9 GEOLOGY, MINERAL RESOURCES, OVERBURDEN AND SOILS

9.1 INTRODUCTION

This chapter outlines the geology, mineral resources, overburden and soil characteristics of the site and details the rehabilitation requirements of the Wandoan Coal Project (the Project). A detailed technical report is presented in TR 9-1-V1.5 Geology, Mineral Resources, Overburden and Soils Impact Assessment. Note that figures and documents with numbering ending in V1.5 refer to figures/documents contained in Volume 1, Book 5 of the EIS.

9.2 METHODOLOGY OF ASSESSMENT

The assessment was conducted in two parts, a soil, land resource and overburden assessment of the mining lease application (MLA) areas and a desktop soil and land resource assessment for the gas supply pipeline and MLA associated infrastructure.

9.2.1 EXISTING INFORMATION

Previous investigations that provided information for this report regarding soil, overburden and landscape characteristics (topography and geomorphology) include:

- Slater, B, Bell, L and Whiteman, P (1980). Wandoan Coal – Resources for Land Rehabilitation. Progress report on the Research for Brigalow Mines Pty Ltd. University of Queensland Department of Agriculture
- Slater, B, Bell, L and Whiteman, P (1983). Land Evaluation of Potential Coal Mine Areas at Wandoan, Queensland. University of Queensland Department of Agriculture
- Gray, H.J and Macnish, S.E (1985) Land Management Field Manual Wandoan District
- Forster, B.A (1985). Evaluation of Agricultural Land in Taroom Shire
- CSR Coal Division (1986). An Assessment of Overburden Rehabilitation Properties of the Wandoan Coal Project
- Slater, B (1986). Edaphic Properties of Soil and Overburden from a Potential Coal Mine near Wandoan, Queensland. University of Queensland Department of Agriculture
- Godfrey, N (1992). EPC 157 Wandoan March 1992 Drilling Program Slake Testing Report
- Envirosciences Pty Limited (1992). Land Capability and Use. Austinvale and Frank Creek Coal Deposit Areas, Wandoan. MIM Holdings Limited
- MIM Holdings Limited (1997). Consideration of Rehabilitation Strategies Associated with the Austinvale Coal Deposit, Wandoan, Queensland
- Golders Associates Pty Ltd (2008). Report on Geotechnical Evaluation for Open Pit Mining, Wandoan Coal Project, Wandoan, Queensland (Draft).

9.2.2 OVERBURDEN

An overburden investigation was conducted within the MLA areas. An overburden assessment was not conducted for the MLA associated infrastructure or gas supply pipeline, as significant overburden disturbance will not occur for these components of the Project. The investigation was conducted to assess the following characteristics of the overburden and interburden:

- erosion potential
- acid generation potential and heavy metal content
- suitability of overburden for use as a capping layer and growth medium.

The overburden investigation included laboratory analysis of rock cores from four boreholes that were drilled as part of the wider investigation program (refer Figure 9-2-V1.3).

Findings of previous investigations (e.g. CSR Coal Division 1986, Godfrey 1992, Slater 1986) were compared to the overburden laboratory analysis results of the current investigation. Both sets of results were re-assessed and correlated to include most encountered geological units over a wider area of the MLAs.

Selected overburden samples were tested in a NATA registered laboratory for the following physical and chemical properties — the method used for each analysis is included in brackets:

- net acid generation at pH7 (NAG); pH after oxidation; Acid production potential (APP); Acid neutralising capacity (ANC); Net acid producing potential (NAPP)) (Miller (1998), US EPA 600/2-78/054, and Coastech Research methods)
- heavy metals – arsenic, cadmium, chromium, copper, lead, nickel, zinc (US EPA, SW 846, Method 6010)
- exchangeable sodium percentage (ESP) – chemically exchangeable sodium can weaken the bonds between clay particles thus acting as a dispersing agent. Overburden with an ESP of more than 15% are considered dispersive and overburden with an ESP less than 5% are commonly considered as non-dispersive. (Australian Laboratory Services 'in-house' methods)
- cation exchange capacity (CEC) – the overburden's capacity to hold nutrients is estimated by CEC. Low values (below 5) indicate the overburden is infertile and prone to leaching and therefore is likely to be a poor growth medium requiring nutrient application. (Australian Laboratory Services 'in-house' methods).

The potential for acid drainage was based on the requirements of the Assessment and Management of Acid Drainage (Department of Mines and Energy 1995b).

Heavy metal concentrations within the overburden were assessed against the Draft Guidelines for the Assessment of Contaminated Land in Queensland (Environmental Protection Agency 1998) for environmental investigation levels and health-based investigation levels (Department of the Environment 1998).

9.2.3 SOILS

A soil investigation was conducted within the MLA area, MLA associated infrastructure area and gas supply pipeline corridor to:

- characterise the soil types
- define land suitability classification of the sites
- assess available topsoil types and suggested stripping depths
- assess the dispersion and erosion potential of various topsoil and subsoil materials.

The soil investigation comprised a review of existing geotechnical, geological and soil data. Within the MLA area the investigation included the excavation of test pits, a walk-over survey of the area, and laboratory testing of selected samples. The investigation was conducted in accordance with The Planning Guidelines: the Identification of Good Quality Agricultural Land (Department of Primary Industries and Department of Housing, Local Government and Planning, 1993).

Soil survey

Details of test pit locations are shown in Figure 9-1-V1.3. Test pit locations were selected based on the geological and topographic features of the site, in consideration with the provisional layout of the proposed mining operations.

Test pit log records are shown in Attachment A of TR 9-1-V1.5: Geology, Mineral Resources, Overburden and Soils Impact Assessment, together with a set of explanatory notes, which define the terms and symbols used in their preparation. Topsoil (A1 horizon) descriptions are in accordance with those used in the Australian Soil and Land Survey, Field Handbook (McDonald et al. 1990).

Fieldwork investigations for the Project, which assessed the soil and land capability, consisted of the following:

- excavation and sampling of 41 test pits within the MLAs
- topsoil, topographic, vegetation and geomorphic observations were also made at opportunistic locations, such as cuttings, washouts and creeks.

Test pits were excavated up to 2.3 m depth, using a rubber tyred backhoe, hand auger or a hand shovel. Selected disturbed samples of surface soils and subsurface material were obtained either at regular intervals or at the change of strata for material identification and laboratory testing.

The locations of test pits were recorded using a Garmin hand held GPS unit, and checked (approximately) against site features and map readings. The accuracy of this survey method is considered to be within an accuracy of approximately 7 m in plan. The approximate surface elevation (RL) of test locations were determined by GIS (geographic information systems) using standard interpolation methods from a supplied digital terrain model.

Soil classification system

Classification of soils on the Project was based on field observations, laboratory analytical data and published soil classification data (refer TR 9-1-V1.5 Geology, Mineral Resources, Overburden and Soils Impact Assessment).

The adopted soil classification system is the *Australian Soil Classification* System (Isbell 1996). Where soil descriptions correlate with soil types in the resources listed in Section 9.2.1, soil names used in these resources have been adopted.

Laboratory testing

Selected soil samples were tested in a NATA registered laboratory for the following physical and chemical properties — the method used for each analysis is included in brackets:

- exchangeable sodium percentage (ESP) – ESP is a measure of the sodicity of soils. Chemically exchangeable sodium can weaken the bonds between clay particles thus acting as a dispersing agent. Soils with an ESP of more than 15% are considered dispersive and soils with an ESP less than 5% are commonly considered as non-dispersive. (Australian Laboratory Services ‘in-house’ methods)
- cation exchange capacity (CEC) – the soil’s capacity to hold nutrients is estimated by CEC. Low values (below 5) indicate the soil is infertile and prone to leaching and therefore is likely to be a poor growth medium requiring nutrient application. (Australian Laboratory Services ‘in-house’ methods)
- conductivity (EC), pH, sulphate as SO_4, chloride, total nitrogen, total phosphorous, organic carbon, water soluble nitrogen, and DTPA soluble iron, manganese, copper and zinc content of soil (Australian Laboratory Services ‘in-house’ methods).

Laboratory test results are shown in Attachment C of TR 9-1-V1.5 Geology, Mineral Resources, Overburden and Soils Impact Assessment.

9.2.4 LAND SUITABILITY ASSESSMENT

A land suitability assessment was carried out over the Project area based on the requirements of Attachment 2 of the Land Suitability Assessment Techniques (Department of Mines and Energy, 1995a). The Project area was assessed for its suitability for various uses including dry-land cropping and cattle grazing on improved pasture.

The findings of the land suitability assessment were then assessed against the GQAL mapping under the former Taroom Shire Council Planning Scheme. (Taroom Shire Council, 2006) to assess the accuracy of the GQAL mapping (see Section 9.3.7).

The land suitability of the proposed Year 30 mine landform was then compared to the existing landform to assess the potential impacts of the Project.

9.3 EXISTING ENVIRONMENT

9.3.1 TOPOGRAPHY AND GEOMORPHOLOGY

Topography

Mining lease application area and MLA associated infrastructure

A contour map of the Project area is shown on Figure 9-3-V1.3. Two main terrain elements were identified in the Project area:

- alluvial floodplains of Woleebee Creek, Wandoan (also known as Sundown) Creek, Frank Creek, Mud Creek, Spring Creek, and their tributaries. These floodplains vary in width from less than 500 m to about 2 km, and generally have a very gentle slope towards the creek channel and downstream, generally less than 2%. This landscape unit occurs at a reduced level (RL) between approximately 230 m and 250 m Australian height datum (AHD). The floodplains have largely been cleared for agricultural uses, including beef cattle grazing and limited fodder cropping on the floodplain edges. Remnant riparian vegetation is present along the creek lines
- low undulating hills, with an RL of between 250 m and 295 m AHD make up the majority of the Project area. Slopes are generally less than 4%, but up to 15% gradient for upper slopes in the western portion of the study area. The undulating hills are generally at a higher altitude in the south of the Project area than to the north. This is due to a regional slope away from the Great Dividing Range in the south towards the Dawson River Valley in the north. Land in the undulating terrain is largely cleared for agricultural uses, with limited fodder crops cultivation on the flatter gradients, and beef cattle grazing on steeper slopes. Common fodder crops include oats, wheat and leucaena *(Leucaena leucocephala)*. Grain cropping used to be prevalent over this area, but has been greatly reduced during the past 20 years, reportedly due to changed rainfall patterns and economic conditions.

Gas supply pipeline

The topography of the gas supply pipeline corridor is also shown on Figure 9-3-V1.3. The terrain elements are similar to those in the MLA area, with an overall slope downwards to the west, and can be described as:

- alluvial floodplains of Roche Creek, Stakeyard Creek and their tributaries. These floodplains display similar landforms as the floodplains in the MLA area described above, and occur at an RL between approximately 250 m and 300 m AHD in the vicinity of the gas supply pipeline corridor
- low undulating hills, with an RL of between 250 m and 280 m AHD in the western portion of the corridor, increasing in altitude to between 300 m and 340 m AHD in the eastern portion of the corridor. These hills have a similar form to the undulating hills in the MLA area described above.

9.3.2 GEOLOGY

Regional geology

The WJV has conducted detailed studies of the geology of the Wandoan region including photogeological interpretation (Snodin 2004). This photogeological mapping supports, but is more detailed than, the Geological Survey of Queensland's 1:250,000 series Roma and Taroom sheets. The geologic units in the wider Wandoan region occur in generally west-north-west to east-south-east trending bands, sub-parallel to the elevated topography of the Great Dividing Range, which is approximately 50 km south of Wandoan. Soils and the underlying geology of the Project site are from the following main geological units:

- quaternary age alluvium
- Middle to Upper Jurassic age Injune Creek Group, which, within the Project area, consists of:
    - the Westbourne Formation (siltstone, mudstone and fine grained sandstone)
    - the Springbok Sandstone (friable sandstone with beds of mudstone and thin coal seams near its base)
    - the Juandah Coal Measures, consisting of sandstone, siltstone, mudstone and coal
    - the Tangalooma Sandstone, consisting of clayey sandstone, minor siltstone, mudstone and coal.

A map illustrating the geology of the Project area is shown on Figure 9-4-V1.3, and a schematic cross sections provided in Figure 9-5. The field investigation carried out for this assessment confirmed the presence of the above units.

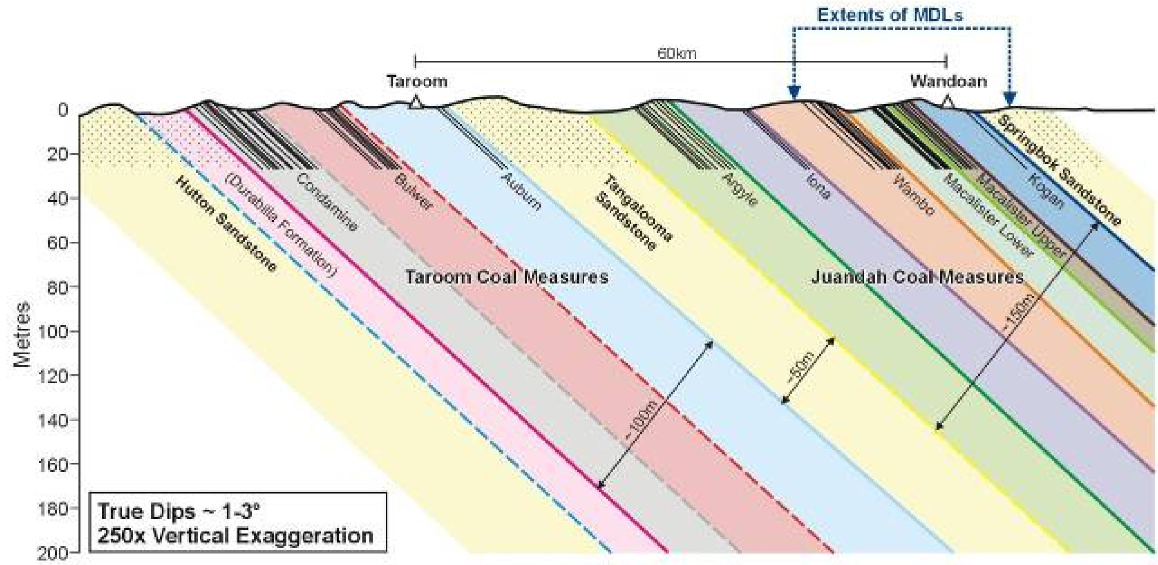

Figure 9-5: Geological cross section

Quaternary alluvium

The source material of the Quaternary age alluvium along the drainage lines is anticipated to be the Injune Creek Group rocks for the shorter drainage lines, including Frank Creek, Spring Creek, Mud Creek, Stakeyard Creek, Roche Creek and their associated tributaries. The alluvium of these creeks largely comprises sandy clay materials.

The longer Woleebee Creek has a higher discharge and flows through the Orallo Formation and Gubberamunda Sandstone that is further upstream from the Project site. Floodplain sediments along Woleebee Creek are influenced by these geological units and the higher discharge in this creek, and are mainly clayey sands.

Injune Creek Group

The Injune Creek Group includes the Westbourne Formation, Walloon Subgroup and Springbok Sandstone. The units that occur within the Project are the Walloon Subgroup (including the Juandah Coal Measures) and Springbok Sandstone.

The Juandah Coal Measures contain the economic coal reserves of the Project and comprises medium to coarse grained lithic sandstone, siltstone, mudstone and coal seams. The particle size generally increases with depth (Slater 1986).

The Taroom Coal Measures are sub-labile, medium grained sandstone, grading upwards to interbedded sandstone, siltstone, mudstone and coal. This unit outcrops north of the Project area.

9.3.3 GEOMORPHOLOGY

Drainage over the Project area is generally towards the north, with sediment slowly transported by the creeks via the floodplains towards the Dawson River, located to the north of the Project.

The narrow floodplains, gentle slopes, bedrock controlled channels and confined meanders of drainage lines suggest the landscape within the Project area is geologically young. The ephemeral creeks are slowly cutting into and eroding the undulating hills, with lateral erosion of the valleys being the main large-scale landscape altering activity, together with channel deepening. Temporary deposition of eroded material occurs on the narrow floodplains.

Erosion rates are anticipated to be low due to the relatively dry climate and low topographic gradient. Most erosion will occur during infrequent high rainfall events.

9.3.4 MINERAL RESOURCES

A number of individual coal deposits are present within the Project area as shown on Figure 9-5. Exploration permits for coal (EPC), mineral development leases (MDLs) and mining lease applications (MLAs) over these deposits are held by the WJV. The Project will involve the extraction of coal from these deposits.

No mineral exploration permits or leases exist over the Project area. A petroleum lease (PL171, held by Roma Petroleum NL), intersects the southern portion of MLA 50230. No pits or infrastructure are currently proposed within the area of PL171. Petroleum lease PL176 (granted), held by Santos QNT Ltd, intersects the gas supply pipeline corridor. This petroleum lease is part of the Peat-Scotia coal seam gas fields from which the gas supply for the Wandoan Coal Project is proposed to be sourced.

A number of exploration permits for petroleum (EPP) and exploration permits for coal (EPC) exist over the Project area (refer Figure 9-6-V1.3). These EPP and EPC are summarised below:

- EPP867 (application) held by Paillard Energy Pty Ltd
- EPP869 (application) held by Bow Energy Resources Ltd
- EPP852 (granted), held by Pure Energy Resources Limited
- EPP870 (application) held by Pure Energy Resources Limited
- EPP768 (granted) held by BNG (Surat) Pty Ltd
- EPP606 (granted) held by Origin Energy CSG Limited
- EPP747 (application) held by Arrow Energy Ltd
- a small portion of EPP810 (granted) held by Arrow Energy Ltd
- a small portion of EPP868 (application) held by Vamgas Pty Ltd
- a small portion of EPP692 (granted) held by Origin Energy CSG Limited
- a small portion of EPP 651 (granted) held by Queensland Gas Company Limited
- EPC 1500 (application) held by Holloman Mineral Pty Ltd
- EPC1322 (application) held by Surat Coal Pty Ltd
- EPC1205 (granted) held by Taroom Coal Pty Ltd
- EPC640 (relinquished) formally held by Anglo Coal (Taroom) Pty Ltd
- EPC838 (granted) held by Xstrata Coal Queensland Pty Ltd
- EPC788 (granted) held by Xstrata Coal Queensland Pty Ltd
- EPC792 (granted) held by Xstrata Coal Queensland Pty Ltd.

According to the Department of Mines and Energy's Interactive Resource and Tenure online maps (http://www.webgis.dme.qld.gov.au, accessed on 1 August 2008), two exploration boreholes have previous been drilled within the MLA area, both in the southern portion of MLA50230. Well 55 was drilled in 1962 for petroleum, with no hydrocarbons located. Well 58380 was drilled in 2002 for coal seam gas, also with no gas located. Further details are available from company report numbers 897 and 37652 respectively from the Department of Mines and Energy's Queensland Digital Exploration Reports System (QDEX).

Numerous exploration and development gas wells occur in the vicinity of the gas supply pipeline, within the Peat Scotia gasfields. Gas wells in the vicinity of the pipeline include:

- Exploration well 50327 drilled in 1996 with no hydrocarbon located
- Exploration well 57298 drilled in 1996 with gas located
- Exploration well 57333 drilled in 1997 with gas located
- Appraisal well 57671 drilled in 2000 with gas located
- Gas development well 58162, 58138, 58204, 59057, 58567, 59049, 58566, 59048, 59095.

Coal resource

Stratigraphy

The Juandah Coal Measures contain the economic coal reserves of the Project. The coal seams are relatively flat, with a regional dip of approximately zero to two degrees to the south-west (Golder Associates 2008), with localised steeper dips. Geotechnical drilling has identified the following seam groups within the Wandoan MLAs:

- **Kogan.** The Kogan coal seams generally occur in the southern portion of the MLAs and at shallower depths. The group consists of approximately seven seams, each of which generally vary in thickness between 0.1 m and 5.0 m
- **Macalister Upper.** The Macalister Upper coal seams occur below the Kogan seams. The group consists of approximately five seams, each of which generally vary in thickness between 0.05 m and 4 m
- **Macalister Lower.** The Macalister Lower coal seams occur below the Macalister Upper seams. The group consists of approximately six seams, each of which generally vary in thickness between 0.01 m and 3.0 m
- **Wambo.** The Wambo coal seams occur at shallower depths in the northern portion of the MLAs and below the Macalister Lower seams in the rest of the MLAs. The seam consists of approximately seven seams, each of which generally vary in thickness between 0.1 m and 3.0 m.

Coal volumes and delineation

Geological models have been generated to enable estimation of JORC compliant resources for MDL221 and MDL222 within the Juandah Coal Measures. The status of all boreholes were made on a seam by seam basis. A set of criteria were used to define resource category areas according to JORC guidelines. All resources were calculated at an in-situ moisture of 12% and using modelled relative density where available. Ash content was reported at 10% inherent moisture.

The work undertaken to prepare the geological model and delineate the resource is described in Appendix 9-1-V1.4. Table 9-1 presents the resources for MDL221 and MDL222. MDL221 underlies MLA50230 and 50231, while MDL222 underlies MLA50229.

Table 9-1: In-situ coal resources

Tenement	Average raw ash	Estimate quantity (million tonnes)			
	(%air dried, 10% inherent moisture)	Measured	Indicated	Inferred	Total
MDL221	22.2	116.5	469.2	737	1,323
MDL222	26.9		295.3	663	958
Total		**116.5**	**764.5**	**1,400**	**2,281**

Approximately 500 Mt of the coal resource has a strip ratio of less than 3:1, with the remainder of the coal typically being in the range of 3:1 to 5:1. A summary of the economic coal resources for each group of pits in shown in Table 9-2.

Table 9-2: Coal resource summary

Group of mine pits	Estimated quantity (million tonnes ROM)
Austinvale	92.1
Woleebee	116.6
Leichhardt	17.2
Frank Creek	58.4
Woleebee Creek	122.9
Mud Creek	156.4
Summer Hill	152.5
Turkey Hill	113.8
Satellite Pits	15.9

Coal quality

An indicative specification of the coal quality expected from the Project is provided in Table 9-3.

Table 9-3: Indicative coal quality

Property	Unit
Total moisture (%)	15
Proximate Analysis	
Moisture (% air dried)	10
Ash (% air dried)	9 – 10
Volatile Matter (% air dried)	40
Total Sulphur (% air dried)	0.35
Chlorine (% air dried)	0.03
Calorific Value	
Gross as received (kcal/kg)	5,800
Nett as received (kcal/kg)	5,500
HGI	35
Ash Fusion (Reducing)	
Initial deformation (^{o}C)	1,300 – 1,400
Size Range	
50 mm by 0 (5 normal)	100

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9.3.5 OVERBURDEN

Overburden and interburden was assessed within the MLA areas. Unless specific characteristics are described, the term overburden implies both overburden and interburden. Overburden is defined as all the material overlying the shallowest coal seam and interburden is the material between economic coal seams.

Overburden in the Austinvale and Woleebee areas consist mostly of sandstone, siltstone, mudstone, claystone and coal, with minor ironstone. Upward fining sequences are common, and vertical and lateral changes of facies were observed.

The average depth of overburden is about 23.0 m in the Austinvale area, with about 1.2 m soil. In the Woleebee area the average depth of overburden is 26.0 m, with soil to about 3.2 m. The depth of the weathering ranges from 10.0 m to 15.0 m in the eastern portion of the Project area, and from 8.0 m to 25.0 m in the western portion of the Project area.

Acid producing potential

The oxidation of sulfidic material to produce sulphuric acid is a natural process resulting from the exposure of minerals such as pyrite (iron sulfate) to atmospheric conditions (Environment Australia 1997), and is calculated as the acid producing potential in kg H_2SO_4/t. This process can be accelerated during mining operations if large volumes of sulfidic material are exposed. The resulting acidity may also dissolve metals within overburden rock. Transport by water can generate highly acidic runoff with high concentration of dissolved salts of heavy metals.

Carbonate minerals and exchangeable bases, on the other hand, have the ability to neutralise acid (calculated as the acid neutralising capacity in kg H_2SO_4/t). Carbonate minerals (mainly calcite, aragonite and dolomite) have the most significant acid neutralising capacity.

The net acid producing potential (NAPP), is the difference between the acid producing potential and the acid neutralising capacity of a material. NAPP gives an indication of a materials potential to generate acid. A positive result shows acid generation potential and a negative result indicates that the material is non-acid producing (Department of Mines and Energy 1995b).

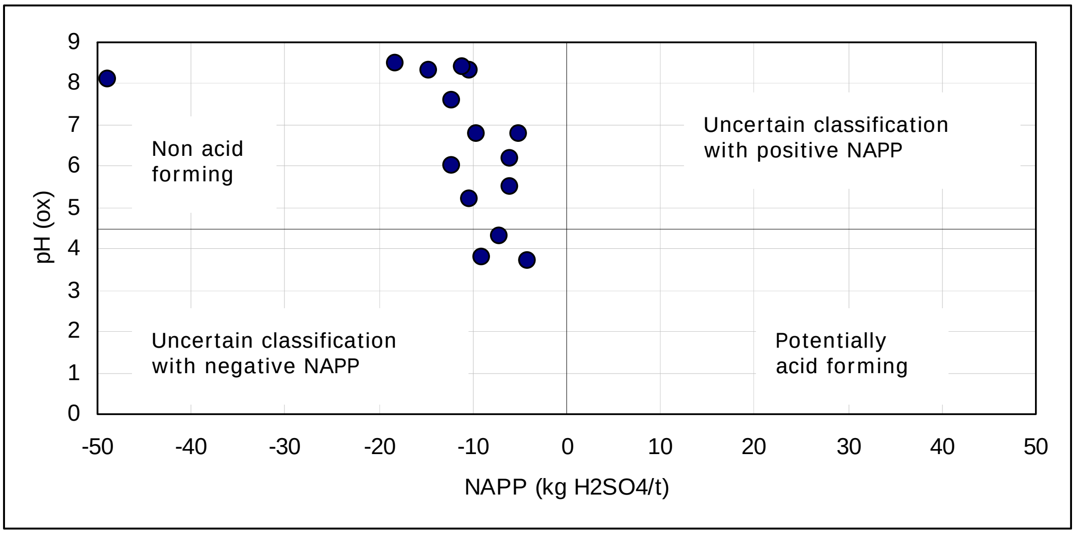
Net acid generation (NAG) differs from the acid producing potential in that it measures the actual acid production and neutralisation of material, as opposed to the total theoretical potential. NAG provides an indication of the potential for acid generation following exposure and weathering of material, and can be used to confirm the NAPP.

Laboratory tests were carried out on samples obtained from five exploration boreholes through the overburden, with the results summarised in Table 9-4. The negative NAPP results showed that no samples have the potential to produce acid mine drainage, due to high acid neutralising capacity (ANC). The test results are shown in Table 9-4 and in TR 9-1-V1.5 Geology, Mineral Resources, Overburden and Soils Impact Assessment.

Table 9-4: Acid generation and neutralisation potential in overburden samples analysed for this study

Parameter	Range in values encountered	
	Weathered rock	Fresh rock
Net Acid Production Potential (kg H_2SO_4/t)	-14.6 – -10.4	-48.8 – -4.1
Net acid generation (pH 4.5) (kg H_2SO_4/t)	<0.1	<0.1 – 11.7
Net acid generation (pH 7.0) (kg H_2SO_4/t)	<0.1	<0.1 - 62.2
pH after oxidation	8.3	3.7 – 8.5
Acid neutralising capacity (kg H_2SO_4/t)	10.7 – 15.6	6.0 – 50.0
Total Sulfur (%)	0.01 – 0.03	0.03 – 0.14

All samples tested as part of the current investigation have negative NAPP, and therefore plot in the left side of the diagram in Figure 9-7. The samples with a pH(ox) less than 4.5 have low sulphur content, and therefore plot typical of organic acid effects on samples with minor or no acid rock drainage potential (Miller, 2008).



Source: after Miller 2008

Figure 9-7: Classification of acid production potential

The non acid forming nature of the overburden is supported by water quality testing undertaken at the bulk sample pit site in March 2006 and September 2008, which found water in the bulk sample pit, water management dam and seepage from rehabilitated overburden to have neutral to slightly alkaline pH.

Heavy metals

Heavy metal content in the overburden samples were assessed against environmental and health based investigation levels established by the *National Environmental Protection (Assessment of Site Contamination) Measure 1999* (National Environment Protection Council 1999). Heavy metal analysed include arsenic, cadmium, copper, chromium, lead, nickel and zinc.

The overburden samples were assessed against the environmental investigation levels and health-based investigation levels to provide an indication of the potential for overburden dumps to be a source of heavy metal contaminated leachate, based on the concentrations in the in-situ overburden material.

As shown in Table 9-5, the concentrations of all heavy metals within the overburden tested were below the investigation level concentrations. The solubility of most heavy metals could increase with elevated acidity. However, the overburden is not anticipated to generate significant acid mine drainage. The above two findings indicate the stockpiling of overburden is unlikely to be a source of heavy metal contamination.

Table 9-5: Heavy metal concentrations in overburden samples

Substance	Environmental investigation level mg/kg	Health based investigation level mg/kg	Concentration range in analysed overburden samples mg/kg	Samples exceeding environmental and health investigation levels*
Arsenic	20	100	<5 – 6	None
Cadmium	3	20	<1	None
Copper	100	1,000	12 – 45	None
Chromium (III)	400	12%	<2 – 10	None
Chromium (VI)	1	100	8 – 24	None
Lead	600	300	2 – 12	None
Nickel	60	600	5 – 133	None

* Based on 'Standard' residential use as defined in Department of the Environment 1998. This includes garden/accessible soil (home-grown produce contributing less than 10% of fruit and vegetable intake; no poultry); this category includes children's day-care centres, preschools and primary schools.

Erosion potential

The main erosion agents within the Project area are:

- raindrop impact
- water
- wind.

When environmental factors (e.g. vegetation cover and climate) are equal, then the erosion potential of stockpiled overburden is dependant of the chemical and physical characteristics of the material.

Dispersion and slaking both result in erosion. Slaking is the breakdown of a materials structure when exposed to water (e.g. slumping). Dispersion is the transformation of a solid material into a colloid when in contact with water.

The potential for slaking and dispersion was assessed by Golders Associates (2008). This assessment found that clay rich, slake prone rocks are present throughout the overburden across the Project area, although some non-slaking materials were encountered. These findings support the findings by Godfrey (1992).

CSR Coal Division (1966) tested both the general dispersive potential of overburden and the potential for failure by tunnel erosion when used for earthworks. Most overburden was found to be highly dispersive, with some siltstone/sandstone materials dispersive (overburden with more than 70% sandstone and siltstone, with more siltstone than sandstone) or non-dispersive (overburden with more than 70% siltstone/coal and sandstone, with more siltstone/coal than sandstone). All materials tested were found to be highly susceptible to tunnel erosion.

Dispersion is caused by chemically exchangeable sodium dominated clays that form weak bonds between individual clay particles and layers within the clay minerals, thus acting as a dispersing agent. Soils with an exchangeable sodium percent (ESP) of more than 15% are considered dispersive and soils with an ESP less than 5% are commonly considered as non-dispersive. The current study found ESP values of 23 to 28 for weathered rock and 40 to 71 for fresh rock, indicating the overburden will be highly dispersive. These findings are in accordance with those by Slater (1986), which found sodium as the dominant base cation, and ESP values of 14 to 34.

Nutrients and trace elements

The nutrient and trace element content of overburden material relates to the suitability of the material for use as a plant growth medium. Table 9-6 contains suggested values for various parameters in soil and overburden that are suitable for plant growth. Values outside the suggested critical values may result in toxicities, or shortages in essential nutrients required for plant growth.

Table 9-6: Criteria for suggested nutrient availability in soils and overburden

Parameter	Suggested critical values[1]	Range in values encountered	
		Weathered rock[2]	Fresh rock[2]
pH	5.5-8.5	9.2 – 9.9	9.7 – 10.4
Electrical conductivity (µS/cm)		763 – 1080	280 – 1020
Exchangeable calcium (meq/100 g)	min. 1.2	15.5 – 15.6	2.8 – 22.3
Exchangeable magnesium (meq/100 g)	0.4-0.8	8.9 – 10.5	0.8 – 5.4
Exchangeable potassium (meq/100 g)	0.2-0.3	0.50 – 0.58	0.46 – 0.97
Extractable Iron (mg/kg)	2.5-4.5	7 – 24	13 – 16
Extractable manganese (mg/kg)	min. 2	4 – 5	3 – 5
Extractable copper (mg/kg)	min. 0.2	1.0 – 1.6	3.7 – 5.5
Extractable zinc (mg/kg)	0.5-1.0	1.0 – 1.6	3.7 – 5.5
Exchangeable sodium (meq/100 g)		8.02 – 9.81	8.82 – 24.0
Cation exchange capacity (meq/100 g)		34.6	16.8 – 42.4
Exchangeable sodium percent (%)		23.2 – 28.3	40.0 – 71.2

Source: 1. CSR Coal Research (1986) Table 5.3
2. After Slater 1986, Table 4.3, and this current study

The overburden has very low organic matter and nitrogen content. The pH of overburden was found generally to be alkaline, with some siltstone and sandstone samples acidic (Slater located this acidic overburden under the Rolleston soil profile). The concentration of exchangeable cations is low, and is dominated by calcium and sodium.

Electrical conductivity levels were medium to high, and trace elements (iron, manganese, copper, zinc) levels medium to high.

Fossil material

There is a potential for fossilised material to be discovered during drilling, excavation and mining activities. Fossilised leaf impressions were identified in some sandstone samples collected as part of the geotechnical investigations for the Project (e.g. borehole C7073).

Most fossils uncovered by the mining activities will be common. The significance of a fossil is not necessarily indicated by the fossil size, with fossils such as budding plants, uncommon plants or insects being of interest to the Queensland Museum.

Geotechnical properties

Geotechnical characteristics of the overburden related to stability have been investigated by Golders Associates (2008).

Rock strength from boreholes in the eastern portion of the Project was found to be low to approximately 25 m depth, and then increase to medium strength. In the western portion of the Project area surface rock strength was also very low to medium, increasing to low to high strength from about 20-30 m depth.

Clay rich, slake prone rocks are present throughout the overburden and interburden deposits, although siltstone and mudstone resistant to slaking was encountered at one borehole site. Material prone to slaking is also present in the proposed pit floors. Atterberg limit tests of the slaked material indicated this material is highly plastic with poor engineering properties.

9.3.6 SOILS

Land resource areas

Land resource areas (LRAs) are reoccurring landscape units with similar geology, landforms, soils and vegetation associations. They are used to simplify and aid quick field identification of land resource unit mapping and subsequent management.

The LRAs of the Project are identified and described in the Wandoan District Land Management Field Manual (Gray and Macnish 1985), and Evaluation of Agricultural Land in Taroom Shire (Forster 1985). These studies identified two LRA, which relate to the landscape units identified in Section 9.3.1, being:

- **Brigalow uplands.** Undulating plains with broad ridges and low hills, on sandstones and shales
- **Poplar box alluvia.** Floodplains of generally narrower width than Coolibah LRA; often associated with active secondary stream channels; mixed and sandy alluvia.

Identified soil types were related to LRA soil profiles in these references. This allowed additional physical and chemical characteristics to be inferred for some soils.

Soil types and descriptions

The soil types encountered in the Project area are shown in Figure 9-8-V1.3 and are described below. Further details of soils encountered, including photographs, are provided in TR 9-1-V1.5 Geology, Mineral Resources, Overburden and Soils Impact Assessment.

Brigalow upland cracking clays

Brigalow upland cracking clays occur mainly on the mid to lower slopes of the undulating hills on gradients varying from 1% to 4%. Surface soils are neutral to slightly alkaline, with low salinity and non-dispersive. Subsoils are generally moderately to strongly alkaline and are dispersive. Four soil types were identified within the Brigalow upland cracking clay soils, relating to the soil position in the landscape. These sub-types were:

- **Rolleston.** These soils occur on mid and lower slopes. The topsoil is dark brown-grey heavy clay with blocky peds. Subsoils are dispersive, and lower sub-soils are strongly acidic or strongly alkaline. Under the Australian Soil Classification these soils are Brown Dermosols.
- **Teviot.** These soils occur on gently inclined midslopes. The topsoil is brown-grey to dark brown grey clay. Subsoils are grey-yellow-brown clays and are moderately alkaline, moderately saline and dispersive, tending to strongly dispersive with depth. Under the Australian Soil Classification these soils are Brown Vertosols.
- **Downfall.** These soils occur on mid to lower slopes on areas of sediment/slopewash accumulation. The topsoil is shallow brown-grey clay. Lower subsoils are dispersive grey and/or yellow brown heavy clays and are strongly alkaline. Under the Australian Soil Classification these soils are Brown Vertosols.
- **Rugby.** These soils occur on ridgetops and are potentially present within the gas supply pipeline corridor. The topsoil is a yellow-brown sandy loam to clay loam. The soil has a shallow profile with weathered sedimentary rock generally encountered at less than 0.5 m depth. Under the Australian Soil Classification these soils are Brown Dermosols.

Brigalow upland non-cracking clays

The soils are shallow non-cracking uniform clays. The topsoil has low to moderate salinity and is non-dispersive. The soil has formed on weathered sandstone.

Two soil types were identified within the Brigalow upland non-cracking clay soils, relating to the soil position in the landscape. These sub-types were:

- **Cheshire.** These soils occur on steeper gradient upper slopes (up to 3%). The topsoil consists of dark sandy clay to light clay, tending to dispersive in the lower topsoil (A2). The subsoil is strongly alkaline, highly saline and dispersive. Under the Australian Soil Classification these soils are Brown Dermosols.
- **Kinnoul.** These soils occur on ridgetops and upper slopes, and are commonly covered by Brigalow regrowth. The topsoil consists of dark sandy clay or light clay with well developed blocky structure. Kinnoul is a shallower version of Cheshire, and often grades into Cheshire on upper slopes. The yellow-brown subsoil encountered in Cheshire is generally absent in Kinnoul. Under the Australian Soil Classification these soils are Brown Dermosols.

Poplar box alluvial uniform soils

One soil type was identified within the poplar box alluvial uniform soils. This soil is:

- **Juandah.** These soils occur on floodplains with less than 1% gradient. The topsoil consists of high plasticity dark brown-grey clay with granular to blocky structure. Subsoils are dispersive with slight to moderately alkaline pH and low to medium salinity. Lower subsoils are yellow-brown, massive alkaline clays. The soil profile is generally greater than 1.5 m deep, and underlain by alluvium. Under the Australian Soil Classification these soils are Brown Vertosols.

Poplar box alluvial texture contrast soils

Two soil types were identified within the Poplar box alluvial texture contract soils, relating to the soil position in the landscape. These sub-types were:

- **Retro.** These soils occur on the floodplains on slopes less than 0.5%, and are typically uncleared of vegetation. The topsoil consists of dark brown-grey clayey loam, which is non-dispersive, and has neutral pH and low salinity. The subsoils are dark brown heavy clays with medium blocky peds. Subsoils are non-dispersive with alkaline pH. The soil profile is approximately 1.0 m deep and underlain by alluvial sediment or colluvium. Under the Australian Soil Classification these soils are Brown Chromosols.
- **Woleebee.** These soils occur on the floodplains of Woleebee Creek and Juandah Creek. The topsoil consists of a grey silty loam, which is dispersive, has neutral pH and low to medium salinity. The subsoils are dark medium clay, and are strongly alkaline with medium to high salinity from approximately 0.5 m. Under the Australian Soil Classification these soils are Brown/Grey Sodosols.

9.3.7 LAND SUITABILITY AND AGRICULTURAL LANDS

Land suitability

The land suitability assessment was based on the Land Suitability Classification for Cropping and Grazing in the Semi-arid Sub-tropics of Queensland (Department of Mines and Energy, 1995). This classification system evaluates whether an area of land can sustain potential agricultural uses, regardless of its current use.

The land suitability classes for the Project corridor were derived from a combination of the identified soil types and geomorphic/topographic position and are not simply a reflection of spatial distribution of the various soils.

All land within the Project corridor was within one of the following land use classes for either dryland cropping or beef cattle grazing:

- Class 1 – suitable land with negligible limitations and is highly productive requiring only simple management practices
- Class 2 – suitable land with minor limitations which either reduce production or require more than simple management practices to sustain the use
- Class 3 – suitable land with moderate limitations – land which is moderately suited to a proposed use but which requires significant inputs to ensure sustainable use
- Class 4 – marginal land with severe limitations which make it doubtful whether the inputs required to achieve and maintain production outweigh the benefits in the long-term

- Class 5 – unsuitable land with extreme limitations that preclude its use.

Distribution of land suitability classes for rain-fed cropping is provided in Figure 9-9-V1.3, and land suitability for beef cattle grazing is provided in Figure 9-10-V1.3.

The findings of this assessment correlate well with the findings of previous assessments (Forster (1985), Slater (1986) and Enviroscience (1992)). The Project area is mainly classified as Class 3 and Class 4 for dry land cropping.

The soils of Cheshire and Kinnoul, which occur on the upper slopes, have been classified as Class 3 for dry land cropping due to high erosion potential by surface runoff and the presence of alkaline subsoils that results in low nutrient availability. Alluvial soils are rated Class 3 due to the potential of flooding.

Downfall, Teviot and Rolleston soils, occurring on the lower slopes, were rated as Class 4 due to high alkalinity within 0.6 m of the soil surface resulting in nutrient deficiency. Some cropping currently occurs within this Class 4 land, however, long term sustainability is limited due to low nutrient and high alkalinity conditions, shallow rooting depth, and heavy application of fertilisers. Small portions of land on the upper margins of the floodplains with alluvial soils, but impacted by flood to a lesser extent, are considered to be Class 2 land for dryland cropping. Due to the limited extent of these areas, they have not been included on the mapping.

All land in the Project area is considered Class 2 for beef cattle grazing.

Good quality agricultural land

In accordance with Section 2 and Attachment 2 of 'The Planning Guidelines: The Identification of Good Quality Agricultural Land' (Department of Primary Industries and Department of Housing, Local Government and Planning Queensland 1993), agricultural land classes A, B and C are considered GQAL in the area formerly known as the Taroom Shire.

Agricultural land classes A, B and C are respectively defined as:

- Class A: Crop land – land that is suitable for current and potential cropping with limitations to production which range from none to moderate level
- Class B: Limited crop land – land that is marginal for current and potential cropping due to severe limitations, and suitable for pastures. Engineering and/or agronomic improvements may be required before the land is considered for cropping
- Class C: Pasture land – Land that is suitable only for improved or native pastures due to limitations which preclude continuous cultivation for crop production, but some areas may tolerate a short period of ground disturbance for pasture establishment.

Under the Taroom Shire Planning Scheme almost all land within the Project area, other than along creek lines, is classified as Class A agricultural land, as shown in Figure 9-11-V1.3.

The findings of this land suitability assessment indicate greater than 'moderate' limitations to dryland cropping for areas over the lower slopes of the Brigalow Upland Soils. Consequently, the findings of this assessment suggest a different distribution of GQAL than the Taroom Shire Planning Scheme, with Class B agricultural land as a more appropriate classification for the lower slopes these areas, and the floodplains and upper slopes being Class A, as shown by land suitability Class 4 and 3 respectively in Figure 9-9-V1.3.

9.3.8 SOIL CONSERVATION PLANS

Soil conservation plans can be developed by the Department of Natural Resources and Water for individual properties or a collection of neighbouring properties to manage water runoff flow. These plan are generally prepared at the request of landowners, and consist of a map and specification for soil conservation measures and practices to control erosion. Plans can also be approved under the *Soil Conservation Act 1986*.

Eighteen properties in the Project area have registered soil conservation plans with NRW (refer Table 9-7). Two of the plans are 'approved soil conservation plans' under the *Soil Conservation Act 1986*. Additional properties may have implemented soil conservation works (e.g. contour banks) and had plans prepared by Department of Natural Resources and Water officers, but for which there had been no need to coordinate with neighbouring properties or utilities, so the plans were not registered as soil conservation plans. The soil conservation plans show a preferred, or recommended, layout of soil conservation works used to control erosion, principally on cultivation land; however, the plans may not necessarily reflect what has actually been implemented.

Table 9-7: Soil conservation plans

Soil conservation Plan No.	Approved Y / N	Lot / Plan description
SC345036	N	Lot 38 CP899702
SC345024	N	Lot 29 FT467
SC345024	N	Lot 25 FT481
SC345002	N	Lot 29 FT490
SC345034	N	Lot 34 FT490
SC345096	N	Lot 40 FT503
SC345208	N	Lot 42 FT505
SC345033	N	Lot 53 FT505
SC345019	N	Lot 51 FT507
SC345001	N	Lot 50 FT508
SC345084	N	Lot 58 FT556
SC345022	N	Lot 36 FT575
SC345228	N	Lot 37 FT575
SC345695	N	Lot 3 FT695
SC345049	N	Lot 86 FT782
SC345034	N	Lot 35 FT987
SC345079	Y	Lot 41 FT603
SC345103	Y	Lot 99 FT815

9.4 DESCRIPTION OF PROPOSED DEVELOPMENT

9.4.1 MLA AREA

A description of the proposed mine development is provided in Chapter 6 Project Operations.

Mining pits will be excavated to a maximum depth of between 25 m and 60 m depth, dependent on the depth of the coal seams. Prior to the initial box cut, vegetation will be cleared, and topsoil will be stripped and stockpiled for use in future rehabilitation and revegetation. Initial box-cut strips in each pit are generally proposed to be 60 m wide.

Subsequent mining strips will be approximately 80 m wide, with overburden being placed in the preceding strip void. Partings and coarse rejects will be used as fill between the overburden stockpiles. Overburden stockpiles will be levelled out and shaped to provide a gently undulating landform. Given the low strip ratios, the final landform is anticipated to be similar to the existing topography, with up to around 5 m, and a maximum of 25 m increased elevation compared to existing landform. Rehabilitation and revegetation of the landform is anticipated to commence within two years following a pit strip being mined.

Typically a single final void will remain after completion of mining for each pit. The final void will be formed by reducing the outer/boxcut slopes and adjacent overburden stockpiles to a maximum of 15% gradient to infill the void, bringing the pit floor up towards natural topographical surface. Depths of final voids will vary with the volume of material available at each pit for infilling. The proposed landform at Year 30 is provided in Figure 9-12-V1.3. This landform is not the final landform, as available coal resources may result in future mining beyond the current proposed mining lease, subject to future lease approvals.. A final landform will be developed for approval by relevant administrative bodies closer to the proposed closure of the mine.

Following the completion of mining of the Austinvale North Pit in approximately Year 1, this pit will be used for tailings disposal. Once the Austinvale North pit is filled, tailings placement will be placed in the Austinvale Pit, which is expected to have capacity to accept tailings over the remaining life of the mine.

9.4.2 PROJECT INFRASTRUCTURE

The Project includes various items of on-MLA and off-MLA infrastructure as described in Chapter 6 of the EIS, and shown in Figure 6-3-V1.3. Construction of this on-MLA and off-MLA area infrastructure will generally involve topsoil stripping, cutting, filling and benching.

9.4.3 GAS SUPPLY PIPELINE CORRIDOR

Geology and soils vary over the length of the pipeline, with construction of the pipeline expected to disturb soils up to around 2 m below natural surface. However depth of pipeline burial may be deeper in some sections due to risk assessments and topographical considerations over the length of the pipeline that are to be investigated during detailed design. Clearing widths for the pipeline will typically be 10 m, but up to 20 m may be required for various sections of the pipeline.

9.5 POTENTIAL IMPACTS

9.5.1 TOPOGRAPHY AND GEOMORPHOLOGY

The mining activities will result in topographical changes to the Project area during mine operation and post-mining, through the removal of existing topographical relief during overburden stripping and mining, the creation of new topographic highs through the placement of spoil strips and spoil piles, and topographic lows in the form of voids. Changes to the location and width of the floodplains will also occur as a result of mining and creek diversions.

The gas supply pipeline will have negligible impact on topography.

9.5.2 GEOLOGY

Coal resource

The WJV has undertaken an extensive drilling program to identify and delineate the coal resource within the MLAs, and have developed a conceptual 30 year mine plan outlining the extraction of coal resources to ensure it is undertaken in a planned and effective method.

The location of infrastructure associated with the Project external to the MLAs was selected considering publically available information on the locations of coal deposits and gas resources and this infrastructure has been positioned considering the underlying resources to minimise the sterilisation of coal and gas resources.

Uncovering fossil material

There is a potential for fossilised material to be discovered during drilling, excavation and mining activities. Most fossils uncovered by the mining activities will be common.

If a large potential fossil is discovered during mining activities, then work in the vicinity of the find will stop, to preserve the potential fossil, while the Queensland Museum is alerted to the find.

9.5.3 OVERBURDEN

An overburden assessment was only conducted over the MLA area, and did not include the MLA associated infrastructure or the gas supply pipeline corridor.

Acid producing potential

The overburden and interburden rocks were found to be generally not acid forming material and are therefore not expected to pose a risk of acid mine drainage (refer Figure 9-7).

Borehole logs show some coal seams to be pyritic, and layers of overburden adjacent to coal seams could therefore contain pyrite and have a total sulphur content higher than the bulk samples tested. These pyritic layers could produce some acid drainage if they are concentrated near the surface of the spoil. The ANC of the rocks in the spoil is anticipated to neutralise all acid produced by overburden and interburden material, therefore the potential impact from acid production is considered low.

Heavy metals

Heavy metal concentrations in all overburden samples tested were below environmental and health investigation levels. The excavation and stockpiling of overburden is expected to have low risk of producing heavy metal contamination by leachate seepage or surface runoff from the overburden stockpiles.

Growth medium potential

Overburden material was found to have low nutrient and organic matter content. The dispersive nature of the overburden, combined with the low organic matter content, is anticipated to result in a hard setting surface crust. Untreated, this crust will limit seedling emergence and water infiltration and will increase overland surface runoff during rain events, increasing the risk of sheet flow and gully erosion.

Glasshouse trials of buffel grass, wheat and siratro on various overburden substrate conducted by Slater (1986) found that, even when nutrient deficiencies were overcome by fertiliser addition, generally other overburden properties such as moisture holding capacity, pH, salinity and sodicity remained hostile to plants.

The results of these trials suggest weathered sandstone has similar growth medium potential as subsoils. Fresh sandstone was able to support buffel grass growth when high rates of fertiliser were applied. Fresh and weathered siltstone were found to be poor growth media due to high salinity and alkalinity. Wheat and siratro germination and growth rates were poor on all overburden samples.

Dispersion, slaking and erosion potential

When environmental factors (e.g. vegetation cover, climate etc) are equal then the erosion potential of stockpiled overburden is dependent on the chemical and physical characteristics of the material and the topography (natural or created) of the terrain. Much of the overburden has high sodium content, and therefore will readily disperse when left exposed on the soil surface or otherwise exposed to water (which may lead to tunnel erosion).

The overburden also has medium to high salinity (measured as EC). Moderate or higher salinity generally increases erosion potential indirectly by making it more difficult for plants to take on water, thereby reducing establishment and growth rates of some plants (Henderson 2008). The greater the period bare spoil is exposed, the higher its erosion potential.

Stability

Assessments of potential slope stability issues have been undertaken by Golder Associates (2008) and CSR Coal Division (1986). These assessments identified the following potential issues for highwalls, low walls and overburden dumps:

- highwall:
  - face instability and rock fall due to slaking and differential weathering of freshly exposed material
  - planar failure (deemed unlikely by Golder Associates)
  - failure of discrete wedges (large wedge failure deemed unlikely by Golder Associates)
  - circular slip failure (deemed unlikely by Golders Associates).

- low wall:
  - face instability and rock fall due to slaking and differential weathering of freshly exposed material
  - bi-linear two wedge failure (Golder Associates deemed this to be restricted to limited sections of low wall)
  - failure of discrete wedges (large wedge failure deemed unlikely by Golders Associates)
  - circular slip failure (deemed unlikely by Golder Associates).
- overburden dumps:
  - dump strength highly dependant of the dip of the seam floor, presence of weakness plains in the floor rocks, angle of repose and dump height
  - bi-linear two wedge failure
  - circular slip failure.

9.5.4 SOILS

The following section contains potential impacts from the construction and operation of the mine, MLA associated infrastructure and gas supply pipeline.

Alkalinity, sodicity and dispersivity

Cheshire, Woleebee, Rolleston and Teviot soils have moderate to extreme alkalinity and sodicity within the subsoils and are strongly dispersive. All other subsoil within the Brigalow Uplands LRA can be considered dispersive to a lesser extent (refer Figure 9-13-V1.3).

Alkaline and sodic soils are generally dispersive, and have high erosion potential if exposed. Sodic, alkaline soils are also poor plant growth mediums due to low nutrient availability, and should not be used as such in rehabilitation of disturbed areas. The topsoil portion of these soils, as shown in Table 9-9, is suitable for use in rehabilitation.

Erosion

All soils in the Project area will be subject to erosion if vegetation is removed and rehabilitation is not undertaken within an appropriate timeframe.

Soils most susceptible to wind erosion are soils with sandy or loamy topsoils, which include the alluvial soils of Woleebee and Retro.

Soils most susceptible to erosion by flowing water are those with dispersive (sodic) topsoil or upper subsoil as discussed in “Alkalinity, sodicity and dispersivity” above. Soils on steep and moderate upper slopes, as occur on the undulating terrain and spoil piles, have higher risk from erosion by water than soils on gentle slopes and floodplain.

Exposure of dispersive subsoils as described in Section 9.5.3 has the potential to cause gully erosion problems, even if only small areas of subsoil are exposed. Photo 9-1 illustrates gully formation on a gentle slope due to water runoff over dispersive soils. After initiation of erosion, for example after vegetation removal or ground disturbance, this erosion will continue to expand upslope and expose more dispersive soils.

Photo 9-1: Gullyhead erosion caused by exposure of dispersive soils in a drainage line on a gentle slope near WS26

Salinity

Soil salinity in the Project area is of limited extent and is not considered a high risk. However, the subsoils of Cheshire, Teviot and Woleebee are moderately to highly saline and changes to the soil moisture regime due to vegetation removal or other impact may increase near surface soil salinity.

The use of saline CSM water for dust suppression on roads is unlikely to have a significant impact on the salinity of soils surrounding roadways due to the moderate salinity of the water (up to 4,000 mg/L total dissolved solids), the volumes of water that will be used for dust suppression, relative to other activities that will occur on the site.

Compaction

All soils in the project area will be susceptible to compaction if used for infrastructure, laydown, or other trafficked areas. The compaction of soil breaks down the natural structure in the surface soils, reducing rainwater infiltration and increasing runoff. Compaction increases the potential for rainwater induced erosion, and reduces the success of seed germination and root establishment of vegetation.

9.5.5 SOIL CONSERVATION PLANS

Pipeline construction works are likely to impact on two properties with approved soil conservation plans. These works may require the destruction or alteration of contour banks or other soil conservation measures.

9.5.6 LAND USE SUITABILITY

During the operation of the mine, existing land uses, such as cattle grazing and broad acre cropping, may be able to continue within the MLAs in areas not directly impacted by mining. Areas required for the operation of mining and associated activities will be excluded from agricultural purposes during the operation of the mine.

Land disturbed by mining will be rehabilitated following mining. Without mitigation measures, long term impacts to the land suitability classes, as defined in Section 9.3.7, are expected as follows:

- undisturbed land will be returned to (or retained in) its pre-mining land suitability class
- land used for infrastructure components of the Project (roads, MIA, etc) will have limitations related to water availability (through compaction and breakdown of the subsoil structure), and will generally be Class 4 cropping land or Class 3 cattle grazing land
- spoil stockpiles and tailings dam sites will have limitations related to water availability, salinity, gradient, erosion and nutrient content, and will generally be Class 5 cropping land or Class 4 or 5 grazing land
- final voids will be unsuitable for agricultural use, generally being Class 5 for cropping and cattle grazing.

Planned rehabilitation and mitigation measures to obtain better land suitability classification are detailed in Section 9.6.5.

9.6 MITIGATION MEASURES

The following section generally contains mitigation measures related to the construction and operation of the mine, MLA associated infrastructure and gas supply pipeline. Mitigation measures related to the decommissioning of the mine, including post-mine land suitability, are covered in Chapter 25 Rehabilitation and Decommissioning.

9.6.1 TOPOGRAPHY

Mining lease application (MLA) area

The design of the post-mining landform should consider, and where practicable replicate, the topographic elements discussed in Section 9.3.1. This does not infer that the topography should be returned to the pre-mining profile, but where hills (e.g. overburden dumps) are formed, they should be constructed to a similar height, slope angle and profile (shape) as occur naturally in the area, and if floodplains are formed as part of the final landform, they should be of similar width and slope angle to those in the Project area pre-mining if practicable. In general, these measures can be described as:

- concave slope profile

- slope gradients of up to 15% (the erosion potential of longer slopes and gradients of floodplains will need to be considered)
- irregular dump shapes (e.g. with uneven heights, ridgelines and spurs)
- spoil pile relief (height) of up to 50 m between the floor of the floodplain and the hill crest.

Gas supply pipeline corridor and MLA associated infrastructure

No specific topography related mitigation measures are recommended for the gas supply pipeline or MLA associate infrastructure as these are expected to have negligible impact on topography.

9.6.2 OVERBURDEN

The following discussion only applies to the MLA area. The gas supply pipeline only impacts the top couple of metres of soil, and therefore will not impact overburden.

Acid producing potential

There is a low to negligible risk of development of acid mine drainage within the overburden and interburden. Despite this, the following measures are proposed to be implemented, where appropriate:

- laboratory characterisation of selected samples of overburden material will be conducted during overburden stripping to confirm the acid generation potential prior to removal. This characterisation should be in accordance with the Assessment and Management of Acid Drainage (Department of Primary Industries 1995) and/or other relevant guidelines
- coal coarse rejects will be fully characterised and a management strategy for this material developed with regards to potential acid production potential
- layers of coal roof and floor material, partings, coarse coal rejects and any material that is visually assessed at the time of mining as containing pyrite, will be assessed for acid producing potential prior to placing within the spoil pile
- layers of coal roof and floor material, partings, coarse coal rejects and any material that is visually assessed at the time of mining as containing pyrite will not be placed near the surface of spoil stockpiles unless laboratory testing confirms that the material is non acid forming
- any potentially acid forming material, as identified by visual assessment or laboratory characterisation, will not be used as capping material and should be buried within the waste rock dump together with waste rock that has a positive acid neutralising capacity.

Growth medium potential

The overburden was found to generally be a poor growth medium, but weathered and fresh sandstone has some limited potential to be used as a subsoil media to provide cover of spoil and bedding to topsoil. The following measures are proposed be implemented, where appropriate, in regard to overburden as growth medium:

- the use of overburden material as a topsoil will be avoided

- overburden will be capped with subsoil and topsoil prior to revegetation unless vegetation trials show certain types of overburden as being suitable for direct revegetation
- spoil dominated by siltstone and mudstone overburden will not be used as a subsoil media or placed within the rooting zone of plants, unless vegetation trials show acceptable plant germination and establishment rates to allow successful revegetation
- field trials will be conducted to determine minimum topsoil cover over overburden which will provide a suitable growth medium for recommended plant communities
- further field trials should be held into the suitability of fresh and weathered sandstone as a subsoil material.

Dispersion

Much of the overburden is considered dispersive and erosion prone. The following measures are proposed to be implemented where appropriate in regard to overburden:

- testing of dispersion and slaking potential will be conducted prior to or during overburden stripping. Less dispersive overburden should be managed for use as capping material
- appropriate designs and locations for spoil pile erosion and drainage control measures will be established based on the results of dispersion and slaking testing, spoil management plans, and through the use of drainage and erosion potential trials. Designs may include the use of 'durable rock' lined drains
- due to the potential susceptibility of the overburden to tunnel erosion, the detailed design and management of benches and/or contour banks on spoil slopes will consider this risk, will be undertaken by a suitably qualified person
- trials at varying slope angles will be conducted in relation to erosion from dispersion and slaking. These trials will assist in establishing suitable final landform gradients
- sediment control structures will be used to control surface runoff from all rehabilitated and disturbed areas to reduce the amount of final sediment loads. An assessment of available technologies will be undertaken prior to selection of sediment control structures
- all out of pit spoil piles will be shaped, topsoiled and re-vegetated to reduce potential for concentration of surface runoff and erosion of spoil material
- rehabilitation strategies will be monitored and adjusted as required to reduce the risk of spoil erosion and destabilisation of spoil stockpiles.

Stability

The following measures are proposed be implemented, where appropriate, in regard to the stability of overburden:

- the setback distance of overburden piles from the crest of the wall to consider the wedge failure potential of the low wall
- design overburden dumps to limit dump heights or use benching on dumps to improve overall stability
- toe of stockpiles to be buttressed with interburden waste as soon as possible after coal is removed

- a comprehensive strength testing program for both fresh and slaked materials will be undertaken
- a 5 m wide bench will be left between the toe of a weathered overburden cut and the crest of a weathered overburden cut to reduce the rock fall hazard
- preliminary high wall and low wall and overburden dump design will be conducted to the cut angles contained in Table 9-8 (Golder Associates 2008).

Table 9-8: Preliminary slope designs angles

Formation	Overall angle
Weathered overburden (low wall)	45 degrees
Unweathered overburden or interburden	76 degrees for a 24 m wall height in unweathered material 70 degrees for a 24 to 36 m wall height in unweathered material 63 degrees for a wall height above 36 m in unweathered material
Dragline overburden dump	35 degrees for dump height up to 30 m 30 degrees for dump height greater then 30 m

Fossil material

There is a potential for fossils to be located during mining activities. In the event potentially significant fossilised material is located, the following measures are proposed to be implemented:

- fossils can be sent to the Queensland Museum Geosciences unit for identification (Dr Sue Parfrey 2007, per. comm., 25 October 2007)
- if potentially significant fossils, such as large dinosaur bones, are discovered during mining activities, then work in the vicinity of the find should stop, to preserve the potential fossil, while the Queensland Museum is immediately alerted to the find.

9.6.3 SOILS

Dispersion and erosion

Cheshire, Woleebee, Rolleston and Teviot soils have moderate to extreme alkalinity and sodicity within the subsoils and are strongly dispersive. All other subsoils within the Brigalow Uplands LRA can be considered dispersive to a lesser extent. The following mitigation measures are proposed to be implemented where appropriate:

- preparation of infrastructure specific sediment and erosion control plans following detailed design and implemented prior to the commencement of construction
- the sediment and erosion control plans should specify the locations and types of sediment and erosion control measures to be used
- design of all drainage around proposed structures and permanent landforms will consider the presence of dispersive soils and apply suitable erosion reduction methods. All disturbed areas should be revegetated, or covered with material that has low erosion potential, to minimise the potential for erosion

- dispersive, clayey soils are suitable for use as embankment materials for water management structures, provided strict construction quality control measures are implemented
- gypsum or lime should be used in the treatment of sodic alkaline soils to improve geotechnical characteristics
- erosion will be remediated as soon as practicable. This may include levelling the eroded area, capping with non-dispersive topsoil, application of seed and applying erosion control measures to prevent water impacting the site
- for disturbed or cleared land, including infrastructure areas and pipelines:
  - unnecessary exposure of alkaline or sodic subsoils (e.g. Cheshire, Woleebee, Rolleston and Teviot) should be avoided, and should be limited to the minimal amount of time practicable. Any exposure should be covered with non-dispersive soil or other suitable material to minimise the infiltration of water into these soils. Sub-soils from these areas should be buried within the spoil stockpiles and covered in accordance with site spoil management procedures
  - clear the minimal amount of vegetation (including grass cover) required for Project works
  - minimise disturbance of the ground layer of vegetation by controlled operation of machinery and equipment selection
  - site drainage, erosion and sediment controls should be implemented and in place prior to, or as soon as possible, following the removal of vegetation
  - water runoff should be directed around topsoil stockpile areas using diversion bunds, contour banks, and catch drains as appropriate
  - divert clean water away from disturbed areas
  - revegetate exposed soils as soon as practical after works have been completed. This includes the rehabilitation of spoil piles
  - use watering trucks during windy conditions for dust suppression
  - install erosion and sediment control measures on disturbed natural or constructed slopes to minimise erosion and sediment released into waterways. This is especially important for soils with dispersive subsoils (e.g. Cheshire, Woleebee, Rolleston and Teviot).
- for infrastructure areas and pipelines:
  - minimise areas cleared during earthworks, by delineating areas to be cleared with survey markers or other suitable marking
  - install sediment traps and silt fences or other suitable sediment control measures where appropriate
  - install sediment fencing or other sediment control measures down slope of disturbed areas to prevent sediment laden water leaving the site.
  - confine traffic to maintained roads
  - minimise slope grade within infrastructure areas where possible based on results of geotechnical data obtained during detailed design phase
  - locate infrastructure, parking and laydown areas at sites with minimal slope grade
  - construct hardstands from erosion resistant material

- install scouring protection works in drains and intensely gullied areas adjacent to proposed infrastructure
- revegetate disturbed areas surrounding infrastructure sites
- control drainage and divert away from infrastructure
- exposure of alkaline or sodic subsoils (e.g. Cheshire, Woleebee, Rolleston and Teviot) should be avoided where possible, and should be limited to the minimal amount of time practicable
- alkaline or sodic subsoils should not be left exposed on the surface, and should be covered with topsoil or other material.

- for topsoil and overburden stockpiles:
  - long-term stockpiles of topsoil and overburden should be planted with vegetation to minimise entrainment of soil particles into the air and minimise erosion through raindrop impact
  - when areas with topsoil susceptible to wind erosion (e.g. Woleebee and Retro) are stripped and stockpiled, even if for only a few months, the stockpiles should be covered by grass, other vegetation, geofabric or less erosion prone topsoil to minimise wind erosion
  - divert clean water from areas upslope of all topsoil, subsoil and spoil stockpiles around stockpile areas using contour banks or diversion channels, thereby reducing water flowing into the stockpile area
  - all topsoil, subsoil and spoil stockpiles should be bunded by earthen bunds or similar, with sediment traps or similar features installed downslope of stockpiles to prevent eroded sediment entering waterways.
- for the gas supply pipeline:
  - any soil conservation measures, such as contour banks, that are disturbed during works should be reinstated following construction
  - long-term (greater than three months) stockpiles of topsoil will be planted with vegetation to minimise entrainment of soil particles into the air and minimise erosion through raindrop impact
  - fill around the pipeline should be compacted to at least the density of the surrounding soil material, and the filled trench left slightly higher than the natural land surface to minimise ponding or infiltration around the trench
  - all dispersive soils along the corridor should be fully capped with at least 0.2 m of non-dispersive topsoil. Deeper topsoil depths have the potential to store rainwater and reduce infiltration into dispersive subsoils
  - the final land surface should be designed to prevent the ponding of water on Teviot soils, to reduce the potential for infiltration into subsoils
  - regular (e.g. weekly or fortnightly) monitoring for erosion should be conducted during construction, including the trench and water management infrastructure
  - erosion monitoring should continue until the vegetation cover has become fully established
  - monitoring for the development of tunnel erosion should be undertaken every three months for the 12 months following the completion of construction

- if monitoring indicates the formation of tunnel erosion, remediation works should be undertaken immediately, with further monitoring of the area until vegetation cover has become fully established.

Salinity

High salinity levels are toxic to many plant species, and rehabilitation of saline soils can be difficult and costly. The following measures are proposed to be applied in relation to soil salinity:

- the topsoil of Teviot is saline and generally will be avoided as a topsoil layer in rehabilitation. Where suitable supply of other topsoil is available, this will be used in preference to Teviot, or Teviot soil mixed with this soil. Salt tolerant vegetation species may be required for rehabilitation on Teviot topsoils
- the subsoils of Cheshire, Teviot and Woleebee are saline and as far as practicable will be buried within spoil stockpiles and covered with materials that are more stable, or for the pipeline and infrastructure, should be buried as low as feasible to avoid the rooting depth of plants and crops.

Compaction

The compaction of soil increases the potential for rainwater induced erosion, and reduces the success of seed germination and root establishment of vegetation. The following measures are proposed to be applied where appropriate in relation to compaction:

- compaction of topsoil will be reduced by selection of appropriate earthmoving machinery when working with these soils (i.e. light weight vehicles with large wheel/track size)
- soils that will be trafficked or compacted during the operation of the mine will have water control and sediment containment measures installed to minimise potential erosion and sediment entering into waterways
- previously compacted areas that are to be rehabilitated will be remediated where practicable by ripping the top layer of soil/overburden material, and then applying layers of subsoil and topsoil as required to establish a suitable plant growth environment. The depth of ripping/reworking required is dependent on the impact, and will be assessed at the time or rehabilitation
- ripping the top layer of soil breaks down the soil structure, and as a result protection of these areas from re-compaction (i.e. vehicles or grazing animals) after ripping is required to allow the soil structure to reform.

Topsoil reuse

Topsoils and subsoils are anticipated to be stripped from all disturbed areas and should be stockpiled for use in rehabilitation of disturbed areas. Suggested stripping depths and identified constraints for various encountered soil types are provided in Table 9-9 below. Topsoil is proposed to be managed where appropriate as follows:

- topsoil will be stripped separately from subsoil and stockpiled during clearing
- topsoil will be stored in stockpiles no more than 3 m high to retain seed germination potential
- topsoil will be stored for the shortest period practicable, and where possible reused within six months of stripping to maximise the retention of the seed bank in the soil

- control measures such as fencing will be installed where practicable on newly topsoiled areas to exclude vehicle or stock access until a vegetation cover has established
- for the pipeline, topsoil will be reused in the general area from which it was stripped
- for the pipeline, topsoil will be spread to a minimum depth of approximately 0.2 m.

Table 9-9: Topsoil stripping depths and potential constraints for reuse

Soil type	Surface soil composition	Topsoil stripping depth (m)	Subsoil stripping depth (m from surface)	Potential constraints
Brigalow Uplands Cracking Clays				
Downfall	Clay	0.15	0.5	▪ shallow topsoil depth ▪ dispersive subsoil
Teviot	Clay	0.2	0.6	▪ dispersive subsoil ▪ moderately alkaline and saline
Rolleston	Clay	0.2	0.6	▪ alkaline ▪ topsoil may be dispersive ▪ dispersive subsoil
Brigalow Uplands non-cracking clays				
Cheshire	Light clay	0.4	—	▪ highly alkaline and saline subsoil ▪ dispersive subsoil
Kinnoul	Clay	0.3	0.5	▪ low nutrient availability in topsoil ▪ dispersive subsoil ▪ shallow soil depth
Rugby	loam	0.4	—	▪ sodic lower subsoil
Poplar box alluvial uniform soils				
Juandah	Clay	0.1	1.0	▪ dispersive A2 horizon ▪ poor workability when wet
Poplar box alluvial texture contrast soils				
Woleebee	Silty loam	0.15	—	▪ shallow topsoil depth ▪ dispersive topsoil and subsoil ▪ highly alkaline and saline subsoils ▪ low nutrients and organic matter ▪ poor workability when wet
Retro	Clay loam	0.15	1.0	▪ shallow topsoil depth ▪ poor workability when wet

Mining specific mitigation measures

As detailed in Section 6.4.4 of TR 9-1-V1.5 Geology, Mineral Resources, Overburden and Soils Impact Assessment, the stripping of topsoil on the MLA will result in approximately 2.3 million m^3 of topsoil and 6.4 million m^3 of subsoil available for use in rehabilitation over the 30 years of mining activities. In addition to the measures provided above, the following measures are proposed to be applied to topsoil reuse in the MLAs where appropriate:

- the placement of topsoil should consider the landscape position the topsoil was stripped from, with soils of the undulating topography (Brigalow uplands cracking clays and non-cracking clays), used on slopes and hilltops, and the alluvial soils (Juandah, Woleebee and Retro) used in lower slopes and areas where water accumulation may occur
- the stripping of topsoil should be incorporated into a 'permit to disturb' system to ensure suitable topsoil and subsoil are salvaged prior to disturbance
- a site topsoil register should also be developed for the Project, recording the locations and volumes of topsoil stockpiles
- topsoil and subsoil should be stripped to the depths shown in Table 9-9.

Soil conservation plans

Two approved soil conservation plans exist along the proposed gas supply pipeline, and other soil conservation measures are present in the Project area. The following measures are proposed to be undertaken in regard to existing soil conservation measures:

- discussions will be entered into with the Department of Natural Resources and Water and landowners to amend or revoke the two registered soil conservation plans
- existing soil conservation measures will be retained and maintained where they currently exist and the land is not required for mining activities
- any soil conservation measures, such as contour banks, that are disturbed during works will be reinstated following construction.

9.6.4 CONSTRUCTION MATERIALS

Mine infrastructure works will include water management structures (e.g. dams and levees), haul roads, and a mine infrastructure area. Most of these structures will require embankment and bulk fill material, but material quality requirements range widely.

Embankment materials for water management structures should generally have high clay content, intermediate plasticity and low dispersibility potential. Bulk fill for roads and industrial structures will require physical characteristics that would make them withstand loads and remain durable in service.

Alluvial soils encountered to about 2-3 m depth, and potentially present to greater depths along the creeks, comprise clay, silty and sand with minor gravel. Field observations indicate that the near surface sandy and silty clays of this sequence are of high plasticity and potentially high shrink-swell potential.

Residual soils encountered on the lower slopes in the undulating terrain were generally pale grey or pale brown silty/sandy clays of intermediate plasticity and high dispersion potential.

Clayey soils with a liquid limit less than about 70% and low to moderate dispersion potential (Emerson class number 4 or higher) could be considered for dam and levee embankment construction.

Based on available data, the alluvial soils are considered more suitable than the residual soils for water retaining structures, as they are less likely to be dispersive. Physical and chemical characteristics of soils considered for these structures will need to be confirmed for each potential source.

Interbedded sandstone and siltstone excavated from road cuttings and quarried from a number of pits in the area, is used by local authorities for construction of sealed and unsealed road. This material occurs throughout the MLA areas and appears to be suitable for use as bulk fill and sub-base for sealed roads, hardstands and pads. It is not considered suitable for use as base layer for sealed roads or trafficking layer of unsealed roads due to the presence of high plasticity fines, low durability of gravel fraction and estimated relatively low California bearing capacity ratio (CBR) value (PB, 2007). Base quality pavement materials are expected to be sourced off-site from third parties.

Bedding sand for the proposed pipeline is anticipated to be sourced from local sand/loam pits. Excavated materials from trench excavations are anticipated to be suitable for use as backfill, except rock fragments larger than about 150 mm. Most excavated weathered rock is anticipated to be suitable for use as backfill after tracked with heavy earthmoving machinery such as dozers.

9.6.5 POST MINING LAND USE

The gas supply pipeline is expected to have minimal impact on land suitability as the pipeline will be buried underground and grazing or dryland cropping is expected to be able to continue over the top of the pipeline. The erection of structures will be restricted along the gas pipeline corridor. The gas supply pipeline is therefore not included in the discussion below.

Post mining land uses are proposed to generally consist of beef cattle grazing and nature conservation. The post mining land suitability classes proposed to be established for this Project at a minimum are:

- undisturbed land returned to (or retained in) its pre-mining land suitability class, and should be able to be used for beef cattle grazing or dry land cropping as existed prior to mining
- land used for infrastructure components of the Project (e.g. roads and MIA) should be returned to Class 4 cropping land or Class 3 grazing land, and generally be able to be used for beef cattle grazing
- spoil stockpiles and tailing dam sites be returned to Class 4 cropping land or Class 3 grazing land, and generally be able to be used for low stock rates of beef cattle grazing, or alternatively for nature conservation
- final voids will be unsuitable for agricultural use being Class 5 for cropping and cattle grazing, and should be investigated for alternative beneficial uses such as wetlands or recreational facilities.

The relative areas of land under each suitability class pre-mining and post-mining are provided in Table 9-10. Comparing pre and estimated post mine land suitability class areas, the largest reduction will occur from Classes 3 and 4, for dry land cropping to Classes 4 and 5, with approximately 1,452 ha of Class 5 land, comprising the final voids. For beef cattle grazing there will be a reduction in land class from Class 2 to Class 3 with the total estimated area of Class 5 land the same as for dry land cropping. The anticipated changes for beef cattle grazing are considered acceptable as the land area will remain largely available for the activity for which it is considered suitable at the present.

Table 9-10: Estimated pre- and post-mine land suitability areas

Land suitability class	Estimated area of land			
	Pre-mining dry land cropping (ha)	**Post-mining dry land cropping* (ha)**	**Pre-mining beef cattle grazing (ha)**	**Post-mining beef cattle grazing* (ha)**
1	0	0	0	0
2	0	0	32,191	19,793
3	12,564	4,833	0	10,946
4	19,627	25,906	0	0
5	0	1,452	0	1,452

Note: * assume 30 year mine life

Land currently classified as Class 3 for dry land cropping, which will be disturbed by mining operations, will not be suitable for cropping in the post mine period but will largely be suitable as pasture land, therefore remaining in agricultural use.

Returning the land to class 4 cropping or class 3 beef cattle grazing will result in a lower value land use, and so is not an ideal outcome under the rehabilitation strategy. Rehabilitation activities should aim to return land occupied by infrastructure and low gradient stockpile slopes to class 3 cropping or class 2 beef cattle grazing. General limitations that need to be met to obtain this land suitability are contained in Table 6-4 of TR 9-1-V1.5 Geology, Mineral Resources, Overburden and Soils Impact Assessment. Site specific investigations will need to be undertaken to define whether these limitations can practically be developed for the final landform as the Project progresses.

Ideally, where the landform and the land class limitation characteristics can be met, the preferred post mining land uses proposed to be established are:

- land used for infrastructure components of the Project (e.g. roads and MIA) should be returned to Class 3 cropping land or Class 2 grazing land, and generally be able to be used for beef cattle grazing
- flatter gradient sections of spoil stockpiles and tailing dam sites should be returned to Class 3 cropping land or Class 2 grazing land, and generally be able to be used for beef cattle grazing. Steeper gradient spoil slopes should be used for nature conservation.

9.6.6 FINAL LANDFORM DESIGN

Final voids

Final mining voids will exist as part of the post-mining landform. It is estimated that fifteen void areas will be present at Year 30, occupying approximately 1,452 ha. The banks of the final void (i.e. the highwall, lowwall and endwalls) will be reshaped to achieve long term geotechnical stability.

The final voids are not proposed to be used for agricultural purposes, due to steep gradients and potential to fill with water. Where appropriate, it is proposed to use the final voids for nature conservation or some other beneficial uses such as wetlands or recreational facilities. Final landform slopes greater than 20% are proposed be vegetated with native vegetation, based on Department of Mines and Energy guidelines (1995a).

The coal seam should be covered using pre-strip overburden from adjacent overburden stockpiles. Voids should be partially filled.

The final slope gradients of each void, including the outer boxcut spoil slopes, low wall of the final voids, and highwall slopes should be assessed and recommended by a suitably qualified person based on the risk of long term geotechnical instability. The assessment can be based on the preliminary investigations undertaken by Golders Associates (2008), and should consider the implications of the final voids filling with water, and the proximity of final voids to creek and drainage lines.

Infrastructure areas and roads

Following decommissioning, infrastructure areas and roads should be returned to the pre-mining landform where practicable. Where this is not practicable, bench cuts should be removed and any steep grades reduced, and the landform returned to a similar profile of landforms in the region (as defined in Section 9.3.1).

The post mining land use of areas containing infrastructure or roads is proposed to be beef cattle grazing and dry land cropping, as occurs in the area pre-mining. The Project should therefore aim to return infrastructure areas to the same land suitability class as existed pre-mining, or at a minimum, one land suitability class less than the existing pre-mining class.

Spoil piles and tailing dams

Spoil piles should be progressively rehabilitated over the life of the mine, and rehabilitation should commence within two years of the land becoming available for rehabilitation. The tailings dams should commence being rehabilitated within two years of reaching capacity and no longer being required for tailings disposal. Spoil piles and tailings dams should be reshaped to stable landforms in accordance with Sections 9.6.1 and 9.6.5. Generally the final gradient should be no more than 15%.

The post mining land use of spoil piles and tailings disposal facilities is proposed to be beef cattle grazing, with native vegetation on steeper slopes and other areas in which trials show cattle grazing to be unsustainable.

Spoil piles should aim to be returned to the highest available land suitability class applicable for the given slope gradient, as outlined in Section 9.6.5. This will be Class 2 to Class 4 grazing land, or Class 3 to Class 5 cropping land, dependent on slope gradient.

Final landform slopes greater than 20% should be vegetated with native vegetation.

Creek diversions

Creek diversions will be retained following mine closure. The initial design of the creek diversion structures will incorporate stability and long term sustainability requirements, and ongoing monitoring during operation of the mine, as detailed in Chapter 11 and associated technical reports. At the conclusion of mining, the creek diversions should be left in a stable and sustainable condition.

9.6.7 MINE REHABILITATION

Detailed rehabilitation objectives and strategies for the Project are provided in Chapter 25. The following section contains objectives, indicators and strategies related to overburden and soils.

The broad rehabilitation objectives related to this chapter are:

- to establish a permanent, stable, self sustaining vegetation complex to support the agreed post mining land use
- to create a stable landform with rates of soil erosion not exceeding the pre-mine conditions
- to maintain downstream water quality, during the construction, operational and post operation phases of the Project.

Rehabilitation indicators

Rehabilitation indicators provide an auditable means of measuring progress towards the rehabilitation objectives. The following indicators are proposed for the Project in relation to soil and overburden properties and final landform:

- slope angle, length and profile
- rate of soil loss
- chemical properties of topsoil and growth medium within plant rooting depth (e.g. pH, salinity, sodicity, trace elements, nutrients)
- upstream and downstream surface and ground water quality (e.g. sediment load, pH, heavy metal content)
- physical properties (e.g. depth of topsoil, water infiltration, slope gradient, crusting)
- vegetation cover comparable to desired and agreed land use
- weed cover
- rehabilitation progress and success rate
- achievement of agreed final land use
- ongoing sustainability of agreed final land use.

Rehabilitation strategies

Rehabilitation strategies to be implemented to address the rehabilitation objectives and indicators include the mitigation measures covered in Sections 9.6.1 to and 9.6.3, and the following additional measures:

- the area of disturbed land at any one time will be minimised through planning, staged development and designation of specific site areas. The following site specific plans and procedures (or similar) will be developed where appropriate and incorporated into the operation of the mine:

- erosion and sediment control plan
- topsoil management plan, including a topsoil register
- overburden dump construction procedure
- rehabilitation and revegetation plan
- stormwater management plan
- permit to disturb system
- final void geotechnical report.

- the landform design will accommodate spoil limitations, including slope gradient and profile
- progressive rehabilitation will be undertaken over the life of the mine, and should commence within two years of land becoming available for rehabilitation. Progressive rehabilitation of mining rock and soil wastes will consider the following techniques:
  - all rehabilitation work to be conducted progressively as part of the overall mine process
  - the slope gradient to be determined from the results of the physical properties analysis of the spoil, and to be based on the ability of the spoil to sustain vegetation and resist erosion
  - progressive revegetation of disturbed areas or stockpiles to be undertaken as soon as practicable
  - revegetation to use native species and species suited for particular landforms and soil types, where practicable.
- weed management is proposed to be conducted as specified in the Chapter 17A Ecology of Volume 1, and consider appropriate State and local legislation, policies and guidance
- revegetation is proposed be conducted as specified in Chapter 17A Ecology of Volume 1, and consider appropriate State and local legislation, policies and guidance
- clean water runoff from upstream of undisturbed areas will be directed around disturbed areas using diversion bunds and catch drains as appropriate
- training of site personnel will include the concepts of minimising land disturbance and the philosophy of the erosion and sediment control program. Training in how to implement erosion and sediment control measures will be part of the site induction where appropriate and ongoing training
- where long term stockpiles are created for progressive and post operations rehabilitation, stockpiles will be incorporated into the landscaping process and vegetated
- a period of time will be required following rehabilitation to allow for development of protective vegetation cover, to prevent surface deterioration and potential impact on downstream catchments. No agricultural activities will be carried out on rehabilitated land prior to full rehabilitation, to reduce the risk of degradation of the surface capping soil, and erosion

- caution will be applied when assessing rehabilitated spoil stockpiles for suitability of cattle grazing. Stocking levels should be correctly assessed and managed to prevent erosion of the stockpile slopes.

9.7 RESIDUAL IMPACTS

Following mitigation, the residual impacts are anticipated to be as follows:

- change to the land use, both during the mine operation and post-mining. The main post mining land uses are envisaged to be cattle grazing and nature conservation
- reduction in areas of land suitability classes from Class 3 pre-mining to Class 4 post-mining for dry land cropping and Class 2 to Class 3 for beef cattle grazing
- redistribution of existing landforms but maintaining general topographic character
- diversion of sections of a number of creeks that traverse the MLAs, including change in landscape form
- addition of final voids into the landscape. These may fill up with water and become wetlands or be used for recreational purposes.

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