5 Mineral Waste

5.1 Introduction

This section provides an assessment of the geochemical characteristics for the overburden and coal interburden sedimentary sequences, collectively referred to as 'spoil', for the proposed Daunia Coal Mine Project (the Project). The objective of the geochemical assessment is to determine the following:

- the potential for acid mine drainage;
- the concentrations of trace metals in the spoil, and potential for contamination; and
- the feasibility of using the spoil material for site rehabilitation.

Coal is deposited within environments that typically have a high potential to produce sulphides within the sediments during deposition. The mining of coal and removal of the overburden and interburden can result in the oxidation of the sulphides upon exposure to air and water, generating sulphuric acid. The resulting acid mine drainage is characterised by highly acidic waters with elevated metal and sulphate concentrations. Accordingly, the geochemical assessment includes the analysis of sulphide content of the spoil and determination as to whether the contained sulphides will potentially form acidic conditions, if oxidised.

The interburden material close to the coal beds, which has been characterised, is considered to be representative of the projected rejects material and thus provides a guide to its potential for generating acidic conditions. Should the Project proceed, the rejects material will be analysed to determine their geochemical characteristics, disposal requirements, and implications for site rehabilitation. It is planned that there will be no disposal of coal rejects or fine coal tailings outside of the pit; instead these will be disposed of as solids within the spoil dumps.

5.2 Geological Setting

The Project Site is located in the northern part of the Permo-Triassic Bowen Basin containing principally fluvial and some marine sediments. The coal deposits are contained in the Late Permian sediments of the Rangal Coal Measures, which are overlain by Late Permian to Early Triassic sediments of the Rewan Group. It is the Rewan Group sediments that are the sedimentary sequence of interest for the geochemical assessment. A cross section showing the Daunia deposit stratigraphy is presented in **Figure 5-1**.

The Permo-Triassic sediments are overlain by an average of 2 m of surface soil and clay, which may range from 0.5 m to 8 m and is derived from the complete weathering of the underlying sediments. Tertiary sediments have not been identified within the Project area.

Non-coal Permian sediments consist of moderately weak to strong sandstones, siltstones, with minor mudstones and carbonaceous mudstones. The sandstone is usually massive, fine-grained, equigranular, with sub-angular to sub-rounded grains, which have been cemented by both clay and carbonate materials.

5.3 Overburden and Coal Interburden - Waste Stream Identification

The spoil generated by the Project will comprise the following materials:

- Weathered Zone – Primarily Cainozoic sediments consisting of sands and clays (not characterised as part of the geochemical assessment).

- Un-weathered Overburden – Permian units consisting of interbedded sandstones, siltstone, and claystone. Carbonaceous zones occur near the base of the overburden.
- Interburden – Sandstones, siltstones, and claystones with carbonaceous zones.
- Coal Rejects and Tailings.

Weathered zone materials found at, or near, the surface were not characterised as part of the geochemical assessment. These materials represent highly weathered rock, thus there is a low likelihood of acid mine drainage and toxic metal levels being present. Discussion on soils for the Project is found in **Section 4**.

The un-weathered overburden and coal interburden materials are the focus of this geochemical assessment and were sampled and analysed to determine their geochemical characteristics as waste rock.

Coal rejects and tailings were not characterised directly as part of the geochemical assessment. The interburden material close to the coal beds is considered to be representative of the rejects material providing an indication of its potential for generating acidic conditions.

5.4 Site Investigations and Laboratory Analysis

20 drill holes were drilled over the Project Site to provide representative samples of the overburden and interburden material to be moved during the Project (see **Figure 5-2**). Chip samples were collected and composited over representative drill depths, usually by lithological unit, with two samples collected from each sampling interval. The samples taken are shown in **Table G-1**, **Appendix G**. All tables referred to in this report are presented in **Appendix G**.

Samples were transported to a laboratory and a total of 199 samples were analysed using NATA certified methods for the following parameters:

- Paste pH and Electrical Conductivity (EC).
- Cation Exchange Capacity (CEC) (including exchangeable calcium, potassium, magnesium, and sodium).
- Trace Metals (arsenic, chromium, copper, manganese, nickel, selenium, and zinc).
- Total Sulphur.

A total of 59 samples that were found to contain greater than 300 mg/kg total sulphur during the initial analysis, were also analysed for the following parameters:

- Sulphide Sulphur by the Chromium Reducible Sulphur (CRS) method.
- Acid Neutralising Capacity (ANC).
- Net Acid Production Potential (NAPP).
- Fizz Rating.

The additional analyses were used to assess the presence of acid forming sulphides (principally pyrite) and to determine if any acid neutralising potential was present. Samples with high sulphide-sulphur contents and low ANC potential are more likely to develop acid mine drainage in the future due to the oxidation of the sulphides found in the material.

Paste pH was used to detect the presence of natural acidity within the samples. This acidity may be related to oxidation of acid forming sulphides under natural vadose zone conditions.

Paste EC, CEC and trace metal analysis were included to determine the suitability of materials for use in site rehabilitation works as well as handling requirements for materials with a high trace metal content.

5.5 Geochemical Analysis

5.5.1 Sulphur and Acid Generation Potential

Total sulphur analysis provides a method of screening samples that may comprise acid-producing material, principally in the form of pyrite sulphur. Generally, where total sulphur is less than 300 mg/kg (0.03%), there is a negligible risk of acid generation (CoA, 1997). In many coal deposits a significant proportion of sulphur reported as total sulphur is from organically bound non-acid forming sulphur. Other sources of sulphur that may be reported as total sulphur may be from sulphate derived from saline groundwater or where the overburden has been previously oxidised and contains the products of oxidised sulphides. The presence of sulphide sulphur can be determined using the CRS analysis method and is used to calculate the Acid Producing Potential (APP) of the materials. However, the APP does not account for the natural ANC of the materials, which must be subtracted from the APP to calculate the NAPP. Most rocks have an inherent ANC due to the rock forming minerals they contain. Carbonates provide an excellent neutralisation capacity, but so may silicates, clays, and other minerals. Calculating the NAPP thus provides a more accurate indication of the potential for acid formation in materials due to the oxidation of sulphides.

If the NAPP value is negative, then the material is less likely to generate acidic conditions over time, as the acid formed by the oxidation of sulphides will be neutralised by the reaction with other minerals within the material, given the appropriate reaction kinetics. However, a general rule of thumb is that there is an “unknown” zone when NAPP is between -10 and +10 kg/t H_2SO_4 where the neutralising potential of the material based on NAPP results is difficult to assess. In these cases, further analysis may be required to more accurately determine the likelihood for acid generation. **Table G-2, Appendix G** presents the total sulphur results for each sample taken. Nearly 70 per cent (140 of 199) of the samples analysed had total sulphur of 0.03% or less, and are considered to be of negligible risk for acid generation.

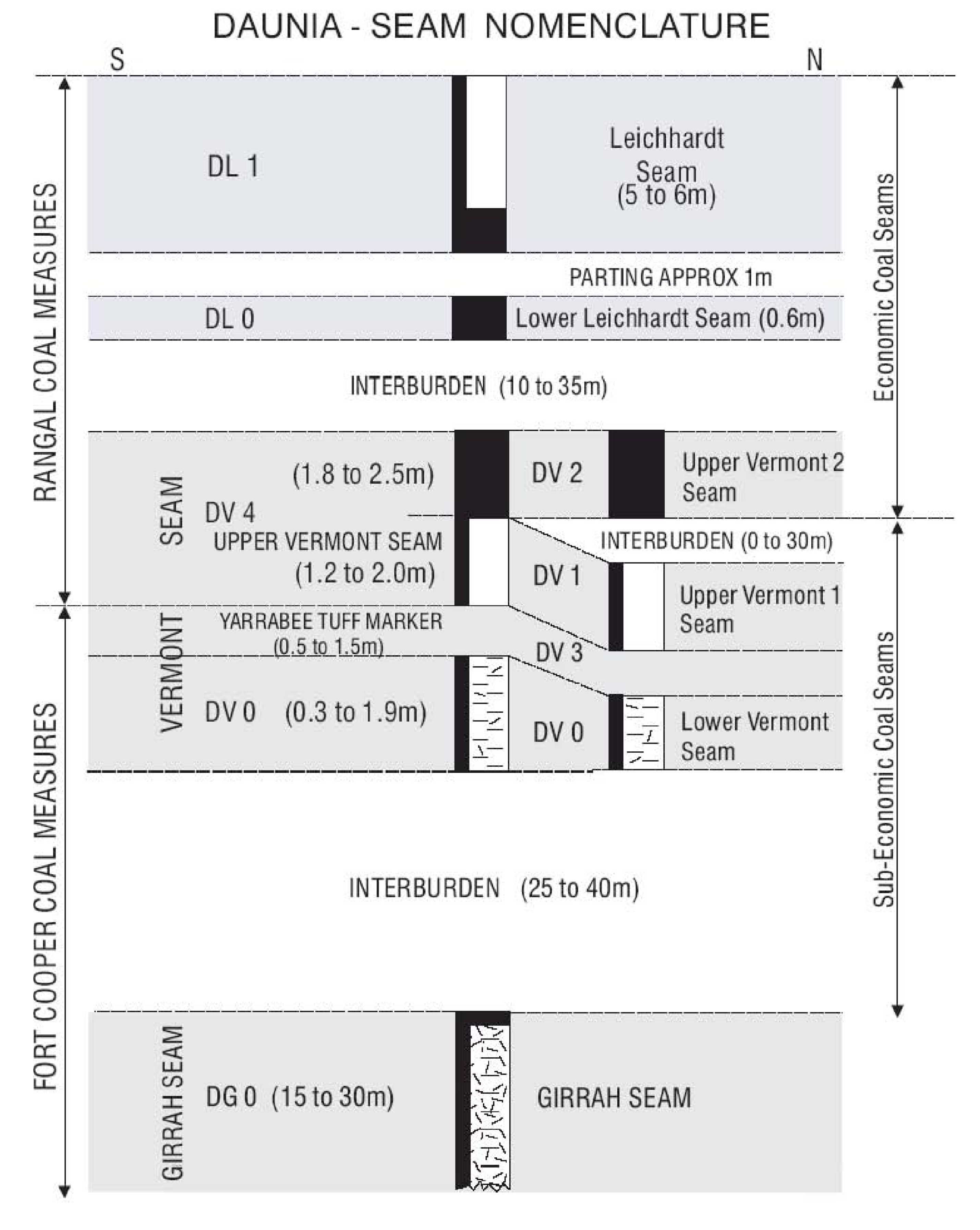
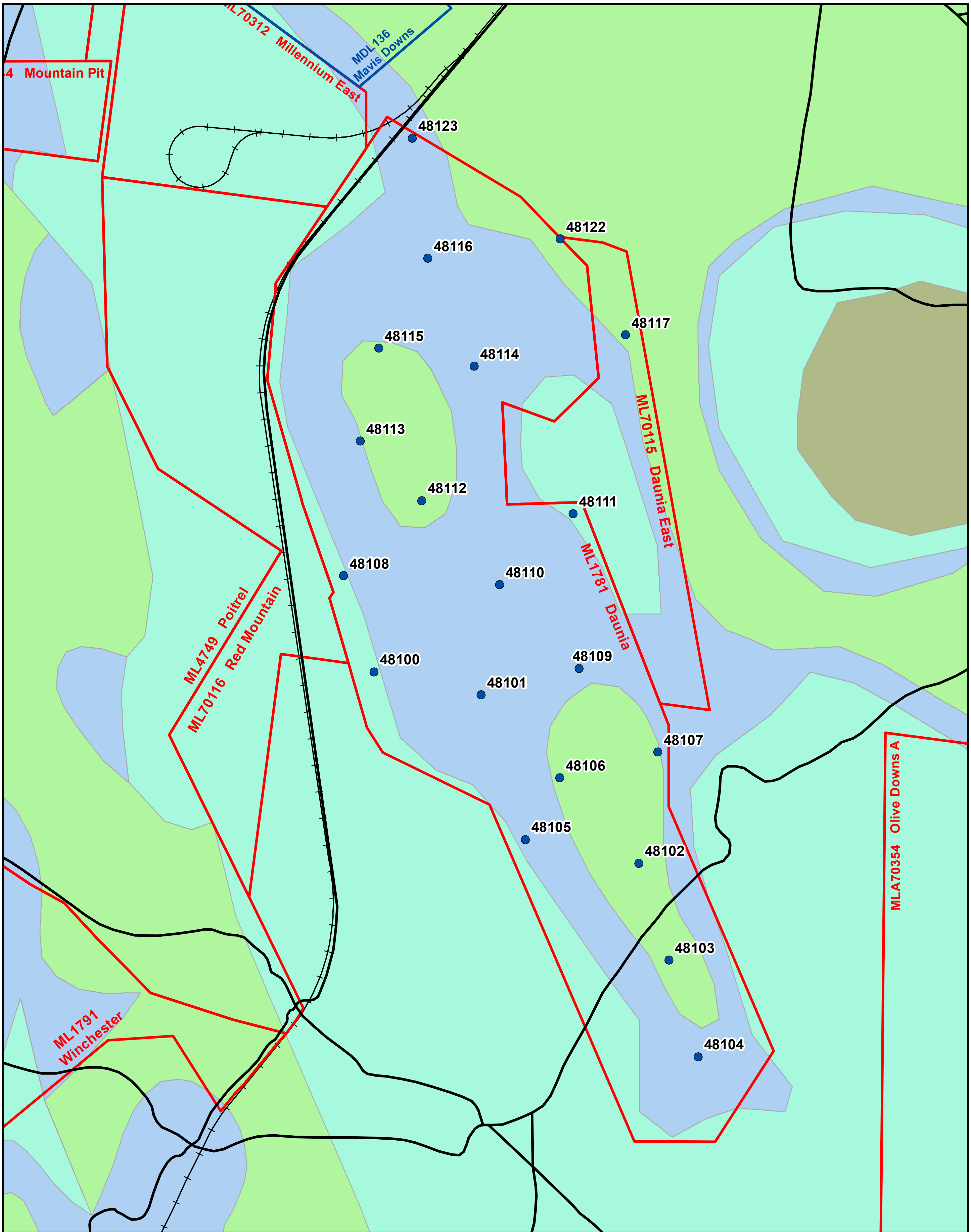


FIGURE 5-1

DAUNIA COAL MINE EIS

DAUNIA COAL DEPOSIT
TYPICAL STRATIGRAPHIC SECTION

BHP Billiton Mitsubishi Alliance



LEGEND

- Geochemistry Sample Sites
- Roads
- Existing Railway
- Mining Lease
- Mineral Development Licence

Regional Geology Boundaries

- Qpa - Quaternary Pleistocene alluvium
- Qa - Quaternary alluvium
- TQa - Tertiary/Quaternary alluvium
- Ts - Suttor Formation
- Re - Rewan Group
- Pwb - Rangal Coal measures

FIGURE 5-2

DAUNIA COAL MINE EIS

GEOCHEMICAL SAMPLE SITES

0 0.5 1 1.5 2

Kilometres

Scale 1:50,000 on A4

Projection: Australian Map Grid - Zone 55 (AGD84)

BMA

BHP Billiton Mitsubishi Alliance

I:\QENV\Projects\QE06520\1800 Spatial\Arc_MXD\Figures\Fig_5-2_Geochemical_Sample_Sites_v3.mxd Produced: 7/10/2008 This figure should be read in conjunction with the data disclaimer at the front of this report.

The remaining 59 samples that had total sulphur values greater than 0.03% were analysed for the additional acid base accounting parameters (NAPP, ANC, CRS and fizz rating). These are also presented in **Table G.2. Table G.3** shows a statistical summary of these results.

Of the 59 samples, 25 samples were found to have CRS greater than 0.03% with a maximum reported value of 0.87%. The 59 samples were found to have an APP ranging from 0.2 to 29 kg/t of H_2SO_4 with a mean value of 1.3 kg/t H_2SO_4. However, the materials were also found to contain a high degree of neutralisation capacity, with the ANC ranging from 2 to 214 kg/t H_2SO_4, with a mean value of 40 kg/t H_2SO_4 equivalents. The effectiveness of the natural acid neutralising capacity of the materials was demonstrated by the NAPP values, which showed that 75% of the 59 samples had NAPP values less than -11 kg/t H_2SO_4. Of the remaining 25% of samples, 10 had NAPP values between -10 and +10 kg/t H_2SO_4, with only two samples having a NAPP exceeding +10 kg/t H_2SO_4. The two samples were as follows:

- Sample 126519, drill hole 48106 (interburden): 14.5 kg/t H_2SO_4
- Sample 126893, drill hole 48113 (interburden): 11.2 kg/t H_2SO_4

The results show that although the interburden material generally has a higher total sulphur content than the overburden material, ANC values are also higher, resulting in generally lower overall NAPP values (interburden mean NAPP -38.5 kg H_2SO_4/t, overburden mean NAPP -25 kg H_2SO_4/t). This suggests that reject material from this deposit should have a low risk for producing ARD.

Tailings material is generated from the coal seams. Total sulphur in the coal seams ranges from 0.43% to 0.55%. This is at the upper end of the range of total sulphur in the interburden or rejects material. However, similar to the interburden material, the neutralising capacity of the tailings is also likely to be higher. This suggests that acid mine drainage from coal tailings will be manageable by providing sufficient cover over this material. It is proposed that a minimum 5 m depth of benign spoil is placed over coal reject and tailings material. It is also proposed that investigations to confirm the characteristics of tailings material commence in the first year of operation and continue throughout the life of mine.

Given the limited number of samples with positive NAPP values and the overall findings of low total sulphur, low sulphide and high neutralising capacity, it is considered that the overburden and interburden materials at the Project Site pose a low risk of acid generation. It is recommended that sampling of the spoil material be undertaken on a regular basis to ensure that specific zones within the mining operations do not fall outside of the findings demonstrated by the geochemical analysis.

5.5.2 Exchangeable Cations

Cation exchange analysis provides information on the quality of leachate that may drain from spoil after contact with water and the suitability of the spoil as a plant-growing medium. Cations are held on the surface of charged soil minerals, organic matter and within the crystalline framework of clay minerals. The movement of cations from their current position and replacement by other cations is known as cation exchange. Some surfaces and minerals have a greater capacity to hold ions than others. The ability of a soil to hold major cations (Ca, Mg, Na, and K) is a measure of the general fertility of the soil.

The ratio of the individual cations to the potential CEC is particularly important in the overall geochemical analysis. An imbalance in these ratios is linked to poor soil properties and low fertility which has implications for rehabilitation of the mined land.

Tables G-4 and **G-5** present analytical results on overburden and coal interburden materials for CEC, Exchangeable Cations, paste pH, and paste EC (salinity). There is little difference observed in the values for these parameters between the overburden and the interburden. The best growth of pasture in the Bowen Basin appears to be achieved at near neutral pH (ACARP, 2001), however, pH between 5.5 – 8.5 should not be limiting to the growth of pasture species (ACARP, 2001). The geochemical analysis indicated paste pH values generally between 7 to 9 which is slightly higher (more alkaline) than the optimal range. The minimum paste pH value was 4.7, which suggests a potential for acid formation. The maximum paste pH value observed was 9.5 and may indicate a sodic soil. The salinity threshold for EC at which expected salt damage may occur for typical pastures in this area is 6,000 μS/cm (DNR, 1997), while for other plant species this is lower (depending on soil type and plant species). None of the samples were found to have a paste EC exceeding this value.

Tables G-4 and **G-5** also present the Exchangeable Sodium Percent (ESP) values, calculated as the ratio of exchangeable sodium to CEC. The desirable ESP range for good soil fertility and maintaining a strong soil structure is below 1 percent, with up to 7 per cent being generally considered non-sodic. None of the samples have ESP values below 1 per cent; however 25 per cent are below 7 per cent and considered to be generally non-sodic. The majority of the samples, however, are moderately to strongly sodic with 75 per cent of the samples having an ESP range between 7 – 46%. These higher values are from both the overburden and interburden, and it is unlikely that these materials will be suitable for rehabilitation without treatment or topsoil. Further information on the suitability of topsoils for use in rehabilitation is presented in **Section 4**.

Approximately 80 per cent of the samples were found to have an exchangeable magnesium ratio outside the desirable range for general fertility of 10 to 15 per cent. Most samples were higher than the desirable range. Approximately 50 per cent of the samples were found to have exchangeable calcium ratio within the desired range for general fertility of 65 to 85 percent, with most of the other samples being lower than the desired range. Approximately 60 per cent of the samples were found to have an exchangeable potassium ratio within the desired range for general fertility of 1 to 5 percent, with most of the other samples being higher than the desired range.

5.5.3 Trace Metal Composition

Table G-6 presents results for arsenic, chromium, copper, manganese, mercury, nickel, selenium, and zinc. **Table G-7** summarises these results and provides a comparison to the typical trace element concentrations for shale (Berkman, 1989). Shale has been used here for comparison as it represents the finer grained materials found within the interburden in a consolidated form and published composition data exists from many sources.

Trace metal concentrations for the samples were found to be very similar to those of typical shale, which is generally representative of the sediments that dominate the geology in the region. The spoil material composition, based on trace metal composition, will be typical of the naturally occurring background materials. There is little difference in observed trace metal composition between the overburden and the interburden.

In terms of the ability to revegetate the spoil dumps, the metal content for these samples is below the phytotoxicity levels presented in the NSW EPA guidelines (2002) with minor exceptions: four samples have arsenic concentrations above 20 mg/kg and one sample has a zinc concentration above 200 mg/kg. However, as stated in the NSW EPA guidelines (2002) and Naidu *et al*. (2003), phytotoxicity levels are highly variable based on soil and plant type. The five elevated levels found in the geochemical analysis are not considered problematic, given the minor proportion of the total volume affected and the variable susceptibility of plants to trace metal concentrations. Additionally, the phytotoxicity values presented are the only guideline values currently published in Australia, and are considered to be conservative (Naidu *et al.* 2003).

Comparison of the metal concentrations to the National Environment Protection Measure (NEPM) for Assessment of Site Contamination (NEPC, 1999) indicates that the metal concentrations were generally well below health investigation levels for residential and other sensitive land uses. The only exception was manganese, which was found to be above the health investigation levels (HIL) in 11 out of 199 samples (see **Table G-6**).

5.6 Discussion and Mitigation Measures

All lithological units that will be disturbed by the Project are considered to present negligible risk in terms of acid generation. Nearly 70 per cent of the samples analysed had a low concentration of total sulphur and of the remaining 30 per cent, approximately 17 per cent were found to have a low concentration of sulphide sulphur, indicating that the majority of the sulphur would be organically bound or present as sulphate derived from saline groundwater. The total dissolved solids in groundwater from this region, can typically reach 10,000 mg/L (see **Section 7**). Less than 13 per cent of the total samples had sulphide sulphur in excess of 0.03 per cent and thus could potentially generate significant acid. However, these materials were also found to possess a high degree of neutralisation capacity that would act to counter any acid generation from the oxidation of sulphide. Accounting for the natural acid neutralising capacity, only 2 samples out of 199 were found to have a net acid producing potential (**Table G-2**).

Although the overall indication is that little to no acid generation will occur from the oxidation of sulphides contained within the overburden and coal interburden, these materials should continue to be evaluated regularly during mining operations to assess acid generating capacity. Spoil found to contain sufficient sulphides to generate acid conditions should be isolated and/or mixed with spoil having an excess acid neutralisation capacity (NAPP < 10 kg/t H_2SO_4 equivalent).

Given the relatively high sodicity of the spoil it is likely that the material will be dispersive. Erosion and sedimentation controls will therefore be an important management tool. The high sodicity is the most significant concern regarding the revegetation of the waste spoils. Highly sodic soils have a tendency to lose aggregation and to develop clay dispersion, impermeable layers, surface crusting, and poor aeration (Baker and Eldershaw, 1993). To minimise these effects spoil dumps will be managed by:

- Stripping topsoil ahead of mining operations and directly placing topsoil on rehabilitation where possible, otherwise manage topsoil stockpiles for later use.
- Application of fertilisers and other soil treatments as required.
- Rehabilitating spoil dumps with appropriate species.

It may be necessary to treat surfaces of spoil dumps to ensure that negative revegetation impacts do not occur. Further information on topsoil stockpiling, storage and rehabilitation is found in **Section 4**.

5.7 Conclusion

The spoil associated with the proposed Project consists of unconsolidated clays and sands within the weathered zone, and predominantly interbedded sandstone and siltstone within the un-weathered zone. This material is geochemically benign, with negligible acid generation potential.

Between the primary coal layers (interburden) lie sandstone, siltstone, and claystone with occasional carbonaceous zones. This interburden material is characterised by a variable sulphur content, which is likely to be contained in organically bound sulphur and possibly sulphate derived from saline groundwater. The interburden material has a negligible acid generation potential based on the geochemical analysis.

The material tested is likely to be suitable for revegetation. Topsoil will also be used as a surface treatment prior to revegetation to minimise any effects from sodic spoil. Alternatively consideration may be given to incorporating calcium into the surface horizon of the final spoil dump to reduce the sodicity and minimise issues related to high sodicity. Taking this action may assist in maintaining the structure of the soil and help to prevent erosion of the underlying sodic material.

Results suggest that acid mine drainage from coal tailings will be manageable by providing sufficient cover material. During the initial phases of operation, and continuing throughout life of mine, it is proposed to carry out analysis of tailings material to confirm its geochemical characteristics.