VICKERY EXTENSION PROJECT
ENVIRONMENTAL IMPACT STATEMENT

APPENDIX M
GEOCHEMISTRY ASSESSMENT

WHITEHAVEN COAL

VICKERY EXTENSION PROJECT

GEOCHEMISTRY ASSESSMENT OF OVERBURDEN, INTERBURDEN AND COAL REJECTS

April 2018

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1.0 Introduction

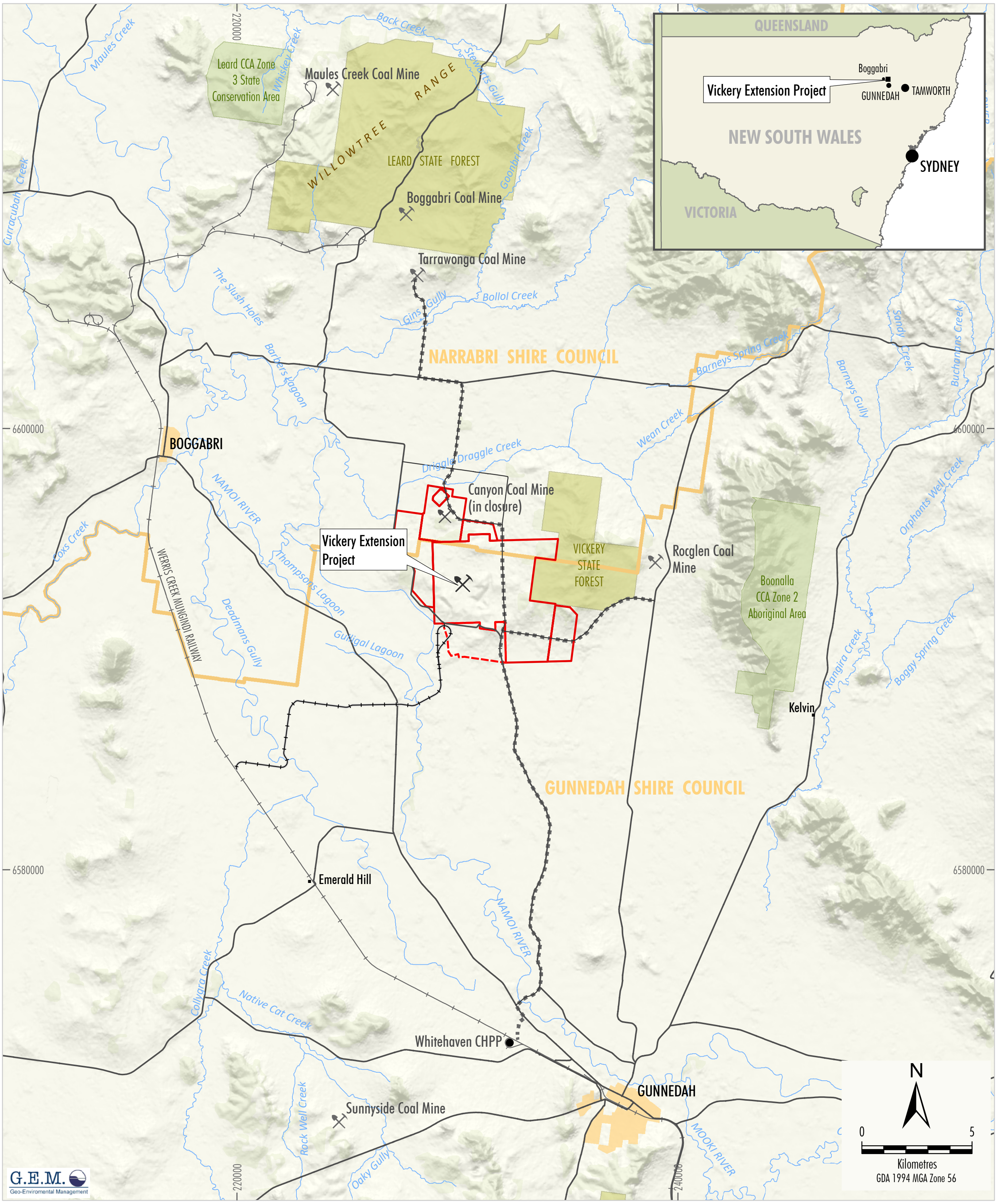
The former Vickery Coal Mine and the former Canyon Coal Mine are located approximately 25 kilometres (km) north of Gunnedah, in New South Wales (NSW) (Figure 1). Open cut and underground mining activities were conducted at the former Vickery Coal Mine between 1986 and 1998. Open cut mining activities at the former Canyon Coal Mine ceased in 2009. The former Vickery and Canyon Coal Mines have been rehabilitated following closure.

The approved Vickery Coal Project (herein referred to as the Approved Mine) is an approved, but yet to be constructed, project involving the development of an open cut coal mine and associated infrastructure, and would facilitate a run-of-mine (ROM) coal production rate of up to approximately 4.5 million tonnes per annum (Mtpa) for a period of 30 years.

Whitehaven Coal Limited (Whitehaven) is seeking a new Development Consent for extension of open cut mining operations at the Approved Mine (herein referred to as the Vickery Extension Project [the Project]). This would include a physical extension to the Approved Mine footprint to gain access to additional ROM coal reserves, an increase in the footprint of the waste rock emplacement, an increase in the approved ROM coal mining rate and construction and operation of a Project Coal Handling and Preparation Plant (CHPP), train load-out facility and rail spur (Figure 2). This infrastructure would be used for the handling, processing and transport of coal from the Project, as well as other Whitehaven mines.

Geo-Environmental Management Pty Ltd (GEM) was commissioned to conduct the environmental geochemistry assessment of the Project for inclusion as an appendix to an Environmental Impact Statement (EIS). The geochemistry assessment has been prepared cognisant of the Secretary's Environmental Assessment Requirements (SEARs) for the Project (dated 19 February 2016 and revised 19 July 2018) and the Supplementary Assessment Requirements relevant to the *Environment Protection and Biodiversity Conservation Act 1999* including the *Information Guidelines for Independent Expert Scientific Committee advice on coal seam gas and large coal mining development proposals* (Independent Expert Scientific Committee, 2015).

This report presents the results and findings of the geochemical assessment, identifies the geochemical implications for the Project, and provides any recommendations for environmental management and any future geochemical testing requirements for the Project.



LEGEND

- Mining Tenement Boundary (ML & CL)
- Mining Lease Application (MLA)
- Local Government Boundary
- State Forest
- State Conservation Area, Aboriginal Area
- Major Roads
- Railway
- Approved Road Transport Route
- Indicative Project Rail Spur

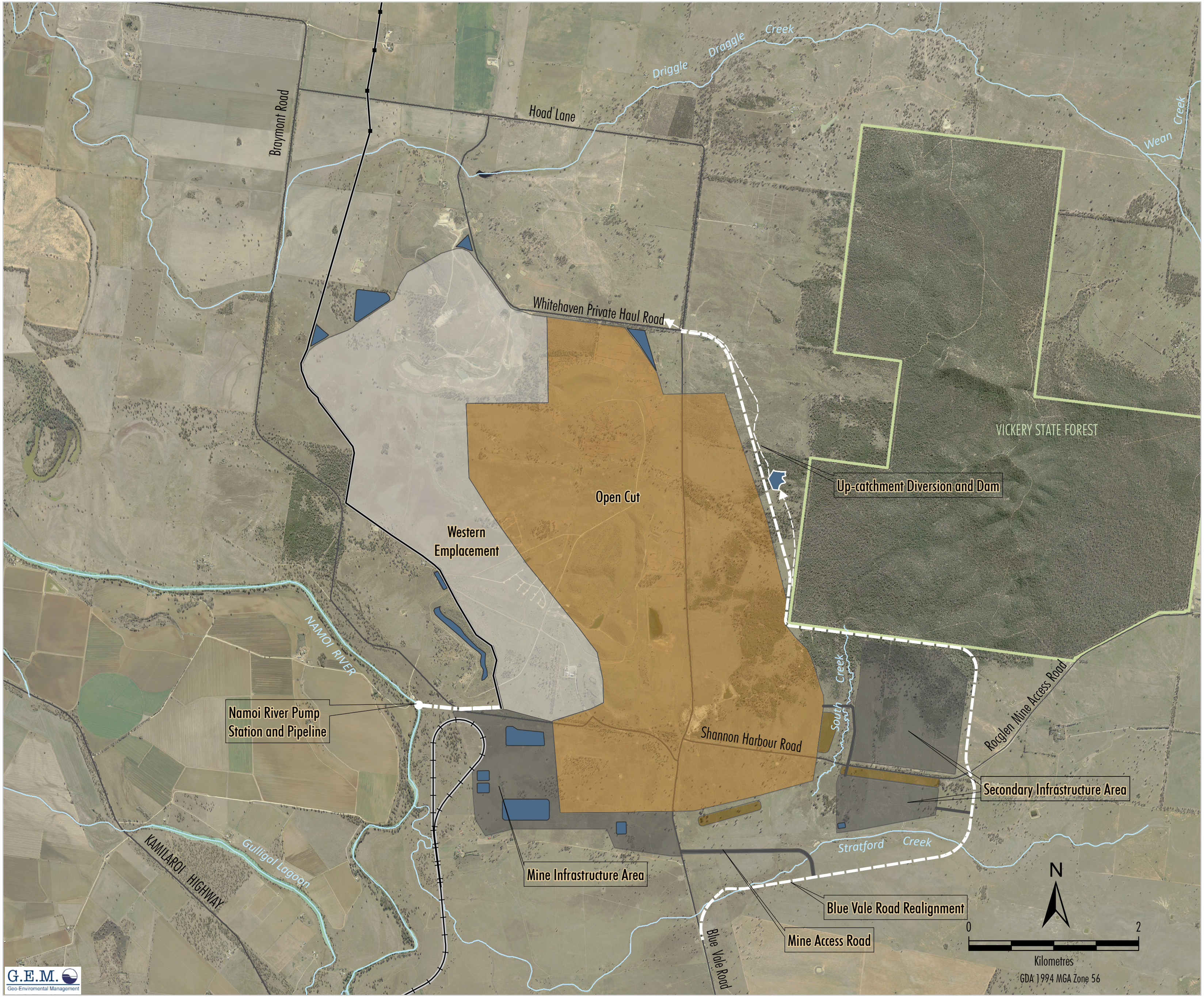
Source: LPMA - Topographic Base (2010); NSW Department of Industry (2015)

WHITEHAVEN COAL

VICKERY EXTENSION PROJECT

Project Location

Figure 1



LEGEND

State Forest

Project Components

- Indicative Extent of Open Cut
- Indicative Extent of Out of Pit Waste Rock Emplacement
- Indicative Extent of Infrastructure Area
- Indicative Extent of Soil Stockpile
- Indicative Extent of Water Storage
- Indicative Mine Access Road Alignment
- Indicative Namoi River Pump Station and Pipeline
- Indicative Road Realignment
- Indicative Up-catchment Diversion and Dam Location
- Indicative Rail Spur Alignment
- Indicative Location of Groundwater Bores and Pipeline

Source: Orthophoto - Department of Land and Property Information, Aerial Photography (July 2011); Department of Industry (2015); Essential Energy (2015)

WHITEHAVEN COAL

VICKERY EXTENSION PROJECT

Project General Arrangement - Project Mining Area

Figure 2

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1.1 Project Description

The Project involves mining the coal reserves associated with the Approved Mine, as well as accessing additional coal reserves within the Project area. ROM coal would be mined by open cut methods at an average rate of 7.2 Mtpa over 25 years, with a peak production of up to approximately 10 Mtpa.

As described in Section 1, the Project would include a physical extension to the Approved Mine footprint to gain access to additional ROM coal reserves, an increase in the footprint of waste rock emplacement area, an increase in the approved ROM coal mining rate and construction and operation of the Project CHPP, train load-out facility and rail spur (Figure 2). This infrastructure will be used for the handling, processing and transport of coal from the Project, as well as other Whitehaven mining operations.

Waste rock, comprising overburden and interburden excavated from the open cut, would be placed in the Western Emplacement and within the footprint of the open cut void. At the completion of open cut mining there would be a residual void in the south-eastern corner of the open cut.

The Project CHPP would produce coal rejects, produced through mechanical dewatering. Following commencement of coal processing at the Project, dewatered coal rejects would be co-disposed with waste rock.

A detailed description of the Project is provided in Section 2 in the Main Report of the EIS.

1.2 Study Objectives

The objectives of this study were to:

1. Review the relevant available information for the Project, including the proposed mine plan, drill-hole locations and logs, and from the Approved Mine, including sampled drill-hole locations, local geology/stratigraphy and geochemical test work results in order to identify any of the previous test results that could be used for the proposed assessment, and determine if additional drill-holes are required.
2. Select the additional drill-holes (if required) and the required intervals to be sampled for inclusion in the geochemical testing program. The intervals would be selected to provide representative samples of the major overburden and interburden rock types, and the ROM coal that will potentially be stockpiled on-site.

3. Select the required test work parameters and preferred analytical laboratories to be utilised to assess the salinity, sodicity, acid forming potential, and element enrichment and solubility of the selected waste rock and coal seam samples.

4. Manage the testing program identified in Item 3 of samples collected and prepared by Whitehaven's on-site personnel.

5. Receive and interpret the test work results.

6. Prepare a geochemistry assessment report which describes in detail the sampling and test work programs and documents, the results from the Approved Mine's assessment used to strengthen the current assessment (Items 1 to 6 above) and provides a discussion and evaluation of all of the available test results in regard to salinity, sodicity, acid forming potential, and metal enrichment and solubility of the overburden and interburden from the open cut and ROM coal that may be temporarily stockpiled on-site.

2.0 Previous Investigations

A geochemical assessment of the overburden and interburden, and coal rejects from the Approved Mine was conducted by GEM in 2012 (GEM, 2012). The findings from this assessment are summarised below.

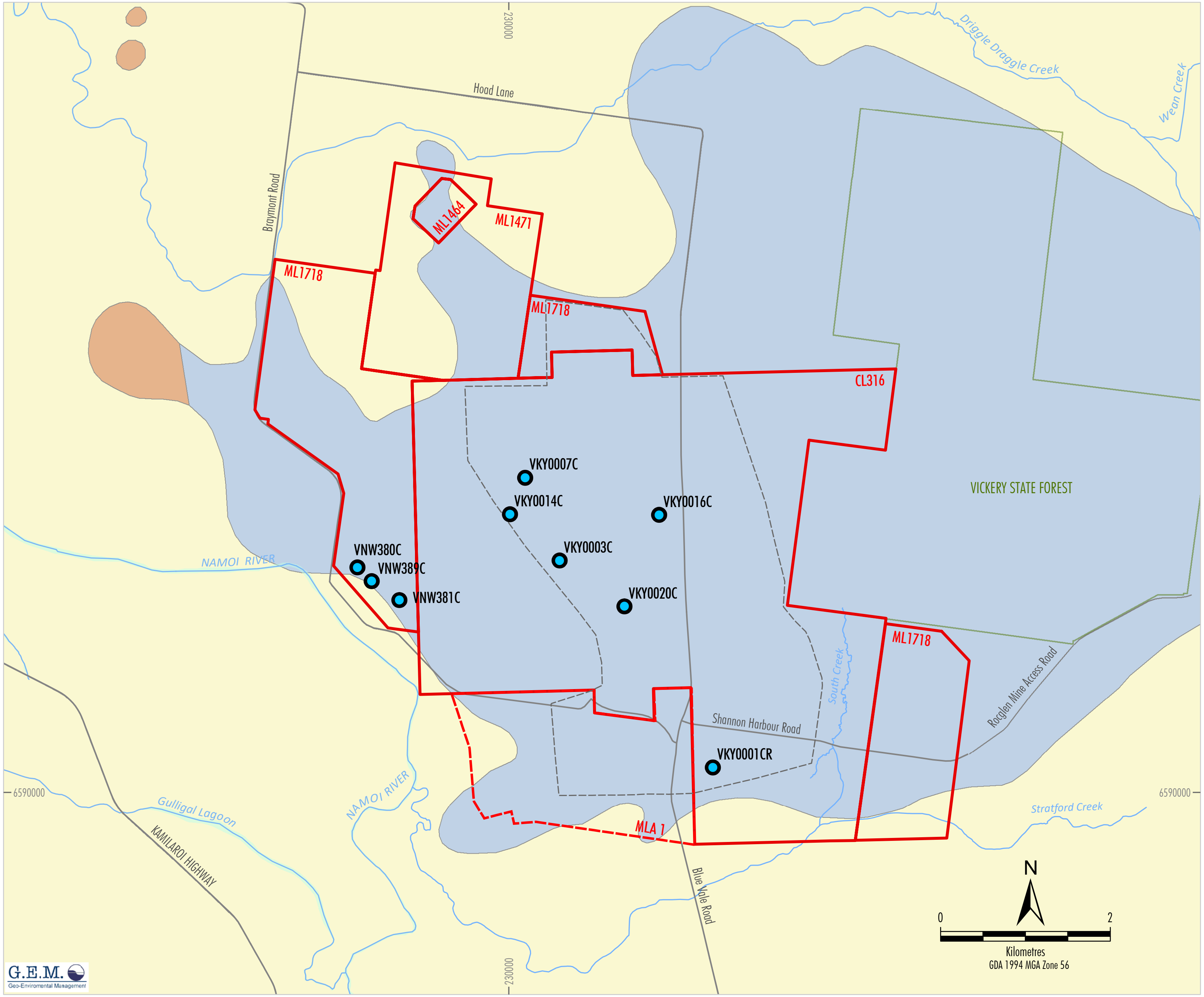
2.1 Overburden and Interburden

Detailed geochemical characterisation testing was conducted on 107 overburden and interburden samples from six drill-holes distributed across the Project mining area shown on Figure 3. The characterisation test work included pH, electrical conductivity (EC), acid base accounting, net acid generation tests, a sodicity assessment, and element enrichment and solubility analysis. It was concluded that the overburden and interburden generated from the approved open cut would generally be expected to have a low sulfur (S) content and be non-acid forming (NAF). A small quantity of overburden, typically identified as non-continuous units adjacent to some coal seams, was identified as containing increased S concentrations with a low acid generating capacity. It was anticipated that these materials only have the potential to develop acidic conditions if they are left exposed to atmospheric oxidation for a number of years.

A small quantity of interburden material (typically mudstone) was identified containing increased S concentrations, with a relatively high acid generating capacity. It was anticipated that this material has the potential to generate acidic conditions within a relatively short period of exposure to atmospheric oxidation (i.e. within weeks).

The normal operating regime in a multi-seam coal mine involving blasting excavation, transport, dumping, dozing and shaping utilising dump trucks, excavators and dozers would ensure thorough mixing of the overburden and interburden materials and dilution of potentially acid forming (PAF) materials thus ensuring negligible risk of exposure of deleterious materials.

The test results indicated that the overburden and interburden materials would typically be alkaline and non-saline, and that Aluminium (Al), Arsenic (As), Molybdenum (Mo) and Selenium (Se) would be soluble to some extent under quasi-neutral to moderately alkaline pH conditions (i.e. pH >6).



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Geochemistry Drill-hole Sample Locations

Figure 3

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A sub-set of samples was selected for exchangeable cation analysis and determination of Exchangeable Sodium Percent (ESP) in order to assess the potential sodicity risk (i.e. risk of being dispersive). The sodicity test results indicated that the majority of the overburden and interburden material is expected to be non-sodic or slightly sodic, with a relatively small amount of material predicted to be moderately to highly sodic. If these moderately to highly sodic materials were left exposed on the waste rock emplacement surfaces or final pit walls they may become dispersive over time (GEM, 2012).

As indicated above the risk of exposure would be negligible.

2.2 Coal Rejects

The geochemical characteristics of coarse and fine rejects currently generated by the Whitehaven CHPP were assessed in 2012 by GEM and concluded:

- The coarse rejects are expected to be non-saline and NAF, with a relatively low to moderate total S content.
- The fine rejects are expected to be slightly to moderately saline and NAF, with a low to moderate total S content.

Based on the results of the geochemical characterisation of coal seams from the Project mining area, it is expected that the ROM coal from the Project would have a moderate S content and there is potential for some coal rejects to be PAF, albeit a small proportion when compared to the NAF overburden and interburden volumes. For this reason coal rejects placement is managed to ensure that no concentrated areas of PAF material occur within the Western Emplacement.

Element enrichment and solubility analysis undertaken on coal rejects (e.g. coarse rejects, fine rejects and coal seams) indicated that As, Mo and Se are soluble to some extent under the expected quasi-neutral to moderately alkaline pH conditions (i.e. pH >6), (GEM, 2012).

3.0 Deposit Stratigraphy

The Project coal deposits occur within the Early Permian Maules Creek sub-basin.

The Boggabri Volcanics, consisting of dacite, rhyolite, basalt and pyroclastic rocks (acid volcanics), form the basement of the sub-basin and are unconformably overlain by the sub-basin sediments of the Maules Creek Formation. The Maules Creek Formation is the primary coal bearing unit and consists of interbedded coal, conglomerate, sandstone, siltstone and mudstones. The basement Boggabri Volcanics within the Project mining area consists of acid volcanics (dacite, rhyolite).

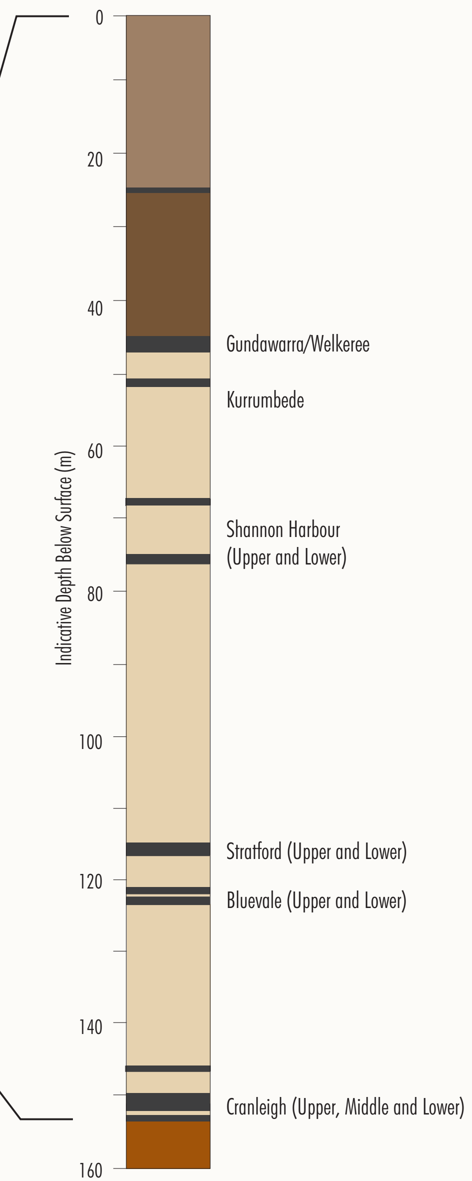
Sedimentation during the development of the Maules Creek Formation was influenced by the topography of the underlying Boggabri Volcanics, with some of the lower coal seams onlapping a structural feature known as the Boggabri Ridge. The Karu and Woodlands Faults generally form the eastern extent of the proposed open cut, while the Womboola Fault generally defines the western extent. The average depth of weathering across the site is approximately 24 metres (m).

There are seven coal seams of economic interest within the Project mining area. The seams generally dip to the east and range in thickness from approximately 0.5 m to greater than 3 m. The Cranleigh Seam marks the base of the targeted open-cut mining and ranges in depth from 100 to 250 m. The seam names and codes are provided on Table 1 and Figure 4 is a stratigraphic section of the coal measures showing the average depth and thickness of each seam.

Table 1: Economic coal seams of the Maules Creek Formation.

Seam Name		Seam Code
Tralee		
Gundawarra/Welkerree		
Kurrumbede		KUR
Shannon Harbour	Upper	SHU
	Lower	SHL
Stratford	Upper	STU
	Lower	STL
Bluevale	Upper	BLU
	Mid	BLM
	Lower	BLL
Cranleigh		CNW

BASIN	PERIOD		GROUP/FORMATION	
GUNNEDAH	TRIASSIC	MIDDLE	Napperby Formation	
		EARLY	Digby Formation	
	PERMIAN	LATE	Black Jack Group	
		EARLY	Millie Group	
			Bellata Group	Maules Creek Formation
				Goonbri Formation
				Leard Formation
			Boggabri Volcanics	



LEGEND

- Coal Seam
- Weathered Overburden
- Overburden
- Interburden
- Floor Rock

Source: Engenicom (2012) and NSW Industry and Investment (2011)

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VICKERY EXTENSION PROJECT

Indicative Stratigraphy of the Project Area

Figure 4

WHC-15-33_App GeoChem_001B

G.E.M. Geo-Environmental Management

4.0 Geochemical Assessment Program

4.1 Testing Methodology and Program

The laboratory program included the following tests and procedures:

- pH and EC determination;
- total S assay;
- acid neutralising capacity (ANC) determination;
- net acid producing potential (NAPP) calculation;
- single addition net acid generation (NAG) test;
- kinetic NAG test;
- sulfide sulfur (sulfide S) analysis (chromium reducible sulfur);
- acid buffering characteristic curve (ABCC) determination;
- exchangeable cation analysis; and
- multi-element scans on solids and water extracts.

The acid-base analyses (total S assays and ANC determinations), NAG testing, sulfide S analyses, ABCC determinations and exchangeable cation analyses were performed by Australian Laboratory Services Pty Ltd (ALS) in Brisbane, 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.

4.1.1 pH, Salinity and Sodicity Determination

pH and Electrical Conductivity Determination

The pH and EC of a sample is determined by equilibrating a solid sample in deionised water for a minimum of 2 hours. Variations to this test include mixing the solids with water at a ratio of 1:2 or 1:5 by weight (w/w), or as a saturated paste. Typically, a ratio of 1:2 is used for providing an indication of the inherent acidity and salinity of a material when it is initially exposed. The salinity rankings based on EC values from 1:5 extracts ($EC_{1:5}$), 1:2 extracts ($EC_{1:2}$) and saturation extracts (EC_{sat}) are provided below:

$EC_{1:5}$ (dS/m)	$EC_{1:2}$ (dS/m)	EC_{sat} (dS/m)	Salinity
< 0.2	< 0.5	< 2.0	Non-Saline
0.2 to 0.3	0.5 to 1.5	2 to 4.0	Slightly Saline
0.3 to 0.4	1.5 to 2.5	3 to 8.0	Moderately Saline
> 0.4	> 2.5	> 8.0	Highly Saline

(Rhoades *et al*., 1999) dS/m = deci-siemens per metre

Exchangeable Cation Analysis

Exchangeable cation analyses are carried out to determine the sodicity of a sample. Sodicity occurs in materials that have high concentrations of exchangeable Sodium (Na) relative to the other major cations Calcium (Ca) and Magnesium (Mg), causing the material to be highly dispersive. The ESP is used to determine the sodicity of a sample by comparing the amount of exchangeable Na to Ca and Mg concentrations. The ESP is used to rank materials according to sodicity and likely dispersion characteristics as shown below:

ESP	Sodicity	Dispersion
< 6	Non-Sodic	Not Dispersive
6 to 15	Slightly Sodic	Slightly Dispersive
15 to 30	Moderately Sodic	Moderately Dispersive
> 30	Highly Sodic	Highly Dispersive

4.1.2 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 sulfide 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.

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:

$$FeS_2 + 15/4\ O_2 + 7/2\ H_2O \Rightarrow Fe(OH)_3 + 2\ H_2SO_4$$

According to this reaction, the MPA of a sample containing 1 %S as pyrite would be 30.6 kilograms (kg) of sulfuric acid (H_2SO_4) per tonne of material (i.e. kg H_2SO_4/t). Hence the MPA of a sample is calculated from the total S content using the following formula:

$$MPA\ (kg\ H_2SO_4/t) = (Total\ \%S) \times 30.6$$

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

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 same units as the MPA, which is kg H_2SO_4/t.

Determination of the ANC using the Modified Sobek[1] method provides an indication of the total neutralisation capacity of a material. However, in some materials not all mineral phases will be readily available to neutralise sulfide generated acidity. For these material types ABCC can be used to determine the amount of ANC that is available to neutralise any sulfide 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. Careful evaluation of the plot provides an indication of the portion of ANC within a sample that is readily available for acid neutralisation.

The NAPP 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/t 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.

[1] Sobek, A.A., Schuller, W.A., Freeman, J.R., and Smith, R.M., 1978. *Field and Laboratory Methods Applicable to Overburdens and Minesoils*., EPA-600/2-78-054, p.p. 47-50.

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 5 is an acid-base account 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 5 also shows the plotted lines corresponding to ANC/MPA ratios of 2 and 3.

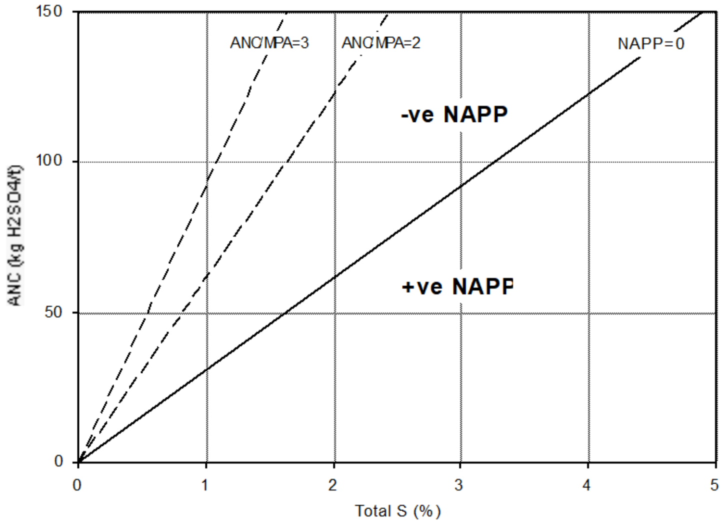

Figure 5: Typical acid-base account plot.

Net Acid Generation Test

The single addition NAG test is used in association with the NAPP to classify the acid generating potential of a sample. The standard (single addition) NAG test involves reaction of a sample with hydrogen peroxide to oxidise any sulfide minerals contained within a sample. During the NAG test, acid generation and neutralisation reactions occur simultaneously and the end result represents a direct measurement of the net amount of acid generated by the oxidised sample. The pH of the NAG solution on completion of the oxidation reaction is referred to as the NAGpH. 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. An indication of the capacity of the sample to generate acid is provided by titrating the NAG solution to the pH end-points of 4.5 and 7.0. This value is commonly referred to as the NAG capacity and is expressed in the same units as the NAPP (i.e. kg H_2SO_4/t). The titration value at pH 4.5 includes the acidity produced due to free acid (*i.e.* H_2SO_4) as well as soluble iron (Fe) and Al. The titration value at pH 7 also includes metallic ions that precipitate as hydroxides.

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

4.1.3 Multi-Element Analysis

Multi-element scans are carried out on the 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. 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 also are 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.

4.2 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.
- NAF.
- PAF.
- Potentially Acid Forming Low Capacity (PAF/LC).
- Acid Consuming (AC).
- 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 ≤ 0.1 %S and an ANC ≤ 10 kg H_2SO_4/t.

Non-Acid Forming
A sample classified as NAF may or may not have a significant S content, but the availability of the ANC within the sample is adequate to neutralise all of the acid that could theoretically be produced by the contained sulfide 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 ≥ 4.5.

Potentially Acid Forming / Potentially Acid Forming Low Capacity
A sample classified as PAF always has a significant S content, the acid generating potential of which exceeds the inherent ANC 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 classified as PAF if it has a positive NAPP and a final NAGpH < 4.5. Typically, if a PAF sample has a NAPP ≤ 5 kg H_2SO_4/t it is considered to only have a low capacity (LC) to generate acid and is classified as PAF/LC.

Acid Consuming
A sample is classified as AC if it has the same characteristics as NAF material, but has sufficient ANC to result in a NAPP of ≤ -100 kg H_2SO_4/t.

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 ≤ 4.5).

Figure 6 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 in the acid-base and NAG test results, and further testing is required to determine the geochemical classification of these material types.

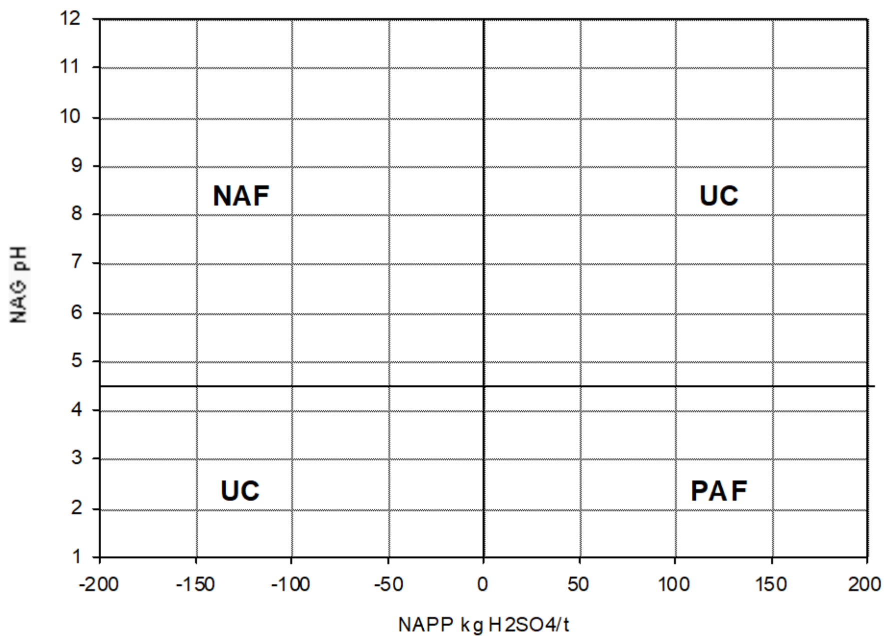

Figure 6: Typical geochemical classification plot.

4.3 Sample Selection and Preparation

Due to the proximity of the drill-holes sampled for the Approved Mine to the extent of the proposed open cut and the relative consistency in stratigraphy and geochemical characteristics throughout the Project mining area, the samples obtained and the test results reported for the Approved Mine geochemistry assessment (GEM, 2012) are expected to be representative of the overburden and interburden and coal rejects from the extent of the proposed open cut. In addition to the drill-holes within the Approved Mine area, three drill-holes approximately 2 km west of the open cut (herein referred to as the 'additional testing area') were selected for sampling in order to obtain additional representative samples of the overburden and interburden, and coal and coal rejects.

The locations for the drill-holes that were sampled for the Approved Mine and the additional testing area (VNW380C, VNW389C and VNW381C), along with the limits for the extent of the proposed open cut, are shown on Figure 3.

The drill-hole samples representing the overburden and interburden from the additional testing area were collected by site personnel under instruction from GEM and the coal seam and floats/sinks samples were obtained from the ALS Coal Division's coal quality and flotation testing. The drill-hole, coal seam and coal rejects sample collection and preparation details are provided in Attachment A (Tables A-1 to A-6) and a summary of the sample type and quantity included in the assessment program is provided in Table 2.

Table 2: Sample type and quantity included in the geochemistry assessment program for the Vickery Extension Project.

Lithology/Material Type	Quantity	Weathering/Seam/Fraction	Quantity
Overburden and Interburden (34 samples)			
Conglomerate	11	Highly Weathered	2
		Moderately Weathered	7
		Fresh	2
Sandstone	7	Highly Weathered	2
		Moderately Weathered	2
		Slightly Weathered	1
		Fresh	2
Sandstone, Siltstone	4	Fresh	4
Siltstone	5	Highly Weathered	2
		Fresh	3
Volcanics	2	Fresh	2
Claystone, Carb. Claystone	1	Moderately Weathered	1
Claystone	1	Fresh	1
Carb. Mudstone	1	Fresh	1
Carb. Mudstone, Claystone	1	Fresh	1
Coal	1	Fresh	1
Coal Seam and Coal Rejects (10 samples)			
Coal Seam	7	Seam 1	2
		Seam 2	2
		Seam 3	2
		Seam 4	1
Floats/Sinks	3	F1.45	1
		S1.45 - F1.6	1
		S1.6	1

4.3.1 Drill-Hole Samples

A total of 34 drill-hole samples representing the overburden and interburden from the additional testing area were collected for the assessment program. Two drill-holes were initially selected (VNW380C and VNW381C) for this program. The drill-holes are typically open-hole drilled through the upper zone due to the friable nature of the weathered material. The open-hole drilling produces rock-chips that are bagged in 1 m intervals. However, the rock-chips from the upper open-holed section of the selected drill-holes were not available for sampling and in order to ensure adequate representation of the weathered overburden materials, the rock-chip materials were collected from a more recent drill-hole (VNW389C). Using these materials, a number of composite samples representing the different lithologies were prepared for inclusion in the testing program.

A total of 26 individual drill-core samples (Tables A-1 and A-2) and 8 composited rock-chip samples (Table A-3) were obtained for inclusion in the geochemical assessment program. These samples were sent to ALS in Brisbane for preparation and analysis, where they were crushed to less than 4 millimetres (mm) and a 200 gram (g) split was pulverised to less than 75 micrometres (µm) prior to testing.

4.3.2 Coal and Coal Reject Samples

Drill-hole samples of the coal seams from the additional testing area were prepared by ALS Coal Division for coal quality testing. The excess coal seam (< 4mm) and flotation test samples produced from drill-holes VNW380C and VNW381C were provided by ALS for inclusion in the geochemical assessment program. The coal seam samples were composited according to the seam for each of these drill-holes (Tables A-4 and A-5), producing a total of 7 composite coal seam samples.

The float/sink fractions produced during the ALS flotation testing include:

- F1.45 (material floats at a density of 1.45), representing the clean coal;
- S1.45-F1.6 (material floats at a specific density of 1.6 and sinks at a specific density of 1.45) representing the coal rejects; and
- S1.6 (material sinks at a specific density of 1.6) representing the coal rejects.

The float/sink samples produced from drill-hole VNW381C were provided by ALS for inclusion in the geochemical assessment program. The samples from each seam/ply were composited according to the fraction for each of these drill-holes (Table A-6), producing a total of 3 composite float/sink samples.

5.0 Overburden and Interburden Geochemistry

The geochemical test results for the overburden and interburden samples from the additional testing area, including the $pH_{(1:2)}$ and $EC_{(1:2)}$, and acid forming characteristics of all of the samples, and sodicity assessment and element enrichment and solubility of selected samples, are provided in Attachment B (Tables B-1 to B-8).

5.1 pH, Salinity and Sodicity

The overburden and interburden samples from the additional testing area are neutral to moderately alkaline with $pH_{1:2}$ values ranging from 6.7 to 8.9 and a median value of 7.8. The $EC_{1:2}$ values range from 0.099 to 1.024 dS/m indicating that the overburden and interburden represented by these samples is expected to range from non-saline to slightly saline with the majority of the samples (82%) being non-saline with $EC_{1:2}$ values less than 0.5 dS/m. and only 6 of the samples (18%) are classified as slightly saline with $EC_{1:2}$ greater 0.5 dS/m. The slightly saline samples predominately comprise the moderately to highly weathered lithologies including the conglomerate and claystone/carbonaceous claystone.

Thirteen of the drill-hole samples were selected for exchangeable cation analysis and determination of the ESP in order to assess the sodicity risk presented by the different overburden and interburden material types. The results from these analyses are provided in Attachment B (Table B-5).

Figure 7 is a plot of the ESP values compared to the $pH_{1:2}$ values showing the sodicity ranking for the different overburden and interburden material types. This plot shows that the selected samples generally range from non-sodic to moderately sodic with ESP values ranging from 2.3 to 16.6 %. The samples with a $pH_{1:2}$ below 7.5 generally have higher sodicity with one sample with a $pH_{1:2}$ below 7.0 having a moderate sodicity ranking. The identified sodic materials, including eight slightly sodic samples and one moderately sodic sample, are not restricted to any particular lithology or degree of weathering. These results are comparable to those from the previous investigations for the Approved Mine where it was found that the majority of the overburden and interburden material is expected to be non-sodic or slightly sodic, with a relatively small amount of material predicted to be moderately to highly sodic.

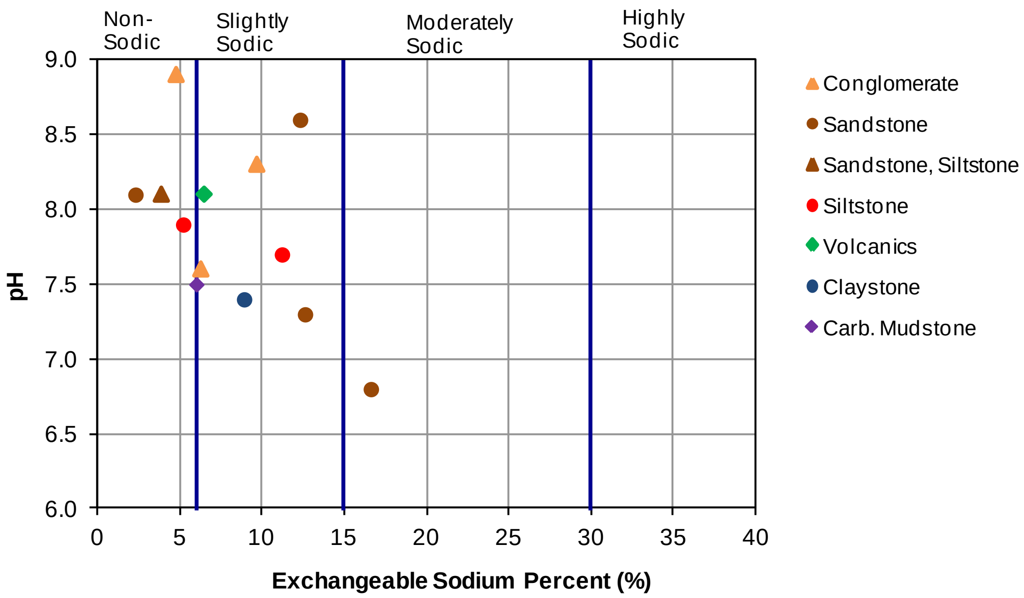

Figure 7: Sodicity ranking compared to pH for selected overburden and interburden drill-hole samples.

5.2 Acid Forming Characteristics

The total S content of the overburden and interburden samples is relatively low ranging from <0.01 to 0.28 %S with an average of only 0.04 %S. The majority of the samples have a low S content with 15 samples (44%) having a total S content of less than 0.1 %S and only 2 samples (6%) having a content of 0.10 %S or greater.

Seven of the overburden and interburden samples had a total S content greater than 0.05 %S and were selected for sulfide S analysis (Tables B-1 and B-2 in Attachment B). The sulfide S content of these samples ranges from <0.005 to 0.066 %S. Although the proportion of the total S that occurs as sulfide S ranges widely from 5 to 94%, these results generally indicate that a relatively high proportion (>50 %) of the contained S in the higher S samples (i.e. total S content > 0.05 %S) occurs in a non-sulfide form (e.g. sulfate [SO_4^{2-}]).

The ANC of the overburden and interburden samples varies widely from 1 to 149 kg H_2SO_4/t with an average of 34 kg H_2SO_4/t. Seventeen of the samples (50 %) have a low ANC (i.e. < 10 kg H_2SO_4/t) and only 3 samples (9 %) have a relatively high ANC (i.e. > 100 kg H_2SO_4/t).

Figure 8 is the ABA plot for the different overburden and interburden material types. Samples that plot above the NAPP = 0 line are NAPP negative, indicating an excess in acid buffering capacity over potential acidity. This plot shows that all but one of the samples are NAPP negative.

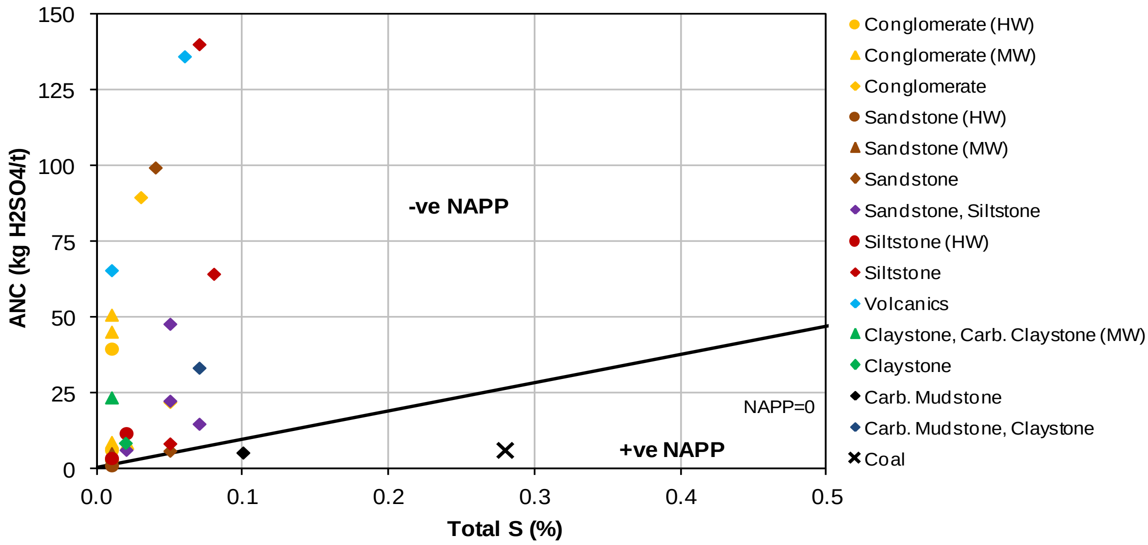

Figure 8: Acid-base account plot for the different overburden and interburden material types (MW = Moderately Weathered, HW =Highly Weathered).

The NAPP positive sample (VCM380/13) is a sample of uneconomic coal with a total S content of 0.28 %S, an ANC of 6 kg H_2SO_4/t and a resulting NAPP of 3 kg H_2SO_4/t. The 3 samples with a relatively high ANC (VCM380/6, VCM380/15 and VCM381/14), comprising sandstone, siltstone and volcanic, have NAPP values ranging from -148 to -134 kg H_2SO_4/t and these samples are classified as acid consuming (AC).

Figure 9 is a geochemical classification plot where the NAPP values are plotted against the NAGpH values for the different overburden and interburden material types. This plot shows that all but two of the samples plot in the upper left quadrate with negative NAPP values and NAGpH values greater than 4.5, and these samples are classified as NAF, with the 3 high ANC samples being classified as AC. The uneconomic coal sample (VCM380/13) is NAPP positive with a NAGpH less than 4.5 and this sample plots in the lower left quadrate, and is therefore expected to be PAF. However, this sample has a sulfide S content of 0.050 %S with a resulting NAPP of -5 kg H_2SO_4/t and the classification of this sample is uncertain (UC). Additional to this, a sample of the carbonaceous mudstone (VCM380/12) collected from immediately above the uneconomic coal sample, is NAPP negative with a NAGpH below 4.5 and although this sample is expected to be NAF, it has an uncertain (UC) classification.

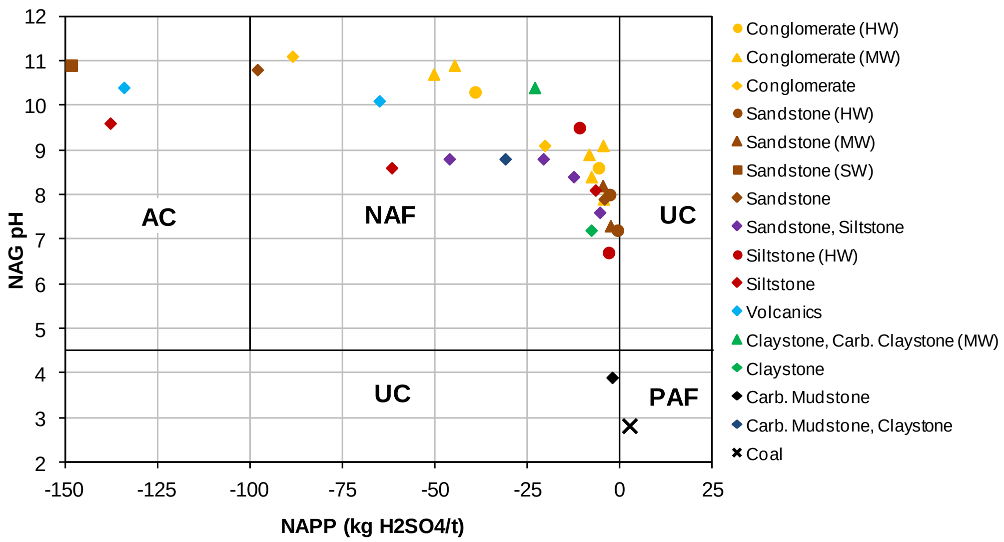

Figure 9: Geochemical classification plot for the different overburden and interburden material types (MW = Moderately Weathered, HW =Highly Weathered).

Five of the overburden and interburden samples with a range in ANC values were selected for ABCC determinations. The plots from these determinations are provided in Attachment C (Figures C-1 to C-5) and indicate that 20% to 100% of the total ANC is expected to be readily available to neutralise sulfide generated acidity in these materials. Generally the high ANC samples have a relatively high proportion of readily available ANC ranging from 50% to 100%, confirming the acid consuming characteristics of the samples classified as AC. Based on the ABCC for the carbonaceous mudstone sample with an UC classification (VCM380/12), this sample has a readily available ANC of 3 kg H_2SO_4/t, and with a resulting NAPP of -5 kg H_2SO_4/t this sample is expected to be NAF.

Kinetic NAG tests were conducted on the two UC samples, the uneconomic coal sample (VCM380/13) with a classification of UC (expected to be PAF) and the carbonaceous mudstone sample with an UC (expected to be NAF) classification (VCM380/12). The temperature and pH profiles for these tests are provided in Attachment D (Figures D-1 and D-2). These profiles confirm that sample VCM380/12 is NAF and that sample VCM380/13 is PAF. The pH of the NAG solution for sample VCM380/13 decreased to below 4.0 after 290 minutes and it is expected that the material represented by this sample is slow reacting with relatively long geochemical lag period. Based on these results it is expected that acid conditions would develop in this material if it were left exposed to atmospheric oxidation after a number of years.

5.3 Metal Enrichment and Solubility

Eleven overburden and interburden samples were selected for multi-element analyses based on their stratigraphic location, lithology and geochemical characteristics. The results from these analyses and the geochemical abundances indices for the selected samples are provided in Attachment B (Tables B-6 and B-7). These results indicate that Silver (Ag), As, Boron (B), Antimony (Sb) and Se are slightly enriched in some of the overburden and interburden samples, and that Ag, Sb and Se are significantly enriched in the uneconomic coal sample (VCM380/13) and Ag is significantly enriched in a highly weathered siltstone sample (VCM381/6). The enrichment of Ag, Sb and Se is a common characteristic of the regional coal deposits of the Gunnedah Basin. The significantly enriched concentrations of Ag, Sb and Se in these samples are compared to average crustal abundances in Table 3.

Table 3: Concentrations of the significantly enriched elements in the overburden and interburden samples compared to the average crustal abundance.

Element	*Average Crustal Abundance (mg/kg)	Concentration (mg/kg)	
		Siltstone (HW) (VCM381/6)	Coal (VCM380/13)
Ag	0.7	2.31	6.32
Sb	0.2	-	1.75
Se	0.05	-	0.78

mg/kg = milligrams per kilogram
*Bowen (1979)

Multi-element scans were performed on the water extracts (1 part sample per 2 parts deionised water) from the selected overburden and interburden samples in order to provide an indication of relative element solubility in these materials under the existing pH conditions. The results from these scans are presented in Attachment B (Table B-8) and indicate that As, Mo and Se are relatively soluble under the neutral to slightly alkaline test pH conditions. The concentration ranges of these elements are compared to Australian and New Zealand Environment Conservation Council (ANZECC) irrigation water quality guidelines (ANZECC, 2000) in Table 4 in order to provide an indication of the relative solubility of these elements.

Table 4: Concentration ranges and ANZECC (2000) irrigation water quality guideline values for readily soluble elements in selected overburden and interburden drill-hole samples.

Element	Units	Concentration Range	Irrigation Water Quality Guideline (ANZECC, 2000)	
			Short-Term Exposure	Long-Term Exposure
As	µg/L	0.6 - 87.0	2000	100
Mo	µg/L	1.56 - 122.19	50	10
Se	µg/L	1.1 - 95.6	50	10

µg/L = micrograms per litre

These results indicate that the dissolved Mo concentrations exceed the long-term exposure guidelines in 80% of the samples and exceed the short-term guidelines in 40% of the samples. The dissolved Se concentrations exceed the long-term exposure guidelines in 67% of the samples and exceed the short-term guidelines in 33% of the samples. Although relatively soluble in the majority of the samples, the dissolved As concentrations do not exceed the short-term or long-term exposure guidelines in any of these samples.

Detailed elemental analysis and evaluation of the site water quality is provided in the *Vickery Extension Project Surface Water Assessment* (Advisian, 2018) and the *Vickery Extension Project Groundwater Assessment* (HydroSimulations, 2018).

6.0 Coal and Coal Reject Geochemistry

The geochemical test results for the coal seam samples from the additional testing area (and corresponding coal reject samples through flotation tests), including the $pH_{(1:2)}$ and $EC_{(1:2)}$, acid forming characteristics, and element enrichment and solubility, are provided in Attachment B (Tables B-4 and B-6 to B-8).

6.1 pH and Salinity

The additional testing area samples range from acidic to slightly alkaline with $pH_{1:2}$ values from 2.1 to 7.8. The $EC_{1:2}$ values typically range from 0.101 to 0.948 dS/m indicating that the coal seams are likely to be non-saline or slightly saline. One of the Seam 1 samples (VCM380/S1) has an $EC_{1:2}$ value of 7.566 dS/m indicating that the coal seam represented by this sample is likely to have high salinity.

The flotation test samples, with the F1.45 fraction representing the clean coal and the S1.45-F1.6 and S1.6 fractions representing the coal reject, range from slightly acid to slightly alkaline with $pH_{1:2}$ values ranging from 5.1 to 7.7. The $EC_{1:2}$ values range from 0.208 to 6.656 dS/m indicating that, similar to the coal seam samples, the coal rejects are likely to vary widely from non-saline to highly saline.

6.2 Acid Forming Characteristics

The total S content of the coal seam samples ranges from 0.28 to 1.99 %S with an average of 0.63 %S. However, the sulfide S contents are significantly lower, ranging from 0.014 to 0.107 %S with an average of 0.061 %S. The proportion of total S occurring as reactive sulfide in these samples ranges from 4 to 18% indicating that the contained S in the coal seams primarily occurs in a non-reactive S form, such as sulfate or organic S. The samples representing the coal rejects (VCM381/R2 and VCM381/R3) have a total S content of 0.38 to 0.32 %S, respectively.

The ANC of the coal seam samples varies widely from 0.5 to 92 kg H_2SO_4/t and for the coal reject samples, it is 14 and 25 kg H_2SO_4/t. Four of the coal seam samples representing Seams 1 through to 4 (i.e. VCM381/S1, VCM381/S2, VCM381/S3 and VCM380/S4) were selected for ABCC determination. The plots for these determinations are provided in Attachment C (Figures C-6 to C-9) and indicate that 50 to 80% of the total ANC is expected to be readily available to neutralise sulfide generated acidity.

Figure 10 is the ABA plot for the coal seam and coal reject samples. This plot shows that the majority of the coal seam samples and both of the coal reject samples are NAPP negative, and that both of the samples representing Seam 2 and one of the samples representing Seam 1 are NAPP positive.

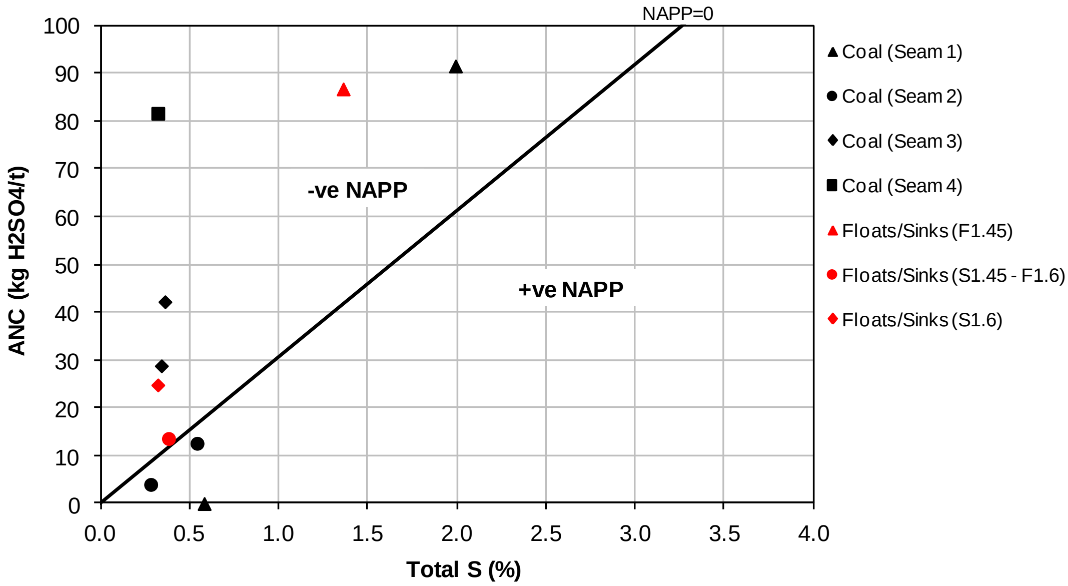

Figure 10: Acid-base account plot for the coal seam and coal reject samples.

The single addition NAG test results indicate that all but one of the coal seam samples and both of the coal reject samples (VCM381/R2 and VCM381/R2) have NAGpH values of less than 4.5. The coal seam sample representing Seam 1 (VCM380/S1) and the flotation sample representing the clean coal have NAGpH values of 8.3 and 8.4, respectively. Figure 11 is the geochemical classification plot for these samples and it shows that the three NAPP positive coal seam samples have NAGpH values below 4.5 and the samples are classified as PAF. The coal seam and flotation test sample with NAGpH values of 8.3 and 8.4, are NAPP negative and these samples are classified as NAF. The other coal seam samples and both of the coal reject samples are NAPP negative with NAGpH values below 4.5 and these samples have an UC classification.

Carbonaceous materials present within the coal seam and flotation test samples have the potential to interfere with the NAG test reaction. These materials have the potential to prematurely breakdown the hydrogen peroxide, and the incomplete NAG reaction can result in misleadingly low NAGpH values. Based on this, it is expected that the low NAGpH values reported for the uncertain coal seam and coal reject samples are attributed to the presence of carbonaceous material rather than due to acid generation through sulfide oxidation, and the expected classification of these samples should be based on the ABA test results. Based on these results it is expected that the coal seam materials are likely to NAF or PAF depending on the S content, and that the coal rejects are likely to be NAF.

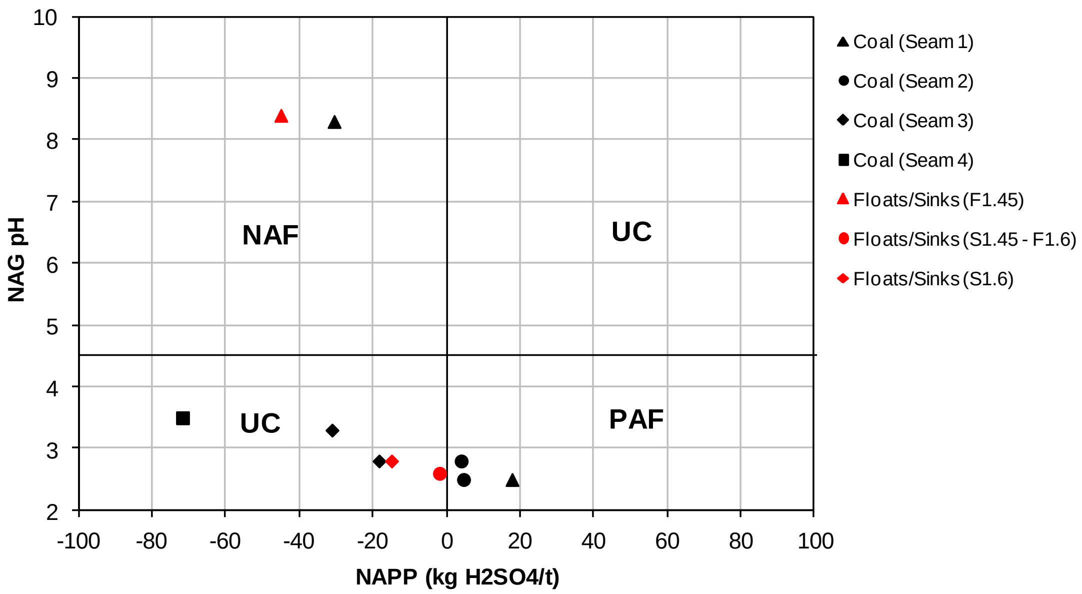

Figure 11: Geochemical classification plot for the coal seam and coal reject samples.

6.3 Metal Enrichment and Solubility

Multi-element scans were performed on the solids and water extracts (1 part solid per 2 parts deionised water) for four of the coal seam samples representing Seams 1 through to 4 (VCM381/S1, VCM381/S1, VCM381/S1 and VCM380/S4) and the two flotation test samples representative of the coal rejects (VCM381/R2 and VCM381/R3). The results of these scans and the geochemical abundance indices are provided in Attachment B (Tables B-6, B-7 and B-8). These results indicate the significant enrichment of Ag and Se in the coal seam samples, and of Ag, As, Mercury (Hg) and Se in the coal reject samples. Table 5 provides the concentration ranges of the identified enriched elements in the coal seam and coal reject samples compared to the respective average crustal abundance.

Table 5: Concentration range and average crustal abundance for significantly enriched elements in the coal seam and coal reject samples.

Element	*Average Crustal Abundance (mg/kg)	Concentration Range (mg/kg)	
		Coal Seam	Coal Rejects
Ag	0.07	4.61 to 21.48	5.45 to 11.56
As	1.5	-	3.3 to 28.7
Hg	0.05	-	1.142 to 3.079
Sb	0.2	-	0.34 to 0.98
Se	0.05	0.21 to 4.10	0.44 to 0.99

mg/kg = milligrams per kilogram *Bowen(1979)

The results of the multi-element scans performed on the water extracts indicate a range in pH values from 2.1 to 7.3 for the coal seam samples, and from 5.1 to 7.7 for the coal reject samples. Seam 1 and Seam 2 of the coal seam samples (VCM381/S1 and VCM381/S2) have acidic pH values of 2.1 and 4.8, respectively, and the S1.6 fraction of the coal reject samples (VCM381/R3) has an acidic pH value of 5.1. The other coal seam and coal reject samples have neutral pH values from 7.2 to 7.7. These results indicate that As, Mo and Se are relatively soluble in all of the coal seam and coal reject samples, including the acidic and non-acidic samples. The concentration ranges of these elements are compared to ANZECC (2000) irrigation water quality guidelines in Table 6 in order to provide an indication of the relative solubility of these elements under acidic and non-acidic conditions. The acidic samples provide an indication of element solubility if acid conditions are allowed to develop in these materials. Although most of the contained metals, including Beryllium (Be), Cadmium (Cd), Cobalt (Co), Nickel (Ni), Lead (Pb) and Zinc (Zn), are expected to be soluble under acidic conditions (i.e. pH <5.5), Ag, Hg and Sb are not expected to be soluble.

Table 6: Concentration ranges and ANZECC (2000) irrigation water quality guideline values for readily soluble elements in the coal seam and coal reject samples.

Element	Units	Concentration Range			Irrigation Water Quality Guideline (ANZECC, 2000)	
		Coal Seam	Coal Rejects	Acidic Samples (pH < 5.5)	Short-Term Exposure	Long-Term Exposure
As	µg/L	0.2 – 0.7	1.2	<0.1 – 12.1	2000	100
Mo	µg/L	13.77 – 76.46	17.54	0.2 – 63.91	50	10
Se	µg/L	28.8 – 51.3	7.4	7.4 – 12.4	50	10

These results indicate that, although relatively soluble in a number of the samples, the dissolved As concentrations do not exceed the short-term or long-term exposure guidelines in any of the selected samples. However, the dissolved Se concentrations exceed the long-term exposure guidelines in a number of the coal seam samples, and the dissolved Mo concentrations exceed both the long-term and short-term exposure guidelines in these samples.

7.0 Conclusions and Recommendations

A detailed geochemical assessment of the Approved Mine was carried out in 2012 (GEM, 2012). This assessment involved the geochemical characterisation of the overburden and interburden excavated from the extent of the open cut, the ROM coal excavated and cleaned on-site, and the coal rejects generated at the Whitehaven CHPP. The strategies that were recommended for geochemically secure management of the waste rock, coal and coal rejects from the Approved Mine were based on:

- disposal of the waste rock within the out-of-pit waste rock emplacement and within the footprint of the open cut void;
- crushing and stockpiling the ROM coal on-site prior to processing and train load-out; and
- on-site disposal of coal rejects (i.e. coarse and fine rejects) from the Whitehaven CHPP, including processing of the ROM coal from other Whitehaven mines.

The Project includes an extension to the approved open cut as shown on Figure 2. Due to the proximity of the drill-holes sampled for the Approved Mine to the extent of the proposed open cut, and the relative consistency in stratigraphy and geochemical characteristics throughout the Project mining area, the samples obtained and the test results reported for the Approved Mine assessment (GEM, 2012) are expected to be representative of the overburden and interburden, coal and coal rejects from the extent of the proposed open cut. However, in order to obtain additional representative samples of the overburden and interburden, coal and coal rejects, the samples from three additional drill-holes selected from within the additional testing area were included in the assessment program.

The following recommendations for management of the overburden and interburden waste rock, ROM coal and coal rejects are provided.

7.1 Overburden and Interburden

The overburden and interburden that will be excavated as waste rock will be disposed within a dedicated waste rock emplacement as well as being placed within the footprint of the open cut void.

A total of 141 drill-hole samples representing overburden and interburden from the Project were geochemically characterised for this assessment, including 107 samples from the open cut area and 34 samples from the additional testing area.

The results of this assessment indicate that the overburden and interburden generally have a low S content and is expected to be NAF with a low salinity risk. Therefore the bulk of the overburden and interburden is expected to be relatively barren with no risk of generating acid or saline conditions. A small proportion of the strata are expected to contain increased S concentrations and these materials present a risk of being PAF. The identified PAF strata typically occur as non-continuous units of mixed (finely interbedded) lithology located immediately adjacent to some of the coal seams (i.e. roof and floor rock) or uneconomic coal, and most of these materials are expected to only have a low capacity to generate acid (<10 kg H_2SO_4/t). These materials are also expected to have a relatively long geochemical lag period and acid conditions are only likely to develop if these materials are left exposed to atmospheric oxidation for a period ranging from a year to a number of years.

Due to the increased S concentrations identified in the mudstone strata occurring immediately above the Shannon Harbour and Cranleigh Seams in the open cut, this roof rock material, which only represents a small proportion of the total waste material, has the potential to be PAF with a moderate capacity to generate acid (approximately 40 kg H_2SO_4/t). This material is expected to have a relatively short geochemical lag period, and acid conditions could develop within weeks of exposure of this material to atmospheric oxidation. Due to the predicted small proportion of PAF overburden and interburden and the typically low capacity of this material to generate acid (<10 kg H_2SO_4/t), it is expected that operational blending during ROM dumping for this multi-seam coal mining operation utilising dump trucks and excavators, would produce an overall NAF and non-sodic material within the waste rock emplacement.

This assessment also indicates the presence of sodic materials within the overburden and interburden. The majority of the overburden and interburden was found to be non- or slightly sodic and therefore has limited risk of becoming dispersive over time. A minor proportion of this material within the open cut is expected to be moderately to highly sodic and this material may become dispersive, resulting in increased erosion potential, if left exposed on the dump surface for some time. However, during ROM overburden removal from multi-seam mining, transport and dumping, considerable mixing of the relatively small quantity of moderate to highly sodic material with the predominant slightly to non-sodic material, is expected to produce an overall low sodicity waste rock blend.

The overburden and interburden material of the open cut is typically expected to contain enriched concentrations of As, Ag, B, Sb and Se compared to the average crustal abundance of these elements (GEM, 2012). Under the prevailing quasi-neutral to moderately alkaline pH conditions of the overburden and interburden, As, Mo and Se are likely to be readily soluble. If acid conditions are allowed to develop in these materials (e.g. through prolonged exposure to atmospheric oxidation), it is expected that the resulting decrease in pH would cause an increase in the solubility of the contained elements including As, Co, Ni, Pb, Se and Zn.

Based on these findings the following recommendations are made:

1. The overburden and interburden material, comprising predominantly NAF material with a small proportion of PAF material, will be emplaced within the Western Emplacement and the footprint of the open cut void. Based on this assessment, blending of this material during excavation, transport and dumping is expected to produce an overall NAF material. In order to ensure that no areas of concentrated PAF material are exposed on the surface of the waste rock emplacement an undertaking would be made to ensure that the final lift of the waste rock emplacement does not contain any PAF material.
2. In order to ensure long-term stability and erosion control for the waste rock emplacement, any areas of the final face that exhibit erosion would be treated with gypsum. In general as part of the mine's rehabilitation strategy, soil that has been stripped from the site in advance of mining would be used to cover the waste rock emplacement faces to facilitate rehabilitation.
3. It is recommended that water quality monitoring for sediment dams capturing runoff from the waste rock emplacement include the following parameters:
   - pH, EC, total suspended solids, total alkalinity/acidity, SO_4, Al, As, Mo and Se.
4. It is recommended that ongoing geochemical characterisation assessment is conducted on the overburden and interburden for any expanded or new mining areas to confirm the findings of this assessment.

7.2 ROM Coal

The ROM coal will be crushed and stockpiled on-site. A total of 21 drill-hole samples representing the economic coal seams within the open cut (14 samples) and additional testing area (7 samples) were geochemically characterised for these assessments. The results indicate that the coal seams generally have a relatively consistent moderate total S content of around 0.5 %S, and a bimodal population in ANC values. The samples with relatively high ANC values (>10 kg H_2SO_4/t) were determined to be NAF, while those with low ANC values (<10 kg H_2SO_4/t) were determined to be PAF.

The presented test results indicate that the ROM pad is expected to contain some PAF material which is likely to be relatively reactive with a short geochemical lag period. The ROM coal is also expected to be enriched in a number of environmentally significant metals including As, B, Hg, Sb and Se. Additionally, As, Mo and Se are expected to be readily soluble under the near-neutral pH conditions and the solubility of additional metals including Be, Cd, Co, Ni, Pb and Zn is expected to increased if lower pH conditions (i.e. pH >6) are allowed to develop within the stockpile.

It is understood that the surface drainage and seepage from the ROM pad would be contained and re-used on-site.

7.3 Coal Rejects

The ROM coal from the Approved Mine, along with that from other Whitehaven mines (including the Tarrawonga and Rocglen Coal Mines) and from the proposed open cut, would be washed and processed, as required, at the Project CHPP. Geochemical characterisation of the coal rejects generated from the Whitehaven CHPP during the previous investigations for the Approved Mine (GEM, 2012), along with those of the coal seam and coal rejects (flotation test samples) from the additional testing area, provides an indication of the expected geochemical characteristics of the coal rejects that would be generated from the Project CHPP.

The results from the previous assessment indicate that the coarse reject materials are expected to have a relatively low to moderate total S content and ANC, and this material is classified as NAF and non-saline. The fine reject materials are typically expected to have a moderate total S content and ANC, and this material is also expected to be NAF and to be slightly to moderately saline. As some of the coarse and fine rejects are likely to have a very low ANC, there is a risk that some of these materials will be PAF. However, due to the low total S content, any PAF coarse rejects are expected to only have a low capacity to generate acid (i.e. <5 kg H_2SO_4/t).

The results from the current investigations are consistent with the previous investigations and indicate the coal rejects from the open cut are expected to be non-to-slightly saline and to be NAF. A small proportion of the coal and/or coal rejects may have a very low ANC (i.e. <10 kg H_2SO_4/t) and have a risk of some of the fines material being PAF.

From the previous investigations, the coarse and fine rejects from the Whitehaven CHPP are slightly enriched in As, B, Sb and Se, and one of the coarse reject samples was found to be significantly enriched in As, B, Hg and Se. Coal rejects from the open cut are expected to be significantly enriched in Ag, As, Hg and Se. Additionally, Mo and Se were found to be readily soluble under the prevailing neutral pH conditions of the Whitehaven CHPP samples and the current flotation test samples.

Following commencement of coal processing at the Project, dewatered coal rejects would be co-disposed with waste rock within the Western Emplacement and within the footprint of the open cut void. Based on the quantity and low acid capacity (i.e. <5 kg H_2SO_4/t) of this material, the co-disposed material is expected to be overall NAF. No coal reject materials would be placed within 30 m of the edge of the Western Emplacement, and coal reject materials would be covered with at least 5 m of inert material on the outer surfaces of the waste rock emplacement. Dewatered coal reject materials would be co-disposed in locations such that any runoff or infiltration would report to the mine water management system (Advisian, 2018).

The coal rejects disposal strategy would be provided in the Mining Operations Plan.

Project material should be periodically sampled during the mine life to confirm geochemical characteristics, and enable the coal rejects disposal strategy to be adjusted as necessary.

It is recommended that water quality monitoring of groundwater surrounding and within the footprint of the open cut void containing emplaced coal rejects include EC, total alkalinity/acidity, SO_4, As, Mo and Se.

8.0 References

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Attachment A

Geochemical Sample Details

Table A-1:	Drill-Core samples collected from drill-hole VNW380C for the geochemistry assessment program, Vickery Extension Project.
Table A-2:	Drill-Core samples collected from drill-hole VNW381C for the geochemistry assessment program, Vickery Extension Project.
Table A-3:	Rock-Chip samples collected from drill-hole VNW389C for the geochemistry assessment program, Vickery Extension Project.
Table A-4:	Coal seam composite samples (-4mm) prepared for the geochemistry assessment program from drill-hole VNW380C, Vickery Extension Project.
Table A-5:	Coal seam composite samples (-4mm) prepared for the geochemistry assessment program from drill-hole VNW381C, Vickery Extension Project.
Table A-6:	Composite samples prepared from selected coal flotation test (Floats/Sinks) samples for the geochemistry assessment program, Vickery Extension Project.

Table A-1: Drill-Core samples collected from drill-hole VNW380C for the geochemistry assessment program, Vickery Extension Project.

Sample ID	Depth (m)			Lithology	Weathering
	from	to	inter.		
VCM380/2	7.90	16.43	8.53	Conglomerate	Moderately Weathered
VCM380/3	19.03	19.95	0.92	Siltstone	Highly Weathered
VCM380/4	19.95	20.38	0.43	Sandstone	Highly Weathered
VCM380/5	21.18	30.13	8.95	Conglomerate	Moderately Weathered
VCM380/6	30.13	30.77	0.64	Sandstone	Slightly Weathered
VCM380/7	30.77	40.50	9.73	Conglomerate	Fresh
	40.50	40.87	0.37	Coal - BLU (Seam 1)	
VCM380/8	40.87	48.31	7.44	Sandstone, Siltstone	Fresh
	48.31	49.41	1.10	Coal - BLM (Seam 2)	
VCM380/9	49.41	49.88	0.47	Siltstone	Fresh
	49.88	50.55	0.67	Coal - BLL (Seam 3)	
VCM380/10	50.55	51.00	0.45	Siltstone	Fresh
VCM380/11	51.14	58.93	7.79	Sandstone, Siltstone	Fresh
	58.93	61.27	2.34	Coal - CNW (Seam 4)	
VCM380/12	61.27	61.48	0.21	Carb. Mudstone	Fresh
VCM380/13	61.48	61.69	0.21	Coal	Fresh
VCM380/14	61.69	64.49	2.80	Carb. Mudstone, Claystone	Fresh
VCM380/15	64.49	66.44	1.95	Volcanics	Fresh

Table A-2: Drill-Core samples collected from drill-hole VNW381C for the geochemistry assessment program, Vickery Extension Project.

Sample ID	Depth (m)			Lithology	Weathering
	from	to	inter.		
VCM381/5	27.61	29.31	1.70	Conglomerate	Moderately Weathered
VCM381/6	29.31	29.73	0.42	Siltstone	Highly Weathered
VCM381/7	30.28	30.99	0.71	Sandstone	Highly Weathered
VCM381/8	30.99	31.79	0.80	Sandstone	Moderately Weathered
VCM381/9	32.28	38.26	5.98	Sandstone	Fresh
VCM381/10	38.26	43.05	4.79	Sandstone, Siltstone	Fresh
	43.05	44.55	1.50	Coal - BLM (Seam 1)	
VCM381/11	44.55	45.01	0.46	Sandstone, Siltstone	Fresh
VCM381/12	45.01	45.98	0.97	Sandstone	Fresh
VCM381/13	45.98	51.21	5.23	Conglomerate	Fresh
	51.21	52.52	1.31	Coal - BLL (Seam 2)	
VCM381/14	52.52	53.01	0.49	Siltstone	Fresh
	53.01	55.35	2.34	Coal - CNW (Seam 3)	
VCM381/15	55.35	55.70	0.35	Claystone	Fresh
VCM381/16	55.70	60.24	4.54	Volcanics	Fresh

Table A-3: Rock-Chip samples collected from drill-hole VNW389C for the geochemistry assessment program, Vickery Extension Project.

Sample ID	Depth (m)			Lithology	Weathering
	from	to	inter.		
VCM389/1	1.0	2.0	1.0	Conglomerate	Highly Weathered
VCM389/2	2.0	8.0	6.0	Conglomerate	Highly Weathered
VCM389/3	10.0	12.0	2.0	Conglomerate	Moderately Weathered
VCM389/4	13.0	14.0	1.0	Claystone, Carb. Claystone	Moderately Weathered
VCM389/5	15.0	18.0	3.0	Conglomerate	Moderately Weathered
VCM389/6	18.0	19.0	1.0	Sandstone	Moderately Weathered
VCM389/7	19.0	26.0	7.0	Conglomerate	Moderately Weathered
VCM389/8	26.0	34.0	8.0	Conglomerate	Moderately Weathered

Table A-4: Coal seam composite samples (-4mm) prepared for the geochemistry assessment program from drill-hole VNW380C, Vickery Extension Project.

Composite Coal (-4mm) Samples				Individual Coal (-4mm) Samples					
Sample ID	Depth (m)			Seam/Ply	Sample ID	Depth (m)			Proportion of Composite
	from	to	inter.			from	to	inter.	
VCM380/S1	40.78	41.15	0.370	Seam1_1	001	40.78	41.15	0.370	100%
VCM380/S2	48.55	49.65	1.100	Seam2_1	002	48.55	49.03	0.480	44%
				Seam2_2	003	49.03	49.65	0.620	56%
VCM380/S3	50.10	50.77	0.670	Seam3_1	004	50.10	50.77	0.670	100%
VCM380/S4	59.15	61.46	2.310	Seam4_1	005	59.15	59.80	0.650	28%
				Seam4_2	006	59.80	60.40	0.600	26%
				Seam4_3	007	60.40	60.85	0.450	19%
				Seam4_4	008	60.85	61.46	0.610	26%

Table A-5: Coal seam composite samples (-4mm) prepared for the geochemistry assessment program from drill-hole VNW381C, Vickery Extension Project.

Composite Coal (-4mm) Samples				Individual Coal (-4mm) Samples					
Sample ID	Depth (m)			Seam/Ply	Sample ID	Depth (m)			Proportion of Composite
	from	to	inter.			from	to	inter.	
VCM381/S1	45.79	47.14	1.350	Seam1_2	002	45.79	46.98	1.190	88%
				Seam1_3	003	46.98	47.14	0.160	12%
VCM381/S2	54.26	54.81	0.550	Seam2_3	006	54.26	54.81	0.550	76%
	55.13	55.30	0.170	Seam2_6	009	55.13	55.30	0.170	24%
VCM381/S3	55.79	58.11	2.320	Seam3_1	010	55.79	55.97	0.180	8%
				Seam3_2	011	55.97	56.96	0.990	43%
				Seam3_3	012	56.96	57.81	0.850	37%
				Seam3_4	013	57.81	58.11	0.300	13%

Table A-6: Composite samples prepared from selected coal washability test (Floats/Sinks) samples for the geochemistry assessment program, Vickery Extension Project.

Composite Samples		Individual Floats/Sinks Samples		
Sample ID	**Fraction***	**Drill-Hole**	**Seam/Ply**	**Fraction***
VCM381/R1	F1.45	VNW381C	Seam1_2	F1.45
		VNW381C	Seam2_2	F1.45
		VNW381C	Seam2_3	F1.45
		VNW381C	Seam2_5	F1.45
		VNW381C	Seam3_2	F1.45
		VNW381C	Seam3_3	F1.45
VCM381/R2	S1.45 - F1.6	VNW381C	Seam3_2	S1.45 - F1.6
		VNW381C	Seam3_3	S1.45 - F1.6
VCM381/R3	S1.6	VNW381C	Seam1_2	S1.6
		VNW381C	Seam2_2	S1.6
		VNW381C	Seam2_4	S1.6
		VNW381C	Seam3_2	S1.6
		VNW381C	Seam3_3	S1.6

* Fractions Produced:

F1.45 - Floats at a specific density of 1.45.

S1.45-F1.6 - Floats at a specific density of 1.6 and sinks at a specific density of 1.45.

S1.6 - Sinks at a specific density of 1.6.

Attachment B

Geochemical Test Results

Table B-1: Acid forming characteristics of overburden and interburden samples from drill-hole VNW380C, Vickery Extension Project.

Sample ID	Depth (m)			Lithology/ (Weathering)	$pH_{1:2}$	$EC_{1:2}$	ACID-BASE ANALYSIS							NAG TEST			Geochem. Class.
	from	to	interval				Total %S	Sulfide %S	MPA	ANC	NAPP	NAPP (sulfide)	ANC/ MPA	NAGpH	$NAG_{pH4.5}$	$NAG_{pH7.0}$	
VCM380/2	7.90	16.43	8.53	Conglomerate (MW)	7.8	0.165	<0.01		0	5	-4		15.7	7.9			NAF
VCM380/3	19.03	19.95	0.92	Siltstone (HW)	6.7	0.385	<0.01		0	3	-3		11.1	6.7		2	NAF
VCM380/4	19.95	20.38	0.43	Sandstone (HW)	6.8	0.287	<0.01		0	1	-1		3.3	7.2			NAF
VCM380/5	21.18	30.13	8.95	Conglomerate (MW)	6.8	0.212	0.02		1	8	-8		13.7	8.4			NAF
VCM380/6	30.13	30.77	0.64	Sandstone (SW)	8.1	0.241	0.02		1	149	-148		243.5	10.9			AC
VCM380/7	30.77	40.50	9.73	Conglomerate	7.6	0.446	0.05		2	22	-20		14.3	9.1			NAF
	40.50	40.87	0.37	Coal - BLU (Seam1)													
VCM380/8	40.87	48.31	7.44	Sandstone, Siltstone	7.8	0.406	0.05		2	48	-46		31.2	8.8			NAF
	48.31	49.41	1.10	Coal - BLM (Seam2)													
VCM380/9	49.41	49.88	0.47	Siltstone	7.8	0.354	0.05		2	8	-7		5.4	8.1			NAF
	49.88	50.55	0.67	Coal - BLL (Seam3)													
VCM380/10	50.55	51.00	0.45	Siltstone	7.9	0.383	0.08	0.041	2	64	-62	-63	26.2	8.6			NAF
VCM380/11	51.14	58.93	7.79	Sandstone, Siltstone	8.1	0.334	0.05		2	22	-21		14.6	8.8			NAF
	58.93	61.27	2.34	Coal - CNW (Seam4)													
VCM380/12	61.27	61.48	0.21	Carb. Mudstone	7.5	0.176	0.10	<0.005	3	5	-2	-4	1.7	3.9	7	24	UC(NAF)
VCM380/13	61.48	61.69	0.21	Coal	7.0	0.217	0.28	0.050	9	6	3	-5	0.7	2.8	66	120	UC(PAF)
VCM380/14	61.69	64.49	2.80	Carb. Mudstone, Claystone	7.4	0.485	0.07	0.026	2	33	-31	-32	15.5	8.8			NAF
VCM380/15	64.49	66.44	1.95	Volcanics	7.7	0.470	0.06	0.042	2	136	-134	-134	74.1	10.4			AC

KEY

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

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

MPA = Maximum Potential Acidity (kgH_2SO_4/t)

ANC = Acid Neutralising Capacity (kgH_2SO_4/t)

NAPP = Net Acid Producing Potential (kgH_2SO_4/t)

NAGpH = pH of NAG liquor

$NAG_{(pH4.5)}$ = Net Acid Generation capacity to pH 4.5 (kgH_2SO_4/t)

$NAG_{(pH7.0)}$ = Net Acid Generation capacity to pH 7.0 (kgH_2SO_4/t)

Weathering Key

(HW) = Highly Weathered

(MW) = Moderately Weathered

(SW) = Slightly Weathered

ARD Classification Key

NAF = Non-Acid Forming

PAF = Potentially Acid Forming

AC = Acid Consuming

UC = Uncertain (expected classification)

Table B-2: Acid forming characteristics of overburden and interburden samples from drill-hole VNW381C, Vickery Extension Project.

Sample ID	Depth (m) from	Depth (m) to	Depth (m) interval	Lithology/ (Weathering)	$pH_{1:2}$	$EC_{1:2}$	ACID-BASE ANALYSIS Total %S	Sulfide %S	MPA	ANC	NAPP	NAPP (sulfide)	ANC/ MPA	NAG TEST NAGpH	$NAG_{pH4.5}$	$NAG_{pH7.0}$	Geochem. Class.
VCM381/5	27.61	29.31	1.70	Conglomerate (MW)	7.3	0.100	<0.01		0	4	-4		14.1	8.0			NAF
VCM381/6	29.31	29.73	0.42	Siltstone (HW)	7.7	0.183	0.02		1	12	-11		19.0	9.5			NAF
VCM381/7	30.28	30.99	0.71	Sandstone (HW)	7.7	0.099	<0.01		0	3	-3		10.1	8.0			NAF
VCM381/8	30.99	31.79	0.80	Sandstone (MW)	7.6	0.152	<0.01		0	3	-3		9.5	7.3			NAF
VCM381/9	32.28	38.26	5.98	Sandstone	7.4	0.520	0.04		1	99	-98		81.1	10.8			NAF
VCM381/10	38.26	43.05	4.79	Sandstone, Siltstone	7.8	0.415	0.07	0.066	2	15	-13	-15	6.9	8.4			NAF
	43.05	44.55	1.50	Coal - BLM (Seam1)													
VCM381/11	44.55	45.01	0.46	Sandstone, Siltstone	7.9	0.263	0.02		1	6	-5		10.0	7.6			NAF
VCM381/12	45.01	45.98	0.97	Sandstone	7.3	0.226	0.05		2	6	-4		3.8	7.9			NAF
VCM381/13	45.98	51.21	5.23	Conglomerate	7.6	0.356	0.03		1	90	-89		97.5	11.1			NAF
	51.21	52.52	1.31	Coal - BLL (Seam2)													
VCM381/14	52.52	53.01	0.49	Siltstone	7.6	0.499	0.07	0.027	2	140	-138	-140	65.4	9.6			AC
	53.01	55.35	2.34	Coal - CNW (Seam3)													
VCM381/15	55.35	55.70	0.35	Claystone	7.4	0.281	0.02		1	8	-8		13.7	7.2			NAF
VCM381/16	55.70	60.24	4.54	Volcanics	8.1	0.238	<0.01		0	65	-65		213.7	10.1			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 (kgH_2SO_4/t)
ANC = Acid Neutralising Capacity (kgH_2SO_4/t)
NAPP = Net Acid Producing Potential (kgH_2SO_4/t)
NAGpH = pH of NAG liquor
$NAG_{(pH4.5)}$ = Net Acid Generation capacity to pH 4.5 (kgH_2SO_4/t)
$NAG_{(pH7.0)}$ = Net Acid Generation capacity to pH 7.0 (kgH_2SO_4/t)

Weathering Key

(HW) = Highly Weathered
(MW) = Moderately Weathered
(SW) = Slightly Weathered

ARD Classification Key

NAF = Non-Acid Forming
PAF = Potentially Acid Forming
AC = Acid Consuming
UC = Uncertain (expected classification)

Table B-3: Acid forming characteristics of overburden samples from the weathered zone of drill-hole VNW389C, Vickery Extension Project.

Sample ID	Depth (m) from	Depth (m) to	Depth (m) interval	Lithology/ (Weathering)	$pH_{1:2}$	$EC_{1:2}$	ACID-BASE ANALYSIS Total %S	Sulfide %S	MPA	ANC	NAPP	NAPP (sulfide)	ANC/ MPA	NAG TEST NAGpH	$NAG_{pH4.5}$	$NAG_{pH7.0}$	Geochem. Class.
VCM389/1	1.0	2.0	1.0	Conglomerate (HW)	8.1	0.939	<0.01		0	6	-6		19.9	8.6			NAF
VCM389/2	2.0	8.0	6.0	Conglomerate (HW)	8.9	0.774	<0.01		0	40	-39		129.1	10.3			NAF
VCM389/3	10.0	12.0	2.0	Conglomerate (MW)	8.3	1.024	<0.01		0	51	-50		165.7	10.7			NAF
VCM389/4	13.0	14.0	1.0	Claystone, Carb. Claystone (MW)	8.5	0.833	<0.01		0	23	-23		76.5	10.4			NAF
VCM389/5	15.0	18.0	3.0	Conglomerate (MW)	8.4	0.562	<0.01		0	9	-8		28.4	8.9			NAF
VCM389/6	18.0	19.0	1.0	Sandstone (MW)	8.6	0.165	<0.01		0	5	-5		16.3	8.2			NAF
VCM389/7	19.0	26.0	7.0	Conglomerate (MW)	8.8	0.243	<0.01		0	5	-5		16.0	9.1			NAF
VCM389/8	26.0	34.0	8.0	Conglomerate (MW)	8.6	0.296	<0.01		0	45	-45		147.4	10.9			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 (kgH_2SO_4/t)

ANC = Acid Neutralising Capacity (kgH_2SO_4/t)

NAPP = Net Acid Producing Potential (kgH_2SO_4/t)

NAGpH = pH of NAG liquor

$NAG_{(pH4.5)}$ = Net Acid Generation capacity to pH 4.5 (kgH_2SO_4/t)

$NAG_{(pH7.0)}$ = Net Acid Generation capacity to pH 7.0 (kgH_2SO_4/t)

Weathering Key

(HW) = Highly Weathered

(MW) = Moderately Weathered

(SW) = Slightly Weathered

ARD Classification Key

NAF = Non-Acid Forming

PAF = Potentially Acid Forming

AC = Acid Consuming

UC = Uncertain (expected classification)

Table B-4: Acid forming characteristics of composited coal seam and flotation (float/sink) test samples, Vickery Extension Project.

Sample ID	Seam / Fraction	$pH_{1:2}$	$EC_{1:2}$	ACID-BASE ANALYSIS							NAG TEST			Geochem. Class.
				Total %S	Sulfide %S	MPA	ANC	NAPP	NAPP (sulfide)	ANC/ MPA	NAGpH	$NAG_{pH4.5}$	$NAG_{pH7.0}$	
COMPOSITED COAL SEAM SAMPLES														
VCM380/S1	Seam 1	4.2	7.566	1.99		61	92	-31		1.5	8.3			NAF
VCM380/S2	Seam 2	6.9	0.101	0.28		9	4	5		0.5	2.5	175	279	UC(PAF)
VCM380/S3	Seam 3	7.8	0.315	0.34		10	29	-18		2.8	2.8	105	188	UC(NAF)
VCM380/S4	Seam 4	7.2	0.350	0.32	0.014	10	82	-72	-81	8.3	3.5	48	116	UC(NAF)
VCM381/S1	Seam 1	2.1	0.948	0.58	0.107	18	0.5	18	3	0.0	2.5	131	214	UC(PAF)
VCM381/S2	Seam 2	4.8	0.728	0.54	0.085	17	13	4	-10	0.8	2.8	93	169	UC(NAF)
VCM381/S3	Seam 3	7.3	0.619	0.36	0.038	11	42	-31	-41	3.8	3.3	43	101	UC(NAF)
COMPOSITED COAL FLOTATION TEST (FLOATS/SINKS) SAMPLES														
VCM381/R1	F1.45	7.7	0.437	1.36		42	87	-45		2.1	8.4			NAF
VCM381/R2	S1.45 - F1.6	7.7	0.208	0.38		12	14	-2		1.2	2.6	128	214	UC(NAF)
VCM381/R3	S1.6	5.1	6.656	0.32		10	25	-15		2.5	2.8	106	192	UC(NAF)

<u>KEY</u>

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

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

MPA = Maximum Potential Acidity (kgH_2SO_4/t)

ANC = Acid Neutralising Capacity (kgH_2SO_4/t)

NAPP = Net Acid Producing Potential (kgH2SO4/t)

NAGpH = pH of NAG liquor

$NAG_{(pH4.5)}$ = Net Acid Generation capacity to pH 4.5 (kgH_2SO_4/t)

$NAG_{(pH7.0)}$ = Net Acid Generation capacity to pH 7.0 (kgH_2SO_4/t)

<u>ARD Classification Key</u>

NAF = Non-Acid Forming

PAF = Potentially Acid Forming

AC = Acid Consuming

UC = Uncertain (expected classification)

Table B-5: pH and EC, exchangeable cations and exchangeable sodium percent (ESP) for selected overburden and interburden samples, Vickery Extension Project.

Sample ID	Lithology	Weathering	$pH_{1:2}$	$EC_{1:2}$	Exch. Cations (meq/100g)				ESP
					Ca	Mg	K	Na	
VCM380/4	Sandstone	Highly	6.8	0.287	2.0	2.0	0.2	0.8	16.6
VCM380/6	Sandstone	Slightly	8.1	0.241	20.8	2.2	0.3	0.5	2.3
VCM380/7	Conglomerate	Fresh	7.6	0.446	3.9	1.2	0.2	0.4	6.3
VCM380/10	Siltstone	Fresh	7.9	0.383	9.4	3.5	0.6	0.7	5.2
VCM380/11	Sandstone, Siltstone	Fresh	8.1	0.334	15.4	3.2	0.6	0.8	3.9
VCM380/12	Carb. Mudstone	Fresh	7.5	0.176	8.6	1.7	0.2	0.7	6.0
VCM381/6	Siltstone	Highly	7.7	0.183	9.2	5.4	0.4	1.9	11.2
VCM389-2	Sandstone	Fresh	7.3	0.226	20.4	2.8	0.5	3.4	12.6
VCM381/12	Claystone	Fresh	7.4	0.281	3.1	0.9	0.2	0.4	8.9
VCM381/15	Claystone	Fresh	8.1	0.238	21.0	0.4	0.2	1.5	6.5
VCM381/16	Volcanics	Fresh	8.9	0.774	29.3	0.3	0.2	1.5	4.8
VCM389/3	Conglomerate	Moderately	8.3	1.024	23.8	3.1	0.6	2.9	9.7
VCM389/6	Sandstone	Moderately	8.6	0.165	4.3	1.8	0.8	1.0	12.3

KEY
$pH_{1:2}$ = pH of 1:2 extract
$EC_{1:2}$ = Electrical Conductivity of 1:2 extract (dS/m)
CEC = Cation Exchange Capacity (meq/100g)
ESP = Exchangeable Sodium Percent (%)

Table B-6: Multi-element composition of selected overburden and interburden, coal seam and floats/sinks samples, Vickery Extension Project.

Parameter		Detect. Limit	Overburden and Interburden											Coal Seam				Floats/Sinks	
			Conglom. (HW)	Conglom.	Sandstone (HW)	Sandstone	Sandstone /Siltstone	Siltstone (HW)	Siltstone	Volcanics	Claystone	Carb. Mudstone	Coal	Seam 1	Seam 2	Seam 3	Seam 4	S1.45 - F1.6	S1.6
			VCM 389/2	VCM 380/7	VCM 381/7	VCM 381/12	VCM 380/11	VCM 381/6	VCM 380/10	VCM 380/15	VCM 381/15	VCM 380/12	VCM 380/13	VCM 381/S1	VCM 381/S2	VCM 381/S3	VCM 380/S4	VCM 381/R2	VCM 381/R3
Ag	mg/kg	0.05	0.39	0.27	0.30	<	0.06	2.31	<	0.47	0.29	<	6.32	5.32	21.48	4.61	12.66	5.45	11.56
Al	%	0.005%	6.545%	6.056%	7.449%	6.945%	8.618%	8.230%	8.005%	10.459%	14.780%	12.422%	5.841%	2.570%	2.471%	2.869%	1.096%	1.013%	5.683%
As	mg/kg	0.5	6.4	7.6	8.9	9.1	10.0	6.4	4.2	4.3	4.3	3.7	3.3	8.4	9.0	4.6	1.0	3.3	28.7
B	mg/kg	50	<	74	<	<	78	<	59	<	<	<	<	<	<	<	<	<	<
Ba	mg/kg	0.1	834.2	823.0	635.7	566.7	873.9	447.0	325.5	50.3	68.3	64.0	127.7	123.4	65.6	56.8	44.0	20.8	121.3
Be	mg/kg	0.05	1.91	1.83	2.65	1.49	1.81	3.13	1.75	1.99	2.55	2.26	2.96	2.98	5.08	1.03	0.99	0.71	2.29
Ca	%	0.005%	1.338%	0.644%	0.161%	0.162%	0.791%	0.575%	2.272%	5.371%	0.523%	0.260%	0.293%	0.089%	0.481%	1.558%	3.145%	0.976%	3.941%
Cd	mg/kg	0.02	0.05	0.19	0.06	0.06	0.15	0.15	0.14	0.10	0.23	0.17	0.25	0.05	0.22	0.13	0.07	0.21	0.21
Co	mg/kg	0.1	4.7	7.4	6.7	7.6	9.9	7.7	5.2	34.8	5.8	3.7	6.0	13.3	5.2	25.2	8.4	43.2	19.6
Cr	mg/kg	5	31	28	30	17	28	30	29	60	35	21	20	15	10	10	21	7	13
Cu	mg/kg	1	11	26	13	8	43	23	37	37	28	47	159	16	19	17	42	16	18
Fe	%	0.01%	1.27%	1.01%	2.44%	1.44%	1.88%	2.00%	2.39%	3.52%	0.99%	0.61%	0.35%	0.46%	0.57%	0.42%	0.14%	0.11%	1.76%
Hg	mg/kg	0.001	0.020	0.029	0.005	0.016	0.135	0.017	0.071	0.127	0.060	0.099	0.118	0.35	0.346	0.105	0.019	3.079	1.142
K	%	0.002%	2.703%	2.888%	2.089%	2.335%	1.979%	2.186%	1.715%	0.062%	0.179%	0.102%	0.054%	0.621%	0.388%	0.157%	0.033%	0.016%	0.565%
Mg	%	0.002%	0.388%	0.277%	0.190%	0.193%	0.461%	0.421%	0.545%	0.205%	0.066%	0.074%	0.030%	0.066%	0.129%	0.064%	0.023%	0.009%	0.174%
Mn	mg/kg	1	196	142	297	134	204	202	148	732	18	18	14	8	29	56	31	25	136
Mo	mg/kg	0.1	0.8	1	0.9	0.8	0.9	0.6	0.9	0.6	1.0	2.4	4.2	1.1	0.7	2.4	3.8	3.2	3.3
Na	%	0.010%	1.235%	0.965%	0.534%	0.374%	0.150%	0.354%	0.074%	0.046%	0.073%	0.033%	0.019%	0.070%	0.022%	0.021%	<	<	0.032%
Ni	mg/kg	1	16	14	19	15	34	21	21	83	41	22	37	30	12	28	40	37	45
P	mg/kg	10	206	222	282	270	433	322	245	1023	127	312	1087	76	43	79	208	39	115
Pb	mg/kg	0.5	16.1	18.6	17.0	16.6	25.1	19.4	21.1	19.4	22.6	19.3	13.5	8.6	11.3	13.3	4.5	5.3	15.6
Sb	mg/kg	0.05	0.72	0.76	0.77	0.56	0.96	0.56	0.66	0.45	0.60	0.90	1.75	0.56	0.41	0.63	0.26	0.34	0.98
Se	mg/kg	0.01	0.02	0.03	0.05	0.05	0.17	0.03	0.17	0.08	0.23	0.32	0.78	0.45	0.21	0.46	4.10	0.44	0.99
Si	%	0.1%	33.1%	35.1%	33.1%	34.4%	29.5%	31.3%	24.8%	19.0%	22.3%	15.7%	12.1%	8.2%	7.9%	7.5%	2.4%	3.2%	14.8%
Sn	mg/kg	0.1	2.1	1.9	2.0	1.8	3.3	2.9	3.3	2.7	2.7	2.7	1.4	1.0	1.4	0.9	0.5	0.5	4.3
Th	mg/kg	0.01	10.9	10.7	9.4	10.0	13.3	11.5	12.7	5.5	5.4	9.5	8.3	3.5	4.3	3.3	1.6	1.6	9.5
U	mg/kg	0.01	2.25	2.27	1.83	2.25	3.25	2.79	3.17	1.54	1.80	3.77	2.84	0.93	1.23	0.86	0.53	0.37	1.73
V	mg/kg	1	43	34	61	47	108	104	111	174	177	73	60	48	38	33	13	18	42
Zn	mg/kg	5	54	59	94	57	108	93	83	65	129	35	33	26	25	91	10	54	49

< element at or below analytical detection limit.

Table B-7: Geochemical abundance indices for selected overburden and interburden, coal seam and floats/sinks samples, Vickery Extension Project.

Element	***Mean Crustal Abund.**	**Overburden and Interburden**											**Coal Seam**				**Floats/Sinks**	
		Conglom. (HW)	Conglom.	Sandstone (HW)	Sandstone	Sandstone /Siltstone	Siltstone (HW)	Siltstone	Volcanics	Claystone	Carb. Mudstone	Coal	Seam 1	Seam 2	Seam 3	Seam 4	S1.45 - F1.6	S1.6
		VCM 389/2	VCM 380/7	VCM 381/7	VCM 381/12	VCM 380/11	VCM 381/6	VCM 380/10	VCM 380/15	VCM 381/15	VCM 380/12	VCM 380/13	VCM 381/S1	VCM 381/S2	VCM 381/S3	VCM 380/S4	VCM 381/R2	VCM 381/R3
Ag	0.07	2	1	2	-	-	**4**	-	2	1	-	**6**	**6**	**6**	**5**	**6**	**6**	**6**
Al	8.2%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As	1.5	2	2	2	2	2	2	1	1	1	1	1	2	2	1	-	1	**4**
B	10	<2	2	<2	<2	2	<2	2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Ba	500	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Be	2.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ca	4.0%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cd	0.11	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Co	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Cr	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cu	50	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Fe	4.1%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hg	0.05	-	-	-	-	1	-	-	1	-	-	1	2	2	-	-	**5**	**4**
K	2.1%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mg	2.3%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn	950	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mo	1.5	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	1	1
Na	2.3%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ni	80	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P	1000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pb	14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sb	0.2	1	1	1	1	2	1	1	1	1	2	**3**	1	-	1	-	-	2
Se	0.05	-	-	-	-	1	-	1	-	2	2	**3**	**3**	1	**3**	**6**	**3**	**4**
Si	27.7%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sn	2.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Th	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
U	2.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
V	160	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Zn	75	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

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

Table B-8: Chemical composition of water extracts from selected overburden and interburden, coal seam and floats/sinks samples, Vickery Extension Project.

Parameter		Detect. Limit	Overburden and Interburden											Coal Seam				Floats/Sinks	
			Conglom. (HW)	Conglom.	Sandstone (HW)	Sandstone	Sandstone /Siltstone	Siltstone (HW)	Siltstone	Volcanics	Claystone	Carb. Mudstone	Coal	Seam 1	Seam 2	Seam 3	Seam 4	S1.45 - F1.6	S1.6
			VCM 389/2	VCM 380/7	VCM 381/7	VCM 381/12	VCM 380/11	VCM 381/6	VCM 380/10	VCM 380/15	VCM 381/15	VCM 380/12	VCM 380/13	VCM 381/S1	VCM 381/S2	VCM 381/S3	VCM 380/S4	VCM 381/R2	VCM 381/R3
pH		0.1	8.9	7.6	7.7	7.3	8.1	7.7	7.9	7.7	7.4	7.5	7.0	2.1	4.8	7.3	7.2	7.7	5.1
EC	dS/m	0.001	0.774	0.446	0.099	0.226	0.334	0.183	0.383	0.470	0.281	0.176	0.217	2.844	2.184	0.619	0.350	0.208	6.656
SO4	mg/l	0.3	41.9	148.9	3.7	53.6	51.8	12.1	36.4	157.3	71.3	30.9	54.9	1209.7	1044.5	218.7	96.3	52.7	3131.5
Cl	mg/l	2	166	6	17	8	10	32	12	<	3	4	<	<	<	<	<	<	<
Al	mg/l	0.01	0.29	0.05	0.49	0.32	0.38	0.2	0.17	0.13	0.82	0.41	0.01	8.2	<	0.03	<	<	<
B	mg/l	0.01	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
Ca	mg/l	0.01	2.6	27.66	0.38	13.31	17.15	1.01	18.66	35.31	9.18	6.84	19.19	88.0	342.0	104.96	60.17	38.83	582.6
Cr	mg/l	0.01	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
Cu	mg/l	0.01	<	<	0.01	<	<	<	<	<	<	<	<	0.5	<	<	<	<	<
Fe	mg/l	0.01	0.08	<	0.14	0.03	0.05	0.04	0.01	<	0.07	0.01	<	459.8	85.3	0.04	<	<	959.6
K	mg/l	0.1	2	9.1	0.8	4.5	9.3	1.5	10.9	3.5	1.2	1.8	1.8	4.5	3.3	1.5	1	0.3	4.6
Mg	mg/l	0.01	1.71	10.39	0.17	2.82	3.69	0.37	4.96	2.32	0.13	1.09	2.18	17.6	21.9	4.7	3.69	0.85	39.9
Mn	mg/l	0.01	<	<	0.02	<	<	0.01	<	<	<	<	<	0.2	0.8	0.07	0.02	0.03	3.6
Na	mg/l	0.1	156.9	37.2	17.6	21.7	39.9	31.5	40.7	52.3	44.3	27.6	15	13.3	10.3	13.8	3.2	1.8	16.9
Ni	mg/l	0.01	<	<	0.01	<	<	<	<	<	<	<	<	2.8	0.4	0.04	<	0.04	6.8
P	mg/l	0.1	0.1	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
Si	mg/l	0.05	5.47	2.71	3.47	4	3.79	3.94	3.72	3.05	3.61	2.82	1.16	5.0	0.8	0.78	0.4	0.19	0.8
V	mg/l	0.01	0.01	<	<	<	<	<	<	0.01	0.02	<	<	<	<	<	<	<	<
Zn	mg/l	0.01	<	<	<	<	<	<	<	<	<	<	<	1.8	0.3	0.01	<	<	0.7
Ag	ug/l	0.01	0.01	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	0.3
As	ug/l	0.1	4.8	6.8	1.1	18.9	87	2.8	27.6	6.2	6.1	7.4	0.6	12.1	<	0.7	0.2	1.2	0.8
Ba	ug/l	0.05	23.71	19.67	7.54	10.64	11.96	4.35	14.4	9.28	4.07	3.11	6.69	30.4	95.4	41.98	19.92	9.51	64.6
Be	ug/l	0.1	<	<	<	<	<	<	<	<	<	<	<	19.4	<	<	<	<	<
Cd	ug/l	0.5	<	<	0.6	<	<	1.1	<	<	<	<	<	47.0	2.1	<	<	<	<
Co	ug/l	0.1	0.1	3.6	0.2	1.9	0.3	0.2	0.2	2.8	<	<	0.2	917.9	226.4	23.3	0.4	20.5	2633.1
Hg	ug/l	0.1	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
Mo	ug/l	0.05	25.08	55.65	1.56	42.55	92.7	3.37	122.19	20.04	84.63	64.75	13.19	1.7	0.2	13.77	76.46	17.54	2.4
Pb	ug/l	2	<	<	<	<	<	<	<	<	<	<	<	81.8	<	<	<	<	<
Sb	ug/l	0.01	0.3	1.29	0.02	0.9	2.61	0.1	0.67	0.43	0.13	0.07	0.19	0.1	<	0.12	0.4	0.03	<
Se	ug/l	0.5	<	2.4	<	5.5	54.4	1.1	57.6	22.6	95.6	52.9	22.7	7.9	12.4	28.8	51.3	7.4	20.0
Sn	ug/l	0.1	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
Th	ug/l	0.005	0.079	0.013	0.101	0.054	0.023	0.079	0.024	<	0.039	0.057	<	3.3	<	<	<	<	<
U	ug/l	0.005	0.336	0.441	0.023	0.084	1.913	0.031	2.75	0.072	0.017	0.033	0.025	7.5	0.0	0.19	1.736	0.067	0.1

Attachment C

Acid Buffering Characteristic Curves

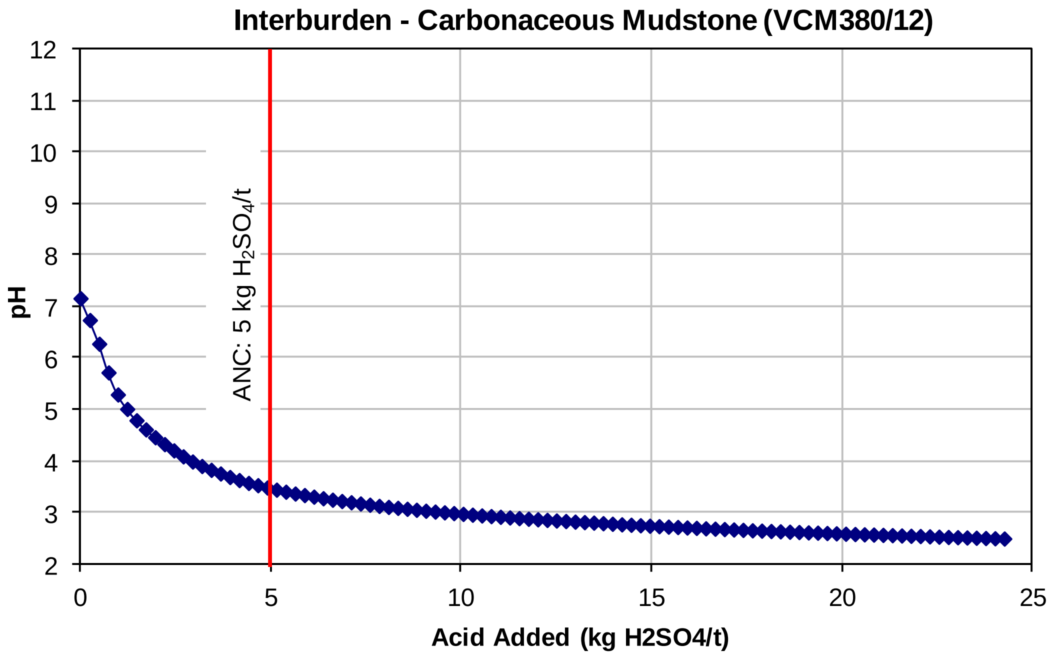

Figure C-1: Acid buffering characteristic curve for sample VCM380/12.

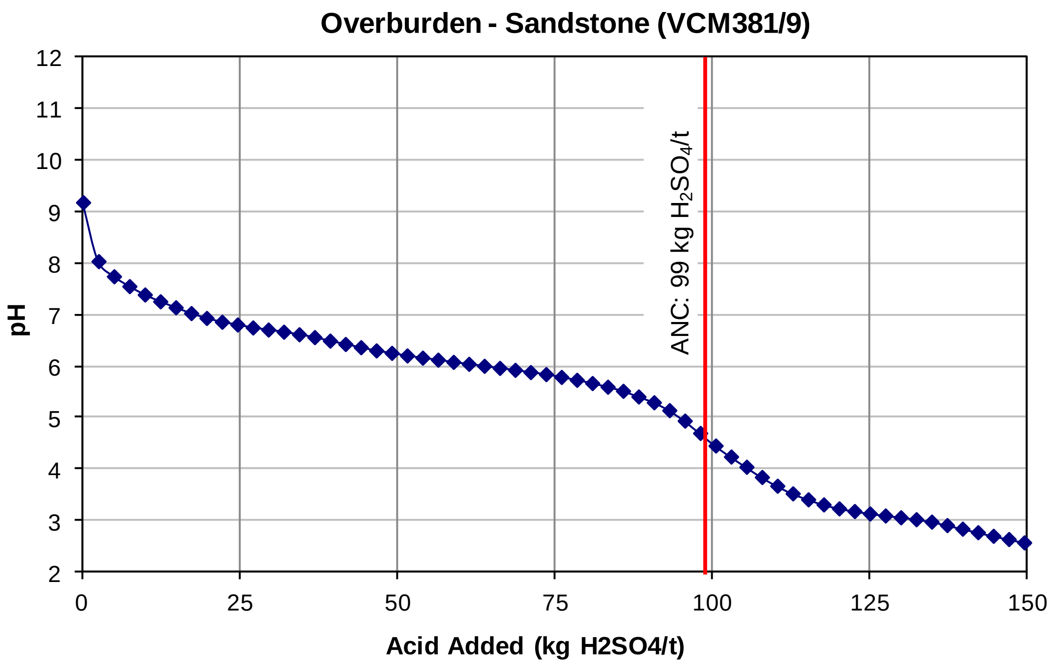

Figure C-2: Acid buffering characteristic curve for sample VCM381/9.

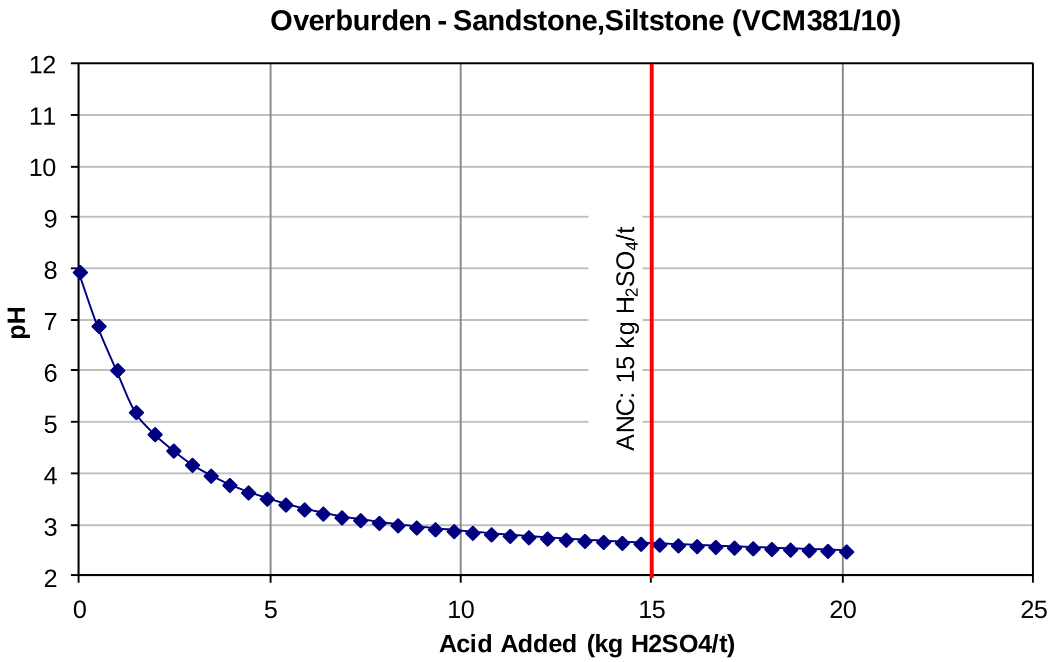

Figure C-3: Acid buffering characteristic curve for sample VCM381/10.

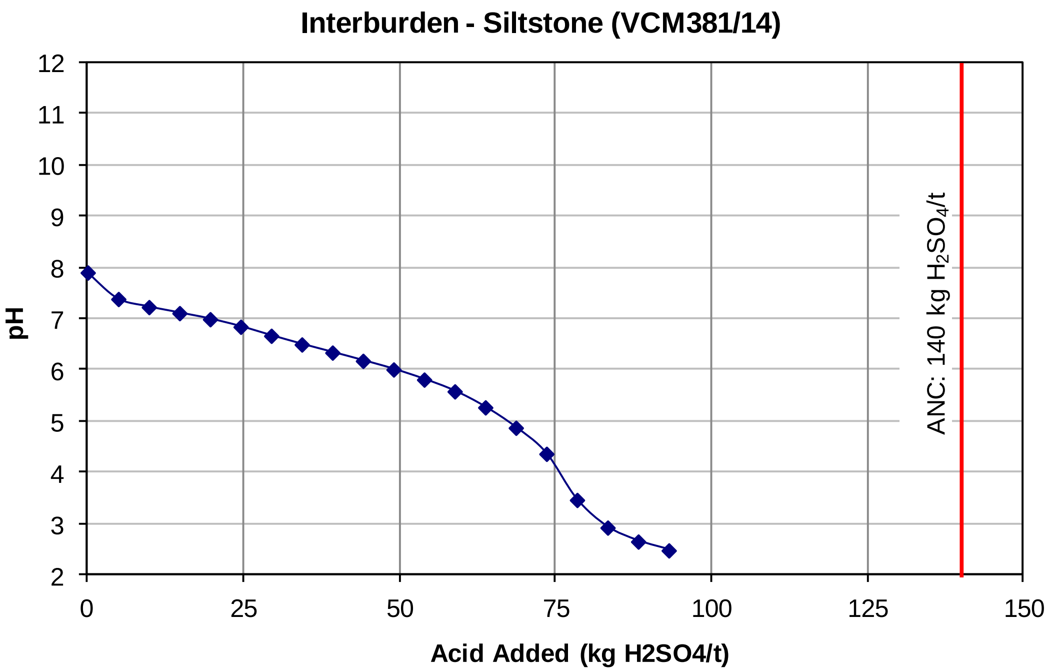

Figure C-4: Acid buffering characteristic curve for sample VCM381/14.

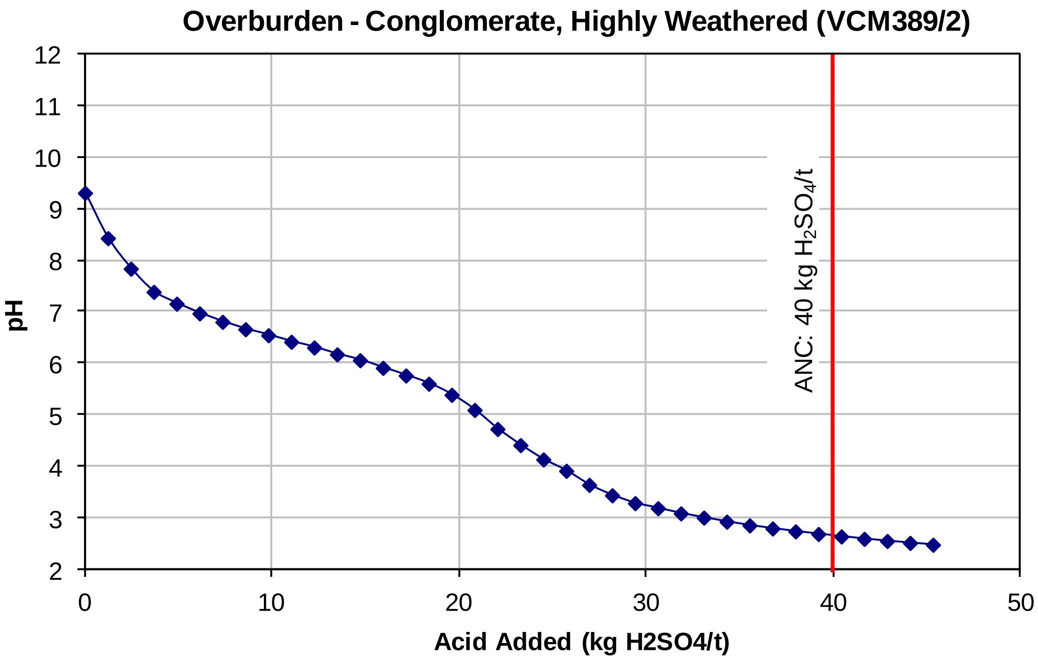

Figure C-5: Acid buffering characteristic curve for sample VCM389/2.

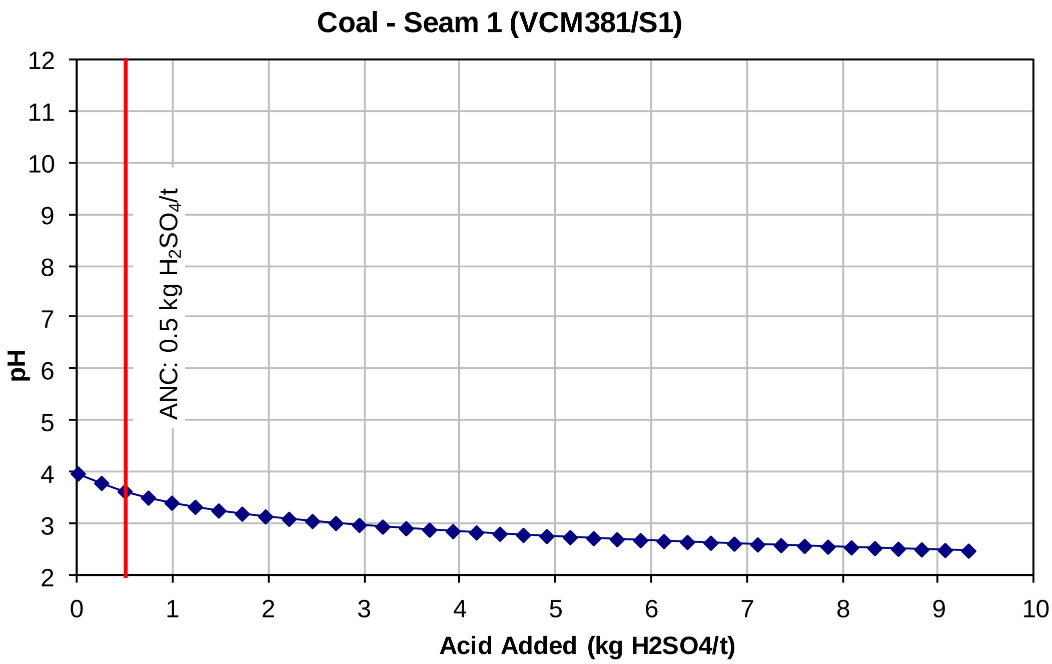

Figure C-6: Acid buffering characteristic curve for sample VCM381/S1.

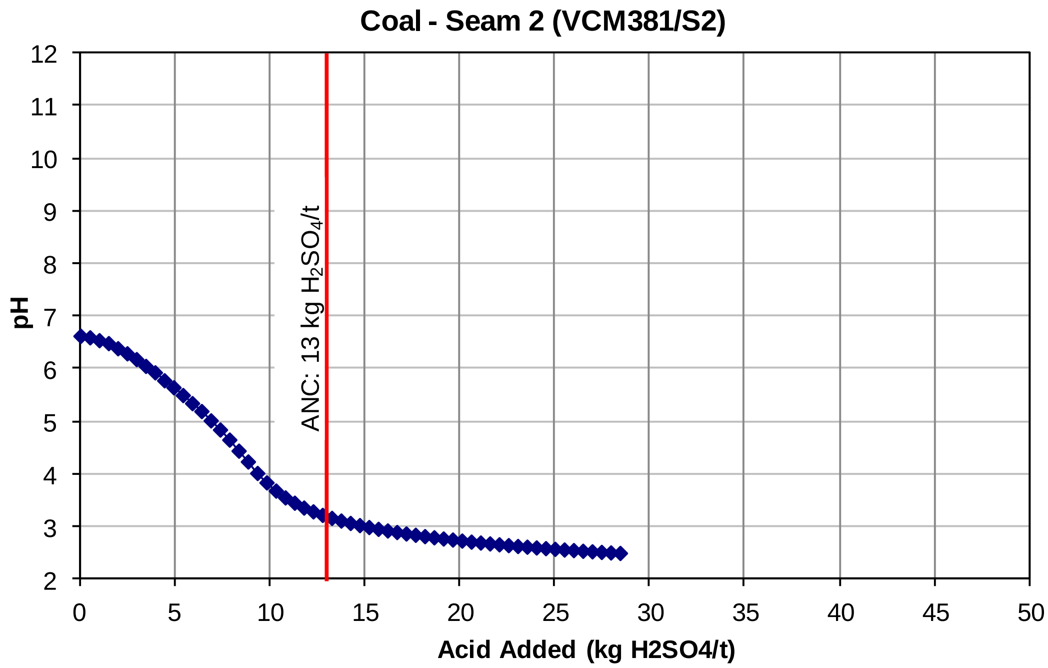

Figure C-7: Acid buffering characteristic curve for sample VCM381/S2.

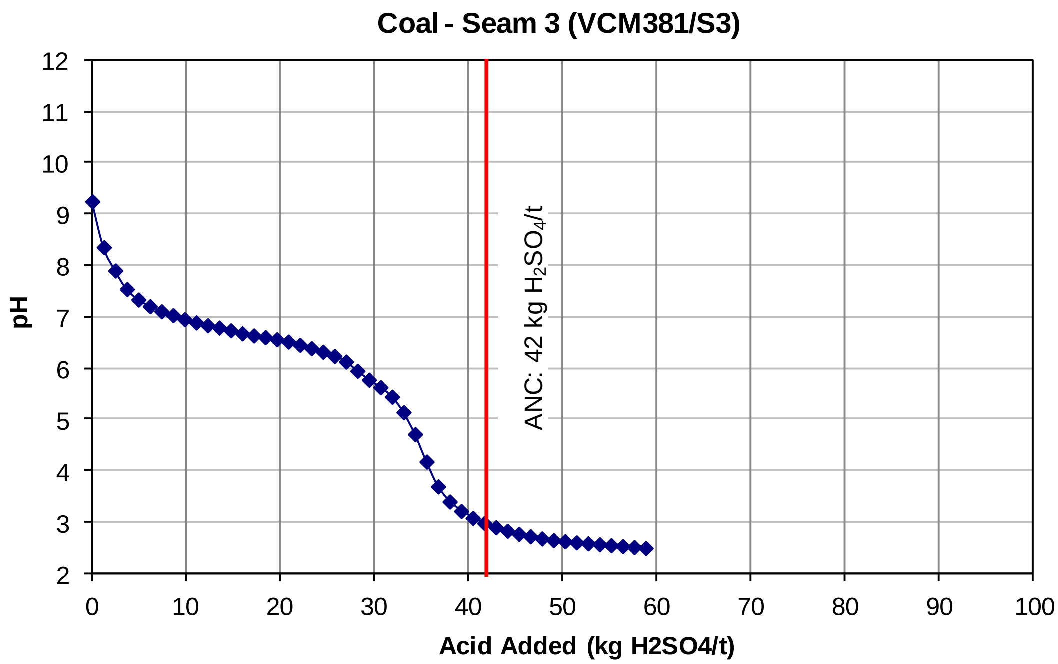

Figure C-8: Acid buffering characteristic curve for sample VCM381/S3.

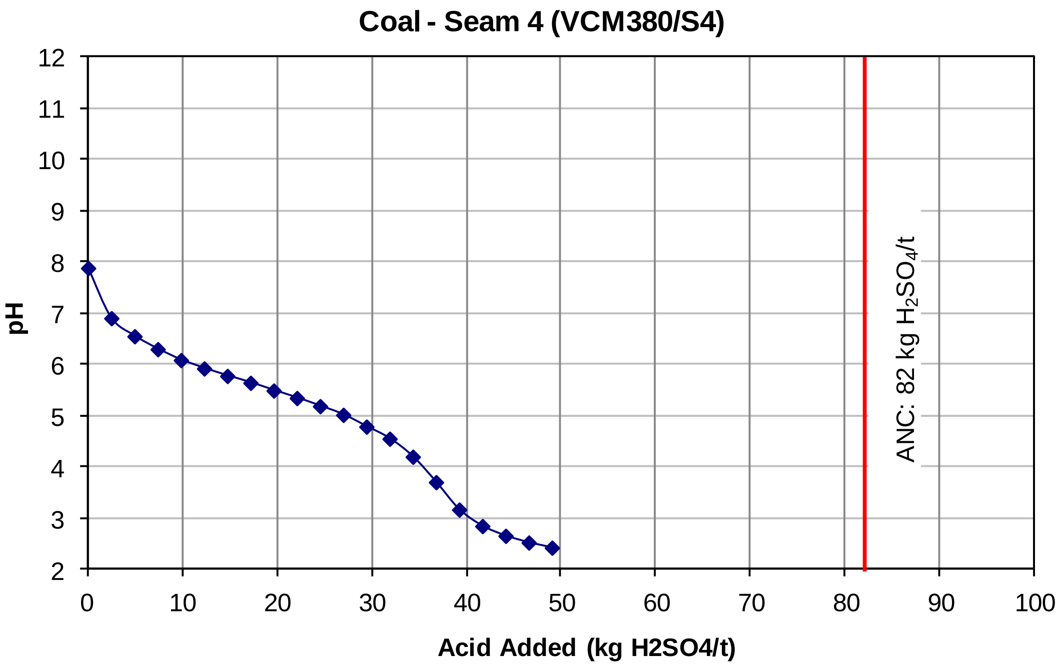

Figure C-9: Acid buffering characteristic curve for sample VCM381/S4.

Attachment D

Kinetic NAG Test Plots

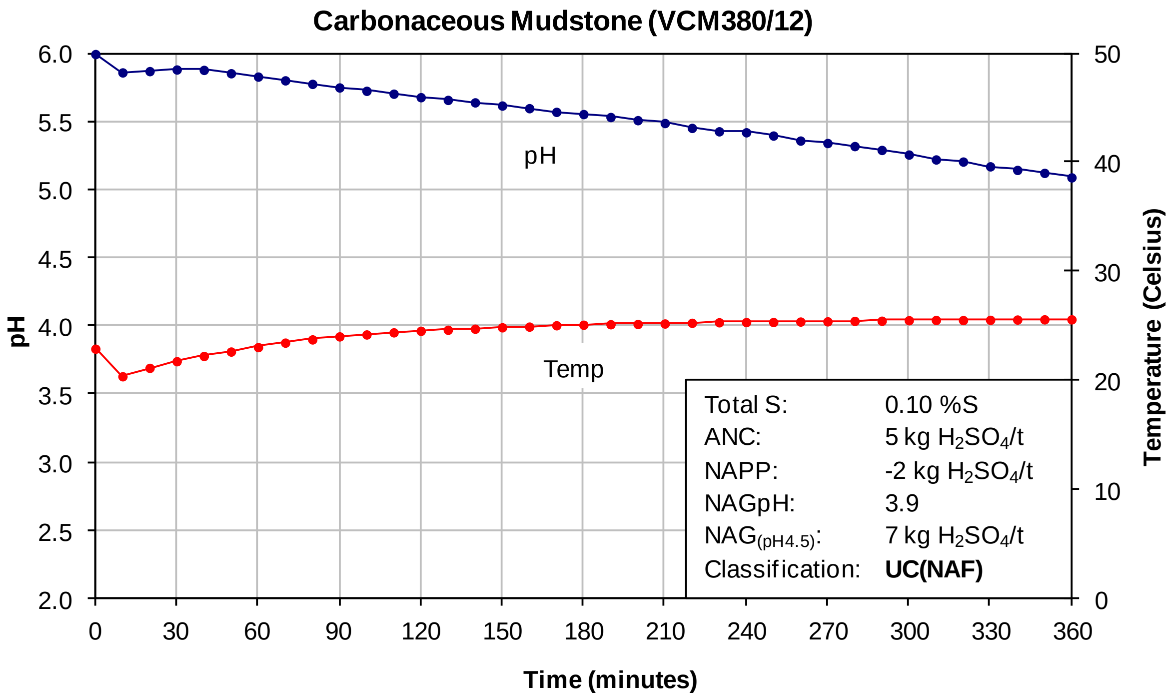

Figure D-1: Kinetic NAG test profiles for sample VCM380/12.

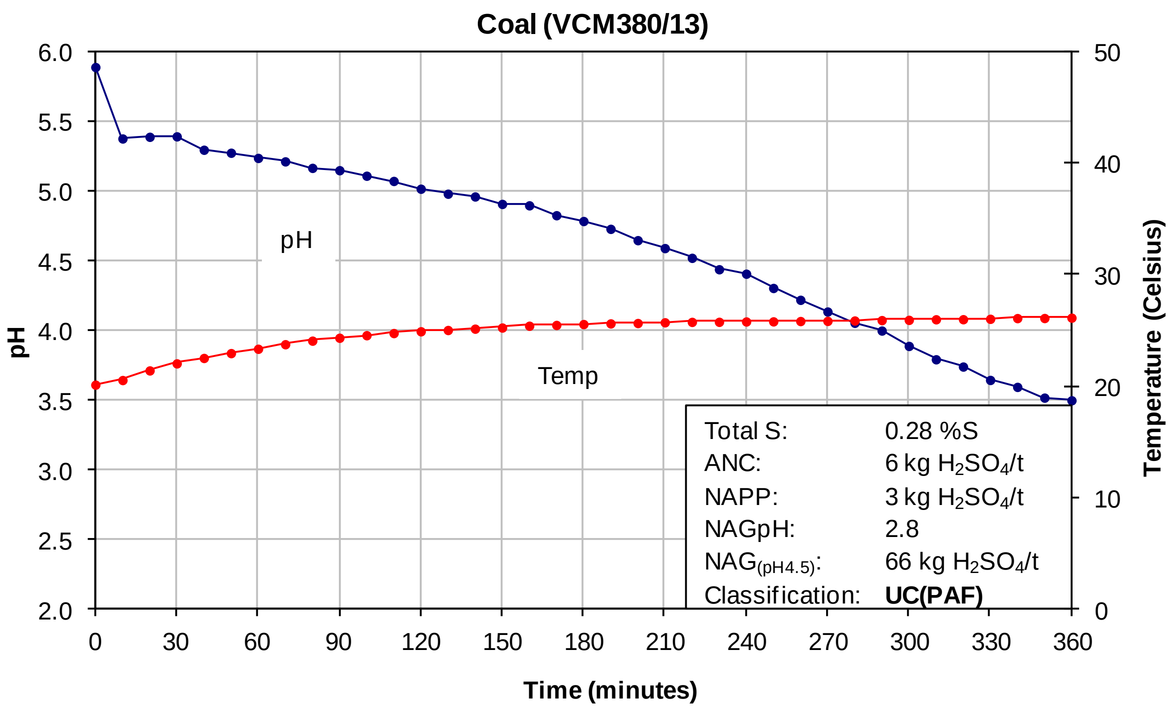

Figure D-2: Kinetic NAG test profiles for sample VCM380/13.