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MALABAR COAL

MAXWELL PROJECT

APPENDIX P

Geochemistry Assessment

ENVIRONMENTAL GEOCHEMISTRY ASSESSMENT OF THE MAXWELL PROJECT

June 2019

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Abbreviations and Glossary

ABA	Acid-base account
ABCC	Acid buffering characteristic curves
AF	Acid forming
ANC	Acid neutralising capacity
ANZECC	Australian and New Zealand Environment Conservation Council
CHPP	Coal Handling and Preparation Plant
CL	Coal Lease
CRS	Chromium reducible sulphur
dS/m	deciSeimens per metre
EC	Electrical Conductivity
EIS	Environmental Impact Statement
EL	Exploration Licence
GAI	Geochemical Abundance Index
kg	Kilograms
m	Metres
MCS	Milbrodale Claystone
ML	Mining lease
MPA	Maximum potential acidity
NAF	Non-acid forming
NAG	Net acid generation
NAPP	Net Acid Producing Potential. The difference between the maximum potential acidity (MPA) and the acid neutralising capacity (ANC)
PAF	Potentially acid forming
PAF-LC	Potentially acid forming – Low capacity
pH	A unit of measure which describes the acidity or alkalinity of a solution
ROM	Run-of-mine
Salinity	A measure of all the salts dissolved in water
Sodic	Pertaining to or containing sodium
UC	Uncertain

1.0 Introduction

Maxwell Ventures (Management) Pty Ltd, a wholly owned subsidiary of Malabar Coal Limited (Malabar), is seeking consent to develop an underground coal mining operation, referred to as the Maxwell Project (the Project).

The Project is in the Upper Hunter Valley of New South Wales (NSW), east-southeast of Denman and south-southwest of Muswellbrook (Figure 1).

Underground mining is proposed within Exploration Licence (EL) 5460, which was acquired by Malabar in February 2018. Malabar also acquired existing infrastructure within Coal Lease (CL) 229, Mining Lease (ML) 1531 and CL 395, known as the "Maxwell Infrastructure". The Project would include the use of the substantial existing Maxwell Infrastructure, along with the development of some new infrastructure.

This assessment forms part of an Environmental Impact Statement (EIS) which has been prepared to accompany a Development Application for the Project in accordance with Part 4 of the *NSW Environmental Planning and Assessment Act 1979*. This environmental geochemistry assessment will be provided as an appendix to the EIS.

This report presents the results and findings of the geochemical assessment for the Project along with the findings from previous geochemical investigations undertaken in the immediate area. Based on this information, the report identifies the geochemical implications for the Project, and provides recommendations for management, mitigation and/or monitoring practices.

1.1 Project Description

The Project would involve an underground mining operation that would produce high quality coals over a period of approximately 26 years. At least 75% of coal produced by the Project would be capable of being used in the making of steel (coking coals). The balance would be export thermal coals suitable for the new generation High Efficiency, Low Emissions power generators.

LEGEND
- Mining Operation
- Proposed Mining Operation
- Railway
- Local Government Boundary
- State Forest
- National Parks and Wildlife Service Estate
- Maxwell Project Exploration Licence Boundary
- Maxwell Project Mining and Coal Lease Boundary
- Indicative Extent of Underground Development

Source: © NSW Department of Planning and Environment (2019); NSW Department of Finance, Services and Innovation (2019); Office of Environment and Heritage NSW (2019)

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MAXWELL PROJECT

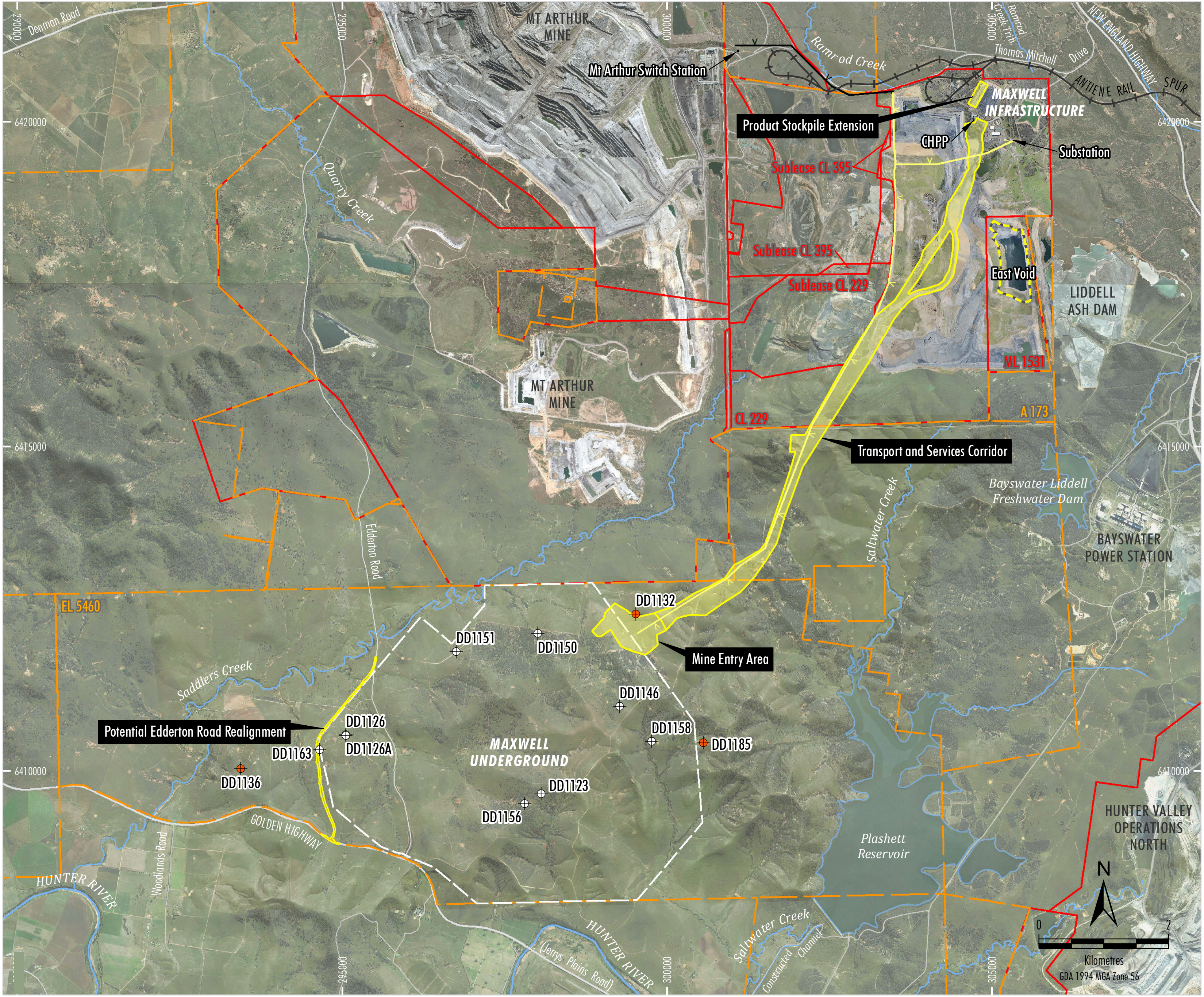
Regional Location

Figure 1

SHM-18-03 Maxwell_EIS_App_Figure 1_Rev D

The Project underground mining area is located entirely within EL 5460. The Project would involve the following activities relevant to the geochemistry assessment (Figure 2):

- Underground bord and pillar mining with partial pillar extraction in the Whynot Seam.
- Underground longwall extraction in the Woodlands Hill Seam, Arrowfield Seam and Bowfield Seam.
- Development and use of a mine entry and associated infrastructure, services and facilities that support underground mining and coal handling activities and provide for personnel and materials access to the underground mine.
- Establishment of infrastructure associated with mine ventilation and gas management.
- Use of existing water management systems.
- Progressive development of dams, sumps, pumps, pipelines, water storages, water treatment and other water management infrastructure.
- Construction and use of a covered overland conveyor system to transport run-of-mine (ROM) coal from the underground mine entry area to the existing Coal Handling and Preparation Plant (CHPP) at the Maxwell Infrastructure for processing.
- Transportation of early ROM coal via internal roads from the mine entry area to the existing CHPP.
- Handling and processing of coal and loading of coal onto trains at the existing Maxwell Infrastructure.
- Emplacement of coarse rejects, tailings and brine within existing voids in CL 229 and ML 1531.
- Rehabilitation activities within CL 229, ML 1531 and CL 395, including the rehabilitation of previously mined areas and overburden emplacement areas.



LEGEND
- Railway
- Exploration Licence Boundary
- Mining and Coal Lease Boundary
- Indicative Extent of Underground Development
- Proposed Surface Development Area
- CHPP Reject Emplacement Area
- Proposed 66 kV Power Supply
- Proposed Ausgrid 66 kV Power Supply Extension#
- Drill-Hole Sampled for the Geochemisty Asssessment
- Drill-Hole Sampled for RGS Environmental 2012

\# Subject to separate assessment and approval.

Source: © NSW Department of Planning and Environment (2019); NSW Department of Finance, Services & Innovation (2019) Orthophoto Mosaic: 2018, 2016, 2011

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MAXWELL PROJECT

Project Layout

Figure 2

SHM-18-03 Maxwell_EIS_App Geochem_202E

1.2 Assessment Objectives

The objectives of this assessment were to:

- assess the sodicity of rock excavated during the establishment of the mine entry area and drifts (termed herein 'establishment rock');
- assess the acid forming potential and the potential for migration of metals and/or salts from the establishment rock, underground workings, coal stockpiles and reject emplacement areas;
- identify the geochemical implications for management of the establishment rock, underground workings, coal stockpiles and reject emplacement areas; and
- provide recommendations for management, mitigation and/or monitoring practices for the Project.

This was achieved through:

- Reviewing the available geology, drill logs along with previous geochemical assessments relevant to the Project.
- From the review, determining the geochemical test work required to adequately characterise the establishment rock, ROM coal, coarse rejects and tailings in terms of the objectives.
- Coordinating the collection of samples representing the target coal seams, intra-seam partings, roof and floor rocks and establishment rock.
- Coordinating testing programs to assess the acid forming potential, salinity and sodicity, and metal enrichment and solubility of the collected samples.
- Interpreting the geochemical characterisation test results.

2.0 Stratigraphy

The Project area is situated within the Hunter Coalfield, which encompasses a significant portion of the northern part of the Sydney Basin. The Sydney Basin consists of coal bearing rocks of Permian age deposited during periods of marine and terrestrial sedimentation. Three major periods of coal formation in the Hunter Coalfield area are represented by the Greta Coal Measures, the Wittingham Coal Measures and the Newcastle Coal Measures (formerly known as Wollombi Coal Measures) (Beckett, 1988).

The target coal seams for the Project belong to the Jerrys Plains Subgroup of the Wittingham Coal Measures and include the Whynot, Woodlands Hill, Arrowfield and Bowfield Seams. The Jerrys Plains Subgroup consists of sediment deposits up to 800 metres (m) thick comprising several coal bearing and non-coal bearing deposits. The non-coal bearing strata typically consist of claystones, siltstones, sandstones and to a lesser extent conglomerates.

Figure 3 is a schematic stratigraphic column showing the typical stratigraphy of the coal seams and inter-seam strata for the Project area.

<table>
<tr><th>AGE</th><th colspan="4">STRATIGRAPHY</th></tr>
<tr><td>QUATERNARY</td><td colspan="4">Silt, Sand, Gravel</td></tr>
<tr><td>TERTIARY</td><td colspan="4">Basalt (flows, sills and dykes)</td></tr>
<tr><td>JURASSIC</td><td colspan="4">Basalt (flows, sills and dykes)</td></tr>
<tr><td rowspan="2">TRIASSIC</td><td colspan="4">Hawkesbury Sandstone</td></tr>
<tr><td colspan="4">NARRABEEN GROUP</td></tr>
<tr><td rowspan="11">LATE PERMIAN</td><td rowspan="11">SINGLETON SUPERGROUP</td><td rowspan="5">NEWCASTLE COAL MEASURES</td><td colspan="2">Glen Gallic Subgroup</td></tr>
<tr><td colspan="2">Doyles Creek Subgroup</td></tr>
<tr><td colspan="2">Horseshoe Creek Subgroup</td></tr>
<tr><td colspan="2">Apple Tree Flat Subgroup</td></tr>
<tr><td colspan="2">Watts Sandstone</td></tr>
<tr><td rowspan="6">WITTINGHAM COAL MEASURES</td><td colspan="2">Denman Formation</td></tr>
<tr><td colspan="2">Jerrys Plains Subgroup</td></tr>
<tr><td colspan="2">Archerfield Sandstone</td></tr>
<tr><td rowspan="2">Vane Subgroup</td><td>Bulga Formation</td></tr>
<tr><td>Foybrook Formation</td></tr>
<tr><td colspan="2">Saltwater Creek Formation</td></tr>
<tr><td rowspan="4">MIDDLE PERMIAN</td><td rowspan="3">MAITLAND GROUP</td><td colspan="3">Mulbring Siltstone</td></tr>
<tr><td colspan="3">Muree Sandstone</td></tr>
<tr><td colspan="3">Branxton Formation</td></tr>
<tr><td rowspan="2">GRETA COAL MEASURES</td><td colspan="3">Rowan Formation</td></tr>
<tr><td>EARLY PERMIAN</td><td colspan="3">Skeletar Formation</td></tr>
</table>

SHM-18-03 Maxwell_EIS_App Geochem_001A

Source: Department of Mineral Resources (1988)

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M A X W E L L   P R O J E C T

Stratigraphic Column
of the Hunter Coalfield

Figure 3

3.0 Related Geochemical Investigations

A summary of geochemical investigations conducted for coal mining operations in the Project region is provided in Table 1. The operations include proposed developments along with existing operations undergoing expansion that have targeted various coal seams primarily within the Jerrys Plains Subgroup of the Wittingham Coal Measures. This summary indicates relative consistency in the geochemical characteristics of the stratigraphy throughout the region. These characteristics include:

- The overburden and interburdens typically have a low sulphur content, are non-acid forming (NAF) and have low salinity. However, they have the risk of being moderately to highly sodic.
- The strata associated with the coal seams (i.e. roof and floor rock) have a risk of being potentially acid forming (PAF) or PAF low capacity (PAF-LC).
- The coal preparation plant rejects include some coal plus rock, typically delivered as coarse rejects and tailings, have a risk of being PAF. The PAF coarse rejects are more likely to be PAF-LC, whereas the tailings, due to their propensity for fine coal entrainment, are expected to have a higher sulphur content and therefore to have a higher capacity to generate acid.
- The strata are likely to be enriched with arsenic (As), antimony (Sb) and selenium (Se) relative to the average crustal abundance.

Analysis of the water quality implications for the existing waste rock and rejects emplacements is undertaken using representative water quality samples for these areas in the Groundwater Assessment (HydroSimulations, 2019) and Surface Water Assessment (WRM Water and Environment, 2019) for the Project.

Table 1: Summary of geochemical investigations conducted on coal mining operations and developments in the Project region.

Project	Target Seams	Samples	Analyses ( ) sample count	Findings and Recommendations	Reference
Bengalla Mine Continuation	Warkworth Mt Arthur Piercefield Vaux Broonie Bayswater Wynn Edderton	105 Overburden 9 Coal Rejects	pH & EC (all) Acid-Base Account (all) Sodicity (20) Multi-Element Scans (20) *Leach Tests (8)	Apart from the Archerfield Sandstone, classified as PAF, the overburden is typically barren and NAF. The majority of the overburden is expected to be sodic with low salinity. Coal rejects from the Wynn Seam are expected to be PAF and from the Vaux and Bayswater Seams are expected to be NAF. No significant metal enrichments were reported for the overburden or rejects. NAG testing was not used to confirm the geochemical classifications.	Geochemical Impact Assessment (EIS Appendix L), Jun 2013, RGS Environmental Pty Ltd
Drayton South Coal Project	Whybrow Redbank Ck Wambo Whynot Blakefield	30 Overburden 8 Coal Rejects	pH & EC (all) Acid-Base Account (all) Sodicity (15) Multi-Element Scans (15) *Leach Tests (5)	The overburden and coal rejects have low S with moderate ANC and are expected to be NAF. The majority of the overburden is expected to be sodic with low salinity. No significant metal enrichments were reported for the overburden or coal rejects. Molydbenum and selenium were found to be readily soluble in the overburden and coal rejects. NAG testing was not used to confirm the geochemical classifications.	Geochemical Impact Assessment of Overburden and Coal Reject Materials (EA Appendix P), Apr 2012, RGS Environmental Pty Ltd
Hunter Valley Operations and Mt Thorley/ Warkworth Mine	Whybrow Redbank Ck Wambo Whynot Bakerfield Glen Munro Woodlands Hill Arrowfield Bowfield Warkworth Mt Arthur Piercefield	All of the available data on the geochemical characteristics (salinity, sodicity & acid forming characteristics) of overburden and coal rejects (tailings & coarse rejects) from the Wittingham Coal Measures in the Hunter Coalfield area were evaluated during this review.		The overburden typically has low S with moderate ANC and is expected to be NAF. PAF materials occurr within and associated with the Archerfield Sandstone. The overburden typically contains some units that are saline and/or sodic. The coal seams lower in the stratigraphy generally have higher S with lower S higher in the profile. Due to the moderate S content, the coarse rejects from some seams are expected to be PAF/LC and some of the tailings are expected to be PAF. The rejects and tailings from seams stratigraphically lower in the profile have the highest risk of being PAF.	Acid Rock Drainage Prediction and Control Strategy Review, Sep 2005, Geo-Environmental Management Pty Ltd
Mt Arthur North Coal Project	Mt Arthur Piercefield Vaux Broonie Bayswater Wynn Ramrod Ck	99 Overburden 10 Coal Rejects	pH & EC (109) Acid-Base Account (109) NAG Test (52) Sodicity (49) Multi-Element Scans (19) *Leach Tests (19)	The majority of the overburden is expected to be relatively barren and NAF, however, some materials associated with the coal seams (roof and floor) are likely to be PAF. Some of the overburden is expected to be saline and/or sodic. The coal rejects are typically expected to have high S with low ANC and to be PAF. However, NAG tests were not performed to confirm the geochemical classificationon of these samples. Arsenic, antimony, selenium are expected to be enriched in the overburden and coal rejects. Mercury is also expected to be enriched in some of the coal rejects.	Geochemical Characterisation of Overburden and Reject Coal (EIS Appendix D), Apr 2000, Dames and Moore

*The leach tests used for a number of these investigations have been modified from the industry standard Leach Column Test procedure. These tests have a short duration (5 to 12 weeks) and it is likely that any PAF materials have remained within their geochemical lag phase throughout the test duration.

NOTE 1: Overburden refers to overburden and interburden.

NOTE 2: The coal seam roof and floor rock were included with the overburden and interburden for a number of these assessments.

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Table 1: Summary of geochemical investigations conducted on coal mining operations and developments in the Project region CONTINUED.

Project	Target Seams	Samples	Analyses ( ) sample count	Findings and Recommendations	Reference
Mt Arthur Coal Open Cut Modification	Bowfield Warkworth Bayswater Wynn Ramrod Ck	139 Overburden	pH & EC (139) Acid-Base Account (139) NAG Test (59) Sodicity (40) Multi-Element Scans (25)	The overburden is typically expected to have low S with low to moderate ANC to be NAF. Some of the roof and floor rock may be PAF or PAF/LC and these materials are expected to have a short geochemical lag and likely to develop acid conditions within a short period of exposure. The overburden is expected to have low salinity, but a significant proportion is expected to be sodic. Arsenic, antimony and selenium are expected to typically be enriched in the overburden and mercury may also be slightly enriched in some of the overburden material. Arsenic, molybdenum and antimony are expected to be relatively soluble under near neutral conditions in the overburden. The coal rejects are expected to be geochemically similar to those currently being produced which are PAF.	Geochemical Assessment of Overburden and Interburden (EA Appendix I), Nov 2012, Geo-Environmental Management Pty Ltd
Mt Arthur Coal Open Cut Mine	Bowfield Warkworth Bayswater Wynn Ramrod Ck	60 Overburden	pH & EC (60) Acid-Base Account (60) NAG Test (30) Multi-Element Scans (15)		Geochemical Characterisation of Overburden and Interburden from Drill-Holes ID1173 and ID1178, Nov 2012, Geo-Environmental Management Pty Ltd
Wambo Development Project	Whybrow Redbank Ck Wambo Arrowfield Bowfield	21 Overburden 4 Coal Rejects	pH & EC (25) Acid-Base Account (25) NAG Test (25) Sodicity (25) Multi-Element Scans (25) Shake Solubility Test (21)	The overburden is expected to have low S and to be NAF with low salinity. However, it is typically expected to be sodic. The coarse rejects typically have moderate S and low ANC, and are expected to be PAF-LC. The tailing typically have relatively high S and low ANC, and are typically expected to be PAF. Arsenic and selenium were significantly enriched in some of the overburden samples. Selenium was significantly enriched some of the tailings samples and arsenic was slightly enriched in the coarse reject samples. No metals were found to be soluble in the overburden or rejects under near-neutral pH conditions.	Waste Rock and CHPP Rejects/Tailings Management (EIS Appendix G), Apr 2003, Resource Strategies Pty Ltd
Spur Hill Underground Coking Coal Project	Whybrow Wambo Whynot Bowfield Warkworth	38 Overburden 25 Roof & Floor 10 Coal/Rejects	pH & EC (73) Acid-Base Account (73) NAG Test (73) Sodicity (20) Multi-Element Scans (25)	The overburden, and coal seam roof and floor rock is expected to be NAF, with low S and moderate ANC, and low salinity. However, the overburden is typically expected to be sodic. The coal rejects are expected to be NAF with low S and moderate ANC, with low to moderate salinity. The ROM coal is typically expected to be NAF, however some material from the Whynot and Bowfield Seams is expected to be PAF-LC. Arsenic, antimony and selenium are expected to be slightly enriched in the overburden and ROM coal, and significantly enriched in the roof and floor rock and coal rejects. The arsenic and selenium in all of these materials are expected to be relatively soluble.	Conducted by Geo-Environmental Management Pty Ltd,May 2014

*The leach tests used for a number of these investigations have been modified from the industry standard Leach Column Test procedure. These tests have a short duration (5 to 12 weeks) and it is likely that any PAF materials have remained within their geochemical lag phase throughout the test duration.

NOTE 1: Overburden refers to overburden and interburden.

NOTE 2: The coal seam roof and floor rock were included with the overburden and interburden for a number of these assessments.

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EC = electrical conductivity; EA = Environmental Assessment; NAG = net acid generation; ANC = acid neutralising capacity.

4.0 Geochemical Assessment Program

Representative samples of the coal seam roof and floor rock, coal and coal rejects were selected for geochemical characterisation. The geochemical characterisation of these samples provided for the geochemical classification of the different material types and the identification of any geochemical implications for managing these materials.

4.1 Sample Selection and Preparation

The samples for this assessment included roof and floor rock associated with each coal seam which was obtained from stored drill core, along with coal provided as product and rejects fractions.

4.1.1 Roof and Floor Rock Samples

A total of 12 samples representing the roof and floor rock for each coal seam were collected from 3 drill holes, DD1132, DD1136 and DD1185. The samples were collected from immediately above and below each seam, with intervals ranging from 0.24 to 1.13 m. Table 2 provides the roof and floor rock sample details.

Table 2: Details for the coal seam roof and floor rock.

Sample ID	Drill-Hole	Strata	Depth (m)		
			From	To	Interval
178730	DD1136	Whynot Floor	34.88	35.82	0.94
178731	DD1136	Whynot Roof	31.36	31.85	0.49
178732	DD1132	Woodlands Hill Floor	155.96	157.09	1.13
178733	DD1132	Woodlands Hill Roof	146.60	147.23	0.63
178734	DD1132	Woodlands Hill Floor	153.97	154.50	0.53
178735	DD1185	Woodlands Hill Floor	235.13	235.71	0.58
178736	DD1136	Woodlands Hill Roof	187.96	188.57	0.61
178737	DD1185	Bowfield Floor	324.46	324.88	0.42
178738	DD1185	Woodlands Hill Floor	235.76	236.18	0.42
178739	DD1185	Woodlands Hill Roof	229.58	230.25	0.67
178740	DD1185	Arrowfield Roof	315.47	315.91	0.44
178741	DD1185	Arrowfield Floor	324.22	324.46	0.24

4.1.2 Coal and Coal Reject Samples

A total of 13 samples, including 6 samples representing clean coal, 6 samples representing the coal rejects, and one sample representing the Milbrodale Claystone forming the base of the sequence, were prepared by SGS Australia Pty Ltd (SGS) in Mayfield West. Table 3 provides the details for these samples. The clean coal and coal reject samples were composited into the Whynot, Woodlands Hill, Arrowfield and Bowfield Seams using the sub-seams listed in Table 3.

Table 3: Details for the clean coal and reject samples.

Sample ID	Material Type	Coal Seam
WN-CC	Clean Coal	WN1+WN2+WN3 (Whynot)
WH1-CC	Clean Coal	WH1+WH131 (Woodlands Hill)
WH2-CC	Clean Coal	WH132+WH141+WH142 (Woodlands Hill)
AF-CC	Clean Coal	AF0+AF1+AF2 (Arrowfield)
BF1-CC	Clean Coal	BF11+BF12+BF2 (Bowfield)
BF2-CC	Clean Coal	BF3 (Bowfield)
WN-R	Reject	WN1+WN2+WN3 (Whynot)
WH1-R	Reject	WH1+WH131 (Woodlands Hill)
WH2-R	Reject	WH132+WH141+WH142 (Woodlands Hill)
AF-R	Reject	AF0+AF1+AF2 (Arrowfield)
BF1-R	Reject	BF11+BF12+BF2 (Bowfield)
BF2-R	Reject	BF3 (Bowfield)
MCS	Milbrodale Claystone	Seam Floor Strata

4.2 Testing Methodology

In preparation for analysis the samples were crushed to minus 4 millimetres, and a 300 to 500 grams sub-sample pulverised to minus 75 micrometres by International Resource Laboratories Pty Ltd (IRL) in Brisbane.

The geochemical characterisation program involved a range of static geochemical tests performed on the rock samples and the composited clean coal and reject samples. The analytical program included the following tests and procedures:

- pH and electrical conductivity (EC) determination (all samples);
- total S assay (all samples);
- sulphide S analysis (selected samples);
- ANC determination (all samples);
- single addition net acid generation (NAG) test (all samples);
- extended boil NAG test (selected samples); and
- multi-element scans on solids and water extracts (selected samples).

The total S assays were performed by IRL and SGS, and the sulphide S analyses were performed by Australian Laboratory Service Pty Ltd (ALS). The ANC determinations and NAG testing were performed by Environmental Geochemistry International Pty Ltd (EGi), and the multi-element analyses were performed by Genalysis Laboratories Pty Ltd in Perth.

An overview of the tests and procedures used for the assessment is presented below.

4.2.1 pH and Salinity Determination

The pH and EC of a material is determined by equilibrating the sample in deionised water for a minimum of 2 hours at a solid to water ratio of 1:2 (weight for weight [w/w]). This test provides an indication of the inherent acidity and salinity of the material when it is initially exposed. Table 4 provides the salinity rankings based on $EC_{1:2}$ values.

Table 4: Salinity ranking based on the electrical conductivity (EC) value.

$EC_{1:2}$ (dS/m)	Salinity
< 0.5	Non-Saline
0.5 to 1.5	Slightly Saline
1.5 to 2.5	Moderately Saline
> 2.5	Highly Saline

(Rhoades *et al*., 1999) dS/m = deciSiemens per metre

4.2.2 Acid Forming Characteristic Evaluation

A number of test procedures are used to assess the acid forming characteristics of mine waste materials. The most widely used assessment methods are the acid-base account (ABA) and the NAG test. These methods are referred to as static procedures because they involve a single measurement in time.

Acid-Base Account

The ABA involves laboratory procedures that evaluate the balance between acid generation processes (oxidation of sulphide minerals) and acid neutralising processes (dissolution of alkaline carbonates, displacement of exchangeable bases, and weathering of silicates). The values arising from the ABA are referred to as the maximum potential acidity (MPA) and the ANC, respectively. The difference between the MPA and ANC value is referred to as the NAPP (Net Acid Production Potential).

The MPA is calculated using the total S content of the sample. This calculation assumes that all of the S measured in the sample occurs as pyrite (FeS_2) and that the pyrite reacts under oxidising conditions to generate acid according to the following reaction:

$$4FeS_2 + 15\,O_2 + 14\,H_2O \Rightarrow 4Fe(OH)_3 + 8\,H_2SO_4$$

According to this reaction, the MPA of a 1 tonne sample containing 1% S as pyrite would be 30.6 kilograms (kg) of sulphuric acid (H_2SO_4). Hence the MPA of a 1 tonne sample is calculated using the following formula:

$$\text{MPA (kg } H_2SO_4\text{/t of sample)} = (\text{Total \%S}) \times 30.6$$

The use of the total %S to estimate the MPA is conservative because S may occur in forms other than pyrite. Sulphate-S and native S, for example, are non-acid generating. Also, S may occur as other metal sulphides (e.g. covellite, chalcocite, sphalerite, galena) that yield less acidity than pyrite when oxidised. The chromium reducible sulphur (CRS analysis) analysis method is used to determine the proportion of total S within a sample that occurs as sulphide.

The acid formed from pyrite oxidation will to some extent react with acid neutralising minerals contained within the sample. This inherent acid neutralisation is quantified in terms of the ANC and is determined using the Modified Sobek method. This method involves the addition of a known amount of standardised hydrochloric acid (HCl) 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 giving the ANC expressed in the units of kg H_2SO_4/tonne.

Determination of the ANC using the Modified Sobek method (Sobek *et al*., 1978) provides an indication of the total neutralisation capacity of the sample. However, in some materials not all mineral phases will be readily available to neutralise sulphide generated acidity. For these material types acid buffering characteristic curves (ABCC) can be used to determine the amount of ANC that is available to neutralise any sulphide generated acidity under more natural weathering conditions. The ABCC's are obtained by slow titration of a sample with acid while continuously monitoring pH and plotting the amount of acid added against pH. The plot provides an indication of the portion of ANC within a sample that is readily available for acid neutralisation.

The NAPP (Net Acid Production Potential) is a theoretical calculation commonly used to indicate if a material has the potential to produce acid. 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 H_2SO_4/tonne and is calculated as follows:

$$\text{NAPP} = \text{MPA} - \text{ANC}$$

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.

The ANC/MPA ratio is used as a means of assessing the risk of acid generation from mine waste materials. 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. Generally, an ANC/MPA ratio of 3 or more signifies that there is a high probability that the material is not acid generating.

Figure 4 is an ABA plot which is commonly used to provide a graphical representation of the distribution of S and ANC in a sample set. This figure shows a plotted line where the NAPP=0 (i.e. ANC = MPA or ANC/MPA=1). Samples that plot to the lower-right of this line have a positive NAPP and samples that plot to the upper-left of it have a negative NAPP. Figure 4 also shows the plotted lines corresponding to ANC/MPA ratios of 2 and 3.

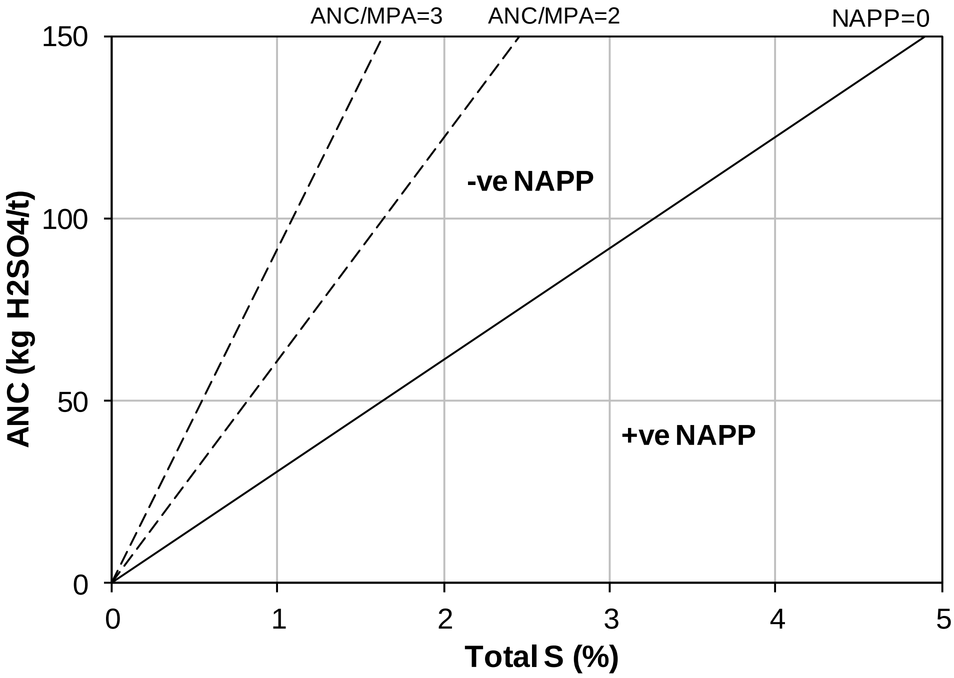

Figure 4: Typical acid-base account plot.

Net Acid Generation Test

The net acid generation (NAG) test involves the addition of hydrogen peroxide to a sample to oxidise the contained reactive sulphide, then measurement of pH and titration of any net acidity produced. A NAGpH < 4.5 indicates that acid conditions remain after all acid generating and acid neutralising reactions have taken place and a NAGpH > 4.5 indicates that any generated acidity has been neutralised. Therefore, the NAG test provides a direct assessment of the potential for a material to produce acid after a period of exposure and weathering and is used to complement the results of the theoretical NAPP predictions. In samples containing carbonaceous material, organic acids may be generated during the NAG reaction which can lead to misleading low NAGpH values and acidities. To overcome this effect an ‘extended boil’ NAG test has been developed by Environmental Geochemistry International Pty Ltd (EGi), where the organic acids are decomposed in order to ensure that the NAGpH and acidity of the NAG solution are due solely to sulphide oxidation.

4.2.3 Multi-Element Analysis

Multi-element scans are carried out on solid samples to identify any elements that are present at concentrations that may be of environmental concern with respect to water quality and revegetation. The assay results from the solid samples are compared to the average crustal abundance for each element to provide a measure of the extent of element enrichment. The extent of enrichment is reported as the Geochemical Abundance Index (GAI) which relates the actual concentration with the crustal abundance on a log 2 scale. The GAI is expressed in 7 integer increments (i.e. 0 through to 6), where a GAI of 0 indicates the element is present at a concentration similar to or less than the average crustal abundance, and a GAI of 6 indicates a 100-fold or greater enrichment above average crustal abundance. As a general rule, a GAI of 3 or greater signifies enrichment that warrants further examination. However, identified element enrichment does not necessarily mean that an element will be a concern for revegetation, water quality, or public health and this technique is used to identify any significant element enrichments that warrant further examination.

Multi-element scans are also performed on liquor samples to determine the chemical composition of the solution and identify any elemental concerns for water quality. Multi-element scans are performed on water extracts, typically extracted from a 1 part sample to 2 parts deionised water suspension, in order to identify any elements that are likely to be readily soluble under the existing pH conditions. These analyses are designed to identify any elements that may be a concern for water quality and warrants further investigation.

4.3 Geochemical Classification

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

- Barren;
- Non-Acid Forming (NAF);
- Potentially Acid Forming (PAF);
- Acid Forming (AF); and
- Uncertain (UC).

Barren

A sample classified as barren essentially has no acid generating capacity and no acid buffering capacity. This category is most likely to apply to highly weathered materials. In essence, it represents an 'inert' material with respect to acid generation. The criteria used to classify a sample as barren may vary between sites, but it generally applies to materials with a total S content $\leq$ 0.1%S and an ANC $\leq$ 10 kg H_2SO_4/tonne.

Non-Acid Forming

A sample classified as NAF may or may not have a significant S 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 sulphide minerals. As such, material classified as NAF is considered unlikely to be a source of acidic drainage. A sample is usually defined as NAF when it has a negative NAPP and a final NAGpH $\geq$ 4.5.

Potentially Acid Forming

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 risk that such a material, even if pH is circum-neutral when freshly mined or processed, could oxidise and generate acidic drainage if exposed to atmospheric conditions. A sample is classified as PAF if it has a positive NAPP and a final NAGpH < 4.5. Typically, if a PAF sample has a NAPP $\leq$ 5 kg H_2SO_4/tonne it is considered to only have a low capacity to generate acid and is classified as PAF-LC.

Acid Forming

A sample classified as AF has the same characteristics as the PAF samples however these samples also have an existing pH of less than 4.5. This indicates that acid conditions have already been developed, confirming the acid forming nature of the sample.

Uncertain

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 $\leq$ 4.5).

Figure 5 shows a typical geochemical classification plot for mine waste materials where the NAPP values are plotted against the NAGpH values. Samples that plot in the upper left quadrate, with negative NAPP values and NAGpH values greater than 4.5, are classified as NAF. Those that plot on the lower right quadrate, with positive NAPP values and NAGpH values of 4.5 or less, are classified as PAF. Samples that plot in the upper right or lower left quadrates of this plot have an uncertain geochemical classification (UC) due to a contradiction between the NAPP and NAG test results.

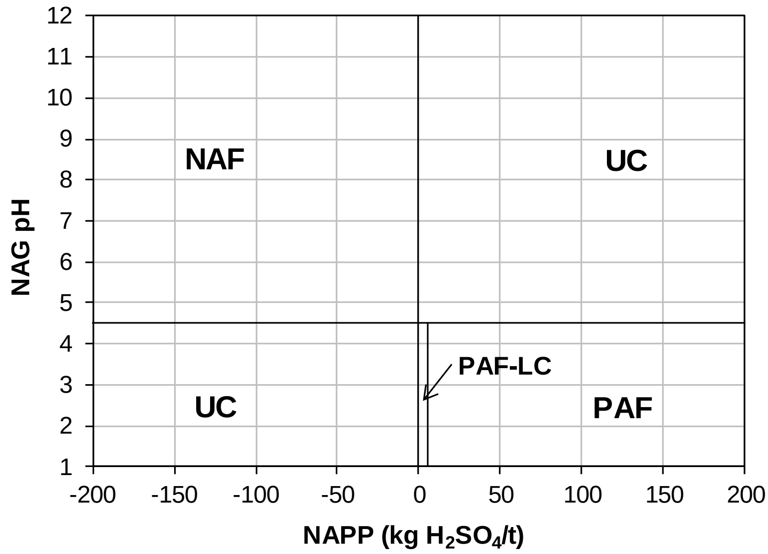

Figure 5: Typical geochemical classification plot.

5.0 Roof and Floor Rock Geochemistry

The geochemical characteristics assessed for the coal seam roof and floor rock samples include the pH and salinity, the acid forming characteristics, and the element enrichment and solubility. The $pH_{1:2}$ and $EC_{1:2}$, and acid forming characteristic results are presented on Table 5.

5.1 pH and Salinity

The $pH_{1:2}$ and $EC_{1:2}$ results are used to assess the pH and salinity of the samples. For the Project, results indicate that the roof and floor rock samples are generally alkaline, ranging from pH 7.3 to 9.1, apart from two of the Woodlands Hill rock samples that have a pH of 4.6 and 4.8, respectively. The $EC_{1:2}$ values range from 0.188 to 1.377 dS/m, indicating that these samples range from non-saline to slightly saline. The low pH samples also had the highest $EC_{1:2}$ values at 1.206 and 1.377 dS/m, respectively.

5.2 Acid Forming Characteristics

Figure 6 is a plot of the total S content compared to the ANC and Figure 7 is a geochemical classification plot where the NAPP values are plotted against the NAGpH. These figures show that, with the exception of sample 178734, all samples were classified as NAF (Non-Acid Forming).

Sample 178734 was classified as PAF-LC because:

- It has a positive NAPP value, indicating that its capacity to generate acid exceeds its capacity to neutralise acid, and it has a NAGpH less than 4.5, indicating that this sample developed acid conditions when oxidised.
- It has a NAPP value of less than 5 kg H_2SO_4/tonne (3 kg H2SO_4/tonne) and therefore is considered to have a low capacity to generate acid.

Table 5: Acid forming characteristics of coal seam roof and floor rock samples.

Sample ID	Drill-Hole ID	Strata	$pH_{1:2}$	$EC_{1:2}$	ACID-BASE ANALYSIS					NAG TEST			Geochem. Class.
					Total %S	MPA	ANC	NAPP	ANC/ MPA	NAGpH	$NAG_{pH4.5}$	$NAG_{pH7.0}$	
178730	DD1136	Whynot Floor	7.8	0.47	0.04	1	11	-10	9.2	7.2	0	0	NAF
178731	DD1136	Whynot Roof	7.4	0.51	0.03	1	8	-7	9.9	7.3	0	0	NAF
178732	DD1132	Woodlands Hill Floor	8.9	0.36	0.01	0	17	-17	46.3	7.7	0	0	NAF
178733	DD1132	Woodlands Hill Roof	8.2	0.93	0.06	2	8	-6	4.3	7.9	0	0	NAF
178734	DD1132	Woodlands Hill Floor	4.8	1.38	0.29	9	6	3	0.7	3.9	1	12	PAF-LC
178735	DD1185	Woodlands Hill Floor	7.5	0.38	0.06	2	7	-5	3.8	6.9	0	0	NAF
178736	DD1136	Woodlands Hill Roof	9.1	0.48	0.03	1	14	-13	17.9	7.2	0	0	NAF
178737	DD1185	Bowfield Floor	7.8	0.30	0.04	1	4	-3	3.4	7.1	0	0	NAF
178738	DD1185	Woodlands Hill Floor	8.0	0.53	0.05	2	24	-22	15.7	7.3	0	0	NAF
178739	DD1185	Woodlands Hill Roof	4.6	1.21	0.18	6	6	0	1.1	6.1	0	2	NAF
178740	DD1185	Arrowfield Roof	7.3	0.27	0.03	1	6	-5	7.8	7.1	0	0	NAF
178741	DD1185	Arrowfield Floor	7.9	0.19	0.03	1	2	-1	2.5	6.2	0	0	NAF

KEY

$pH_{1:2}$ = pH of 1:2 extract

$EC_{1:2}$ = Electrical Conductivity of 1:2 extract (dS/m)

MPA = Maximum Potential Acidity (kg H_2SO_4/t)

ANC = Acid Neutralising Capacity (kg H_2SO_4/t)

NAPP = Net Acid Producing Potential (kg H_2SO_4/t)

NAGpH = pH of NAG liquor

$NAG_{pH4.5}$ = Net Acid Generation capacity to pH 4.5 (kg H_2SO_4/t)

$NAG_{pH7.0}$ = Net Acid Generation capacity to pH 7.0 (kg H_2SO_4/t)

ARD Classification Key

NAF = Non-Acid Forming

PAF = Potentially Acid Forming

PAF-LC = PAF Low Capacity

UC = Uncertain (expected classification)

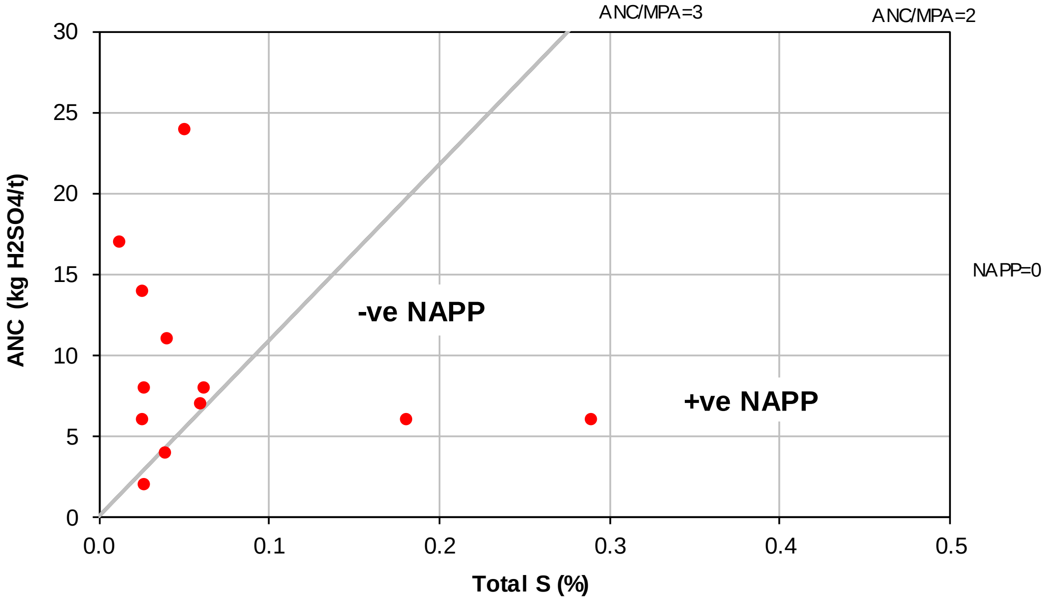

Figure 6: Acid-base account plot for the coal seam roof and floor rock.

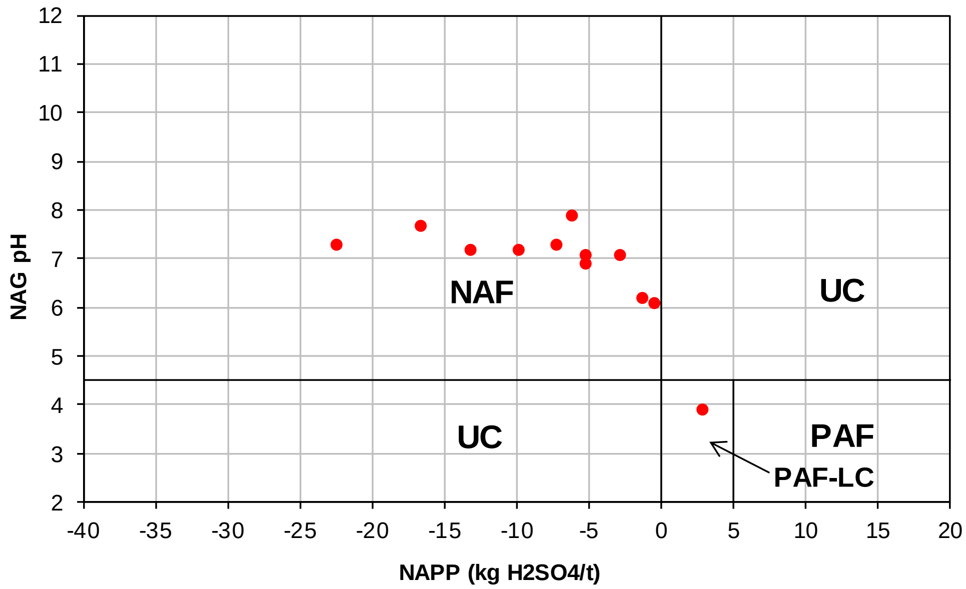

Figure 7: Geochemical classification plot for the coal seam roof and floor rock.

5.3 Metal Enrichment and Solubility

Multi-element scans were performed on the solids and water extracts (1 part sample/ 2 parts deionised water) of 8 samples representing the coal seam roof and floor. The results from these analyses, including the GAI, are provided in Attachment A (Tables A-1, A-2 and A-3). The results from these analyses indicate that As, Sb and Se are slightly to significantly enriched in these samples, with GAI values ranging from 1 to 3.

The sulphate concentrations in the water extracts from these samples range from 34 to 1,041 milligrams per litre (mg/L), with an average of 326 mg/L, and for chloride, range from 7 to 61 mg/L, with an average of 21 mg/L. These results indicate that sulphate salts are the primary salts contributing to the relatively low salinity in these materials. In comparison to the Australian and New Zealand Environment Conservation Council (ANZECC) (2000) trigger values for aquatic ecosystems and the author's experience, As, Mo and Se were found to be readily soluble under the test pH conditions. The dissolved concentration of these elements is compared to ANZECC (2000) irrigation water quality guidelines in Table 6 in order to provide an indication of the concentration of these elements that are acceptable for short and long-term exposure.

Table 6: Concentration ranges and ANZECC (2000) irrigation water quality guideline values for readily soluble elements in selected roof and floor rock samples.

Element	Units	Concentration Range	Irrigation Water Quality Guideline (ANZECC, 2000)	
			Short-Term Exposure (up to 20 years)	Long-Term Exposure (up to 100 years)
As	µg/L	3.7 - 1120.2	2000	100
Mo	µg/L	2.1 - 216.4	50	10
Se	µg/L	66.8 - 313.8	50	10

µg/L = micrograms per litre.

The implications of the above on water quality is considered in the Project Surface Water and Groundwater Assessments.

6.0 Coal and Coal Reject Geochemistry

The geochemical characteristics assessed for the coal and coal reject samples includes the pH and salinity, the acid forming characteristics, and the element enrichment and solubility. The $pH_{1:2}$ and $EC_{1:2}$, and acid forming characteristic results are presented on Table 7.

6.1 pH and Salinity

The 'as received' clean coal and coal reject samples are acidic with $pH_{1:2}$ values for the clean coal ranging from 2.6 to 3.4, and for the rejects less acidic, ranging from 3.6 to 4.7. The $EC_{1:2}$ values for the coal samples range from 0.42 to 1.38 dS/m indicating that the material represented by these samples is likely to be slightly saline, whereas the $EC_{1:2}$ values for the reject samples range from 1.80 to 3.83 dS/m indicating that this material ranges from moderately to highly-saline.

6.2 Acid Forming Characteristics

Figure 8 is the ABA plot for the coal seam and reject samples from the different seams using the total S (solid markers) and the sulphide S (hollow markers). Figure 9 is the geochemical classification plot for the coal seam and reject samples. Review of these figures indicates that:

- All coal seam samples were classified as NAF.
- The Milbrodale Claystone Sample (MCS) was classified as NAF.
- One reject sample was classified as NAF.
- Five reject samples were classified as PAF, of which 3 were PAF-LC.

The 5 reject samples were classified as PAF because they have positive NAPP values when calculated using both the total S and sulphide S contents, and have NAGpH values less than 4.5.

Three of the PAF reject samples were classified as PAF-LC because they have a NAPP value less than 5 kg H_2SO_4/t.

Table 7: Acid forming characteristics of the coal and reject samples.

Sample ID	$pH_{1:2}$	$EC_{1:2}$	ACID-BASE ANALYSIS							NAG TEST (Standard)			NAG TEST (Extended Boil)			Geochem. Class.
			Total %S	Sulphide %S	MPA	ANC	NAPP (total S)	NAPP (sulphide S)	ANC/ MPA	NAGpH	$NAG_{pH4.5}$	$NAG_{pH7.0}$	NAGpH	$NAG_{pH4.5}$	$NAG_{pH7.0}$	
CLEAN COAL																
WN-CC	3.4	0.61	0.41	0.02	13	2	11	-1	0.2	2.1	154	235	7.1	0	0	NAF
WH1-CC	3.4	0.42	0.40	0.02	12	4	8	-3	0.3	2.1	139	208				NAF
WH2-CC	3.4	0.44	0.41	0.03	13	3	10	-2	0.2	2.1	150	231				NAF
AF-CC	3.3	0.50	0.33	0.04	10	1	9	0	0.1	2.2	75	114	7.1	0	0	NAF
BF1-CC	3.2	0.50	0.32	0.04	10	3	7	-2	0.3	2.1	120	184	6.9	0	0	NAF
BF2-CC	2.6	1.38	0.56	0.04	17	0	17	1	0.0	2.2	52	80	5.7	0	3	NAF
REJECTS																
WN-R	3.8	3.63	0.47	0.25	14	8	6	0	0.6	3.8	4	29				PAF-LC
WH1-R	4.7	3.06	0.56	0.35	17	11	6	0	0.6	4.5	0	15	4.5	0	4	NAF
WH2-R	4.4	1.80	0.72	0.44	22	9	13	5	0.4	4.4	0	20	4.4	0	1	PAF-LC
AF-R	3.6	3..83	0.72	0.41	22	1	21	12	0.0	2.9	9	24				PAF
BF1-R	3.8	2.40	0.86	0.47	26	1	25	13	0.0	2.9	9	25	3.2	7	10	PAF
BF2-R	4.1	1.91	0.25	0.07	8	1	7	1	0.1	3.9	1	12				PAF-LC
MCS	I/S	I/S	0.07	-	2	9	-7	-	4.2	7.4	0	0				NAF

KEY

$pH_{1:2}$ = pH of 1:2 extract

$EC_{1:2}$ = Electrical Conductivity of 1:2 extract (dS/m)

MPA = Maximum Potential Acidity (kg H_2SO_4/t)

ANC = Acid Neutralising Capacity (kg H_2SO_4/t)

NAPP = Net Acid Producing Potential (kg H_2SO_4/t)

NAGpH = pH of NAG liquor

$NAG_{pH4.5}$ = Net Acid Generation capacity to pH 4.5 (kg H_2SO_4/t)

$NAG_{pH7.0}$ = Net Acid Generation capacity to pH 7.0 (kg H_2SO_4/t)

ARD Classification Key

NAF = Non-Acid Forming

PAF = Potentially Acid Forming

PAF-LC = PAF Low Capacity

UC = Uncertain (expected classification)

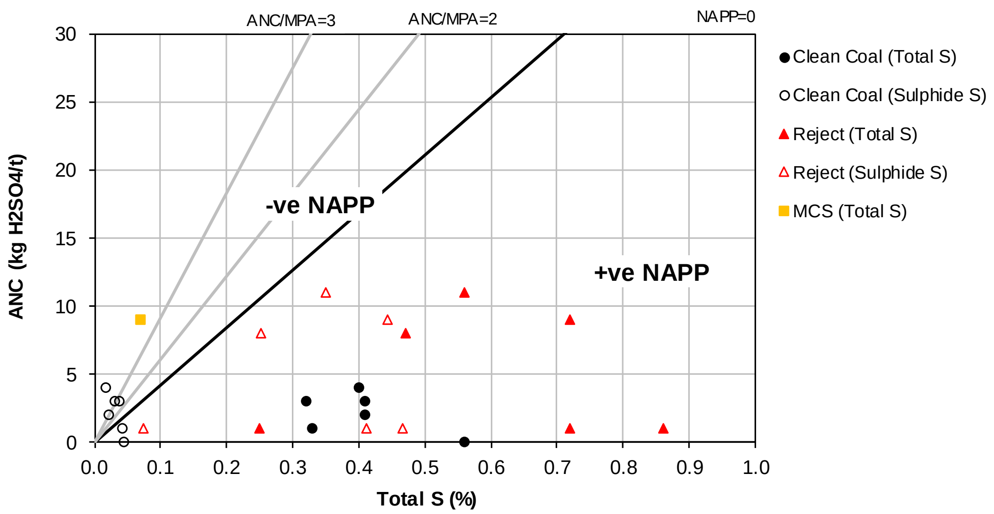

Figure 8: Acid-base account plot for the clean coal and coal reject samples.

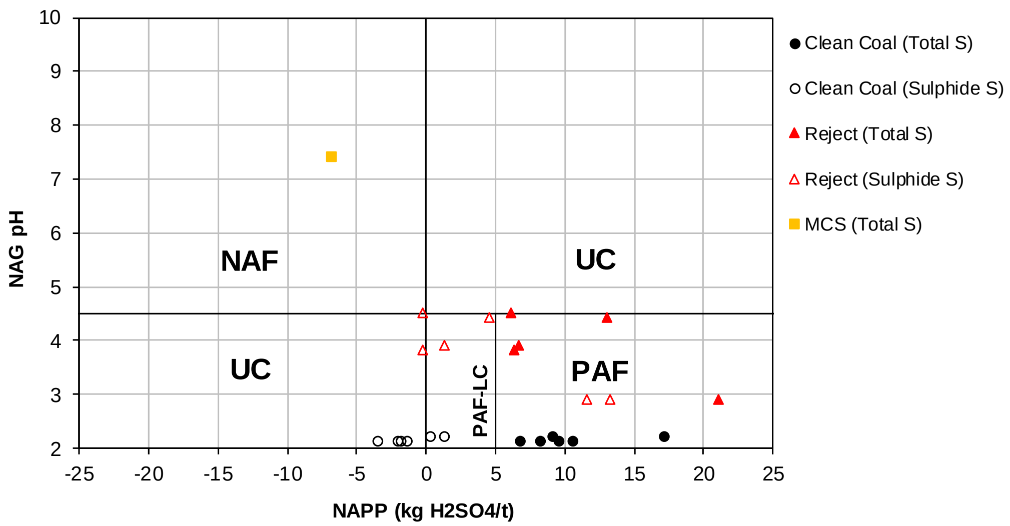

Figure 9: Geochemical classification plot for the clean coal and coal reject samples.

6.3 Metal Enrichment and Solubility

Multi-element scans were performed on the solids and water extracts (1 part sample/ 2 parts deionised water) of a composite sample of the clean coal and a composite of the coal rejects. The results from these analyses including the GAI are provided in Attachment A (Tables A-1, A-2 and A-3). These results indicate that Se is significantly enriched in the coal and reject composites, with GAI values of 3 and 4, respectively, and slightly enriched in Sb. Additional to these, As is slightly enriched in the reject composite.

The results of the water extracts from these samples indicate that the greater salinity of the reject samples is due primarily to the presence of chloride salts. Additionally, based on the ANZECC (2000) trigger values for aquatic ecosystems, Se was found to be readily soluble under the prevailing low pH conditions. As a guide to the relative dissolved concentrations, the concentration of Se in the coal and reject samples are compared to ANZECC irrigation water quality guidelines (ANZECC, 2000) in Table 8.

Table 8: Concentrations and ANZECC (2000) irrigation water quality guideline values for readily soluble Se in composited coal and reject samples.

Element	**Concentration (μg/L)**		**Irrigation Water Quality Guideline (ANZECC, 2000)**	
	Coal Comp.	**Reject Comp.**	**Short-Term Exposure** (up to 20 years)	**Long-Term Exposure** (up to 100 years)
Se	16.1	73.5	50	10

The implications of the above on water quality is considered in the Project Surface Water and Groundwater Assessments.

7.0 Conclusions and Recommendations

7.1 Mine Establishment Rock

Based on a review of the detailed geochemical characterisation of the overburden and interburden from the surrounding open cut and underground mining operations, it is expected that the rock excavated during establishment of the Project underground operations would be NAF (Non-Acid Forming) with low salinity. However, these materials have a risk of being sodic. As is typical for the stratigraphy of the Wittingham Coal Measures in this region, the establishment rock is expected to be enriched with As, Sb and Se and the contained As and Se is likely to be readily soluble.

Recommendations

The following recommendations are provided for the establishment rock:

- Based on these findings the establishment rock will not require any specific handling for disposal. However, due to the risk of this material being sodic, it is recommended that allowance is made to treat these materials (e.g. gypsum) to negate the sodicity, as required. No untreated sodic materials should be used for construction or site earthworks.
- It is recommended that As, Sb and Se are included in the site water quality monitoring program.

7.2 Coal Rejects

The coal rejects produced at the Maxwell Infrastructure CHPP and to be disposed within the existing voids, are expected to be moderately to highly saline and have an acidic pH, most likely due to the presence of organic acids. The rejects are also expected to have moderate S, the majority of which is likely to occur as reactive sulphide, and low ANC. Based on these characteristics it is expected the rejects will typically be PAF with only a low capacity to generate acid (i.e. PAF-LC).

The rejects are expected to be enriched with As, Sb and Se in varying degrees and the contained Se is likely to be readily soluble.

Recommendations

Based on these findings, the following recommendations are provided for the coal rejects:

- As part of the ongoing process for managing CHPP rejects emplacements, geochemical characterisation should be undertaken to maintain an understanding of the materials classification.

- The recommended geochemical characterisation of the CHPP rejects should include kinetic NAG testing to determine the geochemical lag period (period of exposure to atmospheric oxidation before acid conditions are developed) of this material. Surface alkali treatment to extend the geochemical lag period of the rejects or over-dumping with rejects within the geochemical lag period may be required so that acid conditions do not develop during active dumping.
- Due to the expected presence of moderate salinity, PAF-LC material, the closure plan for the in-pit reject emplacement where applicable should be designed to prevent the reactive rejects from oxidising and the salts from migrating to the revegetation layer.
- It is recommended that the water quality monitoring program for the reject emplacement facilities includes pH, EC, alkalinity/acidity, sulphate (SO_4), As, Sb and Se. This program is designed to identify the ongoing processes of sulphide oxidation, and acid generation and neutralisation resulting from the exposure of PAF-LC materials prior to acid conditions developing.

7.3 Coal Stockpile

The cleaned coal will be stockpiled on-site prior to train load-out. It is expected to have a relatively acidic pH, most likely due to the presence of organic acids, low salinity, and is expected to be NAF. The clean coal is also expected to be enriched relative to the average crustal abundance with Sb and Se, while Se was found to be readily soluble.

Recommendations

Based on these findings the coal is expected to be NAF and selective handling of this material will not be required.

7.4 Underground Mine Workings

The Project involves underground mining of the Wittingham Coal Measures, including the Whynot, Woodlands Hill, Arrowfield and Bowfield Seams, exposing the roof and floor strata of these seams to atmospheric conditions (i.e. oxygen and water). This assessment indicates that the roof and floor rock is typically alkaline and NAF with low salinity. However, higher S material that is likely to be PAF-LC was identified in the roof and floor rock of the Woodlands Hill Seam. These results also indicate that As, Sb and Se are expected to be enriched and that As, Mo and Se are expected to be readily soluble in these strata.

Recommendations

Due the alkaline pH and low to moderate ANC of these materials, it is expected that the overall water quality from the underground workings will not be impacted by the identified PAF-LC strata. However, in order to monitor any potential impacts on water quality due to the presence of any PAF or PAF-LC strata, it is recommended that the water quality is monitored at key locations (i.e. the dam used to store water that accumulates in the underground workings). It is also recommended that the water quality monitoring includes pH, EC, alkalinity/acidity, SO_4, As, Mo, Sb and Se.

The alkalinity/acidity and SO_4 concentrations are included in this program in order to identify any potential sulphide oxidation and acid generation reactions occurring within the exposed strata.

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Attachment A

Multi-Element Analysis Results

Table A-1: Multi-element composition of selected roof and floor rock, and composited coal and reject samples from the Maxwell Project.

Element	Unit	Detect. Limit	Element Concentration									
			Coal Seam Roof and Floor Rock								Coal Comp.	Reject Comp.
			178730	178731	178733	178734	178737	178739	178740	178741		
Ag	mg/kg	0.05	0.12	0.12	0.11	0.12	0.1	0.09	0.09	0.11	0.03	0.11
Al	%	0.005%	9.207%	9.784%	9.641%	7.777%	10.147%	9.281%	9.931%	10.579%	1.103%	7.016%
As	mg/kg	0.5	10.2	17.3	19.1	7.0	15.2	9.6	20.3	2.2	<	6.0
B	mg/kg	50	<	<	<	<	<	<	<	<	<	<
Ba	mg/kg	0.1	438.1	377.8	301.5	342.2	424.7	296.2	342.5	364.4	45.8	354.8
Be	mg/kg	0.05	1.30	1.59	1.56	1.79	1.63	1.61	1.36	1.86	1.05	1.25
Ca	%	0.005%	0.234%	0.150%	0.276%	0.155%	0.080%	0.149%	0.198%	0.057%	0.055%	0.267%
Cd	mg/kg	0.02	0.14	0.20	0.13	0.11	0.17	0.16	0.12	0.13	0.08	0.15
Co	mg/kg	0.1	8.2	16.0	8.7	9.2	14.9	11.0	9.4	1.4	4.1	6.7
Cr	mg/kg	5	49	141	53	35	51	54	64	57	6	39
Cu	mg/kg	1	25	37	16	18	14	24	17	18	13	25
Fe	%	0.01%	2.66%	1.30%	1.55%	1.80%	0.94%	2.19%	1.68%	0.74%	0.19%	5.95%
Hg	mg/kg	0.2	<	<	<	<	<	<	<	<	<	<
K	%	0.002%	2.540%	2.187%	1.818%	2.264%	2.484%	1.988%	2.043%	2.349%	0.070%	1.144%
Mg	%	0.002%	0.890%	0.629%	0.643%	0.544%	0.308%	0.462%	0.402%	0.321%	0.026%	0.395%
Mn	mg/kg	1	289	102	200	112	75	261	236	53	14	605
Mo	mg/kg	0.1	0.6	1.6	0.8	1.0	1.5	0.9	1.1	1.4	1.0	2.2
Na	%	0.002%	0.686%	0.602%	0.811%	0.679%	0.725%	0.129%	0.728%	0.258%	0.009%	0.077%
Ni	mg/kg	1	27	72	24	18	27	22	26	12	4	22
P	mg/kg	50	558	373	514	275	126	540	582	97	247	665
Pb	mg/kg	0.5	17.0	20.1	17.3	18.7	18.0	17.1	16.6	18.0	6.0	23.8
Sb	mg/kg	0.05	0.85	0.73	0.57	1.06	0.98	1.10	0.88	0.80	0.65	0.58
Se	mg/kg	0.01	0.14	0.32	0.15	0.10	0.43	0.13	0.70	0.11	0.63	0.92
Si	%	0.001	0.28	0.29	0.28	0.26	0.31	0.28	0.30	0.30	0.02	0.19
Sn	mg/kg	0.1	2.6	3.6	2.7	3.0	2.9	2.5	2.5	3.0	0.8	3.0
Th	mg/kg	0.01	10.53	12.82	9.43	12.07	11.33	11.43	10.01	12.04	2.20	9.05
U	mg/kg	0.01	3.25	4.26	2.51	3.47	3.16	3.33	4.39	2.97	0.82	2.45
V	mg/kg	1	129	131	121	115	90	128	114	94	18	54
Zn	mg/kg	1	99	105	96	72	83	92	88	39	16	57

< element at or below analytical detection limit.

Table A-2: Geochemical abundance indices for selected roof and floor rock, and composited coal and reject samples from the Maxwell Project.

Element	Unit	*Mean Crustal Abund.	Geochemical Abundance Indices									
			Coal Seam Roof and Floor Rock								Coal Comp.	Reject Comp.
			178730	178731	178733	178734	178737	178739	178740	178741		
Ag	mg/kg	0.07	-	-	-	-	-	-	-	-	-	-
Al	%	8.2%	-	-	-	-	-	-	-	-	-	-
As	mg/kg	1.5	2	**3**	**3**	2	**3**	2	**3**	-	-	1
B	mg/kg	10	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Ba	mg/kg	500	-	-	-	-	-	-	-	-	-	-
Be	mg/kg	2.6	-	-	-	-	-	-	-	-	-	-
Ca	%	4.0%	-	-	-	-	-	-	-	-	-	-
Cd	mg/kg	0.11	-	-	-	-	-	-	-	-	-	-
Co	mg/kg	20	-	-	-	-	-	-	-	-	-	-
Cr	mg/kg	100	-	-	-	-	-	-	-	-	-	-
Cu	mg/kg	50	-	-	-	-	-	-	-	-	-	-
Fe	%	4.1%	-	-	-	-	-	-	-	-	-	-
Hg	mg/kg	0.2	-	-	-	-	-	-	-	-	-	-
K	%	2.1%	-	-	-	-	-	-	-	-	-	-
Mg	%	2.3%	-	-	-	-	-	-	-	-	-	-
Mn	mg/kg	950	-	-	-	-	-	-	-	-	-	-
Mo	mg/kg	1.5	-	-	-	-	-	-	-	-	-	-
Na	%	2.3%	-	-	-	-	-	-	-	-	-	-
Ni	mg/kg	80	-	-	-	-	-	-	-	-	-	-
P	mg/kg	1000	-	-	-	-	-	-	-	-	-	-
Pb	mg/kg	14	-	-	-	-	-	-	-	-	-	-
Sb	mg/kg	0.2	2	1	1	2	2	2	2	1	1	1
Se	mg/kg	0.05	1	2	1	-	**3**	1	**3**	1	**3**	**4**
Si	%	27.7%	-	-	-	-	-	-	-	-	-	-
Sn	mg/kg	2.2	-	-	-	-	-	-	-	-	-	-
Th	mg/kg	12	-	-	-	-	-	-	-	-	-	-
U	mg/kg	2.4	-	-	-	-	-	-	-	-	-	-
V	mg/kg	160	-	-	-	-	-	-	-	-	-	-
Zn	mg/kg	75	-	-	-	-	-	-	-	-	-	-

*Bowen H.J.M.(1979) Environmental Chemistry of the Elements.

NOTE: The detection limit 50 mg/kg for boron (B) is greater than the average crustal abundance (10 mg/kg), therefore a concentration < than the detection limit has a GAI of <2.

Table A-3: Chemical composition of water extracts from selected roof and floor rock, and composited coal and reject samples from the Maxwell Project.

Parameter	Unit	Detection Limit	Chemical Compostion									
			Coal Seam Roof and Floor Rock								Coal Comp.	Reject Comp.
			178730	178731	178733	178734	178737	178739	178740	178741		
pH		0.1	7.8	7.4	8.2	4.8	7.8	4.6	7.3	7.9	2.7	3.2
EC	dS/m	0.001	0.470	0.510	0.925	1.377	0.304	1.206	0.267	0.188	0.622	3.442
SO4	mg/l	0.3	86.1	179.6	288.0	1041.3	124.6	757.3	98.1	34.1	187.7	826.4
Cl	mg/l	2.0	61	47	13	7	7	10	12	8	135	1640
Major Constituents												
Al	mg/l	0.01	0.25	0.03	2.46	0.16	1.13	0.68	4.74	1.56	1.58	1.39
B	mg/l	0.01	0.05	0.03	0.1	0.19	0.03	0.19	0.03	0.06	0.11	0.14
Ca	mg/l	0.01	3.95	10.51	1.12	30.77	0.78	28.25	0.94	0.19	23.25	219.61
Cr	mg/l	0.01	<	<	<	<	<	<	0.01	<	<	<
Cu	mg/l	0.01	<	<	<	<	<	0.05	<	<	0.12	0.03
Fe	mg/l	0.01	0.09	<	0.30	5.34	0.10	20.05	0.54	0.11	43.66	30.10
K	mg/l	0.1	10.0	14.9	4.2	15.7	4.1	20.6	5.7	2.1	4.1	19.3
Mg	mg/l	0.01	6.42	17.79	1.11	29.29	1.45	61.18	2.31	0.49	26.41	314.37
Mn	mg/l	0.01	0.0	0.0	<	0.4	<	0.8	<	<	0.5	7.8
Na	mg/l	0.1	79.9	79.0	210.6	399.7	70.8	176.2	70.4	47.6	23.6	125.6
Ni	mg/l	0.01	<	<	<	0.17	<	0.65	<	<	0.11	0.40
P	mg/l	0.1	<	<	<	<	<	<	<	<	<	<
Si	mg/l	0.05	5.74	4.55	10.58	9.30	6.59	11.70	12.37	7.55	1.58	4.38
V	mg/l	0.01	<	0.03	0.03	<	<	<	0.02	<	<	<
Zn	mg/l	0.01	<	<	<	0.7	<	1.66	<	0.01	0.59	0.73
Minor Constituents												
Ag	ug/l	0.01	<	0.04	<	0.04	0.06	0.02	<	<	0.04	0.07
As	ug/l	0.1	68.4	95.6	379.1	7.7	54.4	3.7	1120.2	68.4	5.7	2.2
Ba	ug/l	0.05	11.72	26.68	8.20	62.51	4.17	59.15	10.67	3.57	73.26	112.08
Be	ug/l	0.1	0.2	<	<	1.2	<	4.3	0.1	<	6.8	8.1
Cd	ug/l	0.50	<	<	<	1.80	<	3.20	<	<	2.70	5.00
Co	ug/l	0.1	4.7	4.3	2.4	154.1	3.2	442.5	7.9	3.0	103.3	257.2
Hg	ug/l	0.1	<	<	<	<	<	<	<	<	<	<
Mo	ug/l	0.05	50.34	213.14	136.67	2.12	216.36	2.62	124.21	25.82	1.57	1.42
Pb	ug/l	2.0	<	<	<	<	<	6.0	<	<	11.0	11.0
Sb	ug/l	0.01	2.57	5.07	2.63	0.12	5.52	0.13	13.59	1.62	0.19	0.14
Se	ug/l	0.5	97.4	209.6	84.5	71.2	148.9	108.1	313.8	66.8	16.1	73.5
Sn	ug/l	0.1	0.3	0.4	0.7	0.4	0.3	0.3	0.4	0.2	0.3	1.1
Th	ug/l	0.005	0.020	<	0.275	0.005	0.094	0.007	0.535	0.294	0.100	0.034
U	ug/l	0.005	0.198	0.380	0.833	0.341	0.108	0.926	1.067	0.169	3.812	0.634

< element at or below analytical detection limit.