land tenement (refer Figure 1.1)	Land resource Project Area (refer Section 4)	Soil Grouping (refer Section 4.3)	Landform
to 308)			approximately KP 295 the pipeline crosses the Calliope River where the terrain generally consists of broad level alluvial plains.
Transmission pipeline (approximately KP308 to 313)	Capricornia Coast	1c 4c	This portion of the pipeline traverses through rolling steep hills on acid and intermediate volcanic rocks and steeply dipping sedimentary rocks. The landform is classified as mountains and hills with slopes up to 40%. The pipeline traverses level to gently undulating plains and low hills between most high slope areas; however, at approximately KP 312, slope greater than 20% occurs.
Transmission pipeline (approximately KP313 to 337)	Capricornia Coast	1b/1c 2a/2c 3c 4c	The terrain in the southern portion of this pipeline section is described as undulating to rolling low hills and rises on sedimentary rocks and greenstone. The landform here is classified as low hills and rises. In the central portion (approximately KP 316 to 321), the terrain is broad and level alluvial plains with landform classified as level to gently undulating plains. The northern portion (approximately KP 321 to 337) changes to undulating to rolling low hills and fans on fine grained sedimentary rocks and unconsolidated sediments, and landform rises and undulating plains. Along this section, slopes can reach 40%; however, the pipeline traverses slopes mostly between 0% and 10%.
Transmission pipeline (approximately KP336 to 348)	Capricornia Coast	1c 2a 3c 4c	Terrain is described as rolling to steep hills on acid and intermediate volcanic rocks and steeply dipping sedimentary rocks. The landform is classified as mountains and hills with slopes up to 40%. The pipeline generally traverses level to gently undulating plains and low hills between high slope areas.
Transmission pipeline (approximately KP348 to 350)	Capricornia Coast	2a/2c 3a 6	Terrain is described as gently undulating rises and plains on sedimentary rocks, alluvial fans and lower colluvial slopes of the lower coastal hills and marine plains with extensive bare tidal flats. Landform is classified as rises and undulating plains transitioning to level to gently undulating plains and low hills to level to gently undulating plains. Slopes are generally less than 10%.





LEGEND

- Observation Locations
- Towns
- Road
- Preferred pipeline alignment
- Major Drainage
- Reservoir
- Study Area

Walloons Gas Fields Development Areas

- Combabula / Ramyard
- Woleebee
- Carinya
- Condabri
- Talinga / Orana
- Dalwogan
- Kainama
- Gilbert Gully

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Figure 4.1a Study Area Digital Slope Analysis
Map 1 of 6

Project No: 301001-00448 | Figure: 00448-00-EN-DAL-0294 | Rev: 0

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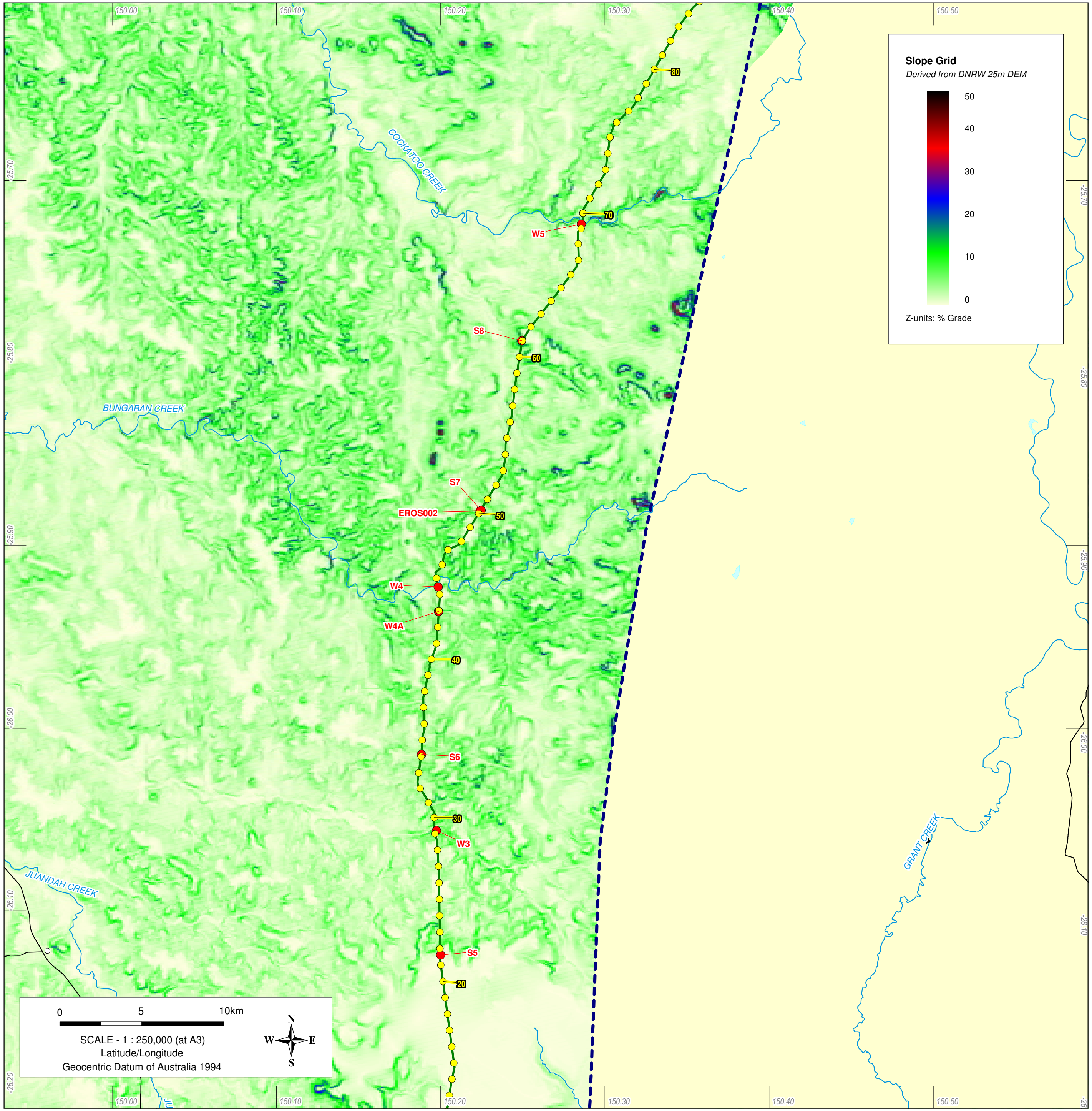

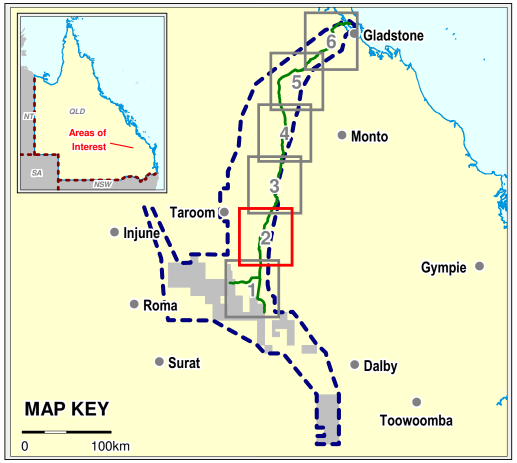

LEGEND

- Observation Locations
- Towns
- Road
- Preferred pipeline alignment
- Major Drainage
- Reservoir
- Study Area

Walloons Gas Fields Development Areas

- Combabula / Ramyard
- Woleebee
- Carinya
- Condabri
- Talinga / Orana
- Dalwogan
- Kainama
- Gilbert Gully

Rev	Date	Revision Description	ORIG	CHK	ENG	APPD
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Figure 4.1b Study Area Digital Slope Analysis
Map 2 of 6

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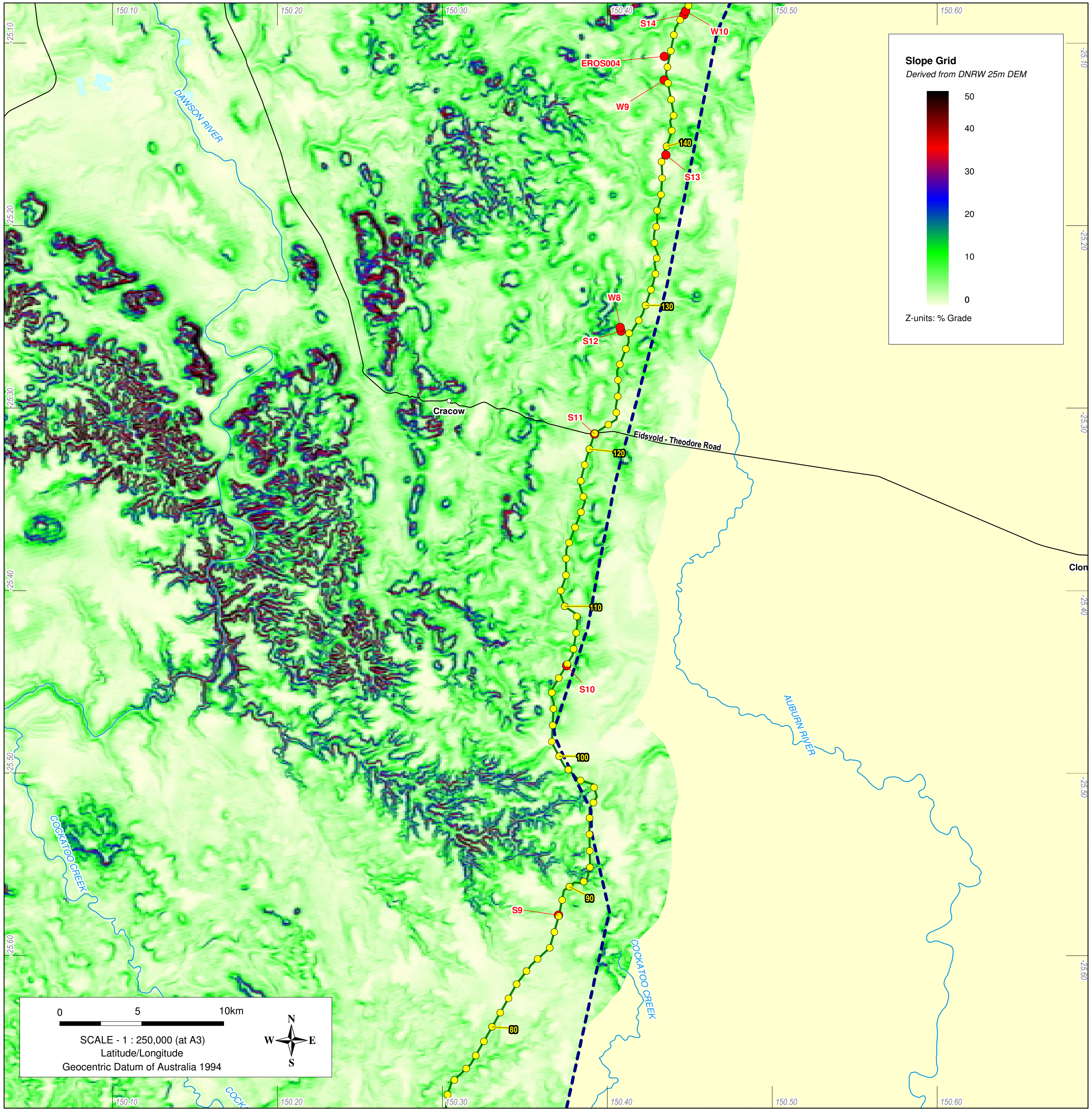

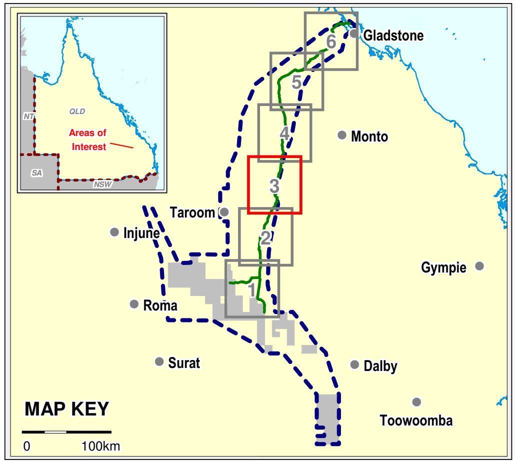

LEGEND

- Observation Locations
- Towns
- Road
- Preferred pipeline alignment
- Major Drainage
- Reservoir
- Study Area

Walloons Gas Fields Development Areas

- Combabula / Ramyard
- Woleebee
- Carinya
- Condabri
- Talinga / Orana
- Dalwogan
- Kainama
- Gilbert Gully

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AUSTRALIA PACIFIC LNG PROJECT
Figure 4.1c Study Area Digital Slope Analysis
Map 3 of 6

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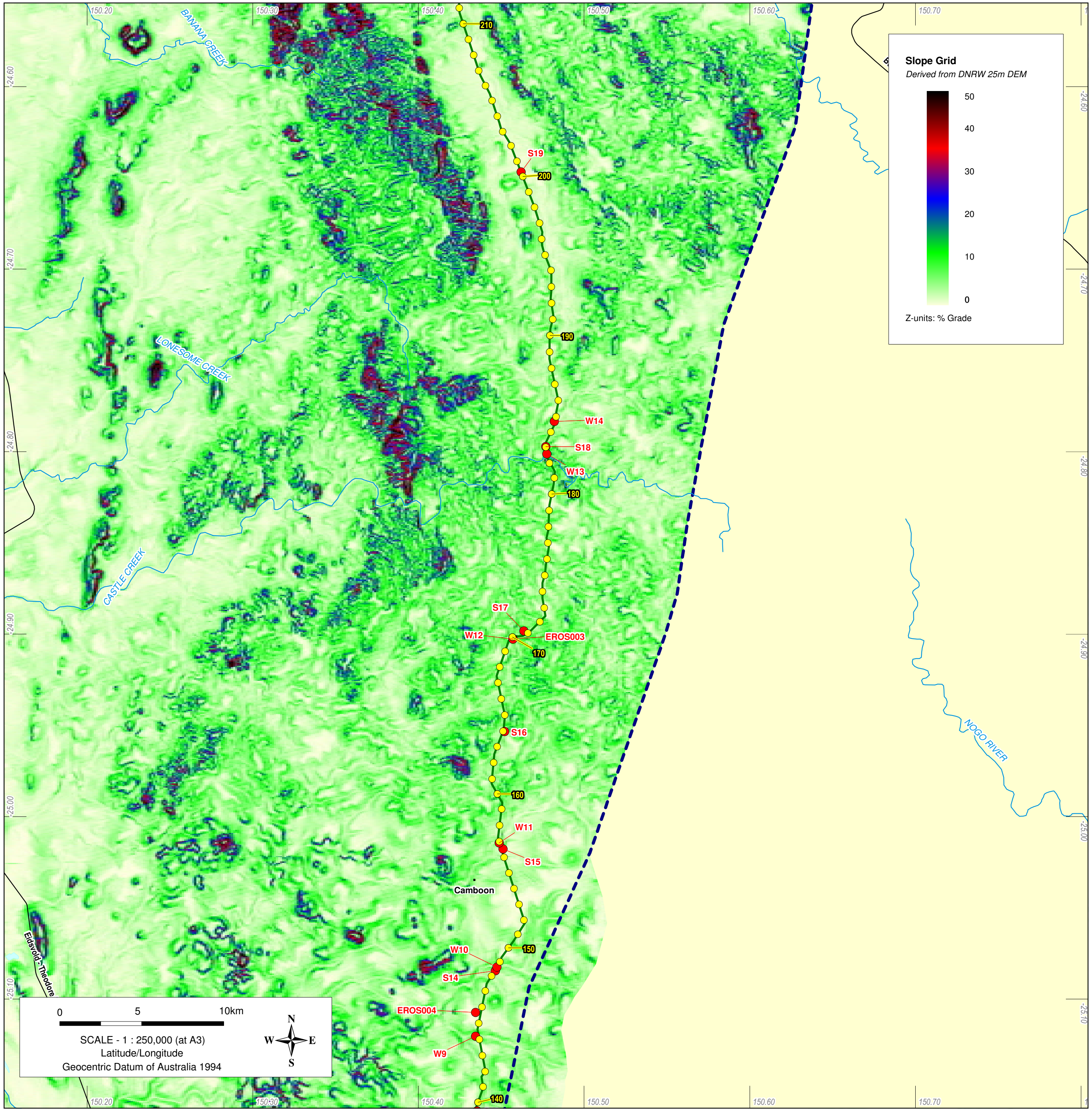

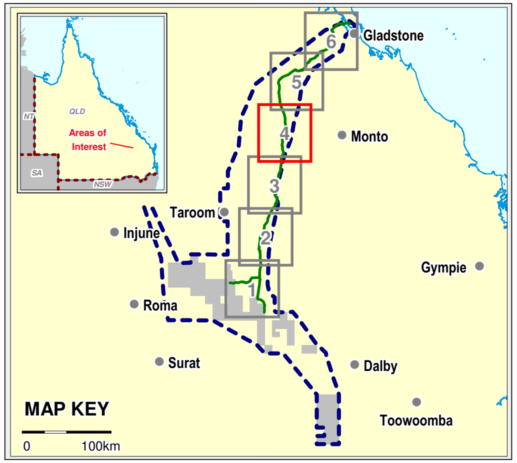

LEGEND

- Observation Locations
- Towns
- Road
- Preferred pipeline alignment
- Major Drainage
- Reservoir
- Study Area

Walloons Gas Fields Development Areas

- Combabula / Ramyard
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Figure 4.1d Study Area Digital Slope Analysis
Map 4 of 6

Project No: 301001-00448 | Figure: 00448-00-EN-DAL-0297 | Rev: 0

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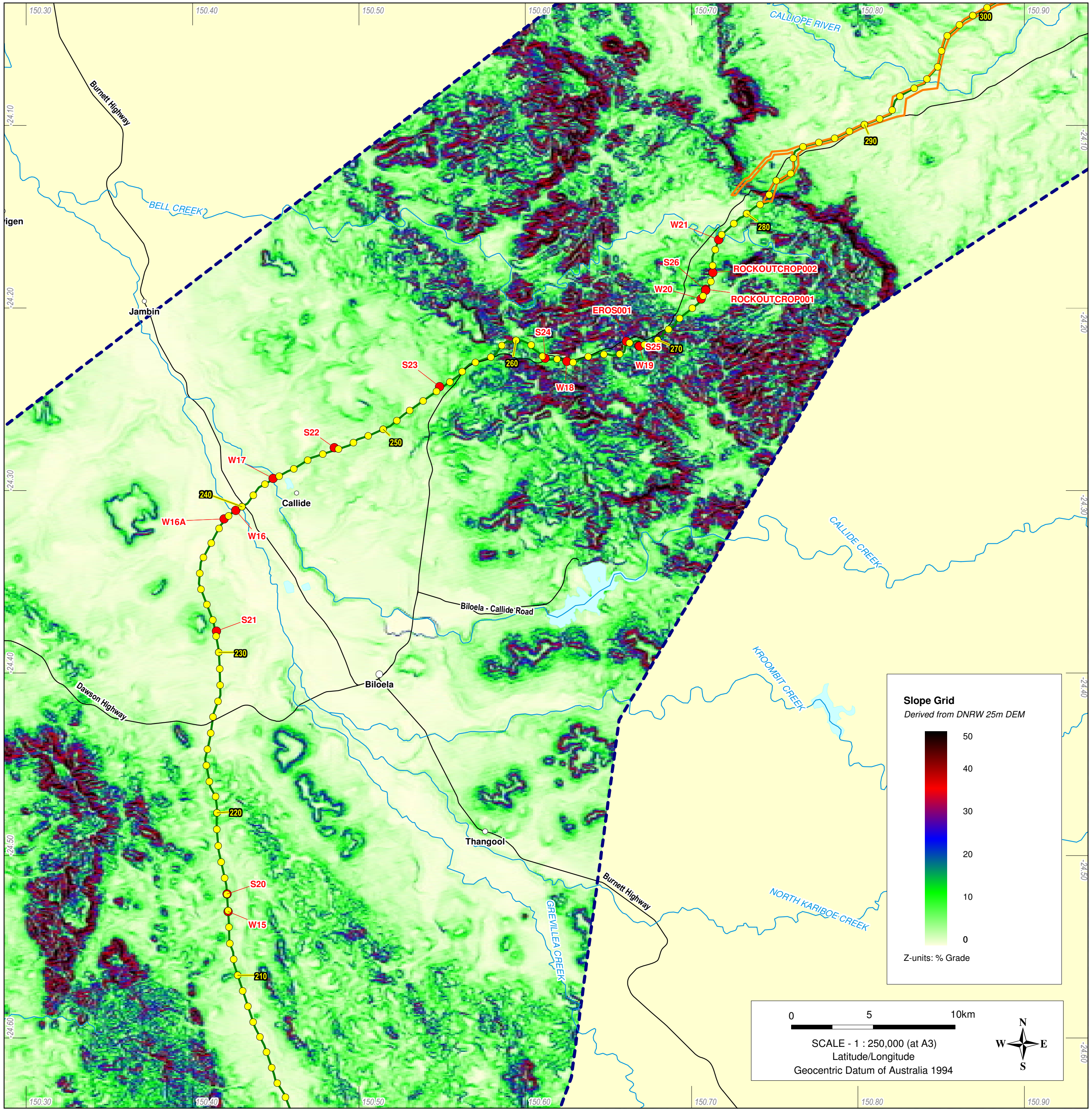

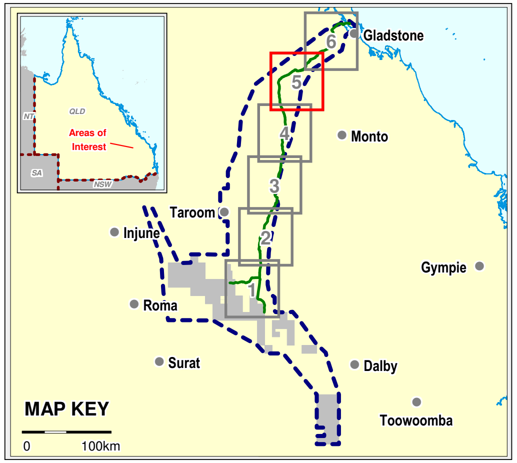

LEGEND

- Observation Locations
- Towns
- Road
- Preferred pipeline alignment
- Major Drainage
- Reservoir
- Study Area

Walloons Gas Fields Development Areas

- Combabula / Ramyard
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- Condabri
- Talinga / Orana
- Dalwogan
- Kainama
- Gilbert Gully

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Figure 4.1e Study Area Digital Slope Analysis
Map 5 of 6

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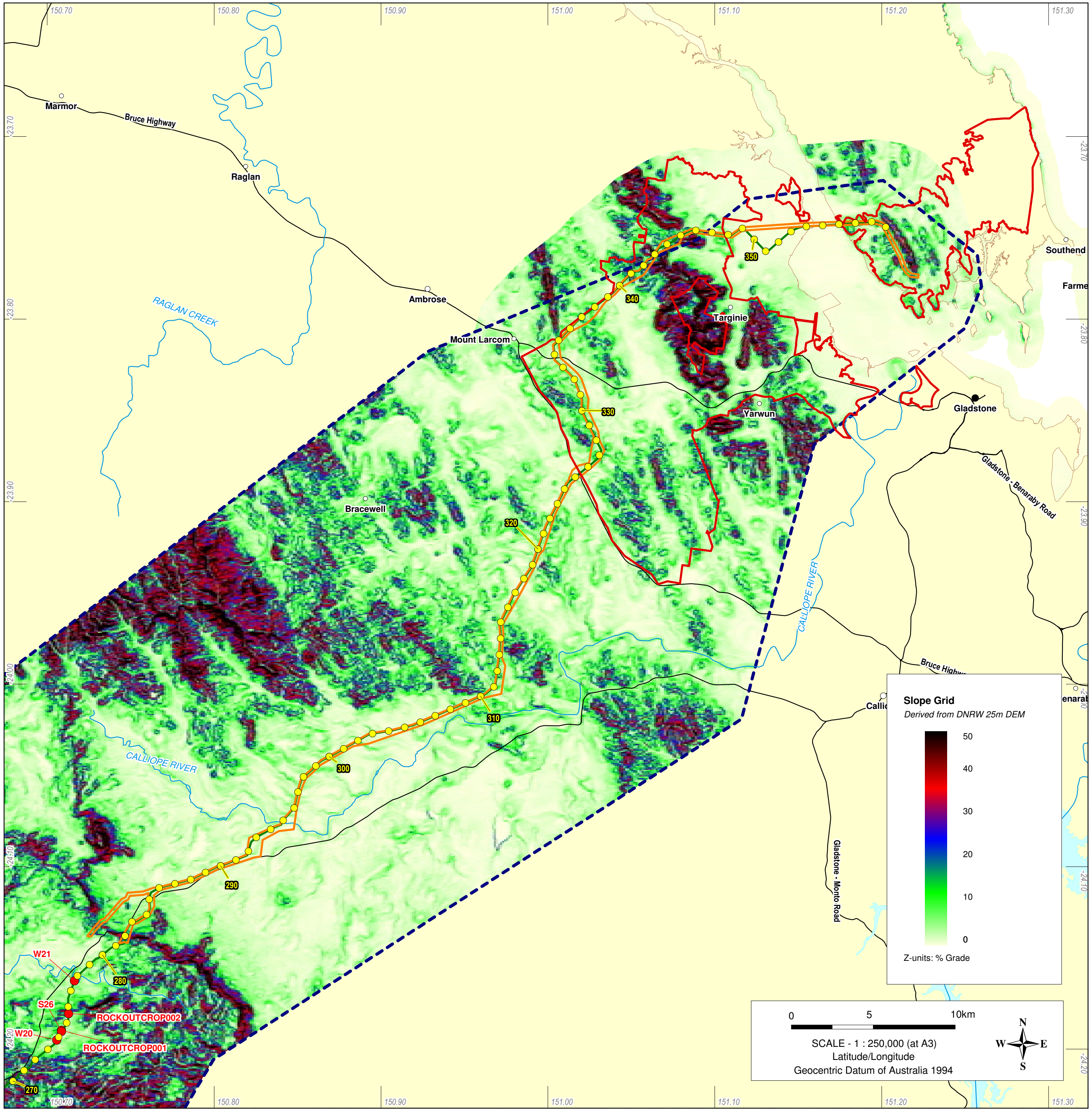

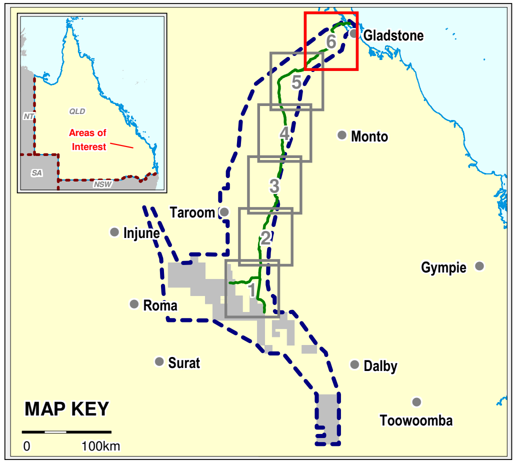

LEGEND

- Observation Locations
- Towns
- Road
- Preferred pipeline alignment
- Major Drainage
- Reservoir
- Study Area

Walloons Gas Fields Development Areas

- Combabula / Ramyard
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- Condabri
- Talinga / Orana
- Dalwogan
- Kainama
- Gilbert Gully

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Figure 4.1f Study Area Digital Slope Analysis
Map 6 of 6

Project No: 301001-00448 | Figure: 00448-00-EN-DAL-0299 | Rev: 0

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4.2 Field topography assessment

This section describes topography and landform according to observations made during the fieldwork assessment undertaken from 21 to 29 October 2009. Terrain assessments were made in conjunction with the soils investigation (refer Section 4.3) at 57 locations observed within the study area. At each location, topography was classified in relation to the specific location, terrain and slope. Terrain was classified using the following descriptions:

1. Low: The terrain is flat to gently undulating with slopes generally less than 10%. The unit generally has broadly spaced, mostly shallow incised drainage channels or gullies.
2. Medium: The terrain is dissected land with local relief up to about 50m between crests and adjacent valleys, with surface slopes typically in the range of 11% to 32%.
3. High: The terrain is dissected and/or hilly lands with local relief in the range 50m to over 150m between ridge and spur crests and adjacent valley or gully floors, with steep valley side slopes up to 32% or greater.

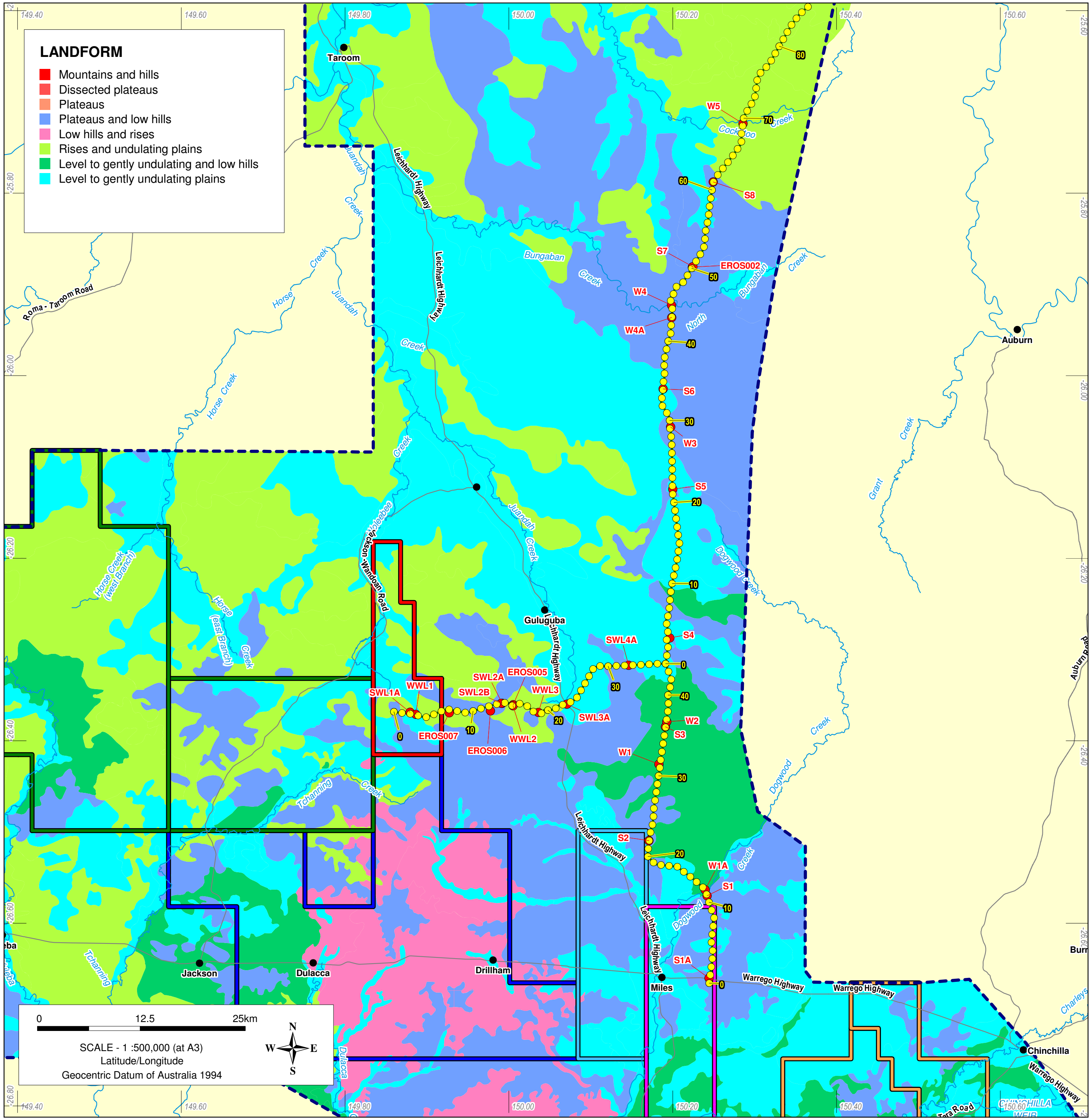
The predominant slope was classified as follows:

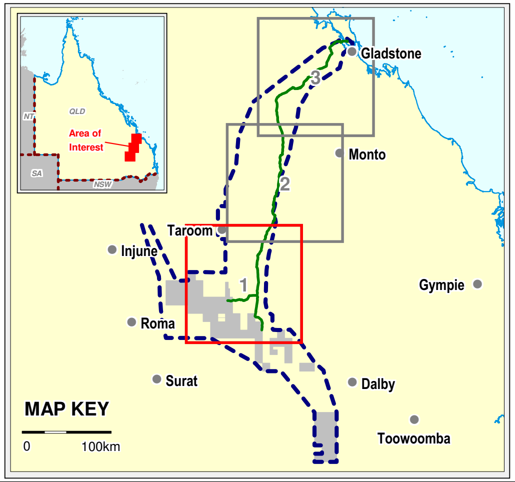
- Flat <2 %
- Gentle 2-5%
- Low slope 5-10%
- Moderate slope 10-25%
- Steep slope >25%
- Very steep >50%.

Table 4.2 describes the terrain and predominant slope classifications as noted during fieldwork at each borehole location.

Table 4.2 Field terrain and slope analysis

Location	Terrain	Predominant slope
S1, S2, S3, S4, S19, S21, S22, S23, SWL3a, SWL4a, WWL2	1	1
S7, S16, S20, S26, SWL2a, SWL2b, W1, W3, W4a, W8, W9, W11, W14, W15, W16, W17, W20	1	2
S9, S10, S11, S13, S15, W1a, W2, W4, W10, W12, W21, WWL3	1	3
S1a	2	3
S5, S6, S8, S12, S14, S17, S18, S25, SWL1a, W5, W13, W18, W19, WWL1	2	4
S24	3	4





LEGEND

- Observation location
- Pipeline kilometre point
- Town
- Road
- Gas pipeline route
- Major drainage
- Study area

Walloons Gas Fields Development Areas

- Combabula / Ramyard
- Woleebee
- Carinya
- Condabri
- Talinga / Orana
- Dalwogan
- Kainama
- Gilbert Gully

Landforms combined and interpreted from Department of Natural Resources Area maps by WorleyParsons December 2009.

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Figure 4.2a Study area landform
Map 1 of 3

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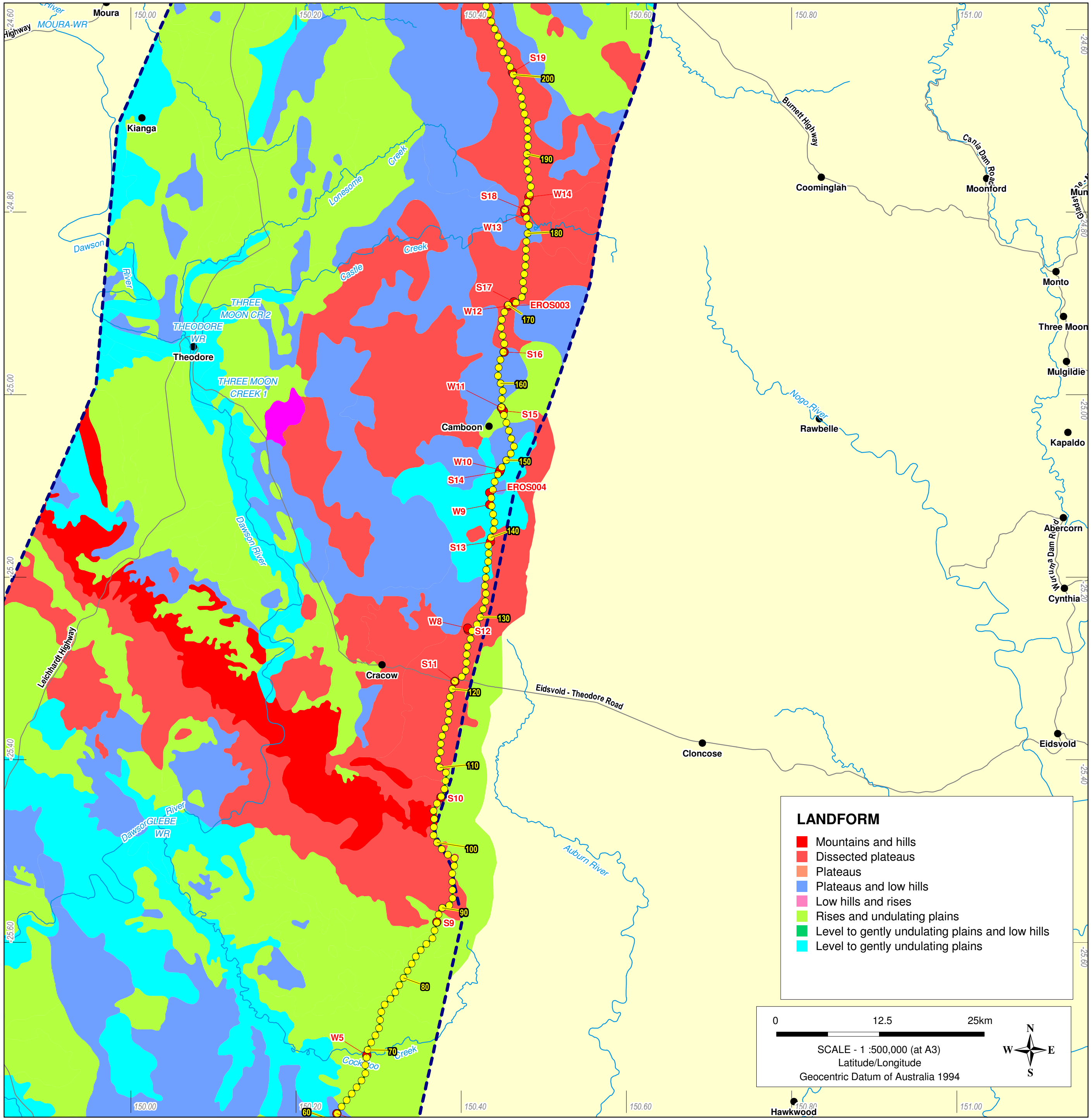

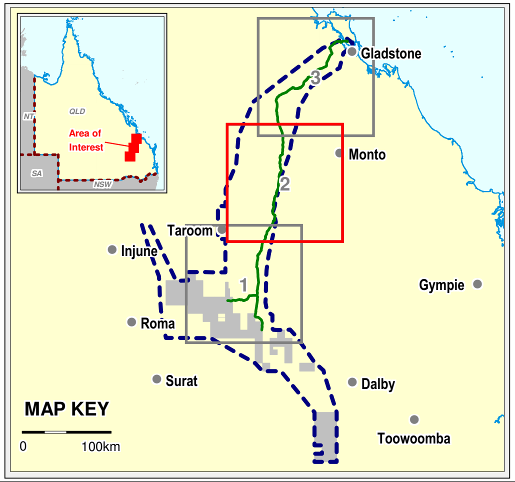

LEGEND

- Observation location
- Pipeline kilometre point
- Town
- Road
- Gas pipeline route
- Major drainage
- Study area

Walloons Gas Fields Development Areas

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Landforms combined and interpreted from Department of Natural Resources Area maps by WorleyParsons December 2009.

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Figure 4.2b Study area landform
Map 2 of 3

Project No: 301001-00448 | Figure: 00448-00-EN-DAL-0320 | Rev: 0

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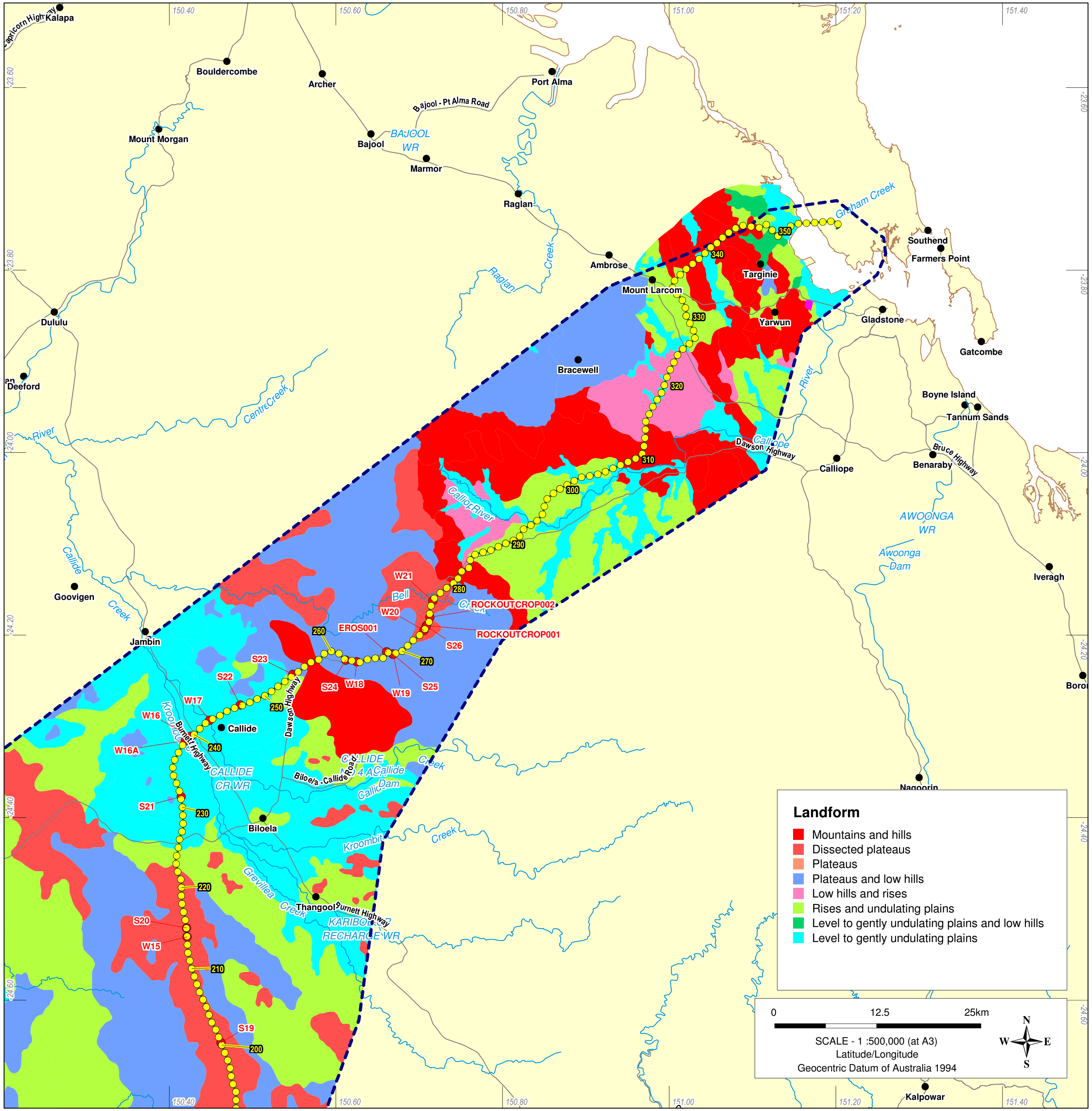

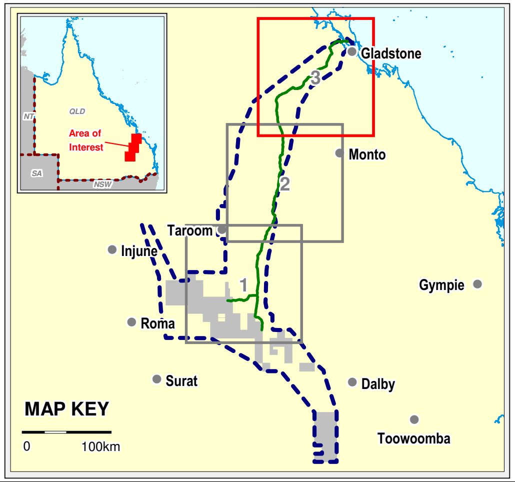

MAP KEY

0 100km

LEGEND

- Observation location
- Pipeline kilometre point
- Town
- Road
- Gas pipeline route
- Major drainage
- Study area

Walloons Gas Fields Development Areas

- Combabula / Ramyard
- Woleebee
- Carinya
- Condabri
- Talinga / Orana
- Dalwogan
- Kainama
- Gilbert Gully

Landforms combined and interpreted from Department of Natural Resources Area maps by WorleyParsons December 2009.

Landform

- Mountains and hills
- Dissected plateaus
- Plateaus
- Plateaus and low hills
- Low hills and rises
- Rises and undulating plains
- Level to gently undulating plains and low hills
- Level to gently undulating plains

0 12.5 25km

SCALE - 1 :500,000 (at A3)
Latitude/Longitude
Geocentric Datum of Australia 1994

N W E S

0	20/01/2010	Issued for use	JB	MZ		
Rev	Date	Revision Description	ORIG	CHK	ENG	APPD

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Figure 4.2c Study area landform
Map 3 of 3

Project No: 301001-00448 | Figure: 00448-00-EN-DAL-0321 | Rev: 0

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4.3 Waterway crossings

Several waterway crossings were observed during the fieldwork component (21 to 29 October 2009) of this assessment (refer Figure 1.1). Specific waterway crossings were selected for field investigation based on their stream flow (that is, having a stream order classification of 3 or greater - refer EIS Volume 3, Chapter 11 – Surface water and watercourses) with the exception of WWL1, SWL2b and WWL3. At each location, the following observations were recorded:

- Erosion
- Terrain class
- Predominant slope
- Bank stability
- Vegetation
- Stream width (high flow channel) and height
- Bank slope (refer Table 1b, Appendix B).

A sample of the bed substrate was also collected to assess particle size distribution to provide the basis for scour potential (refer to EIS Volume 3, Chapter 11 – Surface water and watercourses). Note that width, height and slope measurements are only approximate and should not be used for engineering purposes. In addition, an erosion risk and excavation rating was determined for each location, based on the assessments detailed in sections 5.2.5 and 6.1.1 respectively.

Photographs were also collected at each location. These, along with a brief description of the observation, are provided in Table 1b, Appendix B. Table 4.3 provides a list of waterways inspected along with the respective stream order, erosion risk and excavation rating.

Table 4.3 Waterway observations

Mapped soil group	Location	Stream order	Existing erosion (refer Section 5.2.4)	Erosion risk (refer Section 5.2.5)	Excavation rating (refer Section 6.1.1)
2b	WWL1 (KP 3 – Woleebee Lateral) [unknown creek]	<3	1	4	1
2d	SWL2b (KP 14 - Woleebee Lateral) [unknown creek]	<3	2	2	2
2b	WWL2 (KP 15 – Woleebee Lateral) [Juandah Creek]	3	2	4	1
2b	WWL3 (KP 19 – Woleebee Lateral) [unknown creek]	<3	3	4	1-2
2b	W1a (KP12 – Condabri Lateral) [Dogwood	3	2	4	2

Mapped soil group	Location	Stream order	Existing erosion (refer Section 5.2.4)	Erosion risk (refer Section 5.2.5)	Excavation rating (refer Section 6.1.1)
	Creek]				
2b	W1 (KP 31 – Condabri Lateral) [L Tree Creek]	4	2	4	2
2b	W2 (KP 37 – Condabri Lateral) [Bottle Tree Creek]	3	1	4	2
2c	W3 (KP 29 – Main pipeline) [Roche Creek]	4	1	4	2
2c	W4 (KP 44 – Main pipeline) [Bungaban Creek]	4	1	4	2
2c	W4a (KP43 – Main pipeline) [Bottle Tree Creek]	3	1	4	2
4b/5b	Not assessed (KP65 – Main pipeline) [Kennedy Creek]	3	Not assessed	2	Not assessed
5b	W5 (KP 60 – Main pipeline) [Cockatoo Creek]	4	1	1	2
2c	W8 (KP 128 – Main pipeline) [Cracow Creek]	3	2	4	3-4
2c	W9 (KP 144 – Main pipeline) [Horse Creek]	3	2	4	3-4
2c	W10 (KP 149 – Main pipeline) [Delusion Creek]	3	1	4	3-4
2c	W11 (KP 157 – Main pipeline) [Oxtrack Creek]	3	2	4	3-4
2c	W12 (KP 170 – Main pipeline) [South Creek]	3	3	4	3-4
2c	Not assessed (KP176 – Main pipeline) [Keen Creek]	3	Not assessed	4	Not assessed
2c	W13 (KP 183 – Main	4	1	4	4

Mapped soil group	Location	Stream order	Existing erosion (refer Section 5.2.4)	Erosion risk (refer Section 5.2.5)	Excavation rating (refer Section 6.1.1)
	pipeline) [Pump Creek]				
5b	W14 (KP 185 – Main pipeline) [Twenty Mile Creek]	3	1	1	4
2c/5b	Not assessed (KP200 - Main Pipeline) [Prospect Creek Tributary]	3	Not assessed	4 / 1	Not assessed
5b	W15 (KP 214 – Main pipeline) [Prairie Creek]	3	2	1	1-2
2a	W16a (KP 239 – Main pipeline) [unknown creek]	4	1	2	2
2a	W16 (KP 240 – Main pipeline) [Kroombit Creek]	4	1	2	2
2a	W17 (KP 243 – Main pipeline) [Callide Creek]	4	1	2	2-3
1c	W18 (KP 264 – Main pipeline) [unknown creek]	3	1	2	3-4
1c	W19 (KP 269 – Main pipeline) [unknown creek]	3	1	2	3
2c	W20 (KP 274 – Main pipeline) [unknown creek]	3	1	4	2-3
2c	W21 (KP 278 – Main pipeline) [Bell Creek]	4	1	4	3-4
2a	Not assessed (KP295 - Main Pipeline) [Calliope Creek]	4	Not assessed	2	Not assessed
2a	Not assessed (KP303 - Main Pipeline) [Harper Creek]	3	Not assessed	2	Not assessed
2c	Not assessed (KP320 –	4	Not assessed	4	Not assessed

Mapped soil group	Location	Stream order	Existing erosion (refer Section 5.2.4)	Erosion risk (refer Section 5.2.5)	Excavation rating (refer Section 6.1.1)
	Main pipeline) [Larcom Creek]				
2c	Not assessed (KP327 – Main pipeline) [Larcom Creek]	3	Not assessed	4	Not assessed

Of the 26 waterway crossings inspected, 10 were observed to have medium to high existing erosion (in the form of gully and bank incision). However, based on the overall erosion classification discussed in Section 5.2.5, 19 of these observed waterways occur in soil with an erosion rating of 4 (very high) [mainly soil group 2b and 2c]. Observed locations where erosion was minor or absent were characterised by well established riparian vegetation or rock outcrops which limit erosion.

These erosion observations were confirmed within the report on surface water and watercourses (refer EIS, Volume 3, Chapter 11) which indicated that most creek beds encountered during the field investigation, with the exception of Dogwood Creek (refer W1a), are prone to scour during flood events. Most significant streams pass through alluvium, with predominantly texture contrast soils and deep but sodic (and significantly dispersive) subsoil (refer Section 5.2.3). Such soils, where adjacent to or in proximity to the stream channel, are prone to stream bank erosion with localised gully and tunnel erosion.

As a result, for each significant watercourse, detailed scour assessments will be required to determine the appropriate depth of cover or scour protection measures to be adopted at each crossing (refer Section 7.2).

5. Existing soils

5.1 Soil desktop assessment

5.1.1 Soil types and occurrence

The study area occurs across three land system mapping areas (as mapped in DPI, DNR CSIRO and DNRM reports). Table 5.1 presents a summary of the land systems present within the pipeline study area. This table indicates the associated landform character, most common soil types and typical native vegetation characteristics (where intact). It also indicates the GQAL classification for each of these land systems, which is further assessed in Section 5.3 and within the Land use chapter of the EIS (Chapter 6).

Table 5.1 Study area land systems

Map code	Land system	Landform	Geology	Soils*	Vegetation	GQAL classification (based on SPP1/92 guidelines)
Land systems – Dawson - Fitzroy Area, Queensland Australia, 1: 500,000, CSIRO						
D	Dakenba (Brigalow Scrub)	Undulating to nearly flat, mainly depositional plains with periodically flooded lower parts	Depositional plains	Deep cracking clays (5a)	Brigalow scrub; scrub grass	A
Hm	Hillmore (Mountains)	Hills on dipping Upper Palaeozoic volcanics	Upper Palaeozoic volcanics	Very shallow undifferentiated soils (1c)	Shrub woodlands; eastern mid-height grass	
K	Kiddell	Undulating plains with extensive depositional lower slopes	-	Cracking clays, and dark brown and grey-brown clays (5b/4b)	Brigalow scrub with scrub grass and blue grass grasslands	
Km	Kroombit (Alluvial Plains)	Mainly stable plains with relatively broad leaves	-	Deep texture-contrast and alluvial soils (2a)	Tall grassy woodland and grassy woodlands; frontage grass	
Ci	Conloi	Undulating plains on weathered, subhorizontal sandstone	Sandstone	Shallow to moderately deep texture-contrast soils (2b)	High forests and grassy woodlands, forest grass and eastern mid-height grass	B
E	Eurombah	Undulating plains, mainly on Mesozoic shale, locally capped with Tertiary basalt	Mesozoic shale, locally capped with Tertiary basalt	Moderately deep to deep cracking clays, and dark brown and grey-brown clays (5b/4b)	Softwood and brigalow scrubs	

Map code	Land system	Landform	Geology	Soils*	Vegetation	GQAL classification (based on SPP1/92 guidelines)
H	Highworth (Brigalow Scrub)	Undulating to nearly flat plains with extensive depositional slopes	-	Cracking clays; commonly gilgaied, and texture-contrast soils (2c/5b and 5b[m])	Brigalow scrub, scrub grass	
Mf	Malakoff (Softwood Scrub)	Hills on dipping Upper Palaeozoic sedimentary or volcanic rocks	Palaeozoic sedimentary or volcanic rocks	Very shallow undifferentiated and shallow to deep texture-contrast soils (1c/2c)	Softwood scrub and rosewood forests	
Mn	Mundell (softwood scrub)	Hills and dissected tablelands on flat-lying Jurassic shale and sandstone	Jurassic shale and sandstone	Dark brown and grey-brown clays and cracking clays (4b/5b)	Softwood and brigalow scrubs; scrub grass	
Na	Narran (softwood scrub)	Hills and dissected tablelands on flat-lying Jurassic rocks	Jurassic rocks	Shallow texture-contrast soil and cracking clays (2c/5b)	High forest and softwood and brigalow scrub; scrub and forest grass	
R	Ramsay (softwood scrub)	Undulating to nearly flat plains of colluvium-alluvium	-	Dark brown and grey-brown clays (4a)	Softwood and brigalow scrubs; scrub grasses	
Rr	Redrange (softwood scrub)	Low hills and undulating plains on subhorizonal Mesozoic shale and sandstone	Mesozoic shale and sandstone	Dark brown and grey-brown clays and cracking clays (4b/5b)	Softwood scrub, scrub grass	
T	Thomby	Undulating to nearly flat	-	Texture-contrast soils, cracking	Brigalow and softwood scrub.	

Map code	Land system	Landform	Geology	Soils*	Vegetation	GQAL classification (based on SPP1/92 guidelines)
	(brigalow scrub)	plains with extensive colluvial and erosional slopes		clays, and dark brown and grey-brown clays (2c/5b)		
B	Banana (softwood scrub)	Undulating plains, mainly on Upper Palaeozoic argillaceous rocks	Upper Palaeozoic argillaceous rocks	Cracking clays (5c)	Softwood and brigalow scrubs and grassy woodland; scrub grass and eastern mid-height grass	C1
G	Gelobera (mountains)	Mountains and hills mainly on dipping Upper Palaeozoic volcanic rocks	Upper Palaeozoic volcanic rocks	Very shallow, undifferentiated soils and texture-contrast soils (2b)	Wet sclerophyll forest; sparse forest grass	
Y	Yebna	Hills on flay-lying Mesozoic sandstone	Mesozoic sandstone	Deep texture-contrast soils and very shallow undifferentiated soils (2b/1b)	High forests and grassy woodlands, and eastern mid-height grass.	
Ab	Auburn (undulating plains - high forest)	Undulating upland plains with low lateritic crests and gentle colluvial slopes, on deeply weathered granite rocks	Weathered granite rocks	Deep texture-contrast and very shallow undifferentiated soils (1c/2d)	High forest; three-awn grass	C2
Bl	Bouldercombe (woodlands,	Strongly undulating plains with low hills, on granitic and volcanic	Granitic and volcanic rocks	Texture-contrast and uniform coarse-textured soils (2c)	Grassy woodland; eastern mid-height grass	

Map code	Land system	Landform	Geology	Soils*	Vegetation	GQAL classification (based on SPP1/92 guidelines)
	texture-contrast soils)	rocks				
Mo	Montana	Tributary fluvial plains with extensive erosional slopes on flat-bedded Mesozoic shale and sandstone	Mesozoic shale and sandstone	Shallow to moderately deep texture-contrast soils (2b/2d)	Grassy woodland, eastern mid-height grass	
N	Nathan	Dissected tablelands of flat-lying Mesozoic sandstone	Mesozoic sandstone	Outcrop, very shallow undifferentiated and texture-contrast soils (1b/2b)	Sandstone forest and high forest; forest grass	
Oh	Ohio (woodlands, texture-contrast soils)	Strongly undulating plains, mainly on dipping Upper Palaeozoic volcanics	Upper Palaeozoic volcanics	Shallow to deep texture-contrast soil (2c/2d)	Grassy woodland; eastern mid-height grass	
P	Perch (woodlands, texture-contrast soils)	Undulating plains on Tertiary sedimentary rocks and with extensive colluvial and alluvial slopes	Tertiary sedimentary rocks	Texture-contrast soils and red earths (3a/4b)	Grassy woodland; three-awn and eastern mid-height grass	
Te	Torsdale (texture-	Strongly undulating plains with low hills,	-	Shallow texture-contrast soil and cracking clays (2c/5b)	Grassy woodland; eastern mid-height grass	

Map code	Land system	Landform	Geology	Soils*	Vegetation	GQAL classification (based on SPP1/92 guidelines)
	contrast scrub)	and moderately extensive lower slopes				
We	Woleebee	Tributary fluvial plains with erosional slopes on Mesozoic shale and sandstone	Mesozoic shale and sandstone	Texture-contrast soils (2b/3c)	Grassy woodland, eastern mid-height grass and Three-awn grass	
Ca	Carborough (mountains)	Rocky mountains and hills, formed on flat-lying or gently dipping Mesozoic sandstone	Mesozoic sandstone	Outcrop and very shallow undifferentiated soils (1b)	Sandstone forest; forest grass	
I	Irving (woodlands, eastern mid-height grass)	Hills on granitic and volcanic rocks	Granitic and volcanic rocks	Texture-contrast soils, and outcrop and very shallow undifferentiated soils (2c)	Grassy woodlands; eastern mid-height grass	C3
Land Resource Areas – Murilla, Tara and Chinchilla Shires, 1: 250,000, DPI, Brisbane						
4b	Brigalow plains	Flat clay plains with moderately deep to deep gilgai	-	Grey cracking plains (5b/5b[m])	Extensively cleared brigalow, belah and wilga forest	B
7a	Ironbark / bull oak forest	Flat to gently undulating plains derived from weathered sandstone	Weathered sandstone	Bleached sands over mottled, yellowish brown or brown and red clays (2b)	Bull oak, cypress pine, and narrow-leaved ironbark open forest	C2

Map code	Land system	Landform	Geology	Soils*	Vegetation	GQAL classification (based on SPP1/92 guidelines)
9a	Light forests	Undulating plains and rises, often lateritised	-	Very shallow, gravelly, red soils, bleached sands over mottled, yellowish brown clays, and shallow or deep sands or loams grading to red loams or clays (2b)	Ironbark and wattle layered open forest	
9b	Light forests	Plateaus and low sandstone hills to undulating plains, lateritic scarps are common	-	Very shallow, gravelly, red soils and shallow, gravelly texture contrast soils (1b)	Ironbark, spotted gum, rusty gum and cypress pine open forest	
Land Systems of the Capricornia Coast, map 3 Calliope Area, 1: 250,000, DPI, Brisbane						
Bg	Hills - Bungundarra	Steep to rolling hills with long footslopes on steeply dipping sedimentary rocks	Sedimentary rocks	Red, structured gradational clay loams and uniform clays; shallow, bleached sandy and loamy surface, red duplex soil (3c).	Eucalypt open forest (lemon-scented gum, narrow-leaved ironbark, pink bloodwood) with mixed understory; vine forest	C1
Cp	Floodplains and local alluvial plains - Calliope	Broad, level alluvial plains along the Calliope River and tributaries	Alluvium	Clay loamy surface, black and brown duplex soils; black and grey, alkaline cracking clays with moderate melonhole (2a)	Eucalypt woodland (Moreton Bay ash, bluegum, narrow-leaved ironbark)	

Map code	Land system	Landform	Geology	Soils*	Vegetation	GQAL classification (based on SPP1/92 guidelines)
Nl	Old alluvial plains and alluvial fans – Nulgi	Broad, level to gently undulating alluvial plains on silty and fine textured alluvium	Alluvium	Bleached silty surface, brown and grey, alkaline sodic duplex soils (2a)	Gum-topped box woodland	
Nw	Old alluvial plains and alluvial fans – The Narrows	Alluvial fans and lower colluvial slopes of the coastal hills	Alluvium and colluvium	Bleached silty surface, brown and grey, alkaline sodic duplex soils (2a/2c)	Eucalypt woodland (blue gum, narrow-leaved ironbark, swamp mahogany) with tea-tree understory	
Tr	Undulating plains and Rises – Terise	Gently undulating rises and plains on sedimentary rocks	Sedimentary rocks	Red structured gradational clay loams and uniform clays; bleached loamy surface, grey and brown acid sodic duplex soils (3a)	Eucalypt open forest (narrow-leaved ironbark, blue gum, gum-topped bloodwood); eucalypt woodland (Queensland peppermint, narrow-leaved ironbark)	
Ch	Hills - Chalmers	Rolling to steep hills on acid and intermediate volcanic rocks and steeply dipping sedimentary rocks	Intermediate volcanic rocks and sedimentary rocks	Bleached massive sands and loams; shallow, stony brown and black, structured uniform clays and gradational clay loams (1c/4c)	Eucalypt woodland (narrow-leaved ironbark, lemon-scented gum, pink bloodwood, ghost gum)	C2
Cr	Hills - Carrara	Undulating to rolling low hills and rises and sedimentary rocks	Sedimentary rocks	Shallow brown and black massive loams and clay loams; sandy and loamy surface,	Eucalypt woodland (narrow-leaved ironbark, gum-topped bloodwood, pink bloodwood)	

Map code	Land system	Landform	Geology	Soils*	Vegetation	GQAL classification (based on SPP1/92 guidelines)
				brown and grey, alkaline: sodic duplex soils (1b)		
Gf	Hills - Glassford	Steep to rolling hills and escarpments on granitic rocks	Granitic rocks	Sandy and loamy surface, red and brown duplex soils; brown red and yellow, massive gradational loams and clay loams (1c)	Eucalypt woodland (narrow-leaved ironbark, pink bloodwood or silver-leaved ironbark, gum-topped bloodwood)	
Gw	Undulating rises and plains – Galloway	Gently undulating rises and plains on granitic rocks; isolated low hills	Granitic rocks	Sandy and loamy surface, brown and black duplex soils; bleached sandy and loamy surface, brown and grey, alkaline sodic duplex soils (2b/2c)	Eucalypt woodland (silver-leaved ironbark, gum-topped bloodwood); poplar box woodland	
Mo	Vine forest – Moore	Steep to rolling hills and rises on sedimentary rocks	Sedimentary rocks	Shallow, stony brown, red and dark, structured gradational clay loams and uniform clays (Mo)	Vine forest	
Ng	Hills - Nagoorin	Undulating to rolling low hills and fans on fine grained sedimentary rocks and unconsolidated sediments	Fine grained sedimentary rocks and unconsolidated sediments	Bleached clay loamy and silty surface, brown and grey, alkaline sodic duplex soils (2c)	Gum-topped box woodland	

Map code	Land system	Landform	Geology	Soils*	Vegetation	GQAL classification (based on SPP1/92 guidelines)
Sf	Vine forest - Sugarloaf	Steep hills and escarpments and valley flats on granitic and intermediate volcanic rocks	Granitic and intermediate volcanic rocks	Brown, red and yellow, massive gradational loams and clay loams (1c)	Vine forest; eucalypt woodland (narrow-leaved ironbark, pink bloodwood)	
Sl	Undulating rises and plains - Sleipner	Undulating footslopes and rises, and gently undulating fans below hills on intermediate and acid volcanic rocks, and small areas of granitic rocks	Intermediate and acid volcanic rocks and small areas of granitic rocks	Bleached loamy and clay loamy surface, brown and grey, alkaline sodic duplex soils (2c)	Eucalypt woodland (blue gum, narrow-leaved ironbark)	
Wf	Hills - Wycheproof	Undulating to rolling low hills and rises on sedimentary rocks and greenstone; saline outbreaks on lower slopes and drainage flats	Sedimentary rocks and greenstone	Shallow, stony, brown and black, massive loams and clay loams; shallow, red and brown, structured gradational clay loams (2c)	Eucalypt woodland (narrow-leaved ironbark, gum-topped bloodwood and Moreton Bay ash)	
Bk	Mountains - Berserker	Steep mountains and very steep escarpments on acid and intermediate volcanic rocks and	Acid and intermediate volcanic rocks and minor intrusions	Shallow, stony brown and black, massive loams and clay loams; shallow stony black and brown, structured uniform clays and gradational clay loams (1c)	Eucalypt woodland (lemon-scented gum, white mahogany); vine forest	D

Map code	Land system	Landform	Geology	Soils*	Vegetation	GQAL classification (based on SPP1/92 guidelines)
		minor intrusions				
Ct	Marine plains - Carpentaria	Marine plains with extensive bare tidal flats inundated by tidal waters and dissected by tidal channels		Crusting surface, grey mottled, saline cracking clays; saline muds and sands (6)	Mangrove low closed forest; marine couch grassland; samphire	

Note: * Australia Pacific LNG Project soil groups (described below) presented in brackets

For the purposes of this report, the soil types / soil mapping units described within each of the land system reports that cover the study area (refer Table 5.1) have been assessed and grouped to enable a common description of soil characteristics and management issues of relevance to the Australia Pacific LNG Project. This standardised soil key for the study area is presented in Table 5.2, while Figure 5.1 illustrates the combined soil groups according to this standardised soil key. Mapped soil groups were correlated against soil types encountered during the field assessment to refine soil mapping and provide background data on soil constraints (refer Section 5.2.1).

Table 5.2 Study area soils

Order		Description	
1	Skeletal soils (mainly Rudosols)	a	Alluvial – deep sands
		b	Shallow stony loams derived from sediments
		c	Shallow stony loams derived from mixed sources (metamorphic, intrusive or volcanic parent material)
2	Texture contrast soils (Chromosols / Sodosols / Kurosols)	a	Alluvial – predominantly moderately deep to deep
		b	Shallow mainly sandy surface: i) neutral to acid subsoil (Chromosols / Kurosols) ii) neutral to alkaline subsoil (Sodosols)
		c	Shallow mainly loamy surface: i) neutral to acid subsoil ii) neutral to alkaline subsoil
		d	Moderately deep to deep sands / loams
3	Red/yellow earths (Kandosols / Tenosols)	a	Shallow earths – derived from sediments
		b	Deep earths – derived from sediments
		c	Shallow/ deep earths derived from mixed sources
4	Brown/ grey non-cracking clays (Dermosols)	a	Alluvial
		b	Derived from sediments
		c	Derived from mixed sources (mainly intrusives / volcanics)
5	Brown/grey/dark cracking clays (Vertosols)	a	Alluvial
		b	Derived from sediments (mainly clay plains)
		c	Derived from intrusives / volcanics
		(m)	Melonhole clays
6	Grey mottled saline cracking clays and sands (Hydrosols)	a	Marine deposits

The following describes the main soil groups defined for the study area, their main physical and agronomic characteristics and general management issues. Figure 5.1 illustrates the six soil groups

for the study area. Descriptors below generally include the broad Great Soil Group (GSG) and Australian Soil Classification (ASC) category (the latter in italics below).

Lithosols / *Rudosols* – mainly shallow stony soils or deep structureless sands. This group has been divided into three units as follows:

a) Alluvial – deep sands
These are generally deep infertile soils associated with the floodplains of the major streams. Due to their landscape position and low gradient, they present few management constraints in terms of project development with the possible exception of stream bank erosion control.

b) Shallow stony loams derived from sedimentary material
These soils are generally associated with the steeper hilly lands and derived mainly from mixed sedimentary rocks. Characteristics of these soils (which are prevalent in the northern and southern portions of the study area) are as follows:

i) A shallow surface soil with abundant gravel or stone, this soil generally has little profile development.

ii) Significant rock, often competent, may be found at a shallow depth, often within 15cm of the surface. Rock outcrops may be present.

iii) Nutrient levels are very low and are usually acid soils.

iv) The topsoil is generally very thin constraining its removal for subsequent use to assist vegetative rehabilitation. Topsoils are generally less than 5cm deep.

c) Shallow stony loams derived from mixed sources - mainly igneous and metamorphic rocks, generally of the Permian period or older. There are significant areas of this unit within the study area particularly in the Callide Range area. This soil type predominates between KP258-285 and 340-346 and presents a significant construction and land management constraint. Characteristics are similar to b) but present greater constraints for excavation due to rock. There is often a conspicuous bleach layer between the surface topsoil[2] and the rock layer. The implications of these soils (1b and 1c) for development of the proposed pipeline are:

i) There will only be a thin layer (or complete absence) of topsoil suitable for stripping for rehabilitation.

ii) Trenching/excavation may be difficult due to a predominance of rock at a shallow depth.

iii) Due primarily to the landscape position, these soils are often highly prone to erosion; however, the high proportion of gravel or rock within the surface material may, in many circumstances, tend to protect or mitigate the erosion severity, especially in regard to the potential for gully erosion.

Texture contrast soils / *Chromosols / Sodosols / Kurosols* – This group has been divided into four mapping units as follows:

a) Alluvial soils
The alluvial texture contrast soils may be either *Chromosols* or *Sodosols*. For the *Chromosols*, the topsoil can be quite deep (often >60cm). General characteristics of both these types are

2 In the context of this report, 'topsoil' refers to the surface profile of the soil that is darkened due to organic matter accumulation and/or with a structure generally conducive to use for vegetative rehabilitation (often termed the A1 horizon)

described below; however, the lower slopes and depth of topsoil may limit the propensity for erosion with the exception of stream channels.

b) Shallow, mainly sandy surface

c) Shallow, mainly loamy surface

d) Moderately deep to deep sands/loams (non- alluvial).

These can be further divided into i) neutral to acid subsoil (*Chromosols / Kurosols*) and ii) neutral to alkaline subsoil (*Sodosols*). These soils in the plains and upland areas are derived from mainly fine and coarse grained sedimentary material of Jurassic or Tertiary sedimentary origin.

Solodics / *sodosols* can be classified into the following types, as interpreted from the various land system reports.

- Shallow gravely textured contrast soils: Surface soils range from deep, loose sands to shallow, hard-setting loams and their clay subsoils form well-structured, friable permeable types to coarsely-structured, tough types of low permeability. In nearly all of these soil types, the more clayey subsoil causes some, often severe, impedance of internal drainage, and the hard-setting loamy surface soils lead to excessive runoff from high intensity rainfall. Where the natural cover is reduced by clearing or overgrazing, significant gully erosion can result.
- Texture contrast soils on plains with bulloak and cypress pine: These soils generally have a thin sandy or loamy surface soil (commonly < 30cm), brown to grey-brown in colour, over brown, yellowish brown or reddish brown light to medium clay subsoils. The subsurface soils are commonly lighter in colour and sometimes sporadically or conspicuously bleached. The surface soils are usually slightly acid and there is generally a gradual increase to a strongly alkaline or acid reaction in the subsoils. Structure at the surface is massive and angular blocky, occasionally columnar, in the subsoils where small to moderate amounts of carbonate may be present. The surface soils set hard when dry and subsoil consistence is commonly hard to very hard. These soils occur mainly on very gentle, intermediate or lower slopes.
- Sandy texture contrast soils dominated by poplar box: These soils have a thin loamy sand or sandy loam surface soil (generally <15cm) with an acid surface and neutral to alkaline subsoil that is commonly brownish grey or light yellowish brown. Subsoils are commonly strongly sodic and the deep subsoils can be highly saline. They are very dispersible and prone to gully and tunnel erosion.

Bierenbroodspot and Thew (1982) present general management strategies for these soils which are prevalent in inland areas of southern Queensland. Consequently, appropriate methods of handling these soils have become well established in the gas infrastructure and pipeline construction industry. Common characteristics of these soils are:

- The topsoil is low in organic matter and hard-setting.
- Nutrient levels in the surface soils are low to very low.
- There is usually a moderate to conspicuous bleach between the surface soil and subsoil.
- The depth of topsoil (that is, above the bleach) can be quite variable (sometimes over 60cm).
- The subsoils are usually strongly sodic and highly dispersive as is evidenced by soil sampling undertaken for this project (refer Section 5.2.3). Despite some Emerson dispersion results and two ‘non-dispersive’ subsoil samples (refer Section 5.2.3), all sampling of soils in this group

were sodic to strongly sodic (Na% levels commonly higher than 16%), mostly with a low calcium to magnesium ratio (also indicating a propensity for dispersion).

- These soils are consequently very prone to gully and tunnel erosion with a surface soil that is prone to sheet erosion.

Key management issues for these soils within the proposed pipeline study area are as follows:

- The topsoil depth is quite variable, but the layer suitable for stripping is often between 10cm and 20cm. The topsoil layer is usually readily able to be identified in the field.
- Extreme care should be undertaken with the highly sodic subsoils to ensure careful segregation from the topsoil piles (refer Section 7.3.2 later for handling methods).
- The very low nutrient levels will necessitate some fertilisation to achieve an acceptable rehabilitation standard.
- Ongoing monitoring will be required following rehabilitation due to ensure the continued integrity of the rehabilitation works.

Key characteristics of Chromosols / Kurosols are as follows:

- Surface soils are mainly shallow, sandy loam or loamy, often gravely.
- A bleached A2 horizon is not common.
- Nutrient levels are low.
- Subsoils are generally red, brown or yellow clay with a blocky structure and often moderately permeable. Lateritic layers can occur.
- Subsoils are usually acid to neutral, non-sodic and non-dispersive to moderately dispersive.
- They commonly intergrade with the gradational soils described below or the Solodic / Sodosol soils described previously.

The implications of these soils for project development are similar to those described for the Solodic / Sodosols above, albeit, in many cases, with a lower propensity for tunnel and gully erosion due, in most circumstances, to more stable subsoils. Key constraints include:

- The topsoil is of variable depth for stripping, but generally 10cm to 30cm and readily discernible in the field.
- Topsoil will require fertilisation.
- While subsoils require segregation from the topsoils, they present no special handling constraints due to their relative stability; however, such soils generally occur on steeper terrain requiring intensive erosion control works to control runoff.

Red / yellow earths / *Kandosols / Tenosols* – These soils have a coarse to medium texture and a uniform or gradational profile. This group has been divided into:

a) Shallow earths – derived from sediments

b) Deep earths – derived from sediments

c) Shallow / deep earths derived from mixed sources, only minor areas of which are present within the study area.

Characteristics of these soils include:

- Topsoil is medium depth (typically 15 to 30cm).
- They are generally acid throughout.
- Fertility levels are usually low to very low.
- Shallow earths (3a) can have significant gravel content, often with rock outcrop or broken rock.
- Surface can be loose and prone to sheet erosion.
- Profile drainage can be quick and have a low moisture holding capacity.
- The relative stability of the subsoils make them less susceptible to gully erosion than the texture contrast soils.

The main management implications for these soils are the presence of stone and their rapid drying. The latter issue may limit vegetative rehabilitation success in some areas.

Brown and grey non-cracking clays / *Dermosols* – This soil group has been divided into:

a) Alluvial soils – found along the terraces associated with most major watercourses and can be prone to flooding

b) Soils in upland areas or plains derived from sediments (mainly from Jurassic and Tertiary sources), which are not common within the study area, but more prevalent in the southern portion

c) Soils derived from mixed sources (mainly intrusives / volcanics), which are only present in minor areas of the study area.

Key characteristics and management implications of this soil group are as follows:

- They have relatively deep topsoil (often up to 50cm deep) that merges gradually into medium clayey subsoil. However, clay levels in the surface may be high and limit topsoil stripping opportunities.
- The differentiation between the topsoil and subsoil material can be moderately obscure.
- Surface and subsoil profiles are generally moderately permeable.
- Subsoils are usually moderately sodic and dispersive (based on the results undertaken for this report).
- Fertility levels are generally low to moderate. Fertilisation for rehabilitation purposes would be beneficial.
- They are comparatively stable, particularly 4a. However, significant clay content in the surface soil can result in compaction issues if excessively handled and thus affect rehabilitation success.

Brown/grey/dark cracking clays / *Vertosols*: This soil group has been divided into:

a) Alluvial soils
Found along the terraces and floodplains of some larger watercourses, including the Condamine River floodplain, these soils are generally very deep and present few physical constraints aside from possible flooding issues.

b) Soils derived from sediments (as for 4b)

c) Soils derived from mixed sources (intrusives / volcanics).

The cracking clay soils in non-alluvial locations – that is, 5b and 5c – are generally of medium depth, have friable surface horizons and a moderately high nutrient status. The phosphorus content, although variable, is usually moderate to high. Although large areas of these soils have previously been used for annual cropping, especially in the area near Wandoan and Taroom, low and highly variable rainfall, high evaporation and unavailability of suitable irrigation water limit their long-term cropping potential and most areas are now mainly under improved pasture.

The deep grey and brown cracking clays occur chiefly as grassland plains adjacent to some of the major streams and as small areas of gently undulating plains of older clay sediments. In some areas, there are deep 'melonhole' gilgai on the plains with moderate linear gilgai common on gentle slopes. Deep melonhole areas (as identified in the land system mapping) have been mapped as 5b(m). These soils have moderate to high water holding capacity, but agricultural potential is often limited due to their impeded drainage.

Typical characteristics are as follows:

- Their finely structured surface may form a weak surface.
- Gilgai may or may not be present – where developed, some variation in profile characteristics and surface condition may be seen. For example, gilgai mounds can be reddish and depressions grey; the depth to carbonate layers and acid subsoils is usually greater in depressions than on mounds.
- Management of these soils may be aided by a fine, friable surface and well structured upper subsoil.
- Lower subsoils are generally strongly sodic with very high salinity levels. Dispersion levels are variable. Sampling conducted for this report indicated highly dispersive levels in most cracking clay soil areas.
- Subsoils shrink and swell and may develop large vertical cracks when dry.
- Soil pH is generally neutral to alkaline at the surface, usually becoming strongly alkaline at around 30cm. It may become strongly acid below 100cm.
- Plant available water capacity (PAWC) in the root zone of gilgai mounds is low (50mm-100mm); gilgai depressions have higher PAWC levels.
- Fertility levels are usually medium to high (pasture).

Implications for the development of the proposed pipeline are:

- Careful segregation of the (often shallow) topsoil from the dispersive subsoil will be necessary. Stripping depths may need to be quite shallow (around 10cm) and therefore a site-specific topsoil assessment may be required.
- Visually differentiating topsoil from subsoil can be difficult. The high clay content may limit use of this topsoil for rehabilitation purposes.
- Very careful segregation and handling of the subsoil will be required. Excessive handling and compaction of topsoil may destroy soil structure and affect rehabilitation success.
- Due to the relatively high fertility levels, fertilisation may not be necessary.

Stripping of surface soil where the gilgai is pronounced may prove a significant operational constraint for some machinery, especially graders due to surface undulations which may be up to 1m deep.

Management of surface soils for successful rehabilitation will need to be carefully monitored – some surface material suitable for rehabilitation may need to be 'borrowed' from other areas.

Grey mottled, saline cracking clays and sands / *Hydrosols*: This soil group is mainly comprised of fine textured soils (silty clays); however, medium textured (silty sands) can also occur. They typically occur extensively over low-lying coastal areas, such as tidal mud flats and estuary marine deposits (refer Map Code "Ct" Table 5.1), predominantly below 5mAHD. Within the study area, these soils are associated with intertidal (commonly known as mudflats), supratidal (commonly known as saltpans) and extratidal marine plains (or flats). They are commonly dissected by tidal channels and occupy 525ha of the study area. A key issue with these soils is the presence of acid sulfate soils (see below).

5.1.2 Acid sulfate soils

The Hydrosols described above are commonly associated with pyritic sediments which were deposited in the Holocene Epoch (circa 10,000 years) and are generally known as acid sulfate soils (ASS). ASS is a term that is generally used to describe both actual ASS (AASS) and potential ASS (PASS).

PASS are typically waterlogged soils, rich in pyrite, which have not been oxidised (Ahern et al. 2004). Exposure of PASS to air, causing oxidation, can lead to the creation of AASS: extremely acidic soil layers with field pH values of ≤4 (Ahern et al. 2004). Actual and potential ASS can occur together in the same profile. Typically however, AASS overlie PASS, but may still have reserves of unoxidised sulfides (Ahern et al. 2004).

A study undertaken by Ross (2005) of ASS in The Narrows area indicates ASS, classified as having a high potential for acid generation, are present along the coast at varying depths south of Targinie Creek up to Connor Point. The area of this study relevant to the Project occurs south of Targinie Creek up to the northern point of Worthington Island and east to Friend Point (refer Figure 5.1). A similar study, also undertaken by Ross (2004) indicated ASS, classified as having a high potential for acid generation, are present along the coast at varying depths from Tannum Sands to an area north of Fishermans Landing near Targinie Creek. This forms the boundary between both of these studies. Both studies indicate ASSs occur within 0.5m of the ground surface and have been classified as having a high potential for acid generation.

The ASS assessment undertaken for the Gladstone LNG Project (Santos. 2009) incorporated sampling along the coastal fringe from Friend Point to approximately 1km north of Fisherman's Landing. This sampling involved the testing of 16 borehole locations (#32 to #48) and reported laboratory analysis of samples down to 3mBGL. Samples reported ranged in actual acidity (TAA) from 0.01% to 0.32%S and potential acidity (Chromium Reducible Sulfur) from 0.01%S to 3.95%S (low to high). Some surface colluvial and Pleistocene clays samples were also reported to have acid neutralising capacity which reduced the recommended (calculated) liming rate.

Typical characteristics of AASS within the study area (as noted by Ross, 2004 and 2005) are as follows:

- Supratidal flats consist of thin brown, structured, medium to heavy clay surface horizon overlying greyish brown clay subsoil with abundant pale yellow jarosite mottles or dark brown clays grading into dark yellowish brown structured clays with red and orange mottles. A thin grey layer with jarosite overlies dark grey silty clay with organics.
- Extratidal flats consist of grey mottled medium to heavy clays, strongly acid at shallow depths with a thick layer of jarosite. Angular chert gravels occur throughout the profile.

- Deeper Pleistocene (pre-Holocene) subsoils are mottled olive grey heavy clay, moist and very firm.
- Significant areas comprised already oxidised acidic soils with some unoxidised sulfides.
- Surface gravel and iron segregations are soil features at narrow saltpans.
- Soils were saturated with a high organic content.
- All soils are likely to have a low load-bearing strength (barely able to support the weight of a person).

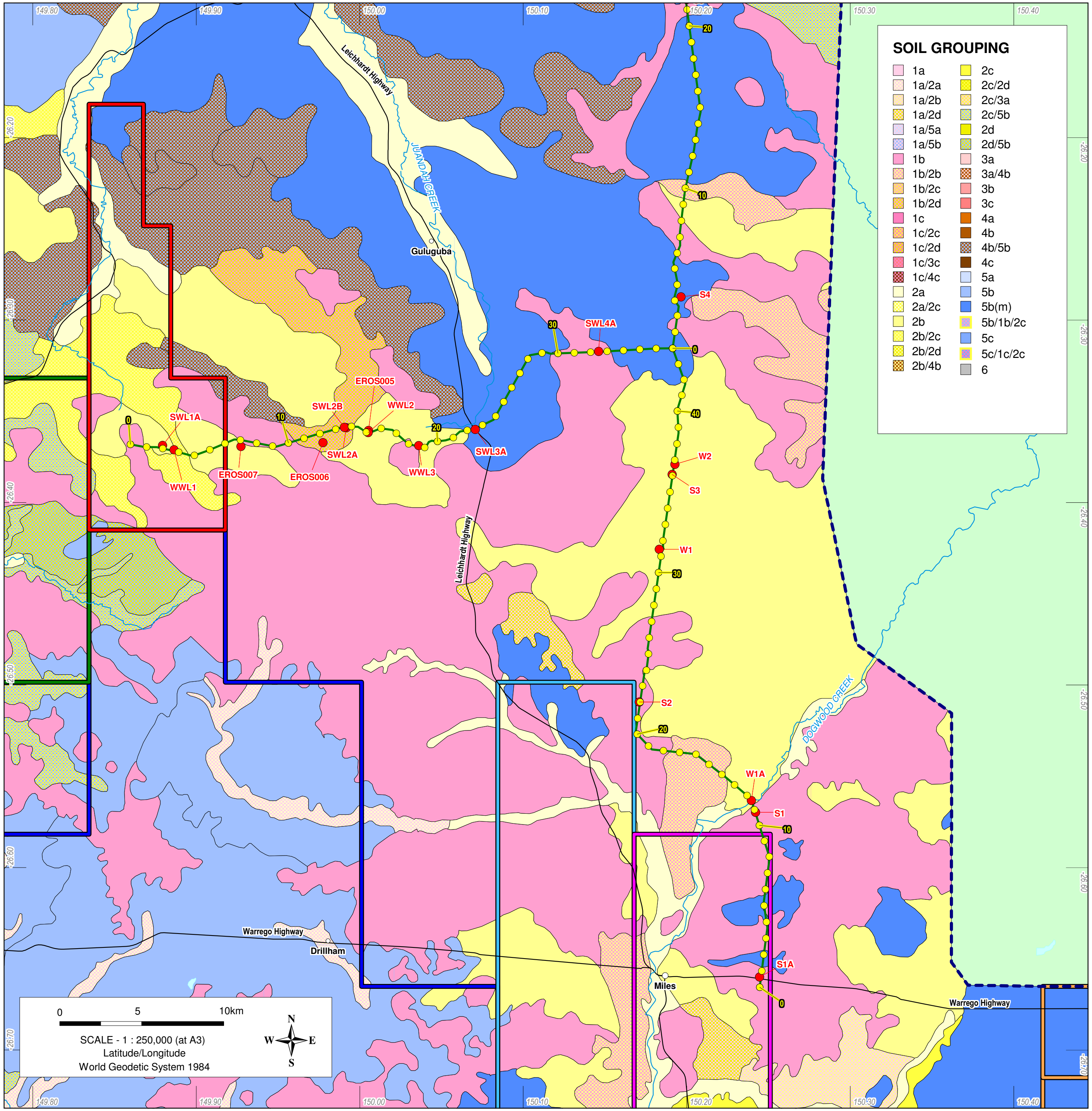
Typical characteristics of PASS within the study area (as noted by Ross 2004 and 2005) are as follows:

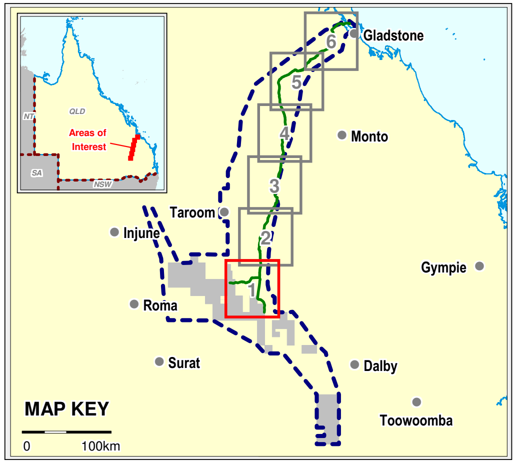
- Located within Targinie Creek, PASS have oxidisable acid levels range from 0.01% (low) to 9.4% (extreme). Moderate to high acidity levels are common near the surface (within 0.5m).
- PASS are dominant throughout this soil group and within the study area and are mostly associated with intertidal flats, but occur at depth within the supratidal salt flats.
- They are generally dark grey, grey or greenish grey silty clays with greyish brown surface horizon.
- Significant organic content occurs throughout the profile.
- PASS may contain appreciable quantities of shells (carbonate material), so much so that net acidity generation becomes close to zero – that is, they are self-neutralising enough that no treatment would be required if disturbed.
- They have a high potential for acid generation.

Implications for the proposed pipeline development in areas of PASS and AASS are:

- Exposure of acid sulfate soils resulting in the oxidation of sulfides and the production of sulfuric acid
- Potential release of heavy metals such as aluminium and iron and deoxygenation of waterways
- Corrosion of unprotected concrete and steel infrastructure including pipes, foundations and bridges
- Provision of poor foundation base due to very low load bearing strength
- Prohibitive treatment cost of extremely acidic layers.

ASS hazard mapping has been undertaken by Ross (2004 and 2005). This mapping is illustrated on Figure 5.1.





LEGEND

Observation location	Major drainage
Town	Road
Existing infrastructure	Study area

Walloons Gas Fields Development Areas

Combabula / Ramyard	Talinga / Orana
Woleebee	Dalwogan
Carinya	Kainama
Condabri	Gilbert Gully

Soil groupings combined and interpreted from Department of Natural Resources Land Resources Area maps by WorleyParsons October 2009.

Rev	Date	Revision Description	ORIG	CHK	ENG	APPD
0	14/01/2010	Issued for use	JB	MZ		

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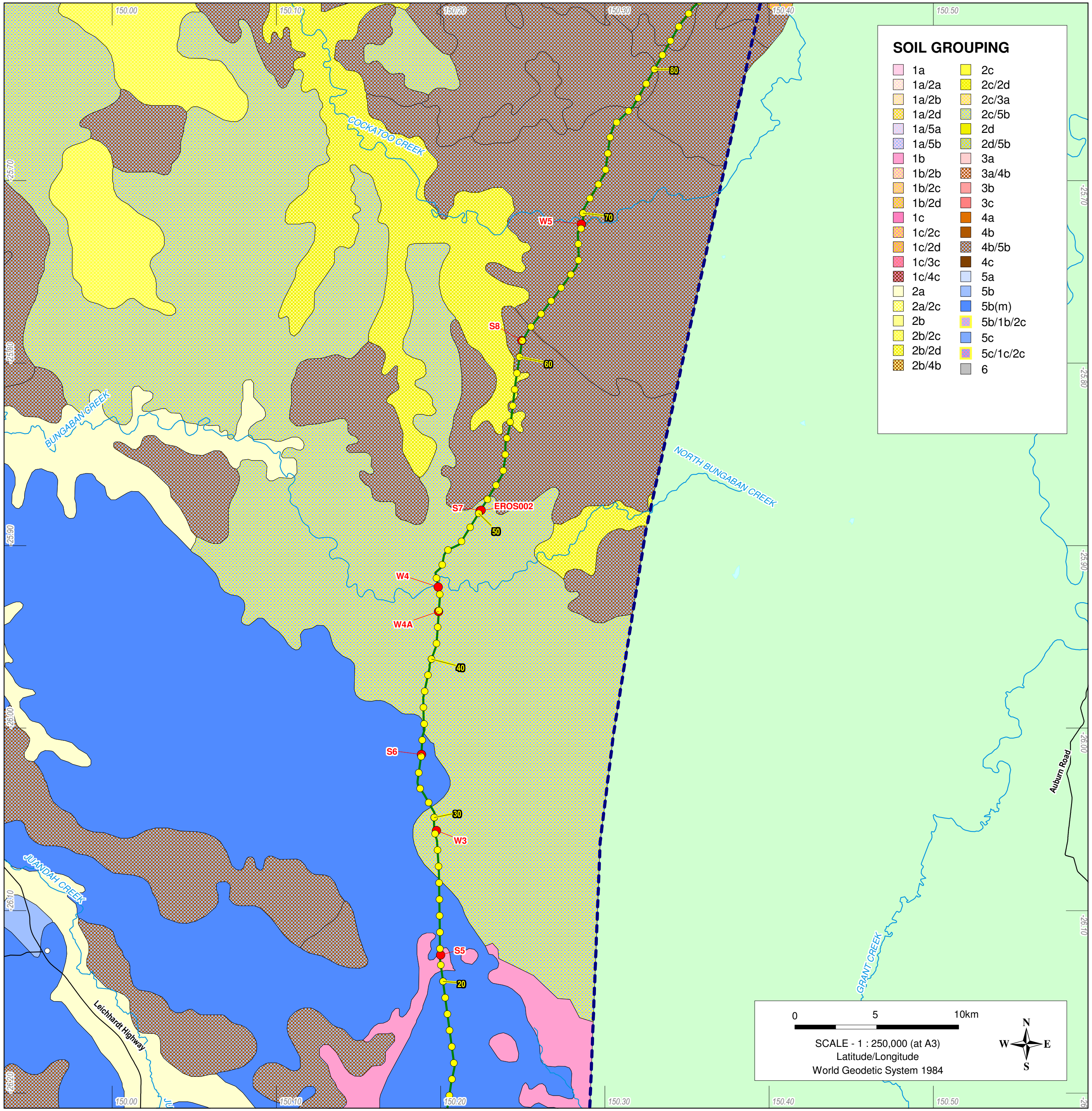
Figure 5.1a Study Area Soil Types
Map 1 of 6

Project No: 301001-00448 | Figure: 00448-00-EN-DAL-0304 | Rev: 0

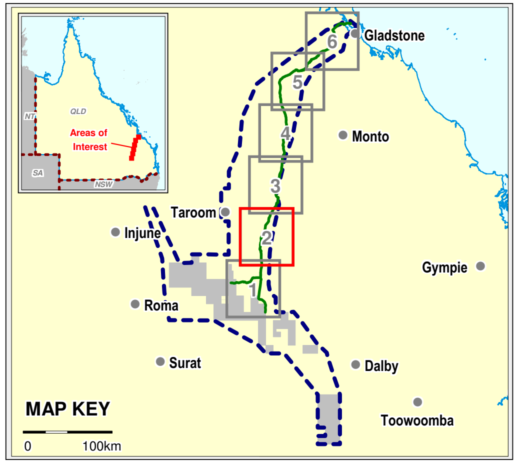


SOIL GROUPING

1a	2c
1a/2a	2c/2d
1a/2b	2c/3a
1a/2d	2c/5b
1a/5a	2d
1a/5b	2d/5b
1b	3a
1b/2b	3a/4b
1b/2c	3b
1b/2d	3c
1c	4a
1c/2c	4b
1c/2d	4b/5b
1c/3c	4c
1c/4c	5a
2a	5b
2a/2c	5b(m)
2b	5b/1b/2c
2b/2c	5c
2b/2d	5c/1c/2c
2b/4b	6

0 5 10km

SCALE - 1 : 250,000 (at A3)
Latitude/Longitude
World Geodetic System 1984



LEGEND

Observation location	Major drainage
Town	Road
Existing infrastructure	Study area

Walloons Gas Fields Development Areas

Combabula / Ramyard	Talinga / Orana
Woleebee	Dalwogan
Carinya	Kainama
Condabri	Gilbert Gully

Soil groupings combined and interpreted from Department of Natural Resources Land Resources Area maps by WorleyParsons October 2009.

Rev	Date	Revision Description	ORIG	CHK	ENG	APPD
0	14/01/2010	Issued for use	JB	MZ		

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Figure 5.1b Study Area Soil Types
Map 2 of 6

Project No: 301001-00448 | Figure: 00448-00-EN-DAL-0305 | Rev: 0

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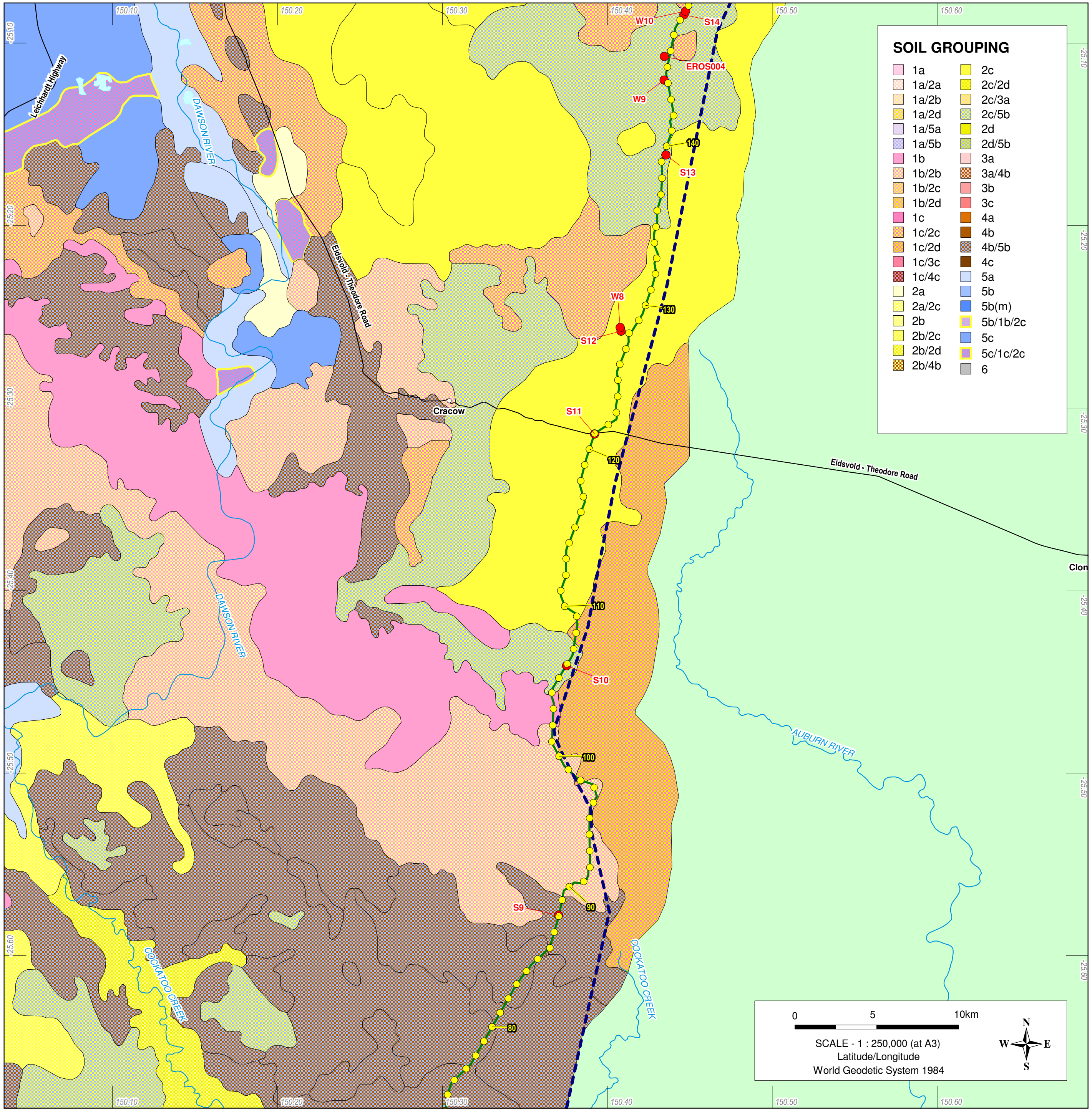

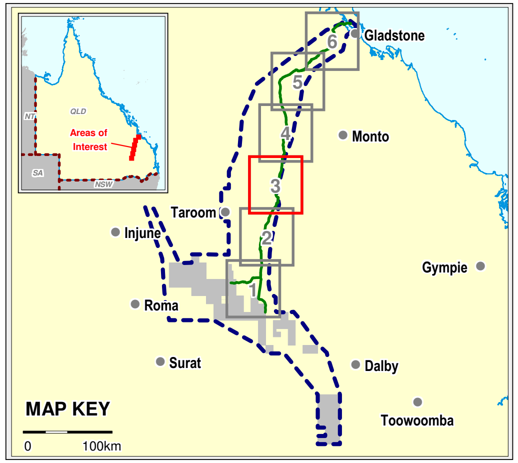

LEGEND

- Observation location
- Town
- Existing infrastructure
- Major drainage
- Road
- Study area

Walloons Gas Fields Development Areas

- Combabula / Ramyard
- Woleebee
- Carinya
- Condabri
- Talinga / Orana
- Dalwogan
- Kainama
- Gilbert Gully

Soil groupings combined and interpreted from Department of Natural Resources Land Resources Area maps by WorleyParsons October 2009.

Rev	Date	Revision Description	ORIG	CHK	ENG	APPD
0	14/01/2010	Issued for use	JB	MZ		

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Figure 5.1c Study Area Soil Types
Map 3 of 6

Project No: 301001-00448 | Figure: 00448-00-EN-DAL-0306 | Rev: 0

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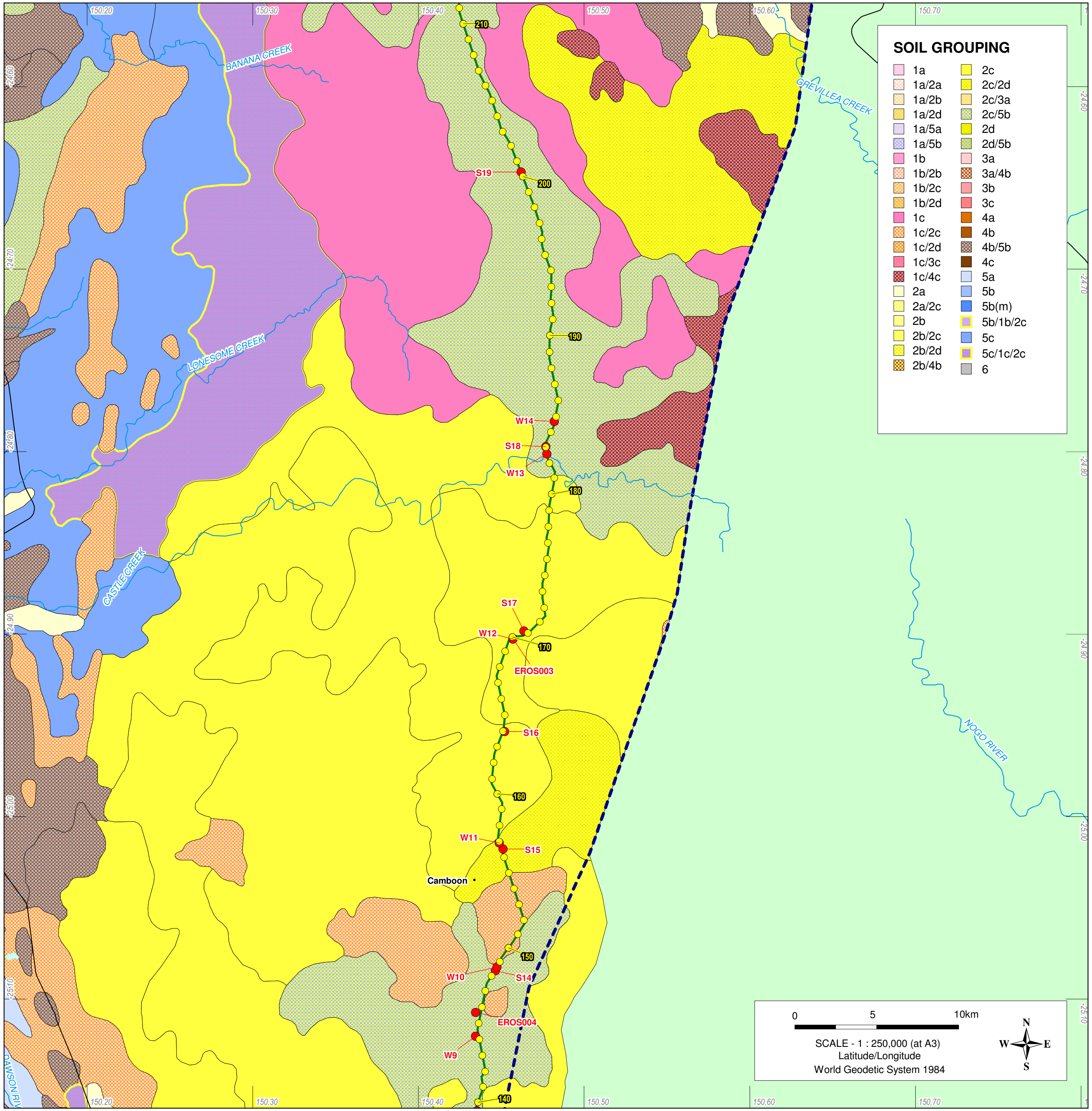

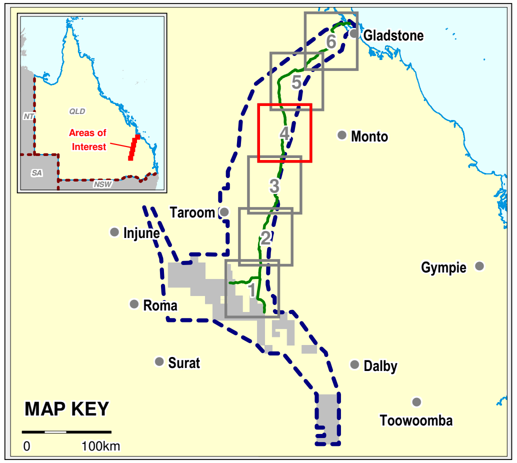

LEGEND

Observation location	Major drainage
Town	Road
Existing infrastructure	Study area

Walloons Gas Fields Development Areas

Combabula / Ramyard	Talinga / Orana
Woleebee	Dalwogan
Carinya	Kainama
Condabri	Gilbert Gully

Soil groupings combined and interpreted from Department of Natural Resources Land Resources Area maps by WorleyParsons October 2009.

Rev	Date	Revision Description	ORIG	CHK	ENG	APPD
0	14/01/2010	Issued for use	JB	MZ		

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Figure 5.1d Study Area Soil Types
Map 4 of 6

Project No: 301001-00448 | Figure: 00448-00-EN-DAL-0307 | Rev: 0

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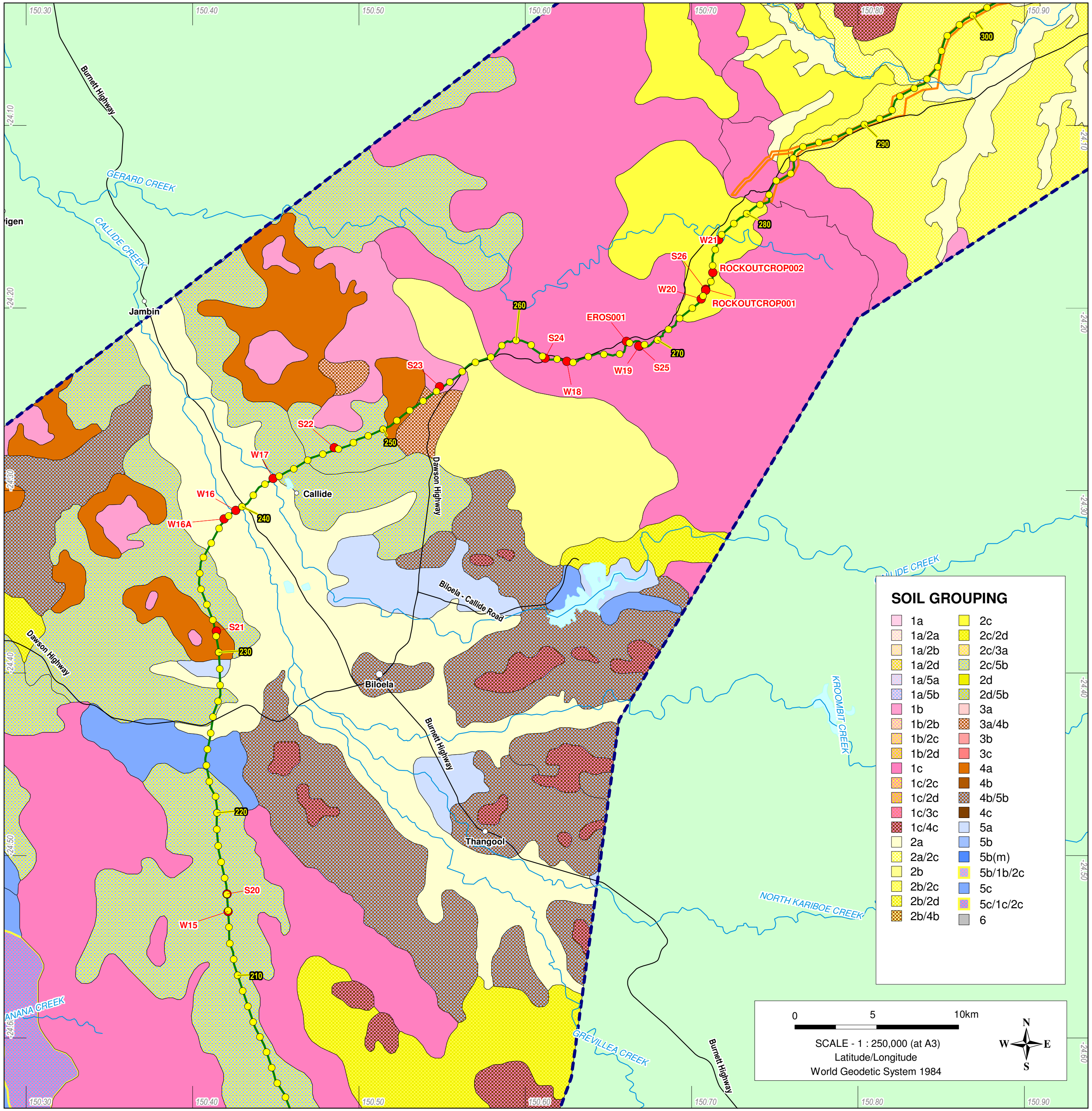

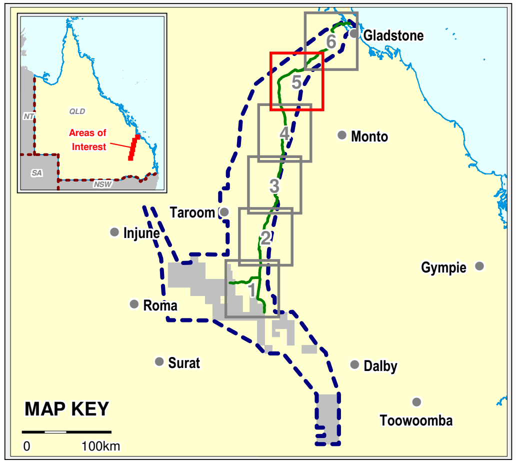

LEGEND

- Observation location
- Town
- Existing infrastructure
- Major drainage
- Road
- Study area

Walloons Gas Fields Development Areas

- Combabula / Ramyard
- Woleebee
- Carinya
- Condabri
- Talinga / Orana
- Dalwogan
- Kainama
- Gilbert Gully

Soil groupings combined and interpreted from Department of Natural Resources Land Resources Area maps by WorleyParsons October 2009.

Rev	Date	Revision Description	ORIG	CHK	ENG	APPD
0	14/01/2010	Issued for use	JB	MZ		

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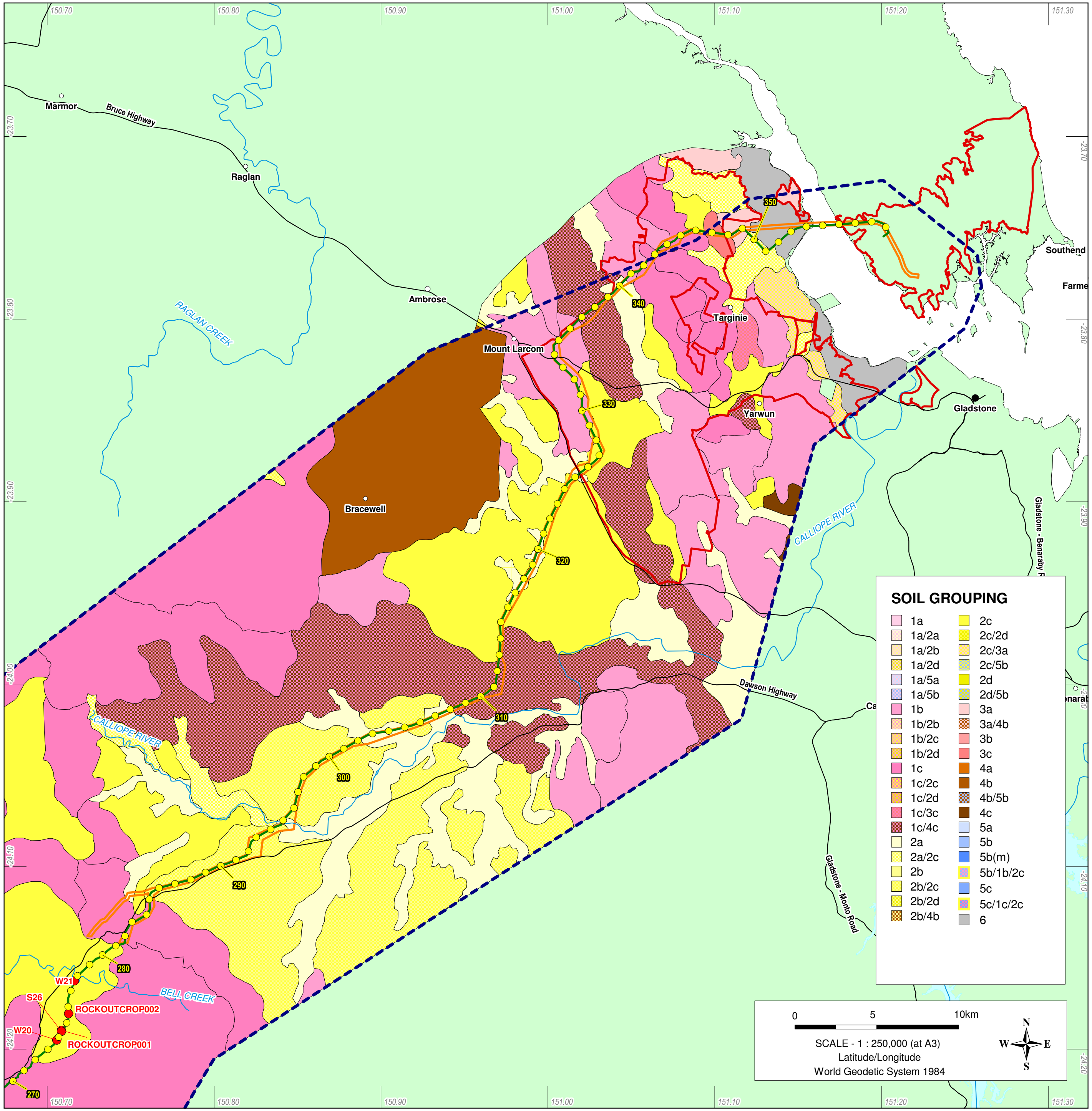
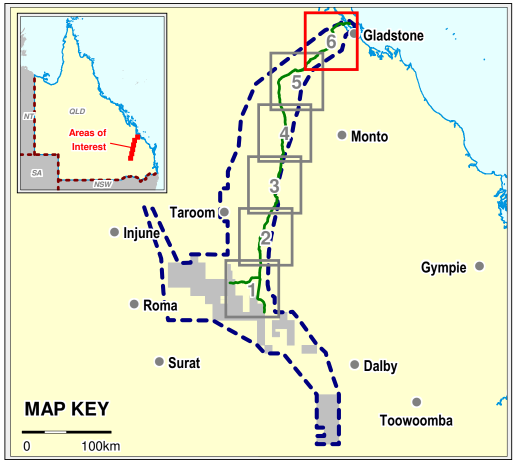
AUSTRALIA PACIFIC LNG PROJECT
Figure 5.1e Study Area Soil Types
Map 5 of 6

Project No: 301001-00448 | Figure: 00448-00-EN-DAL-0308 | Rev: 0





LEGEND

- Observation location
- Town
- Existing infrastructure
- Major drainage
- Road
- Study area

Walloons Gas Fields Development Areas

- Combabula / Ramyard
- Woleebee
- Carinya
- Condabri
- Talinga / Orana
- Dalwogan
- Kainama
- Gilbert Gully

Soil groupings combined and interpreted from Department of Natural Resources Land Resources Area maps by WorleyParsons October 2009.

Rev	Date	Revision Description	ORIG	CHK	ENG	APPD
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Figure 5.1f Study Area Soil Types
Map 6 of 6

Project No: 301001-00448 | Figure: 00448-00-EN-DAL-0309 | Rev: 0

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5.2 Soils field assessment

5.2.1 Soil types and occurrence

Soils at 31 locations within the study area were described in accordance with the Australian Soil and Land Survey Field Handbook (McDonald et al. 1990) and the Australian Soil Classification (Isbell, 1996) [refer Table 1, Appendix B]. The majority of soils sampled generally correlated to mapped soil types (refer Section 5.1.1 and Table 1, Appendix B). Discrete soil samples were collected at all 31 locations. Table 5.3 provides a description of the soils encountered against the mapped soil types (refer Table 5.2) in which they occur (refer Figure 5.1).

Table 5.3 Soil group descriptions

Mapped soil group (Table 5.2)	Occurrence*	Field description (ASC)
1a	Not encountered	N/A
1b	S1	TE
	S2	KU
	S23	RU
1c	S25	RU
2a	Not encountered	N/A
2b	S3	KU
	SWL1a	SO
2c	S7, S19	SO
	S10, S15, S18	CH
	S12, S16	RU
2d	SWL2a	SO
3a	Not encountered	N/A
3b	Not encountered	N/A
3c	Not encountered	N/A
4a	S21	DE
4b	S9	DE
4c	Not encountered	N/A
5a	Not encountered	N/A
5b	S20	VE
5b(m)	SWL3a	VE
5c	Not encountered	N/A

Mapped soil group (Table 5.2)	Occurrence*	Field description (ASC)
5(m)	Not encountered	N/A
No match to mapping	S1a, S24	AN
	S4, S14, S17	TE
	S5, S26	VE
	S6	CH
	S8	RU
	SWL4a	SO
	S11	KA
	S13, S22	DE

Notes: HY – Hydrosols, RU – Rudosols, TE – Tenosols, SO – Sodosols, CH – Chromosols, VE – Vertosols, SO – Sodosols, DE – Dermosols, KA – Kandosols, AN - Anthroposols

Field classifications indicate the majority of soils encountered within the study area are either texture contrast (Kurosols / Chromosols / Sodosols) or skeletal soils (Rudosols / Tenosols). Several Anthroposols were also encountered. This is expected as the pipeline study area generally follows existing road easements and fence lines. Few fine textured clays (Vertosols / Dermosols) were encountered.

5.2.2 Topsoil thickness

Within this report, topsoil refers to the surface layer of soil which generally contains organic material and classified as the A1 horizon within Table 1, Appendix B. Using the A horizon thickness classification provided in the Australian Soil Classification (Isbell 1996) for Chromosols, Kurosols and Sodosols (refer Table 5.4), topsoil thicknesses within the study area have been rated and provided in Table 5.5. This should be regarded as indicative only as there can be marked variation in depth, even within very short distances, due to origin of the topsoil, formation processes, pedological issues, slope, erodibility and land use effect. The topsoil depths for all borehole locations are provided in Table 1, Appendix B.

Table 5.4 Topsoil thickness classification

Horizon thickness (m)	A horizon thickness rating
<0.1	Thin
0.1-0.3	Medium
0.3-0.6	Thick
>0.6	Very thick

Table 5.5 Study area topsoil thickness

Soil type	A1 horizon thickness rating	Typical thickness
1a	Not encountered	Thick
1b	Thin – very thick	Thin
1c	Thick	Thin
2a	Not encountered	Thick – very thick
2b	Medium – thick	Thin – medium
2c	Medium - thick	Thin – medium
2d	Medium	Thick – very thick
3a	Not encountered	Thin – medium
3b	Not encountered	Medium – thick
3c	Not encountered	Thin – thick
4a	Medium	Thin – very thick
4b	Thin	Medium – thick
4c	Not encountered	Thin – thick
5a	Not encountered	Medium – thick
5b	Medium	Medium – thick
5c	Not encountered	Medium – thick
5b(m)	Thin - thick	Medium – thick

Based on field classifications, topsoils were variable in thickness throughout the study area. A site specific assessment will be required prior to disturbance to ascertain the appropriate depth of topsoil to be stripped and segregated from subsoil for later use during rehabilitation works.

5.2.3 Sodic soils and dispersion

Sodicity

Sodicity is a measure of exchangeable sodium (Na) in relation to other exchangeable cations and leads to clay dispersion in the soil (Hazelton and Murphy 2007). Sodic soil can cause severe surface crusting, have low infiltration and hydraulic conductivity, become very hard and is highly susceptible to gully and tunnel erosion (Hazelton and Murphy 2007). Sodicity can be rated by calculating the proportion of exchangeable Na cations to the sum of all exchangeable cations, which is referred to as Cation Exchange Capacity (CEC). This proportion is known as the Exchangeable Sodium Percentage (ESP):

ESP = Exchangeable Na / CEC

Table 5.6 provides sodicity ratings in Australia, which have been applied to the soil results presented in Table 2, Appendix B.

Table 5.6 Sodicity and ESP ratings (Hazelton and Murphy 2007)

Sodicity rating	ESPs proposed for Australian soils (%)
Non-sodic	0-6
Marginally sodic to sodic	6-14
Strongly sodic	>14

Calculated ESP levels ranged from 0.9% (S14/0.2-0.3) [non-sodic] to 41.5% (S3/0.9-1.0) [strongly sodic] with the majority of results reported as non-sodic. Nearly all samples (all but six) which reported sodic to strongly sodic results were subsoils. The remaining six samples were topsoils. With the exception of S7/0.0-0.1 and S21/0.0-0.1, the topsoil samples had higher proportions of magnesium to calcium and also high concentrations of sodium which contributes to these results. This may be the result of previous disturbance and/or erosion processes.

Sodic to strongly sodic ratings calculated for coarser textured soils (that is, S9/0.8-0.9) are likely to result from the small fraction of finer textured material within these soils. These soils are still likely to erode (refer Section 5.2.4) but not because of clay dispersion: their lack of soil structure, limited organic material and higher slope makes them susceptible to erosion.

Sodic to strongly sodic fine textured (that is, mainly within soil groups 2, 4 and 5) subsoils will require careful management and should be kept separate from non-sodic soils if excavated. Additionally, sodic to strongly sodic coarse textured (that is, mainly within soil groups 1, 2 and 3) soils will also require careful management and separation of the subsoil.

Although no samples were collected within soil group 6, these are not expected to be dispersive due to high salinity. These soils will require separate management methods, detailed in Section 7.3.6.

Emerson dispersion results reported for samples collected and analysed within the study area range from non-dispersible (8) to very dispersible (1) with just under half the samples tested for dispersion reported as very dispersive (refer Table 5.8). Field observations where erosion was noted as moderate to severe occurred in mapped soil groups 1b and 2c. A single moderate erosion rating was noted in soil group 5b(m).

The majority of Emerson dispersion results correlate with sodicity results. However those which do not (S1/0.4-0.5, S1A/0.3-0.4, S6/0.3-0.4, S9/0.5-0.6, S10/0.9-1.0, S11/0.9-1.0, S22/0.3-0.4, S25/0.3-0.4, SWL2a/0.3-0.4, SWL2a/0.8-0.9) have higher concentrations of salts (chloride and sulfate) which assist in soil bonding, thereby limiting dispersion.

Sodium adsorption ratio

The sodium adsorption ratio (SAR) describes the activity of the sodium (Na) ion relative to that of calcium (Ca) and magnesium [Mg] (Hazelton and Murphy 2007). It is an indirect measurement of sodicity and is calculated as follows:

$$SAR = Na^{+} / \left(Ca^{2+} + Mg^{2+}\right)^{1/2}$$

Calculated SAR values ranged from 0.02 meq/100g (S7/0.8-0.9, S8/0.0-0.05) to 2.17 meq/100g (S3/0.9-1.0) [refer Table 2, Appendix B]. This range is considered low to high. However, the central tendency of data (0.06 meq/100g to 0.625 meq/100g) indicates sodicity in soils throughout the study area is relatively low. Notably, the highest SAR values calculated were for fine textured subsoils – Kurosols, Sodosols, Vertosols and a single Dermosol – while the lowest were calculated for coarse textured Sodosols, Chromosols, Kanodols, Rudosols, Tenosols and only some Vertosols.

This data indicates sodium activity within the fine textured subsoils of Kurosols, Sodosols and Vertosols is high and therefore correlates well with the ESP data above. With the exception of S6, S9, S21, S22 and SWL3a, samples with both high SAR values and high sodicity results occur in soil groups 1 and 2. As a result, clay dispersion in these soils may require additional focus in terms of erosion control and rehabilitation.

5.2.4 Soil erodibility

The assessment of erosion potential for an area of land needs to take into account the particular soil properties that may induce or inhibit erosion. It is a function of the soil's structural stability and its capacity to absorb rainfall and minimise runoff.

Soils within the study area were assessed according to the classification system described in Table 5.7.

Table 5.7 Erosion potential classification

Field observation	1 – Nil or minor erosion associated with land use	1 or 2 – Little erosion, surface slope wash features	2 – Little erosion, surface slope wash features	2 or 3 – Slope wash, rill, tunnelling and gully erosion	3 – Slope wash, rill, tunnelling and gully erosion
Emerson dispersion class	Class 5 - 8 soils are slightly or non-dispersible. Aggregates disperse at a water content intermediate between field capacity and that of a suspension. Not highly susceptible to erosion.	Class 4 soils are slightly or non-dispersible. Do not disperse after remoulding but contain minerals such as calcite or gypsum. Not highly susceptible to erosion.	Class 3 means soils are slightly dispersible. After remoulding, show dispersion. Soils are generally stable. Gypsum application can reduce crusting.	Class 2 means soils are moderately dispersible. Aggregates slake and partly disperse. Indicate some degree of tunnelling susceptibility	Class 1 means soils are very dispersible. Aggregates slake and disperse completely leaving only sand grains in a cloud of clay. Indicate high tunnelling susceptibility.
Salinity (µS/cm)	< 70 – 150 (sand soils) to 150 – 300 (clays Very low-to-low	150 – 340 (sandy soils) to 300 – 700 (clays) Medium	340 – 630 (sands) to 700 – 1180 High salinity rating.	630 – 930 (sands) to 1180 – 1870 (very high salinity	> 930 (sands) to > 1870 (clays) Extreme salinity rating.

	salinity rating. Sensitive to moderately sensitive crops	soil salinity rating. Moderately tolerant crops	Tolerant crops	rating). Very tolerant crops.	Generally too saline for crops
Erosion potential classification, based on field observations and Emerson dispersion class	1 – nil / slight potential.	1 or 2 – sheet / wind / small scalds may develop.	2 – sheet / wind / small scalds may develop.	3 – gully or sheet and significant scalds may develop or 4 major gullies may develop.	4 – gully or sheet and significant scalds may develop or 4 major gullies may develop.

According to this system, the erosion potential for each soil sample submitted for analysis has been assessed and is shown in Table 5.8. Laboratory reports are presented in Appendix D. It should be noted that other soil properties also affect soil erodibility including soil coherence, infiltration and permeability, topsoil depth and texture (including presence of stone), etc. These factors have generally been taken into account in Section 5.2.5.

Table 5.8 Soil erosion parameters

Sample location	Sample	Mapped soil group	Field ASC	Field slope class	Emerson value	Current landuse	ECe	Erosion potential (field observations)	Erosion potential if area disturbed (i.e vegetation removed)
S1	0.4-0.5	1b	TE	1	8	Road reserve	1805	2	2
S1A	0.3-0.4	1b	AN	2	8	Road reserve	5520	1	2
S2	0.7-0.8	1b	KU	1	1	Road reserve	2784	2	4
S3	0.9-1.0	2b	KU	1	1	Road reserve	870	1	3
S5	0.9-1.0	1b	VE	2	1	Grazing	5452	1	3
S6	0.3-0.4	5b(m)	CH	2	4	Grazing	3600	2	2
S6	0.9-1.0	5b(m)	CH	2	1	Road reserve	1050	2	4
S7	0.4-0.5	2c	SO	1	1	Road reserve	1376	1	3
S7	0.8-0.9	2c	SO	1	1	Road reserve	1380	1	3
S9	0.5-0.6	4b/5b	DE	1	5	Road reserve - grazing	1856	1	2
S9	0.8-0.9	4b/5b	DE	1	2	Road reserve - grazing	2550	1	2
S10	0.9-1.0	2c	CH	1	6	Road reserve - grazing	1118	2	2
S11	0.9-1.0	2c	KA	1	8	Road reserve - grazing	570	1	1
S13	0.9-1.0	2c/5b	DE	1	4	Road reserve - grazing	1275	1	2
S14	0.2-0.3	2c/5b	TE	2	5	Road reserve - grazing	516	1	2
S14	0.9-1.0	2c/5b	TE	2	4	Road reserve - grazing	946	1	2
S15	0.9-1.0	2c	CH	1	5	Road reserve - grazing	1118	1	1
S17	0.9-1.0	2c	TE	2	5	Road reserve - grazing	475	2	2
S18	0.9-1.0	2c	CH	2	8	Road reserve - grazing	1050	1	2
S19	0.9-1.0	2c	SO	1	5	Grazing	430	1	1
S20	0.9-1.0	5b	VE	1	4	Grazing	3010	1	1
S21	0.9-1.0	4a	DE	1	1	Grazing	1450	1	3
S22	0.3-0.4	2c/5b	DE	1	7	Road reserve - grazing	516	1	1
S23	0.9-1.0	1b	RU	1	2	Road reserve	190	1	2
S24	0.3-0.4	1c	AN	3	1	Road reserve	1102	1	3
S25	0.3-0.4	1c	RU	2	8	Natural	285	1	2
S26	0.9-1.0	2c	VE	1	2	Road reserve - grazing	754	1	2
SWLa	0.6-0.7	2b	SO	2	1	Road reserve - grazing	1892	3	4
SWL2a	0.3-0.4	2d	SO	1	5	Road reserve	1634	1	2
SWL2a	0.8-0.9	2d	SO	1	4	Road reserve	1995	1	1
SWL3a	0.4-0.5	5b(m)	VE	1	1	Grazing	7366	1	2
SWL4a	0.9-1.0	1b	SO	1	2	Road reserve - grazing	675	1	2

The above table indicates that most locations where soils were sampled had a low existing erosion

potential (due mainly to existing ground cover and land use); however, with disturbance, the potential is substantially increased.

Based on the classification system provided in Table 5.7, field observations (including texture classifications), Emerson dispersion test results, sodicity ratings and photography have been used to generate classifications for erosion potential provided in Table 5.8. Where vegetative cover has been removed (that is, for development), soils with a classification of 3 or 4 will require focused management as they are highly susceptible to erosion. Soils with an erosion classification of 2 or lower are less likely to erode as a result of non-sodic or high salinity concentrations which limit dispersion.

5.2.5 Overall erosion hazard

The overall classifications for soil erosion potential provided in the last column of Table 5.8 have been used to determine the overall erosion risk for the tenements (refer Section 5.2.1). These are provided in Table 5.9 and illustrated on Figure 5.2.

This table is based on the principle of the more susceptible a soil is to erosion and the steeper the slope, the greater the overall erosion hazard.

Table 5.9 Soil group erosion ratings

Soil group	Soil erodibility ranking*	Slope category				
		1 (0-2%)	2 (2-8%)	3 (8-15%)	4 (15-30%)	5 (30%+)
1a	2	L	N/A	N/A	N/A	N/A
1b	1-2	VL	L	M	H	VH
1c	1-2	VL	L	M	H	VH
2a	2	L	N/A	N/A	N/A	N/A
2a(i)	1	L	N/A	N/A	N/A	N/A
2a(ii)	2	M	N/A	N/A	N/A	N/A
2b	4	M	H	S	S	N/A
2b(i)	3	M	H	VH	VH	N/A
2b(ii)	4	H	VH	S	S	N/A
2c	4	M	H	S	S	N/A
2c(i)	3	M	H	VH	VH	N/A
2c(ii)	4	H	VH	S	S	N/A
2d	2	M	H	VH	N/A	N/A
2d(i)	1	M	H	VH	N/A	N/A
2d(ii)	2	M	H	VH	N/A	N/A
3a	2-3	L	M	H	VH	S
3b	1-2	VL	L	M	N/A	N/A

Soil group	Soil erodibility ranking*	Slope category				
		1 (0-2%)	2 (2-8%)	3 (8-15%)	4 (15-30%)	5 (30%+)
3c	2	L	M	H	VH	S
4a	1	VL	N/A	N/A	N/A	N/A
4b	2	L	M	H	VH	N/A
4c	2	VL	L	M	H	N/A
5a	1	VL	N/A	N/A	N/A	N/A
5b	1	VL	L	M	N/A	N/A
5c	1	VL	L	M	H	N/A
5b(m)	1	VL	L	N/A	N/A	N/A
6	1	L	N/A	N/A	N/A	N/A

Notes

Soil erodibility: 1: low 2: moderate 3: high 4: very high

Erosion hazard: VL: very low L: low M: moderate H: high VH: very high S: severe

N/A: Soil group unlikely to occur on such slopes

Based on the erosion ratings provided in Table 5.9, soil groups 2b and 2c have the highest erosion rating; however, where slope is a factor, the erosion hazard for all soil groups increases. This is particularly notable in the coarser textured soil groups 1, 2 and 3 where there is little structure and organic matter to help bind soil and resist erosion. This also contributes to the lower (meaning more dispersible) Emerson dispersion test results for soils tested within these soil groups. Examples of this erosion were observed throughout the study area (refer Plate 5.1 to Plate 5.7). Notably, these examples occur where vegetation had been cleared for agriculture or infrastructure development purposes (for example, adjacent to roads, fences and creeks) and where stabilisation and/or rehabilitation measures were either unsuccessful or not implemented. Specific measures (refer Section 7.3.3) to minimise soil erosion in areas disturbed by the gas pipeline construction should be implemented to prevent such erosion.

Plate 5.1 EROS001: Soil Group 2c

Plate 5.2 EROS002: Soil Group 2c

Plate 5.3 EROS003: Soil Group 1b

Plate 5.4 EROS004: Soil Group 2b

Plate 5.5 EROS005: Soil Group 2b

Plate 5.6 EROS006: Soil Group 1b

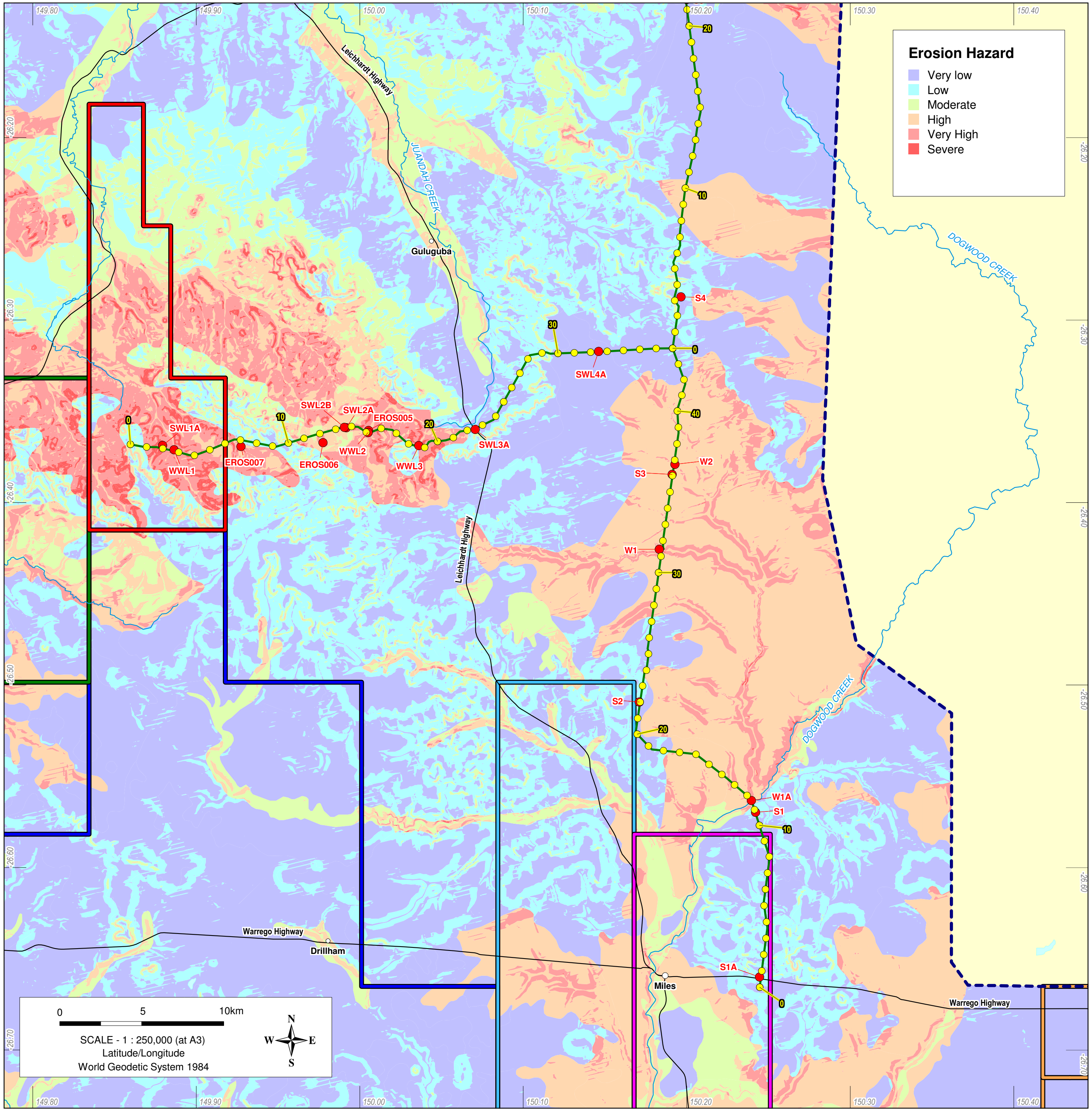
Plate 5.7 EROS007: Soil Group 1b

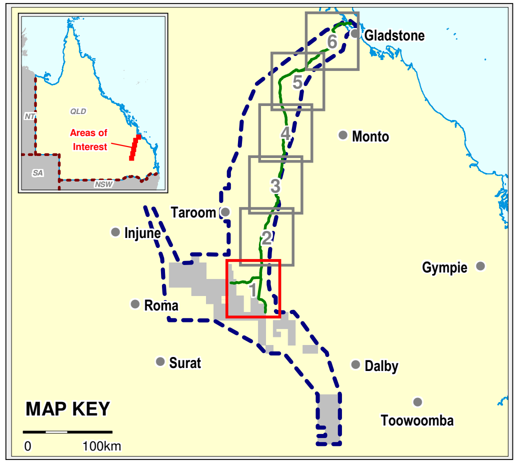
Based on the assessment illustrated in Figure 5.2, the following table presents a summary of the overall erosion hazard within the study area.

Table 5.10 Gas pipeline erosion hazard (incorporating 40m RoW)

KP location along proposed pipeline route	Very low to moderate	High to severe
Condabri Lateral KPs	Refer to Figure 5.2	11 – 18, 27 - 42
Wolleebee Lateral KPs	Refer to Figure 5.2	1 – 7, 10 – 22
Main gas pipeline KPs	Refer to Figure 5.2	8 – 10, 26-31, 36 – 51, 56 – 59, 61, 69, 89 – 102, 104 – 223, 226 – 228, 232 – 236, 243 – 250, 256 – 302, 305 – 306, 313 – 331, 341 – 348, 350 - 351

Each level of erosion hazard – that is, from very low to severe – requires a different level of project planning and management, particularly during the construction phase. Clearly, areas designated with a very high to severe rating will require intensive construction planning, erosion protection measures and rehabilitation strategies. General mitigation measures, described in Section 7, include topsoil and subsoil management (stripping, stockpiling, respreading), sediment and erosion control and slope and drainage line management.





LEGEND

- Observation location
- Town
- Road
- Preferred pipeline alignment
- Major drainage
- Reservoir
- Study area

Walloons Gas Fields Development Areas

- Combabula / Ramyard
- Woleebee
- Carinya
- Condabri
- Talinga / Orana
- Dalwogan
- Kainama
- Gilbert Gully

Rev	Date	Revision Description	ORIG	CHK	ENG	APPD
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Figure 5.2a Study Area Erosion Hazard
Map 1 of 6

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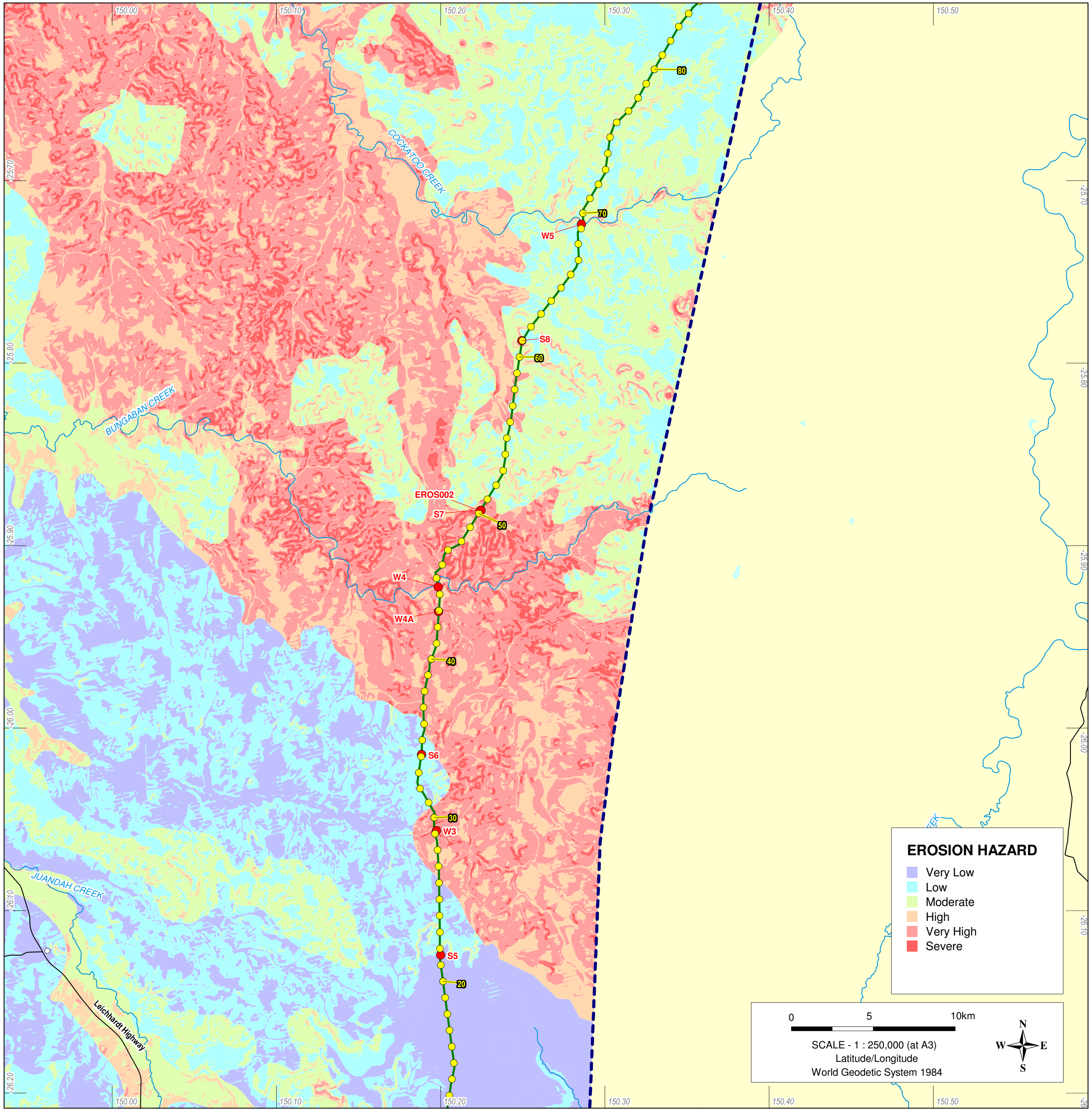

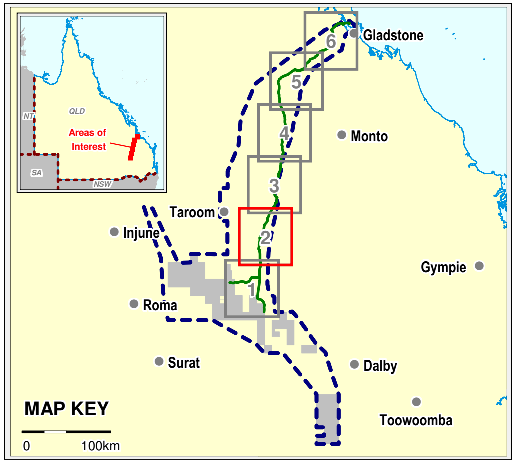

LEGEND

Observation location	Major drainage
Town	Reservoir
Road	Study area
Preferred pipeline alignment	

Walloons Gas Fields Development Areas

Combabula / Ramyard	Talinga / Orana
Woleebee	Dalwogan
Carinya	Kainama
Condabri	Gilbert Gully

Rev	Date	Revision Description	ORIG	CHK	ENG	APPD
0	15/01/2010	Issued for use	JB	MZ		

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Figure 5.2b Study Area Erosion Hazard Map 2 of 6

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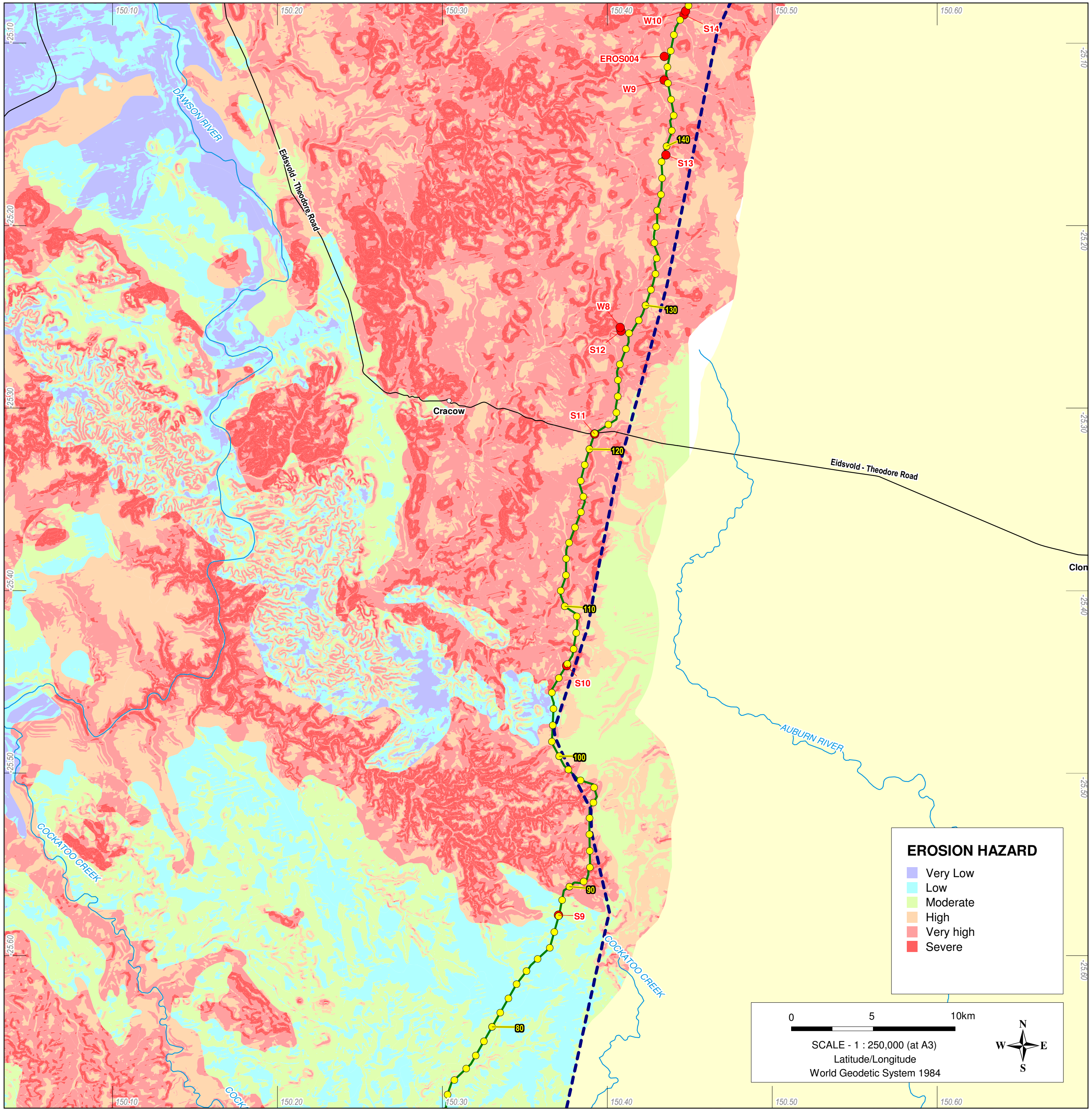

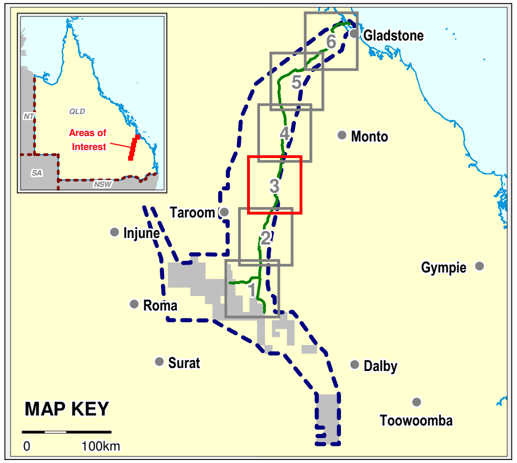

LEGEND

- Observation location
- Town
- Road
- Preferred pipeline alignment
- Major drainage
- Reservoir
- Study area

Walloons Gas Fields Development Areas

- Combabula / Ramyard
- Woleebee
- Carinya
- Condabri
- Talinga / Orana
- Dalwogan
- Kainama
- Gilbert Gully

Rev	Date	Revision Description	ORIG	CHK	ENG	APPD
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AUSTRALIA PACIFIC LNG PROJECT
Figure 5.2c Study Area Erosion Hazard
Map 3 of 6

Project No: 301001-00448	Figure: 00448-00-EN-DAL-0312	Rev: 0

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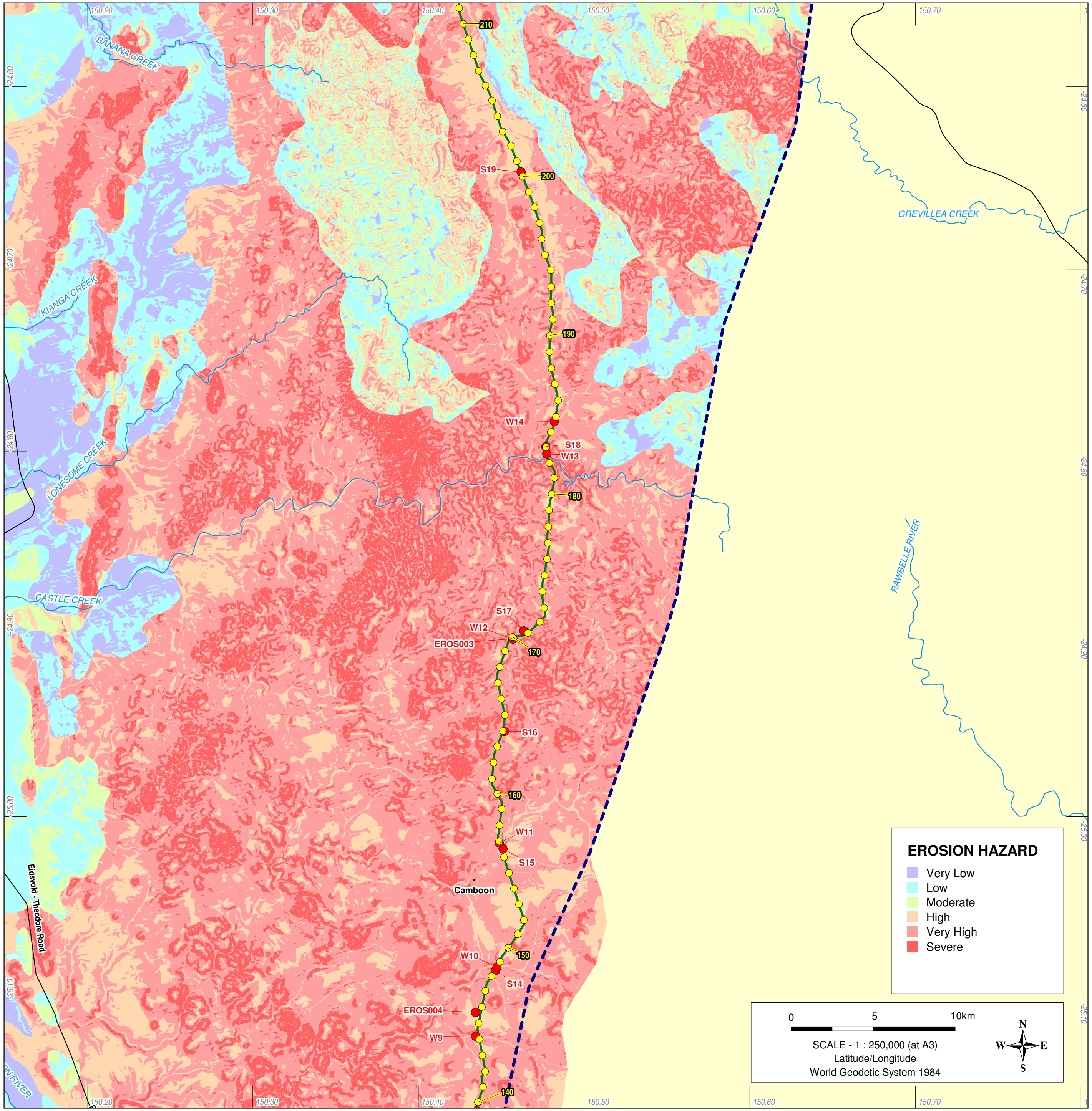
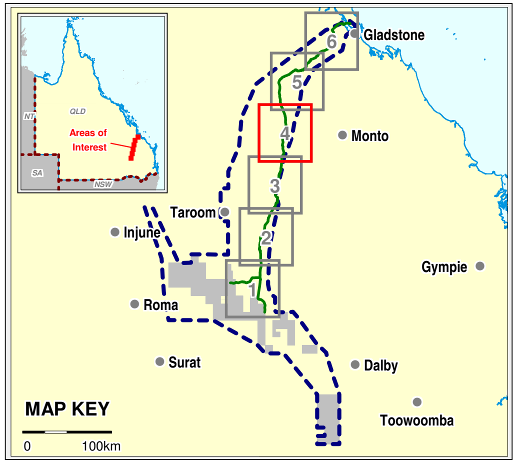


EROSION HAZARD

- Very Low
- Low
- Moderate
- High
- Very High
- Severe

0 5 10km

SCALE - 1 : 250,000 (at A3)
Latitude/Longitude
World Geodetic System 1984



MAP KEY

0 100km

LEGEND

- Observation location
- Pipeline kilometre point
- Town
- Road
- Major drainage
- Pipeline alignment option 3F
- Reservoir
- Study area
- Common infrastructure corridor (CIC)
- Gladstone state development area (GSDA)

Walloons Gas Fields Development Areas

- Combabula / Ramyard
- Woleebee
- Carinya
- Condabri
- Talinga / Orana
- Dalwogan
- Kainama
- Gilbert Gully

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Figure 5.2d Study Area Erosion Hazard
Map 4 of 6

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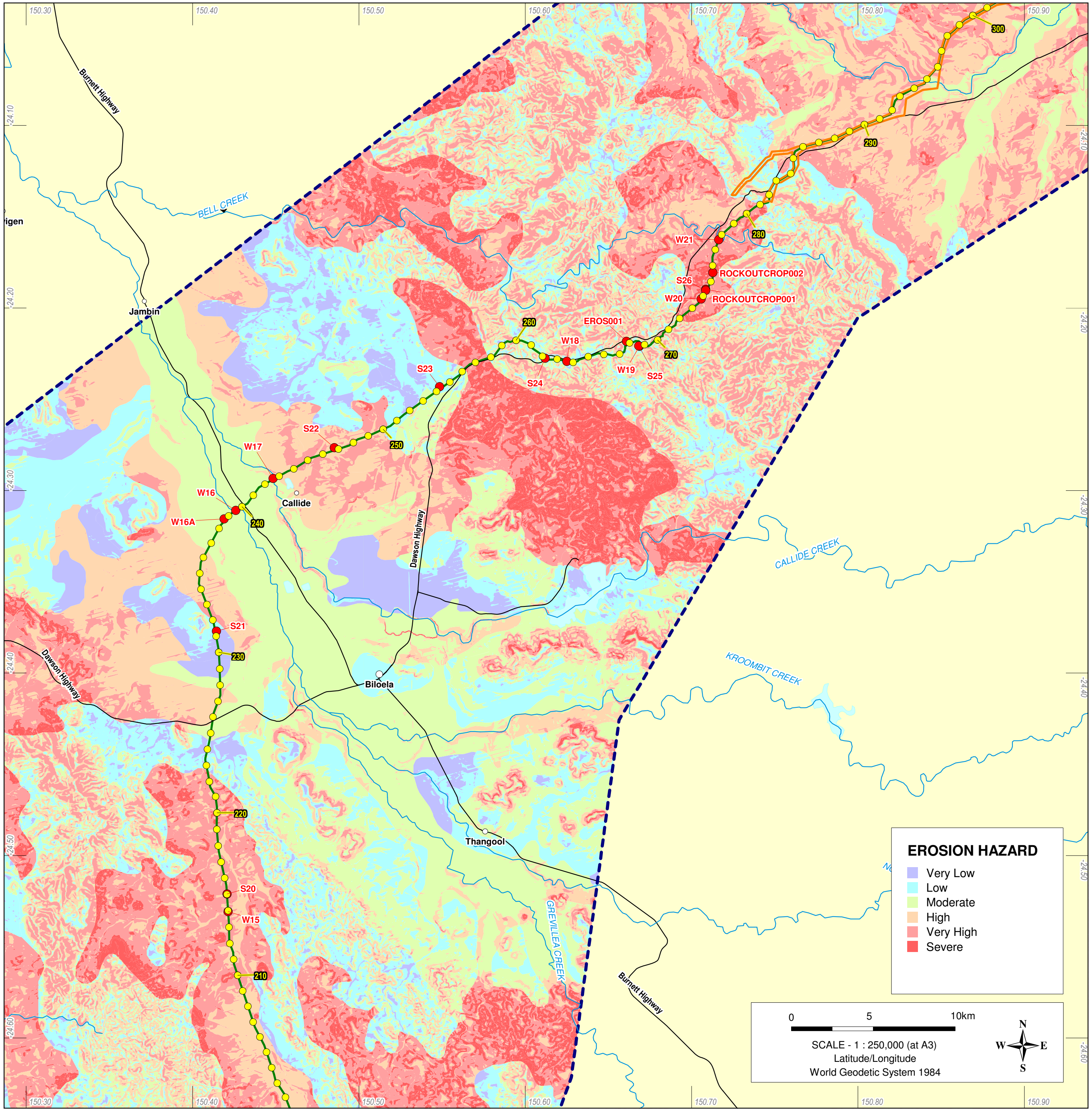

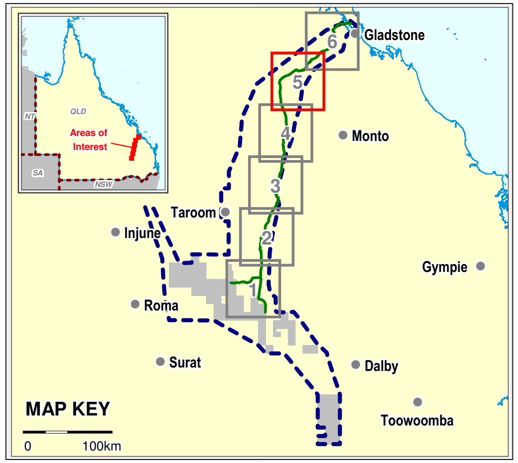

LEGEND

- Observation location
- Town
- Road
- Gas pipeline route
- Major drainage
- Reservoir
- Study area

Walloons Gas Fields Development Areas

- Combabula / Ramyard
- Woleebee
- Carinya
- Condabri
- Talinga / Orana
- Dalwogan
- Kainama
- Gilbert Gully

Rev	Date	Revision Description	ORIG	CHK	ENG	APPD
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AUSTRALIA PACIFIC LNG PROJECT
Figure 5.2e Study Area Erosion Hazard
Map 5 of 6

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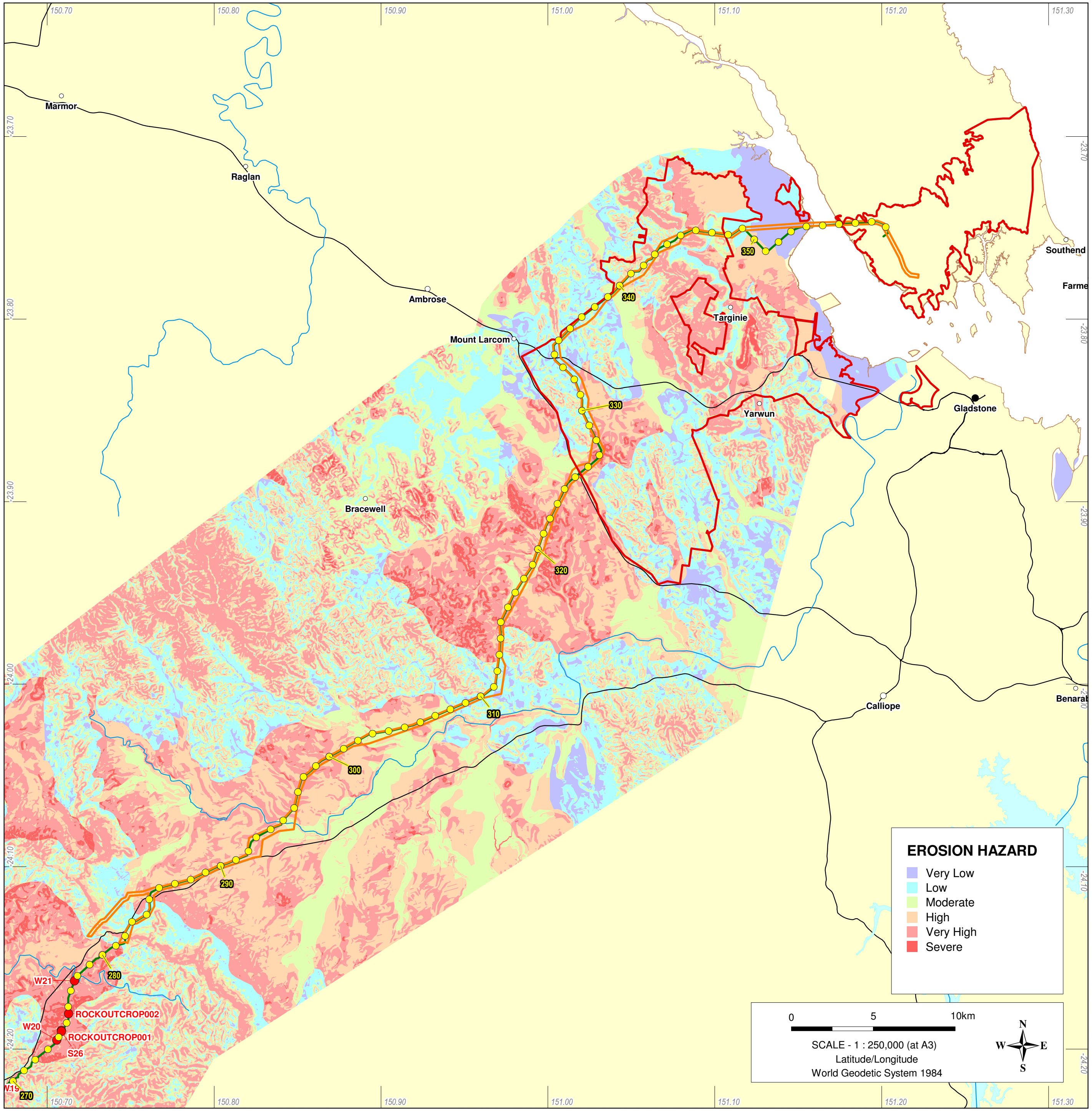

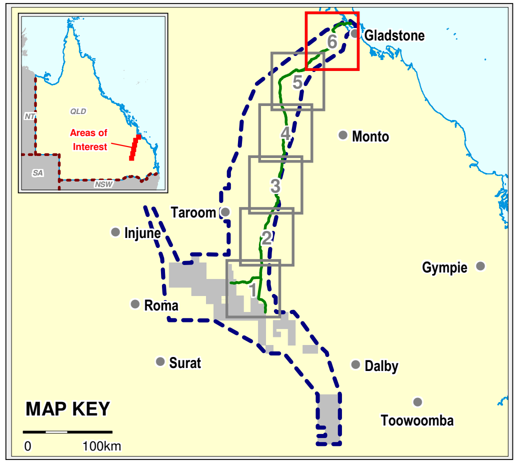

LEGEND

- Observation location
- Town
- Road
- Gas pipeline route
- Major drainage
- Reservoir
- Study area

Walloons Gas Fields Development Areas

- Combabula / Ramyard
- Woleebee
- Carinya
- Condabri
- Talinga / Orana
- Dalwogan
- Kainama
- Gilbert Gully

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Figure 5.2f Study Area Erosion Hazard Map 6 of 6

Project No: 301001-00448 | Figure: 00448-00-EN-DAL-0315 | Rev: 0

5.2.6 Soil pH

Soil pH can be used as an indicator of the chemical processes that occur in a soil – that is, can indicate certain nutrient deficiencies and toxic effects (Hazelton and Murphy 2007), which may have implications for soil management and rehabilitation measures. Table 5.11 presents pH classification ratings used to assess results, while a summary of all results is presented in Table 2, Appendix B.

Table 5.11 pH classification (Hazelton and Murphy 2007)

pH	Rating
> 9.0	Very strongly alkaline
9.0 – 8.5	Strongly alkaline
8.4 – 7.9	Moderately alkaline
7.8 – 7.4	Mildly alkaline
7.3 – 6.6	Neutral
6.5 – 6.1	Slightly acid
6.0 – 5.6	Moderately acid
5.5 – 5.1	Strongly acid
5.0 – 4.5	Very strongly acid

Ranges in pH levels reported for samples collected within the study area, ranged from 4.8 (S2/0.7-0.8, S5/0.9-1.0) to 7.6 (S26/0.9-0.1). This indicates that soils are very strongly acid to mildly alkaline. The central tendency of pH data ranged from 6.2 to 6.8 (neutral) and indicates most soil pH was within the range considered acceptable to plant growth (5 to 7).

Soil samples collected at S1, S1a, S2, S3, S4 and S5 were rated as moderately acidic to very strongly acid. These samples also reported high concentrations of aluminium (Al) (ranging from <1meq/100g to 268meq/100g) which correlates with strongly acidic pH. Notably, these samples all occur within soil group 1b.

This data does not indicate significant constraints; however, if disturbed (that is, through excavation or filling), soils classified as strongly acid should be kept separate from other soils and may require pH amelioration to render them conducive for further use.

Although not tested during this assessment, soils at soil group 6 commonly have a neutral pH in an undisturbed state. If these soils are disturbed, they are likely to become more acidic through oxidation of sulfides. ASS issues are described in Section 5.1.2 and addressed separately in Section 6.3.4.

5.2.7 Salinity

Salinity is the presence of soluble salts in or on soils [mainly Na, but also K, Ca, Mg, sulfate (SO_4) and chloride (Cl)]. High salinity levels in soils may result in reduced plant productivity, including the elimination of native vegetation, and may increase erosion (Hazelton and Murphy 2007).

Table 5.12 presents salinity ratings for soil used to classify results once laboratory EC (1:5) values were converted to ECe, which is the electrical conductivity of the extract obtained from a saturated soil paste. A summary of all results is presented in Table 2, Appendix B.

Table 5.12 Salinity ratings for soil based on ECe (Hazelton and Murphy 2007)

Rating	Electrical conductivity (ECe) (µS/cm)
Non-saline	<2,000
Slightly saline	2,000-4,000
Moderately saline	4,000-8,000
Highly saline	8,000-16,000
Extremely saline	>16,000

Electrical conductivity (ECe) reported for samples collected within the study area ranged from 190µS/cm (S23/0.0.-0.1 and S23/0.9-1.0) [non-saline] to 7366µS/cm (SWL3a/0.4-0.5) [moderately saline]. The central tendency of data was non-saline. Moderately saline concentrations were reported for only three samples (S1A/0.3-0.4, S5/0.9-1.0 and SWL3a/0.4-0.5), all of which had high concentrations of chloride and sulfate. These samples, with the exception of S1A/0.3-0.4, were Vertosols (cracking clays), which retain the majority of salts within subsoils.

The accumulation of salts is an important issue when at or near the surface. A likely cause of this accumulation is lack of leaching due to low rainfall, or elevated salinity in fluctuating near-surface groundwater. The field investigation did not identify any significant areas of salinization or extensive scalding; however, due to the typical nature of subsoils in many soils (notably the 2b, 2c and 5b soil groups), careful management will be required, particularly for rehabilitation purposes.

5.2.8 Fertility

Soil fertility is a function of: (1) the soil's capacity to attract and release exchangeable ions, which is influenced by the amount and type of organic matter and clay; and (2) the presence of nutrients which are available for plant growth, or can be available in the future. In this assessment, Cation Exchange Capacity (CEC), exchangeable ion, Total Kjeldahl nitrogen (TKN) and phosphorus (P) were measured as indicators of soil fertility.

Cation exchange capacity

CEC is a measure of a soil to hold and exchange cations (Hazelton and Murphy, 2007). A soil which has a high CEC has the ability to buffer the effects of changes in pH, available nutrients and structure. High CEC can also indicate a soil's fertility. Table 5.13 and Table 5.14 present the classification of CEC and exchangeable cations which are used to assess soils within the study area, while Table 5.15 presents the fertility results. A summary of all results is presented in Table 2, Appendix B.

Table 5.13 CEC ratings (Hazelton and Murphy 2007)

CEC (meq/100g)	Rating
< 6 (soils low in fertility)	Very low
6 – 12	Low
12 – 25	Moderate
25 – 40	High
> 40	Very high

Table 5.14 Exchangeable cations classification (Hazelton and Murphy 2007)

Cations	Very low	Low	Moderate	High	Very high
Units			(meq/100g)		
Na	0 – 0.1	0.1 – 0.3	0.3 – 0.7	0.7 – 2.0	> 2
K	0 – 0.2	0.2 – 0.3	0.3 – 0.7	0.7 – 2.0	> 2
Ca	0 – 2	2 – 5	5 -10	10 – 20	> 20
Mg	0 – 0.3	0.3 – 1.0	1 - 3	3 - 8	> 8

Ranges of exchangeable ions reported for samples collected within the study area are presented in Table 5.15:

Table 5.15 Exchangeable ions ranges

Analyte (meq/100g)	CEC	Na	K	Ca	Mg	Fe	Al
Unit			meq / 100g			mg / kg	
Value	1.3 – 33.4	<0.1 – 9.8	<0.1 – 3.5	0.1 – 19.4	0.3 – 18.2	<1 - 20	<1 - 268
Rating	Very low to high	Low to very high	Very low to very high	Very low to high	Low to very high	-	-
Central tendency of data	5.55 – 16.3	0.3 – 1.7	0.2 – 0.4	1.75 – 9.4	1.75 – 4.95	1 - 2	1.25 – 63.75

CEC concentrations from very low to high indicate a variable response to fertilization within study area soils. Notably, lower concentrations were reported for sandy and loamy textured soils throughout the study area (predominately soil groups 1 and 2). Higher concentrations were reported from clay textured soils (predominately soil groups 4 and 5). The application of soil additives for fertility, pH or structure amelioration will most likely be required in the sandy textured soils, particularly at soil groups 1, 2 and 3.

Exchangeable cations

Na concentrations were rated as low to very high within study area soils. These values reflect the data reported for ESP and SAR (refer: Section 5.2.3).

Potassium (K) concentrations were rated as very low to very high within study area soils.

Calcium (Ca) concentrations ranged from very low to high within study area soils. Ca concentrations usually decline with depth in the profile. This was the case in most soils; however, in some cases Ca concentrations increased. Where such increases were reported, calcite (denoted by K within field data: Table 1, Appendix B) was usually noted at depth within the profile – that is, at S20, S26, SWL2a and SWL3a.

Magnesium (Mg) concentrations were rated as low to very high and, with the exception of S5, S7, S9, S17 and S19, were generally higher in concentration within subsoils. This is expected as Mg concentrations usually increase with depth in the profile. This data correlates well with pH data which indicates exchangeable Mg should be high as it generally becomes available to plants at pH levels greater than 5.

Exchangeable anions

Exchangeable iron (Fe) concentrations ranged from <1mg/kg to 20mg/kg, while the central tendency of data ranged from 1meq/100g to 2meq/100g, which is considered low. Soils are generally negatively charged, therefore low concentrations of anions (such as Fe) are expected.

Exchangeable aluminium (Al) concentrations ranged from <1mg/kg to 268mg/kg, while the central tendency of data ranged from 50mg/kg to 160mg/kg. High concentrations of Al were reported at S1, S1a, S2, S3, S4 and S5, which also reported low pHs. This is expected as Al generally increases with lower pH. Furthermore, anions concentrations (such as Al) generally increase within weathered or sandy textured soils where cation concentrations are lower.

Nutrients

Table 5.16 presents TKN and P ratings which are used to assess nutrient levels, while a summary of all results is presented in Table 2, Appendix B.

Table 5.16 Soil nutrient level ratings

Analyte	Very low	Low	Moderate	High	Very high
Nitrogen (total) (N) (% weight)	0.05	0.05 – 0.15	0.15 – 0.25	0.25 – 0.5	> 0.5
Phosphorus (P) (mg/kg)	5	5 – 10	10 – 17	17 – 25	> 25

Only topsoil samples were analysed for nutrients TKN and P. These concentrations were as follows:

- Concentrations of TKN ranged from <0.01% (S14/0.0-0.1) [very low] to 0.18% (S8/0.0-0.05) [moderate], while the central tendency of data was also very low to low (0.04% to 0.07%). These concentrations were reported for both coarse and fine textured topsoils. As a significant portion of total soil N is stored within organic matter, it may be used as an indicator for organic matter in soil. These results indicate there is a low organic matter content in most study area topsoils.
- Concentrations of P ranged from 0.4mg/kg (S23/0.0.-0.1) [very low] to 21mg/kg (S8/0.0-0.05) [high], while the central tendency of data ranged from 1.05mg/kg (very low) to 2.65mg/kg (very low). These results indicate that most study area topsoils (both coarse and fine textured) are deficient in P and therefore may require the addition of P fertiliser to support plant growth during revegetation.

These results indicate that topsoils sampled within the study area are low in fertility. However, it should be noted that some Vertosols and Dermosols (where topsoil texture is commonly a clay loam or loamy clay) can have moderate to high fertility levels.

5.2.9 Bulldust

Bulldust formation is common in arid areas and is more likely to occur in soils with high silt and fine sand content as well as those with high calcium carbonate content. Bulldust will generate wind-blown dust and cause dry bogging of vehicles and equipment. Once a soil turns into bulldust, it is very difficult to manage. Grading the bulldust and returning it to the track, a little at a time and wetting it constantly may have some success. Once bulldust has been generated, final rehabilitation and revegetation may be difficult because the soil structure has been destroyed.

Significant levels of bulldust were not observed within the study area; however this does not preclude its development. Loamy soils, particularly soils located within soil groups 1, 2 and 3, are prone to generate bulldust if vegetation is cleared and topsoil heavily trafficked through project development. In addition, soils with appreciable concentrations of Ca may also exacerbate bulldust generation.

As most surface layers of soil within the study area have generally loamy textures, bulldust generation is expected to be widespread if appropriate dust mitigation is not implemented throughout project construction and operation (refer Section 7.3.8).

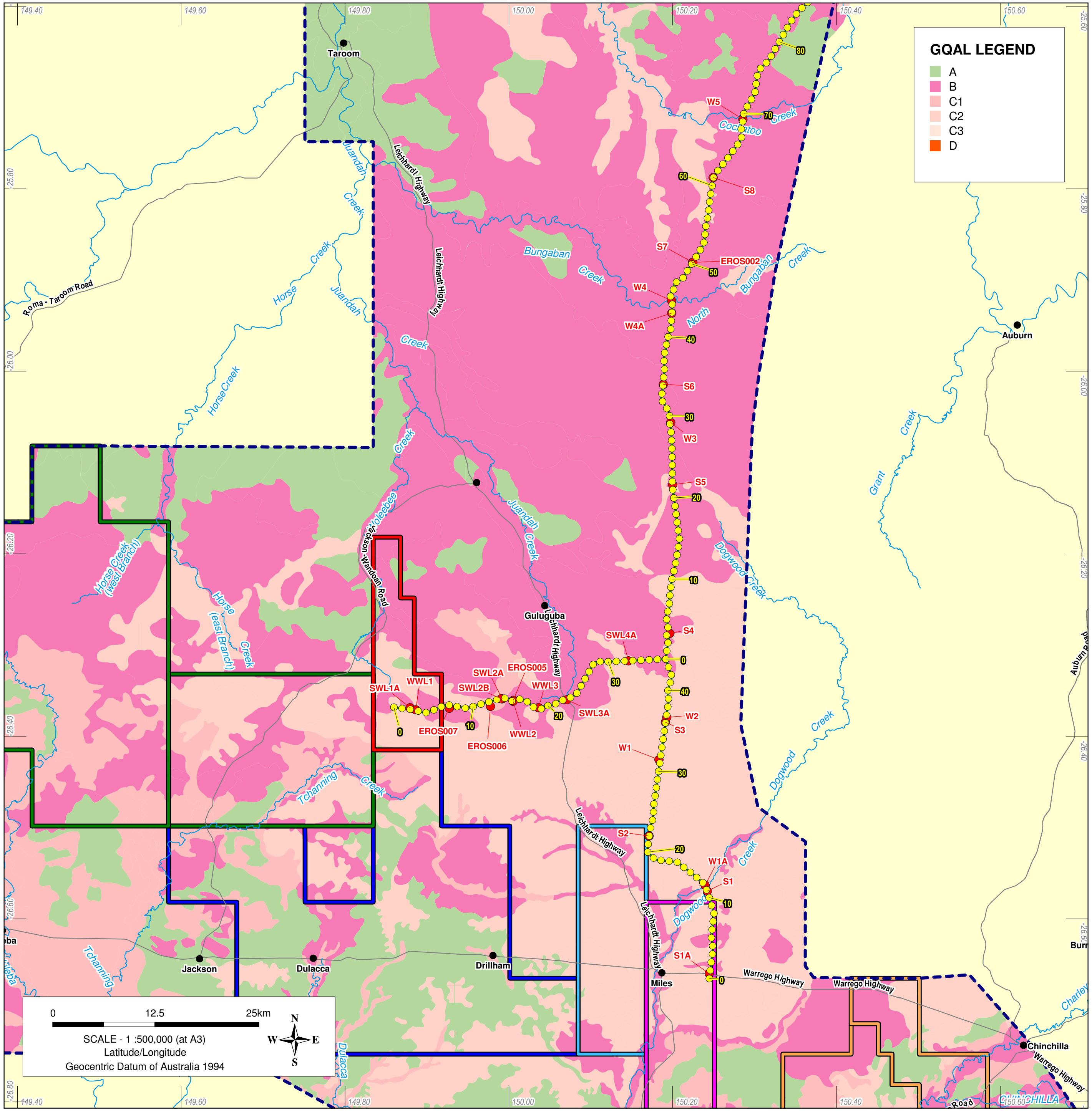
5.3 Agricultural land capability

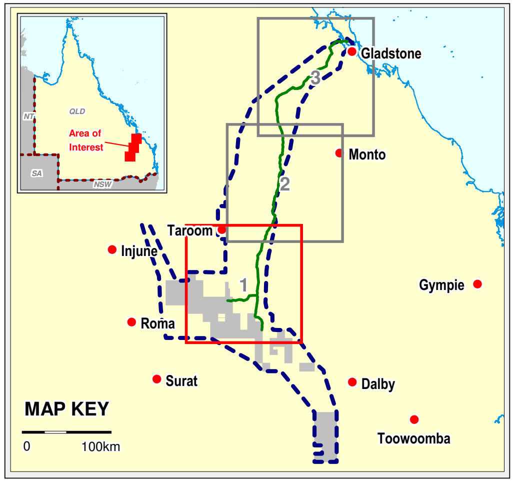
Land systems mapping produced by those reports described in Section 5.1.1, have been used as the basis for determining what areas are considered to be GQAL as per State Planning Policy 1/92 (refer Section 1.1.5). This DERM mapping is presented as Figure 5.3. Table 5.1 presents the GQAL classification for each of the land systems within the study area.

Agricultural land has been classified into four groups, as described in Table 5.17

Table 5.17 Agricultural land classes (Source: DHLGP 1993)

Class	Description
A	**Crop land** Land that is suitable for current and potential crops with limitations to production, ranging from none to moderate levels. There are two sub-classes of crop land: A1 – Crop land suitable for rainfed 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.
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 is considered to be GQAL.
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.





LEGEND

- Observation location
- Town
- Road
- Gas pipeline route
- Major drainage
- Study area

Walloons Gas Fields Development Areas

- Combabula / Ramyard
- Woleebee
- Carinya
- Condabri
- Talinga / Orana
- Dalwogan
- Kainama
- Gilbert Gully

Rev	Date	Revision Description	ORIG	CHK	ENG	APPD
0	04/01/2010	Issued for use	JB	MZ		

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Figure 5.3a Study Area Good Quality Agricultural Land - Map 1 of 3

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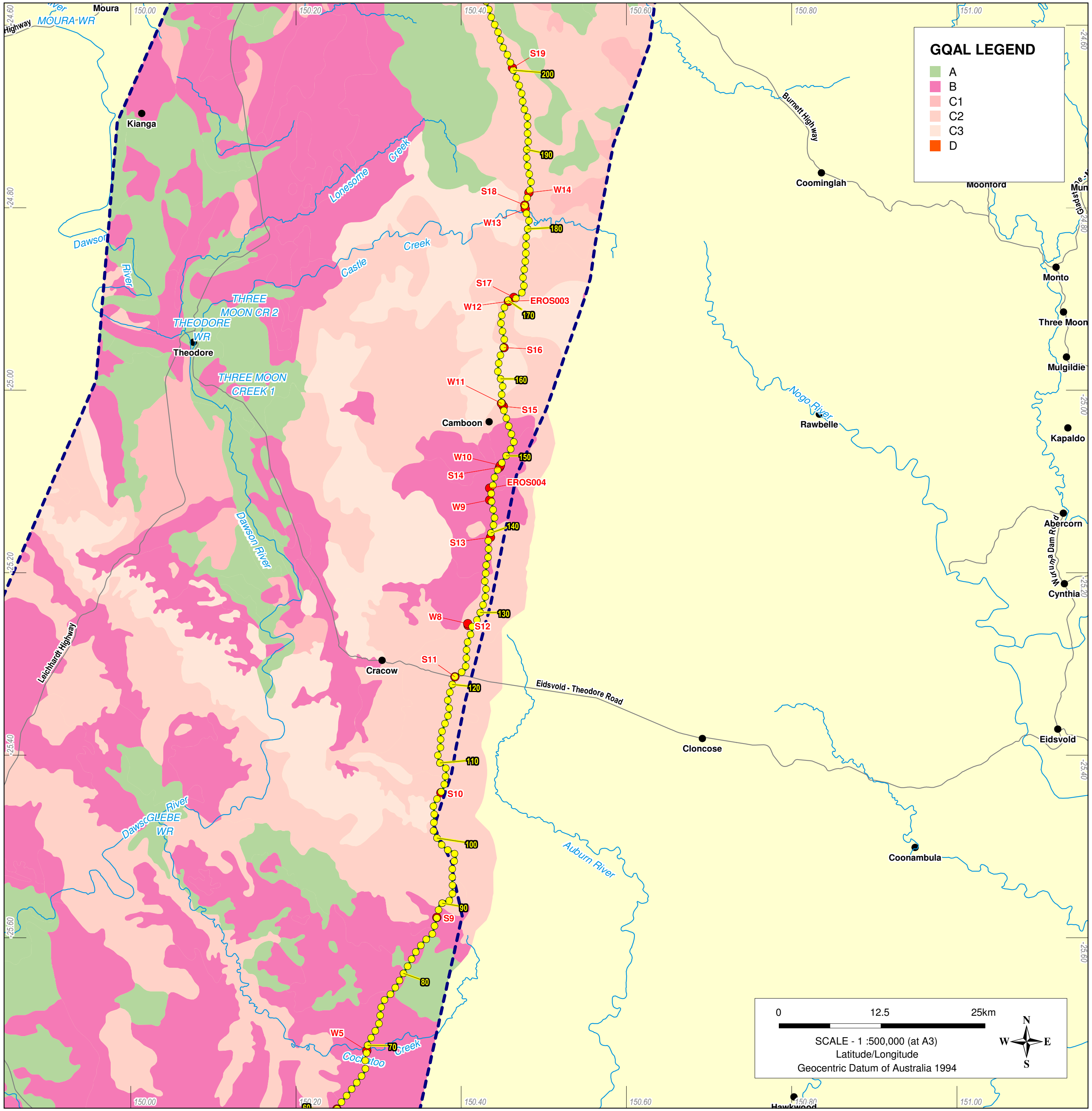

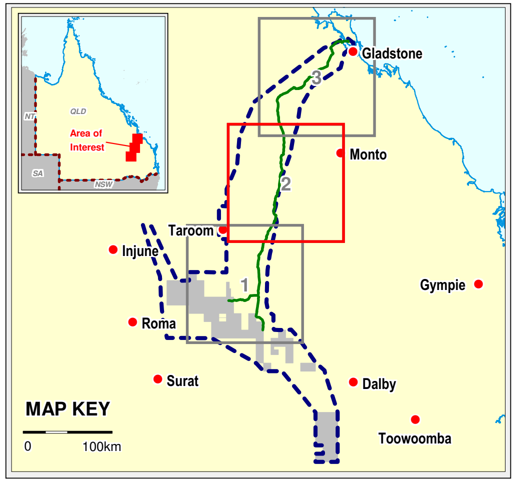

LEGEND

- Observation location
- Town
- Road
- Gas pipeline route
- Major drainage
- Study area

Walloons Gas Fields Development Areas

- Combabula / Ramyard
- Woleebee
- Carinya
- Condabri
- Talinga / Orana
- Dalwogan
- Kainama
- Gilbert Gully

Rev	Date	Revision Description	ORIG	CHK	ENG	APPD
0	04/01/2010	Issued for use	JB	MZ		

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Figure 5.3b Study Area Good Quality Agricultural Land - Map 2 of 3

Project No: 301001-00448 | Figure: 00448-00-EN-DAL-0317 | Rev: 0

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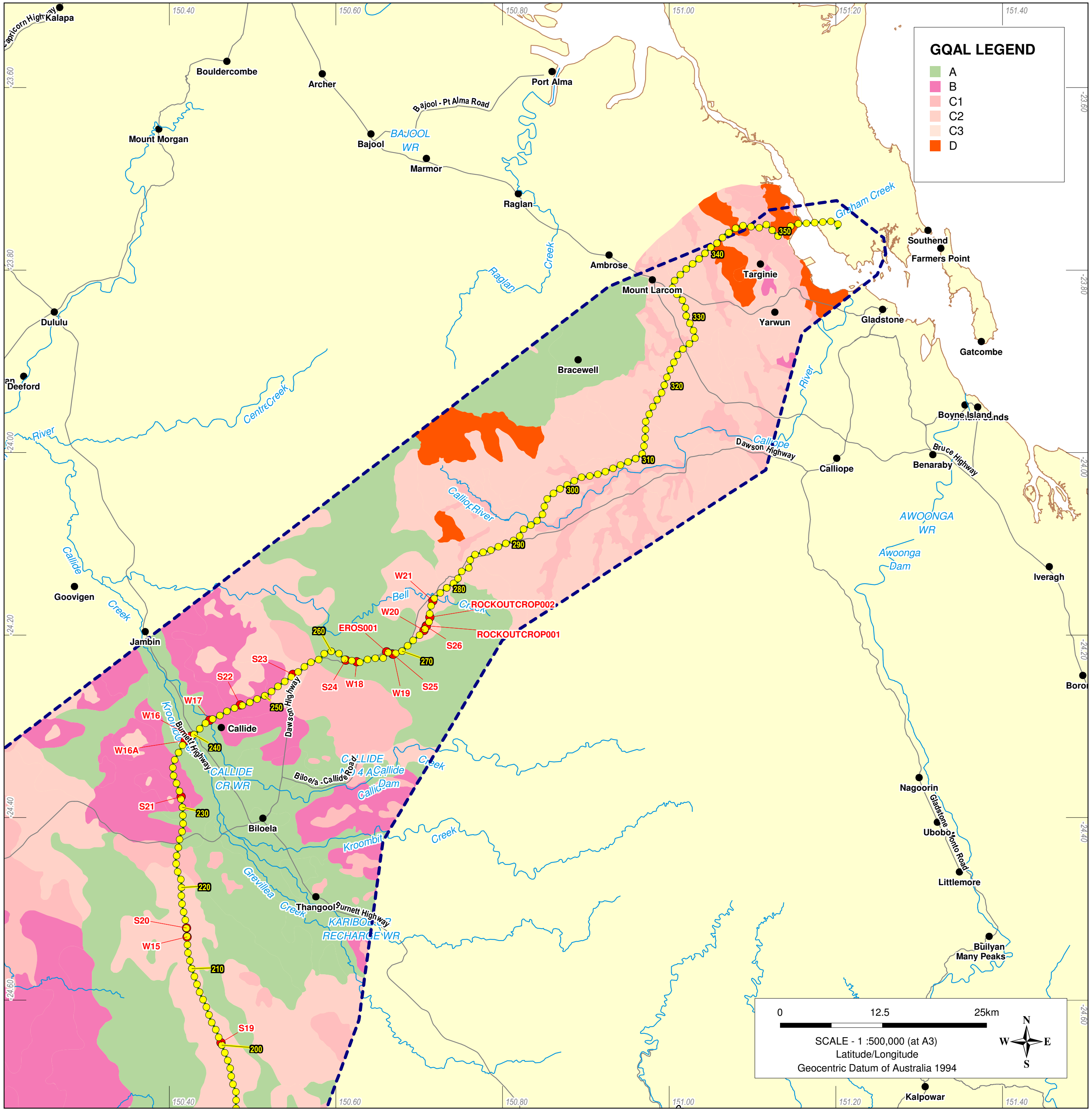

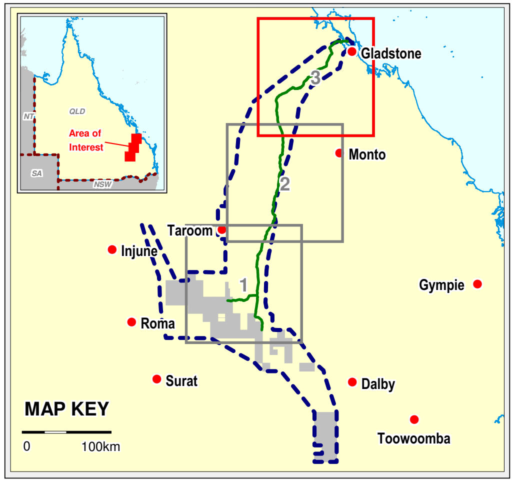

LEGEND

- Observation location
- Town
- Road
- Gas pipeline route
- Major drainage
- Study area

Walloons Gas Fields Development Areas

Combabula / Ramyard	Talinga / Orana
Woleebee	Dalwogan
Carinya	Kainama
Condabri	Gilbert Gully

Rev	Date	Revision Description	ORIG	CHK	ENG	APPD
0	04/01/2010	Issued for use	JB	MZ		

WorleyParsons

AUSTRALIA PACIFIC LNG PTY LIMITED

AUSTRALIA PACIFIC LNG PROJECT
Figure 5.3c Study Area Good Quality Agricultural Land - Map 3 of 3

Project No: 301001-00448 | Figure: 00448-00-EN-DAL-0318 | Rev: 0

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Based on this mapping, the percentages of GQAL along the proposed pipeline RoW have been calculated and provided in Table 5.18. Note these GQAL areas are calculated using a 40m RoW corridor and a total pipeline length of 444km (1,766ha) [refer Table 9.1].

Table 5.18 GQAL area occupied by gas pipeline construction / operation

Class	Area occupied along pipeline RoW (ha)	Percentage of area occupied along pipeline RoW (%)
A	**100**	6%
B	**581**	33%
C1	**92**	5%
C2	**902**	51%
C3	**45**	3%
D	**24**	1%
Unclassified (i.e waterways, roads)	**22**	1%
Total	**1766**	100%

The location of GQAL is required to understand the existing status of the land resource likely to be affected by the proposed pipeline and provide a standard to which rehabilitation should return the land. GQAL is considered to be comprised of classes A, B and, depending on the planning intent of the respective local authority, class C1. When combined, the total GQAL within the study area is 44%.

Based on mapping, GQAL class A occurs along the proposed pipeline route, with the highest percentage between KP237 to 243. GQAL class B also occurs throughout the study area, with the highest portions occurring between KP10-89,135-155, 230-236 and 243-253 and along the Woleebee Lateral from KP1-3, 4-9, 14-30 and 33-37. GQAL class C1 occurs from KP 223-225, 256-258, 302-305, 317-321, 325-326, 339-341, 346-351 and 10-14 along the Woleebee Lateral.

GQAL class C2 and below is not considered to be GQAL and comprises 51% of the pipeline route. The highest portion of non-GQAL occurs from KP 6-11, 89-102, 104-135, 164-179, 181-223, 272-302, 308-317, 321-339 and KP 0 - 11 and 18 - 42 along the Condabri Lateral.

GQAL mapping correlates well with soil group mapping. Generally, areas mapped as soil groups 4 and 5 are also mapped as GQAL class A, B or C1. Soil groups 1, 2, and 3 are generally mapped as GQAL class C2, C3 or D.

6. Potential impacts

The construction of the gas pipeline will involve excavating a trench, laying pipe and backfilling. To do this, it will be necessary to disturb a strip of land approximately 40m wide for the trench RoW. This includes space for personnel and machinery to move around, and space for storing the pipe and backfill materials.

14 temporary accommodation facility sites and lay down areas are also proposed. Existing roads will be used and some of these will need to be upgraded. New access roads will also need to be constructed.

The pipeline is expected to be constructed according to current industry practice, with a 0.9m minimum depth of soil above the pipe in most locations, increasing to 1.2m under roads and cropping areas. The pipeline will be buried deeper (up to 1.8m) where farmers carry out deep ripping of cropland. Deeper trenching will be required at significant watercourse crossings, with the depth determined by the channel depth. The construction footprints or disturbance areas associated with the proposed pipeline, associated temporary accommodation facilities and scraper stations are presented in Table 6.1.

Using the information provided in the above existing land resource assessment, this section discusses the associated impacts of the gas pipeline development to land; specifically existing geology, topography and geomorphology and soil resources.

Table 6.1 Proposed disturbance areas associated with the proposed pipeline

Footprints *(Australia Pacific LNG supplied)*	**Construction** Land area initially cleared (ha)	**Operational** Sterilised land area (ha)
Main pipeline (incl lateral) RoW	1766	1766
Scraper Stations - main pipeline	1.68	1.68
Temporary accommodation facilities and laydown areas	83.45	0
TOTALS	***1851***	***1768***

6.1 Geology

6.1.1 Excavation

An assessment has been undertaken, based on the geological and terrain models for the study area, to establish the potential difficulties and associated impacts relating to the excavation of materials that nominally occur within the upper 2m depth below natural ground surface level. The criteria at the basis of the excavation rating assessment are outlined as follows:

Rating 1: Deep soil-like properties to the full depth of the trench; some low strength (LS), extremely weathered to highly weathered (XW-HW) rock with soil like properties may occur at low levels. A low level of excavation difficulty is likely to be experienced.

Rating 2: Shallow to medium depth soil profile or gravelly soils; underlain by medium strength (MS), highly weathered to moderately weathered (HW-MW) rock, including closer jointed closely fractured/jointed high strength rock. Rocky soils including cobbles and small to medium size boulders may occur. A moderate level of excavation difficulty is likely to be experienced..

Rating 3: Shallow depth soil profile or rocky soils, underlain by high strength (HS), moderately weathered to slightly weathered (MW-SW) rock, including closely fractured/jointed very high strength rock. A moderate to high level of excavation difficulty is likely to be experienced.

Rating 4: Areas of rock outcrops or skeletal to shallow depth rocky soil profile underlain by very high to extremely high strength (VHS-EHS) slightly weathered to fresh (SW-F) rock, including some wider jointed moderately weathered rock. A high level of excavation difficulty is likely to be experienced.

Based on the excavation ratings criteria outlined above and reference to the geological (refer Figure 3.1) and terrain models (refer Figure 4.1), an indicative assessment of the excavation conditions (including probability of rock outcrops) likely to be encountered within the upper 2m depth below natural ground surface level are described in Table 6.2. Note, however, that excavations at waterway crossing may potentially be deeper and will require site-specific geologic assessments.

Table 6.2 Geology description and construction classification

Geology unit	Map symbol	Excavation rating	Excavation difficulties	Probability of surface rock
Human-made deposits	Qmm	Rating 1	Medium	Unlikely
Quaternary (Holocene) Alluvium	Qa	Rating 1	Medium	Unlikely
Tertiary Alluvium	Ta	Rating 1	Low	Unlikely
Late Tertiary to Quaternary Colluvium	TQc	Rating 1	Low	Unlikely
Tertiary Volcanics, mainly Basalt	Tv	Rating 4	Extreme	Most likely
Tertiary Sediments - Biloela Formation	Ts	Rating 2	Moderate	Likely
Cretaceous Volcanics - Double Mountain Volcanics, Peninsula Range Volcanics, Proserpine Volcanics, Whitsunday Volcanics, unnamed volcanics	Kv	Rating 3-4	High to extreme	Most likely
Early to Middle Jurassic Sediments - Precipice Sandstone, Evergreen Formation, Hutton Sandstone	Jp	Rating 2	Moderate	Likely
Middle to Late Jurassic Sediments - Injune Creek Group, Mulguildie Coal Measures, Walloon Subgroup	Ji	Rating 2	Moderate	Likely
Jurassic Sediments - Razorback beds	Jr	Rating 2	Moderate	Likely
Jurassic to Cretaceous Sediments - Bungil Formation, Gubberamunda Sandstone, Hooray Sandstone, Kumbarilla Beds, Longsight Sandstone, Moonga Sandstone, Orallo Formation, Southlands Formation	JKb	Rating 2	Moderate	Most likely
Triassic to Jurassic Sediments - Bundamba Group, Landsborough Sandstone	RJs	Rating 2	Moderate	Likely
Triassic Volcaniclastic Sediments - Callide Coal Measures	Rc	Rating 3-4	High to extreme	Most likely
Triassic Sediments - Moolayember Formation, Clematis Sandstone, Rewan Formation	Rs	Rating 2	Moderate	Likely

Geology unit	Map symbol	Excavation rating	Excavation difficulties	Probability of surface rock
Triassic Volcanics - Agnes Water Volcanics,Aranbanga Volcanic Group,Gayndah Formation,Ooramera Volcanics,Toogoolawah Group	Rv	Rating 3-4	High to extreme	Most likely
Permian to Triassic Intrusive Volcanics, mainly Granite, Diorite and Gabbro	PRg	Rating 3-4	High to extreme	Most likely
Permian Siliciclastic and Carbonate Rocks	Ps/sc	Rating 2	Moderate	Likely
Permian Sedimentary Rocks	Ps	Rating 2	Moderate	Likely
Carboniferous to Perimian Extrustive & Intrusive Volcanics	CPv	Rating 4	Extreme	Most likely
Carboniferous to Permian Intermediate Intrusive Volcanics, mainly Granite, Diorite and Gabbro	CPg	Rating 3-4	High to extreme	Most likely
Carboniferous to Permian Sedimentary and Volcanic Units of the Yarrol & Campwyn Blocks	CPs/v	Rating 3	High	Likely to lost likely
Carboniferous Sediments - Texas Beds	Ctx	Rating 2-3	Moderate to High	Likely
Devonian to Carboniferous Sediments - Curtis Island Group	DCc	Rating 2	Moderate	Likely
Devonian to Carboniferous Metamorphics - Maronghi Creek beds, Sugarloaf Metamorphics	DCm	Rating 3	High	Likely
Devonian to Carboniferous Volcaniclastic Sediments - Mount Alma Formation	DCa	Rating 2-3	Moderate to high	Likely
Devonian Volcanics - Mount Morgan Trondhjemite	Dv	Rating 3-4	High to extreme	Most likely
Silurian to Early Devonian Volcaniclastic Sediments - Erebus Beds	SDe	Rating 3-4	High to extreme	Most likely

This assessment indicates that nearly all of the geologic units within the study area, with the exception of deep Quaternary alluvium, have a likely probability of rock occurring within the profile to be excavated. This was confirmed at some soil sampling and waterway crossing observations. Where there is a likelihood of rock outcrops occurring, particular excavation methods will be required. As this assessment indicates that most geology within the study area has an excavation rating of 2 or higher, such methods will be required in many areas. Investigation (refer Section 7.1.1) will still be required to quantify the environmental impact (such as potential for increased dust, noise and vibration) at site-specific excavations. Further detail is provided in EIS chapters 13 and 15 – air quality and noise and vibration respectively.

Within Holocene-age miscellaneous sediments, the proposed gas pipeline construction comprises basic cut and cover technique with excavations extending up to 3m in depth and slopes battered at 1V:3H. Based on the geological information, these sediments (mainly soil group 6 and comprising intertidal and supratidal flats and coastal grasslands) are mostly encountered in the vicinity of The Narrows and are generally soft, low strength and can be easily excavated using conventional plant. However, due to the high water content of these sediments, it is expected that excavations in these materials are likely to be unstable unless suitably battered or retained. These soft sediments areas are expected to be difficult for vehicular movements and construction of suitable access tracks are likely be necessary. Available geological information indicates that the Holocene-age miscellaneous sediments occur in areas of high groundwater, and therefore localised dewatering is likely to be required for excavation below groundwater level to expedite construction of the pipeline through these soils. These sediments may also be considered unsuitable as a foundation layer beneath some structures such as culverts, bridges, embankments, etc (refer to Section 7.1.1).

As these sediments are commonly associated with ASS where ground elevations are below 5mAHD in the study area (refer Section 5.1.2), disturbing these sediments (through excavation or filling activities) may lead to 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.

Where excavations in the low strength Holocene-age miscellaneous sediments or non-compacted colluvial deposits are proposed, suitable geotechnical investigations will be performed to assess potential impacts. This information will be used to assist in determining appropriate designs and techniques to be used during construction (refer to Section 7.1.1). Furthermore, an ASS investigation will be performed in accordance with Guidelines for Sampling and Analysis of Lowland Acid Sulfate Soils (ASS) in Queensland 1998, version 4.0 (Ahern et al. 1998) – refer Section 7.3.6.

In summary, the presence of rock is expected to be a constraint to development along sections of the proposed pipeline route, especially in the Callide Range area, and associated impacts relating to rock extraction and handling are also expected. This review also revealed a range of materials required for pipeline construction are potentially available; however, trenching equipment may have difficulty generating useable bedding for the pipeline in some areas. As a result, importation of bedding materials is likely to be required for some portions of the route. In addition, the Holocene-age miscellaneous sediments or soil group 6 are easily excavated, but may be unstable during earthworks and could potentially release acidic runoff.

6.1.2 Geologic structural features and faults

The structural features and faults identified along the study area are predominately north to south or east to west to north to west or south to east trending, with the majority occurring in the northern section of the gas pipeline. These faults could potentially comprise zones of weakness in the upper

crust that may be subject to differential movement during a significant seismic event in the region. However based on recorded earthquake data since 1958, the number and magnitude of earthquakes which occurred in the study area have been few and minor.

Should an earthquake occur during the life-cycle of gas pipeline development, damage may occur. An indication of potential levels of public nuisance and damage to infrastructure for the approximate range of earthquake magnitude recorded in Queensland is presented in Table 6.3.

Table 6.3 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, 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 object thrown in the air	6.2 - > 8

Source: http://www.ga.gov.au/urban/factsheets/20010919_15.jsp

The table suggests that structural damage could occur during earthquakes of Richter 4.9 or higher. In such instances, damage to the gas pipeline could result. A 'worst case scenario' would be that an earthquake was of significant magnitude or duration to cause severe damage to the gas pipeline. Whilst such an occurrence may be statistically remote, the potential seismic risk should be appropriately addressed during design.

6.1.3 Extractive resources

Potential impacts on extractive resources associated with development of the proposed Australia Pacific LNG pipeline are as follows:

- New quarries and expansions to existing quarries (operated by others) may be required with development of the proposed gas pipeline and changes to land and road use would potentially occur as a result. To meet the demand of the Australia Pacific LNG Project, any new quarry would be required to undergo an impact assessment as part of gaining a separate development approval prior to commencing the activity.
- While not specifically addressed within this report, the environmental effects of any future quarry developments will require consideration and will need to include the cumulative effects associated with the resource demands of other possible CSG projects in the region. Such effects may include alteration of topography, drainage, leaching of chemical / minerals, removal of vegetation and changed dust, noise and vibration levels. Extractive industry operations would, however, need to comply with DERM and local council operational conditions including compliance with relevant emission levels.

The potential constraints and opportunities relating to demands by the Australia Pacific LNG Project and other proposed CSG projects on the available (or additional sources of) extractive resources in the region requires further investigation by project proponents during front end engineering design (FEED).

6.1.4 Reactive soils

Vertosols (cracking clays - 5b and 5b[m]) encountered within the gas pipeline study area, as described and mapped in Section 5.1.1, are generally expansive dark brown / grey cracking clays. Potential impacts associated with construction in areas where Vertosols are encountered may include:

- Cracking clays are usually highly reactive to moisture variations and can generally lead to extensive subsidence and in turn cause damage to the proposed buildings and roads.
- Potential damage to pipeline infrastructure (that is, damage to the protective coating) in areas of expansive cracking clays.
- Traversing through areas where Vertosols occur may become very difficult when wet.

6.1.5 Sterilisation of resources

The establishment of the gas pipeline RoW has the potential to restrict the future mining of some mineral resources in the region. The pipeline corridor traverses a number of tenements that have overlapping tenure. Should the holders of the affected coal tenures wish to access coal under the pipeline RoW, they may be required to forego coal extraction and / or gasification. This is discussed further in EIS Volume 3, chapter 6 – Land use and planning.

6.2 Topography and geomorphology

The development of the proposed pipeline will involve vegetation clearing and earthworks for pipeline construction, temporary accommodation facilities, installing access tracks, waterway crossings and temporary hydrotest water holding ponds. The study area landform will be altered through temporary changes to existing natural drainage patterns and will involve slope changes and diversion of stormwater around the construction area. Waterway crossings may also result in the exacerbation of waterway bed scour through bank vegetation clearing and earthworks. This may also result in destabilisation of soils within the construction site (refer Section 5.2.4).

If not carefully managed, changes to natural drainage patterns and destabilisation of soils may contribute to erosion, which if not rehabilitated, will scar the land and contribute to downstream water quality degradation. Assessment of erosion susceptibility and likely project impacts is presented in Section 5.2.4 and 6.3.2 respectively. Altered landform and changes to land use will have a range of associated impacts, such as the potential loss of GQAL (refer Section 5.3).

6.3 Soils and land resources

This section discusses potential impacts to soil resources within the study area from the construction and operation of the proposed pipeline, including associated temporary accommodation facilities and access tracks, based on the soil assessment detailed above (refer Section 5). The construction footprints or disturbance areas associated with the proposed pipeline, temporary accommodation facilities and scraper stations are presented in Table 6.1.

6.3.1 Topsoil

Topsoil protects dispersive subsoils, is critical to erosion control and is important for revegetation and weed management. If impacts are not effectively ameliorated (refer Section 7.3.2), construction of the proposed pipeline will impact topsoils, resulting in soil inversion (replacement of topsoils with subsoils) and, if exposed for extended periods, allowing excessive nutrient leaching (loss in fertility) and erosion. Operational impacts would primarily result from poor rehabilitation and drainage management, leading to topsoil and subsoil erosion.

Based on field classifications, topsoils were variable in thickness throughout the study area. As topsoil is generally removed down to the subsoil, site specific assessments will be required pre-disturbance to determine the appropriate removal depth and handling / stockpiling arrangements. Some areas may be encountered (particularly in the shallow stoney soils (soil group 1), shallow texture contrast soil (soil group 2) and those within soil groups 4 and 5 where clay content is significant in surface material), in which there is little or no existing topsoil. A site-specific topsoil assessment should take this into account. Management of soil group 6 will require targeted management approaches discussed in Section 7.3.6.

Fertility of topsoils (both fine and coarse textured) within the study area was rated as low. As a result, additional nutrients (specifically N and P) and/or conditioner may be required during stockpiling and rehabilitation to improve topsoils, stabilise subsoils and support vegetation regrowth. Topsoils associated with the Vertosols (where texture is commonly a clay loam or loamy clay) are likely to have a higher fertility and fertilisation may not be required.

6.3.2 Erosion

Construction of the proposed pipeline would require vegetation clearing which destabilises soils and leaves them exposed to erosion. Potential follow-on effects may include, undermining of structures (fences, gates), pipeline exposure, stream bank erosion (incision of a stream into its banks), downstream sedimentation, decline in fertility through loss of soil structure, increased dust generation and loss of GQAL.

Based on erosion ratings determined for the proposed pipeline route (refer Section 5.2.4), soil groups 2b and 2c have the highest erosion rating; however, the erosion hazard increases where slope increases. This is particularly notable in the coarser textured soil groups where there is little structure and organic matter to help bind soil and resist erosion. Most soil groups were generally highly erodible if disturbed when the slope was more than about 8%. Finer textured soil groups (4 and 5) have a low to moderate erosion rating. Although not frequently encountered during the field investigation, these soils can be sodic to strongly sodic and will erode where vegetation has been removed due to clay dispersion.

Previous erosion assessments undertaken within Australia Pacific LNG's gas fields have indicated that conventional stormwater control through runoff diversion and concentration, combined with scour protection has had mixed success, particular in highly dispersive soil areas. Detailed sediment and erosion plans (as identified later) will be necessary to designate effective control measures, especially in areas designated as having a high to severe erosion hazard. Lessons learned in the refinement of erosion control practices in the gas fields should be applied during rehabilitation of the pipeline construction disturbed areas.

Hydrostatic testing of the transmission pipeline will be required. To complete this testing, approximately 100ML of non-potable water will be sourced locally from a number of sources (that is, treated water from reverse osmosis [RO] plants, re-used water from tested sections, commercial

suppliers, local watercourses and rivers, dams, bores and untreated CSG water). Following completion of hydrostatic testing, the test water will require disposal. Although final disposal options will not be developed until pipeline design and construction commences, where disposal to the environment (that is, discharge on site) is selected, there is a risk that concentrated flows, and therefore erosion, may occur. Furthermore, the test water may contain additives, such as biocides, oxygen scavengers, corrosion inhibitors and other contaminants (that is, heavy metals, raised dissolved salt concentrations), and as such may lead to land contamination. Any discharge to land should comply with the guidelines published in *Analysis of Hydrostatic Test Water (CMIT Report No. CMIT – 2005-259)* and should also meet specific quality criteria outlined by environmental authorities.

Where concentrated flow is proposed (including diversion of stormwater around construction areas), the greatest potential for erosion to occur would be in unprotected (unvegetated), coarse textured soils and dispersive fine textured soils (refer Figure 5.2).

The large volume, concentrated flows proposed have the potential to:

- Exacerbate gully erosion
- Cause notch erosion resulting from reduced variability of flows downstream of discharge points
- Increase bank instability (stream bank erosion)
- Exacerbate meander migration
- Increase entrainment of bed sediments, resulting in redistribution downstream.

6.3.3 Salinity

The majority of ECe results (refer Section 5.2.7) indicated salinity within study area soils, which were field assessed, rated as non-saline (<2000µS/cm). Furthermore, the field assessment did not identify any significant areas of salinisation or extensive scalding. Subsoils at soil group 5, located within the southern portion of the study area near Wandoan and Taroom and associated with the Jurassic Walloon subgroup geological units, can be typically saline due to lack of leaching (due to lack of rainfall). Soil group 6, although not assessed during the field investigation, is expected to have extremely saline soils due to their landform position, being periodically inundated with seawater.

Vegetation has varying tolerance to salinity with only several species tolerating electricity conductivity greater than 8000µS/cm. As a result, moderate to highly saline soils will require special management as they may be corrosive to civil structures and present challenges for revegetation. Geotechnical investigations will be required to assess suitable corrosion protection requirements. Additionally, suitable subsoil handling and progressive rehabilitation should be undertaken to minimise potential blending between non-saline and highly saline soils.

As mentioned previously, hydrotest water requiring disposal may contain additives which result in raised dissolved salt concentrations. As a minimum, any discharge to land should meet specific water quality criteria outlined by environmental authorities.

6.3.4 Soil acidification and acid sulfate soils

The majority of pH results indicated soils, which were field assessed within study area, were neutral with the most acidic results reported for soil group 1b near Miles. Soil group 6, occupying approximately 11.6ha within the gas pipeline RoW at The Narrows, although not assessed during the field investigation, is associated with ASS and are expected to have a near neutral pH in an undisturbed state. If these soils are disturbed (that is, subjected to excavation or filling), they are likely

to become more acidic through oxidation of sulphides (and change from a PASS to an AASS), which may potentially impact the environment and affect civil structures through the mobilisation of acidic runoff and/or groundwater. The low strength of these soils would also result in excessive settlement under the load of structures, services and fill embankments and platforms if these soils were used as foundation material (refer Section 6.1).

A detailed ASS investigation will be required and an Acid Sulfate Soil Management Plan (ASSMP) will need to be developed to mitigate any potential adverse impacts related to disturbance of ASS (refer Section 7.3.6).

This report does not discuss or assess the impacts of PASS which could be located offshore (within Port Curtis) and between the mainland coast and Curtis Island. An assessment, undertaken by Golder Associates for WorleyParsons as part of the Gladstone Ports Corporation Western Basin Dredging and Disposal EIS entitled "*Acid Sulfate Soils Investigation Laird Pt Dredge Study Option 2A Gladstone, Queensland (2009)*" indicated PASS do occur within Port Curtis. In order to fully assess potential PASS impacts associated with the construction of the gas pipeline RoW offshore (i.e. not on the mainland), a separate study will be required.

6.3.5 Bulldust

Loamy soils, particularly soils located within soil groups 1, 2 and 3, are prone to generate bulldust if vegetation is cleared and topsoil heavily trafficked throughout the Project.

As most surface layers of soil within the RoW have generally loamy textures, bulldust generation is expected to be widespread if appropriate dust mitigation is not implemented throughout construction and operation.

6.3.6 Land capability reinstatement

Some 44% of the proposed pipeline RoW (40m corridor) is comprised of GQAL (classes A, B and C1) and this land would be impacted through construction and operation of the proposed pipeline, resulting in:

- Temporary loss of agricultural production (reduced cropping area)
- Interference with overland flow through the modification of runoff controls
- Increased soil compaction through heavy trafficking, reducing water infiltration
- Decreased fertility
- Increased erosion
- Disruptions to farming operations with respect to timing of construction and restriction on land use.

These impacts are expected to be sustained throughout the construction period (refer Table 6.1), after which the land will be reinstated to its original use (refer Section 7.3.9).

Table 5.18 provides the indicative construction footprint of the proposed gas pipeline within each GQAL class. This was determined through analysis of data supplied by Australia Pacific LNG in December 2009. Note that the construction footprint will not remain as the operational footprint through the expected operational period (30 years).

To calculate the areas in Table 5.18, certain assumptions regarding several facility locations and sizes were made due to lack of information (including mapping) at the time of this analysis (December 2009). These assumptions are detailed in Table 9.1.

7. Mitigation measures

7.1 Geology

7.1.1 Excavation

Excavation ratings provided in Table 6.2 correspond with potentially increasing levels of environmental impact including the likely extent of clearing, construction methods and types of equipment required to undertake the work. Such impacts may include increased noise and dust levels, handling / stockpiling of rock and rehabilitation constraints. Other impacts relate to the strength and amount of rock likely to be encountered and the suitability of the excavated spoil for backfilling the pipeline or service trench.

Wherever practicable, clearing of existing natural vegetation should be confined to within the proposed construction disturbance footprint (refer Table 6.2). Where additional clearing is required to permit access for larger equipment, clearing should be kept to the minimum necessary to complete the work.

Where rock breaking and/or blasting is required for rock removal, associated noise and vibration factors, the proximity to receptors as well as potential to damage co-located infrastructure facilities or other buried services should be addressed. If rock breaking and/or drilling and blasting is required for rock removal, the works should be undertaken to minimise the effects of noise and vibration on the surrounding environment (refer EIS Chapters 13 and 15 – air quality and noise and vibration respectively). Blasting should be carried out in accordance with relevant local authority guidelines and AS2885.1: Gas and Liquid Petroleum Guidelines.

Rock spoil, where encountered, should be reused on the construction site or removed from the site and used for erosion control rip-rap, or disposed of in alternative approved locations, wherever practicable. If there is a deficiency of trench backfill material, suitable material (certified weed and disease free) should be imported. Any excess of suitable material should be used for rehabilitation purposes or removed from the site to an approved disposal area.

The Holocene-age miscellaneous sediments are soft, low strength and can be easily excavated however, they must be suitably retained/shored. The use of shoring boxes and/or other retaining structures, incorporating an adequate dewatering system, may also be considered in addition to the proposed battered excavations in these soils. Suitable construction access tracks should be established to ensure trafficability is maintained over the soft sediments, where appropriate. The stability of these sediments, suitable construction methods for access tracks and environmental impacts associated with the preferred construction method should be assessed through geotechnical investigations prior to construction.

Where excavations in low strength Holocene-age miscellaneous sediments or unconsolidated colluvial deposits are proposed, suitable geotechnical investigations should be conducted to assess design and construction techniques. A detailed ASS investigation should be performed in accordance with State Planning Policy 2/02, Planning and Managing Development involving ASS, and an ASS and Dewatering Management Plan should be developed as part of the overall Project Environmental Management Plan, in accordance with Queensland Acid Sulfate Soil Technical Manual – Soil Management Guidelines. Some general ASS mitigation measures are provided in Section 7.3.6.

7.1.2 Geologic structural features and faults

There are a number of faults which occur within the gas pipeline study area, however there are few recorded earthquakes. Nonetheless the design of structures should be undertaken in line with AS1170.4:2007 which sets out data and procedures for determining minimum earthquake loads on structures and their components. This Standard provides the minimum criteria for the protection of life through minimising the likelihood of structures collapsing but excludes the following structures: high-risk structures, bridges, tanks containing liquids, civil structures including dams and bunds, offshore structures that are partly or fully immersed, soil-retaining structures. Therefore structures excluded from this Standard should be designed in accordance with the appropriate standard relating to that structure.

This Standard does not consider the effect on a structure of related earthquake phenomena such as settlement, slides, subsidence, liquefaction or faulting. Geotechnical engineers and structural engineers should therefore need to specifically consider the risk of settlements, slides, subsidence liquefaction or faulting on people and property in the event of an earthquake and the structures designed accordingly, or engineering measures put in place to protect the environment in the event of damage to property.

7.1.3 Extractive resources

Extractive industry operations that supply material to the proposed Australia Pacific LNG 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 the extractive industry is outside the direct control of Australia Pacific LNG. Australia Pacific LNG intends to work with industry to align with its sustainability principals (refer EIS Volume 1, Chapter 3 - Sustainability) The use of borrow material within the study area will necessitate remediation and rehabilitation of treatments where practicable and required. This may include the re-establishment of stable landforms.

To minimise impacts associated with the extractive resources, the following mitigation measures are proposed:

- FEED phases of the Project should quantify and qualify the need for 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.
- The Australia Pacific LNG has not planned to directly develop new quarries as part of the Project. Extractive industry 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. The need for borrow pits and associated approvals will be assessed during FEED phases of the Project.
- Selected existing resources should be assessed during the Project's FEED phases to determine the size and local demand. This would enable an informed assessment to be made regarding adequate resources to service the gas pipeline construction requirements as well as existing community demands.
- Mobile crushers should be considered for use on the Project where practicable so that excess rock that has been excavated can be utilised, minimising the need for quarry materials.

- Construction should be carried out progressively, with remediation of areas scheduled so that rock for construction platforms and temporary access roads can be recycled to minimise the need for quarry materials.

It is probable that development approvals will be necessary for other extractive resources on land held by private operators. These would be the subject of a separate approvals process undertaken by others.

For any extractive activities undertaken by others on behalf of the Project, the environmental issues associated with the extraction of resources should be mitigated through the development of environmental management and operation plans.

Once operations have concluded, finishing earthworks and revegetation should be carried out with all equipment, structures and imported materials removed. Remediation and rehabilitation of any contaminated areas, grading and revegetation of the quarry/borrow pits should be undertaken in accordance with regulatory approval conditions.

7.1.4 Reactive soils

To minimise construction constraints associated with these soils, a number of mitigation measures are proposed:

- Where construction is proposed within soil group 5b and 5b(m), site specific geotechnical investigations, such as those undertaken during FEED phases, should be carried out to assess the potential movement caused by these cracking clays. These investigations will also identify the potential infrastructure protection (i.e. pipeline coatings resistant to stresses from clay movement) required. The potential movement due to the cracking clays will be considered in the design of all buildings, roads and other structures, where located on these soils.
- The gas pipeline is anticipated to be constructed mainly within the lower section of the shrink/swell profile and is thus unlikely to be exposed to the full extent of the movement. At these depths, shrinking, swelling and heaving (Gilgais) of these cracking clays are unlikely to affect the integrity of a welded steel pipeline. However, it may affect the protective coating of the pipeline. An alternative flexible protective coating may be considered in the areas where these cracking clays are encountered, but the need for this can be assessed following geotechnical investigations.
- Construction in reactive soil areas will be limited to dry weather conditions as far as is practicable. Construction of gravel access tracks and working platforms may be warranted to prevent rutting and damage to the soil resource, as these soils are of significant agricultural value.

7.2 Topography and geomorphology

Clearing and earthworks will have the greatest impact on existing landform through the temporary alteration of drainage paths, soil destabilisation and loss of GQAL. Construction of the proposed pipeline at waterway crossings also has the potential to exacerbate erosion and scour the waterway bed substrate. As a result, landform mitigation measures will be subject to site-specific scour assessments (refer EIS, Volume 3, Chapter 11, Surface water and watercourses) and soil characteristics (refer Section 4.3). These sections provide detailed mitigation measures which are also addressed in the Environmental Management Plan (EM Plan).

The general mitigation measures listed below should be addressed throughout the Project to minimise potential impacts on water quality of downstream sites due to erosion and improve the stabilisation of soils to prevent potential sediment and erosion runoff. Detailed soil mitigation measures are provided in Section 7.3.

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

- Surface water runoff from disturbance areas (that is, cleared sites and stockpiles) should be redirected / diverted, but managed in such a way as not to generate concentrated flows, un-controlled channelling or impedance of flow, or cause nuisance to landholders downstream and / or adjacent to the site.
- Sediment and erosion control measures, such as sediment dams, traps and fences should be installed to dissipate the velocity of stormwater which runs across the site (refer Section 7.3.3 and the EIS, Volume 3, Chapter 24 - EM Plan). Where practicable, any vegetation cleared should be mulched and placed as a protective layer on topsoils to assist in fertility retention and sediment and erosion control.
- In areas of site levelling works, proposed formation levels should be set to reduce the need for significant cut and fill areas.
- Reuse of construction materials should be implemented to minimise the volume required from borrow pits.
- Pipeline backfill and compaction of the fill should be controlled to minimise subsidence and the need for excessive temporary soil mounding.
- Progressive clearing should be undertaken immediately prior to construction to ensure the minimum amount of bare soil remains exposed on-site at any one time.
- Progressive rehabilitation of disturbed areas, such as temporary diversion drains, cleared sites and stockpile areas, should be undertaken.
- Slope stability assessment should be carried out on areas where clearing works are required on steep and very steep slopes with gradients great than 20%.
- Structures (such as temporary accommodation facilities, temporary hydrotest water holding ponds) which require substantial earthworks should be sited on relatively level sites for ease of landform rehabilitation following completion of the Project.
- At the completion of the Project, equipment, structures and imported materials should be removed and finishing earthworks and rehabilitation should be undertaken. This should involve remediating and rehabilitating any contaminated areas, then subsequently grading and revegetating the site, returning it to a condition as close to its original state as practicable. This also includes re-establishing the original topography and drainage (including pre-existing erosion management structures) and remediation of soil fertility (refer Section 7.3)
- The detail design of the creek crossings should incorporate works and measures to minimise the following: the risk of damage to the creek banks during construction, change in the sediment transport regime at the crossing, the risk of creek bank collapse or erosion during flood events and the risk of damage to the pipeline during flood events (refer EIS, Volume 3, Chapter 11 – Surface water and watercourses).

7.3 Soil mitigation measures

Mitigation measures in regard to soil disturbance and rehabilitation should focus on avoidance and reinstatement. During construction, existing disturbed areas (such as tracks) will be used where practicable for access. Where avoidance is not practicable, placement of disturbance (such as access tracks) should favour areas likely to cause least impact to land resources (for example, along paddock boundaries and away from overland flow paths).

7.3.1 Land capability

There is potential for sterilisation of GQAL (classes A, B and C1 [in some areas]) during the gas pipeline construction. However the long term impact should be mitigated by rehabilitation at completion of construction (refer Section 7.3.9). The area of GQAL within the construction footprint is approximately 44% (773ha) of the total land required for the gas pipeline development (1,766ha).

To minimise impacts during construction and operational periods, access tracks and accommodation facilities should be located on areas which will have the least impact on the productive capacity and drainage of the land and cause the least changes to landholder operations. Such areas may include fence lines, existing access tracks, road reserves and other areas deemed appropriate by the land owner.

Good topsoil management is also important to facilitate restoration of GQAL which should involve rehabilitation to vegetation types consistent with the surrounding environment (refer Section 7.3.2.) Additional measures, such as good quality fencing, (during construction of pipelines) to restrict stock movement between neighbouring properties, minimising productive soil exposure and appropriately locating signage (that is, on fencing not within paddocks), should be incorporated during construction. Where pipeline installation is to occur within croplands, particularly where deep ripping may be used, additional depth of cover will be required as determined by design engineers and validated by the AS2885 Safety Management Study. This will also be the subject of consultation with affected landholders.

Land capability impacts can also be mitigated through good management of associated water (refer EIS, Volume 3, Managing associated water). Associated water without appropriate treatment should not be used without consideration of soil salinity and impact of other contaminants. Similarly waste management is also important to avoid contamination of GQAL (refer EIS, Volume 3, Chapter 16, Waste).

Sediment and erosion control and careful revegetation of GQAL are also essential to mitigate loss of GQAL (refer subsequent sections).

7.3.2 Topsoil and subsoil management

The following section outlines topsoil and subsoil management strategies to be implemented during and following the construction of various project components in all land areas to be disturbed. During the operations phase of the Project, management should largely include monitoring of rehabilitation and further rehabilitation as required, which is outlined within the EM Plan (refer EIS, Volume 3, Chapter 24). Post-lease rehabilitation should involve the decommissioning and removal of project facilities (refer Section 7.3.9).

Topsoil stripping

Prior to the commencement of topsoil stripping, areas should be cleared of vegetation. Timing of clearing should be co-ordinated with respective landowners to ensure that where GQAL disturbance is

unavoidable, minimal disruption to farming operations will occur. Vegetation clearance should be minimised where practicable to reduce the potential for soil erosion and exposure of dispersive soils, particularly when clearing has not been timed to accord with seasons with higher rainfall (that is early to mid summer – December to March). Vegetation clearance should take place as close as practicable to construction activity and undertaken progressively.

Vegetation which is removed should be stockpiled separately. There should be a distinct break of at least 1m between the vegetation and soil stockpiles, but additional storage space must be accounted for as the subsoil displaced during construction (particularly for underground infrastructure such as pipes) is substantial. Further information regarding vegetation management is contained within the EIS, Volume 3, Chapter 8 – Terrestrial ecology.

Topsoil should then be stripped. Any excess displaced spoil must be prevented from mixing with topsoil as the cost of extra storage space is minor compared with the rehabilitation of soil inversion areas which limit nutrient availability, biomass and productivity. Soil inversion can also affect a soil's permeability and water holding capacity.

Soil stripping should be undertaken in consultation with information provided in this report and subsequent detailed soil assessments, including designation of optional topsoil stripping depths. In areas where both the topsoil and subsoil are to be removed, they should be stripped and stockpiled separately and be located as to minimise loss of material from water and wind erosion. This is necessary to prevent blending of different stockpiled material (that is, during rain events) as this may impact the success of rehabilitation.

Soils should ideally be replaced close to where they are sourced. The separation of coarse textured soils (mainly groups 1, 2 and 3) from fine textured soil groups (4, 5 and 6) at soil type boundaries should be undertaken. Coarse textured soils are often more erosive and generally less fertile than fine textured soils which are generally dispersive. As a result, coarse textured soils will involve differing nutrient / conditioner requirements to that of fine textured soils.

Vegetation which is cleared and chipped may be used to provide a thin surface mulch to improve the topsoil productivity and mitigate erosion. If any vegetation burning is permitted or proposed, remaining ash may be incorporated with the topsoil during the topsoil stripping operations.

Earthmoving plant operators should be trained and/or supervised to ensure that stripping operations are conducted in accordance with stripping plans and in-situ soil conditions. This will ensure that suitable topsoil material resources are salvaged and that the quality of the stripped topsoil is not reduced through contamination with unsuitable soils. Care should be taken during stripping, stockpiling and/or respreading to ensure that structural degradation of the soil is avoided and that excessive compaction does not occur.

Stockpiling

Topsoil stockpiles should not exceed 2m in height, particularly to minimise damage to topsoil and maintain fertility. Gaps should be left every 50m to allow for drainage, and permit the movement of vehicles and wildlife. Stockpiles exposed for extended periods should be deep ripped and sown with seed stock compatible with local conditions in order to keep the soil healthy and maintain biological activity and prevent weeds from growing. Topsoil stockpiles should be clearly sign-posted for easy identification and to avoid any inadvertent losses. Establishment of weeds on the stockpiles should also be monitored and controlled. Rocky surface materials should be removed and stockpiled separately from other material. Information regarding management of weeds is included within the EIS, Volume 3, Chapter 8 – Terrestrial ecology.

Surface stabilisers may be used on soils which have been classified as erosive or dispersive and exposed for prolonged periods.

Respreading

Upon completion of construction, wastes should be removed, temporary access tracks should be closed and soils should be replaced in the order in which they were excavated. If subsoil cannot be reused, then suitable certified backfill material from a registered quarry should be imported. Excess soils should be disposed of appropriately – for example, stockpiled for use in future rehabilitation or respread elsewhere in consultation with landowners avoiding admixing. During the removal of soil from stockpiles, upper and lower sections of the stockpiles should be mixed to spread seed stock and microfauna (of the landowner's choice).

Topsoil application should only take place following initial reinstatement of the subsoil, construction of contour banks on steep slopes and compaction of subsoils to account for subsidence. Topsoils that have been stockpiled for long periods should be re-analysed before reusing to assess whether fertility levels are optimum and if required, conditioners should be added. Topsoils should be respread over watered and scarified / ripped subsoils in even layers at a thickness appropriate for the intended land use of the area to be rehabilitated.

Topsoil should be compacted firmly but left slightly rough to provide a suitable seed bed and revegetation undertaken as soon as practicable after topsoil respreading. Cross ripping of topsoils may be undertaken to encourage rainfall infiltration and minimise runoff. On steep slopes hydroseeding and hydromulching should be used. Vehicle movement should be restricted to permit vegetation to become re-established. In areas where access tracks were utilised, re-profiling to original or stable contours, re-establishing surface drainage lines and other land features should be completed. Other considerations should include:

- Balancing required rehabilitation topsoil quantities against stored stockpile inventories
- Planning the source of topsoil material to maximise direct respreading from stripping areas and to minimise the length of time the material is stored in stockpiles.

Rehabilitation of disturbed areas should be consistent with surrounding conditions (refer Section 5.3 and restoration requirements in the EIS, Volume 5, Terrestrial ecology technical report or Volume 3, Chapter 8) unless developmental conditions are required to be maintained as an approval condition or land owners. Where GQAL has been disturbed, rehabilitation should be to a standard negotiated with the respective landowner. This includes the re-establishment of original topography and drainage (including erosion and water management structures, such as contour banks) and remediation of soil fertility and structure (refer Section 7.3.9).

7.3.3 Water diversion, sediment and erosion control

All soils which are to be disturbed should have sediment and erosion controls measures adopted throughout construction and rehabilitation. This is required for environmental, structural, rural land management and aesthetic reasons. It is much easier to prevent rather than reinstate eroded landscapes, so there should be a focus on prevention rather than reinstatement where required. Such prevention measures should include the consideration of alternative hydrotest water disposal locations. Where reuse is not practicable, discharge locations should be to areas where there is less erosion risk, for example soil group 4 or 5 and where vegetation is well established (refer Table 5.9). Discharge locations should also be discussed with the respective land owner.

The following measures are suggested:

- Divert water around the construction site. Within the site, divert water around excavations and stockpiles.
- Where water diversion involved construction of diversion drains, the preferred method is placing a mound of soil on the uphill side of the excavation from which it was sourced. The mound of soil should be compacted. This method results in water flowing over undisturbed ground.
- Construct sediment fences on the downhill side of the excavation areas.
- Construct sediment fences around the stockpile areas.
- Sediment fences should comprise filter fabric anchored into a 200mm deep trench and extend to the maximum height of fence above ground of 700mm.
- Maximum post spacing: 2m without wire mesh backing.
- Allow at least 2m between fence and a stockpile.
- Where tracks go down slopes, contour banks should be used at appropriate intervals to produce sheet flow rather than concentrated flow and directed to discharge at multiple locations at low velocities and volumes
- Sediment and erosion control measures should be inspected on a regular basis, replaced where damaged and emptied following rainfall events if required.
- Clear vegetation progressively, so as to maximise the area of soil protection.
- Create stable slopes and revegetate soon after disturbance.
- Topsoil stockpiles should be seeded (refer Section 7.3.2).
- 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) should be treated with chemical surface stabilisers or physical alternatives (crushed rock).
- Diversion sediment and erosion control devices should be put in place prior to construction commences. These should remain in place at rehabilitated areas until the area has completely re-established.
- Roads and tracks should ideally go across slopes. Where tracks go down slopes contour banks should be used at intervals appropriate to the slope to control the flow of surface water so as to minimise erosion.
- Where pipes go down slopes, trench breakers should be installed in the backfill at intervals appropriate to the steepness of the slope to prevent water tunnelling along the buried pipe. On surface contour banks should be used to divert water off the disturbed areas.
- If any water is required to be discharged off-site it should be done so through silt fences to prevent erosion.
- In the vicinity of natural watercourses, routine water quality monitoring of pH, electrical conductivity, dissolved oxygen, redox, temperature and turbidity should also be considered to ensure that water quality is maintained.

A comprehensive soil erosion, control and monitoring plan (detailing the measures described above) should be provided in the EM Plan (refer EIS, Volume 3, Chapter 24).

7.3.4 Slope management

The study area is comprised of a variety of landforms with slope ranges from flat to greater than 50%. However, the majority of the proposed gas pipeline route traverses level to gently undulating plains and low hills with slopes less than 20%.

Where the slope is more than 8%, soil and surface stability controls should be constructed and maintained at all times. These measures includes shaping the ground surface where required to maintain slope stability, as well as installing temporary sediment and erosion control (contour banks, diversion drains and silt fences) and maintaining until final construction clean-up and rehabilitation and re-establishment is completed.

Where clearing slopes adjacent to drainage lines is required, sediment and erosion control (such as water diversion banks, sediment fences and a sediment basin at the base of the hill) should be incorporated prior to clearing where practicable. A series of earth banks should be installed at an appropriate spacing depending on gradient and soil types immediately following clearing activities and should be constructed across the entire disturbed width of the working area. They should be directed to frequently spaced vegetated or sediment fence discharge points to minimise scouring. They should be maintained to ensure they are effective at all times until rehabilitation and re-establishment of the site is completed. Earth banks should be high enough to collect water but not so high that they are dangerous to drive over on steep slopes. Clearing in the area immediately adjacent to water courses below slopes should be delayed until construction at the drainage line is imminent.

7.3.5 Drainage line management

Several significant watercourses (as identified earlier) traverse the pipeline alignment (refer Chapter 11 of EIS - Surface water and watercourses). As dispersive and erosive soils are located adjacent to drainage lines in many areas, appropriate management of these soils is required in order to minimise erosion, soil loss, sediment laden runoff and downstream impacts and maximise creek bank stability. It is expected that some pipeline crossings and therefore several vehicle crossings will be required over watercourses with a stream order of 3 or greater.

Temporary earth banks / contour banks or diversion channels should be installed along the slope on approaches to watercourses or waterbodies approaching the Narrows. These may incorporate rock armouring in some locations, to assist in topsoil protection, with check dams at appropriate intervals. These should be maintained until rehabilitation / re-establishment of disturbed areas is complete or when permanent banks are installed. The banks / channels should extend beyond the work area, in a manner which results in runoff water being discharged to the down-gradient side of the disturbance to stable (i.e. vegetated) areas or via sediment settling basins and should not be directed into drainage lines. Where this is not appropriate, runoff should be directed into silt fences installed at the outlet of the earth banks / contour banks or diversion channels.

Where these crossings are required and geologic constraints permit, a 20m buffer of vegetation adjacent to the drainage line should be retained until construction across the drainage line is imminent. When such time arises, trees may be chain sawed and felled away from the drainage line. Clearing should aim to retain the maximum amount of root stock within the construction area.

Where there is to be a vehicular crossing of a water course, the crossing should be reinstated to its previous state following the cessation of use. If there is water flowing or the potential for water to flow during the period of the crossing use, there should be an access road constructed and a strategy prepared for management of the water so that the water will not flow outside its natural course. This could involve culverts or pipes placed through the road embankment or else water pumped from one

side of the road embankment to the other (only suitable when water flows <1000l/s). Any water pumping which may require offsite discharge during construction should be done so through geotextile, sediment fences or gravel outlets to prevent erosion. Further advice is contained in Chapter 11 of the EIS, Surface water and watercourses.

Where the pipeline is to cross a water course, the pipe trench should be excavated perpendicular to the direction of the water flow. There should be a trench breaker the full height of the trench on either side of the water course and the pipe trench backfill should be carefully compacted, and compaction plant used in the upper layers of the pipe trench backfill. If the bank is topsoiled, topsoil should be respread over the area from which it was removed and areas of disturbance seeded.

In areas where rapid water flows are likely rock armour should be used to cover the area of the trench. Where original drainage lines had a surface layer of cobbles and coarse gravel overlaying finer material, it should be removed and stockpiled separately so that it may be replaced during rehabilitation. If this material is not reinstated to its original profile, the bed substrate may erode sufficiently to cause indirect effects such as bank collapse. Where the original material cannot be reused, rock armouring can be adopted. Where this is adopted a maximum bank slope of 2 horizontal : 1 vertical should be prepared. The rock should generally extend 2m up the bank from the toe and across the drainage line floor. Rock armour should be placed to an average thickness of 300mm and pressed into the soil base with an excavator.

Trench crossings should be carried out when the water course is dry. If there is water in the water course at the time of trench construction, then there should be a dam upstream and downstream and water diverted through suitably designed culverts or pipes through the dams or water pumped around (for flows up to 1000l/s). Any water pumping which may require offsite discharge during construction should be done so through geotextile, sediment fences or gravel outlets to prevent erosion. Geotechnical engineers should carry out an assessment of the trench stability as trenches are often unstable in the presence of water. More specific advice including the required depth of the pipe below the water-bearing layers is given in Chapter 11 of the EIS, Surface water and water courses.

Routine and following high or extreme rainfall events, inspections of soils at the crossings should be conducted. These inspections should visually monitor erosion immediately at the crossing and evidence of sediment runoff downstream. For larger watercourses, that is for those of Stream Order 4 or greater, routine water quality monitoring of pH, electrical conductivity, dissolved oxygen, redox, temperature and turbidity may also be conducted upstream and downstream of the crossing to identify trends and water quality degradation. A detailed monitoring plan should be provided in the EM Plan.

The restoration of the drainage line should be to the original state or natural slope with any sheer banks battered back. Stockpiled timber from clearing activities may also be utilised by spreading the timber randomly over the construction area leading down to the drainage line. Sandbag, gabion or other means of scour protection may be applied and should be placed to conform with existing natural contours, as appropriate, with topsoil respread over the sandbags or gabions. Where required by proximity to grazing stock or other threats, access should be prevented to sites (for example, using fencing or barriers) to assist site recovery.

Water used for hydrostatic testing may be provided to farm dams or for irrigation. However in the absence of definite alternatives, discharge to grade in the local area should be assumed, Prior to discharge, locations should be negotiated with land owners and spent hydrostatic testing water should be analysed for contaminants (for example heavy metals and nutrients) to ensure safe discharge.

Additional engineering controls such as scour protection and flow velocity limits may be required.

7.3.6 Acid sulfate soil management

The oxidation of PASS during excavation and / or filling at soil group 6 could occur. This could result in the migration of acidic discharge into receiving waters. As discussed in Section 6.3.4, detailed assessment is required prior to Project development to assess the full extent of the ASS hazard, determine liming rates for treatment of disturbed ASS and geotechnical limitations such as the risk of acid mobilisation and settlement of soft clays. This recommended detailed investigation is to include an ASS Management Plan (ASSMP) which will outline techniques commonly used for ASS management; neutralisation where alkaline materials (lime) are physically incorporated into the soil and geotechnical recommendations regarding soil stability and loadings. This section provides minimum mitigation requirements for ASS management at the Project Area based on the desktop review undertaken and recommended strategies within Queensland ASS guidelines.

- Exposure of this material to air may result in rapid oxidisation due to its fine to medium texture. If there is a rainfall event while the soils are stockpiled, the generated acid is likely to be mobilised.
- This material can be difficult to work, treat and dry and contain variable levels of sulfide.
- The neutralising capacity of the treated soil must exceed the existing plus potential acidity of the soil.
- Post-neutralisation, the soil pH is to be greater than 5.5. Maintaining a pH greater than 5.5 can control leaching of iron and aluminium (Dear et al., 2002).
- Excess neutralising agent should remain within the soil until all acid generation reactions are complete and the soil has no further capacity to generate acidity.
- Verification samples of the treated soil should be collected and analysed to demonstrate compliance with the performance criteria. If the performance criteria are not met, then the soil must be retreated.
- The type of neutralising agent should be such that insoluble coatings of gypsum, iron and aluminium are minimised. These insoluble coatings inhibit neutralisation. Neutralising agents should also be slightly alkaline, with a low solubility and have a pH ranging from 7 to 9 (Dear et al., 2002). These products will not flush out with the first heavy rain event and have minimal potential to contaminate surrounding waterways and groundwater (Dear et al., 2002). The preferred product is fine aglime, CaCO3.
- Treatment of ASS should be conducted on a dedicated treatment or liming pad. The liming pad should incorporate a guard layer of neutralising agent and a compacted non-ASS clayey material (0.3–0.5 m thick) below the guard layer (refer Figure 7.1). Alternatively a physical barrier may be used as an alternative to a guard layer of neutralising agent as a means of protecting groundwater quality and preventing infiltration of acidic water; e.g. a bunded concrete slab, paved area or layer of bitumen may be placed under a temporary treatment pad.
- Stormwater runoff should be contained within treatment pads by appropriate bunds and may be collected in a sump. Diversion drains could also be used to prevent stormwater run-on into the treatment pad.
- An earthworks strategy should ensure that sufficient space is available for the number of treatment pads required to allow adequate drying and treatment of the ASS. Expected rates of drying, mixing, compaction and treatment times must be identified. The earthworks strategy

must also ensure that adequate time is available to obtain the results of verification testing before treatment of the next layer begins.

- The accurate spatial tracking of ASS volumes is critical to ensure that initial soil testing can be correlated with prescribed treatment and any required verification testing.
- Neutralising agents can be applied to artificial drainage lines in the contained treatment areas. This will assist in neutralising acidic stormwater runoff, and to neutralise acidic water entering from acidified groundwater inflows. Silt fences should be used across the drainage lines to capture and remove precipitated heavy metals where acidified water has contacted the neutralising agent. The neutralising agent should not be added to natural drainage lines of waterways as these environments may be pH sensitive.
- Acid water should be treated with hydrated lime pre-mixed into a slurry before adding. Slurry can be prepared in a concrete truck, cement mixer or large vat with an agitator. Treatment effectiveness should be assessed during and after treatment by in-situ pH (should be between 6.5 and 8.5), in-situ iron testing and other laboratory analysis at a NATA accredited laboratory. Applying the slurry can include the following:
  - Spraying the slurry over the water with a dispersion pump
  - Pumping the slurry into the water body with air sparging (compressed air delivered through pipes) to improve mixing once added to water
  - Using mobile water treatment equipment such as the ‘Neutra-mill’ and ‘Aqua Fix’ to dispense neutralising agents to large water bodies.

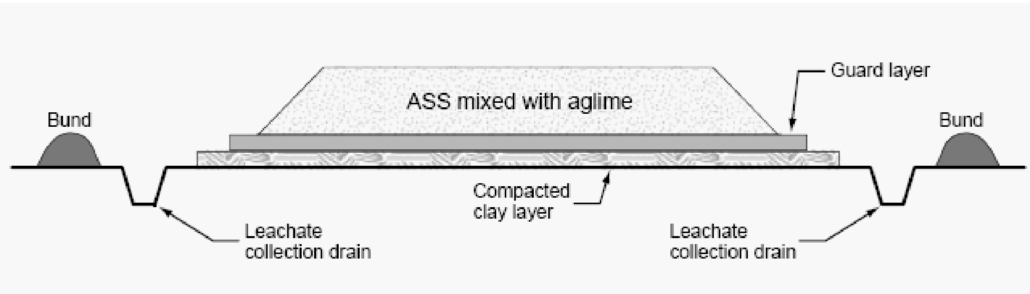

Figure 7.1 Schematic cross-section of a treatment Pad, including a compacted clay layer, guard layer, leachate collection system and containment with bunding (Dear et al., 2002).

7.3.7 Revegetation, revegetation species and weed control

Refer to rehabilitation section within the EIS, Volume 3, Chapter 8 - Terrestrial Ecology.

7.3.8 Access roads and dust mitigation

Once vegetative cover is removed, soils are exposed. When subjected to vehicular traffic, the soil structure diminishes and the soils are more prone to generate dust. This is particularly notable in soils with poorly structured A or B horizons (notably in soil group 2). Dust generation is likely to cause ongoing problems as a result of increased traffic during construction. Similarly on existing road, once there has been too much traffic and subgrade failure occurs, it is difficult to reconstruct roads by backfilling potholes because there will be poor subgrade drainage into potholes and reworking of the structure of the soils in the subgrade.

Appropriate traffic routes should be therefore be assessed. Existing roads should be then assessed for suitability for the anticipated traffic and upgraded if required. Consideration should be given to concurrent CSG activities and activities coordinated if practicable, so that roads are maintained or improved for local residents.

In areas where new access roads are proposed there should be vegetation removal and the stripping and stockpiling of the topsoil layer. Where there are new haul roads, the road should be sheeted with a material appropriate for the subgrade and for the traffic proposed.

Where roads are to be temporary and remain unsealed, the construction methods should aim to reduce the exposure periods for non-vegetated areas and undertake revegetation as soon as practical after construction. Vegetation removal should be limited to the immediate construction area to minimise soil resource degradation (assist in retention of soil moisture and nutrients).

Material being transported should be covered at all times and speed limitation should be adopted to minimise dust creation. Excessive dust should be controlled through the use of spraying water from water trucks. Water should be applied to exposed soils as required to prevent dust generation. Water supplies should be of an appropriate water quality and should not lead to soil contamination (e.g. saline groundwater or contaminated waste water).

On routes which are to be maintained throughout the construction period, and dust is of concern the adoption of specialised additives such as *Dustmag* can be used in order to minimise dust emissions. *Dustmag* is an additive that may be added to the water trucks to help suppress dust if normal measures are not adequate. It is a biodegradable, magnesium chloride preparation, which draws water from the air at night and forms a stabilised compacted surface. The additive may only be required once (generally lasts 3 months) although repeat applications may be required in high use areas. Some watering may be required in extremely dry periods and in problem areas it may be appropriate to remove additional soil layers down to the harder subsoils.

Dust generated from soil stockpiles should be minimised by ensuring exposure time is minimised, seeding with local stock or addition of mulch, applying water, covering stockpiles with protective materials (e.g. hessian, tarpaulins), applying soil additives on stockpiles or exposed slope batters.

Where bulldust occurs on access roads, where it is necessary to retain an access road suitable sheeting material should be used to resurface the road. Where it is practicable to divert traffic, the area should be stripped of bulldust, the topsoil respread, fenced and revegetated.

If all available methods of dust stabilisation fail to suppress dust and it continues to result in unacceptable impacts, construction activities in the affected area may need to be modified while the situation is rectified.

7.3.9 Project decommissioning

Rehabilitation programs will include the decommissioning of the gas transmission pipeline. This will include purging of all hydrocarbon content and the pipeline will be left *insitu* to corrode. Roads, drains, fences, material, equipment, wastes and hardstands should be removed and disposed (if required) offsite.

When all equipment, structures and imported materials have been removed there should be assessment and remediation and rehabilitation of any contaminated areas, then subsequently grading and revegetating the site returning it to a condition as close to its original state as practicable. This includes the re-establishment of original topography and drainage (including pre-existing erosion management structures) and remediation of soil fertility.

Areas which are not returned to pre-development conditions are those which are to be maintained by either land owners or others upon agreement. These areas should be assessed and determined prior to decommissioning.

It has been assumed that Australia Pacific LNG will base future rehabilitation programs on previous successful programs as a minimum. These programs should incorporate comprehensive rehabilitation monitoring and not declared completed until the area is approved by the land owner.

8. Summary of environmental values, sustainability principles, potential impacts and mitigation measures

A summary of the environmental values, sustainability principles, potential impacts and mitigation measures in relation to waste management is presented below in Table 8.1.

In addition, Table 8.1 includes the residual risk levels for land management. A risk assessment has been undertaken to identify the potential risks, causes and consequences to land from the LNG plant development. 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 8.1 Summary of environmental values, sustainability principles, potential impacts and mitigation measures

Environmental values	Sustainability principles	Potential impact	Possible cause(s)	Mitigation measures	Residual risk rating
Management of finite resources	Minimising adverse environmental impacts and enhancing environmental benefits associated with our activities, products or services; conserving, protecting, and enhancing where the opportunity exists, the biodiversity values and water resources in our operational areas. Using resources efficiently, reducing the intensity of materials used and implementing programs for the reduction and reuse of waste.	Alteration of topography, drainage, leaching of chemical / minerals, removal of vegetation, changes to land and road use and changed dust, noise and vibration levels.	Demand on local resources for Project development Development of new and / or expansion of existing quarries.	FEED phases will quantify the need for extractive materials prior to construction, and identify the quality, volume and type of materials required, and the location at which these will be required. Extractive businesses which choose to meet the demand for extractive materials for the Project would be required to follow approvals process in accordance with applicable legislation. FEED phases will identify size and local demand of existing extractive resources. Reuse materials on site where practicable. Mobile crushers may be used to minimise the need for quarry materials from external sources. Maintain private and public road conditions. Extraction operations (where undertaken by Australia Pacific LNG) will be mitigated through environmental management and operation plans and comply with DERM and local council operational conditions including compliance with relevant emission levels.	Low
Landform	Identifying, assessing, managing, monitoring and	Change to topography Destabilisation of soils	Landform modification through stormwater diversion, vegetation clearing,	Implement sediment and erosion control and manage runoff to minimise concentrated flows. Formation levels should be set	Low

Environmental values	Sustainability principles	Potential impact	Possible cause(s)	Mitigation measures	Residual risk rating
	reviewing risks to our workforce, our property, the environment and the communities affected by our activities.	Change to drainage Degraded downstream water quality Slope instability Visual amenity	earthworks and establishment of quarries	Construction materials should be reused where practicable. Compaction of fill should be controlled to minimise soil mounding or settlement. Progressive clearing and rehabilitation. Structures should be sited on relatively level sites where practicable. Undertake a geotechnical slope analysis. Stabilise water crossing following construction, Rehabilitation to a condition as close to the original state as practical or to a condition which is consistent with the surrounding environment. Detailed design of creek crossings should incorporate works and measures to minimise risk of damage to creek banks.	
Soil		Loss of topsoil quality and quantity	Incorrect stripping, prolonged exposure and erosion Soil inversion (replacement of topsoils with subsoils) Poor rehabilitation and drainage management.	Vegetation clearance should be minimised as far as practicable. Undertake site-specific topsoils assessment. Undertaken progressive clearing and rehabilitation. Separate stockpiling of vegetation and soil groups. Account for additional stockpile storage. Addition of nutrients / conditioner or suitable seed stock. Training with earthmoving staff to ensure correct handling. Topsoil stockpiles should be limited to 2m in height to	Low

Environmental values	Sustainability principles	Potential impact	Possible cause(s)	Mitigation measures	Residual risk rating
				maintain fertility and vegetated if stockpiled for extended periods. Rocky material should be removed during stripping, where practicable Monitoring of weeds should be undertaken. Implement sediment and erosion control. Rehabilitation of disturbed areas should be consistent with surrounding conditions.	
Minimise soil salinity		Increased salinity leading to poor rehabilitation and corrosion of civil structures.	Poor soil handling (removal, stockpiling and respreading) leading to soil inversion Blending of non-saline and highly saline soils Inadequate monitoring of rehabilitation.	Undertake geotechnical investigations to assess suitable corrosion protection for civil structures. Implement suitable subsoil handling which minimises blending of non-saline and highly saline soils and soil inversion. Minimise vegetation clearing and stockpile topsoils separately from subsoils. Adoption of EM Plan which incorporates monitoring of rehabilitated areas. Disposal of saline water should meet the requirements identified in Volume 3, Chapter 12 which covers associated water management.	Low
Soil resource		Soil erosion – soil destabilisation Poor rehabilitation and drainage	Vegetation clearing Poor drainage management. Concentrated flow	Implement sediment and erosion control plan which includes redirection and management of runoff to minimise concentrated flows should be developed and implemented. Sediment fences and/or sediment detention structures	Medium

Environmental values	Sustainability principles	Potential impact	Possible cause(s)	Mitigation measures	Residual risk rating
		management. Sedimentation of downstream areas Decline in fertility Undermining of structures (roads, buildings, fencing) where soil has been wash away through runoff	discharge. Improper sediment and erosion controls Inadequate earthworks contractor training and supervision	should be constructed on the downhill side of excavated areas and around stockpiles. Conduct regular inspections of sediment and erosion control measures and areas receiving concentrated flows. Undertake progressive clearing and rehabilitation and creation of stable slopes. Stabilise erosive / dispersive areas which are exposed for extended periods. Sediment and erosion control devices should be installed prior to construction and retained until the area is stabilised. Access tracks should be constructed across slopes, or have contour banks at appropriate intervals where access tracks go down slope. Trench breakers will be installed in the backfill at interval appropriate to slope steepness. Sediment basins will be constructed on the downhill side of facilities when they are near sensitive receptors. Water to be discharged from construction sites will be done so through silt fences or other erosion control measures if required. Conduct routine (and following severe rain events) inspections of natural watercourses. Pipe trenches at watercourses should be excavated perpendicular to direction of water flow and backfilled carefully	

Environmental values	Sustainability principles	Potential impact	Possible cause(s)	Mitigation measures	Residual risk rating
				Where practicable, construction through creeks will be carried out when dry. Existing water will be dammed or diverted around construction Creek rehabilitation will be consistent with surrounding environment and contours of the channel at the time of construction and protected with fencing where required Determination of suitable discharge locations in consultation with landowners and relevant Federal, State or Regional authorities will be undertaken. Point discharges should be into stable waterways and / or drainage lines and engineering controls such as scour protection and flow velocity limits implemented.	
Land capability		Reduced agricultural production area Modification of overland flow Increased soil compaction Decreased fertility Increased erosion Disruption of farming operations	Construction and operation of Project infrastructure	Where practicable, the gas pipeline should be sited on areas which will not impinge on the productive capacity and drainage of the land and cause the least changes to landholder operations. When operating on properties which maintain livestock, ensure gates are kept closed to prevent livestock moving between properties. Install good quality fencing (steel gates on driver side) to restrict stock movement between neighbouring properties, minimising productive soil exposure and installing appropriate signage (that is, on fencing not within paddocks). Incorporate additional depth of cover for pipelines where deep ripping may be used.	Medium

Environmental values	Sustainability principles	Potential impact	Possible cause(s)	Mitigation measures	Residual risk rating
				Undertake progressive rehabilitation of construction areas Remove wastes as per a waste management plan to be prepared for the gas pipeline (refer Volume 3 Chapter 16). Rehabilitate disturbed areas to vegetation types consistent with the surrounding environment.	
Minimise acid generation		Soil acidification - Oxidisation of PASS Degradation of environment and new civil structures from acidic run-off. Unstable excavation	Excavation and / or filling of soil group 6 (Holocene miscellaneous unconsolidated sediments)	Undertake suitable geotechnical investigations pre-construction to assess appropriate design and construction techniques. Undertake a detailed ASS investigation in accordance with Queensland Guidelines, and develop an ASS Management Plan.	Low
Air Soil resource		Degradation of soil structure Dust creation	Clearing of vegetation and increased traffic	Assess appropriate on-site routes and upgrade where required Vegetation and topsoil will be removed where new tracks are required. On-site access roads will be surfaced with gravel and/or geotextile or surface additives. Revegetation should be undertaken as soon as practical. Use watering truck to control dust where required. Apply speed limitations Use watering truck to control dust where required. Where bulldust occurs, consider application of crushed rock, diversion of traffic and rehabilitation of this area.	Low

9. Limitations and assumptions

This assessment of soil conditions within the study area was based on government supplied information and a limited field assessment. It does not constitute a detailed investigation that can be used for engineering purposes. The information provided in this assessment is directly relevant only to the points in the ground where they were obtained at the time of the assessment, considered indicative of field conditions and appropriate to the scale of the Project. The precision with which conditions are indicated depends largely on the frequency and the method of sampling and the uniformity of conditions.

In order to fulfil a number of requirements within the Project Terms of Reference (TOR), a number of assumptions regarding the gas pipeline have been made. Table 9.1 presents the assumptions made to complete the footprint analysis within each GQAL class discussed in Section 6.3.6.

Table 9.1 GQAL footprint assumptions

Footprint	Assumption	Date data supplied	Data origin
Main Pipeline (incl Lateral) – Construction and Operation RoW	Used a 20m buffer around pipeline alignment. Option 3F was used	12/2009	Option 3F pipeline route Supplied by Australia Pacific LNG
Scraper stations	No data		
Access tracks	No data		
Pipeline temporary accommodation facilities	A number of pipeline temporary accommodation facilities have been provided. Mapping data indicating a total area of 152.2ha was provided. This was analysed rather than 83.45ha as indicated in Table 6.1.	12/2009	Australia Pacific LNG

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Appendix A Abbreviations and Glossary

Abbreviations

AASS	Actual acid sulfate soil
ASS	Acid sulfate soil
Ca	Calcium
CEC	Cation exchange capacity
Cl-	Chloride
DERM	Department of Environment and Resource Management
DNR	Queensland Department of Natural Resources
DNR&W	Queensland Department of Natural Resources and Water
DNRM	Queensland Department of Natural Resources and Mines
DPI	Queensland Department of Primary Industries
EC	Electrical conductivity
EHS	Extremely high strength
EPA	Environmental Protection Agency
ESP	Exchangeable sodium percentage
Fe	Iron
FEED	Front end engineering and design
GQAL	Good quality agricultural land
HW	Highly weathered
K	Potassium
LS	Low strength
Mg	Magnesium
MS	Medium strength
MW	Moderately weathered
Na	Sodium
P	Phosphorus
PASS	Potential acid sulfate soils
PAWC	Plant available water capacity
SAR	Sodium adsorption ratio
SO_4^{2-}	Sulfate
SW	Slightly weathered

TAA	Titratable actual acidity
TKN	Total Kjeldahl Nitrogen
UTM	Universal Transverse Mercator
VHS	Very high strength
XW	Extremely weathered

Glossary

A horizon	The original top layer of mineral soil divided into A_1 (typically from 5 to 30 cm thick; generally referred to as topsoil with a high content of organic matter, dark colour and maximum biological activity) and A_2 horizons (usually 5 – 70 cm thick; similar texture to A_1 but paler in colour, poorer in structure and less fertile).
acid soil	Any soil with a pH of less than 6.5
aggregate (soil)	A unit of soil structure consisting of primary soil particles held together by cohesive forces or by secondary soil materials such as iron oxides, silica or organic matter. Aggregates may be natural, such as *peds*.
alkaline soil, alkalinity	Alkaline soils have laboratory measured pH values >8.5. Alkalinity may inhibit the growth of plants.
alluvial terrace	Former floodplain which either no longer floods or rarely floods due to deepening or enlargement of the stream channel.
alluvium	Sediment deposited from the transport by channelled stream flow or over-bank stream flow
andesite	Fine-grained volcanic rock composed of andesine (plagioclase) with one or more mafic constituents
apedal	In the moderately moist to moist state, none of the soil material occurs in the form of peds; it is massive or single-grained and when disturbed, separates into fragments or primary particles.
ASC	Australian Soil Classification—It is a multi-category scheme with classes defined on the basis of diagnostic horizons or materials and their arrangement in vertical sequence as seen in an exposed soil profile.
available soil water	That part of the water in the soil that can be absorbed by plant roots, that can be held between field capacity and the moisture content at which plant growth ceases.
available water holding capacity	The ability to hold that part of the water in the soil that can be absorbed by plant roots. Available water is the difference between field capacity and permanent wilting point.
B horizon	The layer of soil below the A horizons, usually of finer texture (ie, more clayey), denser and stronger in colour. Thickness ranges from 10 cm to 2 m thick and is divided into B_1 and B_2 horizons.
bolus	A small handful of soil which has been moistened and kneaded into a soil ball which just fails to stick to the fingers.

boundaries (soil)	The boundary between soil horizons defines the nature of the change from one horizon to that below. It is specified by two terms—one a measure of the width of the transition zone between the two horizons, the other a description of its shape.
C horizon	Layers below the B horizon which may be weathered, consolidated or unconsolidated parent material little affected by biological soil-forming processes.
Cainozoic	Geological period 65 million years ago to present.
Chromosol	ASC Soil Order classification—Soils with a clear or abrupt textural B horizon where the major half of the B_2horizon is not strongly acid (ie >pH5.5) and non-sodic (can be sodic at depth).
clastic	Rocks built up from fragments of pre-existing rocks generated by weathering and erosion and transported to a point of deposition
colluvium	Unconsolidated soil and rock material transported largely by gravity (ie, mass movement: landslide, mudflow, creep or sheetflow), deposited on a lower slope and/or at the base of a slope. Does not have bedding structure such as alluvium and is has more variable grain size.
deltaic	Sediments deposited at the mouth of a river where it enters a lake or the sea
Dermosol	ASC Soil Order classification—Other soils with B_2horizons that have structure more developed than weak throughout the major part of the horizon, generally non-sodic subsoil, generally gradational textured soils (gradual boundaries).
Devonian	Geological period 395 – 345 million years ago.
Ferrosol	ASC Soil Order classification—Soils with B_2 horizons in which the major part has a free iron oxide content greater than 5% Fe in the fine earth fraction (<2 mm). Soils with a B_2horizon in which at least 0.3 m has vertic properties are excluded.
fluvial	Material deposited by rivers and streams
fore-arc	A forearc is a depression in the sea floor located between a subduction zone and an associated volcanic arc.
fossiliferous	Fossil containing rock formations
gilgai	Microrelief associated with soils containing shrink-swell clays
granite	A granular igneous rock composed chiefly of felspar (orthoclase) and quartz, usually with one or more other minerals, as mica, hornblende, etc.
granodiorite	Plutonic rock consisting of potassium felspar, quartz, plagioclase, biotite and hornblende. Granodiorite is an intermediate between quartz, monzonite and quartz diorite.
gravel	The amount (visual abundance estimate) of gravel-sized (>2 mm) materials that occur on the surface and in the A_1 horizon and include hard (when moist), coarse fragments and segregations of pedogenic origin.
gravelly	Over 60% of surface cover consists of gravel (2 - 60 mm).
GSG	Great Soil Groups of Australia (as defined by Stace *et al* 1968), described in terms of morphology, genesis and land use.

Holocene	Present geological epoch which commenced 10 000 years ago.
Horizon	A layer within the soil profile with morphological characteristics and properties different from layers below and/or above it.
Jurassic	Geological period 295 - 135 million years ago.
Kandosol	ASC Soil Order classification—Other soils that are lacking a strong texture contrast and (i) have well-developed B_2 horizons in which the major part is massive or has only a weak grade of structure, *and* (ii) have a maximum clay content in some part of the B_2 horizon which exceeds 15%.
Kurosol	ASC Soil Order classification—Soils with a clear or abrupt textural B horizon and in which the major part of the upper 0.2 m of the B_2 horizon (or the major part of the entire B_2 horizon if less than 0.2 m thick) is strongly acid (ie pH<5.5).
lacustrine sediment	Sediment mass deposited from transport by waves and from sediment solution and suspension in still water in a closed depression on land
Lithosol	GSG classification—A shallow soil showing minimal profile development and dominated by the presence of weathering rock and rock fragments. Lacking horizons other than an A_1 (one layer only).
loam	A medium, textured soil of approximate composition 10 - 25% clay, 25 - 50% silt and <50% sand.
melonhole	Irregularly distributed large depressions within soil surface, usually greater than 3m in diameter
mottled horizon	A horizon in which mottle abundance is greater than 10% (visual abundance estimate) and contrast between colours is distinct and prominent.
mottling	The presence of more than one soil colour in the same soil horizon, not including different nodule or cutan colours.
oolitic	Sedimentary rock consisting of ooids
paludal	Sediments that accumulated in a march environment
paralic	Sedimentary basins developed in marginal marine environments, i.e. lagoons, littoral basins
ped	An individual, natural soil aggregate.
Pleistocene	First epoch of the Quaternary period, from 2 million years ago to 10 000 years ago.
Quaternary	Period of geological time covering the Holocene plus the Pleistocene. Up to 2.6 million years ago.
red earths	GSG classification—Massive, reddish sandy profiles with a gradual increase in clay content with depth over a diffuse to gradual boundary.
Rudosol	ASC Soil Order classification—Soils with negligible pedologic organisation. They are usually young soils in the sense that the soil forming factors have had little time to pedologically modify parent rocks or sediments. The component soils can vary widely in terms of texture and depth.

sheet erosion	The removal of the upper layers of soil by raindrop splash and/or runoff.
silt	Fine soil particles in the size range 0.02 - 0.002 mm.
skeletal soils	Thin soils
Sodosol	ASC Soil Order classification—Soils with strong texture contrast between A horizons and sodic B horizons which are not strongly acid.
solum	The upper part of a soil profile above the parent material in which current processes of soil formation are active. This is where the living roots and other plant and animal life characteristics are exhibited.
structure (soil)	Is concerned with the arrangement of all soil particles and refers to the distinctness, size, shape and condition of the peds.
Tertiary	Period of geological time, 2 – 65 million years before present.
texture	A measure of the behaviour of a small handful of soil when moistened and kneaded into a ball (bolus) and then pressed out between the thumb and forefinger.
topsoil	A part of the soil profile, typically the A_1 horizon, containing material which is usually darker, more fertile and better structured than the underlying layers.
Triassic	Period of geological time, 180 – 230 million years before present.
Vertosol	ASC Soil Order classification—Clay soils with shrink-swell properties that exhibit strong cracking when dry and at depth have slickensides and/or lenticular structural aggregates. Although many soils exhibit gilgai microrelief, this feature is not used in their definition.

Appendix B Summary of field data and results

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Appendix B **Table 1a: Field Data**

KP Location	Sample Assessment Location	Observation Type	Land Use	Horizon and General Soil Description (depth mBGL)	Mapped Soil Group and Description	Field Classification (ASC)	Soil Description – Topsoil	Soil Description – Subsoil	Existing Erosion 1 2 3	Drainage R W MW I P VP	Terrain Class 1 2 3	Predominant Slope 1 2 3 4 5 6	Slope Position F C U M L D	Aspect N S E W	Watertable	GPS Southing	GPS Easting	Vegetation	Comments
General Information				*Soil Summary*							*Landscape Information*								
1	S1a	Soil	Road reserve	A 0.0-0.1 f-mSZL A 0.1-0.2 f-mSZG C 0.2-0.3 Sandstone C 0.3-0.5 Sandstone	1b	**ANTHROPOSOL (AN)**	(10YR 3/4) f-mSZL: D, LO, NST, NP @ 0.1 (10YR 3/2) f-mSZG: D, STR, NST, NP, abundant f-S coarse fragments	(10YR 3/2) Sandstone: D, WE, NST, NP	2	MW	2	3	M	W	-	S26 39.601	E150 14.669	*Observed vegetation: Highly disturbed - Poplar Box, Ironbark, Cypress Pine, Blue Gum Regrowth* Canopy: - Understory: - Ground strata: sparse grass	- Highly disturbed area between private property, railway line and Warrego Hwy - Observation adjacent to large dumping area - Cut and fill spoil evident throughout
11	S1	Soil	Road reserve	A1 0.0-0.1 ZL A3 0.1-0.2 ZL B1 0.2-0.4 lC B1 0.4-0.5 ZL	1b	**TENOSOL (TE)**	(10YR 4/4 ZL: D, LO, SST, LP, few F coarse fragments, common VF-M roots (10YR 4/4) ZL: D, LO, SST, LP	(10YR 5/1) LC: D, RI, NST, LP @ 0.4 (10YR 5/2) ZL: D, RI, NST, LP @ 0.5 refusal	1	I	1	1	F	-	-	S26 34.187	E150 14.525	*Observed vegetation: Some clearing - Ironbark, Cypress Pine, Blue Gum* Canopy: 20-30m Understory: 5-10m Ground strata: sparse grass and abundant leaf debris	- Observation adjacent to unsealed road
22	S2	Soil	Road reserve	A1 0.0-0.15 ZfSL B1 0.5-0.8 fShC B3 0.8-0.95 fShC C 0.95-1.0 Sandstone	1b	Brown (AB), **KUROSOL (KU)**	(10YR 4/4) ZfSL: D, LO, NST, NP, very few VF coarse fragments, many F-M roots	(10YR 3/1) fShC: D, FI, ST, HP, very few VF roots @ 0.8 (10YR 3/1) fShC: D, FI, ST, HP @ 0.95 (10YR 7/8) Sandstone	2	P	1	1	F	-	-	S26 30.560	E150 10.260	*Observed vegetation: Brigalow, Ironbark* Canopy: 10-20m Understory: 5m Ground strata: sparse grass and abundant leaf debris	- Observation within road reserve and adjacent to unused unsealed road and private property fenceline - Vegetation now regrowing in road - Gully erosion within old road drains and where no vegetation - Surface soil doesn't easily absorb water
36	S3	Soil	Road reserve	A1 0.0-0.1 fSL A3 0.1-0.7 fShC B1 0.7-1.0 hC	2b	Brown (AB), **KUROSOL (KU)**	(10YR 5/2) fSL: D, LO, NST, NP, many F-M roots @ 0.1 (10YR 5/3) fShC: D, STR, SST, HP	(10YR 3/2) hC: SLMOi, STR, SST, HP	1	P	1	1	F	-	-	S26 23.076	E150 11.467	*Observed vegetation: Cypress Pine, Spotted Gum, Ironbark* Canopy: 20m Understory: 5m Ground strata: sparse grass and abundant leaves and debris	- Observation adjacent to unsealed road and private property fenceline - Observation moved to pipeline re-alignment - Surface soil doesn't easily absorb water
3	S4	Soil	Road reserve - grazing	A1 0.0-0.4 ZfSL	5b(m)	**TENOSOL (TE)**	(10YR 5/2) ZfSL: D, LO, NST, NP, abundant F-C coarse fragments, many F-M roots @ 0.4 refusal on bedrock	-	1	MW	1	1	F	-	-	S26 17.237	E150 11.788	*Observed vegetation: Some clearing - Red Gum / Brigalow* Canopy: 20-30m Understory: 5m Ground strata: sparse grass	- Observation adjacent to unsealed road - Road material appears to be the same as S4
22	S5	Soil	Grazing	A1 0.0-0.1 ZhC A3 0.1-0.4 hC B1 0.4-0.7 hC B2 0.7-1.0 hC	1b	Brown (AB) **VERTOSOL (VE)**	(10YR 3/1) zhC: D, C, STR, ST, HP, few F-M coarse fragments, abundant VF-M roots @ 0.1 (10YR 3/2) hC: S, STR, ST, HP	(10YR 3/2) hC: SLMOi, STR, ST, HP @ 0.7 (10YR 3/3) hC: Moi, STR, ST, HP	1	P	2	4	F	-	-	S26 07.460	E150 12.001	*Observed vegetation: Cleared* Canopy: - Understory: - Ground strata: grass	- Greasy clays (organics)
34	S6	Soil	Grazing	A1 0.0-0.1 ZlC (trace fS) A3 0.1-0.2 ZlC (trace fS) B1 0.2-0.4 mC (trace fS) [KC] B2 0.4-1.0 mC (trace fS)	5b(m)	Grey (AD), **CHROMOSOL (CH)**	(10YR 3/3) ZlC (trace fS): D, C, SST, LP, many F-C coarse fragments, abundant VF-M roots @ 0.1 (10YR 3/2) ZlC (trace fS): D, WE, SST, LP, many F-C coarse fragments	(10YR 5-1) mC (trace fS) [KC]: D, STR, ST, MP, common F-C coarse fragments @ 0.4 (5Y 6/3) mC (tract fS): D, STR, ST, MP	2	P	2	4	L	E	-	S26 00.869	E150 11.304	*Observed vegetation: Brigalow, Ironbark* Canopy: 10m Understory: - Ground strata: grass	- Private property - partially cleared, adjacent to fence - Some scattered surface stones - Some gully erosion adjacent to fenceline
50	S7	Soil	Road reserve	A 0.0-0.1 ZL (trace fS) B1 0.1-0.5 ZlC B3 0.5-0.7 ZfSC C 0.7-0.9 Sandstone	2c	Brown (AB) **SODOSOL (SO)**	(10YR 3/3) ZL (trace fS): D, C, NST, LP, many F roots	(10YR 3/4) ZlC: D, STR, SST, MP @ 0.5 (10YR 4/4) ZfSC: D, WE, SST, MP @ 0.7 (10YR 4/6) Sandstone	1	P	1	2	F	-	-	S25 52.839	E150 13.481	*Observed vegetation: Ironbark* Canopy: 10m Understory: 3m Ground strata: grass	- Adjacent to Big Valley Road
61	S8	Soil	Grazing	A1 0.0-0.05 ZL (trace fS) A2 0.05-0.15 ZL (trace fS)	4b	Leptic (CY), **RUDOSOL (RU)**	(5YR 2.5/2) ZL (trace fS): D, LO, NST, NP, few VF coarse fragments, many VF-C roots @ 0.05 (2.5YR 2.5/4) ZL (trace fS): D, LO, NST, NP, few F-M coarse fragments @ 0.15 refusal on bedrock	-	1	I	2	4	C	-	-	S25 47.265	E150 14.968	*Observed vegetation: Cleared for grazing* Canopy: - Understory: - Ground strata: grass	- Private property adjacent to property boundary - Some scattered surface boulders - Rock outcrop nearby
88	S9	Soil	Road reserve - grazing	A1 0.0-0.1 fSmC A2 0.1-0.4 ZfSL B1 0.4-0.65 ZhC B1 0.65-0.9 ZmC (trace fS) B3 0.9-1.0 CfS	4b	Yellow (AC) **DERMOSOL**	(10YR 3/2) fSmC: D, C, SST, MP, many F-C roots @ 0.1 (10YR 3/3) ZfSL: D, LO, SST, NP, few F-C coarse fragments, many F-C roots	(10YR 4/2) ZhC: D, STR, ST, HP, few F roots @ 0.65 (10YR 6/8) ZmC (trace fS): D, WE, ST, MP @ 0.9 (10YR 6/4) CfS: D, STR, NST, NP	1	P	1	3	L	-	-	S25 34.670	E150 22.226	*Observed vegetation: Mostly cleared - Ironbark, Poplar Box* Canopy: 20m Understory: - Ground strata: grass	- Observation adjacent to unsealded road
106	S10	Soil	Road reserve - grazing	A1 0.0-0.15 ZGf-mS A2 0.15-0.45 ZGf-mS B1 0.45-1.0 fSGlC	2c	Brown (AB), **CHROMOSOL (CH)**	(10YR 4/3) ZGf-mS: D, LO, NST, NP, common F-C coarse fragments, common VF roots @ 0.15 (10YR 6/3) ZGf-mS: D, LO, SST, NP, common F-C coarse fragments	(10YR 4/4) fSGlC: D, WE, SST, LP, abundant F-C coarse fragments	2	I	1	3	F	-	-	S25 26.468	E150 22.523	*Observed vegetation: Mostly cleared - Ironbark, Wilga* Canopy: 10-20m Understory: 3m Ground strata: grass	- Some clearing for grazing + regrowth - Original location moved due to access restrictions
121	S11	Soil	Road reserve - grazing	A1 0.0-0.3 f-mSZL A3 0.3-0.5 f-mSZL B1 0.5-1.0 f-mSZG	2c	Brown (AB) **KANDOSOL (KA)**	(10YR 3/4) f-mSZL: D, LO, NST, NP, common F coarse frfagments, many VF rootss @ 0.3 (10YR 4/4) f-mSZL: D, LO, NST, NP, many F coarse fragments	(10YR 6/4) f-mSZG: D, LO, SST, NP, abundant F-C coarse fragments	1	MW	1	3	L	-	-	S25 18.849	E150 23.537	*Observed vegetation: Mostly cleared - Ironbark* Canopy: 20m Understory: 5m Ground strata: grass	- Some clearing for grazing - Observation moved to location along re-alignment - Observation near rolling hills with rock outcrop - Adjacent to private property
128	S12	Soil	Grazing	A1 0.0-0.2 Zf-kS A2 0.2-0.3 Zf-kS	2c	Leptic (CY), **RUDOSOL (RU)**	(10YR 5/2) Zf-kS: D, LO, NST, NP, few F-C coarse fragments, many F roots @ 0.2 (10YR 6/2) Zf-kS: D, LO, NST, NP, abundant F-C coarse fragments	-	1	W	2	4	M	W	-	S25 15.467	E150 24.501	*Observed vegetation: Ironbark, Poplar Box* Canopy: 20m Understory: - Ground strata: grass	- Abundant surface boulders
139	S13	Soil	Road reserve - grazing	A1 0.0-0.2 ZmC A2 0.2-0.6 hC (trace fS) B1 0.65-1.0 mC	2c	Brown (AB) **DERMOSOL (DE)**	(10YR 2/2) ZmC: D, C, ST, HP, few VF roots @ 0.2 (10YR 3/3) hC (trace fS): D, STR, VST, HP	(10YR 6/8) mC: D, WE, SST, HP, many F-C coarse fragments	1	P	1	3	F	-	-	S25 09.675	E150 26.127	*Observed vegetation: Mostly cleared - Blue Gum, Ironbark* Canopy: 20m Understory: - Ground strata: grass	- Mostly cleared for grazing. - Adjacent to unsealed road
148	S14	Soil	Road reserve - grazing	A1 0.0-0.1 f-mSCL A2 0.1-0.55 fSlC B1 0.55-1.0 lC (trace f-KS)	2c	Brown (AB), **TENOSOL (TE)**	(7.5YR 4/3) f-mSCL: D, LO, NS, LP, few VF roots @ 0.1 (5YR 3/4) fSlC: D, FI, VST, HP	(10YR 5/3) lC (trace f-kS): D, WE, SST, HP, common F-C coarse fragments	1	I	2	4	U	N	-	S25 05.070	E150 26.790	*Observed vegetation: Mostly cleared - Ironbark* Canopy: 20m Understory: - Ground strata: grass	- Mostly cleared for grazing - Sandstone outcrops - Recent burn off - Erosion adjacent to creek at road crossing
156	S15	Soil	Road reserve - grazing	A1 0.0-0.3 fSZL B1 0.3-0.6 fSLC B21 0.6-0.9 ZLC (trace fS) B22 0.9-1.0 ZmC (trace kS)	2c	Brown (AB), **CHROMOSOL (CH)**	(10YR 3/4) fSZL: D, LO, NST, NP, few VF roots	(10YR 4/4) fSLC: D, FI, NST, LP, many VF coarse fragments @ 0.6 (10YR 3/6) ZLC (trace fS): D, WE, ST, LP @ 0.9 (10YR 5/4) ZmC (trace kS): D, WE, MS, MP	1	W	1	3	M	N	-	S25 01.060	E150 27.064	*Observed vegetation: Ironbark* Canopy: 20m Understory: 3m Ground strata: grass	- Cleared for grazing - Observation made at the boundary of natural and grazing

Appendix B **Table 1a: Field Data**

General Information				Soil Summary							Landscape Information								
KP Location	**Sample Assessment Location**	**Observation Type**	**Land Use**	**Horizon and General Soil Description (depth mBGL)**	**Mapped Soil Group and Description**	**Field Classification (ASC)**	**Soil Description (texture, structure, consistence, coarse fragments, rooting)** *Topsoil*	*Subsoil*	**Existing Erosion** *1 2 3*	**Drainage** *R W MW I P VP*	**Terrain Class** *1 2 3*	**Predominant Slope** *1 2 3 4 5 6*	**Slope Position** *F C U M L D*	**Aspect** *N S E W*	**Watertable**	**GPS Coordinates of observation** *Southing*	*Easting*	**Vegetation**	**Comments**
164	S16	Soil	Grazing	A1 0.0-0.15 kSZL A2 0.15-0.4 kSZL	2c	Leptic (CY), **RUDOSOL (RU)**	(10YR 4/2) kSZL: D, LO, NST, NP, common VF coarse fragments, few VF roots @ 0.15 (10YR 7/1) kSZL: D, LO, NST, NP, many VF coarse fragments @ 0.4 refusal on Sandstone	-	2	I	1	2	L	W	-	S24 57.201	E150 27.119	*Observed vegetation: Blue Gum, acacia* Canopy: 20m Understory: 3-5m Ground strata: grass	- Cleared for grazing - 30m wide cleared area adjacent to fenceline - Some gully erosion evident adjacent to road
171	S17	Soil	Road reserve - grazing	A1 0.0-0.4 LfS A3 0.4-0.7 LfS B1 0.7-1.0 Zf-kS	2c	Brown (AB), **TENOSOL (TE)**	(10YR 3/6) LfS: D,C SST, NP, few F coarse fragments, few VF roots @ 0.4 (10YR 4/4) LfS: D, LO, SST, NP	(10YR 4/3) Zf-kS: D, LO	2	MW	2	4	U	N	-	S24 53.899	E150 27.819	*Observed vegetation: Ironbark* Canopy: 10-20m Understory: 5m Ground strata: grass	- Partially cleared for grazing - Few surface boulders - Adjacent to unsealed road - Some gully erosion evident
183	S18	Soil	Road reserve - grazing	A1 0.0-0.2 ZmC A2 0.2-0.6 mC B1 0.6-1.0 fSGmC	2c	Brown (AB), **CHROMOSOL (CH)**	(10YR 3/4) ZmC: D, C, SST, MP, many VF-F roots @ 0.2 (10YR 3/6) mC: D, LO, SST, MP	(10YR 5/2) fSGmC: D, LO, SST, MP, abundant F-C coarse fragments	1	P	2	4	U	W	-	S24 47.835	E150 28.611	*Observed vegetation: Ironbark* Canopy: 10-20m Understory: - Ground strata: grass	- Mostly cleared for grazing - Observation made along re-alignment - 10m from unsealed road
200	S19	Soil	Grazing	A1 0.0-0.2 ZL A2 0.2-0.5 ZGL A3 0.5-0.9 ZGLS B1 0.9-1.0 LkS	2c	Brown (AB), **SODOSOL (SO)**	(10YR 3/3) ZL: D, C, SST, LP, few VF coarse fragments, few VF roots @ 0.2 (10YR 3/3) ZGL: D, LO, SST, NP, common VF-C coarse fragments @ 0.5 (10YR 4/3) ZGLS: D, LO, SST, NP, abundant VF-C coarse fragments	(10YR 3/4) LkS: SLMOi, ST, NP, abundant VF-C coarse fragments	1	P	1	1	F	-	-	S24 38.806	E150 27.721	*Observed vegetation: Cleared* Canopy: - Understory: - Ground strata: grass	- Grazing - Observation 30m from fenceline - Adjacent soil type cracking clay
215	S20	Soil	Grazing	A1 0.0-0.2 hC A2 0.2-0.6 hC B1 0.6-0.8 hC B2 0.8-1.0 IC (KC)	5b	Brown (AB), **VERTOSOL (VE)**	(10YR 3/2) hC: D, VFI, ST, HP, many VF roots @ 0.2 (10YR 3/2) hC: D, VFI, ST, HP	(10YR 3/4) hC: SLMOi, VFI, ST, MP @ 0.8 (10YR 6/6) IC (KC): D, WE, SST, MP, many F-C coarse fragments	1	P	1	2	U	SE	-	S24 31.262	E150 25.242	*Observed vegetation: Cleared* Canopy: - Understory: - Ground strata: grass	- Grazing
231	S21	Soil	Grazing	A1 0.0-0.2 mC B1 0.2-0.55 hC (KC) B2 0.55-1.0 hC (massive)	4a	Brown (AB), **DERMOSOL (DE)**	(10YR 4/2) mC: D, ST, common VF-M roots	(10YR 4/1) hC(KC): D, RI @ 0.55 (10YR 5/2) hC: SLMOi, STR, VST, HP, few F coarse fragments	1	P	1	1	F	-	-	S24 22.624	E150 24.863	*Observed vegetation: Cleared - grazing* Canopy: - Understory: - Ground strata: grass	- Private Property - 30m from boundary fence line
247	S22	Soil	Road reserve - grazing	A1 0.0-0.1 ZmC A2 0.1-0.2 fSZL B1 0.2-0.4 ZmC	5b	Brown (AB), **DERMOSOL (DE)**	(10YR 4/2) ZmC: D, VSTR, ST, HP, many VF roots @ 0.1 (10YR 3/2) fSZL: D, LO, SST, NP, few VF roots	(10YR 4/1) ZmC: D, RI @ 0.4 refusal	1	P	1	1	F	-	-	S24 16.592	E150 29.110	*Observed vegetation: Cleared - grazing* Canopy: - Understory: - Ground strata: grass	- Adjacent to fenceline within road reserve
254	S23	Soil	Road reserve and adjacent to '36 gas line' (QLD gas)	A1 0.0-1.0 fSZL	1b	Arenic (AO), **RUDOSOLS (RU)**	(2.5YR 3/6) fSZL: D, LO, many VF roots @ 0.7 SLMOi	-	1	MW	1	1	F	-	-	S24 14.587	E150 32.907	*Observed vegetation: Ironbark regrowth* Canopy: 10m Understory: 5m Ground strata: grass and debris	- Abundant ground debris - Borehole undertaken within road drainage
262	S24	Soil	Road resserve	A1 0.0-0.3 kSZCL B1 0.3-0.5 kShC	1c	Spolic (HW) **ANTHROPOSOL (AN)**	(10YR 4/3) kSZCL: D, LO, abundant VF-S coarse fragments	(10YR 5/6) kShC: D, STR, SST, HP, abundant VF coarse fragments @ 0.5 refusal on stones	1	I	3	4	M	NE	-	S24 13.648	E150 36.713	*Observed vegetation: Blue Gum* Canopy: 10-20m Understory: - Ground strata: grass	- Cleared road reserve - Rocky outcrop adjacent to location-siltstone/sandstone - Large road reserve - very disturbed - Suspect fill throughout location
269	S25	Soil	Natural	A1 0.0-0.4 ZG	1c	Clastic (HH), **RUDOSOL (RU)**	(10YR 7/1) ZG: D,LO abundant F-S coarse fragments, many VF roots @ 0.4 refusal	-	1	MW	2	4	U	W	-	S24 13.245	E150 40.090	*Observed vegetation: Ironbark / Blue Gum* Canopy: 20m Understory: 1m Ground strata: grass	- Location adjacent to rocky outcrop - Fractured bedrock (silt with fractures)
274	S26	Soil	Unfenced Road Reserve with grazing	A1 0.0-0.17 kSCL B1 0.17-0.8 hC (KC) B2 0.8-1.0 hC w trace mS	2c	Crusty (BH), Grey (AD) **VERTOSOL (VE)**	(10YR 3/1) kSCL: D, WE, NST, NP, common VF roots	(10YR 3/1) hC (KC): D, STR, ST, HP @ 0.5 SLMoi @ 0.8 (10YR3/1 with 10YR 4/6 mottling)	1	P	1	2	L	-	-	S24 11.416	E150 42.508	*Observed vegetation: Cleared* Canopy: - Understory: - Ground strata: grass	- Rock outcrops nearby
2	SWL1a	Soil	Road reserve - grazing	A1 0.0-0.3 ZfSL B1 0.3-0.75 fSC C 0.75-0.9 Sandstone	2b	Brown (AB) **SODOSOL (SO)**	(10YR 3/3) ZfSL: D, LO, NST, NP, common F-M coarse fragments	(10YR 3/4) fSC: D, WE, SST, HP @ 0.75 (10YR 7/1) Sandstone, WE @ 0.9 abandoned	3	P	2	4	M	EES	-	S26 22.122	E149 52.765	*Observed vegetation: Ironbark* Canopy: - Understory: - Ground strata: grass	- Observation adjacent to unsealed road - Scattered surface stones throughout - Gully erosion evident adjacent to road
14	SWL2a	Soil	Road reserve	A1 0.0-0.1 ZfS A1 0.1-0.2 ZfS B1 0.2-0.5 fSC B2 0.5-0.9 CfS (KC) C 0.9-1.0 Sandstone	2d	Brown (AB) **SODOSOL (SO)**	(10YR 3/1) ZfS: Moi, SST, NP, many F-C coarse fragments, many F-C roots @ 0.1 (10YR 3/2) ZfS: D, LO, SST, NP, many F-C coarse fragments, many F-C roots	(10YR 3/1) fSC: D, STR, SS, HP @ 0.5 (10YR 6/4) CfS (KC): D, STR, NS, LP @ 0.9 Sandstone	1	MW	1	2	L	-	-	S26 21.540	E149 59.503	*Observed vegetation: Brigalow regrowth* Canopy: 10-20m Understory: 5m Ground strata: grass	- Observation adjacent to unsealed road - Scattered surface stones throughout
22	SWL3a	Soil	Grazing	A1 0.0-0.01 f-mShC B1 0.01-0.2 GhC (KC) B2 0.2-0.5 GhC (KC)	5b(m)	Grey (AD), **VERTOSOL (VE)**	(10YR 4/1) f-mShC: D, LO, SST, HP, many VF-F coarse fragments, many F roots	(10YR 3/1) GhC (KC): D, STR, ST, HP, many F-M coarse fragments @ 0.2 (10YR 3/1) GhC)KC): D, STR, ST, HP, abundant F-S coarse fragments @ 0.5 refusal	1	P	1	1	F	-	-	S26 21.595	E150 04.240	*Observed vegetation: Mostly cleared - Cypress Pine* Canopy: - Understory: - Ground strata: grass	- Some scattered surface stones throughout
32	SWL4a	Soil	Road reserve - some grazing	A1 0.0-0.05 ZfSL A12 0.05-0.2 ZfSL A13 0.2-0.3 ZfSL A14 0.3-0.4 ZfSL B1 0.4-1.0 mC	1b	Brown (AB) **SODOSOL (SO)**	(10YR 5/23) ZfSL: D, LO, NST, NP, many VF-M coarse fragments, many F roots @ 0.05 (10YR 5/2) ZfSL: D, LO, NST, NP, many VF-M coarse fragments, many F roots @ 0.2 (10YR 6/3) ZfSL: D, LO, NST, NP, many VF-M coarse fragments @ 0.3 (10YR 6/2) ZfSL: D, LO, NST, LP	(10YR 4/4) mC: D, FI, ST, MP	1	P	1	1	F	-	-	S26 19.035	E150 08.769	*Observed vegetation: Wilga, Ironbark* Canopy: 20m Understory: 5m Ground strata: sparse grass	- Some scattered surface stones throughout

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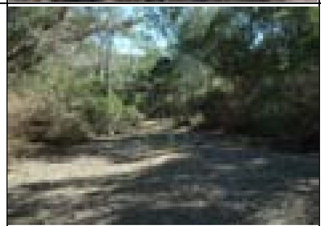
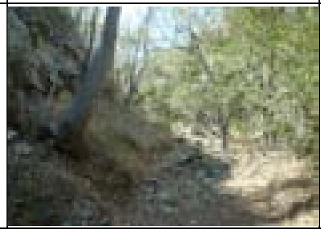
Appendix B **Table 1b: Field Data**

KP Location	Sample Assessment Location	Name	Stream Order	Land Use	Channel Dimensions: Low Flow Channel Width (m)	Channel Dimensions: Depth (m)	Channel Dimensions: Overall Width (m)	Mapped Soil Group and Description	Terrain Class *1 2 3*	Predominant Slope *1 2 3 4 5 6*	Existing Erosion *1 2 3*	Erosion Risk *1 2 3 4*	Excavation Rating *1 2 3 4*	GPS Coordinates of observation: *Southing*	GPS Coordinates of observation: *Easting*	plates	Vegetation	Comments
3	WWL1	Unknown Creek (Woleebee Lateral)	<3	Grazing	1	5-10	180-200	2b/2c	2	4	1	4	1	S26 22.266	E149 53.183		*Observed vegetation: Brigalow, Blue gum* Canopy: 20-30m Understory: 10m Ground strata: grass and sedges	- Wide broad undefined channel - Minor erosion evident within channel, but more evident on slopes - 45% slope upper W bank - 20% slope upper E bank - Sandstone outcrops on upper banks
14	SWL2b	Unknown Creek (Woleebee Lateral)	<3	Grazing	1-2	3-4	10-15	1b/2d	1	2	2	2	2	S26 21.531	E149 59.438		*Observed vegetation: Cleared* Canopy: - Understory: - Ground strata: grass	- Sandstone outcrops - Highly erodable banks - Scattered stones - 90% slope lower E bank - 45% slope upper E bank - 90% slope lower and upper W bank
15	WWL2	Juandah Creek (Woleebee Lateral)	3	Grazing	10	2-3	50-60	2b	1	1	2	4	1	S26 21.700	E150 00.308		*Observed vegetation: Red gum* Canopy: 10m Understory: 1m Ground strata: grass	- No rock outcrops - Scattered surface stones - Where no vegetation, gully erosion evident, otherwise stable - Major bank incision nearby
19	WWL3	Unknown Creek (Woleebee Lateral)	<3	Grazing	5-6	2-3	30-45	2b	1	3	3	4	1-2	S26 22.130	E150 02.167		*Observed vegetation: Mostly cleared - Blue gum, Ironbark* Canopy: 20m Understory: 5m Ground strata: grass	- No rock outcrops - Unstable banks - gully and tunnel erosion evident throughout (very dispersive soils) - Deposits of stones throughout - Nearby constructed dam wall eroded
31	W1	L Tree Creek (Condabri Lateral)	3	Road reserve	10	10	90-120	2b	1	2	2	4	2	S26 25.537	E150 10.992		*Observed vegetation: Blue Gum, Red Gum* Canopy: 30-40m Understory: 10m Ground strata: -	- Mudstone outcrops on S bank - 90% slope lower E and W banks - 0-5% slope upper W bank - 90% slope upper W bank (mudstone and sandstone) - Stable banks where vegetation - Some bank incision evident

KP Location	Sample Assessment Location	Name	Stream Order	Land Use	Channel Dimensions			Mapped Soil Group and Description	Terrain Class	Predominant Slope	Existing Erosion	Erosion Risk	Excavation Rating	GPS Coordinates of observation		plates	Vegetation	Comments
					Low Flow Channel Width (m)	Depth (m)	Overall Width (m)		*1 2 3*	*1 2 3 4 5 6*	*1 2 3*	*1 2 3 4*	*1 2 3 4*	*Southing*	*Easting*			
12	W1a	Dogwood Creek (Condabri Lateral)	4	Road reserve	5	10-15	100-150	2b	1	3	2	4	2	S26 33.794	E150 14.374		*Observed vegetation: Blue Gum, Ironbark, Poplar Box* Canopy: 30-40m Understory: 5-10m Ground strata: grass and sedges	- Sandstone outcrops on S bank - 90% slope lower N and S banks - 45% slope upper N and S banks - Stable banks where vegetation - Some bank incision evident where no vegetation
37	W2	Bottle Tree Creek (Condabri Lateral)	3	Road reserve	2	5	25-35	2b	1	3	1	4	2	S26 22.748	E150 11.569		*Observed vegetation: Blue Gum, Reids, Wilga* Canopy: 20m Understory: 5m Ground strata: sparse grass	- Hard sandstone and easily eroded mudstone on S bank - 90% slope lower and upper S bank - 30% slope N bank, 5-10% upper N bank - Some fine sand deposits on bed - Banks appear stable
29	W3	Roche Creek (Main pipeline)	4	Grazing	8-10	10	85-100	2c/5b	1	2	1	4 / 1	2	S26 03.370	E150 11.851		*Observed vegetation: Blue Gum, Ironbark, Wilga* Canopy: 20m Understory: - Ground strata: grass	- Surface rock throughout - Sandstone outcrop on S bank - 50-60% slope lower S bank - 35-40% slope upper S bank - 45-50% slope lower N bank - 15% slope upper N bank
44	W4	Bungaban Creek (Main pipeline	4	Natural - cleared plains for grazing	20	20	60-100	2c/5b	1	3	1	4 / 1	2	S25 55.343	E150 11.945		*Observed vegetation: Blue Gum, Ironbark, Acacia* Canopy: 20m Understory: 5m Ground strata: -	- Sanstone outcrop throughout - Some water within channel - Stable banks (sandstone and vegetation) - 90% slope N bank - 35-40% slope S bank - Lower S bank
43	W4a	Bottle Tree Creek (Main pipeline)	3	Natural - cleared plains for grazing	3	5	50	2c/5b	1	2	1	4 / 1	2	S25 56.168	E150 11.928		*Observed vegetation: Blue Gum, Ironbark, Acacia, Cypress Pine* Canopy: 20m Understory: 10m Ground strata: Grass	- Sanstone outcrop throughout - Stable banks (vegetation and grass) - 15-20% slope N bank - 45-55% slope S bank
65	Not Assessed	Kennedy Creek	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

KP Location	Sample Assessment Location	Name	Stream Order	Land Use	Channel Dimensions			Mapped Soil Group and Description	Terrain Class	Predominant Slope	Existing Erosion	Erosion Risk	Excavation Rating	GPS Coordinates of observation		plates	Vegetation	Comments
					Low Flow Channel Width (m)	Depth (m)	Overall Width (m)		*1 2 3*	*1 2 3 4 5 6*	*1 2 3*	*1 2 3 4*	*1 2 3 4*	*Southing*	*Easting*			
69	W5	Cockatoo Creek (Main pipeline)	4	Natural - cleared plains for grazing	10	5-10	80-100	4b/5b	2	4	1	2	2	S25 43.432	E150 17.146		*Observed vegetation: Blue Gum, Wilga, Acacia* Canopy: 20m Understory: 5m Ground strata: Grass	- Sanstone outcrop throughout - Sandstone bed with fine to coarse sand and silt deposits - Stable banks (sandstone and vegetation) - 50-60% lower bank slopes into 5-10% upper slopes
128	W8	Cracow Creek (Main pipeline)	3	Natural - cleared plains for grazing	20	2-3	40-50	2c	1	2	2	4	3-4	S25 15.348	E150 24.470		*Observed vegetation: Ironbark* Canopy: 20m Understory: 5m Ground strata: -	- Stable / low banks, only some rill erosion - 10-20% slope N bank - 5-10% slope S bank
144	W9	Horse Creek (Main pipeline)	3	Natural - cleared plains for grazing	3	6	50-70	2c/5b	1	2	2	4 / 1	3-4	S25 07.218	E150 26.067		*Observed vegetation: Blue Gum and Acacia* Canopy: 20m Understory: 5m Ground strata: Grass	- Rock (granite) outcrop on N bank - Scattered surface rocks - Low flow channel 3m wide - 40% S bank, 10% middle S bank, 45-50% upper S bank - 45-50% N bank, 50-200m bench bank, 30% upper N bank - Non-stable banks (where vegetation removed) - Tunnelling at banks - Curltural heritage restriction - sample collected from road reserve
149	W10	Delusion Creek (Main Pipeline)	3	Natural - cleared plains for grazing	5-10	5	75-90	2c/5b	1	3	1	4 / 1	3-4	S25 04.946	E150 26.843		*Observed vegetation: Blue Gum* Canopy: 20m Understory: 5m Ground strata: -	- Stable banks (established vegetation and grass) - S bank sandstone - 5-10m wide low flow - 45% S bank, 10m wide bench, 30-45% upper S bank, 5m deep - 40% N bank, 5m wide bench, 10% upper N bank, 5m deep
157	W11	Oxtrack Creek (Main Pipeline)	3	Natural - cleared plains for grazing	2-3	3	15-20	2c/5b	1	2	2	4 / 1	3-4	S25 00.866	E150 26.926		*Observed vegetation: Blue Gum* Canopy: 10m Understory: 5m Ground strata: -	- Stable banks (established vegetation and grass) - no rock outcrops - N channel - 50% slope N bank, 20% slope S bank - S channel - 45% slope N bank, 20% slope S bank

KP Location	Sample Assessment Location	Name	Stream Order	Land Use	Channel Dimensions: Low Flow Channel Width (m)	Channel Dimensions: Depth (m)	Channel Dimensions: Overall Width (m)	Mapped Soil Group and Description	Terrain Class *1 2 3*	Predominant Slope *1 2 3 4 5 6*	Existing Erosion *1 2 3*	Erosion Risk *1 2 3 4*	Excavation Rating *1 2 3 4*	GPS Coordinates of observation: *Southing*	GPS Coordinates of observation: *Easting*	plates	Vegetation	Comments
170	W12	South Creek (Main Pipeline)	3	Natural - cleared plains for grazing	6	5	20-30	2c	1	3	3	4	3-4	S24 54.166	E150 27.425		*Observed vegetation: Blue Gum, Ironbark* Canopy: 10-20m Understory: 5m Ground strata: -	- No rock outcrops - Bed mainly coarse sand but some clay - Unstable banks where no vegetation - 10% slope upper, 5% slope lower N bank - 7% slope S bank - Geology appears layered with sand and clay deposits - Tunnel erosion (EROS003)
176	Not Assessed	Keen Creek	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
183	W13	Pump Creek (Main Pipeline)	4	Natural - cleared plains for grazing	3-5	5-10	60-80	2c/5b	2	4	1	4 / 1	4	S24 48.076	E150 28.648		*Observed vegetation: Mostly cleared - Ironbark, Acacia* Canopy: 10-20m Understory: 5m Ground strata: -	- Rock outcrops throughout - Bed and bank have surface rocks / bedrock - Stable channel - Observation made at re-alignment - 2 channels - S channel 50% slope N bank, 20% slope S bank - N channel 30% slope N bank, 40% slope S bank
185	W14	Twenty Mile Creek (Main Pipeline)	3	Natural - cleared plains for grazing	5-7	3	15-20	2c/5b	1	2	1	4 / 1	4	S24 47.010	E150 28.923		*Observed vegetation: Cleared* Canopy: - Understory: - Ground strata: -	- Rock outcrops throughout - Bed and bank have clay deposits - Stable channel with bedrock lining - Cultural heritage restrictions at this observation - no sample collected - 30% slope N and S banks - 40% slope upper S bank
200	Not Assessed	Prospect Creek Tributary (Main Pipeline)	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
214	W15	Prairie Creek (Main Pipeline)	3	Natural, grazing on banks	3-4	5-7	45-50	2c/5b	1	2	2	4 / 1	1-2	S24 31.842	E150 25.278		*Observed vegetation: Ironbark , blue gum* Canopy: 10-20m Understory: - Ground strata: -	- No rock outcrops - Stable bank (large size vege, grass) - Abundant debris - 40% slope lower N bank - 5% slope upper N bank - 40% slope lower S bank - ??% slope upper S bank

KP Location	Sample Assessment Location	Name	Stream Order	Land Use	Channel Dimensions: Low Flow Channel Width (m)	Channel Dimensions: Depth (m)	Channel Dimensions: Overall Width (m)	Mapped Soil Group and Description	Terrain Class *1 2 3*	Predominant Slope *1 2 3 4 5 6*	Existing Erosion *1 2 3*	Erosion Risk *1 2 3 4*	Excavation Rating *1 2 3 4*	GPS Coordinates of observation: *Southing*	GPS Coordinates of observation: *Easting*	plates	Vegetation	Comments
240	W16	Kroombit Creek (Main Pipeline)	4	Natural	7	5-10	20-25	2a	1	2	1	2	2	S24 18.654	E150 25.558		*Observed vegetation: Blue Gum, Stringybark, ironbark* Canopy: 20-30m Understory: 5m Ground strata: grass	- No rocky outcrop - Abundant debris - Angular fragments - Stable bank due to large established vegetation - 70% slope lower bank - 45% slope upper bank
239	W16A	Kroombit Creek Tributary (Main Pipeline)	4	Some selected clearing	10	3-5	25-30	2a	1	2	1	2	2	S24 18.933	E150 25.139		*Observed vegetation: Blue Gum, Stringybark, melaluca* Canopy: 20m Understory: 10m Ground strata: -	- No rock Outcrop - Abundant debris/partially decomposed - Banks 20-30% slope - Stable (est veg and grass)
243	W17	Callide Creek (Main Pipeline)	4	Natural	30	10-15	50 - 60	2a	1	2	1	2	2-3	S24 17.603	E150 26.903		*Observed vegetation: Blue Gum, ironbark* Canopy: 20m Understory: - Ground strata: -	- Bank appears stable - Large established vegetation - Rounded stones and gravel - Abundanat debris - 50% slope of bank
264	W18	Unknown Creek (Main Pipeline)	3	Natural	10-15	20-25	100	1c	2	4	1	2	3-4	S24 13.752	E150 37.499		*Observed vegetation: Blue Gum, Acacia* Canopy: 10m Understory: 3m Ground strata: -	- Large boulders (0.5m) - Stable bank (veg) - 70% slope lower bank - 45% slope upper bank
269	W19	Unknown Creek (Main Pipeline)	3	Natural	5	10-15	100-150	1c	2	4	1	2	3	S24 13.256	E150 40.118		*Observed vegetation: Acacia, cypress pine* Canopy: 10m Understory: 5m Ground strata: -	- Meta/sedimentary layered outcrop - Stable (rock and veg) - 0-5% slope on E bank - 90% slope on W bank

KP Location	Sample Assessment Location	Name	Stream Order	Land Use	Channel Dimensions Low Flow Channel Width (m)	Depth (m)	Overall Width (m)	Mapped Soil Group and Description	Terrain Class *1 2 3*	Predominant Slope *1 2 3 4 5 6*	Existing Erosion *1 2 3*	Erosion Risk *1 2 3 4*	Excavation Rating *1 2 3 4*	GPS Coordinates of observation *Southing*	*Easting*	plates	Vegetation	Comments
274	W20	Unknown Creek (Main Pipeline)	3	Cleared - grazing	6	5-8	45	2c	1	2	1	4	2-3	S24 11.701	E150 42.344		*Observed vegetation: Acacia, cypress pine* Canopy: 20m Understory: 5m Ground strata: grass	- Stable (grass) - 20% slope N bank - 30% slope S bank - Grazing land on upper slopes
278	W21	Bell Creek (Main Pipeline)	4	Natural - cleared plains for grazing	25	10	50-60	2c	1	3	1	4	3-4	S24 09.753	E150 42.977		*Observed vegetation: Figs, Acacia* Canopy: 20m Understory: 10m Ground strata: -	- Stable (est vege [large roots], decomposing granite) - 45% slope S upper bank - 5% slope S lower bank - 45% slope N upper bank - 60-70% slope N lower bank
295	Not Assessed	Calliope Creek (Main Pipeline)	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
303	Not Assessed	Harper Creek (Main Pipeline)	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
320	Not Assessed	Larcom Creek (Main Pipeline)	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
327	Not Assessed	Larcom Creek (Main Pipeline)	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Texture	
S	Sand
fS	Fine Sand
kS	Coarse Sand
L	Loam
C	Clay
Z	Silt
G	Gravel
IP	Fibric Peat

Structure	
WE	Weak
MO	Moderate
ST	Strong
WM	Weak to moderate
MS	Moderate to strong
GR	Granular
PL	Platy

Consistence	
LO	Loose
VFR	Very friable / very weak
FR	Friable / weak
FI	Firm
VFI	Very firm
STR	Strong
VSTR	Very strong
RI	Rigid
NST	Non-sticky
SST	Slightly sticky
ST	Sticky
VST	Very sticky
NPL	Non-plastic
SPL	Slightly plastic
PL	Plastic
VPL	Very plastic
D	Dry
SL MOi	Slight moist
MOi	Moist
G	Cracking
M	Self-mulching
H	Hard Setting
C	Surface Crust
K	Calcrete

Course Fragments	
N	None
V	Very few
F	Few
C	Common
M	Many
A	Abundant
D	Dominant
F	Fine gravel
M	Medium gravel
C	Course gravel
CB	Cobbles
S	Stones
B	Boulders
L	Large boulders

Drainage	
R	Rapidly drained
W	Well drained
MW	Moderately well drained
I	Imperfectly drained
P	Poorly drained
VP	Very poorly drained

Rooting	
N	None
V	Very few
F	Few
C	Common
M	Many
VF	Very fine
F	Fine
M	Medium
C	Course

Erosion	
1	Minor
2	Moderate
3	Severe

Terrain Class	
1	Low
2	Medium
3	High

Predominant Slope	
1	Flat
2	Low
3	Moderate
4	High

Slope Position	
C	Crest
U	Upper slope
M	Middle slope
Lo	Lower slope
D	Depression
Le	Level

Sample Location	Sample	Date	Mapped Soil Group	Field Soil Classification (ASC)	Analytical Data: Emerson Class	pH	EC	EC	ECe (EC1:5 x conversion factor)	EC rating	Available Nutrients: TKN	% TKN by weight	P	Exchangeable Sodium Percent (ESP)*	Sodicity	CEC	Exchangeable Ions: Ca	Mg	K	Na	Fe	Al	Cl	Sulfate	SAR*
Units			-	-	*Class number*	*pH units*	*dS/cm*	*µS/cm*	*µS/cm*	*NS, SS, MS, HS, ES*	*mg/kg*	*%*	*mg/kg*	*%*	*NS,S, SS*	*meq/100g*	*meq/100g*	*meq/100g*	*meq/100g*	*meq/100g*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*meq/100g*
Laboratory Detection Level			-	-	-	*0.1*	*1*	*10*	*10*	-	*100*	*1*	*1*	-	-	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*1*	*1*	*1*	*1*	*0.01*
S1	0.0-0.1	29/10/2009	1b	TE		5.2	0.09	90	855	NS	454.0	0.05	0.7	14.9	SS	4.7	0.4	1.3	1	0.7	20	111	90	62	0.76
S1	0.4-0.5	29/10/2009	1b	TE	8	6.7	0.19	190	1805	NS				12.8	S	4.7	0.1	2.4	0.2	0.6	2	127	150	102	0.56
S1A	0.3-0.4	29/10/2009	1b	AN	8	5.4	0.24	240	5520	MS				20.3	SS	6.9	<0.1	4.1	0.2	1.4	1	108	250	84	0.99
S2	0.0-0.1	29/10/2009	1b	KU		5.2	0.05	50	475	NS	364.0	0.04	0.7	8.0	S	2.5	0.5	1	0.4	0.2	2	41	60	60	0.21
S2	0.7-0.8	29/10/2009	1b	KU	1	4.8	0.48	480	2784	SS				33.8	SS	7.1	<0.1	3.6	0.4	2.4	2	63	500	89	1.77
S3	0.0-0.1	29/10/2009	2b	KU		5.2	0.04	40	380	NS	295.0	0.03	0.9	7.7	S	1.3	<0.1	0.3	<0.1	0.1	7	54	55	68	0.34
S3	0.9-1.0	29/10/2009	2b	KU	1	5.9	0.15	150	870	NS				41.5	SS	8.2	<0.1	4.8	<0.1	3.4	<1	<1	265	81	2.17
S4	0.0-0.1	28/10/2009	5b(m)	TE		5.9	0.02	20	280	NS	273.0	0.03	0.6	ID	NS	1.3	0.4	0.4	0.2	<0.1	<1	22	35	65	0.09
S5	0.0-0.1	26/10/2009	1b	VE		5.8	0.15	150	870	NS	498.0	0.05	1.1	7.8	S	15.4	5.8	8.3	0.2	1.2	<1	<1	140	81	0.44
S5	0.9-1.0	26/10/2009	1b	VE	1	4.8	0.94	940	5452	MS				26.3	SS	17.1	1.9	7.5	0.1	4.5	3	268	1099	76	2.08
S6	0.0-0.1	25/10/2009	5b(m)	CH		6.1	0.14	140	1204	NS	702.0	0.07	3.5	1.7	NS	17.7	12	4.9	0.5	0.3	<1	<1	105	68	0.11
S6	0.3-0.4	25/10/2009	5b(m)	CH	4	6.6	0.48	480	3600	SS				10.1	S	26.8	14.8	9.1	0.2	2.7	<1	<1	470	81	0.77
S6	0.9-1.0	25/10/2009	5b(m)	CH	1	7	0.14	140	1050	NS				29.3	SS	33.4	5	18.2	0.4	9.8	2	<1	315	2	0.08
S7	0.0-0.1	25/10/2009	2c	SO		7.2	0.08	80	760	NS	505.0	0.05	1.4	6.7	S	7.5	3.7	2.8	0.5	0.5	1	<1	90	87	0.26
S7	0.4-0.5	25/10/2009	2c	SO	1	7	0.16	160	1376	NS				27.0	SS	11.1	1.3	6.6	0.2	3	<1	<1	320	80	1.50
S7	0.8-0.9	25/10/2009	2c	SO	1	7.2	0.06	60	1380	NS				ID	NS	10.5	8.5	1.6	0.3	<0.1	<1	<1	170	75	0.02
S8	0.0-0.05	24/10/2009	4b	RU		6.6	0.17	170	1615	NS	1769.0	0.18	21.0	ID	NS	16.4	9.9	2.9	3.5	<0.1	2	<1	105	88	0.02
S9	0.0-0.1	26/10/2009	4b	DE		6.8	0.04	40	300	NS	405.0	0.04	1.1	36.4	SS	6.6	0.3	3.8	<0.1	2.4	<1	<1	42	82	1.66
S9	0.5-0.6	26/10/2009	4b	DE	5	6.6	0.32	320	1856	NS				11.8	S	15.3	9.4	4	0.2	1.8	1	<1	379	76	0.69
S9	0.8-0.9	26/10/2009	4b	DE	2	6.7	0.34	340	2550	SS				16.0	SS	10	5.5	2.6	0.1	1.6	1	5	365	47	0.79
S10	0.0-0.1	24/10/2009	2c	CH		6.5	0.04	40	380	NS	363.0	0.04	0.9	ID	NS	2.2	1.4	0.4	0.3	<0.1	<1	1	55	27	0.05
S10	0.9-1.0	24/10/2009	2c	CH	6	6.8	0.13	130	1118	NS				15.6	SS	3.2	0.6	2	<0.1	0.5	<1	<1	155	22	0.48
S11	0.0-0.1	24/10/2009	2c	KA		6.6	0.04	40	380	NS	356.0	0.04	1.1	ID	NS	4.4	2.8	1.1	0.4	<0.1	<1	<1	60	24	0.04
S11	0.9-1.0	24/10/2009	2c	KA	8	6.2	0.06	60	570	NS				7.5	S	6.7	1.4	4.4	0.3	0.5	<1	17	75	25	0.28
S12	0.0-0.1	26/10/2009	2c	RU		6.6	0.04	40	380	NS	392.0	0.04	1.2	ID	NS	2.7	1.4	0.8	0.4	<0.1	<1	1	46	26	0.07
S13	0.0-0.1	23/10/2009	2c	DE		6.4	0.05	50	375	NS	595.0	0.06	1.4	1.1	NS	18	10.9	6.7	0.3	0.2	<1	<1	50	20	0.05
S13	0.3-0.4	23/10/2009	2c	DE		6.4	0.15	150	870	NS	391.0	0.04	0.5	1.3	NS	29.8	17.8	11.5	0.1	0.4	<1	<1	110	20	0.10
S13	0.9-1.0	23/10/2009	2c	DE	4	6.3	0.17	170	1275	NS				1.3	NS	30.1	19.4	10.3	<0.1	0.4	<1	<1	130	20	0.11
S14	0.0-0.1	23/10/2009	2c	TE		6.5	0.11	110	1045	NS	<100	0.00	4.0	ID	NS	8.5	5.9	2	0.5	<0.1	<1	<1	70	24	0.03
S14	0.2-0.3	23/10/2009	2c	TE	5	6.8	0.06	60	516	NS				0.9	NS	11.3	7.5	3.5	0.2	0.1	<1	<1	50	21	0.06
S14	0.9-1.0	23/10/2009	2c	TE	4	5.2	0.11	110	946	NS				1.3	NS	22.9	16.9	5.5	0.1	0.3	<1	<1	75	19	0.10
S15	0.0-0.1	23/10/2009	2c	CH		5.4	0.04	40	380	NS	490.0	0.05	3.5	ID	NS	6.1	3.1	2.4	0.5	<0.1	<1	2	50	25	0.05
S15	0.9-1.0	23/10/2009	2c	CH	5	6.1	0.13	130	1118	NS				3.7	NS	16.1	7.8	7.6	0.1	0.6	<1	<1	135	16	0.21
S16	0.0-0.1	22/10/2009	2c	RU		6.1	0.05	50	475	NS	587.0	0.06	5.1	ID	NS	5.2	3.4	1.4	0.3	<0.1	<1	1	47	16	0.06
S17	0.0-0.1	22/10/2009	2c	TE		6.1	0.04	40	560	NS	427.0	0.04	3.2	ID	NS	8.4	5.8	2.3	0.2	<0.1	1	<1	44	13	0.04
S17	0.9-1.0	22/10/2009	2c	TE	5	6.3	0.05	50	475	NS				1.2	NS	8.1	6.1	1.8	<0.1	0.1	<1	<1	44	15	0.06
S18	0.0-0.1	22/10/2009	2c	CH		6.2	0.06	60	450	NS	763.0	0.08	1.4	ID	NS	12.5	8.4	3.4	0.6	<0.1	<1	<1	50	22	0.04
S18	0.9-1.0	22/10/2009	2c	CH	8	6.4	0.14	140	1050	NS				1.5	NS	20.2	15.9	3.8	0.1	0.3	<1	<1	100	15	0.10
S19	0.0-0.2	22/10/2009	2c	SO		6.4	0.08	80	760	NS	757.0	0.08	6.6	ID	NS	11.1	7.1	3.4	0.5	<0.1	<1	<1	60	14	0.04
S19	0.9-1.0	22/10/2009	2c	SO	5	6.7	0.05	50	430	NS				3.2	NS	6.2	3.9	2	0.2	0.2	<1	<1	50	15	0.10
S20	0.0-0.1	21/10/2009	5b	VE		6.4	0.12	120	696	NS	674.0	0.07	1.0	1.7	NS	17.6	11.8	5	0.5	0.3	1	<1	75	24	0.12
S20	0.9-1.0	21/10/2009	5b	VE	4	6.7	0.35	350	3010	SS				6.0	NS	23.2	15.4	6.1	0.2	1.4	<1	<1	275	19	0.43
S21	0.0-0.1	21/10/2009	4a	DE		6.6	0.38	380	2850	SS	762.0	0.08	4.9	6.2	S	16.2	9.7	5	0.4	1	1	<1	295	17	0.37
S21	0.9-1.0	21/10/2009	4a	DE	1	6.5	0.25	250	1450	NS				32.0	SS	12.8	2.2	6.2	0.3	4.1	1	1	600	25	1.98
S22	0.0-0.1	21/10/2009	5b	DE		6.8	0.08	80	688	NS	681.0	0.07	1.2	3.1	NS	6.4	4.4	1.7	<0.1	0.2	1	<1	75	16	0.13
S22	0.3-0.4	21/10/2009	5b	DE	7	6.9	0.06	60	516	NS				6.9	S	5.8	3.1	2.2	<0.1	0.4	<1	1	60	17	0.26
S23	0.0-0.1	20/10/2009	1b	RU		6.8	0.02	20	190	NS	328.0	0.03	0.4	ID	NS	3.5	1.6	1.6	0.1	<0.1	<1	2	29	15	0.06
S23	0.9-1.0	20/10/2009	1b	RU	2	7	0.02	20	190	NS				ID	NS	3.3	1.5	1.6	<0.1	<0.1	<1	<1	32	14	0.07
S24	0.0-0.1	20/10/2009	1c	AN		6.8	0.08	80	760	NS	323.0	0.03	1.3	4.7	NS	8.6	4.2	3.8	0.2	0.4	<1	<1	50	17	0.18
S24	0.3-0.4	20/10/2009	1c	AN	1	6.8	0.19	190	1102	NS				14.7	SS	11.6	2.4	7.3	0.1	1.7	1	1	160	18	0.78
S25	0.0-0.1	20/10/2009	1c	RU		6.7	0.04	40	380	NS	745.0	0.07	2.1	ID	NS	5.7	3.7	1.6	0.3	<0.1	<1	<1	36	14	0.03
S25	0.3-0.4	20/10/2009	1c	RU	8	7.1	0.03	30	285	NS				6.0	NS	5	2	2.5	0.2	0.3	<1	10	<1	16	0.17
S26	0.0-0.1	21/10/2009	2c	VE		6.4	0.15	150	1425	NS	658.0	0.07	1.5	2.7	NS	7.3	3.8	2.2	1.1	0.2	<1	<1	80	15	0.09
S26	0.9-1.0	21/10/2009	2c	VE	2	7.6	0.13	130	754	NS				13.8	S	22.5	9.4	9.8	0.2	3.1	<1	<1	160	16	1.01
SWLa	0.0-0.1	28/10/2009	2b	SO		7	0.04	40	380	NS	400.0	0.04	1.6	ID	NS	2.3	0.5	0.4	0.6	<0.1	<1	64	31	18	0.08
SWLa	0.6-0.7	28/10/2009	2b	SO	1	6.8	0.22	220	1892	NS				24.6	SS	5.7	0.2	3.7	0.3	1.4	<1	2	200	17	0.96
SWL2a	0.0-0.1	28/10/2009	2d	SO		6.7	0.06	60	570	NS	547.0	0.05	1.4	ID	NS	5.8	4.1	1.3	0.3	<0.1	<1	<1	36	15	0.05
SWL2a	0.3-0.4	28/10/2009	2d	SO	5	6.6	0.19	190	1634	NS				8.4	S	16.6	11.8	3.3	0.2	1.4	<1	<1	95	12	0.51
SWL2a	0.8-0.9	28/10/2009	2d	SO	4	7	0.21	210	1995	NS				7.9	S	19	14.7	2.6	0.1	1.5	<1	<1	100	19	0.52
SWL3a	0.0-0.1	28/10/2009	5b(m)	VE		6.8	0.09	90	522	NS	659.0	0.07	2.1	6.6	S	13.7	9.4	2.9	0.6	0.9	<1	<1	55	15	0.34
SWL3a	0.4-0.5	28/10/2009	5b(m)	VE	1	6.6	1.27	1270	7366	MS				18.6	SS	27.4	18.9	3.2	0.2	5.1	<1	<1	650	431	1.54
SWL4a	0.0-0.05	28/10/2009	1b	SO		6.7	0.05	50	475	NS	309.0	0.03	1.9	ID	NS	5.4	4	0.7	0.6	<0.1	4	<1	40	15	0.04
SWL4a	0.9-1.0	28/10/2009	1b	SO	2	6.8	0.09	90	675	NS				25.0	SS	4.8	0.8	1.9	0.1	1.2	1	73	75	23	1.02

NOTES

*	Calculated Values	**	Soil sample could not be collected deep enough for comparison to mapped soil	NS	Non-saline	HS	Highly Saline
^	Indicates comparible soil with associated soil types.			SS	Slightly saline	ES	Extremely Saline
nd	Not Detected	ID		MS	Moderately Saline		

NS	Non Sodic	SAR	$(Na^{2+}) / \sqrt{[(Ca^{2+}) + (Mg^{2+}) / 2]}$
S	Sodic	ESP	$(Na^{2+})/CEC * 100$
SS	Strongly Sodic		

Appendix C Laboratory analysis plan

Sample ID	Emerson class	pH/EC	TKN /P	CEC	Exchangeable cations
S1/0.0-0.1		x	x	x	x
S1/0.4-0.5	x	x		x	x
S1A/0.3-0.4	x	x		x	x
S2/0.0-0.1		x	x	x	x
S2/0.7-0.8	x	x		x	x
S3/0.0-0.1		x	x	x	x
S3/0.9-1.0	x	x		x	x
S4/0.0-0.1		x	x	x	x
S5/0.0-0.1		x	x	x	x
S5/0.9-1.0	x	x		x	x
S6/0.0-0.1		x	x	x	x
S6/0.3-0.4	x	x		x	x
S6/0.9-1.0		x		x	x
S7/0.0-0.1		x	x	x	x
S70.4-0.5	x	x		x	x
S7/0.8-0.9	x	x		x	x
S8/0.0-0.05		x	x	x	x
S9/0.0-0.1		x	x	x	x
S9/0.5-0.6	x	x		x	x
S9/0.8-0.9	x	x		x	x
S10/0.0-0.1		x	x	x	x
S10/0.9-1.0	x	x		x	x
S11/0.0-0.1		x	x	x	x
S11/0.9-1.0	x	x		x	x
S12/0.0-0.1		x	x	x	x
S13/0.0-0.1		x	x	x	x
S13/0.3-0.4		x	x	x	x
S13/0.9-1.0	x	x		x	x
S14/0.0-0.1		x	x	x	x

Sample ID	Emerson class	pH/EC	TKN /P	CEC	Exchangeable cations
S14/0.2-0.3	x	x		x	x
S14/0.9-1.0	x	x		x	x
S15/0.0-0.1		x	x	x	x
S15/0.9-1.0	x	x		x	x
S16/0.0-0.1		x	x	x	x
S17/0.0-0.1		x	x	x	x
S17/0.9-1.0	x	x		x	x
S18/0.0-0.1		x	x	x	x
S18/0.9-1.0	x	x		x	x
S19/0.0-0.2		x	x	x	x
S19/0.9-1.0	x	x		x	x
S20/0.0-0.1		x	x	x	x
S20/0.9-1.0	x	x		x	x
S21/0.0-0.1		x	x	x	x
S21/0.9-1.0	x	x		x	x
S22/0.0-0.1		x	x	x	x
S22/0.3-0.4	x	x		x	x
S23/0.0-0.1		x	x	x	x
S23/0.9-1.0	x	x		x	x
S24/0.0-0.1		x	x	x	x
S24/0.3-0.4	x	x		x	x
S25/0.0-0.1		x	x	x	x
S25/0.3-0.4	x	x		x	x
S26/0.0-0.1		x	x	x	x
S26/0.9-0.1	x	x		x	x
SWLa/0.0-0.1		x	x	x	x
SWLa/0.6-0.7	x	x		x	x
SWL2a/0.0-0.1		x	x	x	x
SWL2a/0.3-0.4	x	x		x	x
SWL2a/0.8-0.9	x	x		x	x
SWL3a0.0-0.1		x	x	x	x

Sample ID	Emerson class	pH/EC	TKN /P	CEC	Exchangeable cations
SWL3a/0.4-0.5	x	x		x	x
SWL4a/0.0-0.05		x	x	x	x
SWL4a/0.9-1.0	x	x		x	x

Appendix D Laboratory certificates

CERTIFICATE OF ANALYSIS

Analysis By: Bio-Track Pty Ltd
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DATE OF REPORT	21 NOVEMBER 2009	Page 1 of 3 Report Pages.
CLIENT NAME	ALEX KOCHNIEFF c/o WORLEY PARSONS PTY LTD	
CLIENT ADDRESS	PO BOX 585 FORTITUDE VALLEY BRISBANE4006	
PROJECT NAME	PIPELINE ROUTE 3E	YOUR PROJECT/JOB REFERENCE 301001-00448 WBS 1B4070
SAMPLING DATE	10/2009 NUMBER OF SAMPLES 63 SAMPLE TYPE:SOIL SAMPLE	
PACKAGING	SAMPLES LABELLED - INTACT ** SAMPLES DISPOSED ON 1/8/2010	
DATE RECEIVED	02 NOVEMBER 2009 LAB REF. LR02119.382	

METHODOLOGY: EC pH Cl as 1:5 air dried soil in water, 30 minute rolling shake, Cl by ion selective electrode. Na K Mg Ca Fe Al S as 1:20 soil dried soil in 1 N NH4Cl, 60 minute rolling shake, Na Mg Ca Fe Al S measured by ICP OES, K by AAS. CEC (cation exchange capacity) as the sum of extracted cations, SAR (sodium adsorption ratio) as Na/((Ca+Mg)/2)^0.5, %Na as Na% of CEC. (meq/100 =milli-equivalents/100 g soil)

SAMPLE ID	EC	pH	Na	K	Ca	Mg	Fe	Al	Cl	S	CEC	SAR	% Na	Ca:Mg
m depth	dS/m		meq/100	meq/100	meq/100	meq/100	mg/kg	mg/kg	mg/kg	mg/kg	meq/100			
S1 0-0.1	0.09	5.2	0.7	1.0	0.4	1.3	20	111	90	62	4.7	0.76	14.9	0.3
S1 0.4-0.5	0.19	6.7	0.6	0.2	0.1	2.4	2	127	150	102	4.7	0.56	13.1	<0.1
S1A 0.3-0.4	0.24	5.4	1.4	0.2	<0.1	4.1	1	108	250	84	6.9	0.99	20.6	<0.1
S2 0-0.1	0.05	5.2	0.2	0.4	0.5	1.0	2	41	60	60	2.5	0.21	7.1	0.5
S2 0.7-0.8	0.48	4.8	2.4	0.4	<0.1	3.6	2	63	500	89	7.1	1.77	33.5	<0.1
S3 0-0.1	0.04	5.2	0.1	<0.1	<0.1	0.3	7	54	55	68	1.3	0.34	11.8	0.2
S3 0.9-1.0	0.15	5.9	3.4	<0.1	<0.1	4.8	<1	<1	265	81	8.2	2.17	40.9	<0.1
S4 0-0.1	0.02	5.9	<0.1	0.2	0.4	0.4	<1	22	35	65	1.3	0.09	4.3	1.0
S5 0-0.1	0.15	5.8	1.2	0.2	5.8	8.3	<1	<1	140	81	15.4	0.44	7.6	0.7
S5 0.9-1.0	0.94	4.8	4.5	0.1	1.9	7.5	3	268	1099	76	17.1	2.08	26.5	0.3
S6 0-0.1	0.14	6.1	0.3	0.5	12.0	4.9	<1	<1	105	68	17.7	0.11	1.8	2.5
S6 0.3-0.4	0.48	6.6	2.7	0.2	14.8	9.1	<1	<1	470	81	26.8	0.77	9.9	1.6
S6 0.9-1.0	0.14	7.0	9.8	0.4	5.0	18.2	2	<1	315	110	33.4	2.88	29.3	0.3
S7 0-0.1	0.08	7.2	0.5	0.5	3.7	2.8	1	<1	90	87	7.5	0.26	6.1	1.3
S7 0.4-0.5	0.16	7.0	3.0	0.2	1.3	6.6	<1	<1	320	80	11.1	1.50	26.9	0.2
S7 0.8-0.9	0.06	7.2	<0.1	0.3	8.5	1.6	<1	<1	170	75	10.5	0.02	0.4	5.4
S8 0-0.05	0.17	6.6	<0.1	3.5	9.9	2.9	2	<1	105	88	16.4	0.02	0.3	3.4
S9 0-0.1	0.04	6.8	2.4	<0.1	0.3	3.8	<1	<1	42	82	6.6	1.66	36.1	<0.1
S9 0.5-0.6	0.32	6.6	1.8	0.2	9.4	4.0	1	<1	379	76	15.3	0.69	11.7	2.4
S9 0.8-0.9	0.34	6.7	1.6	0.1	5.5	2.6	1	5	365	47	10.0	0.79	16.0	2.1
S10 0-0.1	0.04	6.5	<0.1	0.3	1.4	0.4	<1	1	55	27	2.2	0.05	2.0	3.2
S10 0.9-1.0	0.13	6.8	0.5	<0.1	0.6	2.0	<1	<1	155	22	3.2	0.48	16.8	0.3
S11 0-0.1	0.04	6.6	<0.1	0.4	2.8	1.1	<1	<1	60	24	4.4	0.04	1.3	2.5
S11 0.9-1.0	0.06	6.2	0.5	0.3	1.4	4.4	<1	17	75	25	6.7	0.28	7.1	0.3
S12 0-0.1	0.04	6.6	<0.1	0.4	1.4	0.8	<1	1	46	26	2.7	0.07	2.7	1.8
S13 0-0.1	0.05	6.4	0.2	0.3	10.9	6.7	<1	<1	50	20	18.0	0.05	0.9	1.6
S13 0.3-0.4	0.15	6.4	0.4	0.1	17.8	11.5	<1	<1	110	20	29.8	0.10	1.3	1.5
S13 0.9-1.0	0.17	6.3	0.4	<0.1	19.4	10.3	<1	<1	130	20	30.1	0.11	1.4	1.9
S14 0-0.1	0.11	6.5	<0.1	0.5	5.9	2.0	<1	<1	70	24	8.5	0.03	0.7	3.0
S14 0.2-0.3	0.06	6.8	0.1	0.2	7.5	3.5	<1	<1	50	21	11.3	0.06	1.2	2.2
S14 0.9-1.0	0.11	5.2	0.3	0.1	16.9	5.5	<1	<1	75	19	22.9	0.10	1.5	3.1

Signatory

For and behalf of Bio-Track Pty Ltd

CERTIFICATE OF ANALYSIS

Analysis By: Bio-Track Pty Ltd
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Ph. 07 3289 7179 Fx. 07 3289 7155

DATE OF REPORT 21 NOVEMBER 2009
CLIENT NAME ALEX KOCHNIEFF c/o WORLEY PARSONS PTY LTD
CLIENT ADDRESS PO BOX 585 FORTITUDE VALLEY BRISBANE4006
PROJECT NAME PIPELINE ROUTE 3E YOUR PROJECT/JOB REFERENCE 301001-00448 WBS 1B4070
SAMPLING DATE 10/2009 NUMBER OF SAMPLES 63 SAMPLE TYPE:SOIL SAMPLE
PACKAGING SAMPLES LABELLED - INTACT ** SAMPLES DISPOSED ON 1/8/2010
DATE RECEIVED 02 NOVEMBER 2009 LAB REF. LR02119.382

METHODOLOGY: EC pH Cl as 1:5 air dried soil in water, 30 minute rolling shake, Cl by ion selective electrode. Na K Mg Ca Fe Al S as 1:20 soil dried soil in 1 N NH4Cl, 60 minute rolling shake, Na Mg Ca Fe Al S measured by ICP OES, K by AAS. CEC (cation exchange capacity) as the sum of extracted cations, SAR (sodium adsorption ratio) as Na/((Ca+Mg)/2)^0.5, %Na as Na% of CEC. (meq/100 =milli-equivalents/100 g soil)

SAMPLE ID m depth	EC dS/m	pH	Na meq/100	K meq/100	Ca meq/100	Mg meq/100	Fe mg/kg	Al mg/kg	Cl mg/kg	S mg/kg	CEC meq/100	SAR	% Na	Ca:Mg
S15 0-0.1	0.04	5.4	<0.1	0.5	3.1	2.4	<1	2	50	25	6.1	0.05	1.3	1.3
S15 0.9-1.0	0.13	6.1	0.6	0.1	7.8	7.6	<1	<1	135	16	16.1	0.21	3.5	1.0
S16 0-0.1	0.05	6.1	<0.1	0.3	3.4	1.4	<1	1	47	16	5.2	0.06	1.7	2.4
S17 0-0.1	0.04	6.1	<0.1	0.2	5.8	2.3	1	<1	44	13	8.4	0.04	1.0	2.5
S17 0.9-1.0	0.05	6.3	0.1	<0.1	6.1	1.8	<1	<1	44	15	8.1	0.06	1.5	3.4
S18 0-0.1	0.06	6.2	<0.1	0.6	8.4	3.4	<1	<1	50	22	12.5	0.04	0.8	2.5
S18 0.9-1.0	0.14	6.4	0.3	0.1	15.9	3.8	<1	<1	100	15	20.2	0.10	1.6	4.2
S19 0-0.2	0.08	6.4	<0.1	0.5	7.1	3.4	<1	<1	65	14	11.1	0.04	0.8	2.1
S19 0.9-1.0	0.05	6.7	0.2	0.2	3.9	2.0	<1	<1	50	15	6.2	0.10	2.6	2.0
S20 0-0.1	0.12	6.4	0.3	0.5	11.8	5.0	1	<1	75	24	17.6	0.12	2.0	2.3
S20 0.9-1.0	0.35	6.7	1.4	0.2	15.4	6.1	<1	<1	275	19	23.2	0.43	6.1	2.5
S21 0-0.1	0.38	6.6	1.0	0.4	9.7	5.0	1	<1	295	17	16.2	0.37	6.2	1.9
S21 S21-0.9	0.25	6.5	4.1	0.3	2.2	6.2	1	1	600	25	12.8	1.98	31.8	0.4
S22 0.0-0.1	0.08	6.8	0.2	<0.1	4.4	1.7	1	<1	75	16	6.4	0.13	3.4	2.5
S22 0.3-0.4	0.06	6.9	0.4	<0.1	3.1	2.2	<1	1	60	17	5.8	0.26	7.4	1.4
S23 0-0.1	0.02	6.8	<0.1	0.1	1.6	1.6	<1	2	29	15	3.5	0.06	2.2	1.0
S23 0.9-1.0	0.02	7.0	<0.1	<0.1	1.5	1.6	<1	<1	32	14	3.3	0.07	2.7	0.9
S24 0-0.1	0.08	6.8	0.4	0.2	4.2	3.8	<1	<1	50	17	8.6	0.18	4.2	1.1
S24 0.3-0.4	0.19	6.8	1.7	0.1	2.4	7.3	1	1	160	18	11.6	0.78	14.9	0.3
S25 0-0.1	0.04	6.7	<0.1	0.3	3.7	1.6	<1	<1	36	14	5.7	0.03	0.9	2.3
S25 0.3-0.4	0.03	7.1	0.3	0.2	2.0	2.5	<1	10	<1	16	5.0	0.17	5.0	0.8
S26 0-0.1	0.15	6.4	0.2	1.1	3.8	2.2	<1	<1	80	15	7.3	0.09	2.2	1.7
S26 0.9-1.0	0.13	7.6	3.1	0.2	9.4	9.8	<1	<1	160	16	22.5	1.01	13.9	1.0
SWLa 0-0.1	0.04	7.0	<0.1	0.6	0.5	0.4	<1	64	31	18	2.3	0.08	2.3	1.3
SWLa 0.6-0.7	0.22	6.8	1.4	0.3	0.2	3.7	<1	2	200	17	5.7	0.96	23.9	<0.1
SWL2a 0-0.1	0.06	6.7	<0.1	0.3	4.1	1.3	<1	<1	36	15	5.8	0.05	1.3	3.2
SWL2a 0.3-0.4	0.19	6.6	1.4	0.2	11.8	3.3	<1	<1	95	12	16.6	0.51	8.4	3.6
SWL2a 0.8-0.9	0.21	7.0	1.5	0.1	14.7	2.6	<1	<1	100	19	19.0	0.52	8.1	5.6

Signatory P. Edwards

For and behalf of Bio-Track Pty Ltd

CERTIFICATE OF ANALYSIS

Analysis By: Bio-Track Pty Ltd
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Highvale, Brisbane, Australia, 4520
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DATE OF REPORT 21 NOVEMBER 2009
CLIENT NAME ALEX KOCHNIEFF c/o WORLEY PARSONS PTY LTD
CLIENT ADDRESS PO BOX 585 FORTITUDE VALLEY BRISBANE4006
PROJECT NAME PIPELINE ROUTE 3E YOUR PROJECT/JOB REFERENCE 301001-00448 WBS 1B4070
SAMPLING DATE 10/2009 NUMBER OF SAMPLES 63 SAMPLE TYPE:SOIL SAMPLE
PACKAGING SAMPLES LABELLED - INTACT ** SAMPLES DISPOSED ON 1/8/2010
DATE RECEIVED 02 NOVEMBER 2009 LAB REF. LR02119.382

METHODOLOGY: EC pH Cl as 1:5 air dried soil in water, 30 minute rolling shake, Cl by ion selective electrode. Na K Mg Ca Fe Al S as 1:20 soil dried soil in 1 N NH4Cl, 60 minute rolling shake, Na Mg Ca Fe Al S measured by ICP OES, K by AAS. CEC (cation exchange capacity) as the sum of extracted cations, SAR (sodium adsorption ratio) as Na/((Ca+Mg)/2)^0.5, %Na as Na% of CEC. (meq/100 =milli-equivalents/100 g soil)

SAMPLE ID m depth	EC dS/m	pH	Na meq/100	K meq/100	Ca meq/100	Mg meq/100	Fe mg/kg	Al mg/kg	Cl mg/kg	S mg/kg	CEC meq/100	SAR	% Na	Ca:Mg
SWL3a 0-0.1	0.09	6.8	0.9	0.6	9.4	2.9	<1	<1	55	15	13.7	0.34	6.2	3.2
SWL3a 0.4-0.5	1.27	6.6	5.1	0.2	18.9	3.2	<1	<1	650	431	27.4	1.54	18.7	5.9
SWL4a 0-0.05	0.05	6.7	<0.1	0.6	4.0	0.7	4	<1	40	15	5.4	0.04	1.1	5.9
SWL4a 0.9-1.0	0.09	6.8	1.2	0.1	0.8	1.9	1	73	75	23	4.8	1.02	24.7	0.4

Signatory [signature] For and behalf of Bio-Track Pty Ltd

SOIL ANALYSIS REPORT

Bio-Track

Analysis By: Bio-Track Pty Ltd
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DATE OF REPORT	12 NOVEMBER 2009
CLIENT NAME	ALEX KOCHNIEFF
CLIENT FIRM	WORLEY PARSONS PTY LTD
JOB REFERENCE	301001-00448 WBS 1B4070
CLIENT ADDRESS	PO BOX 585 FORTITUDE VALLEY BRISBANE4006
PROJECT NAME	PIPELINE ROUTE 3E SAMPLING DATE 10/2009
NUMBER OF SAMPLES	32 SAMPLE TYPE SOIL SAMPLE
PACKAGING	SAMPLES LABELLED - INTACT ** SAMPLES DISPOSED ON 1/8/2010
LOG-IN DATE	02 NOVEMBER 2009 LAB REF. LR02119.395

SAMPLE ID	EMN CLAS
S1 0.4-0.5	8
S1a 0.3-0.4	8
S2 0.7-0.8	1
S3 0.9-1.0	1
S5 0.9-1.0	1
S6 0.3-0.4	4
S6 0.9-1.0	1
S7 0.4-0.5	1
S7 0.8-0.9	1
S9 0.5-0.6	5
S9 0.8-0.9	2
S10 0.9-1.0	6
S11 0.9-1.0	8
S13 0.9-1.0	4
S14 0.2-0.3	5
S14 0.9-1.0	4
S15 0.9-1.0	5
S17 0.9-1.0	5
S18 0.9-1.0	8
S19 0.9-1.0	5
S20 0.9-1.0	4
S21 0.9-1.0	1
S22 0.3-0.4	7
S23 0.9-1.0	2
S24 0.3-0.4	1
S25 0.3-0.4	8
S26 0.9-1.0	2
SWL a 0.6-0.7	1
SWL 2a 0.3-0.4	5
SWL 2a 0.8-0.9	4
SWL 3a 0.4-0.5	1
SWL 4a 0.9-1.0	2

ANALYTICAL METHOD
EMN CLASS-Emmerson Aggregate Stability classification per AS1289.3.8.1 1997

Signatory P. Edwards   For and on behalf of Bio-Track Pty Ltd

Determination of Soil Total Nitrogen

CERTIFICATE OF ANALYSIS

Analysis By: Bio-Track Pty Ltd ABN 91 056 237 275781 Mt. Glorious Road Highvale, Brisbane, Australia, 4520 Ph. 07 3289 7179 Fx. 07 3289 7155

DATE OF REPORT	09 NOVEMBER 2009
CLIENT NAME	ALEX KOCHNIEFF c/o WORLEY PARSONS PTY LTD
CLIENT ADDRESS	PO BOX 585 FORTITUDE VALLEY BRISBANE4006
PROJECT NAME	PIPELINE ROUTE 3E
SAMPLING DATE	10/2009 NUMBER OF SAMPLES 31
PACKAGING	SAMPLES LABELLED - INTACT
DISPOSAL	SAMPLES DISPOSED ON 1/8/2010
LOG-IN DATE	02 NOVEMBER 2009 LAB REF. LR02119.400
METHOD	TECATOR AUTOANALYSER KJELDAL DIGESTION/TITRATION

SAMPLE ID	mg/kg %	Percentage KJELDAL NITROGEN [%]
S1 0-0.1	454	0.05%
S2 0-0.1	364	0.04%
S3 0-0.1	295	0.03%
S4 0-0.1	273	0.03%
S5 0-0.1	498	0.05%
S6 0-0.1	702	0.07%
S7 0-0.1	505	0.05%
S8 0-0.05	1769	0.18%
S9 0-0.1	405	0.04%
S10 0-0.1	363	0.04%
S11 0-0.1	356	0.04%
S12 0-0.1	392	0.04%
S13 0-0.1	595	0.06%
S13 0.3-0.4	391	0.04%
S14 0-0.1	< 100	0.00%
S15 0-0.1	490	0.05%
S16 0-0.1	587	0.06%
S17 0-0.1	427	0.04%
S18 0-0.1	763	0.08%
S19 0-0.2	757	0.08%
S20 0-0.1	674	0.07%
S21 0-0.1	762	0.08%
S22 0-0.1	681	0.07%
S23 0-0.1	328	0.03%
S24 0-0.1	323	0.03%
S25 0-0.1	745	0.07%
S26 0-0.1	658	0.07%
SWL 1a 0-0.1	400	0.04%
SWL 2a 0-0.1	547	0.05%
SWL 3a 0-0.1	659	0.07%
SWL 4a 0-0.05	309	0.03%

Method: Boiling H_2SO_4 digest for 45 minutes, steam distillation and titration by Tecator autoanalyser.

Signatory P. Eaton For and behalf of Bio-Track Pty Ltd

Determination of Soil Phosphorus Content

CERTIFICATE OF ANALYSIS

Analysis By: Bio-Track Pty Ltd ABN 91 056 237 275781 Mt. Glorious Road Highvale, Brisbane, Australia, 4520 Ph. 07 3289 7179 Fx. 07 3289 7155

DATE OF REPORT	09 NOVEMBER 2009
CLIENT NAME	ALEX KOCHNIEFF c/o WORLEY PARSONS PTY LTD
CLIENT ADDRESS	PO BOX 585 FORTITUDE VALLEY BRISBANE4006
PROJECT NAME	PIPELINE ROUTE 3E
SAMPLING DATE	10/2009 NUMBER OF SAMPLES 31
PACKAGING	SAMPLES LABELLED - INTACT
DISPOSAL	SAMPLES DISPOSED ON 1/8/2010
LOG-IN DATE	02 NOVEMBER 2009 LAB REF. LR02119.402
METHOD	As per Aust Lab Handbook of Soil & Water Chemical Methods Method 9B1

SAMPLE ID	PHOSPHORUS as bicarbonate extractable P mg/kg
S1 0-0.1	0.7
S2 0-0.1	0.7
S3 0-0.1	0.9
S4 0-0.1	0.6
S5 0-0.1	1.1
S6 0-0.1	3.5
S7 0-0.1	1.4
S8 0-0.05	21.0
S9 0-0.1	1.1
S10 0-0.1	0.9
S11 0-0.1	1.1
S12 0-0.1	1.2
S13 0-0.1	1.4
S13 0.3-0.4	0.5
S14 0-0.1	4.0
S15 0-0.1	3.5
S16 0-0.1	5.1
S17 0-0.1	3.2
S18 0-0.1	1.4
S19 0-0.2	6.6
S20 0-0.1	1.0
S21 0-0.1	4.9
S22 0-0.1	1.2
S23 0-0.1	0.4
S24 0-0.1	1.3
S25 0-0.1	2.1
S26 0-0.1	1.5
SWL 1a 0-0.1	1.6
SWL 2a 0-0.1	1.4
SWL 3a 0-0.1	2.1
SWL 4a 0-0.05	1.9

Signatory P. Edwards For and behalf of Bio-Track Pty Ltd

Appendix E Soil photographs

Photo 1: S1 / 0.0 – 0.5 m

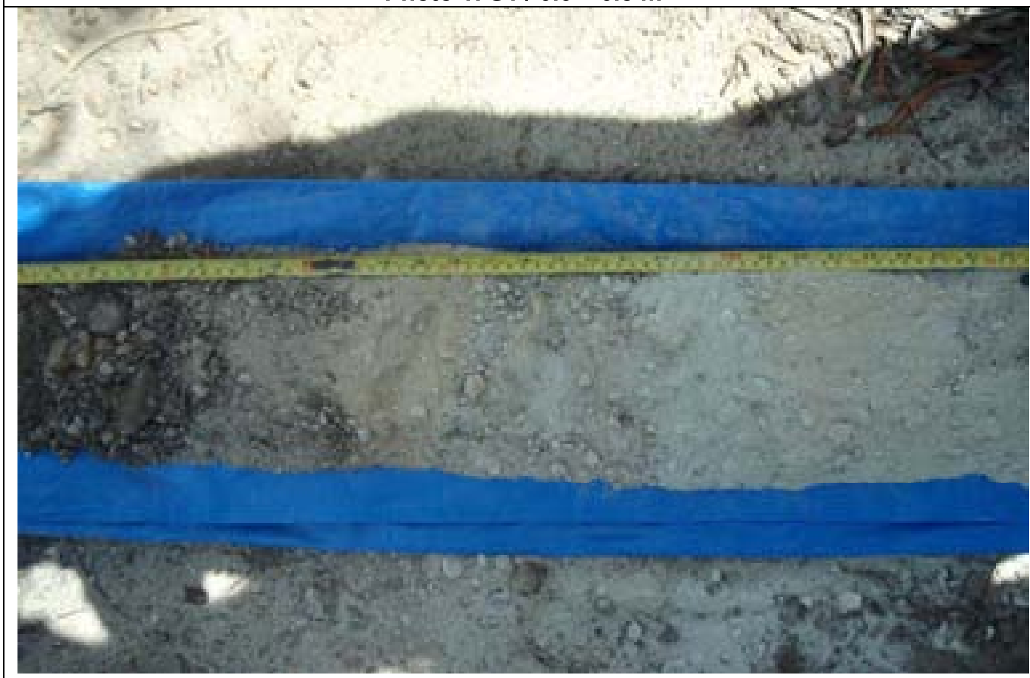

Photo 2: S1a / 0.0 – 0.5m

Photo 3: S3 / 0.0 – 1.0m

Photo 4: S4 / 0.0 – 0.4m

Photo 5: S5 / 0.0 – 1.0m

Photo 6: S6 / 0.0 – 1.0m

Photo 7: / 0.0 – 0.9m

Photo 8: S8 / 0.0 – 0.15m

Photo 9: S9 / 0.0 – 1.0m

Photo 10: S10 / 0.0 – 1.0m

Photo 11: S11 / 0.0 – 1.0m

Photo 12: S12 / 0.0 – 0.3m

Photo 13: S13 / 0.0 – 1.0m

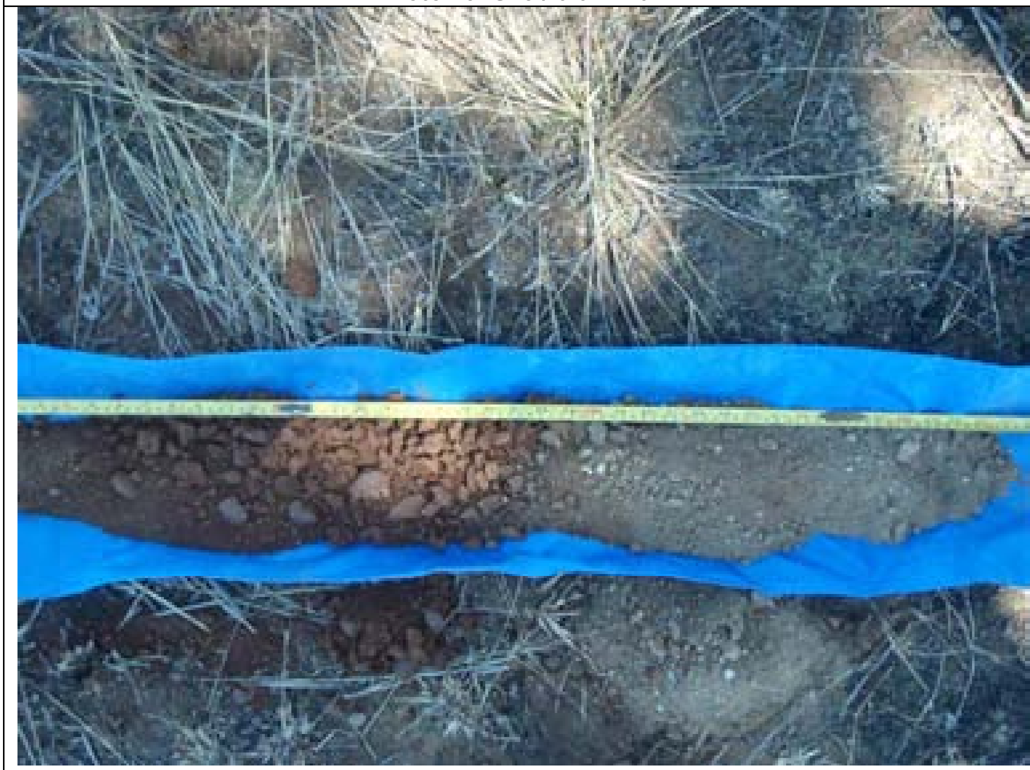

Photo 14: S14 / 0.0 – 1.0m

Photo 15: S15 / 0.0 – 1.0m

Photo 16: S16 / 0.0 – 0.4m

Photo 17: S17 / 0.0 – 1.0m

Photo 18: S18 / 0.0 – 1.0m

Photo 19: S19 / 0.0 – 1.0m

Photo 20: S20 / 0.0 – 1.0m

Photo 21: S21 / 0.0 – 1.0m

Photo 22: S22 / 0.0 – 0.4m

Photo 23: S23 / 0.0 – 1.0m

Photo 24: S24 / 0.0 – 0.5m

Photo 25: S25 / 0.0 – 0.4m

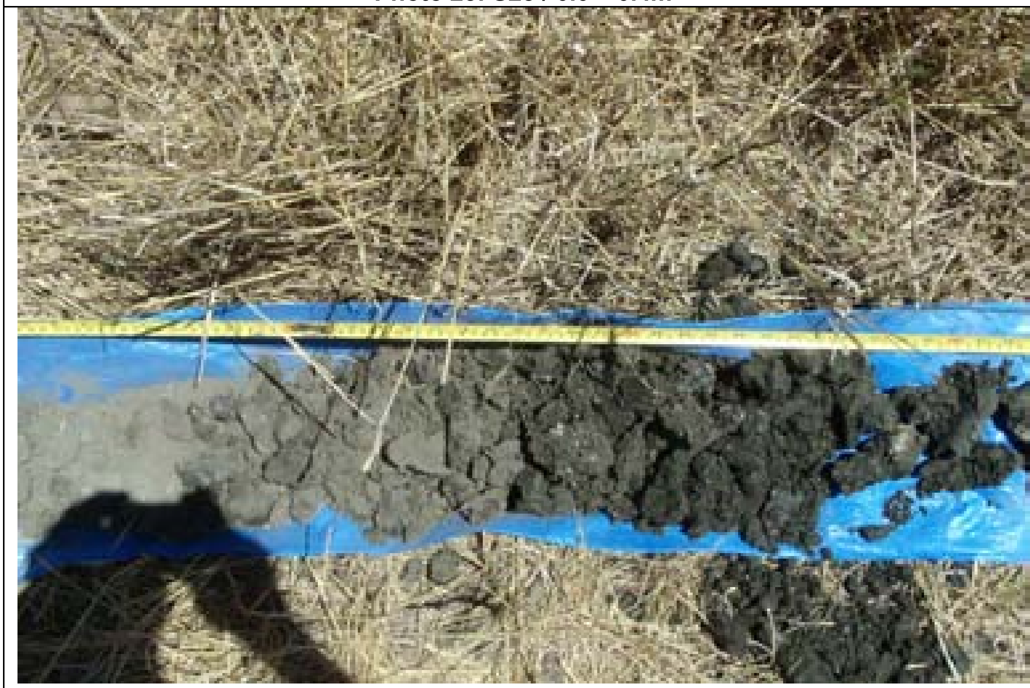

Photo 26: S26 / 0.0 – 1.0m

Photo 27: SWL1a / 0.0 – 0.9m

Photo 28: SWL2a / 0.0 – 1.0m

Photo 29: SWL3a / 0.0 – 0.5m

Photo 30: SWL4a / 0.0 – 1.0m