APPENDIX C

Acid and metalliferous drainage assessment

Cobbora Holding Company Pty Limited

EMM EMGA Mitchell McLennan

www.emgamm.com

GeoTerra

COBBORA HOLDING COMPANY PTY LTD
COBBORA COAL PROJECT
ACID & METALLIFEROUS DRAINAGE ASSESSMENT
Dunedoo, NSW

COB1-R1F
25 JUNE 2012

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GeoTerra

COB1-R1F (25 JUNE 2012)

Cobbora Holding Company Pty Ltd
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Attention: Phillip Towler

Phillip,

RE: Cobbora Coal Project Acid & Metalliferous Drainage Assessment

Please find enclosed a copy of the above mentioned report.

Yours faithfully

GeoTerra Pty Ltd

Andrew Dawkins (AuSIMM CP-Env)

Managing Geoscientist

Distribution:	Original	GeoTerra Pty Ltd
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Date	Rev	Comments
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23.02.2012	A	Incorporate mine plan and ownership changes
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25.06.2012	F	Incorporate CHC comments

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GLOSSARY OF TERMS

ABCC	Acid buffering characteristic curve measures the readily available portion of the inherent acid neutralising capacity (ANC) of a sample by slow acid titration to a set end-point and then calculation of the amount of acid consumed and evaluation of the resultant titration curve.
Acid	A measure of hydrogen ion (H+) concentration; generally expressed as pH
Acid Base Account	Evaluation of the balance between acid generation and acid neutralisation processes. Generally determines the maximum potential acidity (MPA) and the inherent acid neutralising capacity (ANC), as defined below.
AMD	Acid and metalliferous drainage caused by exposure of sulphide minerals in mine waste materials to oxygen and water. Typically characterised by low pH and elevated concentrations of salts, sulphate and metals.
ANC	Acid neutralising capacity of a sample as kg H2SO4 per tonne of sample.
ANC/MPA Ratio	Ratio of the acid neutralising capacity and maximum potential acidity of a sample. Used to assess the risk of a sample generating acid conditions.
CHPP	Coal Handling and Preparation Plant.
EC	Electrical Conductivity, expressed as µS/cm.
CEC	Cation exchange capacity provides a measure of the amount of exchangeable cations (Ca, Mg, Na and K) in a sample. .
ESP	Exchangeable sodium percentage provides a measure of the sodicity of a materials and propensity to erode.
KLC test	Kinetic leach column tests are procedures used to measure the geochemical/ weathering behaviour of a sample of mine material overtime.
MPA	Maximum Potential Acidity calculated by multiplying the total sulfur content of a sample by 30.6 (stoichiometric factor) and expressed as kg H2SO4 per tonne.
NAF	Non-acid forming. Geochemical classification criterion for a sample that will not generate acid conditions.
NAG test	Net acid generation test. Hydrogen peroxide solution is used to oxidise sulfides in a sample, then any acid generated through oxidation may be consumed by neutralising components in the sample. Any remaining acidity is expressed as kg H2SO4 per tonne.
NAPP	Net acid producing potential expressed as kg H2SO4 per tonne. Calculated by subtracting the ANC from the MPA.
Overburden	Material that overlies a coal resource and must be removed to mine the coal.
PAF	Potentially acid forming. Geochemical classification criterion for a sample that has the potential to generate acid conditions.
(Coal) Reject	Mixture of coarse and finely ground materials from which the desired mineral (coal) values have been largely extracted.
Static test	Procedure for characterising the geochemical nature of a sample at one point in time. Static tests may include measurements of mineral and chemical composition of a sample and the Acid Base Account.
(Coal) Tailing	Finely ground materials from which the desired mineral (coal) values have been largely extracted.
TSF	Tailing storage facility designed for the storage of tailing (fine reject) materials produced during coal processing at the CHPP. Supernatant water may be recycled back to the CHPP from a decant pond.
Total Sulfur	Total sulfur content of a sample generally measured using a 'Leco' analyser expressed as % S.
Uncertain	Geochemical classification criterion for a sample where the potential to generate acid conditions remains uncertain and may require further analysis.

EXECUTIVE SUMMARY

The Cobbora Coal Project is a proposed multi-seamed open cut coal mine which consists of Mining Areas A, B and C. Mining operation is planned by conventional truck and excavator method to a maximum depth of 110m.

An acid and metalliferous drainage (AMD) investigation was performed to assess the AMD potential of the overburden, coal, floor rock and washery wastes anticipated to be produced from development of the mine.

The investigation incorporated sampling, laboratory assessment and interpretation of 59 discrete lithological core intervals from overburden, coal seam, seam roof or seam floor material. An additional 11 samples were assessed from washery waste.

The selected samples were geochemically tested for AMD parameters, supported by inspection and sampling of drill cores from bores DDH47, DDH49, DDH51 and DDH97, as well as coal intercepts from open hole hammer bores FEH001 and FEH002.

Mine Plan Variation

The locations of sampled bores were based on a proposed two pit mine layout which was current at the time of sampling in September 2010.

In August 2011 the proposed mine plan changed and an updated pit layout was proposed.

Mining Area B of the current mine plan encompasses bores DDH47 and DDH49. Bore DDH51 is located along strike and 1400m south east of Mining Area B. Bore DDH97 is located down dip and 650m west of Mining Area A.

Mining Area A of the current mine plan encompasses open hammer bore FEH001. Open hammer bore FEH002 is located down dip and 700m southeast of Mining Area B.

Due to the essentially laminar dip and strike of the formations in the project area, bores along strike from the new pits are sampling the same depth and formation in the now “out of pit” bores. Samples obtained from the now “out of pit” down dip bores represent samples with potentially higher total AMD generating sulfide levels, as they were obtained from deeper, less weathered lithologies, which represents the potentially “worst case” scenario.

It was determined that the assessment of the coal washery samples is not affected by the mine plan changes.

The AMD results and conclusions based on the original pit layout remain relevant and are applicable to the updated pit layout.

Overburden and Pit Floor

Geochemical characterisation at each bore location showed the following (ranges of values reflect the results from different bores):

- 57 – 66% of the overburden could be non-acid forming
- 7 - 25% could be uncertain be to non-acid forming
- 6 – 17% could be uncertain to be potentially acid forming
- 0 – 11% could be potentially acid forming – low capacity
- 0 – 9% could be potentially acid forming

The majority of potentially acid forming materials are associated with the unweathered, uneconomic Whaka coal seam, which has the highest sulfur level of 0.43% Total S.

The economic Ulan and Flyblowers coal seams and their associated carbonaceous lithologies with the higher total sulfur content will predominantly be extracted, washed in the CHPP and exported as product coal, with the washery waste placed in tailings dams.

Overall, the overburden and pit floor materials are likely to be non-acid forming (NAF), and should not require any special handling for AMD control.

Pyritic material AMD generation may occur predominantly from the Whaka Seam overburden, this source is anticipated to have a limited AMD potential.

The potentially acid forming (PAF) horizons are primarily associated with coal seams and their immediate roof and floor.

The overburden has limited excess alkalinity. Mixing of mined materials as part of normal operations is expected to mitigate any isolated AMD leachate that may occur.

Salinity is low for the overburden material, whilst pH is circum-neutral.

The overburden is not anticipated to generate bulk leachate that would exceed the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ 2000) for upland streams in NSW or protection of 95% of aquatic species criteria.

Washery Wastes

The washery wastes are likely to be non-acid forming (NAF), and should not require any special handling for AMD control. Although minor pyritic materials may occur in the waste, these are not anticipated to generate adverse leachate.

The washery waste has limited excess alkalinity. Mixing as part of the tailings management is expected to mitigate any isolated AMD leachate that may occur.

Salinity is low for the washery waste material, whilst pH is circum-neutral.

The washery waste is not anticipated to generate bulk leachate that would exceed the upland stream or protection of 95% of aquatic species criteria (ANZECC/ARMCANZ 2000).

Potential Waste Management Actions

Based on the existing data, no specific overburden or tailings waste management handling, storage or testing procedures are considered to be required in regard to AMD management, although additional AMD testing would confirm (or modify) this conclusion in relation to the Whaka Seam.

Most of the overburden and interburden is indicated to be NAF and will not require special handling for AMD control, and can be used to assist management of PAF materials.

If required, and if any additional AMD test work was inconsistent with the current findings, particularly in regard to the Whaka Seam, possible management strategies for PAF washery waste or overburden/interburden could include:

- limestone treatment and interim compaction of PAF materials to increase lag times before onset of acid conditions to manage AMD during operations or until implementation of closure strategies;
- placement of PAF materials below the water table to allow inundation and prevent

further exposure to atmospheric oxidation; or

- construction of a NAF cover zone designed to limit oxygen diffusion and infiltration into PAF materials (where water and oxygen flux modelling will be required to determine the best approach under the local climatic conditions).

The run of mine (ROM) and product coal stockpiles are not anticipated to generate AMD assuming typical residence times and reaction rates, and therefore, provision for capture of runoff/leachate, monitoring and lime treatment associated with the ROM stockpiles is not an anticipated requirement.

A program of routine sampling and testing of washery wastes and overburden/interburden materials should be implemented during active placement to monitor any variation in acid potential and to reconcile the low potential AMD in the overburden.

To assess the performance of any management strategies that may be required, and to determine the need and/or refinement of lime and limestone treatment requirements, water quality monitoring of seepage and runoff from pit walls and floors, waste rock emplacements, ROM stockpiles and washery waste disposal areas should be conducted to monitor for AMD generation.

Routine site water quality monitoring programmes should include pH, EC, acidity/alkalinity, SO_4, Al, As, Co, Cu, Fe, Mn, Ni and Zn to monitor for any effects of pyrite oxidation and AMD generation.

1. INTRODUCTION

Geoterra Pty Ltd (Geoterra) was initially commissioned by the Cobbora Management Company Pty Ltd (CMC) to conduct an acid and metalliferous drainage (AMD) assessment of the proposed Cobbora open cut project in 2010.

The project owner was subsequently changed to the Cobbora Holding Company Pty Ltd (CHC), and the mine plan was modified in August 2011.

The Cobbora Coal Project is located 5km from the village of Cobbora and 22km south west of Dunedoo in the Western Coalfield of New South Wales.

The potential sources of AMD from the operation include:

- overburden waste rock;
- open pit floors
- washery rejects and tailings; and
- raw coal and product coal stockpiles.

1.1 Objectives

The objective of the work was to assess the AMD potential of overburden, coal, floor rock and washery wastes anticipated to be produced from development of the project.

2. PROPOSED MINE PLAN AND MINE WASTE MANAGEMENT

Multiple open cut mining pits will be developed within the three mining areas shown in Figure 1. They are:

- Area A north of the infrastructure area to 70m deep;
- Area B south of the infrastructure area to 110m deep; and
- Area C north-east of the infrastructure area to 100m deep.

There will be three out-of-pit waste rock emplacements:

- AC-OOP between mining areas A and C;
- B-OOP E adjacent to Mining Area B on the east side of Laheys Creek; and
- B-OOP W adjacent to Mining Area B on the west side of Laheys Creek.

The pits and out-of-pit emplacements have been designed and placed to maximise the efficient extraction of the coal resource, while avoiding or minimising impacts on creeks and ecologically significant vegetation.

A conventional load and haul operation is proposed using excavators, front-end loaders and trucks. Initially, trucks will haul waste rock to out-of-pit emplacements. Following this, the majority of the waste rock will be placed in the mined-out voids.

Trucks will haul excavated run-of-mine (ROM) coal to the CHPP where it will be tipped into dump hoppers above the primary crushers or onto secondary ROM stockpiles for later rehandling.

Final, partially water filled, voids are planned to be located in the north and south of Pit C, and the south of Pit B.

The coal handling and preparation plant (CHPP) will treat the ROM coal so that product coal meets the sizing and coal quality requirements of the customers. Subject to the level of impurities (rejects) in the coal and washability characteristics, the ROM will be either crushed and bypassed or washed in the preparation plant. The rejects will typically include waste rock from above, below and within the coal seam as well as mineral matter dispersed within the coal.

Rejects from the CHPP will be disposed within the footprint of the mining area.

The Project will require water primarily for the CHPP and for dust suppression. Water will be sourced by intercepting surface water and by pumping groundwater that enters the mine pits in accordance with the relevant permits and licences. The primary source of water for the Project will be the Cudgegong River. Water will be supplied via approximately 26 km of pipeline from a pump station on the Cudgegong River to the primary raw water dam south-east of the mining area. Pre-existing high security water access licences have been purchased for the Project to allow up to 3.3 gigalitres (GL) of water to be extracted from the river.

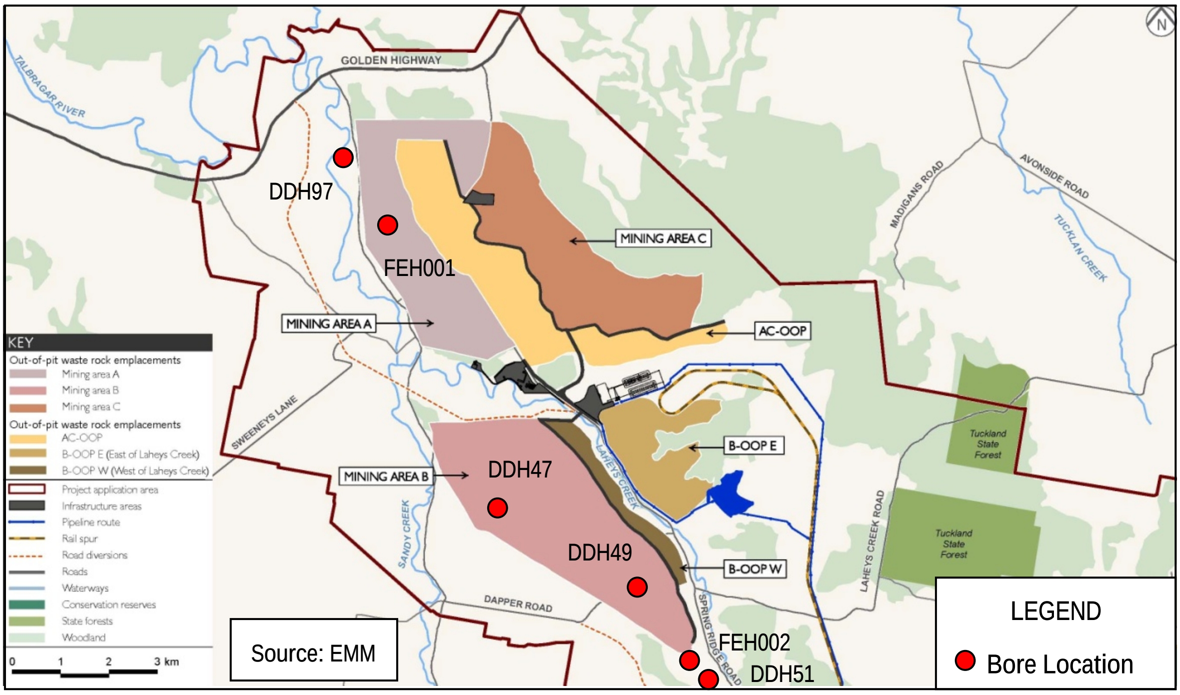

Figure 1 **Proposed Mine Layout**

3. GEOLOGY

The proposed project is located in the western region of the NSW Western Coalfield, with the coal measures contained in the Late Permian Dunedoo Formation.

The proposed pits are located on a 15 - 20^o westerly dipping limb of a 15^o southeasterly plunging syncline.

The project contains the economic Flyblowers Creek, Ulan Upper and Ulan Lower coal seams, along with the uneconomic Trinkey and Whaka plys.

In sequence from the surface, the seams and plys constitute the;

- Trinkey ply (which is uneconomic);
- Whaka Seam (which is uneconomic);
- Flyblowers Creek Seam,
- Ulan Upper Seam, and the
- Ulan Lower Seam

Pyrite (FeS_2) was not visually obvious in the overburden core, although it can be hard to observe if it is fine grained and disseminated. No obvious pyrite oxidation products, such as jarosite, sulfate salts or limonite / goethite after pyrite psuedomorphs were present in the studied core.

The overburden primarily comprises predominantly non-pyritic bedded and massive sandstone, with lesser siltstone, conglomerate and mudstone / claystone, with occasional carbonaceous zones.

Siderite bands were present in the overburden, along with thin calcite veining in the coal seams and overburden.

4. SAMPLE SELECTION, PREPARATION AND ANALYSIS

Numerous drill logs across the project site were assessed prior to inspecting drill core from four bores (DDH47, 49, 51 and 97) at the Gulgong core storage facility to select samples for geochemical assessment.

Drill logs for the 4 selected bores are shown in **Appendix A**.

The coal and, occassionally, the immediate roof and floor had been removed for laboratory analysis prior to our inspection in the cored holes, and a such, the presence or absence of pyrite could not be assessed.

Bores DDH47 (total depth 88m) and DDH49 (total depth 69.3m) are within the proposed Pit B, whilst DDH51 (total depth 69.5m) is 1400m south east, and along strike, of Pit B. Bore DDH97 (total depth 123.7m) is 650m west, and down dip, of Pit A.

As the coal had been removed for metallurgical testing from the DDH drill cores, a split of coal samples were obtained from two open hole hammer drilled bores (FEH001 and FEH002) that were drilled for further metallurgical test work. FEH001 is located within Pit A, whilst FEH002 is situated approximately 700m southeast, and down dip, of Pit B.

A total of 59 discrete lithological core intervals from bores DDH47, 49, 51 and 97 were selected and bagged at the storage facility, then despatched for laboratory geochemical analysis to represent the overburden stratigraphy in the proposed pits.

The core was generally complete except where it had been removed for metalurgical testing, where it was drilled by open hole in the weathered pre-collar, or through less common core loss.

The core was sent to SESL for sample crushing and splitting into -75µm and -4mm splits, then despatched to Sydney Analytical Laboratories for laboratory analsyis. Spare splits of each sample were retained in case follow up testing was required.

As stated previously, no coal cores were available for laboratory analysis, necessitating the drilling of two subsequent open hole hammer drilled bores FEH001 and FEH002.

These hammer drilled bores provided a remnant split of each seam in each bore after a sample had been tested for washability by Earth Data Pty Ltd. Nine composite coal seam samples were sent to SESL for sample crushing and splitting into -75µm and -4mm splits, then despatched to Sydney Analytical Laboratories for laboratory analsyis, with splits of each sample retained in case follow up testing is required.

Two additional samples from the initial washability testing were also despatched for crushing / splitting and laboratory analsyis (spiral reject and 0.063mm raw coal).

Total sulfur analysis by the Leco method was initially conducted on all overburden, coal seam, seam roof, seam floor, and washery waste samples.

Crushed 4mm (or where not available, supplied material) overburden and washery reject samples were tested for $pH_{1:2}$ and electrical conductivity ($EC_{1:2}$) with deionised water extracts using a 1 solid to 2 part water ratio.

The crushed 4mm sample de-ionised water overburden and washery reject leachate samples were analysed for pH, total dissolved solids (TDS), sulfate and selected metals analysis.

Selected overburden samples containing at least 0.05% total sulfur were subsequently analysed for:

- acid neutralising capacity (ANC);
- net acid production potential (NAPP) and;
- a standard single addition net acid generation (NAG) test.

Where the overburden samples had a high organic carbon content, or required further assessment, specialised testing was subsequently carried out on selected samples to address uncertainties in the intial results through:

- total organic carbon (TOC) analysis,
- extended boil NAG tests,
- calculated NAG tests, and;
- chromium reducible sulfur (to differentiate between pyritic acid forming sulfur and non-acid forming sulfate species).

The $pH_{1:2}$ and $EC_{1:2}$ leachate preparation and analysis was conducted by Geoterra and Sydney Analytical Laboratories.

The Leco total sulfur, ANC, TOC, NAG, extended boil NAG and overburden / washery reject leachate analyses were conducted by Sydney Analytical Laboratories.

Chromium reducible sulfur analysis was conducted by Envirolab.

The calculated NAG leachate using S, Ca, Mg, Na, K and Cl ions was conducted by Sydney Analytical Laboratories.

All laboratory test work and data analysis was conducted according to procedures outlined in the Australian Coal Association Research Project C15034 (Environmental Geochemistry International et al, 2008) as well as (AMIRA, 2002) and (Price, W.A, 2009).

Descriptions of the test and analysis procedures used in this assessment are contained in **Appendix B**.

5. OVERBURDEN RESULTS

A total of 59 overburden samples were assayed for $pH_{1:2}$, $EC_{1:2}$ and total sulfur.

Of the 59 samples, 11 containing at least 0.05% total sulfur were tested for ANC, NAPP and single addition NAG.

Of the 11 samples, 5 were tested for chromium reducible sulfur, total organic carbon and extended boil NAG tests.

Of the 6 remaining samples which continued to indicate a potential for acid production, a further two were tested for calculated NAG results.

The $pH_{1:2}$ and $EC_{l:2}$ tests were conducted by equilibrating the sample in deionised water for approximately 24 hours at a solid to water ratio of 1:2 (w/w) to provide an indication of the potential leachate acidity and salinity when the overburden is initially placed in the waste emplacement area.

5.1 Leachate pH and Salinity

The $pH_{1:2}$ of the leachates ranged from 3.04 to 8.08 with a median of 6.3, indicating generally no inherent acidity. Eight samples had a pH of less than 4.5, mainly associated with carbonaceous sandstone, coal and conglomerate. One conglomerate sample (DDH97 54.57-54.69m) had a pH of 3.04.

The results indicate the overburden as represented by the samples generally does not contain significant acidity.

The $EC_{1:2}$ values ranged from 47 - 1161µS/m with a low salinity median of 238µS/m. Four samples exceeded 500µS/m, whilst the highest (moderate) salinity of 1161µS/m was observed in a weathered siltstone in DDH47 (6.29 - 6.59mbgl).

The results indicate the overburden as represented by the samples generally contains low to moderate salinity.

This assessment was conducted using a sample to water ratio of 1:2, however the tests have also been conducted by other researchers using 1:5. In this instance, the 1:2 ratio would provide a “worst case” scenario, as the actual overburden emplacements final seepage water quality will be affected by an as yet undefined and ongoing rainwater or seepage dilution rate.

5.2 Acid Base and Net Acid Production Potential

5.2.1 Using Total S

Total S in the overburden ranged from below detection (0.002%) to 0.43% total sulfur.

Of the 59 overburden samples tested, 31 were classified as Non-acid Forming with total sulfur of less than 0.05%.

A plot of selected samples tested for both total sulfur and ANC indicates the samples have a low, although positive potential for acid drainage as shown in **Figure 2**.

As shown in **Appendix C**, total sulfur is highest in samples dominated by coal, followed by carbonaceous shale then shale and sandstone dominated lithologies.

Acid neutralisation of the tested samples ranged up to a relatively low value of 4.3kg H_2SO_4/t.

The NAPP zero line is shown which defines the NAPP positive and NAPP negative domains, and the line representing an acid neutralisation capacity / maximum potential acidity (ANC/MPA) ratio value of 2 is also plotted, with the NAPP = 0 line being equivalent to an ANC/MPA ratio of 1.

The ANC/MPA ratio is used as an indication of the relative factor of safety within the NAPP negative domain. Usually a ratio of 2 or more signifies a high probability that the material will remain circum-neutral in pH and thereby should not be problematic with respect to AMD. Results show that all of the tested (selected) samples are NAPP positive.

The net acid producing potential (NAPP) acid-base account plot of total sulfur and ANC in **Figure 2** represents the balance between MPA and the ANC.

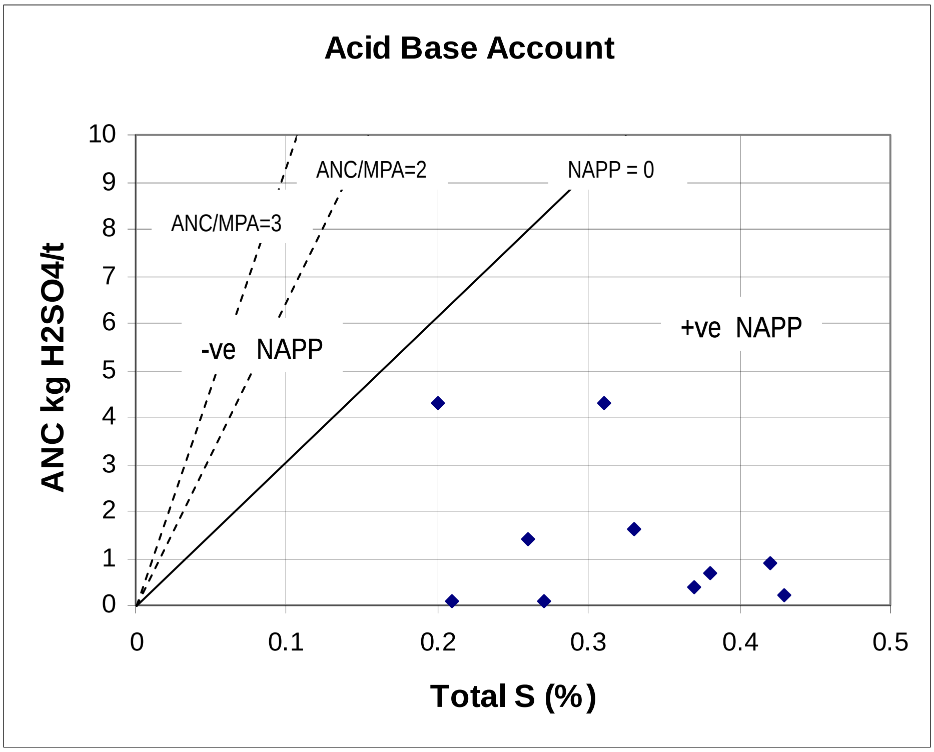

Figure 2 Overburden Acid Base Account (using Total S%)

5.2.2 Using Chromium Reducible Sulfur

Total sulfide (S-) in the tested samples of the overburden ranged from below detection (0.01%) to 0.25%.

A plot of selected samples tested for both total sulfide sulfur and ANC indicates the samples have a range of no to low potential for acid drainage as shown in **Figure 3**.

As shown in **Appendix C**, total sulfide sulfur is highest in samples dominated by coal, followed by carbonaceous shale then shale and sandstone dominated lithologies.

Results show that by plotting sulfide sulfur, as opposed to total sulfur against ANC, the samples all have a lower potential NAPP, with 3 out of the five selected highest total sulfur samples now showing very low to negative NAPP.

The highest NAPP using total sulfur was 13.3 kgH_2SO_4/t in sample 19 which reduced using total chromium reducible sulfide sulfur to 7.45 kgH_2SO_4/t.

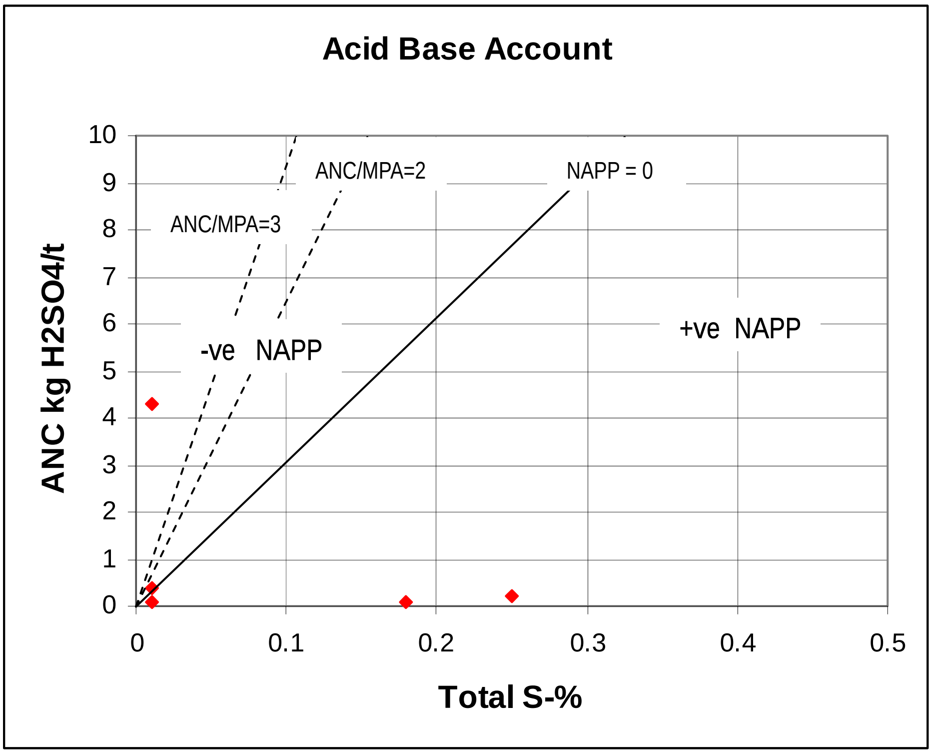

Figure 3 **Overburden Acid Base Account (using Chromium Reducible Sulfide%)**

5.3 Sulfur Speciation

Sulfur speciation testing was carried out on a selection of 5 of the 11 “worst case” total sulfur samples to assess the concentration of total sulfide sulfur (assumed to be present in mineral form as pyrite - FeS_2) as shown in **Appendix C**.

Note that the pyritic sulfide sulfur value should be treated as a guide to the pyrite content in the sample due to issues with variability in the chromium reducible sulfur (CRS) method.

As shown in **Figure 4,** five of the “worst case” total sulfur samples tested, three ranged from from 95 – 97% of the total S being present as low risk organic and non-acid sulfate sulfur. Moderate to significant pyritic sulfur was assessed in two of the five samples, with (19) having 58% and (45) having 86% pyritic sulfur .

Results confirm the presence of pyrite in some of these samples along with generally low ANC (maximum 4.3 kg H_2SO_4/t).

Appendix C includes a re-calculated NAPP based on the proportion of acid generating chromium reducible sulfur and ANC. Results using the chromium reducible sulfur (sulfide) values indicate the NAPP is lower in all five cases that were re-tested.

The original 11 NAPP samples are all positive, but of the five selected re-tested samples, the re-calculated NAPP is negative in 2 samples (5 and 57), or very low (34) due to the presence of non-acid generating S forms, whilst 2 remained positive, although with lower NAPP values (19 and 45).

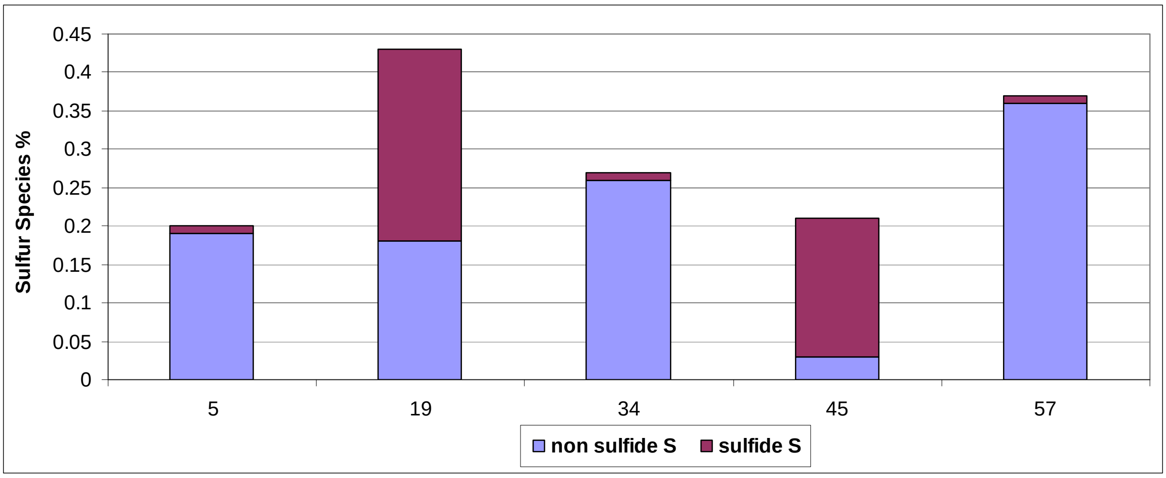

Figure 4 **Overburden Non-acid Producing Sulfur and Sulfide Sulfur Proportions**

5.4 NAG Tests

Generally a standard test NAG pH value less than 4.5 indicates a sample may be acid forming, although lithologies with high organic carbon, such as coal and carbonaceous sediments, can interfere with the standard results due to generation of organic acids through partial oxidation of organic carbon.

Standard NAG tests based on elevated carbon can therefore indicate low NAG pH values and elevated aciditiy, although the acid generation potential may not be completely due to formation of sulfuric acid (H_2SO_4) through oxidation of sulphide minerals.

Standard NAG results are plotted with NAPP values to classify samples according to their acid forming potential. Potentially acid forming (PAF), non-acid forming (NAF) and uncertain (UC) classification domains are shown in **Figure 5**.

A sample is PAF if it has a positive NAPP and NAG pH < 4.5 and NAF if it has a negative NAPP and NAG pH > 4.5.

Uncertain (UC) samples are where there is an apparent conflict between the NAPP and NAG results, i.e. when the NAPP is positive and NAGpH > 4.5, or when NAPP is negative and NAGpH < 4.5.

The 11 standard NAG pH values are all less than 4.5 which indicates positive, although low, NAPP values. This indicates that the selected “worst case” standard NAG test sample results may be potentially acid forming (PAF).

Nine of the 11 samples, however are coal, or contain carbonaceous shales. It should also be noted that the NAPP values are plotted using all forms of sulfur, including acid producing S and non-acid S forms, rather than purely sulfide sulfur. As a result, the samples required further investigation using an Extended Boil NAG test to assess the influence of potential organic acid effects.

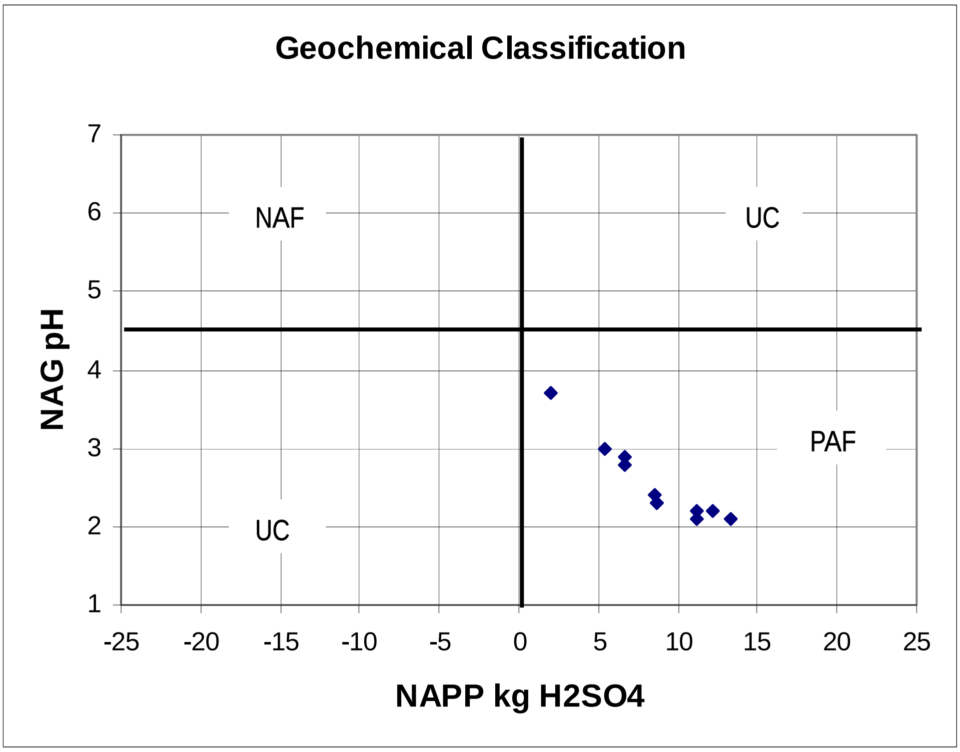

Figure 5 **Overburden Geochemical Classification (using Total S%)**

The standard NAG test pH 4.5 / pH 7.0 results also indicate the acidity is mostly due to metallic ions precipitating as hydroxides between pH 4.5 and 7, with a lesser contribution from free sulfuric acid as shown in **Figure 6**.

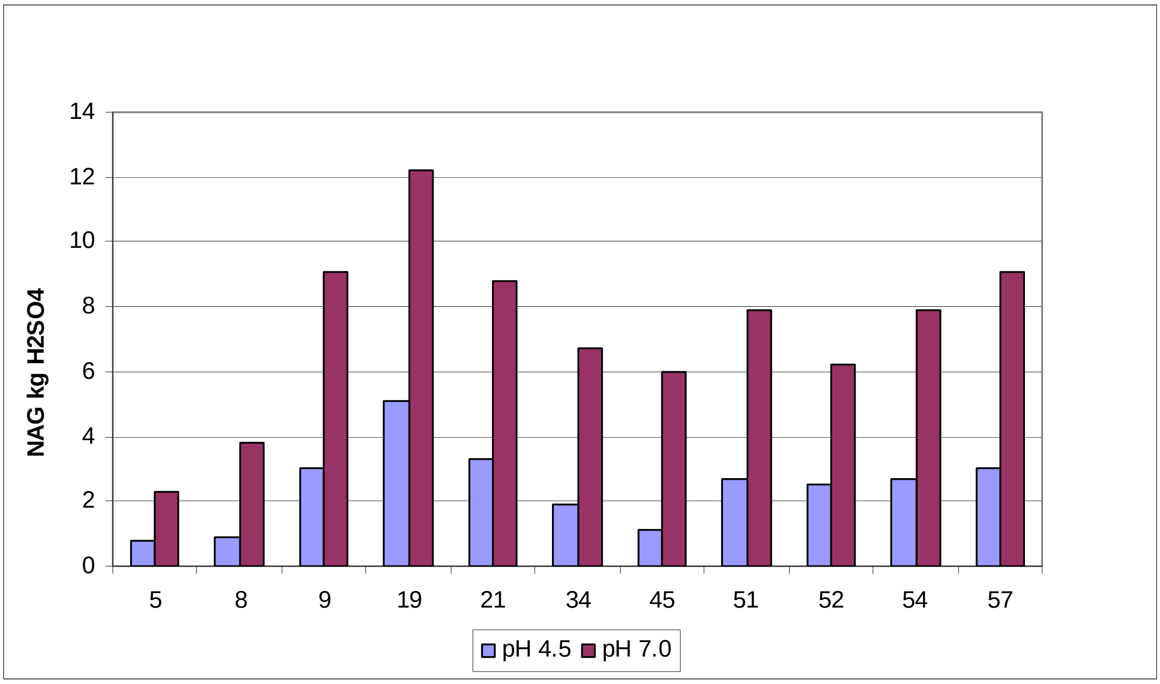

Figure 6 **Standard NAG pH 4.5 and NAG pH 7 results**

5.4.1 Extended Boil NAG Tests

Extended boil NAG tests were conducted on 5 of the 11 “worst case” overburden samples to further assess the classification uncertainty based on standard NAG results.

Appendix C shows that the NAG pH value increases after the extended boiling step, thereby confirming the effect of organic acids.

It should be noted that the extended boil NAG pH can be used to confirm samples are PAF, but does not necessarily mean that samples with pH greater than 4.5 are NAF due to some loss of free acid during the extended boiling procedure.

Three of the five extended Boil NAG pH test values rose above pH 4.5, indicating they are not PAF, whilst 2 remained below pH 4.5, indicating they are potentially acid forming. The potentially acidic samples were;

- Sample 19 (DDH49 28.97 - 29.14mbgl - coal) Extended Boil NAG pH = 2.8
- Sampe 45 (DDH97 54.57 – 54.69mbgl - conglom) Extended Boil NAG pH = 2.7

A plot of Extended Boil NAG pH versus NAPP (using total sulfide chromium reducible sulfur) from five of the selected highest total sulfur samples shown in **Figure 7** indicates that three of the samples are non-acid forming to uncertain, whilst two remain as potentially acid forming.

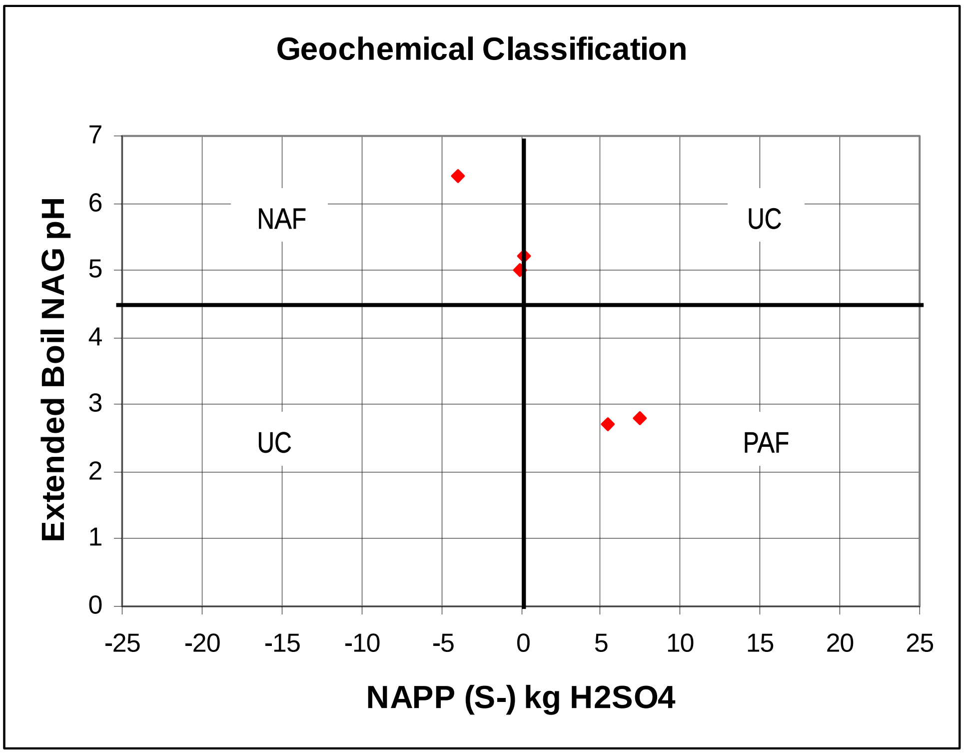

Figure 7 Overburden Geochemical Classification (with Cr reducible sulfide S%)

5.5 Calculated NAG Tests

To address the uncertainty discussed in the previous sections, a potential NAG value was calculated from concentrations of S, Ca, Mg, Na, K and Cl ions in the NAG leachate for the two samples (19 and 45) that remained below NAG pH 4.5 after the extended boiling step.

A calculated NAG less than or equal to 0.0kg H_2SO_4/t indicates the sample is potentially NAF, whilst greater than 0.0kg H_2SO_4/t indicates it may be PAF.

Sample 19 had a calculated NAG of 5.0kg H_2SO_4/t, whilst sample 45 had 5.8kg H_2SO_4/t indicating that they both are potentially acid producing.

5.6 Overburden AMD Classification

The potential acid and metalliferous drainage (AMD) classifications are provided in **Appendix C** based on results and discussions outlined in the previous sections.

Note that the main coal seam cores had been removed from DDH47, 49, 51 and 97 and could not be AMD classified.

All samples with less than or equal to 0.05%S were classified NAF due to the negligible risk of acid formation as shown in **Appendix C**.

A summary of the overburden AMD classification is shown in **Table 1**.

Table 1 Overburden AMD Classification Summary

Category	% of total samples
Non-acid Forming (NAF)	55
Uncertain Non-acid Forming (UC NAF)	15
Uncertain Potentially Acid Forming (UC PAF)	17
Potentially Acid Forming – Low Capacity (PAF-LC)	5
Potentially Acid Forming	8

Approximately 70% of samples were classified NAF or UC (NAF), with 30% classified PAF, PAF-LC or UC (PAF).

There is a close association of PAF / UC (PAF) samples predominantly with coal, and to a lesser degree, carbonaceoues lithologies and immediately adjacent roof and floor horizons. Only one non coal / carbonaceoues sample (DDH97 54.57 to 54.69mbgl – conglomerate) indicated a PAF status.

Figure 8 indicates the potential proportion of each AMD classification contained within the overburden, at each tested bore location, after excluding the economic Flyblowers and Ulan coal seams that will either be seperately exported as product coal or placed in the tailings dams after washing in the CHPP.

The results indicate that, depending on which bore is referred to, from;

- 57 – 66% of the overburden could be non-acid forming,
- 7 - 25% could be uncertain to non-acid forming
- 6 – 17% could be uncertain to potentially acid forming
- 0 – 11% could be potentially acid forming – low capacity, and;
- 0 – 9% could be potentially acid forming

The available data indicates the majority of potentially acid forming materials are associated with the unweathered, uneconomic Whaka coal seam, which has the highest sulfur level of 0.43% Total S.

The economic Ulan and Flyblowers coal seams and their associated carbonaceous lithologies with the higher total sulfur content will predominantly be extracted, washed in the CHPP and exported offsite as product coal, with the washery waste placed in tailings dams.

The remainder of the weathered, uneconomic coal and carbonaceous units from the Whaka and Trinkey seams and their interburden, that will be placed on the waste rock emplacements, have a median total S of 0.04%, which has a low overall risk of AMD generation.

The PAF overburden samples have potentially low overall acid production capacity, with less than 13kg H_2SO_4/t (using total S) and below 7.5kg H_2SO_4/t when only pyritic sulfur is used.

It is unlikely that these materials would result in AMD due to operational mixing with the NAF overburden, even though the ANC is not high, at less than 4.3kg H_2SO_4/t (median

0.9kg H_2SO_4/t).

Overall, the coal seams and their shale dominated, carbonaceous roof and floor lithologies appear to contain relatively low pyritic sulfur.

Due to the low acid neutralisation capacity (ANC) values, and, as a result, their low buffering potential, acid buffering characteristic curve (ABCC) testing was not conducted on the samples.

Although there is not a signifcant excess of ANC compared to MPA (calculated from total S), due to the low potential acid production potential of the positive NAPP results, it is considered there is a low likelihood of AMD conditions developing from overburden waste represented by these samples.

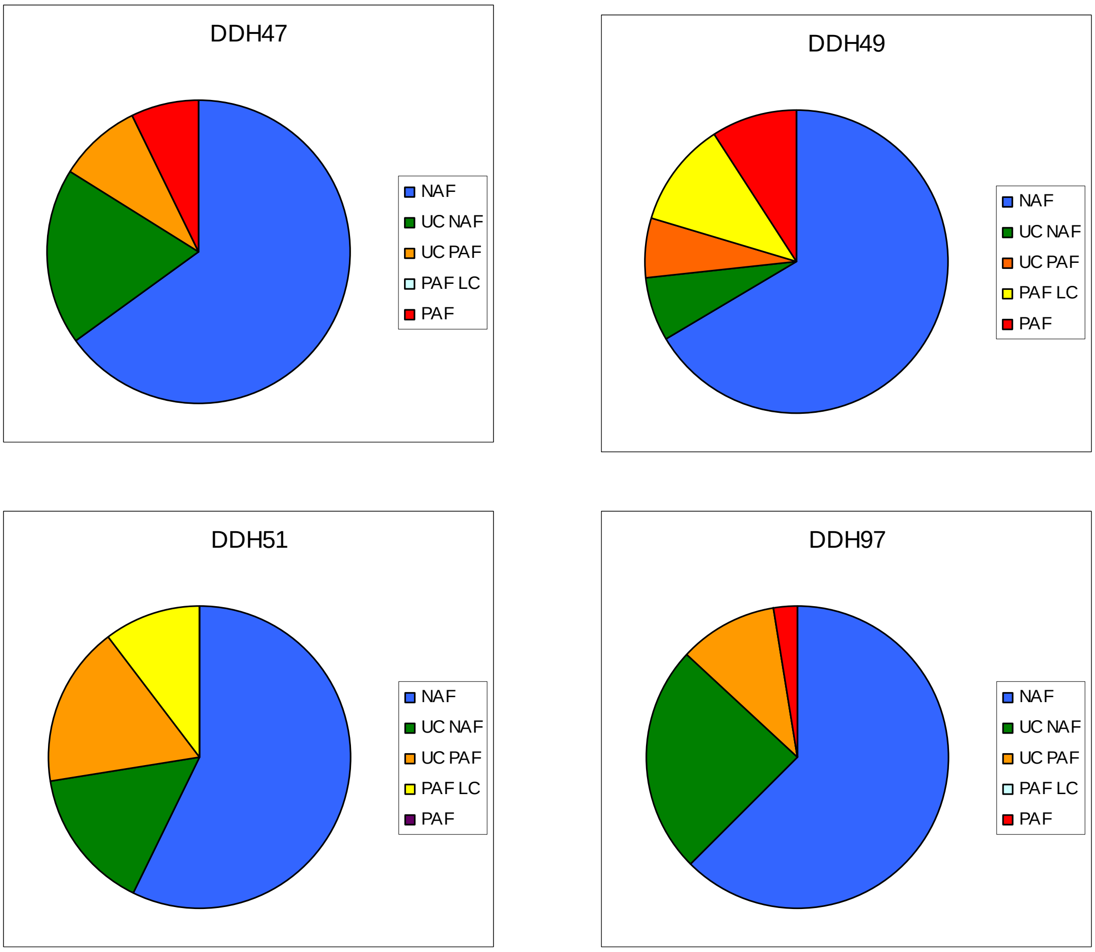

Figure 8 Washery Waste Acid Base Account (using Total S%)

5.7 Cation Exchange Capacity

Laboratory analysis of 13 selected overburden samples indicates the cation exchange capacity (CEC) is generally low, ranging from 0.9 – 6.7 meq% as shown in **Tables 2** and **3**, which is typically within the range of kaolinite dominated soils**.**

Kaolinite CEC typically ranges from 3 – 15 meq%.

The results shown in **Tables 2** and **3** indicate that the tested samples have a low capacity to adsorb nutrient, as well as major ion or metallic cations that may be generated in any AMD leachate, if it is produced.

The overburden emplacements are likely to be pH neutral to slightly alkaline, with low to moderate EC/salinity and low CEC values.

All of the overburden samples tested had an exchangeable sodium percentage (ESP) of less than 1.6%. Where the EC is relatively low, such as in the tested samples, soils are considered sodic if the ESP value is greater than 6% and less than 14% and strongly sodic if the ESP is 15 or more.

Materials classified as sodic may be prone to dispersion and erosion. As a result, the ESP results for the overburden indicate the overburden is unlikely to be sodic and may be suitable for revegetation and rehabilitation activities in final landform surfaces or as a growth medium.

The `desirable' proportions of each major exchangeable cation are shown below;

- Calcium (Ca)	65 – 80%
- Magnesium (Mg)	10 – 15%
- Potassium (K)	1 – 5%
- Sodium (Na)	0 – 1%

When compared to the desirable ranges for exchangeable cations in soil, the preliminary findings of the exchangeable Ca and K proportions in the tested overburden material is low, which may reduce their amenability for revegetation and rehabilitation use in final surfaces or as a growth medium.

Table 2 DDH47 and 49 CEC Results (meq%)

DDH	**47**	**47**	**47**	**49**	**49**	**49**
Depth (mbgl)	**6.29 - 6.59**	**62.37 – 62.55**	**79.02 – 79.15**	**8.79 – 8.99**	**28.97 – 29.14**	**35.01 – 35.17**
CEC	5.8	0.9	4.2	1.0	0.8	1.5
Exch						
Na	1.55	0.03	0.15	0.11	0.02	0.02
K	0.48	0.23	1.05	0.24	0.04	0.17
Ca	1.05	0.37	1.70	0.11	0.02	0.24
Mg	3.10	0.41	1.50	0.49	0.06	0.75
Mn	0.05	<0.01	<0.01	<0.01	<0.01	0.01
Al	<0.01	<0.01	<0.01	<0.01	0.8	0.4
Solubles						
Na	1.50	0.01	0.07	0.28	0.03	0.09
K	0.15	0.07	0.25	0.04	0.03	0.07
Ca	0.103	0.04	0.01	0.01	0.08	0.03
Mg	0.18	0.03	0.06	0.01	0.20	0.05
Mn	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Al	<0.01	<0.01	<0.01	<0.01	0.04	0.02

Table 3 **DDH51 and 97 CEC Results (meq%)**

DDH	51	51	51	97	97	97	97
Depth (mbgl)	**10.12 – 10.25**	**35.44 – 35.59**	**62.92 – 63.05**	**27.54 – 27.69**	**54.57 – 54.69**	**65.55 – 65.70**	**111.45 – 111.59**
CEC	1.2	3.8	3.7	6.7	0.9	1.1	2.9
Exch							
Na	0.11	0.07	0.13	0.17	<0.01	0.02	0.04
K	0.29	0.52	0.60	0.88	0.01	0.12	0.91
Ca	0.14	1.15	1.50	2.35	0.01	0.44	0.97
Mg	0.74	22.05	1.75	3.50	0.02	0.38	1.20
Mn	<0.01	0.03	0.01	<0.01	0.01	<0.01	0.01
Al	<0.1	0.2	<0.1	<0.1	0.8	<0.1	<0.1
Solubles							
Na	0.01	0.19	0.07	0.35	<0.01	<0.01	0.03
K	0.14	0.12	0.22	0.13	<0.01	0.04	0.14
Ca	0.01	0.06	0.02	0.05	0.27	0.03	0.01
Mg	0.05	0.10	0.08	0.10	0.26	0.02	0.02
Mn	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Al	<0.01	<0.01	<0.01	<0.01	0.04	<0.01	<0.01

5.8 Overburden Leachate Results

Laboratory analysis of TDS, sulfate and pH, as well as major metals for bores DDH47, 49, 51 and 97 are shown in **Tables 4** to **7**.

The results are compared to the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ 2000). The ANZECC/ARMCANZ (2000) freshwater guidelines (95% level of protection) were selected as the area is moderately disturbed. The ANZECC/ARMCANZ (2000) guidelines for upland rivers in south-east Australia were also referred to because the site location is >150 m altitude and in NSW.

Although the detection limit was above the Cr(VI) criteria, the prevalent essentially circum neutral pH and oxidising redox conditions within leachate discharging from the waste emplacements or tailings dams would mean that Cr(VI) be geochemically unlikely to occur, whilst total chromium in the sampled leachate was very low.

Table 4 DDH47 Leachate Analyses (mg/L)

(mbgl)		**6.29 – 6.59**	**34.68 - 34.78**	**53.59 - 54.07**	**62.37 - 62.55**
	ANZECC/ARMCANZ (2000)	**wthrd siltstone**	**coal+ferrug oxid shale**	**coal + ferrug oxid sast**	**coal + shale**
pH	6.5 – 7.5	7.2	6.5	6.6	6.9
TDS	350	**1060**	**385**	250	80
SO4	_	76	43	68	13
Al	0.055 (pH>6.5)	<0.01	<0.01	<0.01	<0.01
As	0.024 (As III)	<0.01	<0.01	<0.01	<0.01
Cd	0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Cr	0.001 (CrVI)	<0.01	<0.01	<0.01	<0.01
Co	_	<0.001	<0.001	<0.001	<0.001
Cu	0.0014	0.001	<0.001	<0.001	0.001
Fe	_	<0.01	<0.01	<0.01	<0.01
Pb	0.0034	<0.001	<0.001	<0.001	<0.001
Mn	1.9	<0.01	1.7	1.9	0.15
Ni	0.011	<0.01	<0.01	<0.01	<0.01
Se	0.011	<0.01	<0.01	<0.01	<0.01
Sr	_	0.07	0.04	0.05	<0.01
Sn	_ (organic)	<0.01	<0.01	<0.01	<0.01
Zn	0.008	<0.001	<0.001	<0.001	0.002

NOTE: ANZECC/ARMCANZ (2000) provides trigger values for protection of 95% of aquatic freshwater species and trigger values for physical and chemical stressors for upland streams in NSW

Table 5 DDH49 Leachate Analyses (mg/L)

(mbgl)		8.79 - 8.99	28.97 - 29.14	35.01 - 35.17
	ANZECC/ARMCANZ (2000)	wthrd conglom	coal	coal
pH	6.5 – 7.5	**8.4**	**3.5**	**5.7**
TDS	350	220	190	100
SO4	_	9	115	33
Al	0.055 (pH>6.5)	<0.01	**0.52**	<0.01
As	0.024 (As III)	<0.01	<0.01	<0.01
Cd	0.0002	<0.0002	<0.0002	<0.0002
Cr	0.001 (CrVI)	<0.01	<0.01	<0.01
Co	_	<0.001	0.72	0.004
Cu	0.0014	0.001	**0.042**	**0.006**
Fe	_	<0.01	0.03	<0.01
Pb	0.0034	<0.001	**0.013**	<0.001
Mn	1.9	0.24	0.81	0.05
Ni	0.011	<0.01	**0.50**	<0.01
Se	0.011	<0.01	<0.01	<0.01
Sr	_	0.03	0.05	0.03
Sn	_ (organic)	<0.01	<0.01	<0.01
Zn	0.008	0.004	**15**	**1.7**

NOTE: ANZECC/ARMCANZ (2000) provides trigger values for protection of 95% of aquatic freshwater species and trigger values for physical and chemical stressors for upland streams in NSW

Table 6 DDH51 Leachate Analyses (mg/L)

(mbgl)		10.12 - 10.25	35.44 - 35.99	62.92 - 63.05
	ANZECC/ARMCANZ (2000)	sandstone	shale	shale
pH	6.5 – 7.5	**7.8**	7.2	6.8
TDS	350	90	195	140
SO4	_	16	65	61
Al	0.055 (pH>6.5)	<0.01	<0.01	<0.01
As	0.024 (As III)	<0.01	<0.01	<0.01
Cd	0.0002	<0.0002	<0.0002	<0.0002
Cr	0.001 (CrVI)	<0.01	<0.01	<0.01
Co	_	0.003	<0.003	0.016
Cu	0.0014	**0.002**	0.001	0.001
Fe	_	<0.01	<0.01	<0.01
Pb	0.0034	0.002	<0.001	0.002
Mn	1.9	0.01	0.03	0.05
Ni	0.011	<0.01	<0.01	<0.01
Se	0.011	<0.01	<0.01	<0.01
Sr	_	0.02	0.02	0.04
Sn	_ (organic)	<0.01	<0.01	<0.01
Zn	0.008	**0.087**	**0.34**	**1.8**

NOTE: ANZECC/ARMCANZ (2000) provides trigger values for protection of 95% of aquatic freshwater species and trigger values for physical and chemical stressors for upland streams in NSW

Table 7 DDH97 Leachate Analyses (mg/L)

(mbgl)		27.54 - 27.69	54.57 - 54.69	65.55 - 65.70	68.40 - 68.56	81.74 - 81.87	92.21 - 92.37
	ANZECC/ARMCANZ (2000)	**shale**	**conglom.**	**coal**	**coal / carb. shale**	**carb. shale / coal**	**carb. shale / coal**
pH	6.5 – 7.5	6.9	**2.6**	**6.3**	**6.1**	**6.1**	6.5
TDS	350	**400**	**570**	65	91	**380**	70
SO4	_	200	385	10	33	250	19
Al	0.055 (pH>6.5)	<0.01	**4.5**	0.04	<0.01	<0.01	<0.01
As	0.024 (As III)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cd	0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Cr	0.001 (CrVI)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Co	_	0.029	0.85	0.003	0.002	0.0052	0.002
Cu	0.0014	<0.002	**0.25**	**0.003**	0.001	0.001	0.001
Fe	_	<0.01	9.4	0.04	<0.01	<0.01	<0.01
Pb	0.0034	<0.001	**0.010**	<0.001	0.001	<0.001	<0.001
Mn	1.9	0.26	1.3	0.01	0.03	0.10	0.02
Ni	0.011	<0.01	**5.8**	<0.01	<0.01	<0.01	<0.01
Se	0.011	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sr	_	0.13	0.13	<0.01	0.02	0.13	<0.01
Sn	_ (organic)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zn	0.008	**0.40**	**7.6**	**0.025**	<0.001	**0.018**	<0.001

NOTE: ANZECC/ARMCANZ (2000) provides trigger values for protection of 95% of aquatic freshwater species and trigger values for physical and chemical stressors for upland streams in NSW

The tested samples which exceeded the ANZECC/ARMCANZ (2000) criteria for freshwater upland streams and protection of 95% of aquatic species are summarised in **Table 8.**

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Table 8 **DDH47, 49, 51 and 97 Leachate ANZECC/ARMCANZ (2000) Exceedances**

BORE	Depth (mbgl)	Lithology	Exceeded Parameter
DDH47	6.29 – 6.59	weathered siltstone	TDS
	34.68 - 34.78	coal + ferruginous oxidised shale	TDS
DDH49	8.79 - 8.99	weathered conglomerate	pH
	28.97 - 29.14	coal	pH, Al, Cu, Pb, Ni, Zn
	35.01 – 35.17	coal	pH, Cu, Zn
DDH51	10.12 - 10.25	sandstone	pH, Cu, Zn
	35.44 - 35.99	shale	Zn
	62.92 - 63.05	shale	Zn
DDH97	27.54 - 27.69	shale	TDS, Zn
	54.57 - 54.69	conglomerate	pH, TDS, Al, Cu, Pb, Ni, Zn
	65.55 - 65.70	coal	pH, Cu, Zn
	68.40 - 68.56	coal carbonaceous shale	pH
	81.74 - 81.87	carbonaceous shale / coal	pH, TDS, Zn

As shown in **Table 8**, the main parameters that exceeded the freshwater upland stream and protection of 95% of aquatic species criteria include pH, TDS, Al, Cu, Pb, Ni and Zn.

As the salinity results are derived from pulverised samples, where the surface area in contact with water is much greater than at a typical overburden emplacement area, and that further dilution is likely in the field, this laboratory based result is likely to represent a potential `worst case' scenario.

The risk of saline runoff and seepage from the overburden is anticipated to be low to moderate.

6. WASHERY WASTE

Samples of potential tailings from washery waste laboratory trials were obtained from 2 drill core spiral reject and raw coal (0.063mm fraction) samples, and subsequently from 11 open hammer bore (FEH001 and FEH002) samples.

The acid forming characteristics of the 13 washery trial rejects are presented in **Appendix C**, with the samples analysed for total S, chromium reducible sulfur ANC, NAPP, standard NAG, Extended Boil NAG, $pH_{1:2}$ and $EC_{1:2}$ leachate tests

6.1 Leachate pH and Salinity

The $pH_{1.2}$ ranged from 3.47 – 6.91, with a median of 6.39, which indicates there is potentially no significant existing acidity in the tailings .

$EC_{1.2}$ ranged from 158 – 2010µS/cm, with a median of 206µS/cm.

As the salinity results are derived from pulverised samples, where the surface area in contact with water is much greater than at a typical coal washery reject emplacement area, and that further dilution is likely in the field, this laboratory based result is likely to represent a potential `worst case' scenario.

The risk of saline runoff and seepage from the washery waste is anticipated to be low to moderate.

This assessment was conducted using a sample to water ratio of 1:2, however the tests have also been conducted by other researchers using 1:5. In this instance, the 1:2 ratio would provide a “worst case” scenario, as the actual coal washery waste final seepage water quality will be affected by an as yet undefined and ongoing rainwater or seepage dilution rate.

6.2 Acid Base and Net Acid Production Potential

6.2.1 Using Total S

Total S in the washery wastes range from 0.22 - 0.64% total sulfur.

Of the 13 samples, none had below 0.05% total sulfur.

A plot of total sulfur and ANC indicates the samples have a generally low, although positive potential for acid drainage as shown in **Figure 9**.

As shown in **Appendix C**, total sulfur is highest in samples from the Trinkey and Flyblower seams, followed by the Ulan Upper, then Whaka / Ulan Lower seams, whilst the spiral reject exceeded the raw coal (0.063mm).

Acid neutralisation of the tested samples ranged up to a low 8.7kg H_2SO_4/t with a median of 2.5kg H_2SO_4/t .

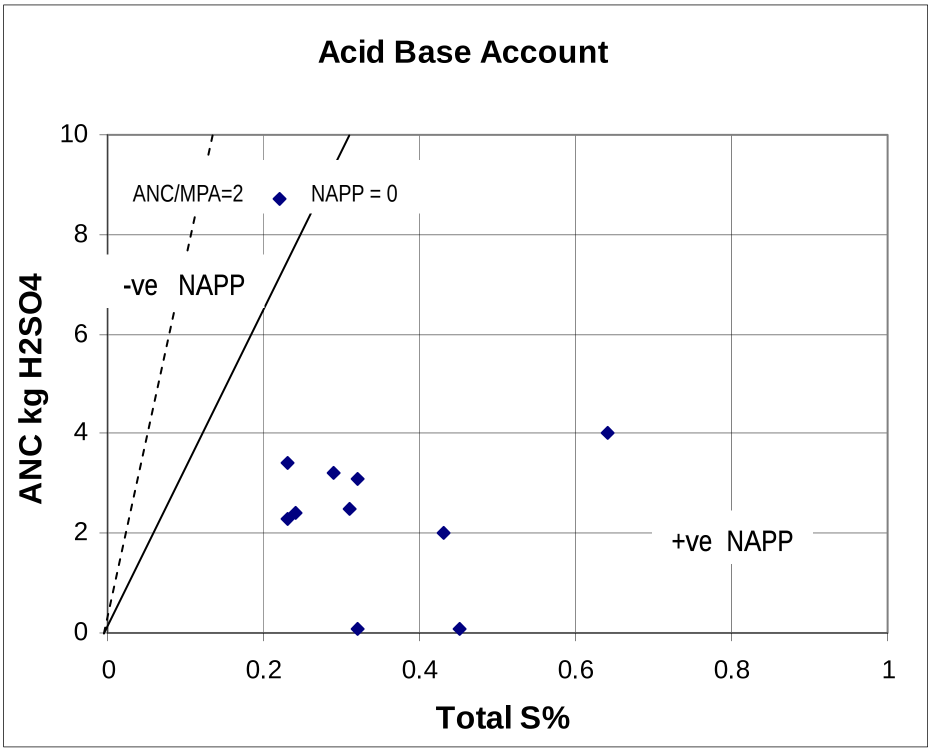

Figure 9 **Washery Waste Acid Base Account (using Total S%)**

6.2.2 Using Chromium Reducible Sulfur

Total sulfide (S-) in the washery waste ranged from below detection (0.01%) to 0.09% in the coal seam samples.

A plot of total sulfide sulfur and ANC shown in **Figure 10** indicates the samples have a low potential for acid drainage.

As shown in **Appendix C**, total sulfide sulfur is highest in the Flyblower and Trinkey seams, followed by the Ulan Upper and Whaka, then the Ulan Lower seam.

Results show that by plotting sulfide sulfur, as opposed to total sulfur against ANC, the samples all have a lower potential NAPP, and are now all potentially non-acid forming, although one is very marginally potentially acid forming (low capacity).

The highest NAPP using total sulfur was 16.0kg H_2SO_4/t in the Trinkey Seam which reduced using chromium reducible sulfide sulfur to -1.9kg H_2SO_4/t.

The majority of samples plot in the NAPP negative domain, with ANC/MPA ratios of around 2 or greater, indicating a low risk of acid production.

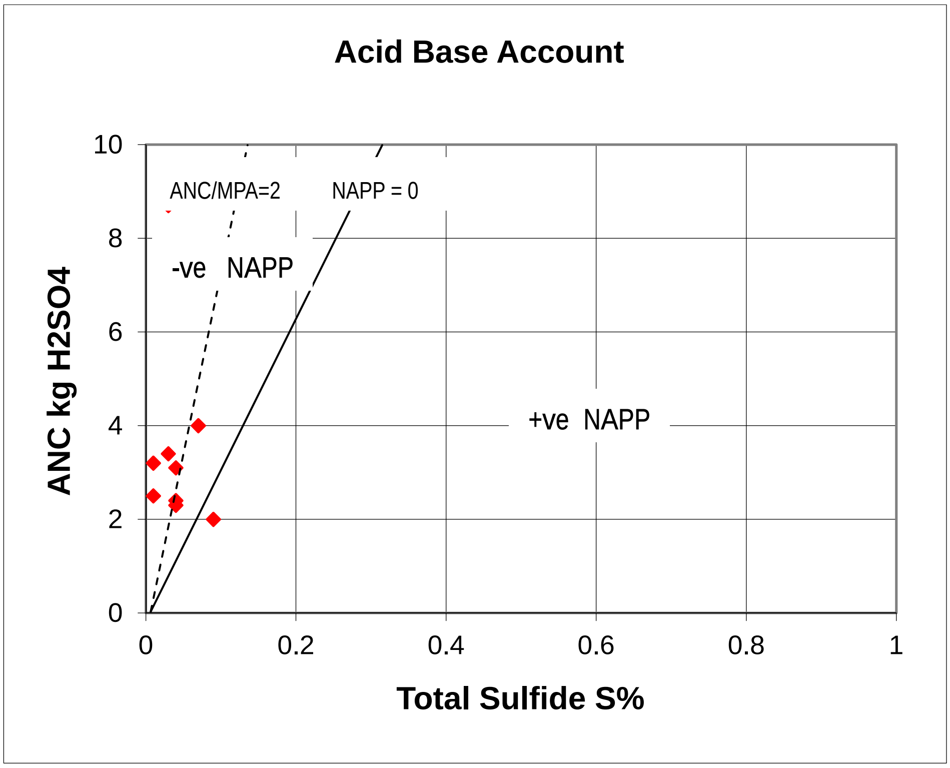

Figure 10 Washery Waste Acid Base Account (using Total S%)

6.3 Sulfur Speciation

Sulfur speciation testing was conducted on the coal seam samples to assess the concentration of total sulfide sulfur (assumed to be present in mineral form as pyrite - FeS_2) as shown in **Appendix C**.

Note that the (sulfide) sulfur should be treated as a guide to the pyrite content in the sample due to issues with variability in the chromium reducible sulfur (CRS) method.

As shown in **Figure 11,** all of the samples have a low proportion of sulfide sulfur, with the majority of sulfur present as low risk organic and non-acid sulfate forms.

Results confirm the low concentration of pyrite in the samples along with low ANC (maximum 8.7 kg H_2SO_4/t).

Appendix C includes a re-calculated NAPP based on the proportion of acid generating chromium reducible sulfur and ANC. Results using the chromium reducible sulfur (sulfide) values indicate the NAPP is significantly lower in all cases.

The original coal seam washery waste NAPP samples are all positive, however, based on sulfide S, all samples revert to a negative NAPP apart from the Flyblower Seam, which had a very low 0.8 kg H_2SO_4/t in the re-tested samples due to the presence of non-acid generating S forms.

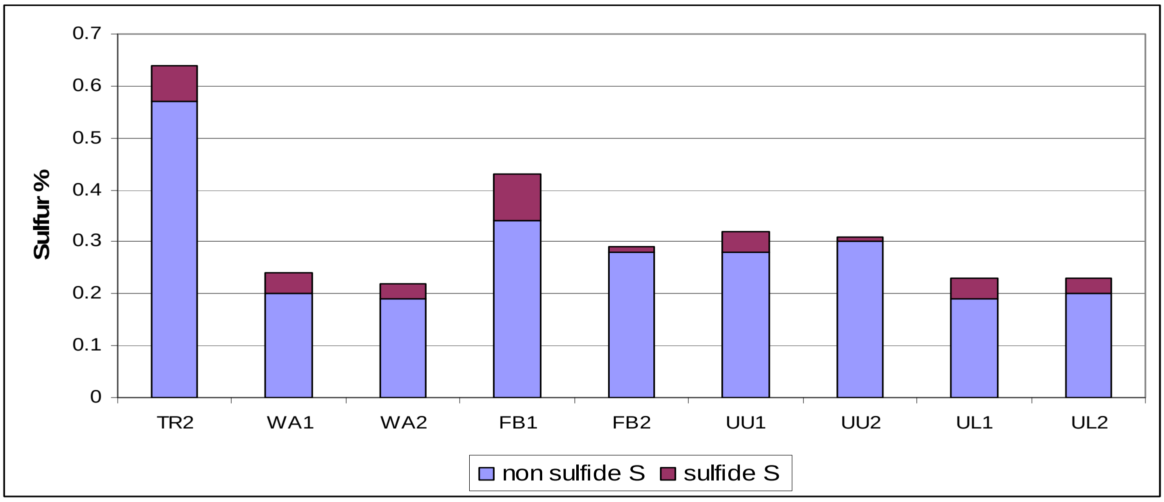

Figure 11 Washery Waste Non-acid Producing Sulfur and Sulfide Sulfur Proportions

6.4 NAG Tests

As shown in **Figure 12**, based on the Total S results, the coal washery wastes may be predominantly uncertain to potentially acid forming (low capacity).

The plot uses all sulfur, including acid producing and non-acid producing slufur forms, rather than purely sulfide sulfur.

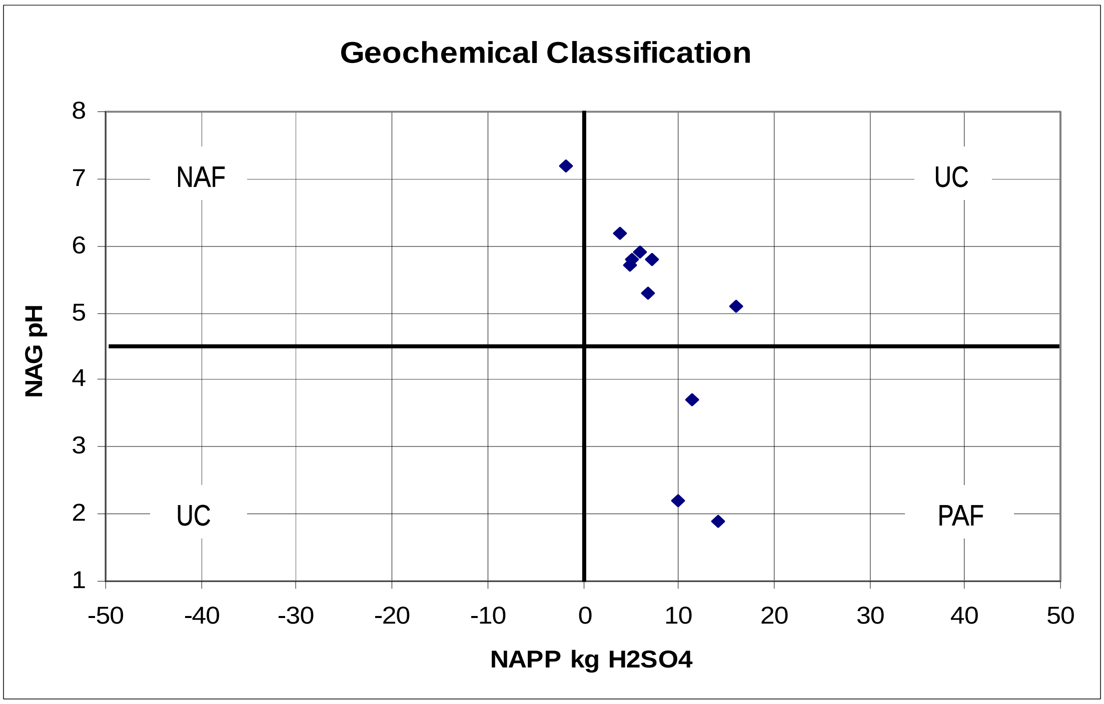

Figure 12 Washery Waste Geochemical Classification (using Total S%)

The combined standard and Extended Boil NAG test pH 4.5 / pH 7.0 results indicate the acidity is mostly due to metallic ions precipitating as hydroxides between pH 4.5 and 7, with a lesser contribution from free sulfuric acid as shown in **Figure 13**.

There are no pH 4.5 plots shown for the coal seam samples except FB1, as the ACARP 2008 procedure outlines that there is no need to continue with analyses if the NAG pH exceeds pH 4.5, which was the case for all samples except FB1.

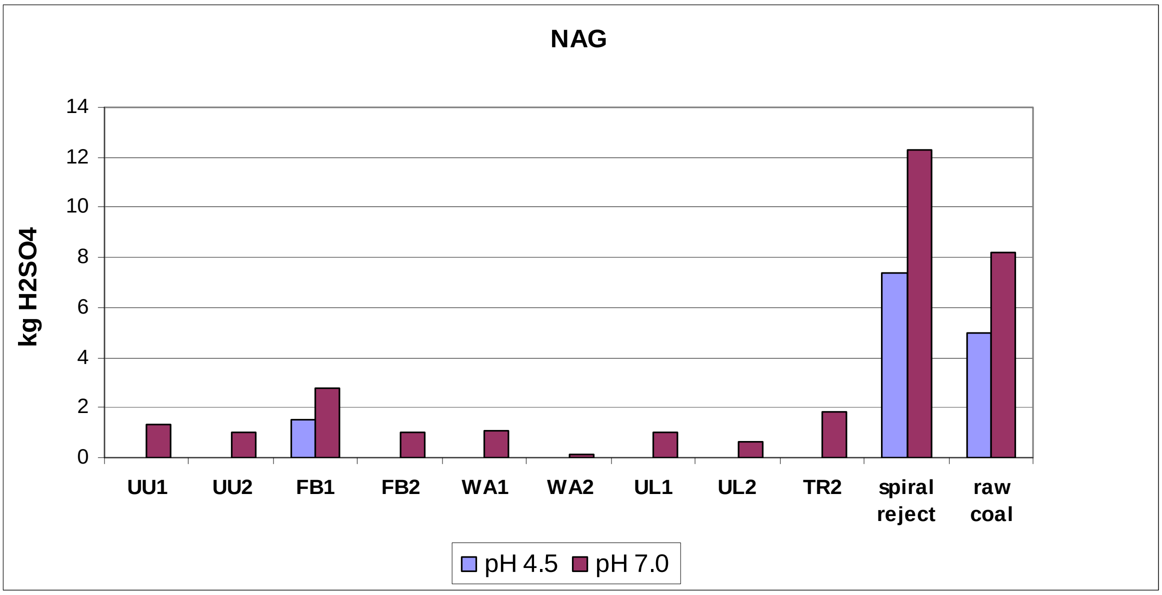

Figure 13 Standard NAG pH 4.5 and NAG pH 7 results

6.4.1 Extended Boil NAG Tests

Further investigation was conducted to determine the acid production potential of the coal washery waste samples using an Extended Boil NAG test due to potential organic acid effects as shown in **Appendix C**.

The majority of the extended Boil NAG pH test values exceeded pH 4.5, indicating they are not PAF, with one sample remaining below pH 4.5, which indicates it may be potentially acid forming. The potentially acidic sample was;

- Flyblowers 1 (Extended Boil NAG pH = 3.7)

A plot of extended boil NAG pH versus NAPP (using total sulfide chromium reducible sulfur) from five of the selected highest total sulfur samples shown in **Figure 14** indicates that all but one of the samples were subsequently classified as Non-acid Forming, with the one positive sample having a very low, but positive NAPP, indicating it is PAF(LC).

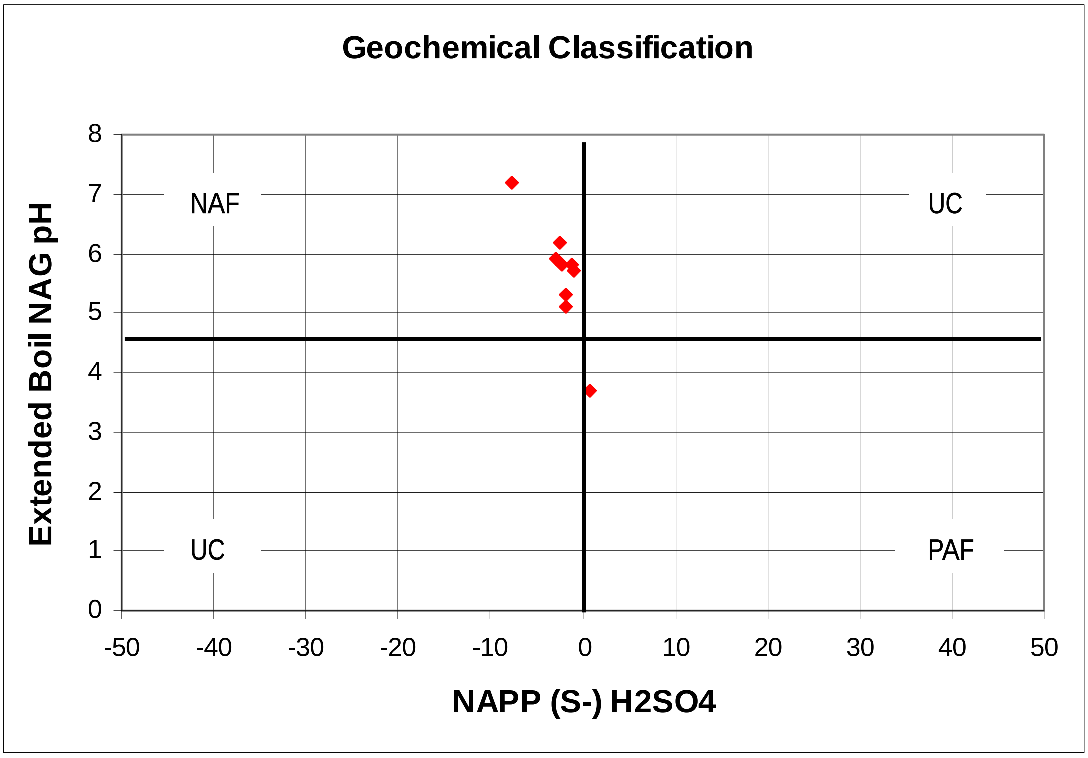

Figure 14 **Washery Waste Classification (with Cr reducible sulfide S%)**

6.5 Calculated NAG Tests

To address the uncertainty discussed in the previous sections, a potential NAG value was calculated from concentrations of S, Ca, Mg, Na, K and Cl ions in the NAG leachate for FB1, which remained below NAG pH 4.5 after the extended boiling step.

A calculated NAG less than or equal to 0.0kg H_2SO_4/t indicates the sample is potentially NAF, whilst greater than 0.0kg H_2SO_4/t indicates it may be PAF.

Sample FB1 had a calculated NAG of 0.50kg H_2SO_4/t, indicating it has a positive, although very low potential for acid production.

6.6 Washery Waste AMD Classification

The potential acid and metalliferous drainage (AMD) classifications are provided in **Appendix C** based on results and discussions outlined in the previous sections.

Note that the washery trial wastes from the coal seams were not available for AMD laboratory testing from DDH47, 49, 51 and 97 and could not be classified, whilst only a spiral reject and raw coal (0.063mm) were intitially available. New bores were drilled (FEH001 and FEH002) to supply samples for both economic coal seam washery test and AMD laboratory analyses.

No samples contained below 0.05% total S as shown in **Appendix C**, which means that on a first pass basis, there is potential for the samples to potentially produce AMD, and that further testwork was required to characterise the AMD potential as outlined in previous sections.

A summary of the washery waste AMD classification is shown in **Table 9**.

Table 9 Washery Waste AMD Classification Summary

Category	% of total samples
Non-acid Forming (NAF)	64
Uncertain Non-acid Forming (UC NAF)	0
Uncertain Potentially Acid Forming (UC PAF)	18
Potentially Acid Forming – Low Capacity (PAF-LC)	9
Potentially Acid Forming	9

Approximately 64% of samples were classified NAF or UC(NAF), with 36% classified PAF, PAF-LC or UC(PAF).

Overall, the results indicate that the washery waste should be non-acid forming to potentially acid forming (low capacity) due to the low total and very low chromium reducible sulfur levels (ie low pyrite), with the highest sulfur (maximum 0.43% Total S, or 0.09% chromium reducible S) contained in the Flyblower Seam in borehole FEH001.

The PAF washery waste has potentially low overall acid production capacity, with less than 14.1kg H_2SO_4/t (using total S) and below 0.8kg H_2SO_4/t when only pyritic sulfur is used.

It is unlikely that these materials would result in AMD due to operational mixing with surrounding higher NAF tailings and washery waste, even though the ANC is not high, with less than 8.7kg H_2SO_4/t (median 2.5kg H_2SO_4/t).

The coal seam washery waste appears to contain relatively low concentrations of pyritic sulfur.

Due to the low acid neutralisation capacity (ANC) values, and, as a result, their low buffering potential, acid buffering characteristic curve (ABCC) testing was not conducted on the samples.

In addition, the ANC/MPA ratio of 2 or more, which was prevalent in the tested samples, provides an adequate factor of safety.

Although there is not a signifcant excess of ANC compared to MPA (calculated from total S), due to the low potentail acid production potential of the positive NAPP results, it is considered there is a low likelihood of AMD conditions developing from washery wastes represented by these samples.

6.7 Cation Exchange Capacity

Laboratory analysis of the spiral reject and raw coal (0.063mm) samples indicates the Cation Exchange Capacity (CEC) is low, ranging from 2.7 – 2.9 meq%, which is typically within the range of kaolinite dominated soils as shown in **Table 10.**

Table 10 Spiral Reject and Raw Coal CEC Results (meq%)

	Spiral Reject	**Raw Coal (0.063mm)**
CEC	2.7	2.9
Exch		
Na	<0.01	<0.01
K	0.12	0.37
Ca	0.79	1.10
Mg	0.51	0.58
Mn	0.18	0.10
Al	1.2	1.0
Solubles		
Na	0.01	0.01
K	0.05	0.04
Ca	2.90	0.40
Mg	1.95	0.21
Mn	0.53	0.03
Al	0.08	0.06

The low CEC values indicate the samples have a low capacity to adsorb cations, and would therefore provide a low adsorptive capacity for the waste to adsorb metallic cations in any leachate that may be produced.

6.8 Overburden Leachate Results

Laboratory analysis of TDS, sulfate and pH, as well as major metals from the selected composite coal washery waste from bores FEH001 and FEH002 are shown in **Table 11**.

Table 11 Coal Seam Washery Waste Leachate Analyses (mg/L)

Seam	**ANZECC / ARMCANZ 2000**	**Trinkey**	**Whaka**	**Flyblowers**	**Ulan Upper**	**Ulan Lower**
pH	6.5 – 7.5	6.9	**7.9**	**7.9**	7.2	7.2
TDS	350	250	320	230	190	160
SO4	_	48	51	43	24	390
Al	0.055 (pH>6.5)	0.02	0.01	<0.01	<0.01	<0.01
As	0.024 (As III)	<0.01	<0.01	<0.01	<0.01	<0.01
Cd	0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Cr	0.001 (CrVI)	<0.01	<0.01	<0.01	<0.01	<0.01
Co	_	0.057	<0.001	<0.001	<0.001	<0.001
Cu	0.0014	0.001	<0.001	0.001	0.001	0.001
Fe	_	0.01	<0.01	<0.01	<0.01	<0.01
Pb	0.0034	<0.001	<0.001	<0.001	<0.001	<0.001
Mn	1.9	0.16	0.17	0.16	0.13	0.18
Ni	0.001	**0.07**	<0.01	<0.01	<0.01	<0.01
Se	0.011	<0.01	<0.01	<0.01	<0.01	<0.01
Sr	_	0.089	0.22	0.270	0.051	0.070
Sn	_ (organic)	<0.01	<0.01	<0.01	<0.01	<0.01
Zn	0.008	**0.081**	0.001	0.002	0.003	0.007

NOTE: ANZECC/ARMCANZ (2000) trigger values For Protection of 95% of Aquatic Freshwater Species and Trigger Values For Physical and Chemical Stressors for SE Australian Upland Streams

The tested lithologies exceeding the ANZECC/ARMCANZ (2000) criteria for freshwater upland streams and protection of 95% of aquatic species as summarised in **Table 12**, with the main parameters exceeding the criteria including pH, Ni and Zn.

Table 12 Coal Seam Washery Reject Leachate ANZECC/ARMCANZ (2000) Exceedances

	Exceeded Parameter
Trinkey	Ni, Zn
Whaka	pH
Flyblowers	pH
Ulan Upper	None
Ulan Lower	None

7. CONCLUSIONS

7.1 Overburden

The results indicate that:

- 57 – 66% of the overburden could be non-acid forming,
- 7 - 25% could be uncertain to be non-acid forming
- 6 – 17% could be uncertain to be potentially acid forming
- 0 – 11% could be potentially acid forming – low capacity, and;
- 0 – 9% could be potentially acid forming

The majority of potentially acid forming materials are associated with the unweathered, uneconomic Whaka coal seam, which has the highest sulfur level of 0.43% Total S.

The economic coal seams and their associated carbonaceous lithologies with the higher total sulfur content will predominantly be extracted, washed in the CHPP and exported as product coal, with the washery waste placed in tailings dams.

The remainder of the weathered, uneconomic coal and carbonaceous units, such as the Whaka and Trinkey seams and their interburden, that will be placed on the waste rock emplacements, have a median Total S of 0.04%, which has an overall low risk of AMD generation.

Overall, the overburden and pit floor materials from the proposed Cobbora Open Cut coal mine are likely to be non-acid forming (NAF).

Preliminary investigation of the Whaka Seam indicates it has a low potential for acid generation. Additional AMD testing is required to confirm this assessment. However, this assessment can be conducted as the Whaka Seam is extracted from the mine.

It is anticipated that although limited sulfuric acid drainage from oxidation of pyritic material may occur, it is likely to be predominantly from the Whaka Seam.

Although current data indicates the remaining spoils have little excess alkalinity, mixing of mined waste material should limit any isolated AMD that may be generated primarily from the coal and carbonaceous shale wastes.

Salinity is low for the overburden waste, with the more elevated leachates generally sourced from the weathered overburden or carbonaceous samples. Overall, the median leachate generated from the overburden was 238µS/cm, whilst the highest individual sample returned a salinity of 1161µS/cm.

The potential overburden leachate pH for the selected samples ranged from 3.04 to 8.08, whilst the median value of 6.26 indicates the leachate pH should potentially be circum neutral.

Although TDS, Al, Cu, Pb, Ni and Zn were present in isolated, individual samples that exceed, or, in the case of pH, were outside the range specified in the ANZECC/ARMCANZ (2000) upland stream or 95% protection of aquatic species criteria, the results from the overburden samples indicates that, on bulk, the overburden waste emplacements are not anticipated to generate leachate water quality in excess of the relevant criteria.

Leachate from the overburden is likely to contain low concentrations of dissolved metals which have low solubility at the predominantly neutral to slightly alkaline pH.

The test results essentially represent pore water chemistry from pulverised samples. Dilution effects from rainfall and natural attenuation are likely to occur in the field, the dissolved metal concentrations in runoff or seepage from the overburden are unlikely to present any significant environmental issues in terms of the potential bulk discharging surface water quality from the site in relation to the ANZECC/ARMCANZ (2000) upland stream or 95% protection of aquatic species criteria.

For unblended PAF materials, there is some potential for dissolved metals in surface runoff and seepage to increase over time, and as a result, these materials may need to be blended and managed on site.

7.2 Washery Wastes

The potential washery wastes from the proposed Cobbora Open Cut coal mine are likely to be non-acid forming (NAF) and should not require any special handling for AMD control.

It is anticipated that minor sulfuric acid drainage from oxidation of pyritic material may occur and that these leachates are likely to be isolated. Current data indicates the washery waste has low excess alkalinity. Mixing of the tailings should limit any isolated AMD that may be generated.

Median leachate generated from the washery waste has low salinity content of approximately 206µS/cm, with a maximum measured salinity value was 2010µS/cm.

The potential overburden leachate pH ranges from 3.47 to 6.91, with a circum neutral median of 6.39.

Although Ni and Zn were present in isolated washery waste samples that exceeded the metals criteria, and/or were outside pH range specified in the ANZECC/ARMCANZ (2000) upland stream or 95% protection of aquatic species, the combined leachate bulk mass from the tailings dams is not anticipated to generate water quality in excess of the criteria.

The test results essentially represent pore water chemistry from pulverised samples Dilution effects from rainfall and natural attenuation are likely to occur in the field, the dissolved metal concentrations in runoff or seepage from the washery waste are unlikely to present any significant environmental issues in terms of the potential bulk discharging surface water quality from the site in relation to the ANZECC/ARMCANZ (2000) upland stream or 95% protection of aquatic species criteria.

For unblended PAF materials, there is some potential for dissolved metals in surface runoff and seepage to increase over time, and as a result, these materials may need to be blended and well managed on site.

8. RECOMMENDATIONS

The results to date indicate the Whaka Seam has a higher potential for AMD, and that this lithology may require additional AMD assessment. and if subsequently assessed to be potentially acid generating, specific waste management measures may be required.

Water quality monitoring of key seepage, pit water and drainage from overburden and washery waste materials should be routinely carried out for indicators of AMD as well as salinity and pH to confirm the expected benign nature of these materials, and to provide advance warning of any anomalous pyritic materials contained within the waste.

Additional chromium reducible sulfur, ANC, NAPP, NAG or Extended Boil NAG diagnostic tests could be conducted on the current suite of incompletely tested samples in order to obtained a clarified assessment of the potential acid generation and buffering capacity of the current sample suite. Notwithstanding this, even though there is a potentially incomplete suite of analyses, it is our assessment that this does not invalidate the overall conclusion of the report, in that AMD is not anticipated to be an issue of concern at the Project Site.

On going monitoring of the leachate generated from the waste emplacements should include pH, EC, $S0_4$ and acidity/alkalinity, with follow up multi element testing if any low pH conditions are detected to ensure that key water quality parameters remain within appropriate criteria.

It is recommended that the Proponent undertakes:

- Pre-stripping of topsoil from areas to be mined for use in final rehabilitation activities for surface cover or vegetation growth medium;
- Placement of overburden at the emplacement area that limits the risk of surface erosion; and;
- Field trials to identify the most appropriate topsoil and overburden materials for revegetation and rehabilitation of final landforms.

For the management of coal washery reject material, it is recommended that the Proponent considers:

- Placement of NAF coal reject materials in the open pit and/or co-disposal with overburden;
- Deep (in-pit) burial of any blended coal reject materials identified as PAF. Out-of-pit disposal of PAF rejects in overburden encapsulated cells may need to be considered until sufficient capacity in the open pit becomes available;
- Deep (in-pit) burial of any PAF roof and floor materials that do not report as dilution to the CHPP. Out-of-pit co-disposal of PAF roof and floor materials in overburden encapsulated cells may need to be considered until sufficient capacity in the open pit becomes available;
- Covering of PAF coal reject and PAF roof and floor material as soon as practical with at least 5 metres of overburden material to minimise the length of exposure to oxidising conditions and to minimise the potential for AMD generation;
- For any co-disposal that may be conducted, placement of NAF coal reject material in a manner that limits the risk of erosion; and;
- Verifying the geochemical characteristics of blended coal reject materials using standard static geochemical tests when bulk samples become available from the CHPP or similar process.

Surface water and seepage from coal washery reject material should be monitored to ensure that key water quality parameters remain within appropriate criteria. It is therefore recommended that the Proponent monitors standard runoff/seepage from coal reject emplacement areas (pH, EC and TSS) on a monthly basis and also dissolved metals, as required.

If required, possible management strategies for PAF washery waste or overburden/interburden could include:

- limestone treatment and interim compaction of PAF materials to increase lag times before onset of acid conditions to manage AMD during operations or until implementation of closure strategies;
- placement of PAF materials below the water table to allow inundation and prevent further exposure to atmospheric oxidation; or
- construction of a NAF cover zone designed to limit oxygen diffusion and infiltration into PAF materials (where water and oxygen flux modelling will be required to determine the best approach under the local climatic conditions).

9. REFERENCES

Amira International, 2002. AMD Test Handbook, Project P387A. Prediction & Kinetic Control of Acid and Metalliferous Drainage.

ANZECC/ARMCANZ, 2000. Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Environment and Conservation Council/Agriculture and Resource Management Council of Australia and New Zealand. Canberra, ACT.

Environmental Geochemistry International, Levay and Co. Environmental Services & ACeSSS – University of South Australia, 2008 Australian Coal Association Research Program Project C15034, Development of AMD Assessment for Coal Process Wastes.

Price, W. A., 2009. Prediction Manual for Drainage Chemistry From Sulphidic Geologic Materials, MEND Report 1.20.1, CANMET Mining and Mineral Sciences Laboratories.

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This report was prepared in accordance with the scope of services set out in the contract between Geoterra Pty Ltd (Geoterra) and the client, or where no contract has been finalised, the proposal agreed to by the client. To the best of our knowledge the report presented herein accurately reflects the client's requirements when it was printed. However, the application of conditions of approval or impacts of unanticipated future events could modify the outcomes described in this document.

In preparing this report, Geoterra has relied upon information and documentation provided by the client and / or third parties. Geoterra did not attempt to independently verify the accuracy or completeness of that information. To the extent that the conclusions and recommendations in this report are based in whole or in part on such information, they are contingent on its validity. Geoterra assume the client will make their own enquiries in regard to conclusions and recommendations made in this document. Geoterra accept no responsibility for any consequences arising from any information or condition that was concealed, withheld, misrepresented, or otherwise not fully disclosed or available to Geoterra.

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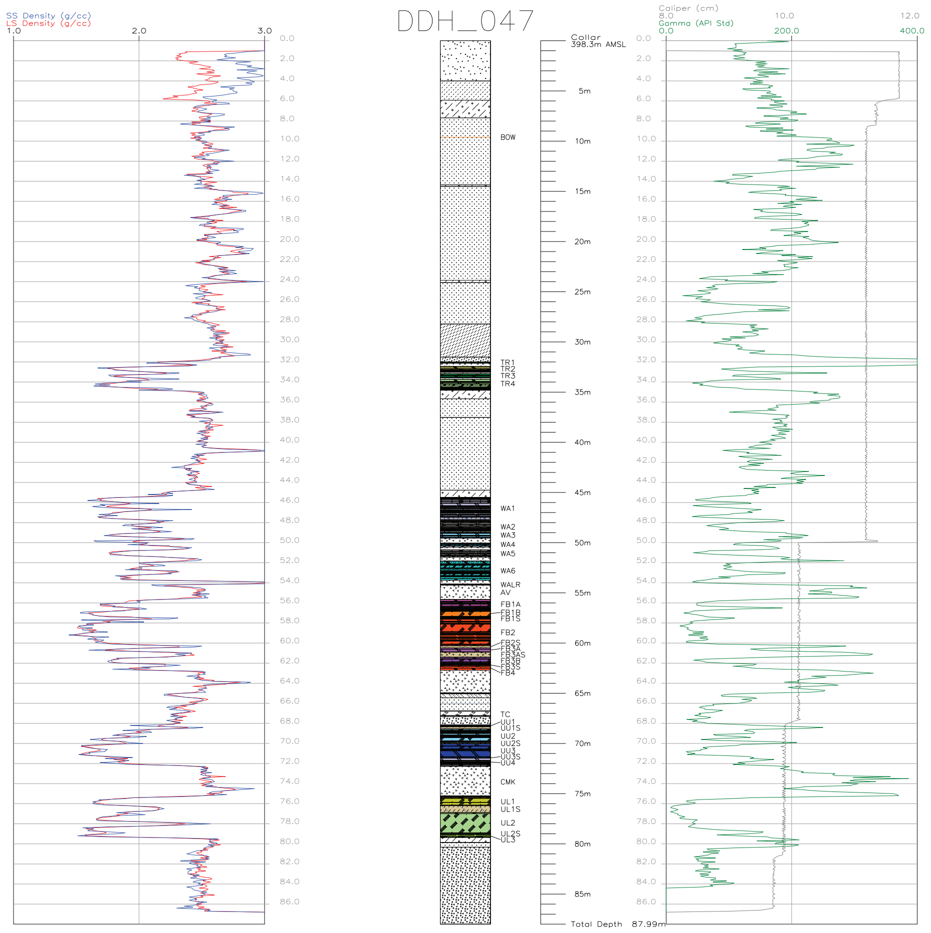
APPENDIX A

DRILL HOLE LOGS



KEY MAP

- Topography Contour (10m)
- Area 710
- Base Area Pits
- DPI Exploration Licence (6093)
- National Forest
- Rivers
- Highway
- Unpaved Roads
- Drill Hole
- Development Area
- Property Boundaries
- Proposed Exploration Licence
- Creeks
- Roads
- Interpreted Fault
- Location of Current Drillhole

LITHOLOGY

- Agglomerate
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- Coal Interbedded Dull & Bright
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- Carb. Claystone
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- Carb. Siltstone
- Claystone Coaly
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- Siltstone Coaly

SEAM PLYS

- TR1
- TR2
- TR3
- TR4
- WAUR
- WA1
- WA2
- WA3
- WA4
- WA5
- WA6
- WALR
- FBUR
- FB1A
- FB1B
- FB1S
- FB2
- FB2S
- FB3A
- FB3AS
- FB3B
- FB3S
- FB4
- FBLR
- UU1
- UU1S
- UU2
- UU2S
- UU3
- UU3S
- UU4
- UL1
- UL1S
- UL2
- UL2S
- UL3
- UL3S
- UL4

COBBORA MANAGEMENT COMPANY PTY LTD

GEOLOGIC MODELLING AND INVITATION TO TENDER

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Graphical Log

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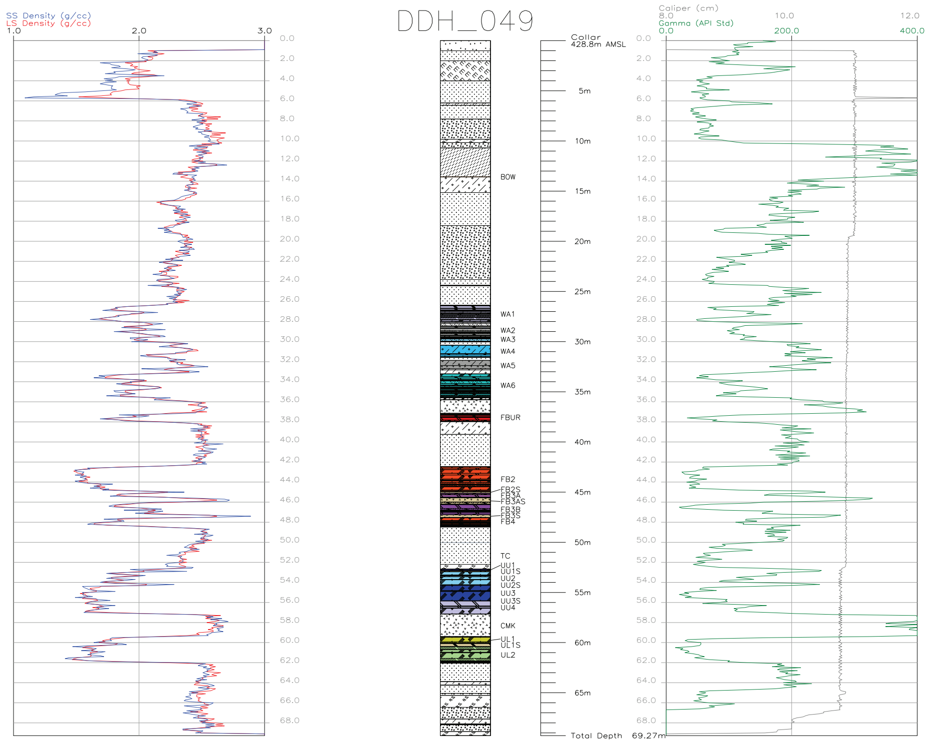
SCALE: 1:250

MARSTON

Drawing No.

E240-044-DDH_047



KEY MAP

Topography Contour (10m)

Area 710	Development Area
Base Area Pits	Property Boundaries
DPI Exploration Licence (6093)	Proposed Exploration Licence
National Forest	Creeks
Rivers	Roads
Highway	Interpreted Fault
Unpaved Roads	
Drill Hole	Location of Current Drillhole

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TR1	FB1A	UU2
TR2	FB1B	UU2S
TR3	FB1S	UU3
TR4	FB2	UU3S
WAUR	FB2S	UU4
WA1	FB3A	UL1
WA2	FB3AS	UL1S
WA3	FB3B	UL2
WA4	FB3S	UL2S
WA5	FB4	UL3
WA6	FBLR	UL3S
WALR	UU1	UL4
FBUR	UU1S	

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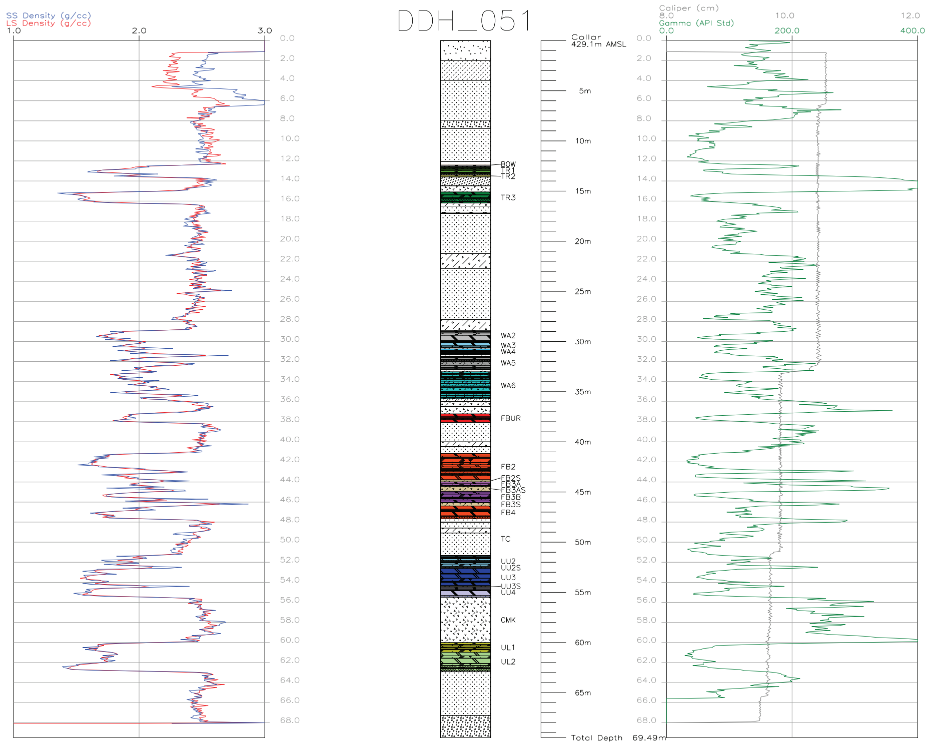

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FB1S
FB2
FB2S
FB3A
FB3AS
FB3B
FB3S
FB4
FBLR
UU1
UU1S
UU2
UU2S
UU3
UU3S
UU4
UL1
UL1S
UL2
UL2S
UL3
UL3S
UL4

COBBORA MANAGEMENT COMPANY PTY LTD

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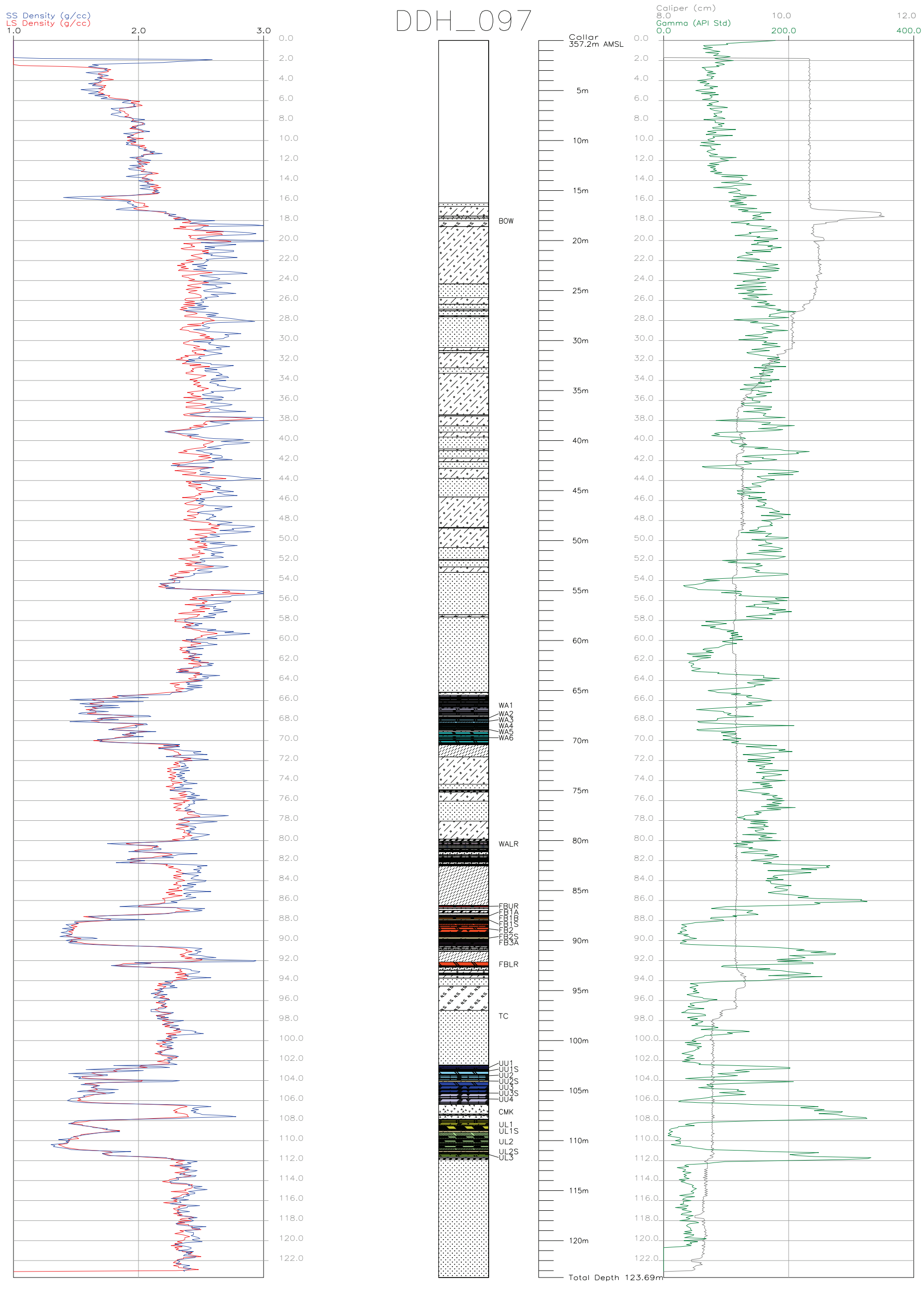

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SEAM PLYS

- TR1
- TR2
- TR3
- TR4
- WAUR
- WA1
- WA2
- WA3
- WA4
- WA5
- WA6
- WALR
- FBUR
- FB1A
- FB1B
- FB1S
- FB2
- FB2S
- FB3A
- FB3AS
- FB3B
- FB3S
- FB4
- FBLR
- UU1
- UU1S
- UU2
- UU2S
- UU3
- UU3S
- UU4
- UL1
- UL1S
- UL2
- UL2S
- UL3
- UL3S
- UL4

COBBORA MANAGEMENT COMPANY PTY LTD

GEOLOGIC MODELLING AND INVITATION TO TENDER

DDH_097
Graphical Log

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MARSTON

Drawing No.

E240-044-DDH_097

APPENDIX B

DESCRIPTION OF AMD TEST AND ANALYSIS METHODS

DESCRIPTION OF TEST AND ANALYSIS METHODS

Acid and metalliferous drainage (AMD) is produced by the exposure of sulfide minerals, such as pyrite, to atmospheric oxygen and water.

The ability to identify waste rock, tailings, as well as pit wall and floor materials that could potentially produce AMD is essential to effectively implement mine waste management strategies.

An outline of methods used to assess and classify mine waste materials is described below.

ACID BASE ACCOUNT

The acid-base account involves static laboratory procedures that evaluate the balance between acid generation processes from oxidation of sulfide minerals, and acid neutralising processes, such as dissolution of alkaline carbonates', displacement of exchangeable bases and weathering of silicates.

The results from an acid-base account are referred to as the potential acidity and the acid neutralising capacity.

The difference between the potential acidity and the acid neutralising capacity is referred to as the net acid producing potential (NAPP).

The chemical and theoretical basis of the ABA are discussed below.

Maximum Potential Acidity

The potential acidity that can be generated by a sample is calculated from an estimate of the pyrite ($FeS2$) content and assumes that the pyrite reacts under oxidising conditions to generate acid according to the following reaction:

$FeS2 + 15/402+ 7/2\ H20 => Fe(OH)3 + 2H2SO4$

Based on the above reaction, the potential acidity of a sample containing 1 %S (as pyrite) would generaste 30.6 kilograms of $H2SO4$ per tonne of material (i.e. kg $H2SO4$/t)

The pyrite content estimate can be based on total S and the potential.acidity determined from total S is referred to as the maximum potential acidity (MPA), and is calculated as follows:

MPA (kg $H2SO4$/t) = (Total %S) x 30.6

The use of an MPA calculated from total sulphur is a conservative approach because some sulphur may occur in forms other than pyrite. .

Sulfate-sulphur, organic sulphur and native sulphur, for example, are non-acid generating sulphur forms.

Also, some sulphur may occur as other metal sulfides (e.g. covellite, chalcocite, sphalerite, galena) which yield less acidity than pyrite when oxidised or, in some cases, may be non-acid generating.

The total sulphur content is commonly used to assess potential acidity because of the difficulty, costs and uncertainty involved in routinely determining the speciation of sulphur forms within samples, and determining reactive sulfide-sulphur contents.

However, if the sulfide mineral forms are known then allowance can be made for non- and lesser acid generating forms to provide a better estimate of the potential acidity.

To better define the potential for sulfide minerals to generate AMD, once Total S "screening" has been done, and to exclude the measurement of oxidised sulfur species (sulfates) which generally do not generate acid on dissolution, (except for jarosite) an assessment of the total sulfide S can also be conducted via the Chromium Reducible Sulfur analytical method..

Acid Neutralising Capacity (ANC)

The, acid formed from pyrite oxidation will to some extent react with acid neutralising minerals contained within the sample. This inherent acid buffering is quantified in terms of the ANC.

The ANC is commonly determined by the Modified Sobek method. This method involves the addition of a known amount of standardised hydrochloric acid (HCI) to an accurately weighed sample, allowing the sample time to react (with heating), then back-titrating the mixture with standardised sodium hydroxide (NaOH) to determine the amount of unreacted HCL

The amount of acid consumed by reaction with the sample is then calculated and expressed in the same units as the MPA (kg H_2SO_4/t).

Net Acid Producing Potential (NAPP)

The NAPP is a theoretical calculation commonly used to indicate if a material has potential to produce acidic drainage. It represents the balance between the capacity of a sample to generate acid (MPA) and its capacity to neutralise acid (ANC). The NAPP is also expressed in units of kg HZSO4/t and is calculated as follows:

NAPP = MPA-ANC

If the MPA is less than the ANC then the NAPP is negative, which indicates that the sample may have sufficient ANC to prevent acid generation. Conversely, if the MPA exceeds the ANC then the NAPP is positive, which indicates that the material may be acid generating.

ANC / MPA Ratio

The ANC/MPA ratio is frequently used as a means of assessing the risk of acid generation from mine waste materials. The ANC/MPA ratio is another way of looking at the acid base account.

A positive NAPP is equivalent to an ANC/MPA ratio less than 1, and a negative NAPP is equivalent to an ANC/MPA ratio greater than 1. A NAPP of zero is equivalent to an ANC/MPA ratio of 1.

The purpose of the ANC/MPA ratio is to provide an indication of the relative margin of safety (or lack thereof) within a material. Various ANC/MPA values are reported in the literature for indicating safe values for prevention of acid generation. These values typically range from 1 to 3. As a general rule, an ANC/MPA ratio of 2 or more signifies there is a high probability that the material will remain circum-neutral in pH and should not be problematic with respect to acid and metalliferous drainage.

NET ACID GENERATION (NAG) TEST

The NAG test is used in association with the NAPP to classify the acid generating potential of a sample. The NAG test involves reaction of a sample with hydrogen peroxide to rapidly oxidise any sulfide minerals contained within a sample. During the NAG test both acid generation and acid neutralisation reactions can occur simultaneously.

The end result represents a direct measurement of the net amount of acid generated by the sample.

The final pH is referred to as the NAGpH and the amount of acid produced is commonly referred to as the NAG capacity, and is expressed in the same units as the NAPP (kg H2SO4/t).

Several variations of the NAG test have been developed to accommodate the wide geoChemical variability of mine waste materials. The four main NAG test procedures are the;

- single addition NAG
- sequential NAG
- kinetic NAG, and;
- the extended boil and calculated NAG test.

Single Addition NAG Test

The single addition NAG test involves the addition of 250m1 of 15% hydrogen peroxide to 2.5g of sample. The peroxide is allowed to react with the sample overnight and the following day the sample is gently heated to accelerate the oxidation of any remaining sulfides, then vigorously boiled for several minutes to decompose residual peroxide.

When cool, the NAGpH and NAG capacity are measured.

An indication of the form of the acidity is provided by initially titrating the NAG liquor to pH 4.5, then continuing the titration up to pH 7. The titration value at pH 4.5 includes acidity due to free acid (i.e. HZSO4) as well as soluble iron and aluminium.

The titration value at pH 7 also ihcludes metallic ions that precipitate as hydroxides at between pH 4.5 and 7.

Sequential NAG Test

When testing samples with high sulfide contents, it is not uncommon for oxidation to be incomplete in the single addition NAG test. This can sometimes occur. when there is catalytic breakdown of the hydrogen peroxide before it has had a chance to oxidise all sulfides in a sample.

To overcome this limitation, a sequential NAG test is often carried out. This test may also be used to assess the relative geochemical lag of PAF samples with high ANC.

The sequential NAG test is a multi-stage procedure involving a series of single addition NAG tests on the one sample (i.e. 2.5g of sample is reacted two or more times with 250ml aliquots of 15% hydrogen peroxide).

At the end of each stage, the sample is filtered and the solution is used for measurement of NAGpH and NAG capacity. The NAG test is then repeated on the solid residue. The cycle is repeated until such time that there is no further catalytic decomposition of the peroxide, or when the NAGpH is greater than pH4.5. The overall NAG capacity of the sample is then determined by summing the individual acid capacities from each stage.

Kinetic NAG Test

The kinetic NAG test is the same as the single addition NAG test, except that the temperature and pH of the liquor are recorded. Variations in these parameters during the test provide an indication of the kinetics of sulfide oxidation and acid generation.

This, in turn, can provide an insight into the behaviour of the material under field conditions. For example, the pH trend gives an estimate of relative reactivity and may be related to prediction of lag times and oxidation rates similar to those measured in leach columns. Also, sulphidic samples commonly produce a temperature excursion during the NAG test due to the decomposition of the peroxide solution, catalysed by sulfide surfaces and/or oxidation products.

Extended Boil and Calculated NAG Test

Organic acids may be generated in NAG tests due to partial oxidation of carbonaceous materials such as coal washery wastes. This can lead to low NAGpH values and high acidities in standard single addition NAG tests unrelated to acid generation from sulfides.

Organic acid effects can therefore result in misleading NAG values and misclassification of the acid forming potential of a sample.

The extended boil and calculated NAG tests can be used to account for the relative proportions of pyrite derived acidity and organic acidity in a given NAG solution, thus providing a more reliable measure of the acid forming potential of a sample.

The procedure involves two steps to differentiating pyritic acid from organic derived acid:

- **Extended Boil NAG** decomposes the organic acids and hence removes the influence of non-pyritic acidity on the NAG solution.
- **Calculated NAG** calculates the net acid potential based on the balance of cations and anions in the NAG solution, which will not be affected by organic acid.

The extended boiling test is carried out on the filtered liquor of a standard NAG test, and involves vigorous boiling of the solution on a hot plate for 34 hours. After the boiling step the solution is cooled and the pH measured.

An extended boil NAGpH less than 4.5 confirms the sample is potentially acid forming (PAF), but a pH value greater than 4.5 does not necessarily mean that the sample is non acid forming (NAF), due to some loss of free acid during the extended boiling procedure.

To address this issue, a split of the same filtered NAG solution is assayed for concentrations of S, Ca, Mg, Na, K and C1, from which a calculated NAG value is determined.

The concentration of dissolved S is used to calculate the amount of acid (as H,SO4) generated by the sample and the concentrations of Ca, Mg, Na and K are used to estimate the amount of acid neutralised (as HZSO4).

The concentration of Cl is used to correct for soluble cations associated with Cl salts, which may be present in the sample and unrelated to acid generating and acid neutralising reactions.

The calculated NAG value is the amount of neutralised acid subtracted from the amount of acid generated. A positive value indicates that the sample has excess acid generation and is likely to be PAF, and a zero or negative value indicates that the sample has excess neutralising capacity and is likely to be NAF.

ACID BUFFERING CHARACTERISTIC CURVE (ABCC) Test

The ABCC test involves slow titration of a sample with acid while continuously monitoring pH. These data provides an indication of the portion of ANC within.a sample that is readily available for acid neutralisation.

ELEMENT ENRICHMENT AND SOLUBILITY

In mineralised areas, enriched elements may be present that have resulted from natural geological mineralisation processes.

Multi-element scans are carried out to identify elements in, or readily teachable, from a material at concentrations that may be of environmental concern with respect to surface water quality, revegetation and public health.

The samples are generally analysed for:

Major elements	Al, Ca, Fe, K, Mg, Na and S.
Minor elements	As, B, Cd, Co, Cr, Cu, F, Hg, Mn, Mo, Ni, Pb, Sb, Se and Zn.

The concentration of these elements can be directly compared with relevant state or national environmental and health based concentration guideline criteria to determine the level of significance.

Water extracts can be used to determine the element solubilities under specific pH conditions, where the following tests can be conducted:

Multi-element composition of solids.

Multi-element composition of solid samples can be determined using a combination of ICP-mass spectroscopy (ICP-MS), ICP-optical emission spectroscopy (OES) and atomic absorption spectrometry (AAS).

WATER EXTRACTS

Multi-element composition of water extracts from solid samples can be determined using a combination of ICP-mass spectroscopy (ICP-MS), ICP-optical emission spectroscopy (OES) and atomic absorption spectrometry (AAS).

Under some conditions (e.g. low pH) the solubility and mobility of common environmentally important elements can increase significantly.

If element mobility under initial pH conditions is deemed likely and/or subsequent low pH conditions may occur, kinetic leach column test work may be completed on representative samples.

The pH and electrical conductivity (EC) of a sample can also be determined by equilibrating the sample in deionised water for a minimum of 12 hours (or overnight), typically at a solid to water ratio of 1:2 or 1:5 (w/w) to provide an indication of the inherent acidity and salinity of the waste material when initially exposed in a waste emplacement area.

CATION EXCHANGE CAPACITY

A cation exhange capacity (CEC) analysis can be used to indicate the' potential for a soil or waste material to adsorb or desorb cations of sodium, calcium, potassium, magnesium, manganese and aluminium, as well as metallic cations and nutrients.

Samples with a low CEC have a low capacity to adsorb / desorb cations, whilst high values indicate a soil or waste can both adsorb (or subsequently desorb) cations, such as metallic cations generated in leachate through acid dissolution of waste materials.

SAMPLE CLASSIFICATION

The acid forming potential of a sample is classified on the basis of the acid base and NAG test results into one of the following categories:

- Non-acid forming (NAF);
- Potentially acid forming (PAF); and
- Uncertain (UC).

Non-acid forming (NAF)

A sample classified as NAF may, or may not, have a significant sulphur content but the availability of ANC within the sample is more than adequate to neutralise all the acid that theoretically could be produced by any contained sulfide minerals. As such, material classified as NAF is considered unlikely to be a source of acidic drainage.

A sample is defined as NAF when it has a negative NAPP and the final NAG pH > 4.5.

Potentially acid forming (PAF)

A sample classified as PAF always has a significant sulphur content, the acid generating potential of which exceeds the inherent acid neutralising capacity of the material. This means there is a high risk that such a material, even if pH circum-neutral when freshly mined or processed, could oxidise and generate acidic drainage if exposed to atmospheric conditions.

A sample is usually defined as PAF when it has a positive NAPP and a final NAGpH < 4.5.

Uncertain (UC)

An uncertain classification is used when there is an apparent conflict between the NAPP and NAG results (i.e. when the NAPP is positive and NAGpH > 4.5, or when the NAPP is negative and NAGpH < 4.5).

Uncertain samples are generally given a tentative classification that is shown in brackets e.g. UC(NAF).

APPENDIX C

OVERBURDEN AND WASHERY WASTE AMD TEST RESULTS

TABLE A OVERBURDEN AMD TEST RESULTS

	HOLE	Depth	Lithology	Tot S	CRS	ANC	NAPP	NAPP (S-)	leach	NAG	NAG	NAG pH 4.5	NAG pH 7	NAG xtnd boil pH 4.5	NAG xtnd boil pH 7	leach	TOC	AMD
Sample No.		mbgl		%	%	kg H2SO4	kg H2SO4	kg H2SO4	$pH_{1:2}$	pH	xtnd boil pH	kg H2SO4	kg H2SO4	kg H2SO4	kg H2SO4	$EC_{1:2}$ uS/cm	%	Classification
1	DDH47	6.29 - 6.59	wthrd siltstone	0.022					8.08							1161		NAF
2		12.08 - 12.20	sandstone / shale	0.051					7.74							518		NAF
3		25.69 - 25.83	sandstone / conglomerate	0.002					7.52							158		NAF
4		31.71 - 31.89	shale/mudstone	0.12					5.51							452		UC (PAF)
5		34.68 - 34.78	**coal+ferrug/oxid shale**	0.2	<0.01	4.3	1.8	-4.0	6.75	3.7	6.4	0.8	2.3	_	6.4	389	22.4	NAF
6		38.46 - 38.60	grn/wh stripy sandstone	0.002					6.96							311		NAF
7		44.10 - 44.25	Carb. mod sandstone	0.1					6.82							258		UC (NAF)
8		53.59 - 54.07	**coal + ferrug/oxid sandstone**	0.31		4.3	5.2		6.78	3		0.9	3.8			238		PAF
9		62.37 - 62.55	**coal + shale**	0.42		0.9	12.0		6.55	2.2		3	9.1			97		PAF
10		64.69 - 64.83	med/fine sandstone + shale	0.094					6.56							134		UC (NAF)
11		67.73 - 67.87	fine conglomerate	0.015					6.38							188		NAF
12		74.79 - 74.94	med/fine stripy sandstone	0.048					6.75							253		NAF
13		79.02 - 79.15	dk grey shale/ mudstone	0.07					6.88							206		UC (NAF)
14	DDH49	8.79 - 8.99	wthrd conglomerate	0.002					7.63							376		NAF
15		14.85 - 15.00	striped fine/med sandstone	0.034					7.4							547		NAF
16		17.58 - 17.72	white med sandstone	0.002					7.53							255		NAF
17		20.46 - 20.60	striped shale fine/med sandstone	0.049					7.26							344		NAF
18		24.09 - 24.22	coarse striped sandst/conglom	0.018					5.2							389		NAF
19		28.97 - 29.14	**coal**	0.43	0.25	0.2	13.0	7.5	4.38	2.1	2.8	5.1	12.2	4.7	6.2	287	32.7	PAF
20		31.72 - 31.88	striped shale /fine sandstone	0.056					4.15							595		UC (PAF)
21		35.01 - 35.17	**coal**	0.38		0.7	10.9		4.34	2.2		3.3	8.8			135		PAF
22		36.92 - 37.06	**tuff/+coaly band/fine sandstone**	0.039					5.27							236		NAF
23		39.82 - 39.95	fine sandstone	0.061					5.51							170		PAF-LC
24		51.23 - 51.38	coarse sandst/fine conglomerate	0.002					5.41							198		NAF
25		59.37 - 59.50	shale/fine sandstone	0.076					4.88							379		PAF-LC
26		61.99 - 62.14	shale	0.043					5.61							215		NAF
27	DDH51	10.12 - 10.25	sandstone	0.002					7.4							123		NAF
28		12.29 - 12.43	stripy shale / sandstone	0.015					3.82							409		UC (PAF)
29		16.06 - 16.19	shale	0.048					5.05							159		NAF
30		18.89 - 19.04	med grain sandstone	0.007					5.86							201		NAF
31		21.09 - 21.26	**shale / coal**	0.11					5.09							162		UC (PAF)
32		26.87 - 27.00	stripy sandstone / shale	0.051					5.31							120		UC(NAF)
33		27.43 - 27.58	crs sandstone / carb. shale	0.039					4.84							287		NAF
34		35.44 - 35.59	shale	0.27	<0.01	<0.1	8.2	0.2	4.38	2.4	5.2	1.9	6.7	_	1.6	244	25.7	PAF-LC
35		36.87 - 37.00	tuff?	0.038					5.65							220		NAF
36		40.84 - 41.00	med sandstone	0.044					4.64							239		NAF
37		44.85 - 45.00	tuff? / sandstone	0.11					6.21							368		UC(NAF)
38		47.86 - 47.98	med sandstone	0.028					6.51							113		NAF
39		59.68 - 59.82	tuff?	0.082					3.8							525		UC (PAF)
40		62.92 - 63.05	shale	0.024					5.86							187		NAF

TABLE A OVERBURDEN AMD TEST RESULTS (cont.)

	HOLE	Depth	Lithology	Tot S	CRS	ANC	NAPP	NAPP (S-)	leach	NAG	NAG	NAG pH 4.5	NAG pH 7	NAG xtnd boil pH 4.5	NAG xtnd boil pH 7	leach	TOC	AMD
No.		mbgl		%	%	kg H2SO4	kg H2SO4	kg H2SO4	$pH_{1:2}$	pH	xtnd boil pH	kg H2SO4	kg H2SO4	kg H2SO4	kg H2SO4	$EC_{1:2}$ uS/cm	%	Classification
41	**DDH97**	**27.54 - 27.69**	shale	0.041					7.67							461		**NAF**
42		**36.54 - 36.69**	shale	0.1					7.44							632		**UC(NAF)**
43		**39.72 - 39.87**	med stripy sandstone	0.032					7.68							210		**NAF**
44		**48.44 - 48.64**	shale	0.028					7.63							254		**NAF**
45		**54.57 - 54.69**	conglomerate	0.21	0.18	<0.1	6.3	5.4	3.04	2.8	2.7	1.1	6	3.2	5.5	863	0.05	**PAF**
46		**55.87 - 56.00**	splotchy fine sandstone	0.024					6.3							124		**NAF**
47		**57.69 - 57.84**	coarse sandst/conglomerate	0.011					6.6							92		**NAF**
48		**59.06 - 59.20**	splotchy sandstone	0.082					6.21							346		**UC(NAF)**
49		**60.69 - 60.84**	med sandstone	0.002					6.76							75		**NAF**
50		**62.84 - 62.96**	conglomerate	0.019					6.21							131		**NAF**
51		**65.55 - 65.70**	**coal**	0.33		1.6	8.5		6.26	2.3		2.3	7.2			47		**UC (PAF)**
52		**68.40 - 68.56**	**coal carbonaceous shale**	0.26		1.4	6.6		6.1	2.9		2.5	6.2			117		**UC (PAF)**
53		**78.15 - 78.27**	shale	0.059					6.18							405		**UC(NAF)**
54		**81.74 - 81.87**	carbonaceous shale/coal	0.33		1.6	8.5		6.26	2.3		2.7	7.9			546		**UC (PAF)**
55		**86.13 - 86.37**	carbonaceous shale/coal	0.18					6.52							55		**UC (PAF)**
56		**91.38 - 91.47**	wthrd med sandstone	0.07					6.59							171		**UC(NAF)**
57		**92.21 - 92.37**	**carbonaceous shale/ coal**	0.37	<0.01	0.4	10.9	-0.1	6.31	2.1	5	3	9.1	_	2	77	26.8	**NAF**
58		**99.57 - 99.61**	conglomerate	0.006					3.73							241		**NAF**
59		**111.45 - 111.59**	carbonaceous shale/shale	0.055					4.94							150		**UC (PAF)**

LEGEND 🟨 exceeds 0.05 S% 🟧 < pH 4.5 🟥 >1000 uS/cm

	Tot S	CRS	ANC	NAPP	NAPP (S-)	leach pH	NAG pH	NAG xtnd boil pH	NAG pH 4.5	NAG pH 7	NAG xtnd boil pH 4.5	NAG xtnd boil pH 7	leach EC	TOC
Max	0.430	0.25	4.3	13.0	7.5	8.08	3.70	6.40	5.1	12.2	4.7	6.4	1161	32.7
Min	0.002	0.18	0.2	1.8	-4.0	3.04	2.10	2.70	0.8	2.3	3.2	1.6	47	0.1
Av	0.097	0.22	1.7	8.3	1.8	6.05	2.55	4.42	2.4	7.2	4.0	4.3	285	21.5
Median	0.049	0.22	1.4	8.5	0.2	6.26	2.30	5.00	2.5	7.2	4.0	5.5	238	25.7

TABLE 2 COAL SEAM WASHERY TRIAL REJECT AMD TEST RESULTS

Lithology	Tot S	CRS	ANC	NAPP	Leach	NAG	Extnd Boil NAG	NAG pH4.5	NAG pH7	Extnd Boil NAG pH 4.5	Extnd Boil NAG pH7	Leach EC	AMD
	%	%	kg H2SO4/t	kg H2SO4/t	pH	pH	pH	kg H2SO4/t	kg H2SO4/t	kg H2SO4/t	kg H2SO4/t	uS/cm	Classification
raw coal	**0.32**	_	0.1	10	3.79	2.2	_	5	8.2	_	_	458	**UC (PAF)**
spiral reject	**0.45**	_	0.1	14.1	3.47	1.9	_	7.4	12.3	_	_	**2010**	**UC (PAF)**
Trinkey 2	**0.64**	0.07	4	16	6.19	_	5.1	_	_	_	1.8	317	**PAF-LC**
Whaka 1	**0.24**	0.04	2.4	5.1	6.39	_	5.8	_	_	_	1.1	206	**NAF**
Whaka 2	**0.22**	0.03	8.7	-1.8	6.91	_	7.2	_	_	_	<0.1	353	**NAF**
Flyblowers 1	**0.43**	0.09	2	11.5	4.91	_	3.7	_	_	1.5	2.8	204	**PAF**
Flyblowers 2	**0.29**	0.01	3.2	5.9	6.3	_	5.9	_	_	_	1	168	**NAF**
Ulan Upper 1	**0.32**	0.04	3.1	6.9	6.9	_	5.3	_	_	_	1.3	178	**NAF**
Ulan Upper 2	**0.31**	<0.01	2.5	7.2	6.86	_	5.8	_	_	_	1	158	**NAF**
Ulan Lower 1	**0.23**	0.04	2.3	4.9	6.69	_	5.7	_	_	_	1	260	**NAF**
Ulan Lower 2	**0.23**	0.03	3.4	3.8	6.63	_	6.2	_	_	_	0.6	192	**NAF**

LEGEND 🟨 exceeds 0.05 S% 🟨 < pH 4.5 🟧 >1000 uS/cm