Australia Pacific LNG Project

Volume 2: Gas Fields

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

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1.1 Introduction

1.1.1 Purpose

This chapter provides the assessment of the land within the Australia Pacific LNG Project (the Project) gas fields study area, which has been conducted in accordance with the terms of reference for this environmental impact statement (EIS). 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.

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

- Volume 5 Attachment 5 – Geology Topography Geomorphology and Soils Assessment
- Volume 5 Attachment 8 – Preliminary Site Investigation – Contaminated Land.

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

Figure 5.1 shows the locations of the gas fields study area, terrain observations and intrusive soil sampling. Laboratory testing was completed on soil samples retrieved from the field investigation.

In preparation of this chapter, Australia Pacific LNG's sustainability principles have been applied to the planning, design, construction and operation of the gas fields, to ensure that construction of the gas fields 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 fields 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.

By adhering to these principals throughout the preparation of this chapter, mitigation measures were developed in a number of ways to ensure no environmental harm or loss of beneficial land use or visual amenity will occur. 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.

Where land is disturbed, active rehabilitation will occur 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 course 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 on-site 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 on-site rock as a 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 requirements 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.

1.1.2 Scope of work

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

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

1.1.3 Legislative framework

The assessment of land within the context of the gas fields study area is governed by a number of Acts, standards, guidance documents and planning policies. These include:

- *Environmental Protection Act 1994 (*EP Act)
- Environmental Protection Regulation 2008
- Environmental Protection (Waste Management) Regulations 2000
- Environmental Protection (Water) Policy 2009
- *Land Protection (Pest and Stock Route Management) Act 2002*
- National Environment Protection (Assessment of Site Contamination) Measure 1999
- *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 Agricultural Land.

1.2 Methodology

1.2.1 Geology, topography, geomorphology and soils

The existing condition of the geology, topography and geomorphology and soil type 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 and land system reports. These are cited within the geology, topography, geomorphology and soils technical report presented in Volume 5 Attachment 5.

This information was supplemented with site observation of soils and waterways, and soil sampling at selected locations. The site observations comprised of terrain assessments, including: terrain type, slope, watercourses and existing condition at 58 locations within the gas fields study area.

Shallow boreholes (0.2-1.0m below ground level) were manually drilled using a hand-held auger, to investigate the soil type and condition also to obtain samples for laboratory analysis of physical and agronomic parameters. This was undertaken at 39 of these locations. Soil sampling and observation locations are shown in Figure 5.1.

The 39 soil observation locations focused on those areas required for potential gas processing facilities. The 19 waterway observation locations were selected based upon the proximity of proposed water treatment facilities, water transfer stations and gas treatment facilities to waterways. This methodology and sampling intensity of approximately one location (observation) every 1044ha (of 40,717ha construction footprint) was considered adequate for the representation of terrain and soils within the gas fields study area (in conjunction with existing published land suitability information). The former Queensland Department of Minerals and Energy's Technical Guidelines for Environmental Management of Exploration and Mining in Queensland (1995) recommends a detailed observation density of 0.04 per km^2 of survey area based on a mapping scale of 1:250000 (as provided in this report). The 39 soil sampling locations described in detail in this report exceed the recommended number of 17, based on a gas field disturbance area of 40,717ha.

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

1.2.2 Contaminated land

A preliminary site investigation (PSI) was carried out using desktop based investigations. The desktop assessment focused on parcels of land where major land disturbances are proposed. This is because disturbance of existing contaminated land presents the greatest risk of project activities affecting the environment and human health.

The major land disturbances considered were the brine ponds, water treatment facilities, water pump stations and gas processing facilities. From the 1,000+ lots located within the gas field area, 60 lots are likely to be affected by the proposed major infrastructure facilities. These 60 lots and the proposed locations of these facilities are identified on Figure 5.2.

The desktop assessment was completed using:

- Recorded notifiable activities as listed in Schedule 3 of the EP Act and land which is listed within Queensland's Environmental Management Register or Queensland's Contaminated Land Register
- Interviews with landholders carried out by Australia Pacific LNG staff. Details about notifiable activities such as fuel storage and use of cattle dips and spray races were sought, but information supplied was limited
- Interviews with the following local council representatives and historians to determine how land uses within the general region of the gas fields had changed over time:
  - Chinchilla Museum
  - Dalby Family History Society Inc.
  - Western Downs Regional Council (Miles)
  - Toowoomba Regional Council
  - Private Historian located in Wandoan
- Data relating to cattle tick-free and non-free zones located within the gas fields, from the Department of Employment Economic Development and Innovation (DEEDI). Interviews with DEEDI inspectors were also carried out
- Site inspections conducted as part of other field studies being conducted for the EIS.
- Historical aerial photographs
- Current aerial photography (2009)
- Satellite imagery from 2007-2008 Google Earth.

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
- Former Department of Environment's Draft Guidelines for the Assessment and Management of Contaminated Land in Queensland, dated May 1998

1.3 Existing environment

1.3.1 Geology

Regional Geology

With reference to maps produced by the Geological Survey of Queensland, the study area is underlain with soils and rocks associated with the Bowen and Surat Basins.

Bowen Basin

The Bowen Basin covers an area of approximately 160,000 square kilometres, extending in a north-south trending belt from the vicinity of Townsville, Queensland and southwards into central northern New South Wales.

To the east of the basin, early phases of deposition laid down fluvial (river) and lake-bed sediments and volcanics, 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 square kilometres, extending from the southern part of central southern Queensland to central northern NSW.

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. The basins have also accumulated numerous deposits of coal, hydrocarbons and associated gas. These sediments have subsequently been overlain in areas by tertiary and quaternary sediments.

Geology of the study area

A map showing the distribution of geological units across the study area and corresponding cross sections is presented as Figure 5.3 and Figure 5.4 respectively. Table 5.1 provides more details of the geology.

Table 5.1 Geological unit summary

Geological unit	Age	Lithology summary	Dominant rock	Map symbol
Late Cainozoic floodout and residual sand, soil and gravel	Cainozoic	Sand, soil and gravel	Miscellaneous unconsolidated sediments	Cz, Czg
Quaternary alluvium and lacustrine deposits	Quaternary	Sand, silt, mud and gravel	Alluvium	Qa, Qs, Qpc
Palaeocene-Oligocene sediments	Tertiary	Sandstone, mudstone, conglomerate	Sedimentary rock	Tl, T,Tpc
Tertiary volcanics, mainly basalt	Tertiary	Volcanics, mainly basalt	Basalt	Tb, Tmb

Geological unit	Age	Lithology summary	Dominant rock	Map symbol
Wallumbilla Formation	Early Cretaceous	Mudstone and siltstone with calcareous concretions	Mudstone	Kl, Klg, Kls, Kld, Klc
Bungil Formation, Gubberamunda Sandstone, Hooray Sandstone, Kumbarilla beds, Longsight Sandstone, Mooga Sandstone, Orallo Formation, Southlands Formation	Jurassic – Cretaceous	Glauconitic, labile to quartzose, siltstone, mudstone; sandstone, minor conglomerate, siltstone; coal	Arenite	JKk, Jug, Juo, Kly, Klm, Klk, Kln, Kli
Injune Creek Group, Mulgildie Coal Measures, Walloon Subgroup	Jurassic	Sandstone, siltstone, mudstone, coal, conglomerate	Sedimentary rock	Ji, Jw
Evergreen Formation, Hutton Sandstone, Marburg Formation (in part), Precipice Sandstone	Jurassic	Siltstone, mudstone, sandstone, oolitic ironstone, coal	Arenite-mudstone	Jlp, Jle, Jlh, Jlm
Texas Beds	Carboniferous	Greywacke, mudstone, slate, local phyllite; subordinate jasper, chert, conglomerate, limestone	Sedimentary rock	Clt

Structural geology

Structural geological features identified within the Bowen and Surat Basins consist of faults and folds, indicative of a regional compression towards west-south-west. Limited information is available regarding to the movement of the identified faults, but no active faults have been observed in recent times in Queensland.

Location and quality of CSG resource

Australia Pacific LNG has the largest portfolio of independently-certified coal seam gas reserves and resources in Australia. The gas fields cover an area of approximately 570,000 hectares, as shown in Figure 5.1.

In-situ gas quality will vary between the fields. The produced gas will predominantly be methane, with very low concentrations of nitrogen, carbon dioxide and ethane. At 30 June 2009, Australia Pacific LNG's reserves and resource position (in accordance with Society of Petroleum Engineers guidelines) included 7,265PJ of 2P reserves, 12,627PJ of 3P reserves and 15,869PJ of contingent resources. Further details on the project description are provided in Volume 2 Chapter 3.

Earthquakes

A map showing the location of earthquakes within Queensland is presented in Figure 5.5. This map indicates few recorded earthquakes have occurred within the gas fields study area.

Standards Australia have produced earthquake loading maps to provide engineers with design coefficients for earthquake risk, based upon a 10% probability of exceedance in 50 years. Using these maps, the hazard factor (Z), (equivalent to peak ground acceleration in ms^{-2}) for the gas fields study area varies between 0.04–0.07 ms^{-2}, depending on the location. A value of 0.05 indicates that in any 50-year period, there is a 10% chance that the peak ground acceleration will exceed 0.05 ms^{-2}.

Induced seismicity

Extraction or injection of material below ground has the potential to trigger small earthquakes. This phenomenon is known as induced seismicity.

In oil and gas extraction, small seismic events have been known to result from stress changes in the ground during and following removal of pore fluid, such as water or oil. Steps such as re-injecting water back into the ground can reduce the effects of induced seismicity.

Seismic events have been also been known to occur with large lagoon and dam construction due to the increased stress on the ground over a widespread area.

In terms of public risk, induced seismic events resulting from engineered activity are generally of low magnitude and of minimal consequence.

Extractive resources

In addition to the coal, hydrocarbon and gas resources existing within the depositional basins, the area contains a number of existing quarries that provide materials for construction, including gravel, sand and hard rock.

The quarries identified in the region within proximity to the gas field area are listed in Table 5.2. Many of these quarries may potentially be used as a source for construction material for the gas fields.

Table 5.2 Existing extractive industry operations

Quarry name	Operator	Status	Production rate(a)	Local authority (based on pre-2007 local authority boundaries)	Operation type	Descriptive locality
Blackswamp Pit	Chinchilla Shire Council	Operating	Low	Chinchilla	Hard rock	Cnr North Kogan/Warra Kogan Roads
Chandlers Quarry	Toowoomba Regional Council	Operating	Low	Millmerran	Hard rock	30km south of Millmerran, via Bringalily on Millmerran-Inglewood Road
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'
Jimbour	Western Downs Regional Council	Operating	High	Wambo	Hard rock	About 20km along Dalby/Bell (Bunya Highway) Road, on the left just after Jimbour Quarry Road turnoff
Juandah Creek	Richards Concrete	Suspended	-	Taroom	Sand	Juandah Creek
Lavelle Road	Toowoomba Regional Council	Operating	Low	Millmerran	Hard rock	
Newton's Quarry	GCM Mining Pty Ltd	Operating	Low	Wambo	Hard rock	
Warra-Kogan	Western Downs Regional Council	Operating	Low	Chinchilla	Hard rock	Warra - Kogan Road, Condamine South
Warrians	Boral Resources (Qld) Pty Ltd - Country	Operating	Low	Bungil	Hard rock	35km up Roma-Taroom Road
Yuleba	Yuleba Minerals Pty Ltd	Suspended	-	Bendemere	Sand, gravel	6km south Yuleba on Yuleba-Surat Road

Note: Extractive industry information obtained for the Australia Pacific LNG gas fields from the Department of Mines and Energy, QRock Database.
Low Production (<80,000tpa) Medium Production (80,000 – 200,000tpa) High Production (>200,000tpa).

1.3.2 Topography and geomorphology

A digital slope analysis of the study area was carried out (refer Figure 5.6). Landforms are presented on Figure 5.7. The topography across the study area is predominantly flat, with gentle undulations and rises. Some plateaus, low sandstone hills and lateritic scarps of a 10 to 20% slope are also found, especially in the north eastern areas of the tenements. There are also numerous broadly spaced water courses within the gas fields, which are discussed in Volume 2 Chapter 11. Field assessments of the topography have generally confirmed these features.

Using a classification system which splits the terrain into categories of low, medium and high, the majority of the observed areas are regarded as low. That is, they are flat and gently undulating terrain with slopes of less than 10% gradient and mostly shallow drainage channels.

Areas of medium terrain (i.e. areas with local relief up to 50m and with slopes between 11 to 32% gradient), were observed at isolated locations throughout the gas fields and mainly in the northern extents of the tenements.

An area classed as high (i.e. 50 to 150m with valley slopes greater than 32% gradient) was observed in the north-east of the gas fields.

1.3.3 Soils

Study area soils

Soils within the gas fields study area have been mapped and described in the various land system studies identified in Section 1.2. These studies have generally mapped the land systems/soil groups at a scale of between 1:250,000 and 1:500,000. Due to the differing land and soil assessment nomenclature, published land system mapping for the area and soils have been assessed and grouped to develop a classification system for the gas fields. Five broad soil groups were identified and referenced 1–5. The standardised soil key is presented in Table 5.3 and illustrated on Figure 5.8.

The main soil groups present in the study area comprise:

- Shallow gravely loams (rudosols) with a predominance of surface stone, found mainly in areas of steeper terrain where slopes are in excess of a 12% gradient
- Texture contrast soils (sodosols, chromosols, kurosols), which mainly have a shallow sandy or loamy topsoil with an abrupt change to a medium to heavy clay subsoil. This subsoil is commonly sodic and dispersive. This is the most extensive soil group in the study area and is very susceptible to erosion
- Shallow to deep-cracking and non-cracking clays (vertosols or dermosols), located mainly on the level or gently sloping plains and alluvial areas which are used extensively for cropping.

Topsoil thickness

With reference to Australian Soil Classification (Isbell 1996), typical topsoil thickness was estimated for each of the soil types, as shown in Table 5.3. This estimate was generally supported by field observations. Based on the field classifications, topsoil depth throughout the gas fields study area was generally thin to medium. Only one observation borehole recorded thick topsoil.

Table 5.3 Generalised soil types in the study area

	Order		Description	Characteristics	Typical topsoil thickness1	Encountered topsoil thickness	Soil erodibility ranking
1	Skeletal soils (mainly rudosols)	a	Alluvial – deep sands	Generally deep infertile soils associated with floodplains and minor streams.	Thick	Medium	2
		b	Shallow stony loams derived from sediments	These soils are generally associated with hilly landscapes within tenements and derived mainly from mixed sedimentary rocks. Characterised by shallow surface soils with gravel and generally underlain by rock at shallow depth (less than 0.15m from surface). Nutrient levels are generally low and topsoils are often very thin.	Thin	Thin–medium	1-2
		c	Shallow stony loams derived from mixed sources (metamorphic, intrusive or volcanic parent material)	Mainly igneous and metamorphic rocks. Not common within study area. Found in only a few locations. Similar in characteristics to 1b.	Thin	Not encountered	1-2
2	Texture contrast soils (chromosols/ sodosols and kurosols)	a	Alluvial – predominantly mod deep to deep	Sodosols – low in organic matter and nutrients; moderate conspicuous bleach between surface soil and subsoil; topsoil depth variable; subsoils usually strongly sodic and highly dispersive; very prone to gully erosion.	Thin–very thick	Thin-medium	2
		a (i)	i) Neutral to acid subsoil (chromosols / kurosols)				1
		a (ii)	ii) Neutral to alkaline subsoil (sodosols)				2
		b	Shallow mainly sandy surface		Thin–medium	Thin-medium	4

Order		Description		Characteristics	Typical topsoil thickness1	Encountered topsoil thickness	Soil erodibility ranking
		b (i)	i) Neutral to acid subsoil (chromosols / kurosols)	Chromosols / kurosols – Variable topsoil depth; low in fertility; bleached A2 horizon; low nutrients; usually red, brown or yellow clay with blocky structure and often moderately permeable; subsoils usually acid to neutral, non-sodic and non-dispersive to moderately dispersive; can intergrade with sodosols.			3
		b (ii)	ii) Neutral to alkaline subsoil (sodosols)				4
		2c	Shallow mainly loamy surface		Thin–medium	Thin-medium	4
		c (i)	i) Neutral to acid subsoil (chromosols / kurosols)				3
		c (ii)	ii) Neutral to alkaline subsoil (sodosols)				4
		2d	Moderately deep to deep sands/loams		Thick – very thick	Medium	2
		d (i)	i) Neutral to acid subsoil (chromosols / kurosols)				1
		d (ii)	ii) Neutral to alkaline subsoil (sodosols)				2
3	Red/yellow earths (kandosols/ tenosols)	a	Shallow earths – derived from sediments	Medium depth of topsoil, typically 0.15 to 0.3m; generally acid throughout with low to very low fertility. Shallow earths (3a) can have significant gravel content with rock outcrop or broken rock; surface can be loose and prone to sheet erosion. The structure can	Thin–medium	Not encountered	2-3
		b	Deep earths – derived from sediments		Medium–thick	Medium	1-2

Order			Description	Characteristics	Typical topsoil thickness1	Encountered topsoil thickness	Soil erodibility ranking
		c	Shallow/ deep earths derived from mixed sources	result in rapid drainage and poor moisture holding capacity. Less susceptible to gulley erosion than Order 2 soils.	Thin–thick	Not encountered	2
4	Brown / grey non-cracking clays (dermosols)	a	Alluvial – predominantly flood plain sediments	Found along terraces associated with most major watercourses. Can be prone to flooding.	Thin–thick	Not encountered	1
		b	Derived from sediments	Found in upland areas or plains and derived from sediments. Common in northern areas of the tenements.	Medium–thick	Thin	2
		c	Derived from mixed sources	Mainly derived from intrusive and volcanic sources. Only small areas found in gas fields study area.	Thin–thick	Not encountered	2
5	Brown / grey / dark cracking clays (vertosols)	a	Alluvial	Most fertile soils in the region, and found along terraces and floodplains of some larger watercourses, including Condamine River floodplain. Soils are generally very deep and present few physical constraints aside from possible flooding issues.	Medium–thick	Not encountered	1
		b	Derived from sediments (mainly clay plains)	As 4b and generally of medium depth with friable surface horizons and generally moderately high nutrient status. Phosphorus content usually moderate to high.		Thin-thick	1-2
		c	Derived from intrusives /volcanics	As 4b and generally of medium depth with friable surface horizons and generally moderately high nutrient status. Phosphorus content usually moderate to high.		Not encountered	1-2
		(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	1

1. Thin: <0.1 m Medium: 0.1 to 0.3 m Thick: 0.3 to 0.6 m Very Thick: >0.6 m, 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 in relation to other exchangeable ions. The sodicity of a soil correlates with its potential to disperse upon contact with water and therefore its susceptibility to erosion. It can also affect a soil's potential to form a surface crust and affect its infiltration characteristics.

The majority of subsoil samples collected and tested within the gas fields study area were sodic to strongly sodic, and were also reported as very dispersive. Sodic to strongly sodic fine textured subsoils (i.e. mainly within soil groups 2, 4 and 5) will require careful management and will be kept separate, where practicable, from non-sodic soils if excavated. Sodic to strongly sodic coarse textured soils (i.e. mainly within soil groups 1, 2 and 3) will also require careful management and separation of the subsoil.

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 soil erodibility potential is given in Table 5.3.

This assessment indicates that, based on the locations sampled, most soil types would be considered to have a low erosion potential in their natural state, mainly due to existing ground cover and land use. However, most soils are considered susceptible to erosion when the soils are disturbed. In particular, where vegetative cover has been removed, soils with a 3 or 4 classification will be highly susceptible to erosion. Soil groups 2b and 2c (i.e. the shallow texture contrast soils, especially the sodosols) were considered the most erodible soils within the gas fields.

Examples of severe erosion were noted to occur where vegetation had been cleared for agriculture or infrastructure development purposes. In many cases, stabilisation and rehabilitation was either unsuccessful or not implemented in these areas.

To determine the overall erosion potential for lands within the gas fields, the soil erodibility factor described in Table 5.3 has been combined with the influence of different slope categories and presented in Table 5.4.

Based on the rankings given in Table 5.4, the erosion potential for the gas field area is illustrated in Figure 5.9. This figure indicates:

- 43% (244,017ha) of the area has an erosion potential of very low to low
- 41% (approximately 237,934ha) has an erosion potential of moderate to high
- 16% (approximately 90,038ha) has an erosion potential of very high to severe.

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						
2b(i)	3	M	H	VH	VH	N/A
2b(ii)	4	H	VH	S	S	N/A
2c						
2c(i)	3	M	H	VH	VH	N/A
2c(ii)	4	H	VH	S	S	N/A
2d						
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	1–2	VL	L	M	N/A	N/A
5c	1–2	VL	L	M	H	N/A
5b(m)	1	VL	L	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					

Soil pH

Most soil samples collected and tested were neutral (between 6.6 and 7.3) and within a pH range acceptable for plant growth.

Salinity

Salinity is the presence of soluble salts in soils. This is mainly sodium, but also potassium, calcium, magnesium, sulfate and chloride. High salinity levels in soil may result in reduced plant productivity, including eliminating native vegetation, and may increase susceptibility to erosion.

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

However, due to the subsoils in many soil groups (notably the 2b, 2c and 5b soils), careful management will be required, particularly for rehabilitation purposes as outlined in Section 1.5.3. These soils have a propensity for salt accumulation 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, 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 fields 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 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 organic matter. 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 will 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. Although this policy is not applicable to petroleum activities, it describes the State's intent towards GQAL.

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

These planning guidelines also define agricultural land as 'land used for crop or animal production, but excluding intensive animal uses such as feedlots, piggeries, poultry farms and plant nurseries based on either hydroponics or imported growth media'. Agricultural land has been classified into four groups, which are described in Table 5.5.

Table 5.5 Agricultural land classes (Source: DPI/DHLGP 1993)

Class	Description
A	Crop land Land 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, but 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 suitable only for improved or native pastures due to limitations which preclude continuous cultivation for crop production. 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 within inaccessible areas. C1 may be considered to be GQAL, depending on the respective 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.

Based on this mapping, the percentages of each agricultural class within the study area have been estimated. These are detailed in Table 5.6.

Table 5.6 Project area good quality agricultural classes

Class	Area occupied within total gas fields area (ha)	Percentage of gas fields area occupied (%)	Area (ha) of GQAL to be impacted by gas fields operation*
A	111,846	19.6	23,726
B	148,727	26.0	
C1	70,614	12.3	
C2	188,756	33.0	16,991
C3	-	-	
D	52,045	9.1	
Total	**571,989**	**100**	**40,717**

The location of GQAL in 'State Planning Policy 1/92: Development and the Conservation of Agricultural Land (GQAL)' is required to understand the existing status of the land resource likely to be affected by the gas fields. It also provides a standard of the condition for future rehabilitation. GQAL is considered to be 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 illustrated in Figures 6.1 to 6.7 within Volume 2 Chapter 6. This GQAL mapping has been derived from the existing the Department of Environment and Resource Management (DERM) database.

Most GQAL (Classes A and B) is comprised of low sloping lands (generally <5% slope) where deep cracking and non-cracking clay soils occur. The deep soils associated with the major alluvia are valued for intensive cropping activity and are well-suited for long term agricultural production.

When combined, the total GQAL within the gas fields' tenement boundaries is 58%.

1.3.4 Land contamination

Within the context of the proposed development, environmental impact from contamination may arise as a result of encountering and disturbing existing areas of contamination, such as an old landfill area. Impacts may also arise as a result of gas field activities, such as spillage during refuelling or leaking of fluids from mechanical plant. Therefore, it is important to evaluate both the existing contaminated land and the potential impacts due to the gas fields, to assess the risk of land contamination to the environment and human health.

A desktop study was undertaken to assess the potential environmental impact from major gas field infrastructure and therefore focussed on those lots where proposed major infrastructure would be constructed. There were 60 lots in total that were assessed plus an additional 5 lots which were identified as containing potential cattle dips or spray races.

The assessment concluded that the gas fields are generally anticipated to be free from widespread adverse concentrations of contaminants, but that some localised risks are likely to be present due to the historic land uses. Given the rural setting and nature of certain rural uses undertaken in the past, the most likely source of contaminants are cattle dips, spray races, unlawful waste disposal and unauthorised waste dumps.

The PSI identified three sites within the footprint of proposed structures that could contain potential contaminants arsing from the use of cattle dips or spray races. These cattle dips and spray were not confirmed but rather identified as areas requiring further investigation. No unlawful waste disposal or unauthorised waste dumps were identified during the PSI but could be present given the rural setting.

The contaminants associated with these treatment methods would likely be arsenic and organochlorine pesticides. Other forms of pesticides also may be used with dips and spray races; however these chemicals are likely to be less environmentally persistent and readily biodegradable, and therefore less likely to be present. The locations of the three sites are shown on Figure 5.2. The structures proposed to be constructed at these sites include two water treatment facilities and one brine pond.

The assessment of the three sites identified should not be considered exhaustive, as this was a desk top study based on limited information. Other existing or buried dips and spray races or landfill/ disposal areas may be present which were not identified during the PSI. In the event the Project is unable to avoid contaminated areas, further historical data and field investigations involving intrusive sampling (i.e. Stage 2 investigations) will be required during the supplementary stage of the EIS.

1.4 Potential impacts

The development of the gas fields will involve constructing and operating a number of facilities. These include gas wells, gas processing facilities, water transfer stations, water treatment facilities, and brine and water storage ponds. These facilities are separated geographically and are likely to be linked by a network of roads and pipelines which form the gathering network for the liquefied natural gas resource.

Using the information provided in the above assessment of existing land conditions, this section discusses the potential impacts of the gas fields' development on local land-based values: existing geology, topography, geomorphology and soils. This section also considers the potential impacts if construction activities disturb contaminated land, as well as potential for land contamination arising out of gas field activities. Cumulative impacts are addressed are discussed at the conclusion of this section and refer to potential impacts in a regional context.

1.4.1 Geology

Effect of geology upon excavation

Based upon the geology presented in Figure 5.3, and terrain models in Figure 5.6, an assessment was undertaken to establish the potential constraints to excavation presented by each geological unit during the construction phase. This assessment was based on excavations up to a nominal 2m depth. It used a rating system that defines the potential excavation difficulty as low, medium or high.

A low rating is one in which, due to the nature and depth of soil cover associated with the 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 this case, progress with a standard excavator may be slow and would require a larger machine, with occasional use of a ripper or hydraulic rock breaker.

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

The assessment has indicated predominantly low and medium impacts associated with excavation activity, mainly due to the predominance of soil and fractured sandstone sediments within the project area. Excavation will therefore mainly require the use of standard plant. It is likely that the environmental impact would proportionally increase with excavation difficulty, including significant noise and vibration levels at the local scale occurring where less weathered rock is present.

Excavation activity is not anticipated to cause significant offsite risks. Normal environmental controls for noise, vibration and dust control would be expected to apply. Further details are provided in Volume 2 Chapter 13 – Air quality and Volume 2 Chapter 15 – Noise and vibration.

Seismicity

Faults and folds within the 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. A study of the distribution of recorded earthquakes in the region has revealed a history of low to moderate magnitude (Richter 3-5) earthquakes.

There is a risk of damage to infrastructure in the unlikely event of a significant earthquake, greater than 4.8 on the Richter scale, occurring during the life of the Project. An indication of potential levels of public nuisance and damage to infrastructure for various earthquake magnitudes is presented in Table 5.7.

Table 5.7 Indicative levels of damage from earthquakes

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

Source: Geoscience Australia (2010)

Table 5.7 suggests that structural damage would have the potential to occur during earthquakes of Richter 4.9 or higher. If so, damage to gas fields' infrastructure could occur, but this is very unlikely with levels below 5.5 on the Richter scale. A worst case scenario would be that an earthquake was of such magnitude or duration that it caused ruptured tanks or gas pipes within the gathering network, causing a release of contaminant into the ground or atmosphere. While such an occurrence may be statistically remote, the potential seismic risk will be appropriately addressed during structural design.

In Section 1.3.1, it was noted that a seismic event could also arise as a result of gas extraction or construction of a large dam. However, no deep dams are proposed as part of the gas fields' project,

so surcharge loading on the Earth is not expected to be significant. Consequently, the risk of seismic events caused by construction of a dam is considered to be negligible.

Possible seismic activity caused by gas extraction, particularly during initial well development, has been considered. However, the depth of extraction is such that surface impacts are likely to be minimal, with the potential for only very localised ground vibrations.

Extractive resources

The construction of gas fields' infrastructure will require the supply of construction material such as cement, bentonite, lime, sand and rock aggregate. At this stage of the Project, precise quantities required are unknown, as is the required quality and type of materials or the location where these will be used.

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

The quarry assessment identified numerous existing quarries within and surrounding the study area (refer Section 1.3.1), most of which 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. However, it is likely that significant expansion and the establishment of new quarries will be required to meet the demand of the Project's gas fields, as well as any other coal seam gas projects in the area.

The establishment of borrow pits and the expansion of local quarries could result in loss of land otherwise suitable for other uses. There would also be an increase in traffic volume during the extractive phase, which may require upgrades to existing roads. This traffic and transport aspect is addressed in Volume 2 Chapter 17.

Other possible environmental issues arising from new quarries or extensions to existing quarries include alteration of local topography and drainage patterns; vegetation removal, and the creation of dust, noise and vibration. Such issues would be addressed as part of existing license conditions applicable to existing operations, or any development approvals that may be required by private operators for the development of new resources.

Sterilisation of resources

There are areas of the gas fields where a number of permits have overlapping tenure for coal mining or extraction of coal seam gas. The extraction of gas could potentially impact other permits for gas, but extraction of gas from coal seams does not impact the ability to mine the coal. In fact, degassing the coal can assist in any future underground coal mining.

Australia Pacific LNG is also working with government to manage the tenure overlaps and sterilisation of resources. In February 2009, the Queensland Government released its underground coal gasification (UCG) policy, which guides the management of such overlaps. Australia Pacific LNG is represented on the UCG Industry Consultative Committee, which was established to advance the policy, and is addressing issues such as potential resource impacts or sterilisation.

Given that the extraction of gas is a tenure issue in this case, rather than an environmental matter, this issue is not considered further in this report.

1.4.2 Topography and geomorphology

The construction of the proposed development will necessitate localised excavation and re-profiling of the existing terrain to create level areas for building infrastructure. This will cause localised changes to topography, which can change the local drainage patterns and visual character. These aspects have been addressed in Volume 2 Chapter 7 and Volume 2 Chapter 11. Levelling works will also cause vegetation clearance on slopes, destabilisation of soils, loss of GQAL and potentially degraded downstream water quality.

Clearing and re-profiling the land could also create potential areas of localised slope instability. However, due to the existing low sloping terrain of lands proposed for the main infrastructure facilities, significant slope instability and failure is not expected. Conservative engineering design parameters will be employed for batter slopes and constructed embankments.

Ultimately, excavations carried out for the gas fields will be backfilled or re-contoured to a suitable stable landform. In the short term backfilling of former water containment structures may create a mounded profile. In time, it is expected that the backfill material will settle to produce a relatively flat profile. 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 change to the local surface drainage patterns. Such changes are likely to be minor if they occur.

Where there are vehicular or pipes crossing of streams, there is the risk of local changes to the stream morphology as well as potential for river bank instability issues. These aspects are addressed separately in Sections 1.4.3 and 1.5.3.

Due to the generally low slopes in the project area, land stability (slope failure and collapse) is not expected to be a significant issue. Effects to drainage patterns have been addressed in Volume 2 Chapter 11.

1.4.3 Soils

Topsoil

It is recognised that the existing topsoil resource in the gas fields needs to be carefully managed.

Site clearance and construction will involve stripping topsoil and associated vegetation to create areas for the new infrastructure. This can result is the loss of topsoil quantity and quality through incorrect stripping, prolonged soil exposure and erosion. In the long-term, it is anticipated that the infrastructure will be removed from most areas and the topsoil replaced.

Where rehabilitation work is proposed, a shortage of topsoil is inevitable in some areas. This is particularly the case in the shallow stony soils (soil group 1), shallow texture contrast soils (soil group 2), and those within soil groups 4 and 5 where clay content is significant in the surface material. In such areas, additional topsoil may need to be sourced from zones with substantial topsoil depths or alternative management measures may be required to overcome the potential shortfall.

Temporary storage of topsoil in stockpiles is likely to be required. If inappropriately handled and managed, stockpiling of topsoils can damage the topsoil structure, resulting in nutrient leaching and loss of fertility. The environmental management plan discussed in Volume 2 Chapter 24 has defined topsoil management measures that will be implemented progressively, to maintain the quality and maximise the utilisation of the topsoil resources within the gas fields.

Reactive soils

Reactive soils comprising cracking clays (soil group 5b and 5b[m], in Table 5.3) were identified within the gas fields. These soils expand and contract due to moisture variations, and can generally lead to heaving and subsidence and in turn cause damage to buildings and roads if these are not appropriately designed.

Even when underground infrastructure such as pipelines is designed to withstand movement, damage to protective coatings still occur from continuous rubbing induced from these expansive clays. Engineering design measures are available to overcome such issues.

Erosion

Development within the gas fields area has the potential to significantly increase soil erosion levels. This could result from the clearing of vegetation, poor drainage management (including concentration of flow), improper sediment and erosion control, and inadequate earthworks contractor training and supervision. Erosion can have an adverse effect on soil productivity and the associated agricultural value, and consequent effects on GQAL. Additional effects can include, but are not limited to, undermining of structures (such as fences), exposure of pipelines, stream bank erosion, downstream sedimentation, decline in fertility through loss of soil structure, and increased dust generation and poor rehabilitation. Additional rehabilitation works are also required for eroded soils.

Development within the gas field study area has the potential to significantly increase soil erosion levels, and it is important to minimise this risk.

Section 1.3.3 noted that significant areas of the tenements have a high or greater erosion potential. However, as most significant facilities will be located on the lower sloping lands (i.e. <5% slope), overall erosion will be minimised. Nevertheless, in the absence of suitable mitigation strategies, the potential for significant adverse impact in this regard is high.

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 it is undisturbed. However, as the subsoils can be generally sodic to strongly sodic, these soils will erode due to clay dispersion where soil is exposed through vegetation removal. Such soils can be particularly prone to gully and tunnel erosion.

Concentrated flows, including those caused by diverting stormwater around construction areas, have the potential to cause the greatest erosion impact, particularly gully erosion. Such flows can also increase bank instability (stream bank erosion) and meandering migration, while increasing the mobilisation of sediment which causes redistribution downstream.

Some discharges will be required as part of the construction process, such as the release of the water used for hydrostatic testing of pipelines and release of treated water from the extraction wells. Impacts in relation to disposal of hydrotest water and water associated with gas processing 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 points, increased erosion may occur. Further detail regarding point-source discharge locations is provided in Volume 2 Chapter 9 and Volume 5 Attachment 5. There is also the potential for follow-on effects where this water contains contaminant concentrations, such as heavy metals, raised dissolved salt concentrations and hydrocarbons.

Preparing and implementing detailed sediment and erosion control measures will be the key to reducing erosion risk to acceptable levels. The intent of such measures is described in the environmental management plan in Volume 2 Chapter 24.

Salinity

The soils in the gas fields study area have recorded salinity levels between non-saline (electrical conductivity levels <2,000µS/cm) and moderately saline (4,000-8,000µS/cm). Vegetation has varying tolerance to salinity, with few species able to tolerate an electrical conductivity level greater than 8,000µS/cm. As a result, moderate to highly saline soils will require special management, as the soils may be corrosive to civil structures and present challenges for revegetation.

Dryland salinity associated with parent soils is not common in the gas field study area, but project activities such as vegetation clearing and management of surface water could contribute to further salinisation of soils. However, given the relatively fragmented nature of proposed clearing of intact vegetation for the gas fields, drainage patterns and existing salinisation within the region, the risk of the gas fields causing significant additional outbreaks of dryland salinity is considered to be low.

Saline water will be generated by the gas well drilling and development process. This water is expected to be treated by reverse osmosis, to produce water suitable for a number of uses. However, the treatment process does produce a highly saline effluent which will initially be stored in management (brine) ponds for evaporation. The option to inject the brine back into geologically suitable aquifers at depth is being investigated.

Hydrotest water also 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. Controls for discharge will be required to minimise impacts.

Good quality agricultural land

An estimated 58% of the gas field area is comprised of GQAL, classes A, B and C1. This land will be impacted through the construction and operation of various gas field components. Impacts to GQAL can result from:

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

Table 5.6 presents an assessment of GQAL areas that will be affected by the Project.

In summary, given the scale of the gas fields development, the potential impact to the productive area of land could be significant in the short to medium term with an estimated 23,726ha GQAL impacted by gas fields infrastructure during the construction phase. This impact, at any one time, will be significantly less than these results due to progressive development and rehabilitation of the gas fields within the tenements where such land is not required for operational activities, or once operations are completed and decommissioned within specific project areas.

The estimated total area of GQAL which will be sterilised during gas fields operation is 4,319ha (0.76% of the tenement area). Individual facility construction and operational footprints within GQAL have been discussed in Chapter 6.

There are likely to be some structures retained for landholder or community use after the gas fields' use expires. This includes some access roads and water storage facilities. While it is likely some permanent loss of GQAL will occur, this loss is not considered significant in the regional context.

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 study area, 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 study area have generally loamy textures, bulldust generation is expected to occur if appropriate dust mitigation is not implemented throughout construction and operation.

1.4.4 Land contamination

Existing land contamination

The desktop contamination assessment has identified the possible presence of arsenic and pesticide contamination, associated with cattle dips and spray races at a number of locations where significant infrastructure is proposed.

Arsenic and organochlorine pesticides are environmentally persistent, which means that the pesticides can remain in the ground for long periods without significant reduction to concentration. Where such contamination is already present, disturbance of the affected soils could mobilise contaminated sediment into local ecosystems and watercourses. This could lead to environmental harm. However, given the small number of locations that are possibly contaminated, the overall risk and potential impacts are considered to be very low.

Another potential impact arising from the presence of contamination is the cost of treatment and/or disposal of affected soils, which may require removal from site and disposal at an appropriately licensed landfill facility. Such action would mean more vehicle movements and, potentially, the need to import soil or disturb greater areas to replace soils designated for disposal. As above, the potential for significant impact with regard to this is likely to be very low.

Land contamination due to gas field activities

Activities associated with the construction of gas field infrastructure such as CSG wells sites, gathering networks for gas and associated water, gas processing facilities and water treatment facilities may generate compounds which have the potential of contaminating soil. These compounds will be predominately generated from the operation of drilling rigs and general construction activities relating to earth moving equipment.

Drilling activities

Potential sources of contamination to soil during drilling activities include the onsite storage of diesel fuel, storage and use of drilling mud and the associated fluids in addition to the storage and use of lubricating oils and hydraulic fluids used for generators, compressors, pumps and hoists.

The compounds of concern, which may lead to soil contamination if released, are short and long chain hydrocarbons from diesel and oils respectively, and low levels of soluble salts contained in the drilling mud.

Quantities of diesel, oils and greases will generally be limited to the amount required to complete the activity of drilling the well, therefore limiting the amount of material which could be released to soil. The storage of diesel fuel will be in aboveground storage tanks. These storage tanks will have secondary containment. Typically one 10,000L storage tank will be refuelled as required to service the drilling equipment.

The transfer of fuel to generators will typically be undertaken via a dedicated line directly to the generator from the tank. Fuelling of vehicles such as front end loaders, if required at site, will be managed via a transfer station from the 10,000L storage tank with a hose and nozzle similar to a service station. Implementation of the procedures for filling vehicles, with minor spills, should they occur, cleaned up 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 absorbents 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 on site.

Drilling mud is comprised of bentonite, freshwater, weighting agents such as potassium chloride and polymers. Volume 2 Chapter 3 provides a description of the drilling process and use of drilling mud. Drilling mud and fluid contain soluble salts which may impact soil. Drill cuttings also contain these salts at lower concentrations. Drill cuttings are the geological material which has been recovered from the well. These cuttings will be separated from the drilling mud, stored in a sump and, at the completion of drilling, mixed with sub-soil and buried on site and capped with subsoil prior to rehabilitation. The separated drilling mud will be transported to a water treatment facility for treatment as required.

General construction activities

Earth moving equipment which is utilised during construction of well sites, gathering systems, gas processing facilities and water treatment facilities may provide a source of contamination from hydrocarbons such as diesel, petroleum fuel, lubricating oils and hydraulic fluids. The storage handling and use of these fluids will be similar to the activities associated with drilling, with the exception of fuel transfer stations which are typically dedicated facilities with containment and spill kits available for minor spills.

The appropriate storage, transfer and use of fuels and oils 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. The earthmoving equipment may also be a source of contamination. Routine maintenance and inspections of the equipment will limit the potential for spillage of contaminated material.

Operation activities gas fields' infrastructure

Once a well site is brought in to production, there will be few potential sources of contamination from the well. Hydrocarbon contamination directly from the well operation will not be possible during normal operation. An event such as an earthquake may damage the integrity of the well and result in an uncontrolled release of natural gas and associated water. This outcome is highly unlikely as previously described in Section 1.4.1.

The low pressure gathering network, which transports gas and associated water from the well to the gas processing facility and water treatment facilities, has the potential to impact soil and water though the likelihood is low. These pipelines will be constructed in accordance with applicable standards. The gathering network will be tested for integrity prior to commissioning using one of two processes depending on the operational constraints. The two proposed methods are pneumatic testing using air pressure for poly pipes or hydrostatic testing using water 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 gathering pipeline network design includes an isolation plan incorporating block valves and check valves to minimise the volume of gas or water which may be released in the event of a leak or rupture. In conjunction with the pipeline isolation plan, 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 and associated water has the potential to impact soil structure and vegetation in a localised area. Soil impacted by natural gas reduces the quality of soil structure and reduces the 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
- On-site remediation
- Validation of the excavation
- Backfilling the excavation with remediated soil.

Following remediation, the soil surface will be rehabilitated consistent with the surrounding vegetation. Any unintentional release of associated water to soil will be investigated in accordance with regulatory guidelines which will determine the need for remedial actions.

Gas processing facilities have a number of potential sources of contamination including fuels such as petroleum or diesel, process chemicals such as glycol, lubricating oils and hydraulic fluids.

Fuel tanks are typically 1,000L and will have secondary containment which is generally designed to hold 110% of the volume of the largest tank within a bunded area. The fuel transfer stations will be dedicated facilities which are designed to inhibit the volume of fuel released.

Lubricating oils and hydraulic fluids are generally stored 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 potentially be spilt.

Glycol is used in the dehydration process to remove water from the feed gas stream. The glycol will be stored in aboveground tanks which will be bunded. The dehydration system will be fed through a dedicated line. Spills during transfer from delivery trucks and operational upsets are uncommon. Glycol is highly mobile in soil where water is present; it is also soluble in groundwater. In the event of glycol being inadvertently released to soil, the area will be excavated, validated and the soil stockpiled

in a bunded area with an impermeable liner and disposed of at an approved disposal facility. As an alternative to off-site disposal, soils impacted by glycol are also generally easily bio-remediated.

Water treatment facilities have a similar contamination potential to gas processing facilities. The notable exception is the by-product of large volumes of concentrated brine (approximately 60 g/L of salt). This concentrated brine 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. Investigations to inject brine into geologically suitable aquifers at depth are underway. The impacts and mitigation measures associated with temporary storage ponds and brine ponds are discussed in detail in Volume 2 Chapter 10.

The potential for fire to occur within gas processing facilities and water treatment facilities is low, but the potential for soil contamination is possible through unintentional release of stored chemicals. Following the event of fire, an assessment will be undertaken to assess potential land contamination and remediation activities will be completed as required.

Decommissioning

At the end of the Project, the gas field infrastructure will be decommissioned. Well sites will be assessed for potential contamination in accordance with the EP Act and rehabilitated. When sections of the pipeline gathering network system become non-operational, the pipelines will be isolated from the network, purged with an inert gas if required, capped and abandoned in place. The purged water will be collected, tested and disposed of in either a storage pond or, if appropriate, to ground. Any aboveground infrastructure and access tracks will be removed and rehabilitated to be consistent with the surrounding area.

The gas processing facilities and water treatment facilities may require Stage 2 contaminated land investigations (as described in Section 1.3.4) and potentially remediation prior to the rehabilitation of the site. Any aboveground infrastructure and access tracks will be removed and rehabilitated consistent with the surrounding area.

Given the proposed controls to be established for the gas fields, the risk of significant land contamination occurring is considered to be low.

Volume 2 Chapter 12 and Volume 2 Chapter 16 provide further details on associated water and waste management, respectively, while the environmental management plan is provided in Volume 2 Chapter 24.

1.4.5 Cumulative impacts

The following section outlines the cumulative impacts to the environment external to the study area resulting from the Project's land disturbance at the gas fields. These impacts are also discussed within Volume 2 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 at 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 infrastructure. An impact will occur due to occupation of GQAL which will be highest during construction but minimised during operation through progressive rehabilitation.

Land contamination

Potential impacts to land from the occurrence of contaminated land will be associated mostly with the construction and operation of the gas fields. Such impacts are likely be caused by spills, leaks and storage of waste products and waste materials and have the potential to result in localised areas of contamination. Significant off-site migration of contamination via soil is not likely given the design and construction of appropriate containment structures and effective on-going management controls.

1.5 Mitigation measures

Section 5.6.1 summarises proposed controls to mitigate and manage potential environmental impacts of the gas fields with regard to geology, topography, geomorphology, soils and land contamination.

1.5.1 Geology

A number of mitigation methods have been identified. Firstly, during the FEED phase of the gas fields, a geotechnical assessment will be needed at the main excavation site. This will enable equipment required for excavation and the associated environmental effects to be assessed.

Secondly, site levels will be set to minimise as far as reasonably practicable the depth of excavation and the requirement for breaking rock, if it is encountered. Where rock breaking and/or blasting is required, consideration will be given to any surrounding land use which is sensitive to vibration and the blasting, as outlined in Volume 2 Chapter 13 and Volume 2 Chapter 15. Blasting will be carried out in accordance with relevant guidelines.

Excavated material will also be re-used onsite, where practicable. An onsite crusher may be engaged to render any excavated rock suitable for re-use, including use as rip-rap.

Seismicity

There are a number of moderately-sized faults and folds which occur within the study area, but there are few recorded earthquakes. However, structure design will be undertaken in line with Australian Standard AS1170.4:2007, or other applicable standards that consider the effect on a structure against related earthquake phenomena such as settlement, slides, subsidence, liquefaction or faulting.

Extractive resources

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

- FEED phases will quantify the need for extractive materials prior to construction. It will also identify the quality, volume and type of materials required, and the location at which it will be required.

- Australia Pacific LNG has not planned to directly develop new quarries as part of the Project. 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 the Project's FEED phases to determine the size and local demand. This will enable an informed assessment to be made regarding adequate resources to service gas field requirements as well as existing community demands.
- Mobile crushers may be used on the gas fields so excess rock excavated can be utilised to minimise the need to externally quarry materials.
- 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.

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

For any extractive activities undertaken by others on behalf of the Project, the environmental issues associated with the extraction of resources 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 removed. Remediation and rehabilitation of any contaminated areas, grading and revegetation of the quarry/borrow pits will be undertaken in accordance with regulatory approval conditions.

1.5.2 Topography and geomorphology

Site clearance and earthworks will have the greatest impact to existing landform through the re-profiling of local topography, alteration of drainage paths and soil destabilisation. In turn, this could change the local drainage patterns, visual character and degraded downstream water quality. General mitigation measures will be addressed throughout the gas fields to minimise potential impacts. These measures are:

- 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.
- Major facilities, including gas plants, water transfer stations, waste treatment facilities and brine and water storage ponds, will be sited on relatively level sites (where practicable) for ease of landform rehabilitation following gas field 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 subsequent landform reinstatement and rehabilitation will be carried out. This may involve remediating and rehabilitating any contaminated areas and subsequently grading and revegetating the site returning it to a stable condition. 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 pipelines during flood events. This is covered in Volume 3 Chapter 11 – Surface water and watercourses.

1.5.3 Soils

Topsoil

Based on field classifications, topsoil depths are predominantly thin (<15cm depth). As topsoil needs to be stripped to the appropriate depth without subsoil disturbance, site specific assessments will be undertaken prior to disturbance, to determine the appropriate removal depth.

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

Fertility of most topsoil within the study area is rated as very low to low. As a result, additional nutrients (specifically nitrate and phosphorus) will be required in some areas to improve topsoils, stabilise the subsoils and support vegetation regrowth during stockpiling and rehabilitation.

Topsoils will be stripped with care and where practicable, stripped topsoil will be re-used by application to areas where a similar soil type is required for rehabilitation. Where this is not practicable, the topsoil will be stockpiled and rocky materials removed. Coarse textured topsoils will be stockpiled separately from fine grained (groups 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 with the stockpile turned over and mixed prior to replacement. Where there are multiple stockpiles, appropriate spacing will be left to allow wildlife and vehicles to negotiate around them. Erosion and sediment 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 need to be replaced at depth and covered with topsoil minimising potential blending and soil inversion. In areas where there is little topsoil or there is evidence of existing salinisation, topsoil may need to be imported to cover saline soils to facilitate revegetation. Vegetation clearing will be minimised 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.

Drilling fines generated from gas well drilling will be isolated (in sumps) and rehabilitated.

Saline solids from brine ponds will be encapsulated or reinjected or removed and disposed of.

Disposal of saline water can affect soil salinity. Disposal of saline waters will therefore meet the requirements for water management identified in Volume 2 Chapter 12.

Reactive soils

Reactive soils are those with a significant shrink/swell characteristic. These are 5b and 5b (m) soils, and occur throughout the project area. To minimise construction constraints associated with these soils, a number of mitigation measures are proposed.

Firstly, where construction is proposed for major infrastructure within soil group 5b and 5b(m), site specific geotechnical investigations, such as those undertaken during FEED phases, 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, substantial pipelines are anticipated to be constructed, mainly within the lower section of the shrink/swell and are 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.

Lastly, construction in reactive soil areas will be limited to dry weather conditions as far as practicable. The construction of gravel access tracks and working platforms may also be warranted in some areas to prevent rutting and damage to soil resource as these soils are of significant agricultural value.

Water diversion, erosion and sediment control

Previous erosion assessments undertaken within the gas fields have indicated that conventional stormwater control through runoff diversion and concentration, combined with scour protection, has required augmentation in some areas. This is particularly the case in highly dispersive soil areas.

Detailed sediment and erosion control measures will therefore be implemented, particularly in areas designated as having a high to severe erosion hazard, as shown in Figure 5.9.

Where applicable, the following mitigation measures are proposed:

- Where diversion of runoff water around the construction site is required, design will need to be mindful of possible erosion effects, including the instigation or exacerbation of gully and tunnel erosion. The sediment and erosion control measures in environmental management plans to be prepared will address measures to prevent such erosion from occurring.
- Sediment fences will be constructed on the downhill side of the excavation areas and, if required, sediment detention structures.
- Sediment fences will be constructed around the stockpile areas.
- Drainage lines and areas of concentrated water flow near major facilities will be inspected regularly for erosion and to determine whether remedial action is required.
- 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 (contour banks) will be placed at frequent intervals along flow paths, and directed to discharge at multiple locations at low velocities and volumes. This will avoid channelling runoff to a central point, which may exacerbate erosion.
- Suitable hydrotest water discharge locations will be assessed.
- Point discharge will be directed into stable waterways and/or drainage lines and engineering controls such as scour protection and flow velocity limits implemented.
- Vegetation will be progressively cleared to minimise the area of soil exposed.
- Stable slopes will be creating and revegetated soon after disturbance.
- 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) will be stabilised as required. This will be done using chemical surface stabilisers or physical alternatives such as crushed rock.
- Diversion sediment and erosion control devices will be installed prior to construction commencing and will remain in place until the area has been effectively rehabilitated
- Roads and tracks will go across slopes, wherever practicable, otherwise contour banks will be used at intervals appropriate to the slope to control the flow of surface water and to minimise erosion.
- Trench breakers will be installed in the backfill at intervals appropriate to the steepness of the slope, where pipes go down slopes to prevent water tunnelling along the buried pipe and contour banks used on surface to divert water off the disturbed areas.
- Sediment basins will be constructed on the downhill side of major facility sites, such as temporary accommodation facilities, when they are near sensitive water courses, as outlined in Volume 2 Chapter 11.
- Water will be discharged through silt fences, or other erosion control measures, if it is required to be discharged off-site.
- Water quality will be monitored in watercourses which may receive runoff from major facilities as outlined in Volume 2 Chapter 11.

A comprehensive list of soil erosion, control and monitoring measures, detailing the measures described above and additional measures will be provided in the environmental management plan, as discussed in Volume 2 Chapter 24.

Creek protection

The study area contains several significant creeks and it will be necessary for pipelines and access tracks to cross them in some locations. The following mitigation measures are proposed, where reasonably practicable:

- Construction through creeks will be carried out when the creeks are dry, where reasonably practicable. If there is water in the water course at the time of construction, then there will be a dam upstream and downstream. Water will be diverted through suitably designed culverts or pipes through the dam, or pumped around for low flows.
- Pipe trench crossing 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 pipeline and the bank.
- Erosion protection such as rock armour or a proprietary geosynthetic layer will be installed where erosion within existing channels may be exacerbated by additional inflows, or where point-discharges are required. Existing soils within the creeks will be excavated and stockpiled so that the soils can be replaced following removal of the temporary protection systems.
- 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 to prevent erosion.
- Inspections of watercourse crossings (routine and following severe rain events) will be conducted during and post construction until the area has been stabilised to visually monitor erosion at the crossing, and downstream for evidence of sediment runoff.
- Creeks will be rehabilitated to a condition consistent with the contours of the channel at the time of construction.
- Access will be prevented to sites, where required by proximity to grazing stock or other threats, through fencing or barriers to assist site recovery.

If construction of pipe trenches through major watercourses is carried out in a wet condition, an assessment of trench stability will be undertaken, as trenches often become unstable in the presence of water. More specific advice, including the required depth of the pipe below the water-bearing layers, is provided in Volume 2 Chapter 11.

Dust control

There is the potential for construction activities to create dust, such as along proposed access roads and from site clearance. Dust management strategies to maintain air quality are described in Volume 2 Chapter 13. Soil management measures will include:

- Careful selection of access roads to minimise road length
- New tracks will have vegetation removed and topsoil stripped and stockpiled
- Surfacing of major access roads with gravel and/or geotextile or the use of water spraying, where appropriate
- Carrying out revegetation as soon as practicable after construction.

Reinstatement of land capability

The location of major infrastructure such as the plants, accommodation facilities and ponds has been selected to minimise the impact to agricultural land's productive capacity. Landholders will be consulted where Project infrastructure (such as access tracks and pipelines) is to be established through GQAL to ensure timing of the works does not unduly affect farming operations. Where possible, access tracks and associated pipelines will use existing tracks, fence lines and road reserves.

Where disturbance of productive land is unavoidable, the careful management of topsoil and subsoil will form an important component of the rehabilitation strategy. To this end, 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, rehabilitate disturbed areas equal to vegetation types consistent with the surrounding environment.

Where pipeline installation is to occur within croplands, particularly where deep ripping may be used, additional depth of cover will be required as determined by design engineers and validated by the AS2885 Safety Management Study. This will also be the subject of consultation with affected landholders to ensure timing of the works does not unduly affect farming operations.

1.5.4 Land contamination

Existing contamination

A number of mitigation measures are proposed for areas of possible existing contamination.

Where notifiable activities, such as but not limited to crop spraying, dips, spray races and any waste dumps, may occur within the infrastructure's footprint, further liaison with landholders will be carried out along with an assessment of the area. This will be done to confirm whether these activities are being carried out. If so, environmental assessment and monitoring will be conducted. This will include soil sampling and testing following the former Department of Environment's draft guideline requirements (now DERM).

If tests reveal adverse levels of contamination then appropriate action can be taken. This may include repositioning facilities and/or altering layout to avoid disturbing affected areas. Depending on levels and types of contamination found during site assessment, remediation or site management measures may need to be implemented. Remediation may include on-site remediation of affected soils or excavation and disposal or treatment of affected soils. Site management may include capping or containment of the contaminated area.

If excavation works uncover unexpected contamination, all work in proximity of the contamination will cease, and an inspection and assessment of contamination levels will be carried out. Remediation measures will then be recommended and implemented before construction continues.

Construction works will be conducted in line with the environmental management plan, as outlined in Volume 2 Chapter 24. This plan includes the procedure to be followed for remediation work if contamination is encountered or suspected during the construction phase.

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 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 gas field activities

Management measures associated with mitigating the potential impacts caused by construction, operations and decommissioning can be achieved by incorporating the following principles:

- Establishing corporate responsibilities and imposing accountability by individuals at all levels of the life of the facilities
- Clearly communicating to the workforce the Project's construction and operational environmental requirements, to ensure compliance with relevant environmental regulations and operating standards
- Establishing a process that provides all project employees with the necessary knowledge, skills and environmental awareness to undertake construction and all aspects of the Project's operations in a safe and environmentally sound manner
- Implementing an incident response plan that provides immediate notification of any incident and subsequent investigation into the root cause, followed by remedial/corrective action which will be monitored to ensure the type of incident cannot reoccur.

The construction of the various gas field elements will result in the use of construction plant that will require fuel and hydraulic oil and engine oil for maintenance. Other chemicals may also be used for construction including paint, concrete additives, lubricants and so on. Additionally, the remoteness of some locations will require the establishment of temporary accommodation facilities for construction staff. These could generate significant volumes of waste, and add to the waste construction materials generated.

Treatment of wastewater generated during the gas extraction process will require the construction of temporary storage ponds, brine ponds and associated water treatment facilities. The brine water is extremely saline (approximately 60g/L of salt) and will initially be stored in brine ponds for evaporation. The preferred option is to inject the brine back into geologically suitable aquifers at depth, if deemed feasible. The impacts and mitigation measures associated with temporary storage ponds and brine ponds are discussed in detail in Volume 2 Chapter 10.

Standard good construction practice will be adopted to protect against land contamination due to construction activities, and to remediate where it occurs. Such measures will include:

- Establishing fuel and chemical stores
- Ensuring permanent fuel and chemical stores, and maintenance and refuelling areas are provided with secondary containment
- Installing interceptor pits or similar to collect runoff and treat where required
- Installing tanks above ground with impermeable liners and bunds around tanks
- Visually inspecting decommissioned and rehabilitated chemical and fuel store areas, and removing and managing any contaminated soil found present, according to DERM guidelines
- Assessing contamination in the event of fire and, where appropriate, remediating or managing in accordance with relevant legislation and guidelines
- Keeping maintenance records and implementing monitoring checks for leaks, for all plant used on the gas fields
- Installing readily accessible spill kits and training staff in their use

- Assessing hydrotest water before use and subsequent release to ensure it meets local surface water discharge criteria.

Given the proposed waste management controls to be established for the gas fields, the risk of significant land contamination occurring is low and potential impacts are therefore also low.

Volume 2 Chapter 12 and Volume 2 Chapter 16 provide further detail on water and waste management respectively, while the environmental management plan in Volume 2 Chapter 24 describes management strategies.

1.6 Conclusion

1.6.1 Assessment outcomes

The mitigation and management strategies presented in Section 1.5 represent measures that are typically implemented by Australian Pacific LNG at its existing coal seam gas operations in the Surat Basin. In addition, Table 5.8 includes the residual risk levels. A risk assessment has been undertaken to identify potential risks, causes and consequences from gas fields' 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.

Australia Pacific LNG will thus commit to continue to implement these measures during the construction, operation and rehabilitation of disturbed areas associated with the gas fields. Such measures will ensure that the overarching sustainability principles and maintenance of existing land-based environmental values are achieved. These are summarised in Table 5.8.

Table 5.8 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 extractive resources to be sourced for construction material.	Minimising adverse environmental impacts and enhancing environmental benefits associated with its 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.	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 extractive resources for gas fields development. Development of new and/or expansion of existing quarries.	Identify size and local demand of existing extractive resources. Require suppliers of extractive materials to follow approvals process in accordance with applicable legislation. Re-use materials on site where practicable. Mobile crushers may be used to minimise the need for quarry materials from external sources. Maintain private and public road conditions. Undertake any direct extraction operations in accordance with environmental management and operation plans and in compliance with DERM and local council operational conditions (including relevant emission levels).	Low
Existing landform character and stability.	Identifying, assessing, managing, monitoring and reviewing risks to its workforce, its property, the environment and the communities affected by its activities.	Change to topography Change to drainage Visual amenity Waterway bank instability	All phases	Landform modification through stormwater diversion, vegetation clearing and	Implement a sediment and erosion control plan, including management of runoff to minimise concentrated flows and sediment runoff. Re-use construction materials, where practicable.	Medium

Environmental values	Sustainability principles	Potential impact	Project phase affected	Possible causes	Mitigation and management measures	Residual risk level
		Destabilisation of soils Degraded downstream water quality.		earthworks	Control compaction of fill to minimise soil mounding or settlement. Site structures on relatively level sites where possible. Undertake a geotechnical slope analysis. Incorporate works and measures to minimise risk of damage to creek banks in detailed design of creek crossings.	
Existing soil resource, including values for agricultural productivity.		Loss of topsoil quality and quantity.	Construction	Incorrect stripping, prolonged exposure and erosion. Soil inversion (replacement of topsoils with subsoils). Poor rehabilitation and drainage management.	Undertake site specific topsoils assessment, if necessary. Coordinate site clearance with landholders. Progressively clear and rehabilitate land. Minimise vegetation clearing, as far as practicable. Mulch vegetation and use as a protective layer to facilitate revegetation and minimise erosion. Remove rocky material during stripping, where practicable. Apply nutrients/conditioner or suitable seed stock to topsoil stockpiles, if required. Re-use stripped topsoils in areas of similar	Low

Environmental values	Sustainability principles	Potential impact	Project phase affected	Possible causes	Mitigation and management measures	Residual risk level
					soil types or stockpile for alternative use. Stockpile vegetation and soil groups separately, taking care not to mix soil types. Limit topsoil stockpiles to 2m in height to maintain fertility and vegetated if stockpiled for extended periods and space stockpiles appropriately. Implement a sediment and erosion control plan. Monitor and control weeds.	
		Increased salinity leading to poor rehabilitation and corrosion of civil structures.	Construction	Poor soil handling (removal, stockpiling and respreading) leading to soil inversion. Blending of non-saline and highly saline soils. Erosion. Inadequate monitoring of rehabilitation.	Undertake a geotechnical investigation to assess corrosion protection requirements within saline subsoils. Replace saline subsoils, where encountered, at depth and covered with topsoil. Import topsoil in areas where there is little topsoil or there is evidence of existing salinisation, where practicable. Undertake progressive rehabilitation and stockpiling of soils near the site of excavation to minimise potential blending between non-saline and highly saline soils. Minimise vegetation clearing, where practicable.	Low

Environmental values	Sustainability principles	Potential impact	Project phase affected	Possible causes	Mitigation and management measures	Residual risk level
					Isolate drilling fines in sumps and rehabilitate. Encapsulate remaining saline solids from brine ponds, or inject into deep formations, or remove and dispose of in an appropriate facility. Dispose of saline water to meet the requirements identified in Volume 2 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	All phases	Vegetation clearing Poor drainage management Concentrated flow discharge (i.e. point discharge) Improper sediment and erosion controls Inadequate earthworks contractor training and supervision	Develop and implement a sediment and erosion control plan which includes redirection and management of runoff to minimise concentrated flows. Construct sediment fences and/or sediment detention structures on the downhill side of excavated areas and around stockpiles and retain until area is stabilised. Undertake regular inspection of sediment and erosion control measures and areas receiving concentrated flows. Install contour banks at appropriate intervals. Undertake progressive clearing and rehabilitation and creation of stable slopes.	Medium

Environmental values	Sustainability principles	Potential impact	Project phase affected	Possible causes	Mitigation and management measures	Residual risk level
		downstream areas Decline in fertility Poor rehabilitation and drainage management			Stabilise erosive/dispersive areas which are exposed for extended periods. Construct access tracks across slopes, or have contour banks at appropriate intervals where access tracks go down a slope. Install trench breakers in the backfill at interval appropriate to slope steepness. Construct sediment basins on the downhill side of facilities when they are near sensitive receptors. Determine suitable discharge locations in consultation with landowners and relevant federal, state or regional authorities. Construct through creeks when they are dry, where practicable and dam or divert existing water around construction site. Excavate pipe trench perpendicular to direction of water flow and backfill carefully. Ensure creek rehabilitation is consistent with surrounding environment and contours of the channel at the time of construction and protected with fencing where required. Locate point discharges into stable waterways and/or drainage lines and	

Environmental values	Sustainability principles	Potential impact	Project phase affected	Possible causes	Mitigation and management measures	Residual risk level
					implement engineering controls such as scour protection and flow velocity limits. Discharge water from construction sites through silt fences or other erosion control measures if required. Conduct routine (and following severe rain events) inspection of waterway.	
		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	All phases	Construction and operation of gas fields' infrastructure.	Locate gas field facilities away from areas that would impinge on the productive capacity, where practicable. Consult landholders regarding farming operations to ensure timing of works does not unduly affect farming operations. Undertake appropriate topsoil management and drainage management. Remove wastes as per regulatory requirements (refer Volume 2 Chapter 16) Rehabilitate disturbed areas with vegetation types consistent with the surrounding environment, where practicable.	Medium

Environmental values	Sustainability principles	Potential impact	Project phase affected	Possible causes	Mitigation and management measures	Residual risk level
		operations and restriction on land use				
Existing qualities of the air environment, including the life, health and wellbeing of the community		Degradation of soil structure and dust generation	Construction	Clearing of vegetation and increased traffic.	Identify appropriate on-site traffic routes. Remove vegetation and topsoil where new tracks are required. Surface on-site access roads with gravel and/or geotextile or surface additives. Revegetate as soon as practical.	Low
Existing condition of soil and water resources.		Contamination of soil and potentially groundwater.	Construction	Pre-existing contamination.	Avoid contaminated areas by relocating infrastructure, where possible, otherwise conduct investigations of all identified areas of potential contamination prior to construction as per the former Department of Environment's draft guidelines. Remediate and/or manage site contamination if disturbance of contaminated area is unavoidable, in accordance with regulatory requirements. Conduct pre-construction surveillance of land to identify potential contamination where practicable. Surveillance to be performed by suitably trained and qualified person.	Low

Environmental values	Sustainability principles	Potential impact	Project phase affected	Possible causes	Mitigation and management measures	Residual risk level
					If unexpected contamination is identified, stop work, investigate the nature of the contamination and determine remedial or site management actions. Notify DERM 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.	
		Contamination of soil and potentially groundwater.	All phases	Drilling fluids Spills and leaks from chemical and fuel storage Pipeline leaks and rupture Discharge of hydrotest water Putrescible waste and leachate Removal of plant, equipment and infrastructure	Store drill cuttings in a sump then mix with sub-soil and bury on site and cap with subsoil prior to rehabilitation and transport drill mud to a water treatment facility for treatment as required. Establish chemical and fuel stores in accordance with relevant Australian Standards, including AS 1940:2004. Implement chemical, fuel and waste handling procedures, including spill kit awareness information in induction training. Remediate or manage contamination under the supervision of a suitably qualified person as per Section 381 of the EP Act and be in accordance with the former Department of Environment's draft guidelines.	Low

Environmental values	Sustainability principles	Potential impact	Project phase affected	Possible causes	Mitigation and management measures	Residual risk level
					Install fuel storage tanks above ground and in accordance with relevant standards (including bunding). Conduct maintenance inspections of plant, equipment pipelines and vehicles. Implement controls measures to collect spills during construction, commissioning, operations and decommissioning. Implement integrity monitoring for spill control measures and pipeline leaks. Implement emergency response plan in the event of pipeline leak or rupture. Store all putrescibles and leachable waste (which is not recycled) in impermeable containers for disposal off-site at appropriate facilities. Undertake a detailed risk assessment of contaminated land prior to removal of plant, equipment and infrastructure and manage or remediate in accordance with relevant guidelines.	

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1.6.2 Commitments

For the construction, operation, and decommissioning of the Project within the gas fields, Australia Pacific LNG will:

- Avoid areas of severe erosion potential where practicable
- 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
- Point discharges will be directed to stable waterways and/or drainage lines with appropriate engineering controls, such as scour protection and flow velocity limits
- 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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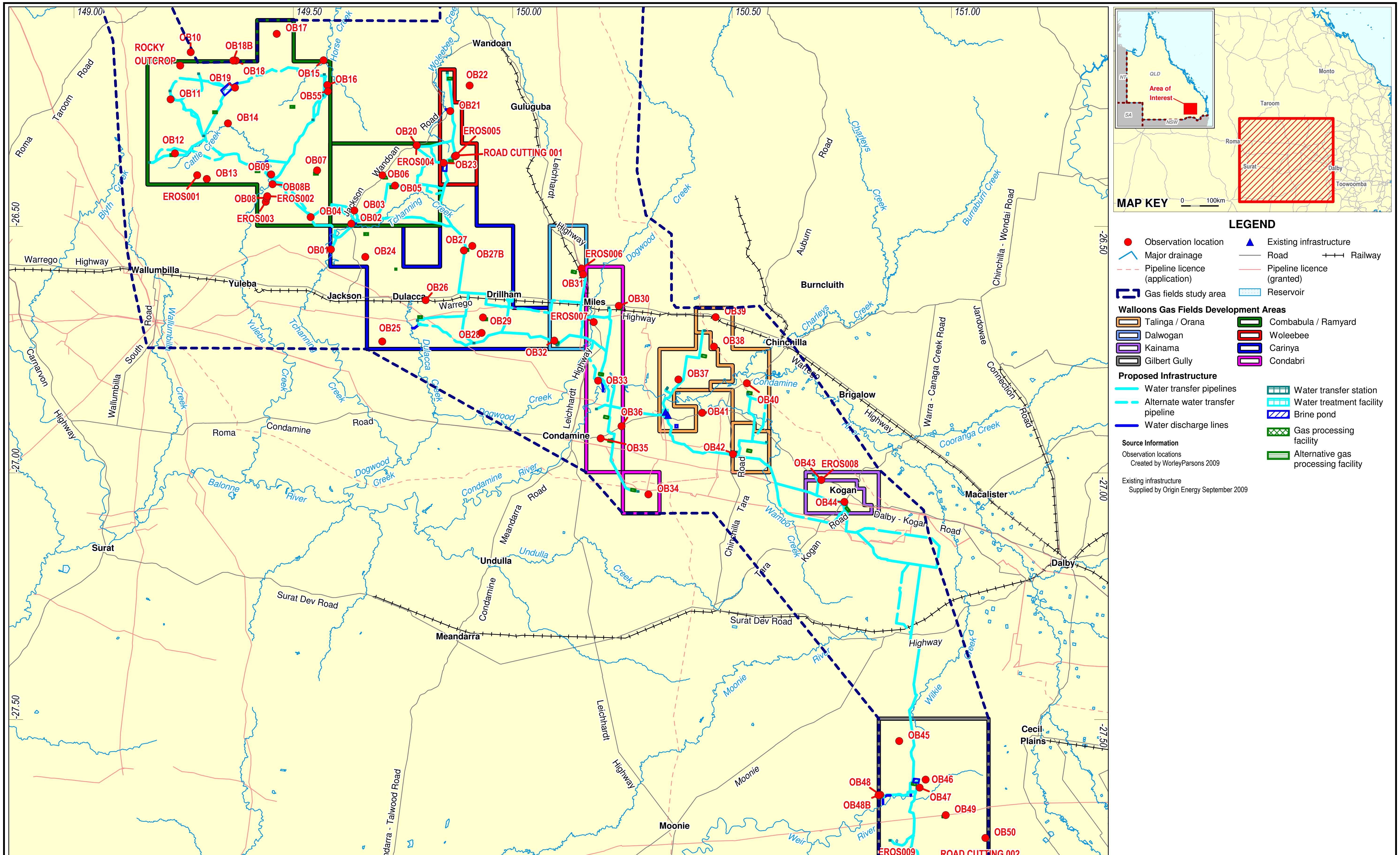
Figures



AUSTRALIA PACIFIC LNG PROJECT

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Figure 5.1 - Overview of study area observation locations

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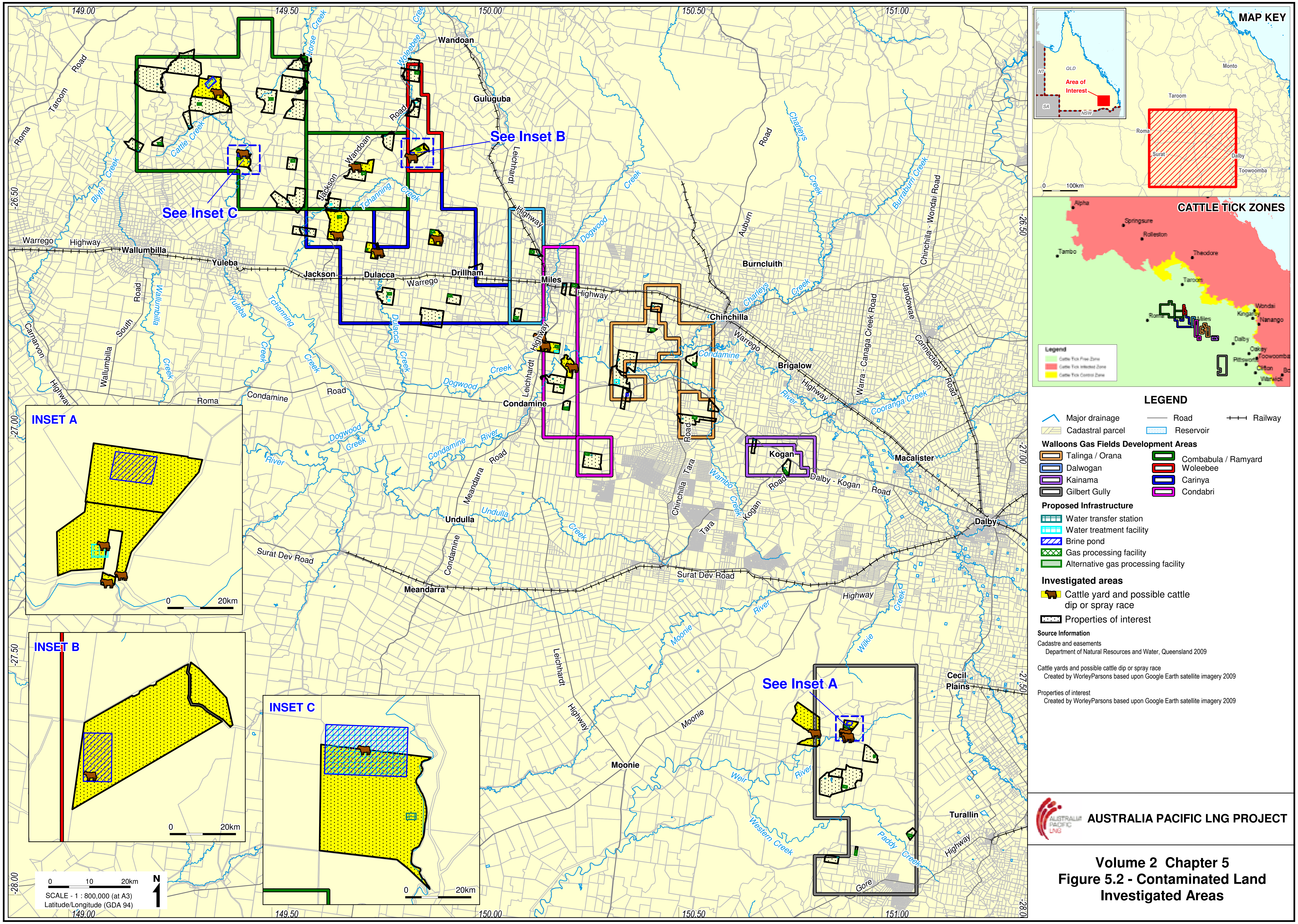

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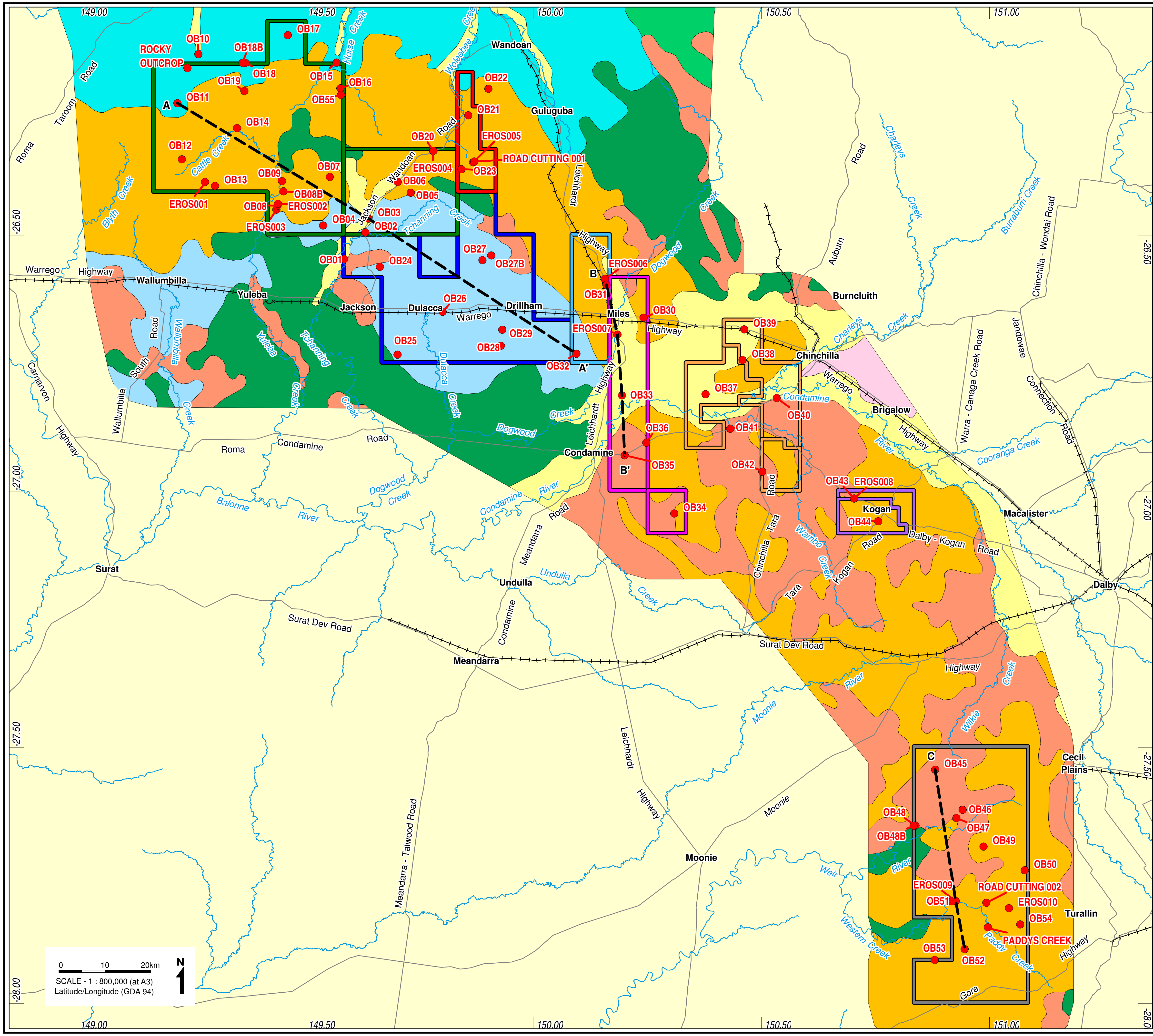
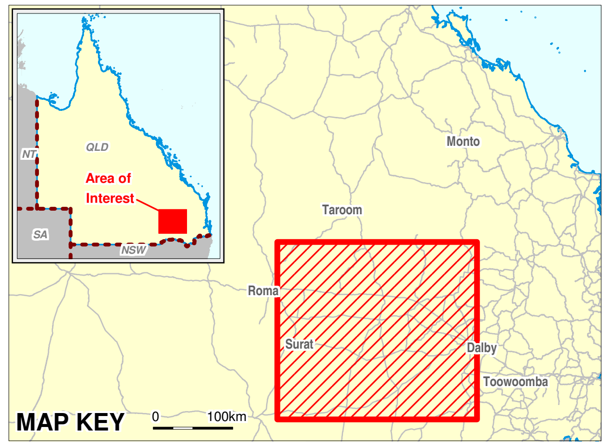
Figure 5.2 - Contaminated Land Investigated Areas

K:\ORIGIN\301001-00448\GIS\Maps\00448-00-EN-DAL-2284-Rev0(Vol2Chp5_Investigated_areas).wor





LEGEND

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

Walloons Gas Fields Development Areas

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

Geology

C5, Cvt, Czs, Dc, DCc, DCy, Ji, JKb, Jlb, Ku, Pb, Plv, Ply, PR1, PR2, Puw, Puy, Qa, Qm, Rc, Re, Rm, Rr, T, Tl, Tm, TQ, Tv

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).

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Figure 5.3 - Overview of study area geology and cross section profile locations

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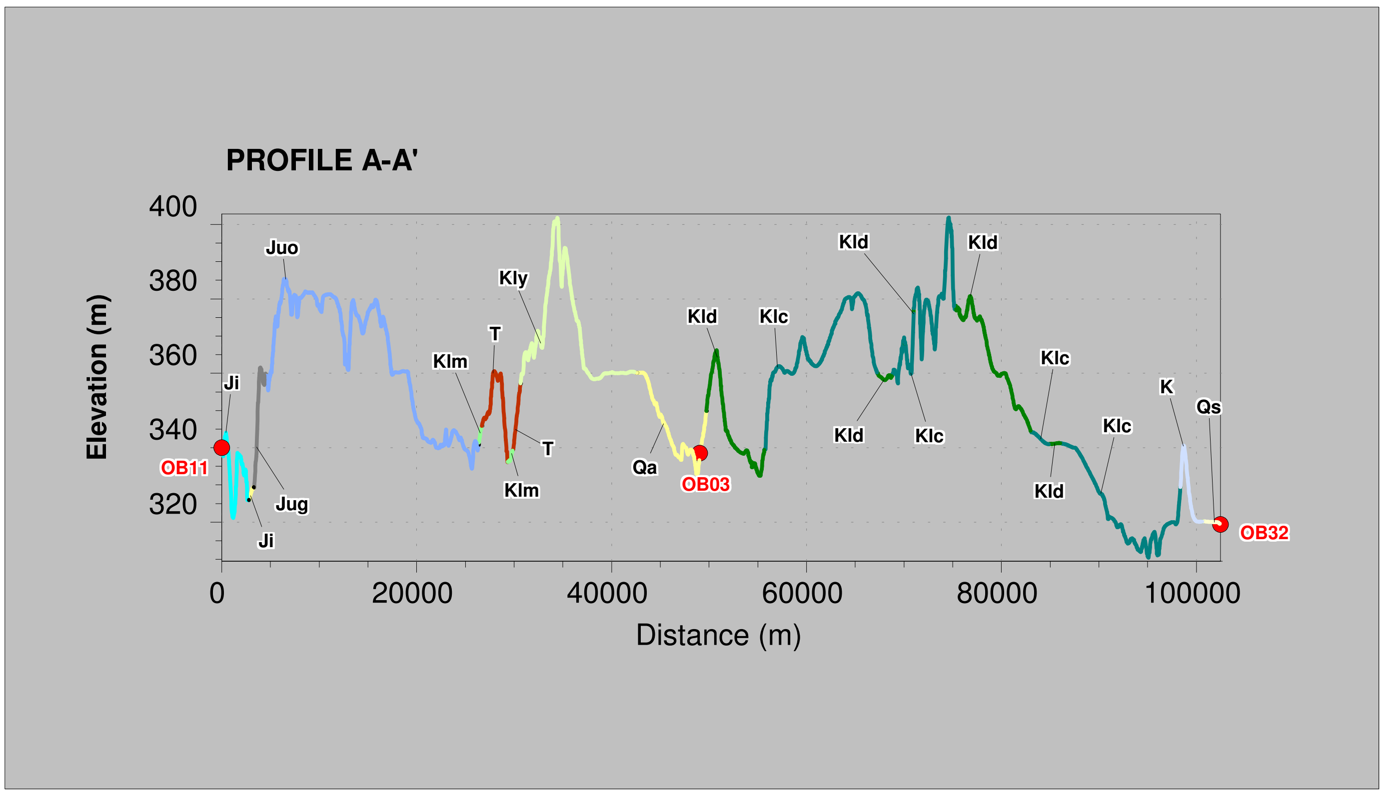

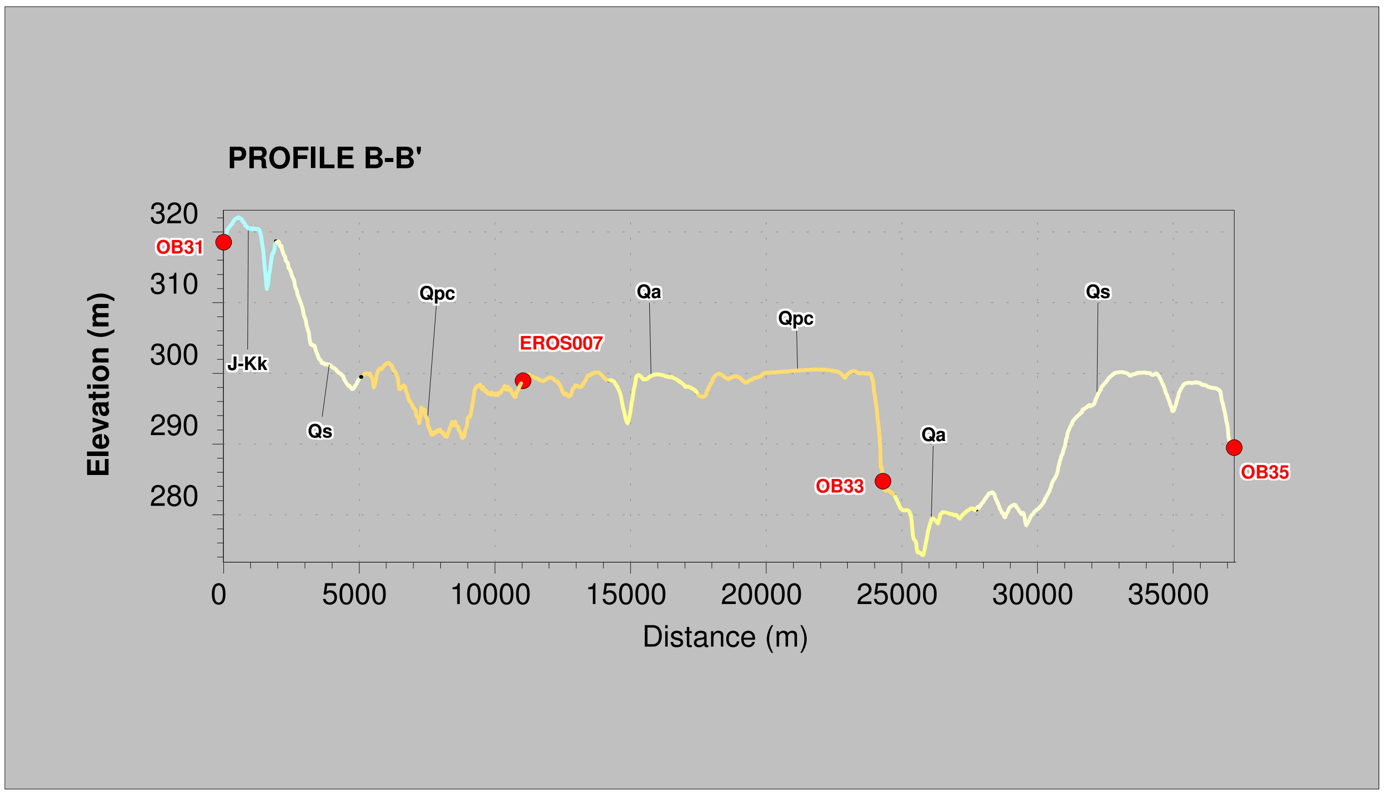

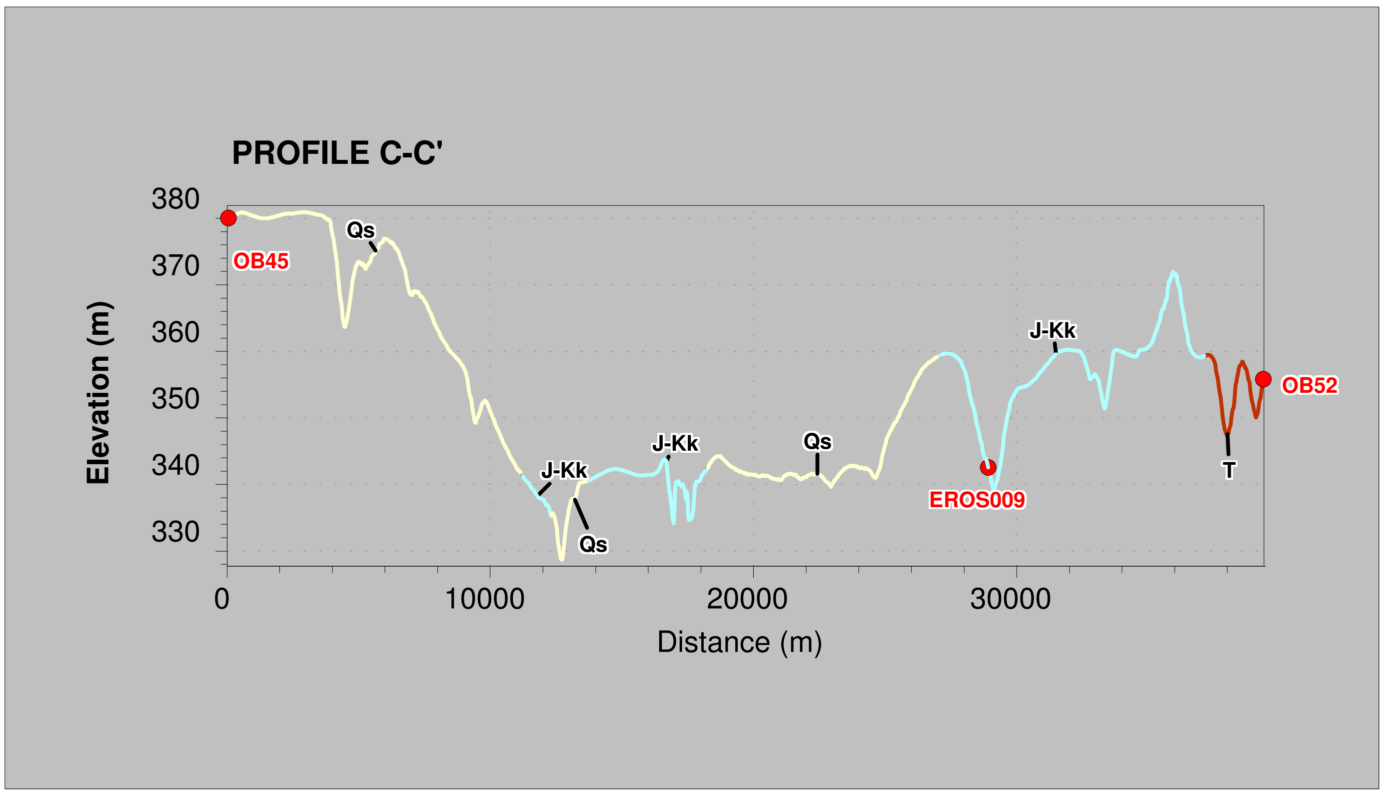

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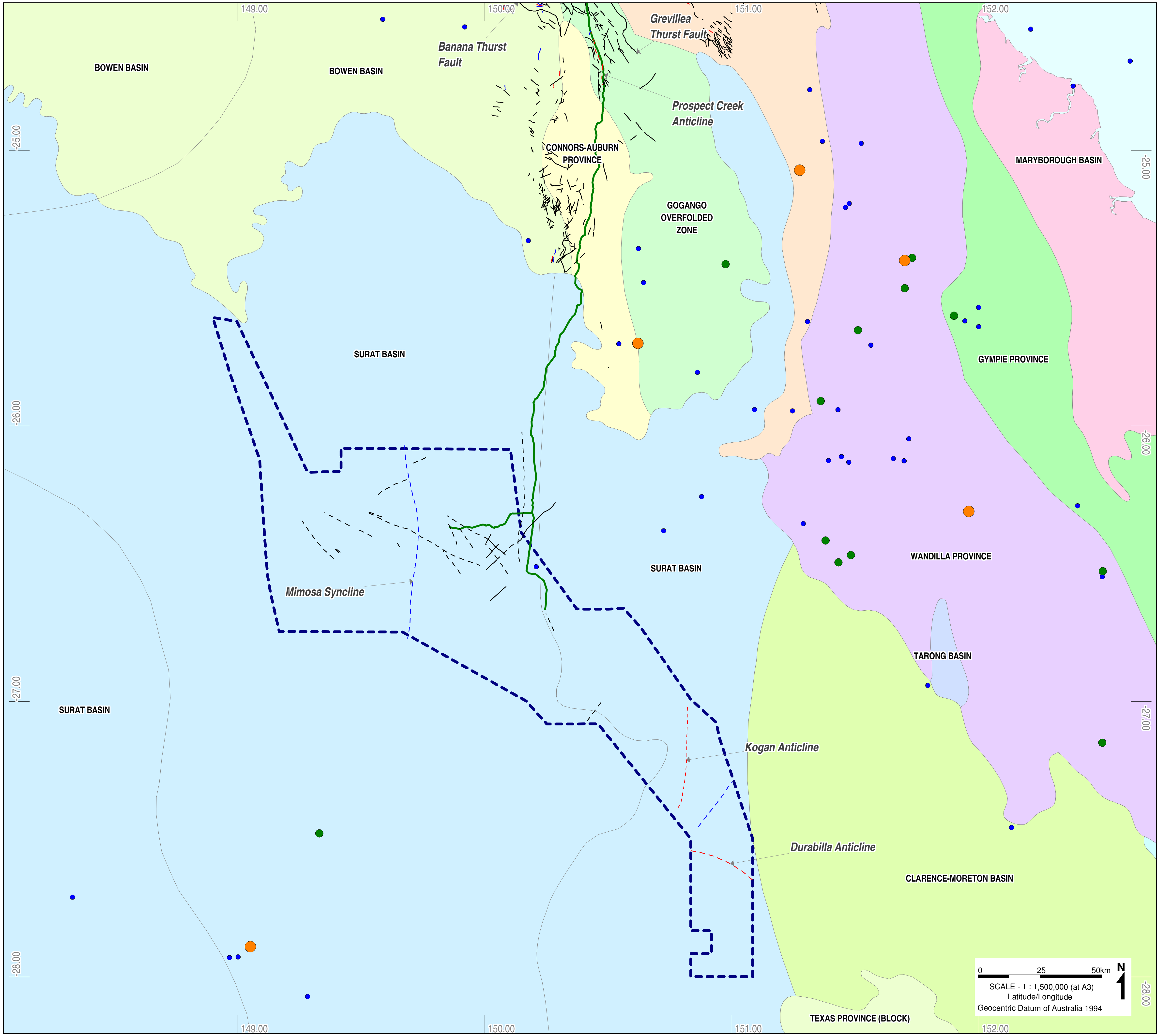
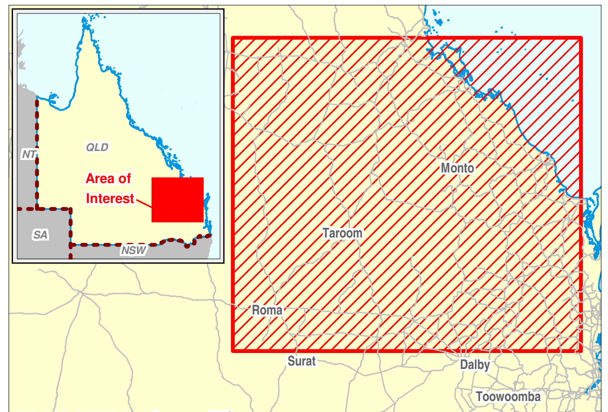
Figure 5.4 Study Area
Geological Cross Sections





MAP KEY

LEGEND

Proposed Infrastructure

- Gas pipeline route
- Gas fields study area
- 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

Tectonics

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

Source Information

Preferred pipeline alignment
Supplied by Origin Energy November 2009

Tectonics
Data downloaded from the Interactive Resource and Tenure Maps (IRTM) website of the Queensland Department of Mines and Energy

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

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Figure 5.5 - Historical earthquakes 1958 onwards and tectonic boundaries

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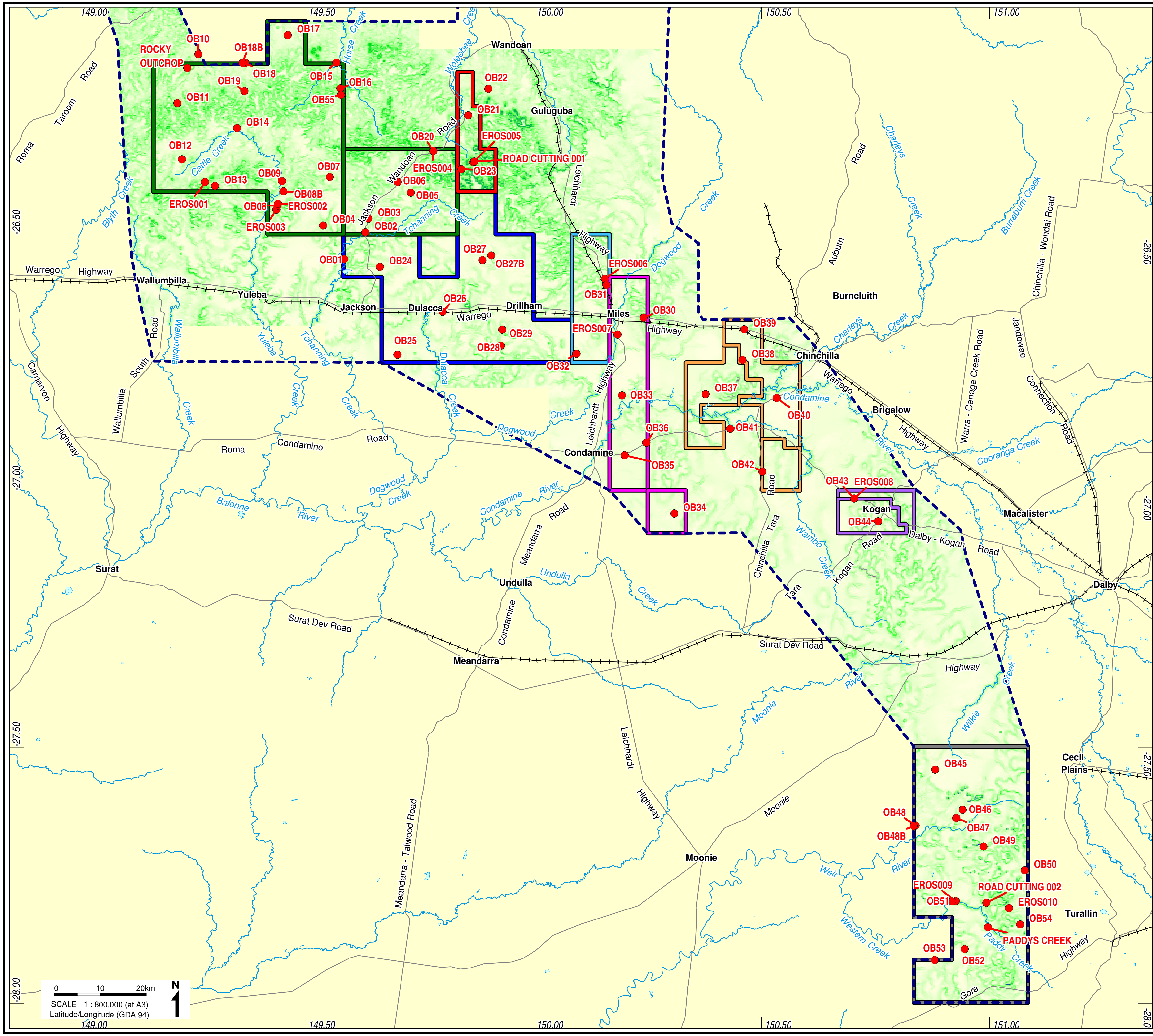
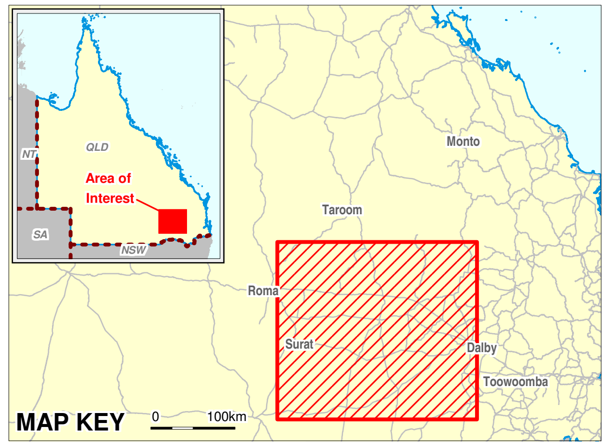


MAP KEY



LEGEND

- Observation location
- Railway
- Road
- Major drainage
- Reservoir
- Gas field study area

Walloons Gas Fields Development Areas

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

Slope Grid

Derived from DNRW 25m DEM

50
40
30
20
10
0

Z-units: % Grade

Source Information

Slope

Created by WorleyParsons November 2009 from 25m DEM (Queensland Department of Natural Resources Mines and Water 2007).

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Figure 5.6 - Overview of study area digital slope analysis

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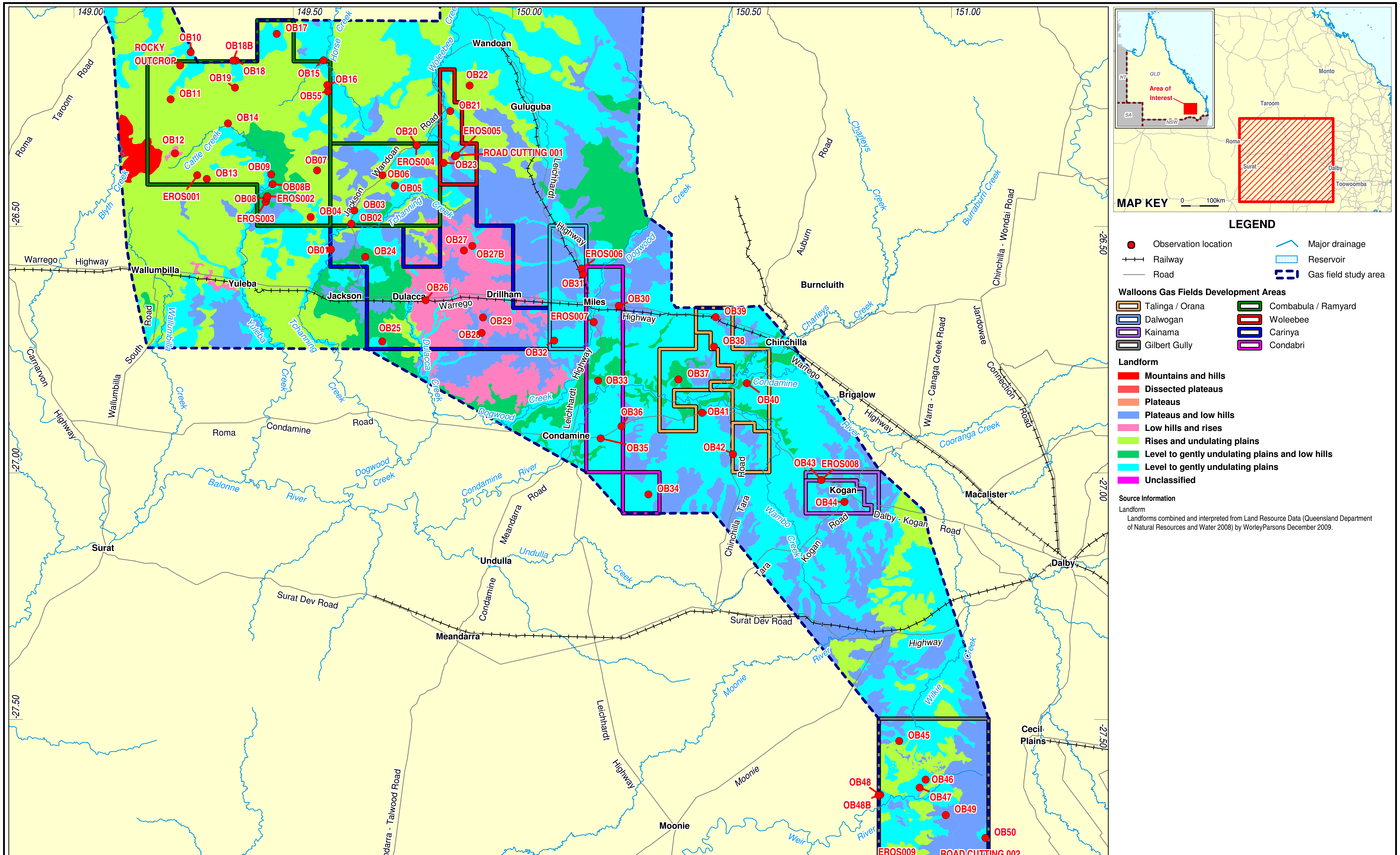

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Figure 5.7 - Overview of study area landform

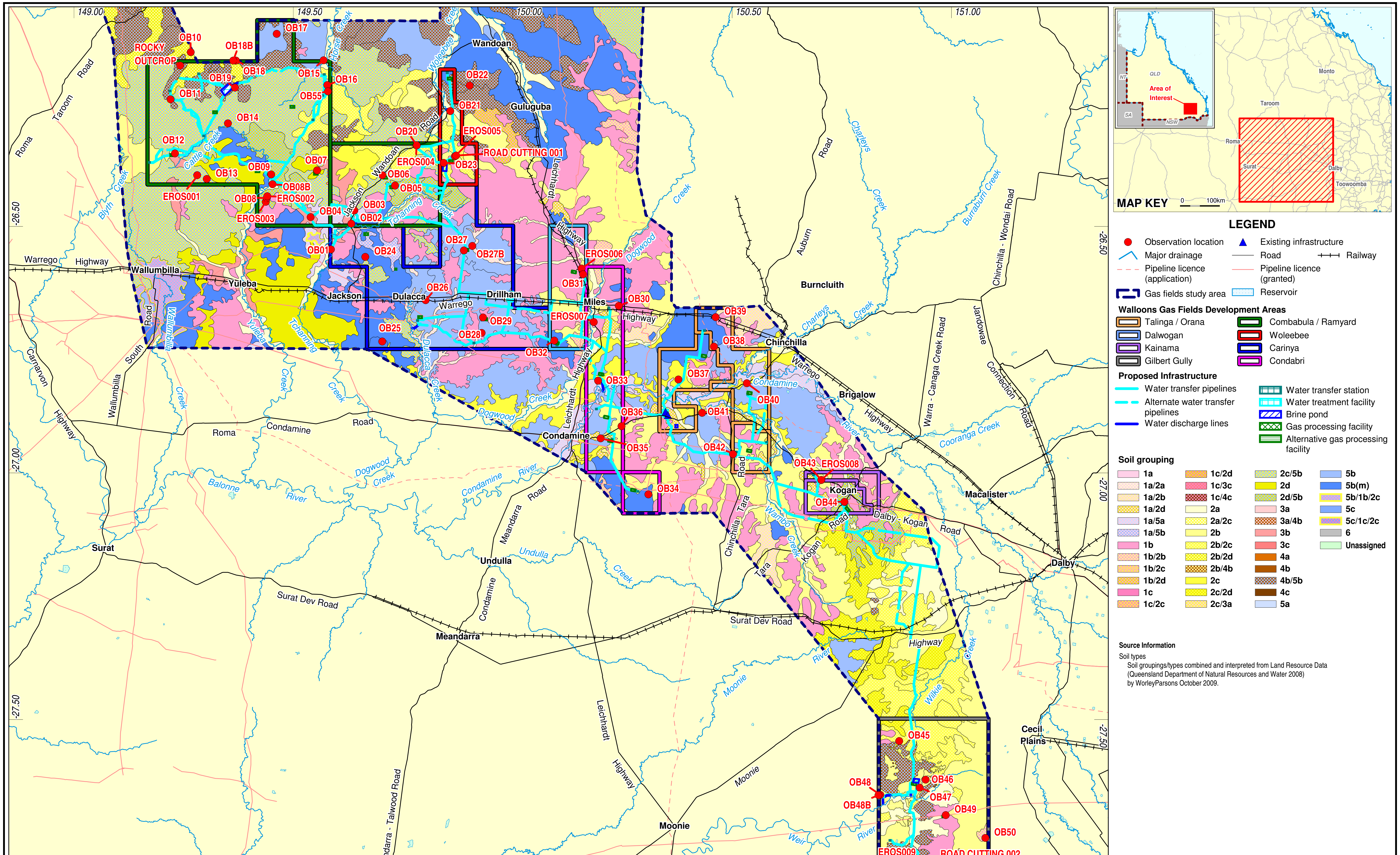

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Figure 5.8 - Overview of study area soil types

K:\ORIGIN\301001-00448\GIS\Maps\00448-00-EN-DAL-2126-Rev0(Vol2Chp5_Soils).wor

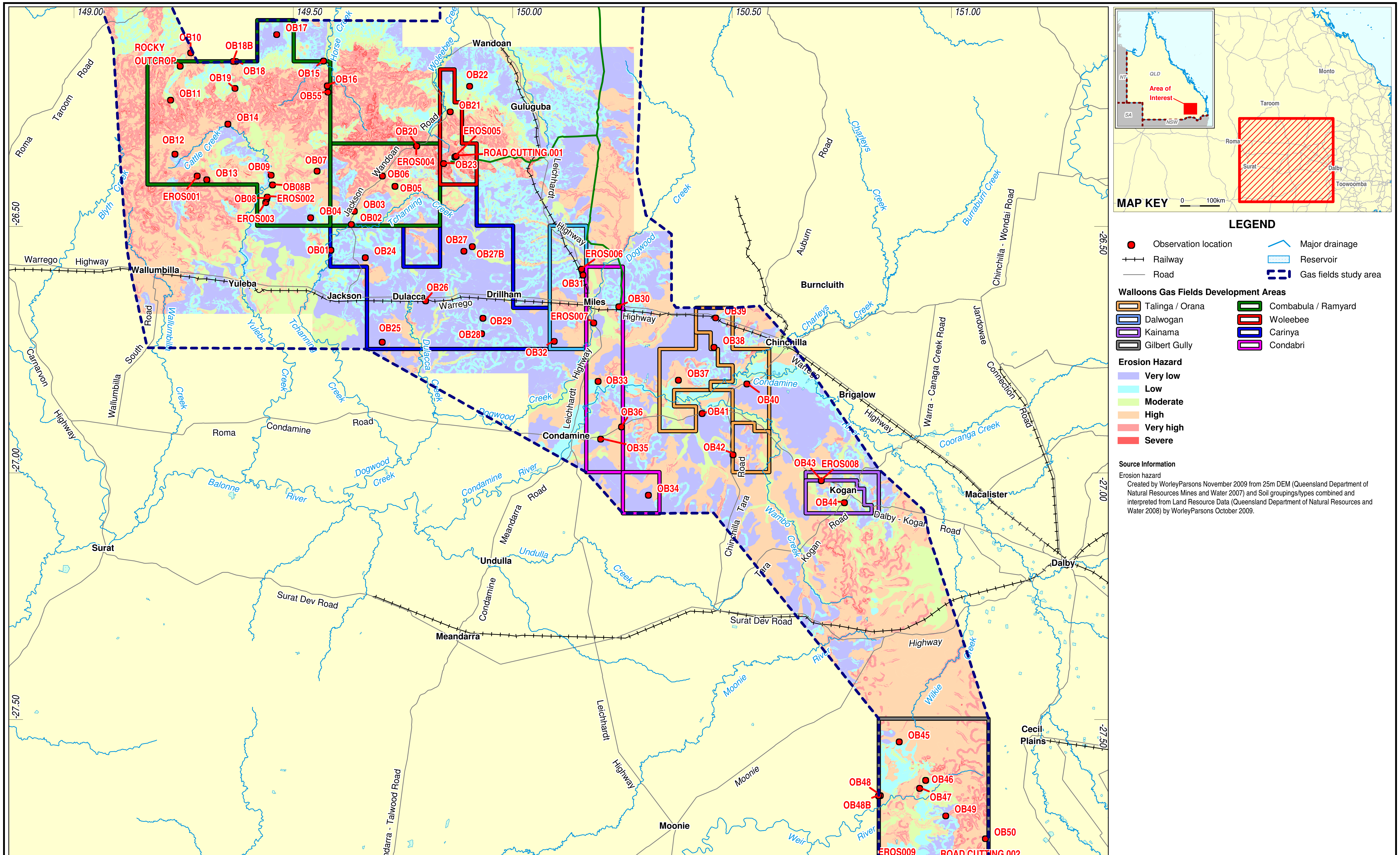

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Figure 5.9 - Overview of study area erosion hazard

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