Australia Pacific LNG Project

Volume 3: Gas Pipeline

Chapter 5: Land - Geology, Geomorphology, Soils and Land Contamination

Contents

5.1 Introduction 1
5.1.1 Purpose 1
5.1.2 Scope of work 2
5.1.3 Legislative framework 2
5.2 Methodology 3
5.2.1 Geology, geomorphology and soils 3
5.2.2 Contaminated land 4
5.3 Existing environment 4
5.3.1 Geology 4
5.3.2 Topography and geomorphology 21
5.3.3 Soils 21
5.3.4 Land contamination 30
5.4 Potential impacts 31
5.4.1 Geology 32
5.4.2 Topography and geomorphology 36
5.4.3 Soils 36
5.4.4 Land contamination 40
5.4.5 Cumulative impacts 41
5.5 Mitigation and management 42
5.5.1 Geology 42
5.5.2 Topography and geomorphology 44
5.5.3 Soils 44
5.5.4 Land contamination 48
5.6 Conclusion 50
5.6.1 Assessment outcomes 50
5.6.2 Commitments 65
References 66

Figures

Figure 5.1 Study area and observation locations 68
Figure 5.2 Investigation areas 69
Figure 5.3 Study area geology and cross section profile locations 70
Figure 5.4 Study area geological cross sections 71
Figure 5.5 Historical earthquakes 1958 onwards and tectonic boundaries 72
Figure 5.6 Study area digital slope analysis 73
Figure 5.7 Study area landform 74
Figure 5.8 Study area soil types 75
Figure 5.9 Study area erosion hazard 76

Tables

Table 5.1 Gas pipeline study area geological unit summary 7
Table 5.2 Existing extractive resources sites within 200km of the gas pipeline route 16
Table 5.3 Soil types in the project area 23
Table 5.4 Erosion potential assessment 26
Table 5.5 Gas pipeline erosion hazard by chainage (incorporating 40m corridor) 27
Table 5.6 Agricultural land classes 29
Table 5.7 GQAL area occupied along the gas pipeline right of way 30
Table 5.8 Geology description and construction classification 33
Table 5.9 Indicative levels of damage from earthquakes 35
Table 5.10 Summary of environmental values, sustainability principles, potential impacts and mitigation measures 51

5 Land - geology, geomorphology, soils and land contamination

5.1 Introduction

5.1.1 Purpose

This chapter provides the assessment of the land within the gas pipeline study area for the Australia Pacific LNG Project (the Project). This has been conducted in accordance with the environmental impact statement (EIS) terms of reference. The purpose of this assessment is to determine those construction and operational activities that may result in significant impacts on the environment, and identify suitable management and mitigation measures to ensure these are prevented, or at least reduce the risk to as low as reasonably practicable. Figure 5.1 shows the locations of the gas pipeline study area, terrain observations and intrusive soil sampling. Laboratory testing was completed on soil samples retrieved from the field investigation.

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

- Volume 5 Attachment 6 – Soils geology topography and geomorphology assessment
- Volume 5 Attachment 9 – Preliminary site investigation – Contaminated land.

This chapter addresses sections 3.2.1 Topography, geomorphology and geology, 3.2.3 Soils, and 3.2.6 Land contamination of the EIS terms of reference (refer to Volume 5 Attachment 1) where they relate to the gas pipeline study area.

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

Of Australia Pacific LNG's 12 sustainability principles, key sustainability principles which relate to land within the gas pipeline study area are:

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

Mitigation measures were developed by adhering to these principals, thus ensuring no environmental harm or loss of beneficial land use or visual amenity will occur. Off-site impacts can be minimised and the need for rehabilitation reduced by implementing water runoff diversion, erosion prevention and sediment controls during construction and operation. Land disturbance will be actively rehabilitated to maintain environmental values. Pollution incidents can be avoided by controlling discharges to land and by undertaking monitoring programs that are consistent with Queensland legislation and National

guidelines. Where pollution does occur, rehabilitation of land will endeavour to return the land to a pre-disturbed standard or better, progressively over the life of the Project. This includes the potential for rehabilitation of previously disturbed land on an opportunistic basis.

Efficient use of resources and waste reduction are also key principles related to land. Opportunities to re-use and recycle onsite materials will be sought as much as possible which should, in turn, reduce the volume of waste generated by the Project. The requirements for quarry materials will also be reduced by using any suitable onsite rock as viable resource. Rock can be processed through a mobile rock crusher to produce gravel for construction purposes.

Communities are also considered. This chapter includes the requirement to consider community needs in the development of quarries as well as the requirement to consult with crop farmers as to their operational requirements, including construction scheduling with respect to crops, and pipeline depths with respect to ploughing depths.

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

5.1.2 Scope of work

The following scope of work was undertaken when assessing potential impacts on land-based environmental values along the gas pipeline route:

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

5.1.3 Legislative framework

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

- *Environmental Protection Act 1994 (EP Act)*
- Environmental Protection Regulation 2008
- Environmental Protection (Waste Management) Regulations 2000.
- Environmental Protection (Water) Policy 2009
- Guidelines for Sampling and Analysis of Lowland Acid Sulfate Soils (ASS) in Queensland 1998
- *Petroleum and Gas (Production and Safety) Act 2004*
- Queensland Department of Mines and Energy: Technical Guidelines for Environmental Management of Exploration and Mining in Queensland (1995)
- *Soil Conservation Act 1986*
- State Planning Policy 1/92 Development and the Conservation of Good Quality Agricultural Land
- State Planning Policy 2/02 Planning and Managing Development involving Acid Sulfate Soils.

The methodology of the assessments which is guided by the above legislation, guidance documents and policies is provided in the following section.

5.2 Methodology

This chapter considers both the main gas transmission pipeline that runs from near Miles to Curtis Island and the Condabri and Woleebee lateral pipelines.

For this assessment, a gas pipeline corridor study area of approximately 5km on either side of the gas pipeline (10km total) was adopted. There are also 14 proposed temporary accommodation facility sites and laydown areas which fall within the corridor.

Figure 5.1 illustrates the gas pipeline study area.

5.2.1 Geology, geomorphology and soils

The existing condition of the geology, geomorphology and soil was assessed using a combination of desktop studies and field investigations. The desktop study was completed using a number of national and state publications. These include geologic, topographic and soils maps, acid sulphate soils and land system reports, which cited in Volume 5 Attachment 6.

This desktop study was supplemented with direct observation of soils and waterways, and soil sampling at selected locations (observation locations). The site observations comprised terrain assessments, including terrain type, slope, presence of watercourses and existing infrastructure. These were made at 57 locations within the gas pipeline study area. Figure 5.1 provides a plan showing the soil sampling and observation locations.

Thirty-one soil observation locations focused on areas that were readily accessible and gave a representative analysis of soils that predominated along the gas pipeline route. This comprised the Condabri lateral (KP0 to 37), the Woleebee lateral (KP0 to 44) and the main gas pipeline (KP0 to 281). Beyond KP281, the gas pipeline will be within common infrastructure corridors which are outside of the scope of this study. This comprised approximately 363km of assessable pipeline length. Twenty-six water crossing observations were selected based on stream order hierarchy, as per the Department of Environment and Resource Management's (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 gas pipeline route. Waterway crossing observation locations were selected based on the inspection of crossings points (where accessible) for a stream order three or greater.

This methodology represents a sampling intensity of approximately one soil observation every 47ha, which equated to 31 locations across the approximate 1,452ha area of disturbance, based on the 40m wide right of way plus associated facilities. This number of locations also exceeded the Queensland Department of Mines and Energy: Technical Guidelines for Environmental Management of Exploration and Mining in Queensland (1995) recommended sampling intensity of one location every 625ha of disturbed area mapped at a scale of 1:250,000.

This was considered adequate to characterise soils within the gas pipeline study area, when combined with existing land suitability information. It provided sufficient information to correlate encountered soils with published land system data. Detailed field methodology is provided in the technical report in Volume 5 Attachment 6, including soil sampling methods, soil descriptions, laboratory analysis, terrain and geologic categorisation.

5.2.2 Contaminated land

A preliminary site investigation (PSI) was based on a desktop study. This was an appropriate and practicable approach for the Project's initial stage of development approval.

No soil sampling and analysis was undertaken for this PSI, but may need to be undertaken to allow the detailed gas pipeline alignment to be confirmed. The study area investigated was a 200m corridor. The location of the study area is shown in Figure 5.2.

The desktop assessment was completed using the following information sources:

- Interviews with landholders, carried out by Australia Pacific LNG staff, to gather details about notifiable activities such as fuel storage and use of cattle dips and spray races
- Notifiable activity as listed in Schedule 3 of the EP Act and land which is listed within the Queensland Environmental Management Register or the Queensland Contaminated Land Register
- Data relating to cattle tick-free and non-free zones located in Queensland from the Department of Employment Economic Development and Innovation (DEEDI), and interviews with DEEDI inspectors
- Site inspections conducted as part of other field studies
- Current aerial photography (2009) and satellite imagery (2007-2008).

This approach was adopted from the methodology that was approved by DERM for the gas fields (refer to Volume 2 Chapter 5). The above approach conducted for the PSI was also in general agreement with the following guiding documents:

- Australian Standard (AS) 4482.2.2-1999 Guideline to the investigation and sampling of site with potentially contaminated soil Part 1: Volatile substances
- AS4482.1-2005 Guideline to the investigation and sampling of site with potentially contaminated soil Part 1: Non-volatile and semi-volatile compounds
- Department of Environment Draft Guidelines for the Assessment and Management of Contaminated Land in Queensland, dated May 1998.

5.3 Existing environment

5.3.1 Geology

Regional geology

With reference to maps produced by the Geological Survey of Queensland, the southern section traversed by the gas pipeline corridor is underlain with rocks and soils of the Bowen Basin and Surat Basin.

The northern and eastern sections of the gas pipeline corridor pass through the Yarrol Province, Connors-Auburn Province, Gogango Overfold Zone and Wandilla Province of the Northern New England Fold Belt. These are described below.

Bowen Basin

The Bowen Basin covers an area of approximately 160,000 square kilometres (km^2). It is a north-south trending belt which extends from Townsville, Queensland, southwards into central northern New South Wales.

In the east of the basin, early phases of deposition laid down fluvial (river) and lake-bed sediments and volcanics are present, while in the west, a thick succession of coals and non-marine clastic sediments was deposited.

Subsequent rifting and subsidence allowed deposition of deltaic and shallow marine sediments as well as extensive coal measures over much of the basin. A period of accelerated subsidence followed, resulting in the deposition of a very thick succession of marine and fluvial sediments, including lake-bed sediments and coal.

Surat Basin

The Surat Basin overlies the southern half of the Bowen Basin and occupies an area of approximately 300,000 km^2, extending from the southern part of central southern Queensland to central northern New South Wales.

Early deposition comprised mostly fluvial (river) and lake-bed deposition followed by coal swamp environments, except in the north where sedimentation continued. Fluvial deposition then occurred again and continued until a period of relative sea level drop occurred, depositing near-shore and marine sediments. The subsequent regression caused a fairly abrupt return to fluvial, lake bed and marshy conditions before sedimentation ceased.

As a result of the depositional conditions and subsequent geological history the basin sediments have lithified to form a succession of sedimentary rocks including mudstone, siltstone, sandstone and conglomerate. Some recent volcanic rock (basalt) is also present. Numerous deposits of coal, hydrocarbons and associated gas have also accumulated in the basins. These sediments have subsequently been overlain in areas by Tertiary and Quaternary sediments.

Connors–Auburn Province

The northern section of the Connors and Auburn consists mainly of a sedimentary sequence of soil and sedimentary rocks. These overlie a basin of marine volcanic rocks which have been folded and faulted by earthquakes producing west-north-west directed thrust faults and associated folding. Along the western side of the Connors-Auburn Province, adjacent to the Bowen Basin, there are volcanic rock outcrops associated with the edge of the basin.

Gogango Overflowed Zone

The Gogango Overfolded Zone is a belt of distinctly layered sandstone, mudstone, and volcanic rocks running between the northern and southern sections of the Connors and Auburn Province. It extends north to St Lawrence and south to Auburn. This belt of rocks is similar to the Bowen Basin, but has been more deformed by thrusting.

Yarrol Province

The Yarrol Province extends north to Bowen and south to about Kingaroy. It is a basin of volcaniclastic sedimentary rocks that become shallower towards the Bowen Basin to the west. Sections of the deposit contain numerous limestone beds.

Wandilla Province

The Wandilla Province extends in a band from Shoalwater Bay to the north, and south into northern New South Wales. The Wandilla Province comprises sedimentary and volcanic rocks which are semi-vertically bedded due to foldings and also contain fossils. Deeper rocks include 'jasper' and 'chert,' there is a central band of 'greywacke' and 'argillite,' and near-surface rocks include 'sandstone' and 'argillite,' particularly in the east.

Geology of the gas pipeline corridor

In summary, the majority of the geology in the gas pipeline corridor comprise sedimentary rocks, including coal beds with more recent deposits of river alluvium in the low lying areas and adjacent to waterways. There are also mud flats near the coast close to Gladstone. But in the central region of the gas pipeline corridor near the Banana and Auburn Ranges, there are granites and other igneous volcanics of the Connors-Auburn Province. In the northern segment of the gas pipeline corridor, there are also volcanics associated with the Yarrol Province.

As mapped in the Geological Survey of Queensland's Geoscience Datasets (refer Figure 5.3 and Figure 5.4), 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 5.1.

Structural geology

Structural geological features identified on existing geological mapping that occur in proximity to the gas pipeline corridor include a number of inferred faults and folds. The approximate locations of these faults and folds are shown on Figure 5.5. The following structural features have been identified, with more detail provided in Volume 5 Attachment 6:

- North-east to south-west and north-south tending faults along the Auburn Range
- North-south and north-west to south-east tending faults near the Banana Range, the Dawes Range, the Mount Larcom Range, Alma Creek and the Callide Range
- East-west tending faults near the Great Dividing Range
- A north-south fault near Friend Point, Kangaroo Island parallel to the western shore of The Narrows channel
- East-west tending fault at Curtis Island.

These zones of possible weakness in the Earth's crust are potential areas of movement in the event of an earthquake. However, no such movements at faults have been observed in Queensland in recent times.

Table 5.1 Gas pipeline study area geological unit summary

Description	Major geological unit	Age	Lithology summary	Dominant rock	Map symbol
Manmade deposits	Manmade deposits	Holocene	Gravel, sand and mud; manmade deposits associated will landfill or mining.	Manmade deposits (tailings, landfill, mine dumps and so on)	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; flood plain 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	
Late Tertiary–Quaternary colluvium	Colluvium	Late Tertiary – Quaternary	Clay, silt, sand, gravel, and soil; colluvial and residual deposits.	Colluvium	TQc

Description	Major geological unit	Age	Lithology summary	Dominant rock	Map symbol
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 coal.	Arenite-mudrock	

Description	Major geological unit	Age	Lithology summary	Dominant rock	Map symbol
	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, Mulguildie Coal measures, Walloon subgroup	Middle Jurassic – Late Jurassic	Calcareous lithic sandstone, siltstone, mudstone, coal, conglomerate.	Sedimentary rock	Ji
Jurassic sediments - razorback beds	Razorback 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	Volcaniclastic sediments	Middle Triassic –	Polymictic, volcaniclastic, pebble to cobble	Mixed sedimentary	Rc

Description	Major geological unit	Age	Lithology summary	Dominant rock	Map symbol
sediments - Callide Coal measures		Late Triassic	conglomerate, volcaniclastic sandstone; trachytic to andesitic, lithic and crystal tuff; quartz-lithic sandstone and siltstone; rare carbonaceous siltstone.	rocks and felsites	
	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	Late Permian – Early Triassic	Medium grained biotite hornblende granodiorite, quartz monzonite and hornblende-biotite tonalite,	Granitoid	

Description	Major geological unit	Age	Lithology summary	Dominant rock	Map symbol
	Zag granodiorite, Rock Point granodiorite, Redshirt granite, Wyalla granite, Targine quartz monzonite, Dumgree tonalite		hornblende-biotite granite, biotite-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 greding into calcareous siltstone and mudstone, silicified limestone and coquinite.	Mixed siliciclastic / carbonate rocks	
4 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 and 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 and 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, 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 granite, 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	Late	Fine to medium grained, porphyritic biotite	Dioritoid	

Description	Major geological unit	Age	Lithology summary	Dominant rock	Map symbol
	monzodiorite, Glen View quartz monzodiorite	Carboniferous – Early Permian	hornblende diorite to quartz diorite and biotite hornblende gabbro.		
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.	Rudite	
	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

Seismicity

The approximate location of earthquakes recorded since 1958 in Queensland are presented on Figure 5.5. This figure indicates that only three earthquakes have been recorded in the gas pipeline study area since 1958, and all of these have been of a magnitude of 2.0 or less. An earthquake with a magnitude of 2 or less would not be expected to cause damage (refer Table 5.9).

Standards Australia has produced earthquake loading maps to provide engineers with design coefficients for earthquake risk, based on a 10% probability of exceedance in 50 years.

Using these maps, the hazard factor (Z) – which is equivalent to peak ground acceleration in ms^{-2} – varies between 0.04 and 0.07 for the gas pipeline study area, depending on the location. A value of 0.05 indicates, in any 50-year period, there is a 10% chance that the peak ground acceleration will exceed 0.05 ms^{-2}.

Location and quality of coal seam gas resources

Information on the location and quality of CSG resources is discussed within the Volume 2 Chapter 5.

Extractive resources

In addition to the coal, hydrocarbon and gas resources existing within the depositional basins, lands near the gas pipeline corridor contain a number of quarries that produce materials for construction. This includes gravel, sand and hard rock. Quarries identified within 200km of the gas pipeline corridor are listed in Table 5.2. These quarries may be used as a source of construction material.

Table 5.2 Existing extractive resources sites within 200km of the gas pipeline route

Quarry name	Operator	Status	Production rate(a)	Local authority (pre-2007 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 to 74.5km, 6km north-east of Biloela
Fairview Road	Moura Sand & Gravel Pty Ltd	Operating	Medium	Banana	Hard rock	
Kianga	Kianga Quarries Pty Ltd	Suspended	-	Banana	Hard rock	20km south of Banana on Leichhardt Highway; 18km south-east of Moura
Yuleba	Yuleba Minerals Pty Ltd	Suspended	-	Bendemere	Sand and gravel	6km south of Yuleba on Yuleba-Surat Road
Warrians	Boral Resources (Qld) Pty Ltd - Country	Operating	Low	Bungil	Hard rock	35km up Roma-Taroom Road
Boyne River	Blomfield Excavations	Operating	Medium	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 Bruce Highway/Tannum Sands Road intersection
Calliope River (Bruce)	Blomfield Excavations	Operating	Low	Calliope	Sand and gravel	North bank of Calliope River, 3 to 4km upstream of Bruce Highway
H & R Quarry	H & R Quarrying Pty Ltd	Operating	Medium	Calliope	Hard rock	Quarry Road 1.5km west of Yarwun, on a property owned by DJ Hall (PO Box 28 Yarwun)

Quarry name	Operator	Status	Production rate(a)	Local authority (pre-2007 boundaries)	Operation type	Descriptive locality
Hurcom	Rayment Excavations	Suspended	-	Calliope	Hard rock	Hurcom Road, Calliope
Tannum Sands	Grahame Allen & Sons Pty Ltd	Suspended	-	Calliope	Sand	1km north on Tannum Sands Road off Bruce Highway
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	Corner of North Kogan/Warra Kogan Roads
Colls Pit	N & J Bobcat Hire	Operating	Low	Chinchilla	Sand	Monmouth Bridge Road (Redhill Road) 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 Road, Condamine South
Bauhinia Downs	Park Equipment Pty Ltd	Suspended	Low	Duaringa	Hard rock	2km north of Bauhinia settlement
Bedford Weir	Whitsunday Crushers Pty Ltd	Operating	Medium	Duaringa	Hard rock	23km north of Blackwater
Blackhill	Department of Main Roads	Suspended	Low	Duaringa	Hard rock	5km north-east of Bluff township
Mimosa Creek	Moura Sand & Gravel Pty Ltd	Operating	Low	Duaringa	Sand and gravel	Mimosa Creek 26.8 to 31.0km, 25km north-west of Moura

Quarry name	Operator	Status	Production rate(a)	Local authority (pre-2007 boundaries)	Operation type	Descriptive locality
Gales	Eidsvold Shire Council	Operating	Low	Eidsvold	Hard rock	Kerwee Road approximately 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	Medium	Fitzroy	Hard rock	McEvoy Road, south-west of Gracemere
Moore	Fitzroy Shire Council	Suspended	-	Fitzroy	Hard rock	Gracemere locality
Pink Lily Sands	Pink Lily Sands	Operating	Medium	Fitzroy	Sand and gravel	Fitzroy River 68.8 to 70km upstream of barrage at Pink Lily Lagoon/Lotus Reserve
Quarry at Midgee	Hopkins Bros	Operating	Medium	Fitzroy	Hard rock	59793 Bruce Highway, Midgee
Ridgelands Gravel Pit	Fitzroy Shire Council	Operating	Low	Fitzroy	Hard rock	1km down Nicholson Road, 20km west of Rockhampton, along Ridgelands Road
Road Paddock	R C Lawrie	Suspended	-	Fitzroy	Hard rock	
Wigginton	Fitzroy Shire Council	Suspended	-	Fitzroy	Hard rock	Gracemere

Quarry name	Operator	Status	Production rate(a)	Local authority (pre-2007 boundaries)	Operation type	Descriptive locality
Kunwarara	Blomfield Excavations	Operating	Low	Livingstone	Hard rock	Bruce Highway, approximately 35km north of Yaamba
Nerimbera	Rinker Australia Pty Ltd	Operating	High	Livingstone	Hard rock	Emu Park-Rockhampton Road/Black Creek Road
Hawkwood Road	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 Rockhampton	Operating	Low	Rockhampton	Hard rock	2km down Rocky-Yeppoon Road 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 turnoff

Quarry name	Operator	Status	Production rate(a)	Local authority (pre-2007 boundaries)	Operation type	Descriptive locality
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 approximately 10km

Note: Extractive industry information obtained for the Australia Pacific LNG gas pipeline from the former Department of Mines and Energy (now DEEDI), QRock database. In this table, low production is <80,000 tonnes per annum (tpa), medium production is 80,000 to 200,000tpa, and high production is >200,000tpa

5.3.2 Topography and geomorphology

A digital slope analysis for the gas pipeline study area is shown on Figure 5.6, while landforms are presented on Figure 5.7. A simple classification system was used as follows:

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

The topography across the study area varies from predominantly flat or gentle undulating plains, to mountains and hills with slopes greater than 50% gradient. But the majority of the route traverses flat to gently undulating plains and low hills with slopes less than 20% gradient. Field assessments of the topography have generally confirmed these features.

There are also numerous watercourses that traverse the gas pipeline corridor, many of which have steep banks. Of the 26 waterway crossings inspected during the field assessment, ten were observed to have a medium to high level of existing erosion. In most other locations there was no evidence of significant erosion, as there was generally either good vegetation or outcropping rock. Volume 3 Chapter 11 provides further information on watercourses.

5.3.3 Soils

Study area soils

Using the available land system mapping discussed in Section 5.2, soils have been assessed and grouped to develop a classification system for the gas pipeline corridor. Six soil groups were identified and referenced as 1 to 6. This standardised soil key is presented in Table 5.3 and illustrated in Figure 5.8. The main soil groups in the gas pipeline corridor are as follows:

- Shallow gravelly loams (Rudosols) with a predominance of surface stone are mainly found in areas of steeper terrain where slopes exceed a 12% gradient. These soils are derived mainly from mixed sedimentary, igneous and metamorphic rocks, generally from the Permian period or older
- Texture contrast soils (mainly Sodosols) are the most extensive soil group in the southern sections of the gas pipeline corridor and are very susceptible to erosion. These soils have mostly shallow sandy or loamy topsoil with an abrupt change to a medium to heavy clay subsoil. This subsoil is commonly sodic and dispersive
- Texture contrast soils (mainly Chromosols and Kurosols) are mainly located near the central and northern section of the gas pipeline corridor. These soils also have a shallow topsoil and medium to heavy clay subsoil, but the subsoil is generally non-sodic with moderate to low levels of dispersion. These soils are also susceptible to erosion, especially on the steeper slopes, but are generally less erosion prone than Sodosols
- Red and yellow earths (Kandosols or Tenosols) are located in isolated locations along the gas pipeline corridor

- Shallow to moderately deep non-cracking clays (Dermosols) are located mainly on the gently sloping to undulating plains, especially in the gas pipeline corridor between Wandoan and Biloela
- Shallow to deep cracking clays (Vertosols) are located mainly on the level to gently sloping plains (including alluvia), and are used extensively for cropping near the gas pipeline corridor
- Saline soils associated with the intertidal and supratidal zone (Hydrosols) are located in the tidal lands on the eastern and western side of The Narrows. These soils are discussed in more detail below.

Topsoil thickness

With reference to Australian Soil Classification (Isbell 1996), potential topsoil thickness was estimated for each of the soil types (refer Table 5.3). This estimate was generally supported by field observations, but many soil types were not tested as part of the field program. Most soils are expected to have a thin to medium depth of topsoil.

Acid sulfate soils

Soil group 6 (the Hydrosols), described above, is commonly known as acid sulfate soils (ASS). These are water logged mudflats with organic soils. Areas shown as soil group 6 on Figure 5.8 have potential to be ASS. This term is generally used to describe both 'actual acid sulfate soils' (AASS) and 'potential acid sulfate soils' (PASS).

AASS may have sulphuric acidic runoff which can cause damage to the environment. If PASS is exposed to air, it tends to oxidise and become AASS.

Often AASS overlie PASS, and sometimes pockets of these exist in non-ASS.

Implications for the project development in areas of PASS or AASS are as follows:

- Exposure of PASS to the air can result in oxidation, creating AASS and (potentially) generating sulfuric acid runoff
- Runoff can also contain heavy metals such as aluminium and iron
- Runoff can result in deoxygenation of waterways
- Concrete and steel infrastructure including pipes, foundations and bridges that come into contact with these soils and runoff water can corrode, unless designed accordingly
- Hydrosols are often soft and can settle under loading, so these soils usually provide poor support for structures
- If extremely acidic layers occur, then the treatment costs can be prohibitive.

Table 5.3 Soil types in the project area

Order			Description	Typical topsoil thickness[1]	Encountered topsoil thickness	Soil erodibility ranking
1	Skeletal soils (mainly Rudosols)	a	Alluvial – deep sands	Thick	Not encountered	2
		b	Shallow stony loams derived from sediments	Thin	Thin to very thick	1–2
		c	Shallow stony loams derived from mixed sources (metamorphic, intrusive or volcanic parent material)	Thin	Thick	1–2
2	Texture contrast soils (Chromosols/ Sodosols and Kurosols)	a	Alluvial – predominantly moderately deep to deep	Thick to very thick	Not encountered	1–2
		b	Shallow mainly sandy surface: neutral to acid subsoil (Chromosols / Kurosols) neutral to alkaline subsoil (Sodosols)	Thin to medium	Medium to thick	3–4
		c	Shallow mainly loamy surface: neutral to acid subsoil neutral to alkaline subsoil	Thin to medium	Medium to thick	3–4
		d	Moderately deep to deep sands/loams	Thick to very thick	Medium	1–2
3	Red/yellow earths (Kandosols / Tenosols)	a	Shallow earths – derived from sediments	Thin to medium	Not encountered	2–3
		b	Deep earths – derived from sediments	Medium to thick	Not encountered	1-2
		c	Shallow/ deep earths derived from mixed sources	Thin to thick	Not encountered	2
4	Brown/ grey non-cracking clays (Dermosols)	a	Alluvial	Thin to very thick	Medium	1
		b	Derived from sediments	Medium to thick	Thin	2
		c	Derived from mixed sources (mainly intrusives/ volcanics)	Thin to thick	Not encountered	2

Order			Description	Typical topsoil thickness[1]	Encountered topsoil thickness	Soil erodibility ranking
5	Brown/grey/dark cracking clays (Vertosols)	a	Alluvial	Medium to thick	Not encountered	1
		b	Derived from sediments (mainly clay plains)	Medium to thick	Medium	1
		c	Derived from intrusives/volcanics	Medium to thick	Not encountered	1
		(m)	Melonhole clays - Give rise to Gilgai on plains and linear Gilgai on gentle slopes. These have a moderate to high water holding capacity and poor drainage.	Medium to thick	Thin to thick	1
6	Grey mottled saline cracking clays and sands (Hydrosols)	a	Marine deposits	Thin	Not encountered	6

1. Thickness:
   Thin: <0.1 m
   Medium: 0.1 to 0.3 m
   Thick: 0.3 to 0.6 m
   Very Thick: >0.6 m

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

Soil sodicity and dispersion

Sodicity of a soil is the measure of exchangeable sodium (Na) in relation to other exchangeable ions. The sodicity of a soil correlates with its potential to disperse on contact with water and therefore its susceptibility to erosion. It can also affect a soil's potential to form a surface crust and its infiltration characteristics.

The samples collected ranged from non-sodic to strongly sodic, although the majority were reported as non-sodic. Sodic to strongly sodic fine textured subsoils – those mainly within soil groups 2, 4 and 5 – will require careful management and should be kept separate from non-sodic soils if excavated. Additionally, sodic to strongly sodic coarse textured soils – mainly within soil groups 1, 2 and 3 – will also require careful management and separation of the subsoil.

Slightly fewer than half the samples tested for dispersion were reported as very dispersive. These correlate well with the sodicity results described above. However, those samples which did not correlate have higher concentrations of salts (chloride and sulfate). Higher concentrations of salts assist in soil bonding, thereby limiting dispersion. This does not necessarily mean a soil is saline, but simply contains concentrations of ions which sustain soil structure.

Although no samples were collected within soil group 6, these soils are not expected to be dispersive due to high salinity.

Erosion potential

The potential for erosion was assessed based on laboratory test results, topsoil depth, presence of existing erosion, soil texture, soil structural stability and the soil's capacity to absorb rainfall. The erosion susceptibility of each of the soil groups is given in Table 5.4.

This assessment indicates that, based on the locations sampled, most of the soil types would be considered to have a low erosion potential in their natural state, mainly due to existing ground cover and land use.

All soils are more susceptible to erosion when disturbed. In particular, where vegetative cover has been removed, soils with a classification of 3 or 4 will be highly susceptible to erosion. Soils with an erosion classification of 2 or lower are less likely to erode due to non-sodic or high salinity concentrations which limit dispersion.

To determine the overall erosion potential for lands within the gas pipeline corridor, the soil erodibility ranking described in Table 5.3 has been combined with the influence of different slope categories and presented in Table 5.1. This table indicates that soils groups 2b and 2c, especially on slopes greater than 8% gradient, are the most susceptible to erosion.

The erosion potential for the gas pipeline corridor is illustrated in Figure 5.9.

Table 5.4 Erosion potential assessment

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
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

Key:
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 assessment presented in Table 5.4 and Figure 5.9, Table 5.5 shows chainages of areas within the 40m-wide gas pipeline right of way with a high, very high or severe erosion hazard potential.

Table 5.5 Gas pipeline erosion hazard by chainage (incorporating 40m corridor)

Kilometre point (KP) location along proposed pipeline route	Very low to moderate	High to severe
Condabri Lateral KPs	Refer to Figure 5.9	11 to 18, 27 to 42
Woleebee Lateral KPs	Refer to Figure 5.9	1 to 7, 10 to 22
Main gas pipeline KPs	Refer to Figure 5.9	8 to 10, 26 to 31, 36 to 51, 56 to 59, 61, 69, 89 to 102, 104 to 223, 226 to 228, 232 to 236, 243 to 250, 256 to 302, 305 to 306, 313 to 331, 341 to 348, 350 to 351
Percentage of pipeline right of way (450km x 40m)	50%	50%

Soil pH

Most of the soil samples collected and tested were neutral (between 6.2 and 6.8) and within a pH range acceptable for plant growth. However, there were soils tested with high concentrations of aluminium, which commonly correlate with acid soils and pH as low as 4.8 (very strongly acidic). No type 6 soils were tested (i.e. PASS or AASS). AASS commonly have a pH less than four.

Salinity

Salinity is the presence of soluble salts in soils. This is mainly sodium, but can be potassium, calcium, magnesium, sulfate and chloride. High salinity levels in soil may reduce plant productivity, kill off native vegetation, and increase erosion.

Most salinity results for samples collected ranged from non-saline to moderately saline, although most samples were non-saline. This was confirmed through field investigation observations, which did not identify any significant areas of salinisation or extensive scalding.

Even so, the elevated salinity levels in the subsoils in many soil groups (notably the 2b, 2c and 5b), will mean careful management is required, particularly for the rehabilitation purposes discussed in Section 5.5.3. This is because these soils have a propensity to accumulate salts, due to lack of leaching from low rainfall. Elevated salinity in fluctuating near surface groundwater may also affect these soils.

Fertility

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

Most cation exchange capacity results ranged from low to high, indicating variable fertility within the gas pipeline study area. In general, lower concentrations were reported for sandy and loamy textured soils (Chromosols, Kandosols and Rudosols), while higher concentrations were noted in the clay soils (predominately Vertosols). This suggests that the sandy and loamy textured soils are less fertile than the clayey soils, which is usually the case.

Analysis for total Kjeldahl nitrogen and phosphorus indicates that the soils on the site contain only minor proportions of nutrients. Both the coarse textured and fine textured soils were found to be deficient in both total Kjeldahl nitrogen and phosphorus, and may require fertiliser to support plant growth during revegetation.

Agricultural land capability

The 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 (Department of Primary Industries/Department of Housing, Local Government and Planning (DPI/DHLGP) 1993). Although this policy is not applicable to petroleum activities, it describes the State's intent towards GQAL.

The Planning Guidelines: The Identification of Good Quality Agricultural Land (DPI/DHLGP 1993) defines GQAL as 'land which is capable of sustainable use for agriculture, with a reasonable level of inputs, and without causing degradation of land or other natural resources.'

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

Agricultural land is classified into four groups which are described in Table 5.6.

Based on this mapping, the percentages of each agricultural class within the gas pipeline right of way have been estimated and provided in Table 5.7. It should be noted that these areas are calculated using a 40m-wide corridor and a total pipeline length of 444km (1,766ha). It excludes associated facilities such as laydown areas, which would be rehabilitated following construction.

Table 5.6 Agricultural land classes

Class	Description
A	Crop land Land that is suitable for current and potential crops with limitations to production which range from none to moderate levels. There are two sub-classes of crop land: • A1 – crop land suitable for 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 may be considered to be GQAL, depending on the local authority planning provisions.
D	Non-agricultural land Land not suitable for agricultural uses due to extreme limitations. This may be undisturbed land with significant habitat, conservation and/or catchment values or land that may be unsuitable because of very steep slopes, shallow soils, rock outcrop or poor drainage. These limitations preclude any interference with land or biological resources for the production of agricultural goods.

Source: DPI/DHLGP 1993

Table 5.7 GQAL area occupied along the gas pipeline right of way

GQAL class	Area occupied (ha)	Percentage of area occupied (%)
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 Project. It will also provide a standard by which rehabilitation is undertaken to return the land to the original condition.

GQAL is comprised of classes A, B and, depending on the planning intent of the respective local authority, class C1. For the purposes of this assessment, class C1 has been considered to be GQAL.

The location of GQAL is shown in Figures 6.1 to 6.7 in Volume 3 Chapter 6.

When combined, the total GQAL within the right of way is 44%. Based on mapping, GQAL class A occurs at various locations along the gas pipeline right of way with the most significant area between KP237 to 243. Class B GQAL also occurs throughout the gas pipeline study area, with significant areas 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 mapping generally correlates with soil group mapping. That is, areas mapped as soil groups 4 and 5 are commonly also mapped as class A, B or C1 GQAL. Soil groups 1, 2, and 3 are generally mapped as class C2 or D GQAL.

5.3.4 Land contamination

Within the context of the proposed development, environmental impact from contamination may arise when an existing contaminated area such an old landfill area is encountered or disturbed. Impacts may also result from project activities themselves, such as spillage during refuelling or leaking of fluids from mechanical plant.

To assess the risk of land contamination, it is important to evaluate both the existing contaminated land impacts and the potential impacts due to disturbance by the gas pipeline construction.

A desktop study was undertaken to assess the impact of the gas pipeline infrastructure on the environment as a result of disturbance of contaminated sites. The assessment concluded that the gas pipeline route is generally anticipated to be free from widespread adverse levels of manmade contaminants, but that some localised risks may be present due to the historic land uses. Cattle dips and spray races and unauthorised waste dumps and possible waste disposal were considered to be the most likely source of contaminants, given the rural setting and associated activities.

The site history revealed the following notifiable activities:

- One potential waste dump (Site 1) located within the road easement of Warrego Highway, which was confirmed by site inspection
- A dip on Lot 3 DW464 (Site 2) although not inspected but confirmed by the landholder. A suspected cattle yard was also identified by satellite imagery which may be the location of the dip but this was not confirmed
- A former dip and current dip on Lot 9 DW19 (Site 3), both of which were not identified by site inspection but confirmed by the landholder. A suspected cattle yard was also identified by satellite imagery which may be the location of the dip but this was not confirmed
- A suspected waste dump (Site 4) and a former dip on Lot 5 DW390 both of which were not confirmed by site inspection. The former dip was identified by the landholder. The suspected waste dump was identified by satellite imagery
- A disused dip, which was confirmed by site inspection on Lot 4 CTN406 (Site 5)
- A suspected dip or spray race on Lot 9 SP200837 (site 6) which was identified by satellite imagery.

Note that the site inspections that were noted as not being undertaken were a result of not being able to obtain land owner access within the timeframes of the Project.

There may also be buried dips and spray races present within the gas pipeline route, particularly within the tick infested zone in the northern part of the gas pipeline corridor between Taroom and Gladstone, or other landfill/disposal areas which were not identified during the PSI. To confirm these findings, further desktop studies and field investigations involving intrusive sampling will be required.

5.4 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 right of way. 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 laydown 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 gas pipeline will be constructed according to current industry practice, with appropriate depth of cover above the pipe in all locations, increasing under watercourses, roads and cropping areas. The pipeline will be buried deeper 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 and potential scour during flood.

This section discusses the potential impacts of the gas pipeline on land-based values, specifically on the existing geology, topography, geomorphology and soils. The potential impacts if construction activities encounter contaminated land is also discussed, along with to potential for land contamination to occur from operational activities. Cumulative impacts are addressed are discussed at the conclusion of this section and refer to potential impacts in a regional context.

5.4.1 Geology

Effect of geology on excavation

Based on the geological maps (Figure 5.3) and terrain mapping (Figure 5.6), an assessment was undertaken to establish the potential construction constraints to excavation from each geology type. This assessment has been based on pipeline excavations up to a nominal 2m depth.

The assessment used a rating system that defines the potential excavation constraint as low, medium or high. A low rating is one in which, due to the nature and depth of soil cover associated with the geological unit, few excavation problems are envisaged. A typical example would be soil deposits that could easily be dug using a standard excavator.

A medium rating implies the presence of a stronger material such as a very dense gravely soil or weathered rock, in which progress with a standard excavator may be slow. In this case, a larger machine and the occasional use of a ripper or hydraulic rock breaker would be required.

A high rating implies that the geology is of high strength and will require special excavation methods, such as ripping, hydraulic breaking or blasting. A good example of a high rating would be fresh granite.

Table 5.8 presents the potential excavation constraints presented by the different geological units along the gas pipeline right of way.

This assessment indicates the presence of rock is expected to be a constraint to development along sections of the gas pipeline right of way, especially in the Callide Range area. Associated impacts relating to rock extraction and handling are also expected.

This review also revealed that a range of materials required for gas pipeline construction are potentially available, but mobile padders may have difficulty generating adequate useable fines for bedding and padding for the pipeline in some areas. As a result, importation of bedding materials may be required for some sections of the route. In addition, while the Holocene-age miscellaneous sediments or soil group 6 will be easily excavated, it may be unstable during earthworks and could potentially release acidic runoff due to the presence of ASS in the area of Friend Point prior to crossing the 'The Narrows'.

Excavation activity is not anticipated to cause significant offsite risks and normal environmental controls for noise, vibration and dust control would be expected to apply. More information about air quality, and noise and vibration impacts is provided in Volume 3 Chapter 13 and Volume 3 Chapter 15 respectively.

Table 5.8 Geology description and construction classification

Geology unit	Map symbol	Excavation rating	Excavation constraint	Probability of surface rock
Manmade 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, Mulgildie 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 constraint	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 Permian extrusive and 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 and Campwyn blocks	CPs/v	Rating 3	High	Likely to least 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

Seismicity

Faults and folds within the gas pipeline study area indicate zones of weakness in the upper Earth's crust. These 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 gas pipeline study area have been few and minor.

Should an earthquake occur during the lifecycle of the Project, damage to infrastructure may occur. An indication of potential levels of public nuisance and damage to infrastructure for various earthquake magnitudes is presented in Table 5.9.

Table 5.9 Indicative levels of damage from earthquakes

Modified Mercalli scale		Level of damage	Richter Scale
1-4	Instrumental to moderate	No damage	</= 4.3
5	Rather strong	Damage negligible. Small, unstable objects displaced or upset; windows rattle, felt by some people.	4.3 to 4.8
6	Strong	Damage slight; windows, dishes, glassware broken,, door swing, felt by everyone	4.9 to 5.4
7	Very strong	Damage slight to buildings with plaster cracking and brick falling	5.5 to 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 to >8

Source: Geoscience Australia (2010)

The table suggests structural damage could occur during earthquakes of Richter 4.9 or higher. In such instances, damage to the gas pipeline could result. The gas pipeline design will address seismic risk during the detailed design process and in accordance with relevant Australian Standards and guidelines. The potential for seismic events affecting the pipeline integrity is considered to be very low.

Extractive resources

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

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

The quarry assessment identified numerous existing quarries within and surrounding the gas pipeline study area, which are provided in Section 5.3.1. Most quarries currently supply materials to local councils and communities for road construction, maintenance and building purposes.

This assessment did not identify the material reserves associated with existing quarries. Australia Pacific LNG does not plan to directly develop new quarries as part of the Project. However, new

quarries and expansions to existing quarries (operated by others) may be required with 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 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.

Sterilisation of resources

Establishing the gas pipeline right of way could restrict the future mining of some mineral resources in the region. The gas pipeline corridor traverses a number of tenements that have overlapping tenure. If holders of the affected coal tenures wish to access coal under the gas pipeline right of way, they may be required to forego coal extraction and/or gasification, or undertake costs to relocate the gas pipeline. This is discussed further in Volume 3 Chapter 6.

5.4.2 Topography and geomorphology

Developing the gas pipeline will involve vegetation clearing and earthworks for gas pipeline construction, temporary accommodation facilities, access track, waterway crossings and temporary hydrotest water holding ponds.

This will require localised excavation and re-profiling of the existing terrain, which could result in localised changes to topography and destabilisation of soils. In turn, this could change the local drainage patterns, visual character and degraded downstream water quality. These aspects have been addressed in Volume 3 Chapter 7 and Volume 3 Chapter 11. Levelling works will also result in vegetation clearing on slopes, destabilisation of soils and temporary loss of GQAL.

Ultimately, excavations carried out for the gas pipeline will be backfilled or re-contoured to a suitable stable landform. In time, it is expected that the backfill material will settle to produce a relatively flat profile compatible with the adjacent undisturbed landform. In some cases, if the backfill is poorly compacted or not enough is used, a surface depression may result. In both instances there is a potential for localised change to the surface drainage patterns. If this occurs, pipeline patrols will note the changes and arrange for corrective actions, and therefore the impacts are likely to be minor.

Where stream crossings are required, there is the risk of local changes to the stream morphology and potential for river bank instability. These aspects are addressed in Section 5.5.2.

Due to the generally low slopes along the gas pipeline route, land stability such as slope failure and collapse is not expected to be a significant issue. Local areas of steep gradient are present, especially in the Callide Range area, but these are comprised mainly of rock. While these will present the significant excavation constraint identified in Section 5.4.1, significant slope failure is not expected.

5.4.3 Soils

Topsoil

Australia Pacific LNG recognises the need to carefully manage the existing topsoil resource within the right of way.

The gas pipeline construction will involve stripping of topsoil and associated vegetation to create areas for the new infrastructure. The right of way will be rehabilitated and restored to a stable landform progressively during and following the construction program. The timing of the impact will be coordinated with landholders to minimise disruption to their farming operations. In the long term, it is anticipated that the gas pipeline will be decommissioned and left buried to eventually corrode.

Topsoils will be stripped with care and rocky materials removed. 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.

Topsoil will not occur in soil group 6. This soil group will require targeted management approaches discussed in Section 5.5.3.

Temporary storage of topsoil in stockpiles is likely to be required. If inappropriately handled and managed, stockpiling of topsoils can damage the topsoil structure, causing nutrient leaching and loss of fertility. The height of the stockpiles will be limited to 2m to avoid damaging the topsoil and maintain fertility. Where there are multiple stockpiles, appropriate spacing will be left to allow wildlife and vehicles to negotiate around them. There will be separate stockpiling of vegetation and soils. Sediment and erosion control and weed control will be implemented around construction and rehabilitation areas. The environmental management plan in Volume 3 Chapter 24 has proposed topsoil management measures. There are to be implemented progressively to maintain the quality and maximise the use of the topsoil resources within the right of way.

Reactive soils

Reactive soil comprise cracking clays, and are the soil groups 5b and 5b(m) described in Table 5.3. These soils were identified within the gas pipeline right of way.

Moisture variations cause reactive soils to expand and contract. This can lead to heaving and subsidence, which damages buildings and roads if not catered for in their design.

Underground infrastructure such as pipelines can be designed to withstand movement. While damage to protective coatings can occur from stresses induced by these expansive clays, engineering design measures can be implemented to overcome such issues.

Erosion

Without mitigation, development of the gas pipeline could significantly increase soil erosion levels. This could result from the clearing of vegetation, poor drainage management (including concentration of flow), improper sediment and erosion controls, and inadequate earthworks contractor training and supervision. While this can have an adverse effect on soil productivity and the associated agricultural value, with consequent effects on GQAL, additional effects may include undermining of structures such as fences, exposure of the pipeline, stream bank erosion, downstream sedimentation, decline in fertility through loss of soil structure, increased dust generation and poor rehabilitation. If soil is eroded, additional rehabilitation works will also be required.

There is a substantial risk of erosion occurring in sections of the gas pipeline right of way, as noted in Section 5.3.3 and shown in Figure 5.9. Due to ecological and terrain constraints, some areas classified with a high to severe erosion hazard are unavoidable. In these areas, there is a high likelihood for significant adverse impacts to occur if suitable mitigation strategies are not implemented.

As indicated in Section 5.3.3, approximately 50% of the gas pipeline has a low to moderate erosion risk, while the remaining 50% has a high or greater erosion risk. Sections with the greatest risk occur around the Callide Range crossing and near the Rockybar State Forest.

Erosion levels are expected to be more significant in the coarser textured soils, where there is little structure and organic matter to assist in binding the soil and resisting erosion. Finer textured soil groups (4 and 5) have a low to moderate erosion rating where undisturbed. However, as the subsoils can be generally sodic to strongly sodic, on steeper slopes (>8% gradient) these soils can be prone to

significant erosion when disturbed. This is due to clay dispersion. Such soils can be particularly prone to gully and tunnel erosion.

Concentrated flows, including those caused from stormwater diversion around construction areas, have the potential to cause the greatest erosion impact, particularly gully erosion.

Some discharges will be required as part of the construction process, such as the release of the water used for hydrostatic testing. Impacts in relation to the disposal of hydrotest water disposal are expected to be similar to the erosion hazards described above. In some instances, it will be necessary to release water directly into existing drainage channels and watercourses. At these point-source discharge locations, increased erosion may occur.

Preparing and implementing detailed sediment and erosion control plans for the construction phase will be the key to reducing erosion risk to acceptable levels. This is especially the case for areas of high or greater erosion risk, and for significant stream crossings. The intent of such environmental management plans is described in Volume 3 Chapter 24.

Salinity

The majority of soils in the study area were non-saline (electrical conductivity levels <2,000μS/cm). Soil group 6, although not assessed during the field investigation, is expected to have extremely saline (electrical conductivity levels >16,000μS/cm) soils due to their landform position, being periodically inundated with seawater.

As discussed previously, these soils will require special management as they may be corrosive to civil structures. No areas of surface salinisation along other sections of the gas pipeline right of way were noted during the field investigation.

Hydrotest water has the potential to have a degree of salinity, depending on where it was sourced. Saline water disposal onto land can impact the local environment significantly, so discharge management controls will be required to minimise impacts.

Soil acidification and acid sulfate soils

Most soil samples collected and tested within the gas pipeline study area were neutral and will not require specific acid management. However, this assessment did not include testing of samples from soil group 6, which are expected to be ASS.

These soils occur within the intertidal area associated with The Narrows and located between approximately KP 351 and 355. Studies conducted within and near the gas pipeline study area by both Ross (2004) and the Gladstone LNG project have indicated these soils have a high potential for acid generation and can occur within 0.5m of the ground surface.

PASS commonly has a neutral pH in an undisturbed state, but becomes highly acidic if exposed to air and allowed to oxidised, such as during excavation activities. The potential acid generated could migrate in runoff, impact the surrounding environment and corrode structures.

Virtually all soils to be disturbed with the intertidal and supratidal areas of The Narrows are expected to be ASS. In the absence of rigorous management measures, the potential impacts associated with their disturbance and handling would be significant.

However, as noted in Section 5.5.3, detailed ASS sampling is proposed where the gas pipeline traverses The Narrows area. This is part of preparing the ASS management plan required under State Planning Policy 2/02. Implementing this plan will ensure that impacts will be minimised to acceptable levels.

This EIS 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 does occur within Port Curtis.

To fully assess potential PASS impacts associated with the construction of the gas pipeline right of way offshore (i.e. not on the mainland), a separate study is required followed by the generation of an ASS management plan prior to disturbance.

Good quality agricultural land

An estimated 44% of the gas pipeline right of way is comprised of GQAL, classes A, B and C1. A portion of this land may be impacted through construction of the proposed gas pipeline, resulting in:

- Loss of agricultural production (reduced cropping area)
- Interference with overland flow through the modification of run-off controls
- Increase in soil compaction through heavy trafficking that reduces water infiltration
- Decrease in fertility
- Increase in erosion
- Disruption to timing of farming operations and restriction on land use.

These impacts are expected to be sustained on 773ha of GQAL (classes A, B and C1) during the construction period only. When construction is complete, most of the land will be reinstated to its original use and condition. This period of loss of agricultural usage may be between three and five months.

This loss is not expected to be significant in the regional context. Minor areas, such as access tracks and pump stations, would not be available for full agricultural utilisation until operations cease, whereupon these areas would be fully rehabilitated.

There are likely to be some areas, such as access tracks, which will be retained for the use of landholders or the community after operations cease. So while there will be some permanent loss of GQAL, the impact of this loss is likely to be minor.

Bulldust

Due to potential high levels of vehicle movement in the gas fields study area, it is likely that dust formation will occur, particularly in soils with high silt and fine sand content, and those with high calcium carbonate content. Where these soils are severely degraded the generation of bulldust can occur. Bulldust generates wind blown dust, causes dry bogging of vehicles and equipment and can be difficult to manage

Significant levels of bulldust were not observed within the gas pipeline corridor, but 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 throughout the Project.

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

5.4.4 Land contamination

Existing land contamination

Section 5.3.4 has indicated there is unlikely to be significant or widespread pre-existing contamination present within the right of way. However, some locations have been identified where previous land use activities (mainly cattle races and dips) may have caused localised areas of contamination. Such areas will need to be the subject of further assessment as part of the front-end engineering design (FEED) stage of the Project. There will also be a low probability of previously unidentified contaminated soils being encountered during earthworks.

Disused cattle dips are often buried. Buried dips may not be evident from the ground surface and current site owners may not even be aware of their existence. These have the potential to:

- Cause contamination (arsenic and pesticides) and potentially impact environmental receptors
- Require contaminated soil to be removed from site to retain environmental values and to return the land to a pre-disturbed standard or better if practicable or managed in accordance with the EP Act.

The risk of encountering buried dips or disused landfills during the construction phase is considered to be low, but implementing the procedures identified in Section 5.5.4 would ensure that any potential adverse effects are minimised.

Construction impacts

Activities associated with the construction of the gas pipeline may generate compounds which have the potential of contaminating soil. These compounds will be predominately generated from general construction activities relating to earthmoving equipment and storage and discharge of hydrotest water.

General construction activities

Earthmoving equipment used during construction of the gas pipeline may provide a source of contamination from associated hydrocarbons such as diesel, petroleum fuel, lubricating oils and hydraulic fluids. Quantities of these fluids will generally be limited to the amount required to complete tasks, therefore limiting the amount of material which could be released to soil.

The storage of diesel fuel will be in aboveground storage tanks at dedicated refuelling stations along the gas pipeline right of way. These storage tanks will have secondary containment. The implementation of refuelling procedures for vehicles, plant and the cleaning up of spills with the assistance of spill kits will limit the potential for soil contamination.

Storage of lubricating oils and hydraulic fluids will be generally maintained in dedicated containers or workshops with grated floors and steel secondary floors which trap small spills and leaks within the building. Transfer of these fluids when refilling oil tanks or hydraulic systems will be done with small volumes thus limiting the quantity of material which could be spilt.

In the event of a small spill, there will typically be several spill response kits comprised of absorbent pads which may be used to clean up any minor spills. The wastes generated from spill response kits will be disposed of via an approved waste handler in conjunction with other wastes generated onsite.

The appropriate storage, transfer and use of diesel, petroleum fuel, lubricating oils and hydraulic fluids will limit the quantity of material that may potentially be released to soil. The storage facilities will have primary and secondary containment along with product handling procedures for transfer and use.

Earthmoving equipment will undergo routine maintenance and inspections to limit the potential for spillage of contaminated material.

Commissioning and operation activities

The gas pipeline has the potential to impact soil though the likelihood is low. An event such as an earthquake may damage the integrity of the pipeline and result in an uncontrolled release of natural gas and hydrostatic water. This outcome is highly unlikely as discussed in Section 5.4.1.

The gas pipeline will be constructed in accordance with applicable standards, such as AS2885. It will be tested for integrity prior to commissioning using a hydrostatic test method for steel pipes. The quality of hydrostatic water will be assessed to ensure it will meet the required surface water discharge quality criteria prior to release.

The gas pipeline design includes an isolation plan incorporating block valves and check valves to minimise the volume of gas which may be released in the event of a leak or rupture. An emergency response plan will be developed which outlines the resources, response and process that Australia Pacific LNG will follow in the event of a pipeline leak or rupture. Leakage of natural gas has the potential to impact soil structure and vegetation in a localised area. Soil impacted by natural gas has reduced soil structure quality and reduced availability of oxygen within the soil. The rehabilitation process for soil affected in this way will be in accordance with regulatory guidelines and may include:

- Excavation
- Onsite remediation
- Validation of the excavation
- Backfilling the excavation with remediated soil.

Following remediation, the soil surface will be rehabilitated consistent with the surrounding vegetation.

Hydrotest water will be stored in an engineered pond. The base and walls of the pond will be reinforced with an impermeable membrane and a dedicated monitoring network established to assess if the liner has lost integrity.

Decommissioning

At the end of the Project, the gas pipeline will be purged with an inert gas if required, capped and abandoned in place. In the event water is collected, it will be disposed of in either a storage pond or removed by an approved waste handler. Any aboveground infrastructure and access tracks will be removed and rehabilitated to be consistent with the surrounding area.

The environmental management plan provided in Volume 3 Chapter 24 describes additional management strategies relating to the decommissioning the gas pipeline.

5.4.5 Cumulative impacts

The following section outlines the cumulative impacts to the environment external to the study area resulting from the Project's land disturbance along the gas pipeline right of way. These impacts are also discussed within Volume 3 Chapter 25.

Geology

Demand on existing or new local extractive material sources (quarries), which may be required for construction, external to the Project and operated by others may increase. Material requirements have

not been determined at this stage but will be determined during FEED phases of the Project. This assessment will need to account for other demands from other LNG projects. If additional material sources are required to be developed, follow-on effects may include increased noise, dust and vibration levels and changes to land and road use.

Soils

The destabilisation of soils (erosion) and sedimentation of downstream areas is a potential cumulative impact during construction resulting from vegetation clearing and earthworks for all LNG project developments and point-source discharges to unstable watercourses. This impact is expected to be low unless appropriate mitigation measures are not implemented.

The loss of GQAL within the region is a potential cumulative impact associated with all LNG project developments resulting from construction and operation of gas pipelines. An impact will occur due to occupation of GQAL which will be highest during construction but minimised during operation through progressive rehabilitation. Some minor areas such as access tracks and pump stations will be sterilised during operation but rehabilitated when operations cease.

Soil acidification and decline in downstream water quality (Port Curtis) is a potential cumulative impact during construction resulting from the disturbance of soil group 6 for all LNG project developments. This impact is expected to be low once detailed ASS and geotechnical investigations are undertaken and outline specific mitigation and management measures and design criteria.

Land contamination

Potential impacts to land from the occurrence of contaminated land will be associated mostly with the construction of the gas pipeline. Such impacts are likely to be caused by spills, leaks and storage of waste products and waste materials and have the potential to result in localised areas of contamination. Off-site migration of contamination via soil or groundwater is not likely from the gas pipeline unless it is ruptured. However, this is considered unlikely given design, construction methods and materials used for the gas pipeline.

5.5 Mitigation and management

Table 5.10 summarises proposed controls to mitigate and manage potential environmental impacts of the Project with regard to geology, topography, geomorphology and soils. Further details of these mitigation measures are given in the following sections.

5.5.1 Geology

The following mitigation measures have been identified:

- During the FEED phase of the Project, a geotechnical assessment of the gas pipeline right of way main excavations will be required, to identify the type of equipment required and assess the associated environmental effects
- Where there is to be site levelling for temporary accommodation facilities and hydro test water storage, site levels are to be set to minimise the depth of excavation and the requirement for breaking out of rock if it is encountered
- Wherever practicable, clearing of existing natural vegetation will be confined to within the proposed construction disturbance footprint. Where additional clearing is required to permit

access for larger equipment, clearing will be kept to the minimum necessary to complete the work

- Where rock breaking and/or blasting is required, consideration will be given to any surrounding land use which is sensitive to vibration. Blasting is to be undertaken so as to minimise to minimise the effects of noise and vibration to these receptors, and will be carried out in accordance with relevant guidelines, as discussed in Volume 3 Chapter 13 and Volume 3 Chapter 15
- Excavated material will be re-used onsite, where possible. An onsite crusher may be engaged to render any excavated rock suitable for re-use onsite, including use as rock armouring for scour protection
- Where excavations in soil group 6 are proposed, detailed geotechnical investigations are to be conducted to assess design and construction techniques. A detailed ASS investigation will be performed in accordance with State Planning Policy 2/02, Planning and Managing Development involving ASS. An ASS and dewatering management plan will also be developed as part of the overall environmental management plan, in accordance with Queensland Acid Sulfate Soil Technical Manual – Soil Management Guidelines.

Seismicity

There are a number of faults which occur within the gas pipeline study area, but there are few recorded earthquakes. Nonetheless the structure design will be undertaken in line with Australian Standard AS 2885.1 - 2007.

Extractive resources

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

- FEED phases of the Project will quantify the need for extractive materials prior to construction, and will identify the quality, volume and type of materials required and the location at which these will be required
- 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 will be assessed during Project FEED phases to determine the size and local demand, which will allow an informed assessment to be made about whether there are adequate resources to service both existing community needs and the Project's requirements
- Mobile crushers may be used on the Project so excess rock excavated can be utilised to minimise the need to quarry materials from external sources
- Construction will be carried out progressively and remediation of areas scheduled so that rock for construction platforms and temporary access roads can be recycled to minimise the need for quarry materials.

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

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

5.5.2 Topography and geomorphology

The general mitigation measures listed below will be addressed throughout the Project to minimise potential impacts to landform:

- In areas of site levelling works, proposed formation levels will be set to reduce the need for significant cut and fill areas
- Re-use of construction materials will be implemented to minimise the volume required from borrow pits
- Pipeline backfill and compaction of the fill will be controlled to minimise subsidence and the need for excessive temporary soil mounding
- Structures, including hydrotest water storages, temporary accommodation facilities and waste transfer stations, will be sited on relatively level sites for ease of landform rehabilitation following construction completion
- Slope stability assessment will be carried out on areas where clearing works are required on steep and very steep slopes with gradients great than 20%
- Surface equipment, structures and imported materials will be removed at completion of the Project, and landform reinstatement and rehabilitation will be carried out. This may involve remediating and rehabilitating any contaminated areas, and subsequently grading and revegetating the gas pipeline corridor returning it to a stable landform. Exceptions may apply when the State or regional authorities for public land, or landowner on private land request and agree with Australia Pacific LNG to leave infrastructure in place
- Detailed design of the creek crossings will incorporate works and measures to minimise the risk of damage to the creek banks during construction, and the risk of damage to the gas pipeline during flood events. This is covered in Volume 3 Chapter 11 – Surface water and watercourses.

5.5.3 Soils

Topsoil

As topsoil needs to be stripped to the appropriate depth without subsoil disturbance, site specific assessments will be undertaken along the gas pipeline right of way prior to disturbance. This will enable the appropriate removal depth to be determined.

Clearing and rehabilitation will be undertaken progressively and timing of site clearance will be coordinated with landholders, so that the disruption to farming operations will be minimised. Vegetation clearance will be minimised to reduce the potential for soil erosion. Vegetation will be chipped for use as a protective mulch layer to facilitate revegetation and minimise erosion.

Fertility of both fine and coarse textured topsoils within the gas pipeline right of way is generally low. Additional nutrients (specifically nitrate and phosphorus) or conditioner will be required in some areas to improve topsoils, stabilise the subsoils and support vegetation regrowth during stockpiling and rehabilitation.

Where practicable, stripped topsoil will be re-used in areas where a similar soil type is required for rehabilitation. Where this is not practicable, the topsoil will be stockpiled and rocky materials removed. Where applicable, coarse textured topsoils will be stockpiled separately from fine grained (group 4 and 5) soils where it can occur in proximity. The height of the topsoil stockpiles should be limited to 2m to avoid damaging the topsoil and maintain fertility. Topsoils stockpiled for extended periods will be vegetated, and the stockpile turned over and mixed prior to replacement. Where multiple stockpiles are required, appropriate gaps will be left between stockpiles to allow wildlife and vehicles to negotiate around them. Sediment and erosion control and weed control will be implemented around construction and rehabilitation areas.

Salinity

Where saline subsoils occur, notably the 2b, 2c and 5b soils will be assessed where required to improve rehabilitation objectives.

Saline subsoils, where encountered, will be replaced at depth and covered with topsoil. In areas where there is little topsoil or there is evidence of existing salinisation, topsoil may need to be imported to facilitate revegetation. There will also be progressive rehabilitation and stockpiling of soils near the site of excavation to minimise potential blending between non-saline and highly saline soils.

Specific measures required to manage soil group 6 will be addressed within site specific geotechnical and ASS investigations.

Disposal of saline water can affect soil salinity. Disposal of saline waters, potentially hydrotest water, will therefore meet the requirements identified in Volume 3 Chapter 12 which covers associated water management.

Reactive soils

Group.5b and 5b(m) soils, called reactive soils, have significant shrink and swell characteristics. These occur throughout the study area. To minimise construction constraints associated with these soils, a number of mitigation measures are proposed.

Firstly, where construction is proposed within soil group 5b and 5b(m), site specific geotechnical investigations will be carried out to assess the potential movement caused by these cracking clays. These investigations will also identify the potential infrastructure protection (that is 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.

Secondly, 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 (Gilgai) 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 protective coating may be considered in the areas where these cracking clays are encountered, but the need for this will be assessed during detailed design.

Finally, 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 in some areas to prevent rutting and damage to the soil resource, as these soils are of significant agricultural value.

Water diversion, sediment and erosion control

Conventional stormwater control through runoff diversion and concentration combined with scour protection has required augmentation in some areas, particularly in highly dispersive soil areas within Australia Pacific LNG's existing gas fields. Detailed sediment and erosion control measures will therefore be implemented, particularly in areas designated as having a high to severe erosion hazard (refer Figure 5.9).

Where applicable, the following measures are proposed:

- Where diversion of runoff water around the construction site is required, design will need to take into account the possible erosion effects, including instigating or exacerbating gully and tunnel erosion. The sediment and erosion control plans to be prepared will address measures to prevent such erosion from occurring
- Sediment fences and, if required, sediment detention structures may be constructed on the downhill side of the excavation areas
- Sediment fences may be constructed around the stockpile areas
- Sediment and erosion control measures and areas receiving concentrated flows will be inspected on a regular basis, replaced where damaged, and emptied following rainfall events if required
- Sediment and erosion control measures such as contour banks may be placed at frequent intervals along flow paths, where appropriate. These will be directed to discharge at multiple locations at low velocities and volumes, rather than channelling runoff to a central point which can exacerbate erosion
- Assess suitable hydrotest water discharge locations in conjunction with landowners and relevant Federal, State or regional authorities
- Point discharge into stable waterways and/or drainage lines and implement engineering controls such as scour protection and flow velocity limits
- Clearing vegetation progressively, to minimise the area of soil exposed
- Creating stable slopes and revegetate soon after disturbance
- Stabilising 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). This will be done using chemical surface stabilisers or physical alternatives such as crushed rock
- Installing diversion, sediment and erosion control devices prior to construction commencing, and keeping these in place until the area has been effectively rehabilitated
- Roads and tracks will ideally go across slopes. Where tracks go down slopes contour banks will 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 will 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 will be used to divert water off the disturbed areas

- Constructing sediment basins on the downhill side of major facility sites, such as temporary accommodation facilities, when they are near sensitive water courses, as outlined in Volume 3 Chapter 11
- Discharging water through silt fences, if it is required to be discharged off-site.

A comprehensive soil erosion, control and monitoring plan, detailing these and other measures will be provided in the environmental management plan (refer to Volume 3 Chapter 24).

Creek protection

The gas pipeline will need to cross several significant watercourses (stream order > 3). As a result, a vehicular access route will also be required at these crossing locations. The following mitigation measures are proposed:

- Construction through creeks will be carried out when the creeks are dry, where practicable. If there is water in the watercourse at the time of construction, then there will be a dam upstream and downstream. Water will then be diverted through suitably designed culverts or pipes through the dam or pumped around for low flows
- Where the gas pipeline is to cross a watercourse, the pipe trench will be excavated perpendicular to the direction of the water flow and the trench backfilled carefully
- Banks will be rehabilitated consistent with surrounding areas where practicable to maintain the integrity of the gas pipeline and the bank
- Where erosion within existing channels may be exacerbated by additional inflows, or where point-discharges are required, erosion protection such as rock armour or a proprietary geosynthetic layer will be installed. Existing soils within the creeks will be excavated and stockpiled so they can be replaced following removal of the temporary protection systems
- To prevent erosion, any water pumping which may require offsite discharge during construction will be undertaken in a manner consistent with the Queensland guidelines for sedimentation and erosion
- Inspections of watercourse crossings (routine and following severe rain events) will be conducted to visually monitor erosion at the crossing, and downstream for evidence of sediment runoff
- The creek will be rehabilitated to a condition consistent with the contours of the channel at the time of construction
- Where required by proximity to grazing stock or other threats, access will be prevented to sites, through fencing or barriers, to assist site recovery.

If construction of pipe trenches through major watercourses is carried out in wet conditions, an assessment of trench stability will be undertaken, as trenches often become unstable in the presence of water.

More specific advice is given in Volume 3 Chapter 11, including the required depth of the pipe below the water-bearing layers.

Dust control

Construction activities could create dust, such as along proposed access roads and due to site clearance. Dust management within the gas pipeline right of way are described in Volume 3

Chapter 13 along with other air quality strategies. Some measures relating to soil management include:

- Careful selection of onsite access roads to minimise road length
- Surfacing of onsite access roads with gravel and/or geotextile and applying water where appropriate
- Clearing vegetation and stripping and stockpiling topsoil where new access tracks are required
- Carrying out revegetation as soon as practicable after construction.

Reinstatement of land capability

The easiest way to achieve the best result from reinstatement is to limit the impact in the first place. To this end, the location of the gas pipeline right of way, temporary accommodation facilities and hydrotest ponds has been selected to create minimum impact to the productive capacity of the land. For example, land owners will be consulted regarding property operations and access tracks could be run alongside existing access tracks, fence line and road reserves.

Where disturbance of productive land is unavoidable, the careful management of topsoil and subsoil, erosion and associated water will form an important component of the rehabilitation strategy. At the completion of construction, wastes will be removed, temporary access routes will be closed, and soils will be replaced in the order in which excavation was carried out. Where practicable, disturbed areas will be rehabilitated to the level of the surrounding environment, and with consistent vegetation types.

Where gas 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 to ensure timing of the works does not unduly affect farming operations.

Acid sulfate soil management

Before gas pipeline construction begins, a detailed ASS and geotechnical investigations will be undertaken and an ASS management plan developed prior to disturbance.

This investigation would be used to prepare a detailed ASS management plan. This will outline management strategies, including any neutralisation requirements where alkaline materials (lime) are physically incorporated into the soil.

5.5.4 Land contamination

Existing contamination

In light of the impacts outlined in Section 5.4.4, the following mitigation measures are proposed:

- Carry out further conversations with landowners, along with site visits of accessible areas, to assess the possible presence and effects of cattle yards and any waste dumps or other notifiable activities
- In the event contamination is suspected and it is not practicable for the Project to avoid the contaminated area, carry out environmental assessment of the contaminated area. If contamination is confirmed, carry out remedial or site management actions, where practicable, of the disturbed areas which will be in accordance with EP Act. In addition, the remediated area will be protected from future impact associated with the source

- If unexpected contamination is found during construction, stop construction at that location and carry out environmental soil sampling and testing. Recommended remediation and site management measures will be implemented prior to construction continuing.

Construction works will be conducted in line with the environmental management plan discussed in Volume 3 Chapter 24. This includes specific measures for existing contamination.

Investigation procedure for contamination incidents

During construction, commissioning, operation and decommissioning, confirmed and potential contamination of land will be immediately reported to Australia Pacific LNG.

Australia Pacific LNG will determine if further actions are required to fulfil their corporate and legislative responsibilities. Further actions may include, but are not limited to:

- An investigation into the cause(s) of the incident
- A qualitative assessment of the incident's extent and severity, and any impacts to environmental values, which may require input by persons that are suitably qualified under Section 381 of the EP Act
- Notification of the DERM if the incident is significant, as required in Section 371 of the EP Act
- A detailed contamination investigation following relevant guidelines existing at the time of the incident.

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

Land contamination due to project activities

The construction of the various elements of infrastructure to support the gas pipeline development will require the use of construction plant, involving the use of fuel, hydraulic oil and engine oil. Other chemicals may also be used for construction, such as paint, concrete additives, lubricants and so on. Due to the remoteness of some locations, temporary accommodation facilities will also be required for construction staff. These could generate significant volumes of waste that will add to the waste generated by construction itself.

Normal good construction practice will be adopted to protect against land contamination from these activities, and remediation implemented where contamination occurs. Such measures will include:

- Establishing fuel and chemical stores aboveground (unless risk of damage) with impervious floors and bunding
- Adopting the waste management measures (refer to Volume 3 Chapter 16)
- Installing triple interceptor pits or similar to collect runoff from maintenance and refuelling areas
- Installing tanks above ground, unless there is a risk of damage, and having bunds around tanks
- During decommission works, minimising the risk of fuel and chemical spills by emptying structures prior to dismantling
- Following chemical and fuel store area decommissioning and rehabilitation, conduct a visual inspection and contamination testing to confirm contaminated soil has been removed
- Where waste has been stored on the ground, removing contaminated soil and testing the site to confirm all contamination has been removed

- In the event of a fire, removing contaminated material and soil, followed up with appropriate testing
- Keeping maintenance records and implementing monitoring checks for leaks for all plant used on the gas pipeline
- Ensuring spill kits are readily accessible and the workforce is trained to use them
- Carrying out works in accordance with the environmental management plan
- Assessing hydrotest water before use and subsequent release to ensure it meets local surface water discharge criteria.

Volume 3 Chapter 12 and Volume 3 Chapter 16 provide further detail on water and waste management respectively, while the Volume 3 Chapter 24 describes environmental management strategies.

5.6 Conclusion

5.6.1 Assessment outcomes

The assessment outcomes for geomorphology, geology, soils and land contamination related to the gas pipeline study area are summarised in Table 5.10.

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

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

Environmental values	Sustainability principles	Potential impact	Project phase affected	Possible causes	Mitigation and management measures	Residual risk level
Existing finite resources to be sourced for construction material	Minimising adverse environmental impacts and enhancing environmental benefits associated with Australia Pacific LNG's activities, products or services; conserving, protecting, and enhancing where the opportunity exists, the biodiversity values and water resources in its operational areas. Using resources efficiently, reducing the intensity of materials used and implementing programs for the reduction and re-use of waste. Identifying, assessing, managing, monitoring and reviewing risks to Australia Pacific LNG's workforce, its property, the environment and the communities affected by its activities.	Alteration of topography, drainage, leaching of chemical / minerals, removal of vegetation, changes to road use and changed dust, noise and vibration levels.	Construction	Demand on local resources for gas pipeline 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. Re-use materials onsite where practicable. Mobile crushers may be used to minimise need for quarry materials from external sources Undertake progressive construction. Maintain private and public road conditions.	Low

Environmental values	Sustainability principles	Potential impact	Project phase affected	Possible causes	Mitigation and management measures	Residual risk level
					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.	
Existing landform character and stability		Changed topography Change to drainage Visual amenity Waterway bank instability Destabilisation of soils Loss of GQAL Degraded downstream water quality	Construction Commissioning Operation Decommissioning	Landform modification through stormwater diversion, vegetation clearing, earthworks and establishment of quarries.	A sediment and erosion control plan will be implemented. Runoff will be managed to minimise concentrated flows and sediment runoff. Set formation levels. Construction materials will be re-used where practicable. Compaction of fill will be controlled to minimise soil mounding or settlement. Structures will be sited on relatively level sites where possible. A geotechnical slope analysis will be undertaken. Detailed design of creek crossings will incorporate works and measures to minimise risk of damage to creek banks.	low

Environmental values	Sustainability principles	Potential impact	Project phase affected	Possible causes	Mitigation and management measures	Residual risk level
Existing soil resource, including values for agricultural productivity Minimise soil salinity Soil resource Land capability		Loss of topsoil quality and quantity.	Construction Commissioning	Incorrect stripping, prolonged exposure and erosion. Soil inversion (replacement of topsoils with subsoils). Poor rehabilitation and drainage management.	Site-specific topsoils assessments will be undertaken if necessary. Site clearance will be co-ordinated with landholders. Progressive clearing and rehabilitation will be undertaken. Vegetation will be chipped and for use as a protective mulch layer to facilitate revegetation and minimise erosion. Nutrients/conditioner or suitable seed stock will be applied to topsoil stockpiles, if required. Stripped topsoils will be re-used in areas of similar soil types. Where this is not possible, topsoils will be stockpiled. Vegetation and soil groups will be stockpiled separately. Topsoil stockpiles should be limited to 2m in height to maintain fertility and vegetated if stockpiled for extended periods. Care will be exercised when stripping topsoil to minimise mixing soil types.	Low

Environmental values	Sustainability principles	Potential impact	Project phase affected	Possible causes	Mitigation and management measures	Residual risk level
					Remove rocky material will be removed during stripping where practicable. Sediment and erosion control plan will be implemented. Appropriate stockpile spacing will be implemented. Monitoring and weed control will be undertaken.	
		Increased salinity leading to poor rehabilitation and corrosion of civil structures.	Construction Commissioning	Poor soil handling (removal, stockpiling and respreading) leading to soil inversion. Blending of non-saline and highly saline soils Erosion Inadequate monitoring of rehabilitation.	A geotechnical investigation will be undertaken to assess corrosion protection requirements within saline subsoils. Saline subsoils, where encountered, will be replaced at depth and covered with topsoil. In areas where there is little topsoil or there is evidence of existing salinisation, topsoil will be imported where practicable. There will also be progressive rehabilitation and stockpiling of soils near the site of excavation to minimise potential blending between non-saline and highly saline soils.	Low

Environmental values	Sustainability principles	Potential impact	Project phase affected	Possible causes	Mitigation and management measures	Residual risk level
					Disposal of saline water will meet the requirements identified in Volume 3 Chapter 12 which covers associated water management.	
		Soil erosion – soil destabilisation. Decrease in soil productivity and associated agricultural value Undermining of structures (roads, buildings, fencing) where soil has been wash away through runoff Stream bank erosion Sedimentation of downstream areas Decline in fertility Poor rehabilitation and drainage management	Construction Commissioning	Vegetation clearing Poor drainage management Concentrated flow discharge (i.e. hydrotest water discharge) Improper sediment and erosion controls Inadequate earthworks contractor training and supervision	A sediment and erosion control plan which includes redirection and management of runoff to minimise concentrated flows will be developed and implemented. Sediment fences and/or sediment detention structures will be constructed on the downhill side of excavated areas and around stockpiles. Regular inspection of sediment and erosion control measures and areas receiving concentrated flows will be undertaken. Contour banks will be installed at appropriate intervals. Progressive clearing and rehabilitation and creation of stable slopes will be undertaken.	Medium

Environmental values	Sustainability principles	Potential impact	Project phase affected	Possible causes	Mitigation and management measures	Residual risk level
					Erosive/dispersive areas which are exposed for extended periods will be stabilised. Sediment and erosion control devices will be installed prior to construction and retained until the area is stabilised. Access tracks will 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. Determination of suitable discharge locations in conjunction with landowners and relevant Federal, State or Regional authorities will be undertaken.	

Environmental values	Sustainability principles	Potential impact	Project phase affected	Possible causes	Mitigation and management measures	Residual risk level
					Where practicable, construction through creeks will be carried out when dry. Existing water will be dammed or diverted around construction. Pipe trench will be excavated perpendicular to direction of water flow and backfilled carefully. Creek rehabilitation will be consistent with surrounding environment and contours of the channel at the time of construction and protected with fencing where required. Point discharge will be into stable waterways and / or drainage lines and implement engineering controls such as scour protection and flow velocity limits implemented. Routine (and following severe rain events) inspection of waterway crossings will be conducted.	
		Loss of agricultural production (reduced cropping area) Interference with	Construction Commissioning Operation	Construction of the gas pipeline	Where practicable, the gas pipeline will be sited to minimise impacts on good quality agricultural land.	Medium

Environmental values	Sustainability principles	Potential impact	Project phase affected	Possible causes	Mitigation and management measures	Residual risk level
		overland flow through the modification of run-off controls Increase in soil compaction through heavy trafficking that reduces water infiltration Decrease in fertility Increase in erosion Disruption to timing of farming operations and restriction on land use.			The pipeline will be buried at an appropriate depth to allow agricultural uses to be undertaken. Appropriate topsoil and drainage management will be undertaken. Wastes will be removed as per regulatory requirements (refer to Volume 3 Chapter 16) Where practicable, rehabilitate disturbed areas equal to vegetation types consistent with the surrounding environment.	
Water and aquatic wildlife quality		Soil acidification - Oxidisation of PASS Degradation of environment and new civil structures from acidic run-off. Unstable excavation.	Construction	Excavation and / or filling of soil group 6 (Holocene miscellaneous unconsolidated sediments).	A suitable geotechnical investigation will be undertaken pre-construction to assess appropriate design and construction techniques. A detailed ASS investigation will be undertaken and an ASS management plan developed.	Low
Existing qualities of the air environment,		Degradation of soil structure and dust generation	Construction	Clearing of vegetation and increased traffic.	Appropriate onsite traffic routes will be assessed.	Low

Environmental values	Sustainability principles	Potential impact	Project phase affected	Possible causes	Mitigation and management measures	Residual risk level
including the life, health and wellbeing of the community					Onsite access roads will be surfaced with gravel and/or geotextile or surface additives. Water will be applied where required. Vegetation and topsoil will be removed where new tracks are required. Revegetation will be carried out as soon as practicable.	
Existing condition of soil and water resources		Contamination of soil and potentially groundwater.	Construction	Pre-existing contamination.	Where possible, avoid contaminated areas by relocating infrastructure. Prior to construction phase, conduct detailed investigations of all identified areas of potential contamination as per the former Department of Environment (now DERM) draft guidelines. If disturbance of contaminated area is unavoidable, remediate and/or manage site contamination in accordance with regulatory requirements. Conduct pre-construction surveillance of land to identify potential contamination where practicable.	Low

Environmental values	Sustainability principles	Potential impact	Project phase affected	Possible causes	Mitigation and management measures	Residual risk level
					Surveillance to be performed by suitably trained and qualified person. If unexpected contamination is identified, stop work, investigate the nature of the contamination and determine remedial or site management actions. DERM notification of any notifiable activities or contamination from hazardous contaminants that are identified on land managed by Australia Pacific LNG, in accordance with Section 371 of EP Act	
Existing condition of soil and water resources		Contamination of soil and potentially groundwater.	All phases.	Chemical and fuel leaks/spills from tanks, compressors, storage areas. Spills and leaks from refuelling of plant and vehicles. Pipes and tank failures resulting in loss of chemicals, fuel, lubricating oils, waste oils	Conduct maintenance inspections of plant, equipment and vehicles Implement control measures to prevent spills during construction, commissioning, operations and decommissioning Chemical and fuel stores will be established in accordance with relevant standards and including bunding. Construction, commissioning and operation inductions will include spill kit awareness information.	Low

Environmental values	Sustainability principles	Potential impact	Project phase affected	Possible causes	Mitigation and management measures	Residual risk level
				Fires within temporary accommodation facilities and construction areas.	If chemical and fuel stores are removed, investigate area for residual contamination. Where appropriate remediate or manage contamination in accordance with relevant legislation and guidelines, This work must be performed under the supervision of a suitably qualified person as per Section 381 of the EP Act and be in accordance with DoE draft guidelines. Management of associated water (refer to Volume 3 Chapter 11) In the event of fire, identified contamination will be assessed and where appropriate remediated or managed in accordance with relevant legislation and guidelines,	
Existing condition of soil and water resources		Contamination of soil and potentially groundwater.	All phases.	Dangerous goods management	Dangerous goods management in compliance with: • *Dangerous Goods Safety Management Act 2001* • AS3833 Storage and Handling of Mixed Classes of Dangerous Goods in Packages and Intermediate Bulk Containers	Low

Environmental values	Sustainability principles	Potential impact	Project phase affected	Possible causes	Mitigation and management measures	Residual risk level
					• AS3833 Storage and Handling of Corrosive Substances • Materials Safety Data Sheets (MSDS) for all chemicals being stored Follow Australia Pacific LNG's chemical storage and handling procedures.	
Existing condition of soil and water resources		Contamination of soil and potentially groundwater.	All Phases	Discharge of hydrotest water.	Hydrotest water will be assessed for surface water discharge criteria prior to release.	Low
Existing condition of soil and water resources		Contamination of soil and potentially groundwater.	All phases.	Putrescible waste could cause soil and groundwater contamination.	Develop waste management guidelines. No waste dumps onsite. Composting and recycling implemented to minimise waste, if feasible. Composting and materials for recycling to be stored in containers or temporarily lined storages, as for putrescibles and leachable waste. All putrescibles and leachable waste (which is not recycled) will be stored	Low

Environmental values	Sustainability principles	Potential impact	Project phase affected	Possible causes	Mitigation and management measures	Residual risk level
					in impermeable containers (e.g. skips). Run-off will be diverted around the area. Identified contamination will be assessed and where appropriate remediated or managed in accordance with relevant legislation and guidelines.	
Soil and groundwater quality		Contamination of soil and potentially groundwater.	All phases.	Excessive use of herbicides for weed control.	Screening of suitable weed management subcontractors and rigorous assessment Undertake audits of herbicide use and storage to confirm adherence with agreed protocols Where contamination has been identified, investigate and where appropriate remediate or manage in accordance with relevant legislation and guidelines	Low
Soil and groundwater quality		Contamination of soil and groundwater during removal of plant, equipment and infrastructure.	Operations and decommissioning.	Removal of plant, equipment and infrastructure.	Contaminated land identified during the removal of plant, equipment and infrastructure will be assessed and where practicable managed or remediated in accordance with relevant guidelines at that time	Low

Environmental values	Sustainability principles	Potential impact	Project phase affected	Possible causes	Mitigation and management measures	Residual risk level
					A detailed risk assessment will be undertaken as part of the preparation works. This will identify areas requiring additional controls/measures to minimise soil erosion, sediment discharge and dust generation, and potential off-site impacts that may occur as a result of earthworks	

5.6.2 Commitments

Australia Pacific LNG commits to the following for the construction, operation, and decommissioning of the Project within the gas pipeline corridor:

- Minimise erosion risk by refining construction techniques, and erosion and sediment control methods
- Creek rehabilitation will be consistent with surrounding environment and contours of the channel at the time of construction
- Direct point discharges to stable waterways and/or drainage lines with appropriate engineering controls, such as scour protection and flow velocity limits
- Complete an ASS investigation and develop an ASS management plan in accordance with relevant Queensland guidelines
- Develop and implement procedures and monitoring programs to identify, investigate and conduct necessary remedial works for potential site contamination to retain environmental values..

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Figures

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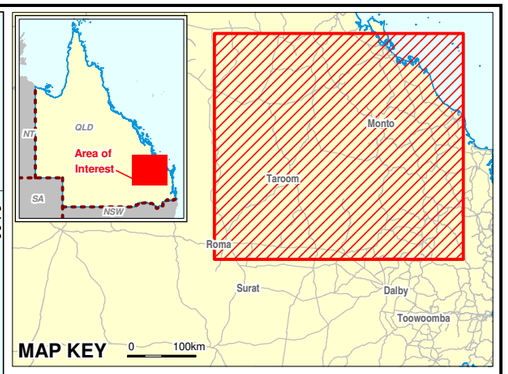
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Roma
Miles
Wandoan
Eidsvold
Chinchilla

Dawson Hwy
Fitzroy Dev Road
Dawson Highway
Theodore Road
Leichhardt Hwy
Roma - Taroom Road
Warrego Highway
Kilcoy - Murgon Road

Mimosa Ck
Planet Ck
Dawson R
Banana Ck
Kianga Ck
Callide Ck
Boyne R
Zamia Ck
Lonesome Ck
Clematis Ck
Nogoa R
Palm Tree Ck
Robinson Ck
Cockatoo Ck
St John Ck
Auburn R
Injune Ck
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Tchanning Ck
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Grant Ck
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SWL2A
EROS005
SWL2B
SWL4A
EROS007
SWL1A
WWL1
WWL2
SWL3A
EROS006
WWL3



LEGEND

- Observation location
- Major drainage
- Railway
- Road

Proposed Infrastructure

- KP010 Kilometre point
- Gas pipeline route
- Study area
- Common infrastructure corridor (CIC)
- Gladstone state development area (GSDA)

Source Information

Observation locations
Created by WorleyParsons 2009

Preferred pipeline alignment
Supplied by Origin Energy November 2009

Common infrastructure corridor and Gladstone state development area
Derived from data supplied by Origin Energy October 2009

0 20 40km
SCALE - 1 : 1,250,000 (at A3)
Latitude/Longitude
Geocentric Datum of Australia 1994
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AUSTRALIA PACIFIC LNG PROJECT

Volume 3 Chapter 5
Figure 5.1 - Overview of study area and observation locations

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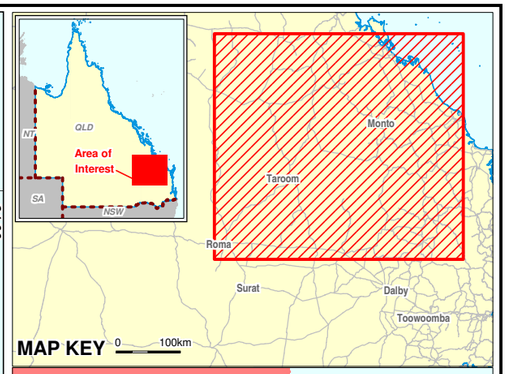
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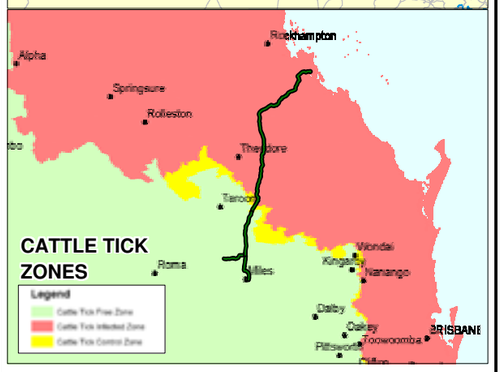
149.00 149.50 150.00 150.50 151.00 151.50 152.00

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Site 6
Gladstone
Site 5
Calliope
Dawson Hwy
Miriam Vale
Biloela
Moura
Site 4
Possible waste dump and cattle dip or spray race
Site 3
Monto
Bundaberg
Theodore
Site 2
Eidsvold
Theodore Road
Mundubbera
Gayndah
Biggenden
Taroom
Wandoan
Murgon
Kingaroy
Site 1
Roma
Warrego Highway
Miles
Chinchilla

Mimosa Ck, Planet Ck, Fitzroy Dev Road, Dawson R, Banana Ck, Kianga Ck, Callide Ck, Callide R, Boyne R, Dawson Highway, Zamia Ck, Lonesome Ck, Clematis Ck, Nogoa R, Palm Tree Ck, Leichhardt Hwy, Robinson Ck, Cockatoo Ck, St John Ck, Auburn R, Injune Ck, Eurombah Ck, Grant Ck, Juandah Ck, Charleys Ck, Dogwood Ck, Roma - Taroom Road, Burgill Ck, Blyth Ck, Tchanning Ck, Kilcoy - Murgon Road, Yuleba Ck





LEGEND

- Major drainage
- Reservoir
- Road
- Railway

Proposed Infrastructure

- KP010 Kilometre point
- Gas pipeline route
- Study area
- Common infrastructure corridor (CIC)
- Gladstone state development area (GSDA)

Investigation areas

- Cattle yard and possible cattle dip or spray race
- Possible waste dump

Source Information

Cadastre and easements
Department of Natural Resources and Water, Queensland 2009

Cattle yards and possible cattle dip or spray race
Created by WorleyParsons based upon Google Earth satellite imagery 2009

Properties of interest
Created by WorleyParsons based upon Google Earth satellite imagery 2009

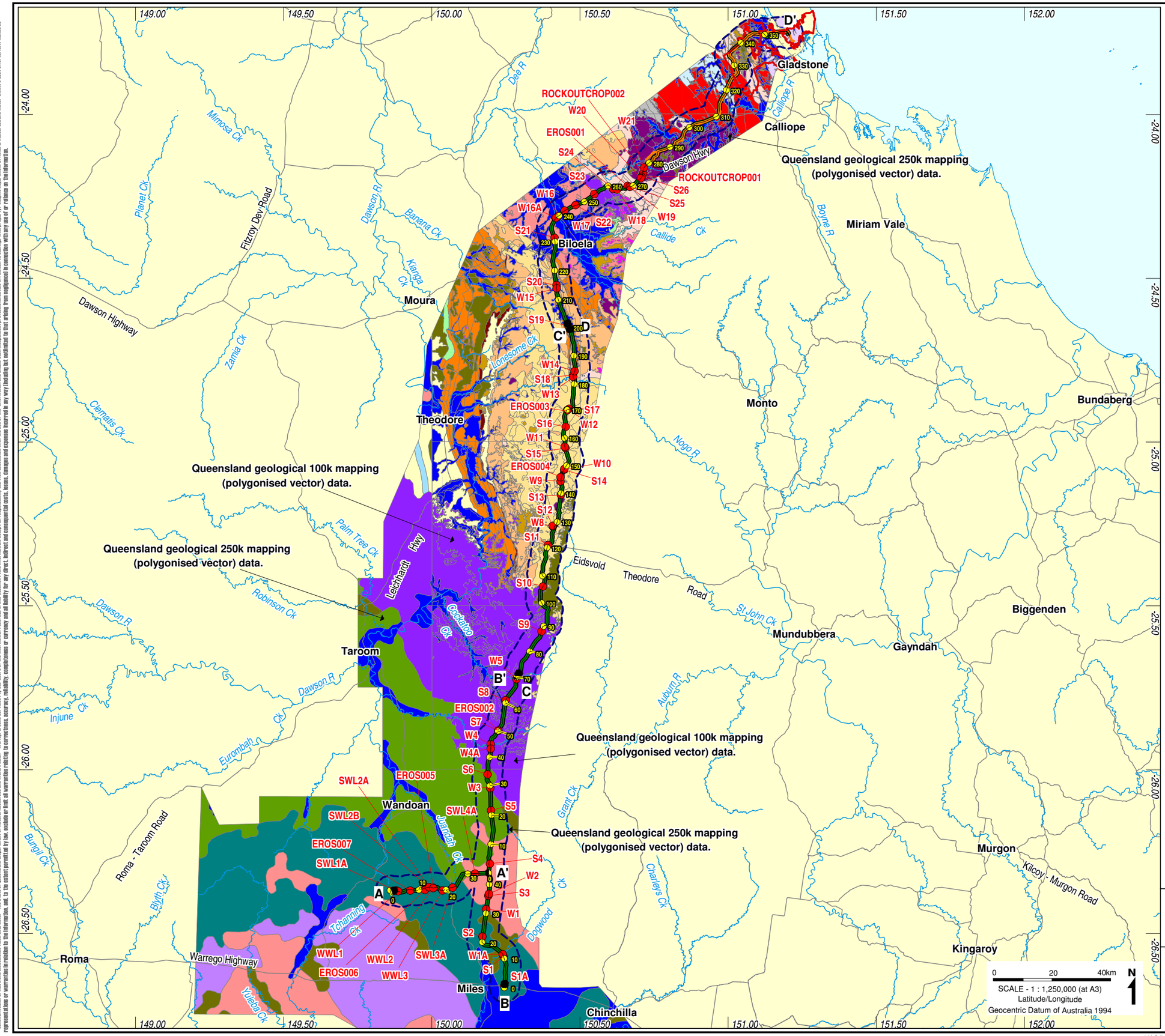
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Latitude/Longitude
Geocentric Datum of Australia 1994
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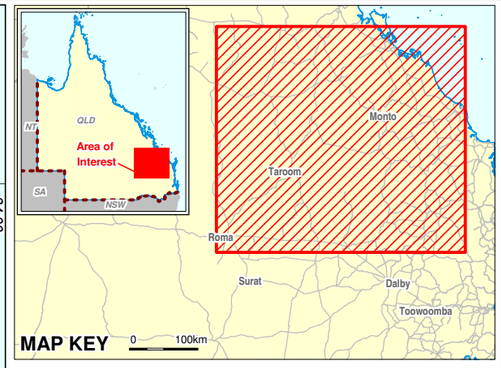
AUSTRALIA PACIFIC LNG PROJECT

Volume 3 Chapter 5
Figure 5.2 - Identified Areas of Potential Contamination

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LEGEND

- Observation location
- Major drainage
- A — A' Cross-section
- Road
- Railway

Proposed Infrastructure

- KP010 Kilometre point
- Gas pipeline route
- Study area
- Common infrastructure corridor (CIC)
- Gladstone state development area (GSDA)

Geology

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

A full description of geology is provided in Table 5.1.

Source Information

Geology

Geology is a combination of Queensland geological 100k mapping (polygonised vector) data (Department of Mines and Energy 2007) and Queensland geological 250k mapping (polygonised vector) data. (Department of Natural Resources, Mines and Energy 2004).

Cross section profiles

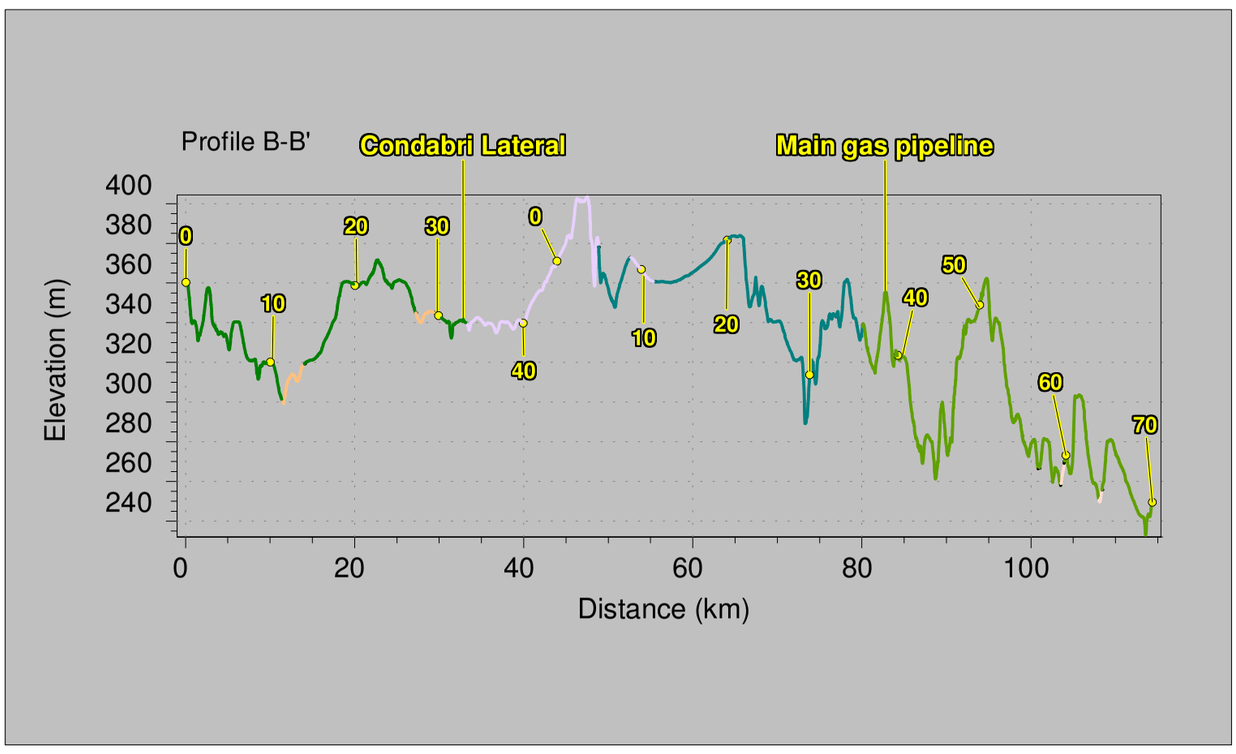
Created by WorleyParsons December 2009 from Geology layers (see above) and 25m DEM (Queensland Department of Natural Resources Mines and Water 2007).

AUSTRALIA PACIFIC LNG PROJECT

Volume 3 Chapter 5
Figure 5.3 - Overview of study area geology and cross section profile locations

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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	

Source Information

Soil types

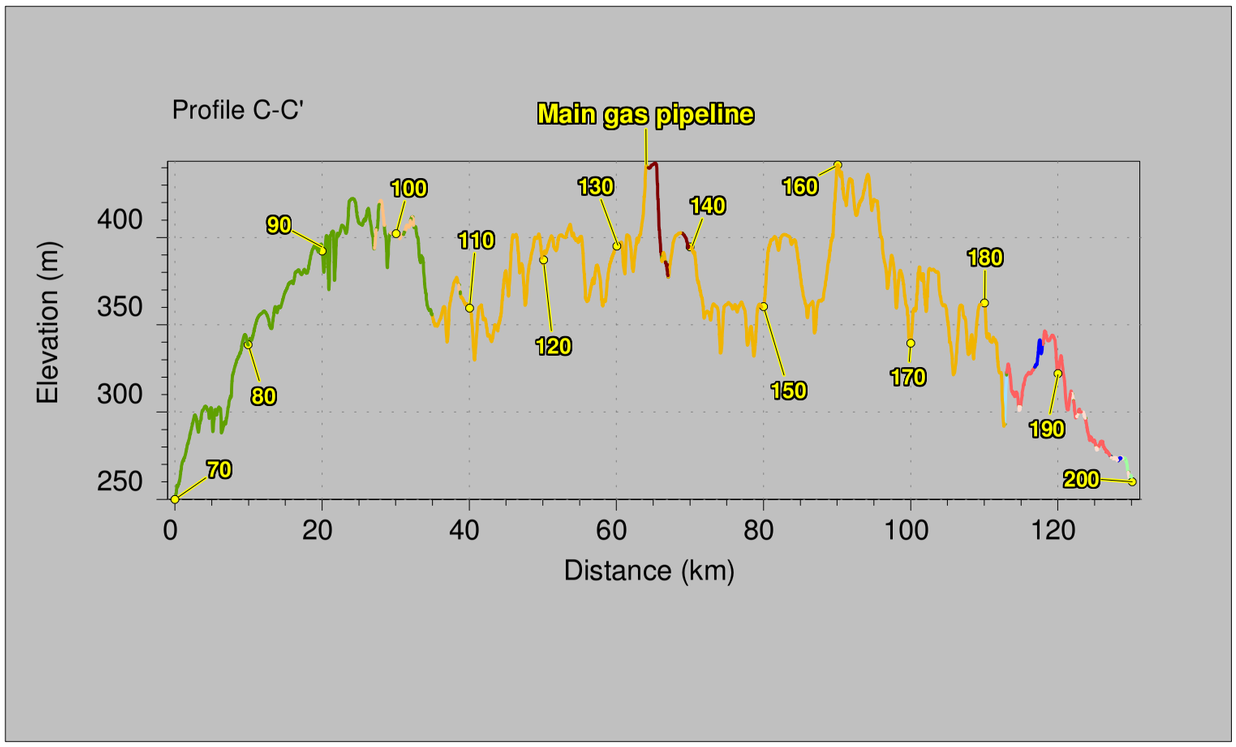
Soil groupings/types combined and interpreted from Land Resource Data (Queensland Department of Natural Resources and Water 2008) by WorleyParsons October 2009.

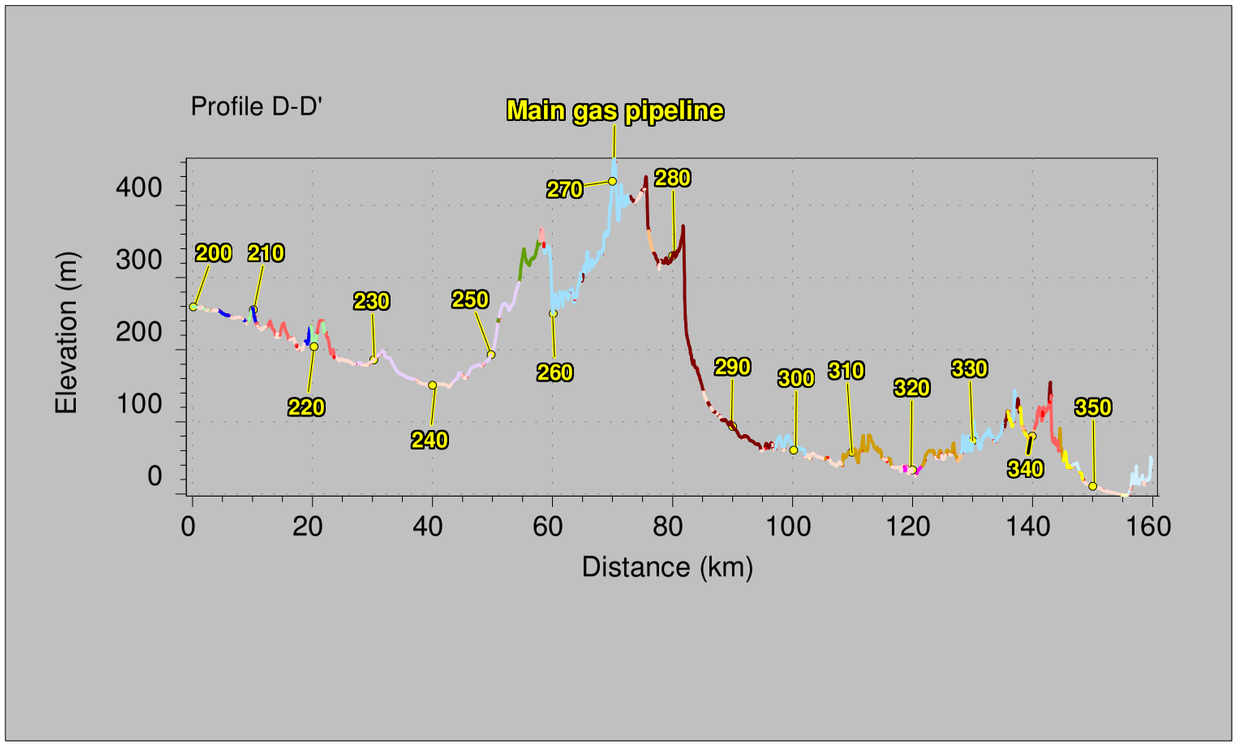
AUSTRALIA PACIFIC LNG PROJECT

Volume 3 Chapter 5
Figure 5.4 Study area geological cross sections - Map 1 of 2

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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	

Source Information

Soil types

Soil groupings/types combined and interpreted from Land Resource Data (Queensland Department of Natural Resources and Water 2008) by WorleyParsons October 2009.

AUSTRALIA PACIFIC LNG

AUSTRALIA PACIFIC LNG PROJECT

Volume 3 Chapter 5
Figure 5.4 Study area geological cross sections - Map 2 of 2

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Tectonics

- Bowen Basin
- Clarence-Moreton Basin
- Connors-Auburn Province
- Gogango Overfolded Zone
- Gympire Province
- Maryborough Basin
- Surat Basin
- Tarong Basin
- Texas Province (Block)
- Wandilla Province
- Yarrol Province

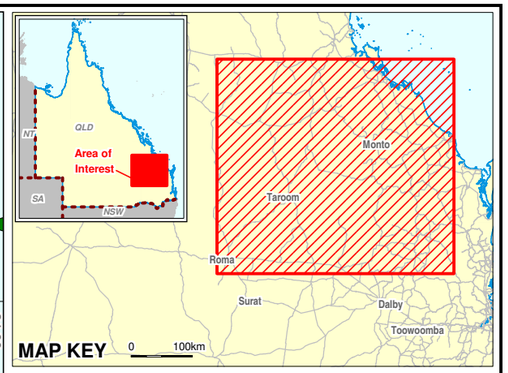
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24.00 25.00 26.00 27.00

BOWEN BASIN
SURAT BASIN
CLARENCE-MORETON BASIN
CONNORS-AUBURN PROVINCE
GOGANGO OVERFOLDED ZONE
YARROL PROVINCE
WANDILLA PROVINCE
MARYBOROUGH BASIN
GYMPIE PROVINCE
TARONG BASIN

Yarrol Fault
Ambrose Fault
Bracewell Fault
Queenslander Fault
Alma Syncline
Harper Fault
Rhyolite Dyke or Vein
Andersite Dyke or Vein
Rhyolite Dyke or Vein
Grevillea Thurst Fault
Rannes Thurst Fault
Fergusson Syncline
Banana Thurst Fault
East End Anticline
Grevillea Thurst Fault
Prospect Creek Anticline
Mimosa Syncline

KP 0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280 290 300 310 320 330 340 350



LEGEND

- Earthquake magnitude > 2
- Earthquake magnitude > 3
- Earthquake magnitude > 4
- Earthquake magnitude > 5
- Faults accurate
- Faults approximate / concealed / inferred
- Anticlines accurate
- Anticlines approximate / concealed / inferred
- Synclines accurate
- Synclines approximate / concealed / inferred
- Dykes or veins

Proposed Infrastructure

- KP010 Kilometre point
- Gas pipeline route
- Pipeline study area

Source Information

Preferred pipeline alignment
Supplied by Origin Energy November 2009
Tectonics
Data downloaded from the interactive Resource and Tenure Maps website of the Queensland Department of Mines and Energy
Earthquake data
Data downloaded from the U.S. Geological Survey website

0 25 50km
SCALE - 1 : 1,500,000 (at A3)
Latitude/Longitude
Geocentric Datum of Australia 1994
N

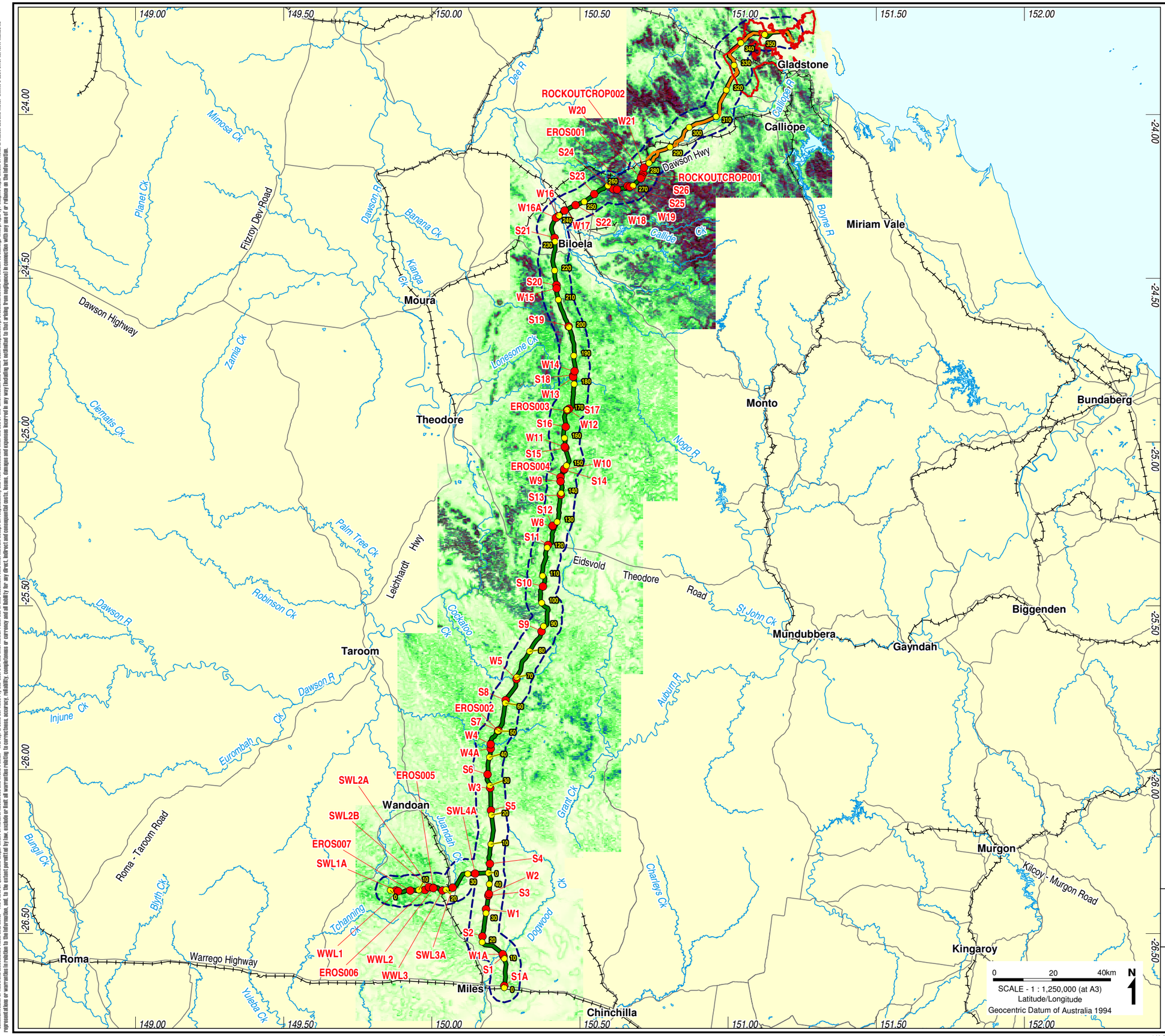
AUSTRALIA PACIFIC LNG PROJECT

Volume 3 Chapter 5
Figure 5.5 - Historical earthquakes 1958 onwards and tectonic boundaries

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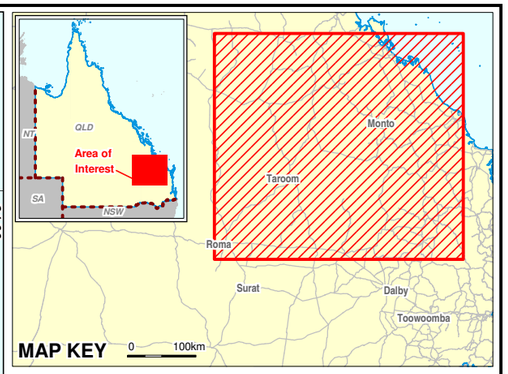
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Calliope
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Moura
Theodore
Monto
Bundaberg
Taroom
Mundubbera
Gayndah
Biggenden
Wandoan
Murgon
Roma
Miles
Kingaroy
Chinchilla

Dawson Hwy
Dawson Highway
Fitzroy Dev Road
Roma - Taroom Road
Warrego Highway
Leichhardt Hwy
Theodore Road
Eidsvold
Kilcoy - Murgon Road

Dee R
Mimosa Ck
Planet Ck
Dawson R
Banana Ck
Kianga Ck
Callide Ck
Boyne R
Calliope R
Lonesome Ck
Zamia Ck
Clematis Ck
Palm Tree Ck
Robinson Ck
Cockatoo Ck
Injune Ck
Eurombah Ck
Blyth Ck
Burgill Ck
Juandah Ck
Tchanning Ck
Dogwood Ck
Charleys Ck
Grant Ck
Auburn R
St John Ck
Nogoa R
Yuleba Ck

ROCKOUTCROP002
W20
W21
EROS001
S24
S23
ROCKOUTCROP001
S26
S25
W16
W16A
W19
W18
W17
S22
S21
W15
S20
S19
W14
S18
W13
EROS003
S17
W12
S16
W11
S15
EROS004
W10
W9
S14
S13
S12
W8
S11
S10
S9
W5
S8
EROS002
S7
W4
W4A
S6
W3
S5
SWL4A
S4
W2
S3
W1
S2
W1A
S1
S1A
SWL2A
EROS005
SWL2B
EROS007
SWL1A
WWL1
WWL2
SWL3A
EROS006
WWL3

340 330 320 310 300 290 280 270 260 250 240 230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0



LEGEND

- Observation location
- Major drainage
- Reservoir
- Road
- Railway

Proposed Infrastructure

- KP010 Kilometre point
- Gas pipeline route
- Study area
- Common infrastructure corridor (CIC)
- Gladstone state development area (GSDA)

Landform

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

Source Information

Landform

Landforms combined and interpreted from Land Resource Data (Queensland Department of Natural Resources and Water 2008) by WorleyParsons December 2009.

0 20 40km

SCALE - 1 : 1,250,000 (at A3)
Latitude/Longitude
Geocentric Datum of Australia 1994

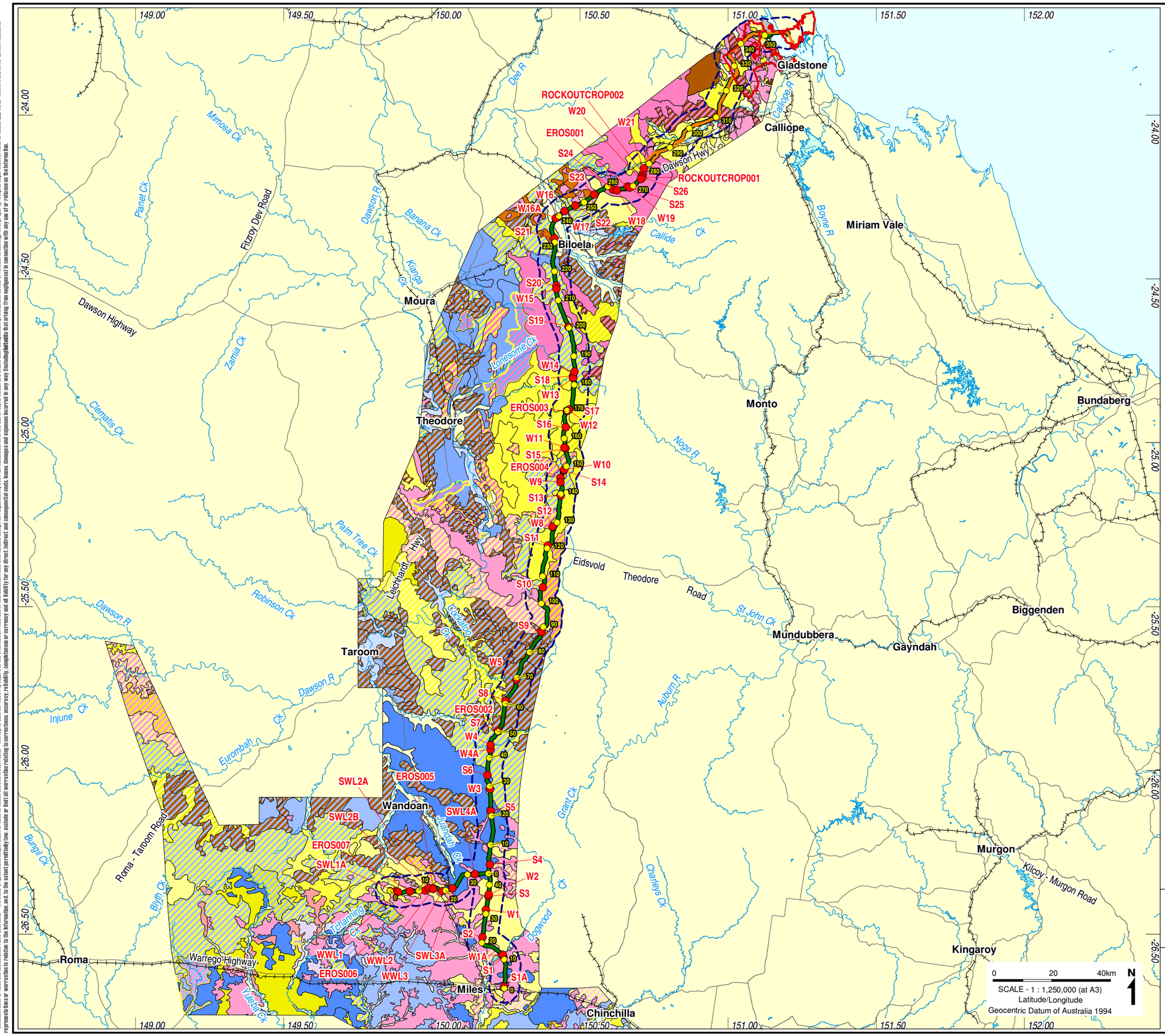
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AUSTRALIA PACIFIC LNG PROJECT

Volume 3 Chapter 5
Figure 5.7 - Overview of study area landform

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Source Information

Soil types

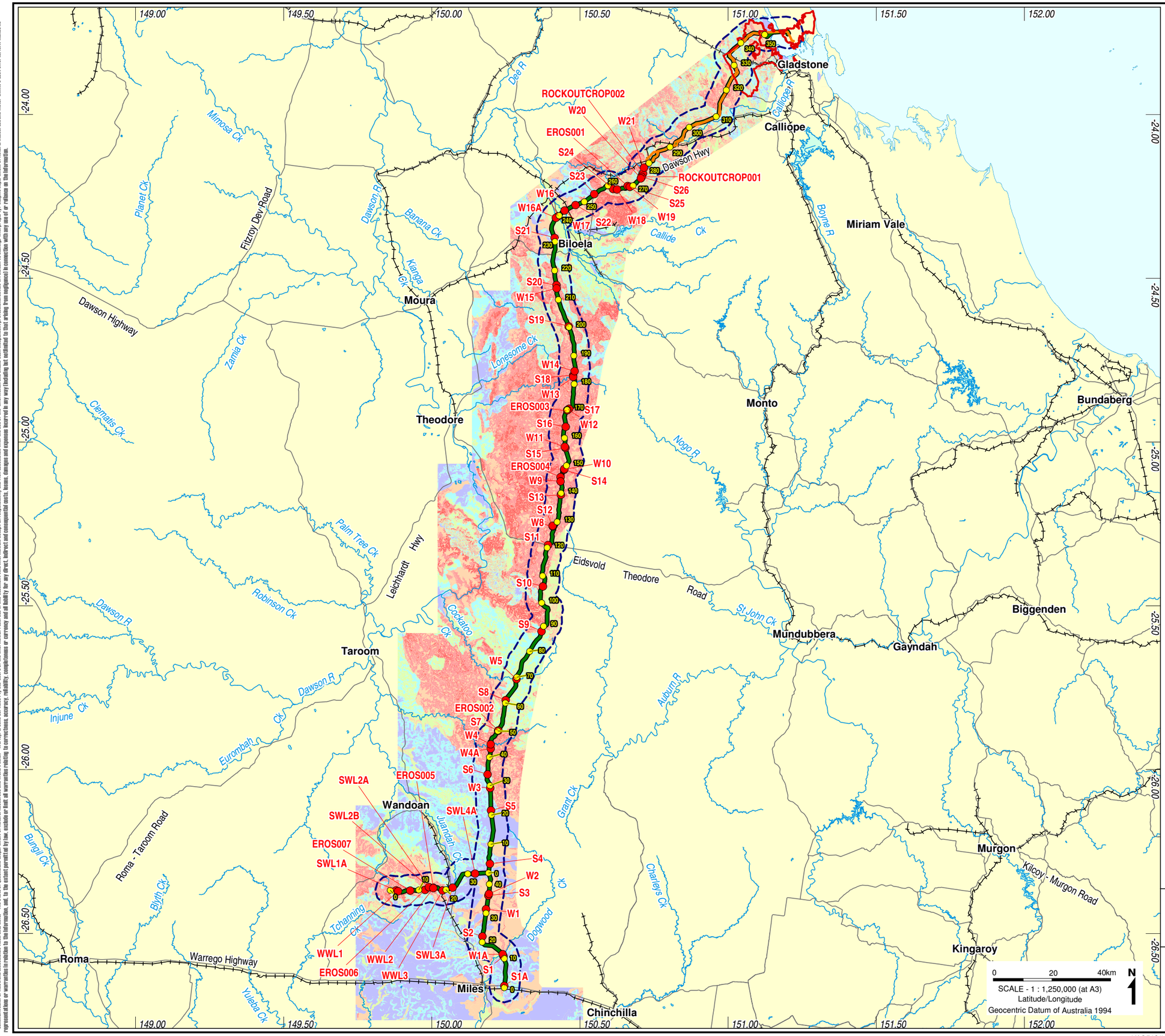
Soil groupings/types combined and interpreted from Land Resource Data (Queensland Department of Natural Resources and Water 2008) by WorleyParsons October 2009.

AUSTRALIA PACIFIC LNG PROJECT

Volume 3 Chapter 5
Figure 5.8 - Overview of study area soil types

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Volume 3 Chapter 5
Figure 5.9 - Overview of study area erosion hazard

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