Appendix N

Environmental Geochemistry Assessment

Narrabri Underground Mine Stage 3 Extension Project

Environmental Impact Statement

Environmental Geochemistry Assessment for the Narrabri Underground Mine Stage 3 Extension Project

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1 Introduction

The Narrabri Mine is located approximately 25 kilometres (km) south-east of Narrabri and approximately 60 km north-west of Gunnedah within the Narrabri Shire Council Local Government Area of New South Wales (NSW) (Figure 1). The Narrabri Mine is operated by Narrabri Coal Operations Pty Limited (NCOPL).

NCOPL is seeking a new Development Consent under the State Significant Development provisions of Part 4 of the NSW *Environmental Planning and Assessment Act, 1979* for the Narrabri Underground Mine Stage 3 Extension Project (the Project). This Geochemistry Assessment forms part of the Environmental Impact Statement (EIS) which has been prepared to accompany the Development Application for the Project. The Secretary's Environmental Assessment Requirements (SEARs) state the following requirement in regard to the geochemistry assessment:

- *identification, quantification and classification of the likely waste streams likely to be generated (including tailings and course (sic) rejects) during construction and operation, and describe the measures to be implemented to manage, reuse, recycle and safely dispose of this waste.*

This report has also considered the following general requirement of the SEARs:

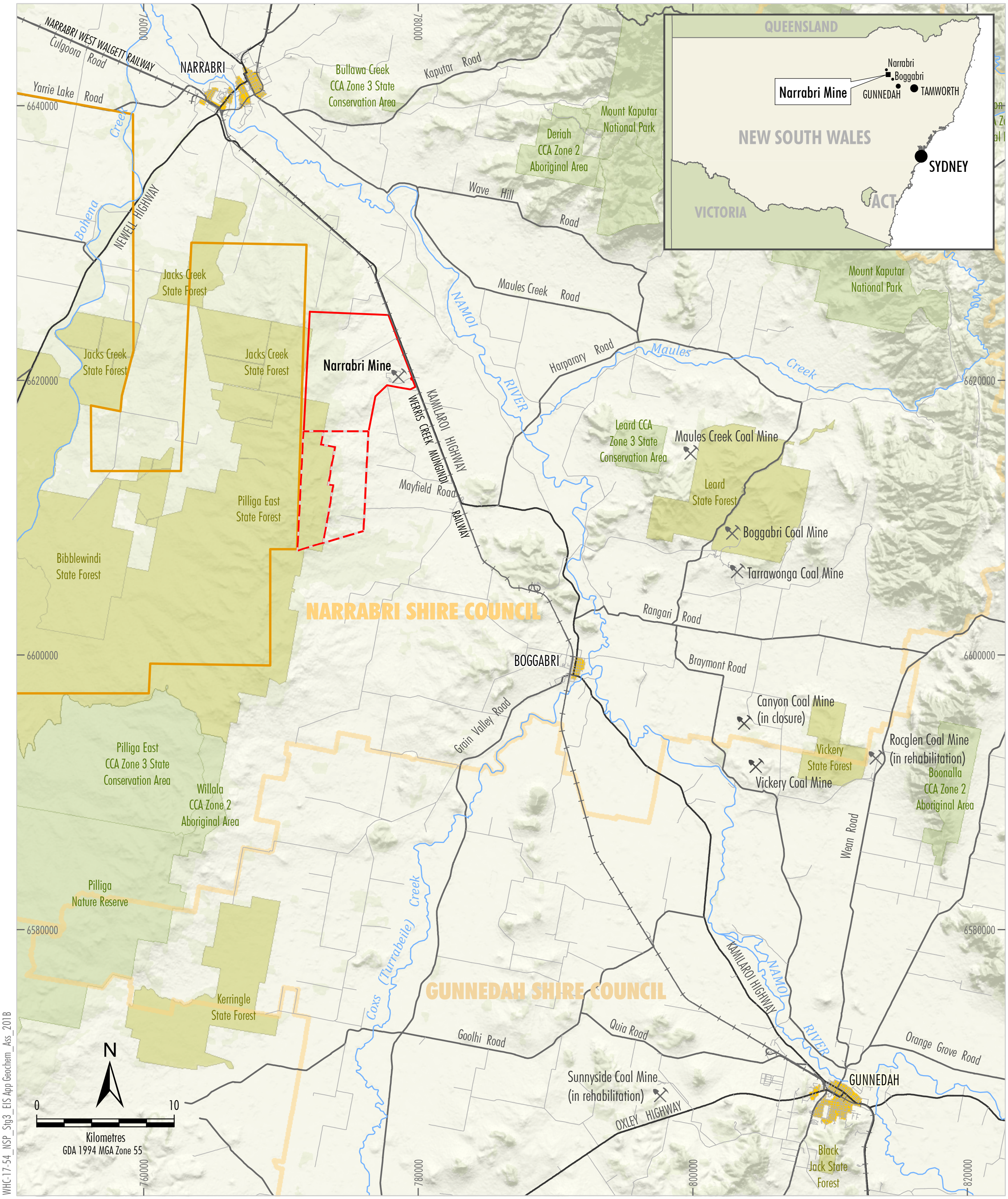
- *a waste (overburden, coarse rejects, tailings, brine etc.) management strategy.*

This report presents the results and findings of the geochemistry assessment and identifies any geochemical implications for the key mine material types, and provides recommendations for the waste management strategy pursuant to the SEAR's requirements.

The brine management strategy is outlined in the Surface Water Assessment (WRM Water and Environment Pty Ltd [WRM], 2020) and the Groundwater Assessment (Australasian Groundwater and Environmental Consultants, 2020).

1.1 Project Description

The Project involves an extension to the south of the approved underground mining area to gain access to additional coal reserves within Mining Lease Applications (MLAs) 1 and 2 (Figure 2), an extension of the mine life to 2044 and development of supporting surface infrastructure. Run-of-mine coal production would occur at a rate of up to 11 million tonnes per annum, consistent with the currently approved limit. A detailed description of the Project is provided in Section 2 in the Main Report of the EIS.



LEGEND

- Mine Site
- Mining Lease (ML 1609)
- Provisional Mining Lease Application Area
- Local Government Boundary
- State Forest
- State Conservation Area, Aboriginal Area
- Narrabri Gas Project (Santos NSW [Eastern] Pty Ltd)

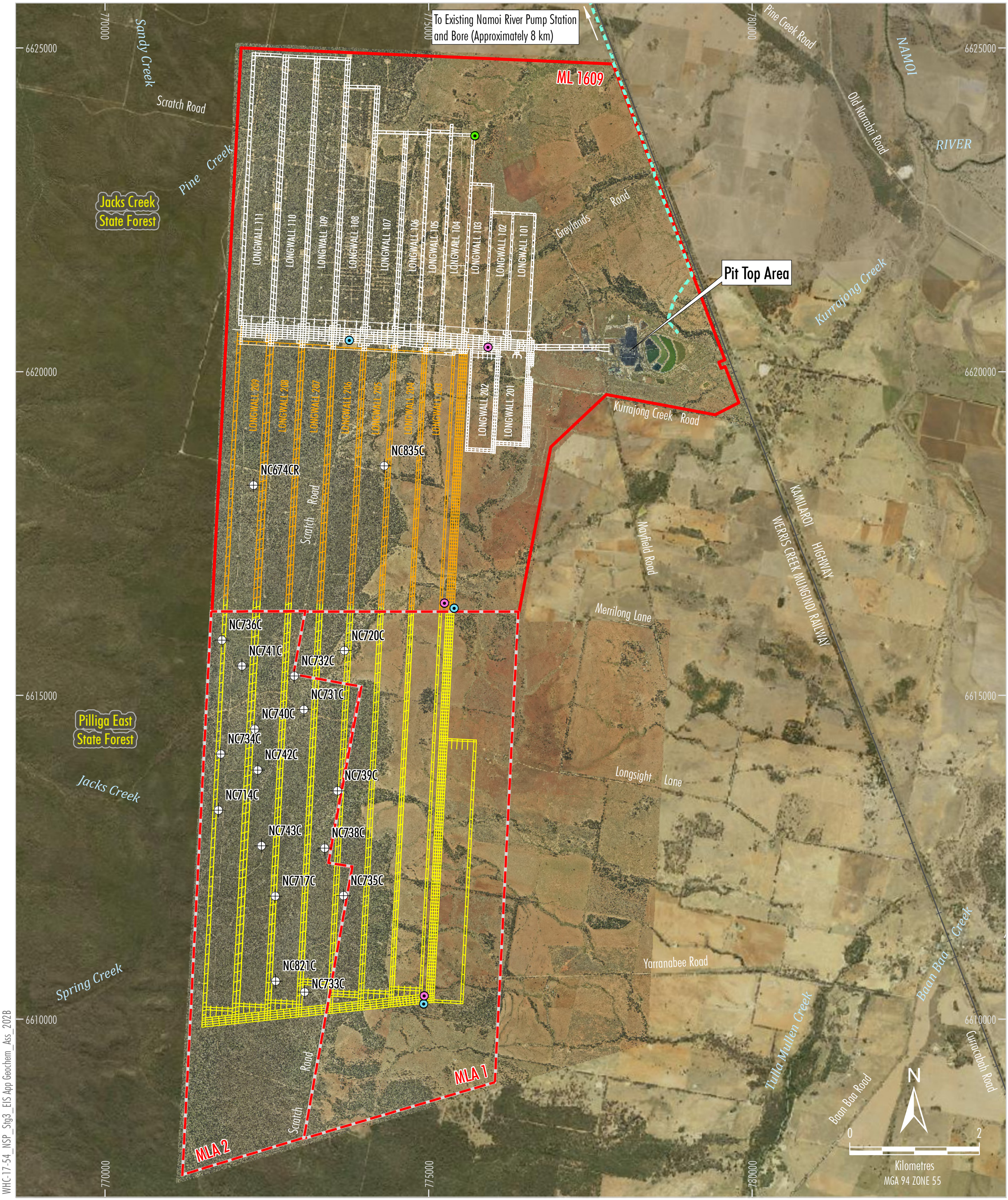
Source: Geoscience Australia (2011); NSW Spatial Services (2019)

WHITEHAVEN COAL

NARRABRI STAGE 3 PROJECT

Regional Location

Figure 1



LEGEND

- Mining Lease (ML 1609)
- Provisional Mining Lease Application Area
- Existing Namoi River Pipeline (Buried)
- Approved Underground Mining Layout
- Indicative Underground Mining Layout to be Extended for Project
- Indicative Underground Project Mining Layout
- Indicative Ventilation Complex (Downcast)
- Indicative Ventilation Complex (Upcast)
- Indicative Ventilation Complex (Upcast - Decommissioned)
- Drill Hole Sample

Source: NCOPL (2019); NSW Spatial Services (2019); GEM (2019)

WHITEHAVEN COAL

NARRABRI STAGE 3 PROJECT

Approved and Project General Arrangement and Drill Hole Sampling Locations

Figure 2

1.2 Study Objectives

The objectives of the study were to:

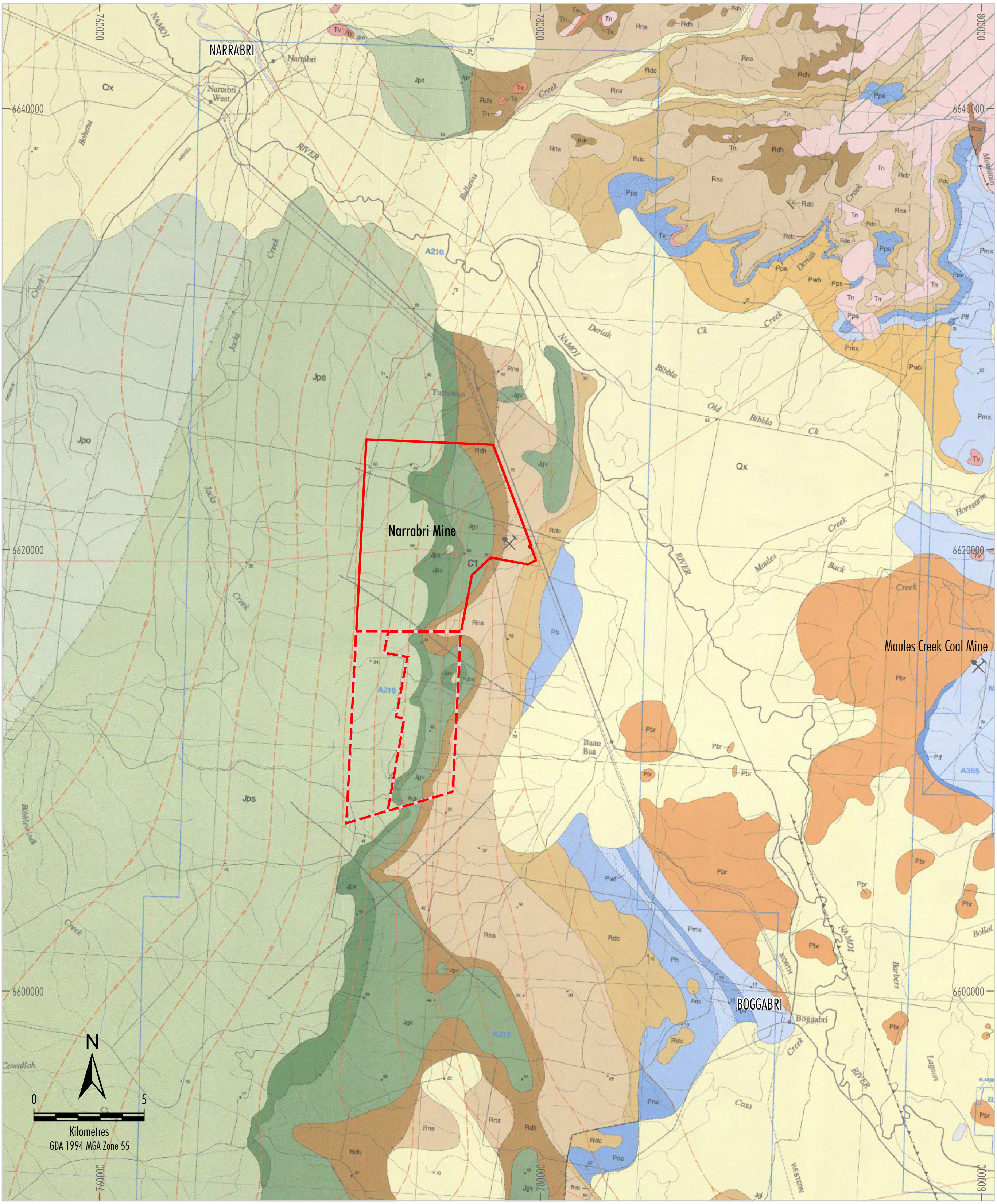
1. Review the relevant information for the Project, including mine plans, drill hole locations, drill logs and stratigraphy, and identify the source materials available to provide the required samples for assessment.
2. Select samples to be collected for the Project that are representative of:
    - development waste – representative of rock material that may be encountered during development activities;
    - mine rock – floor and roof rock that would be representative of material remaining in the underground workings;
    - coarse reject – representative of waste material generated during the processing of coal;
    - raw coal – representative of the coal directly extracted from underground workings;
    - product coal – representative of the processed saleable coal; and
    - exploration drill hole waste – representative of rock material that would be encountered during exploration drilling.
3. Design a testing program and identify suitable analytical laboratories to assess the salinity, acid forming potential and metal enrichment and solubility of the samples selected in Item 2 above.
4. Provide NCOPL with clear instructions to enable on-site and laboratory personnel as required to collect, bag and dispatch the required samples.
5. Coordinate testing of the samples for the required parameters and laboratories identified in Item 3.
6. Receive, tabulate and evaluate the test work results.
7. Prepare a geochemistry assessment report which summarises the relevant results of any previous geochemistry assessments, and describes in detail the sampling and geochemistry test work performed for this Project (Items 1 to 6 above). Using this information, the report evaluates the implications for environmental management, including the acid forming potential, salinity, and metal enrichment and solubility risks associated with the Project.

2 Regional Geology

The Narrabri Mine is located near the northern and western boundaries of the Gunnedah Basin and the eastern margin of the Surat Basin. The stratigraphy of the Narrabri Mine is characterised by two main geological basins (Figures 3a and 3b):

- Surat Basin Units of Jurassic age which include Pilliga Sandstone, Purlawaugh Formation and Garrawilla Volcanics; and
- Gunnedah Basin Units, comprising:
  - Napperby and Digby Formations of Triassic age; and
  - Permian coal measures within the Black Jack Group which includes Hoskissons Seam, Melvilles Seam, and Arkarula and Pamboola Formations. Locally, these coal measures are characterised by an east (shallowest) to west (deepest) gradient (or dip).

Coal resources at the Narrabri Mine are hosted by the Hoskissons Seam, typically comprising thermal quality coal with a medium to low ash content. The depth of the seam varies from approximately 160 metres (m) to 420 m generally increasing towards the west of the Mining Lease (ML1609) and MLAs 1 and 2 (Ditton Geotechnical Services, 2020). A 4.3 m working section from the base of the seam has been defined for the Hoskissons Coal resource. The coal from this working section is considered to be a low to medium ash (8 to 15 per cent [%]) medium volatile (30%) thermal and pulverised coal injection (PCI) product.



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LEGEND

Mine Site

Mining Lease (ML 1609)

Provisional Mining Lease Application Area

Source: NSW Resources & Geoscience (2017)

Note: Refer Figure 3b for Regional Geology Legend.

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NARRABRI STAGE 3 PROJECT

Regional Geology

Figure 3a

Era	Units	Period	Epoch	Group	Subgroup	Formation	Symbol	Lithology
CAINOZOIC		QUATERNARY				undifferentiated sediments	Qx	Undifferentiated alluvial deposits; includes Holocene alluvial channels and overbank deposits of sand silt and clay. Generally does not include residual and veneer colluvial deposits
		TERTIARY				undifferentiated sediments	Ts	Sand, sandstone, pebble sandstone, pebble to cobble gravels, and tuffs
						Nandewar Volcanic Complex	Tn	Basalt, dolerite, teschenite, nephelinite or trachyte sills, dykes, plugs and flows
						undifferentiated volcanics	Tv	Basalt, dolerite, teschenite, nephelinite or trachyte sills, dykes, plugs and flows
MESOZOIC	Surat Basin Units	JURASSIC				Orallo Formation	Jpo	Fine to coarse grained labile to sub-labile clayey sandstone with interbedded siltstone and mudstone
						Pilliga Sandstone	Jps	Quartz pebble and quartzose sandstone with minor lithic sandstone and siltstone
						Purlawaugh Formation	Jpx	Thin bedded lithic labile sandstone interbedded with siltstone and mudstone
						Glenrowan Intrusives	Jgl	Sills and dykes of alkali dolerite and micro-syenodolerite
						Garrawilla Volcanics	Jgv	Vesicular and non-vesicular, alkali olivine basalt, alkali basalt, hawaiite, mugearite, soda trachyte and interbedded pyroclastics
PALAEOZOIC	Gunnedah Basin Units	TRIASSIC	MIDDLE			Deriah Formation	Rdh	Fine to medium grained lithic sandstone rich in volcanic fragments with common mudstone clasts overlain by off-white lithic sandstone and dark grey mudstone
						Napperby Formation	Rns	Coarsening-up sequences of dark-grey siltstone/sandstone laminite overlain by parallel bedded or low-angle crossbedded quartzose sandstone
			EARLY			Digby Formation	Rdc	Poorly sorted volcanic-lithic pebble orthoconglomerate overlain by massive, parallel or cross bedded coarse to fine grained quartz-lithic and then quartzose sandstone
		PERMIAN	LATE	Black Jack Group	Nea Subgroup	Trinkey Formation	Pnc	Claystone, siltstone and fine grained sandstone intercalated with tuff, carbonaceous claystones and tuffaceous stony coal seams
						Wallala Formation		Fining up sequence of dominant lithic conglomerate, sandstone, siltstone, claystone and coal with minor tuff and tuffaceous sediments.
					Coogal Subgroup	Clare Sandstone		Medium bedded, cross stratified medium to coarse grained quartzose sandstone. Quartzose conglomerate locally developed
						Benelabri Formation		Interbedded claystone, siltstone and fine grained quartzose sandstone and coal
						Hoskissons Coal		Coal with subordinate layers of fine grained sandstone, carbonaceous siltstone and claystone, and tuff
					Brothers Subgroup	Brigalow Formation / Arkarula Formation		Fining-up sequence of medium grained quartzose sandstone and siltstone. Fining-up sequence of fine-medium lithic sandstone and siltstone with worm burrows
						Pamboola Formation	Pb	Lithic sandstone, siltstone, claystone, conglomerate and intercalated coals in generally coarsening-up and sporadic fining-up sequences
				Millie Group		Watermark Formation	Pwf	Fining-up sequence of intensely bioturbated silty sandstone to sandstone/claystone laminite with marine fossils overlain by finely laminated siltstone/claystone with little bioturbation, then by coarsening-up sequences of strongly bioturbated silty to sandy laminite
						Porcupine Formation	Pps	Basal conglomerate passing upward into bioturbated silty sandstone and minor siltstone with dropped pebbles
			EARLY	Bellata Group		Maules Creek Formation	Pmx	Basal carbonaceous claystone, pelletoidal clay sandstone, passing into fining-up cycles of sandstone, siltstone and coal. Conglomerate dominant towards top
						Goonbri Formation	*	Carbonaceous siltstone and thin coal grading upwards to fine to medium sandstone
						Leard Formation	Plf	Buff coloured flint (pelletoidal)claystone, conglomerate, sandstone and siltstone
						Werrie Basalt	Pwb	Basaltic lavas with intervening palaeosols and local thin coals
						Boggabri Volcanics	Pbr	Rhyolitic to dacitic lavas and ashflow tuffs with interbedded shale. Rare trachyte and andesite
	New England Orogen Units	CARBONIFEROUS	LATE			Currabubula Formation	Cbc	Paraconglomerate, orthoconglomerate, crossbedded feldspathic and lithic sandstone, siltstone, mudstone and minor limestone. Felsic ashflow and airfall tuff, rhyolitic to andesitic crystal and vitric tuff
						Lark Hill Formation	Cls	Feldspathic arenite, litharenite, subordinate orthoconglomerate and paraconglomerate, siltstone, rhyodacite, and dacitic ashflow and airflow tuff
						Rocky Creek	Crc	Orthoconglomerate, minor feldspathic arenite and litharenite, siltstone and intermediate ashflow tuff
						Plagyan Rhyodacite Tuff Member	Crpr	Multiple beds of rhyolitic to andesitic crystal and vitric tuff
						Conglomerate		
						Clifden Formation	Ccs	Crossbedded feldspathic and lithic sandstones, subordinate conglomerate, shale, rhyodacitic and dacitic airfall tuffs
			EARLY			Caroda Formation – Barneys Spring Andesite Member	Cabb	Porphyritic andesite
						Caroda Formation	Cas	Crossbedded sandstone, minor lenticular oolitic limestone and magnetite sandstone, succeeded by coarse fluvial litharenite, conglomerate, shale, thin coal
		DEVONIAN	LATE	Parry Group		Mostyn Vale Formation	Dpmx	Pebbly lithic wacke, diamictite, lithic wacke, orthoconglomerate, olistostromal volcanic breccia, rhyodacitic to basaltic lavas, tuffs, agglomerates, rare limestones

* Known only from borehole data

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NSW Resources & Geoscience (2017)

Note: Refer Figure 3a for Regional Geology Mapping.

WHITEHAVEN COAL

NARRABRI STAGE 3 PROJECT

Regional Geology - Legend

Figure 3b

3 Related Investigations

3.1 Geochemical Investigations

Table 1 provides a summary of the recent geochemical investigations conducted for current and planned coal mines within the Gunnedah Basin, including the Narrabri Mine (Geo-Environmental Management Pty Ltd [GEM], 2012a and 2019), the Boggabri Coal Mine Continuation (RGS Environmental Pty Ltd, 2009), the Tarrawonga Coal Mine Modification (GEM, 2010), the Tarrawonga Coal Mine (GEM, 2011), the Maules Creek Project (RGS Environmental Pty Ltd, 2011), and the Vickery Coal Project (GEM, 2012b) and Vickery Extension Project (GEM, 2018).

3.1.1 Narrabri Mine

Coarse reject at the Narrabri Mine is disposed of in the Reject Emplacement Area (Figure 4) and this material is expected to typically be NAF with significantly enriched concentrations of As and Se. The contained Se is expected to be readily soluble while the As is expected to be relative insoluble. Although the coarse reject discharged from the CHPP is expected to be non-saline, the reject deposited within the Reject Emplacement Area is typically expected to be moderately to highly saline, indicating that when left exposed to weathering for a period, this material is expected to develop saline conditions. The deposited coarse reject material characterised during the previous investigations was also found to be enriched with Sb.

3.1.2 Other Mining Operations

The Tarrawonga, Vickery, Boggabri and Maules Creek operations are all open-cut mines targeting seams of the Maules Creek Formation, the primary coal bearing unit of the Maules Creek Sub-Basin. The Maules Creek Formation is situated stratigraphically below the Hoskissons Seam of the Black Jack Group (GEM 2010, 2011, 2012b and 2018) and the geochemical characteristics of the overburden from these operations provides information on the potential geochemical characteristics of the Project's development waste.

Overburden to the coal seams of the Maules Creek Formation is characteristically non-saline and NAF. This material exhibits slightly enriched concentrations of As and Sb, and to a lesser extent molybdenum (Mo), and significantly enriched concentrations of Se. Leach testing indicates that high concentrations of dissolved Se in leachates from the overburden is attributed to the flushing of readily soluble Se (GEM 2010, 2011, 2012b and 2018).

Table 1: Summary of geochemical investigations conducted on current and planned coal mines in the Gunnedah Basin.

Project	Target Seams	Samples	Analyses	Findings and Recommendations	Reference
Narrabri Mine	Hoskissons Coal	21 Stockpiled Coarse Rejects	pH & EC Acid-Base NAG Test Multi-Elements	The coarse rejects are non-saline and NAF with a low to moderate sulfur content and ANC. The coarse rejects are expected to be significantly enriched in arsenic and selenium, and the selenium is expected to be readily soluble, most likely due to flushing of relatively high concentrations of dissolved selenium.	Environmental Geochemistry Assessment of Coarse Rejects from the Narrabri Mine, New South Wales (Sep'12). Geo-Environmental Management Pty Ltd
Narrabri Mine	Hoskissons Coal	31 Disposed Coarse Rejects 5 Stockpiled Coarse Rejects 25 Capping Material	pH & EC Acid-Base ABCC Extend Boil NAG Multi-Elements Leach Tests	The stockpiled rejects are alkaline, and generally only slightly saline, while the rejects deposited within the REA are moderately to highly saline. The stockpiled capping material is relatively alkaline with high salinity. The stockpiled and REA rejects are NAF with a low sulfur content and moderate to high ANC, and the stockpiled capping material is NAF and considered barren in terms of acid generation and neutralisation.	Environmental Geochemistry Assessment for the Reject Emplacement Area, Narrabri Coal Mine, Update Report (Oct'19). Geo-Environmental Management Pty Ltd
Tarrawonga Mine	Maules Creek Formation	29 Overburden	pH & EC Acid-Base NAG Test Multi-Elements	The overburden is relatively alkaline and non-saline, and is expected to be NAF and barren in terms of acid generation and neutralisation. The overburden is enrichment in arsenic, antimony and selenium, and arsenic and selenium were found to be relatively soluble under the alkaline test conditions.	Geochemistry Assessment of Tarrawonga Coal Mine Modification, New South Wales (Mar'10). Geo-Environmental Management Pty Ltd
Tarrawonga Mine	Maules Creek Formation	119 Overburden	pH & EC Acid-Base NAG Test Multi-Elements	The overburden is relatively alkaline and non- to slightly saline. The bulk of the overburden is expected to be NAF, however one sample representing the conglomerate and located immediately above Seam 2 (roof rock) was classified as PAF-LC. Consistent with the findings from previous investigations, the overburden is enriched in arsenic, antimony and selenium, and arsenic and selenium are expected to be relatively soluble under the alkaline test conditions. The coarse rejects are expected to be enriched in arsenic and selenium.	Tarrawonga Coal Project – Geochemistry Assessment of Overburden, Interburden and Coarse Rejects (Sep'11). Geo-Environmental Management Pty Ltd

Table 1: Summary of geochemical investigations conducted on current and planned coal mines in the Gunnedah Basin. CONTINUED

Project	Target Seams	Samples		Analyses	Findings and Recommendations	Reference
Boggabri Coal Mine	Maules Creek Formation	47 22	Overburden Roof & Floor Rock	pH & EC Acid-Base Sodicity Multi-Elements	The overburden typically has low S and moderate ANC indicating a significant excess is acid neutralisation over acid generation. However, the overburden materials at Boggabri are expected to be sodic. For this assessment the geochemical characteristics of the coal seam roof and floor were considered to be representative of the coal reject that would be produced, and the presented results indicated that, although the bulk of this material is considered to be low S and relatively barren in terms of acid generation and neutralisation, one sample representing the roof rock was found to have an excess in acid generation over neutralisation. The overburden and roof and floor rock samples were found to have no enriched or readily soluble elements.	Continuation of Boggabri Coal Mine - Geochemical Assessment (Nov'09). RGS Environmental Pty Ltd
Vickery Coal Project	Maules Creek Formation	107	Overburden	pH & EC Acid-Base NAG Test Multi-Elements	The overburden ranges from slightly acidic to slightly alkaline and is typically non-saline. The bulk of the overburden is expected to be NAF, however, a number of PAF materials were identified, including the mudstone and finely laminated mixed lithology materials. The overburden is enriched in arsenic, boron, antimony and selenium, and arsenic, molybdenum and antimony are expected to be relatively soluble under the near neutral test pH conditions.	Vickery Coal Project – Geochemistry Assessment of Overburden, Interburden and Coal Rejects (May'12). Geo-Environmental Management Pty Ltd
		29	Coal & Coal Rejects	pH & EC Acid-Base NAG Test Multi-Elements	The coal seam samples range from acidic to slightly alkaline with low salinity, and the coal reject samples range from pH neutral to slightly alkaline, also with low salinity. The coal rejects are considered to be NAF and the majority of the coal seam samples are classified as PAF. The coal and coal reject samples were found to be enriched in arsenic, boron, antimony and selinium, and mercury was found to be slightly enriched in some of the samples. Arsenic, molybdenum and selenium were found to be relatively soluble under near-neutral to alkaline test conditions of the selected coal seam samples, and molybdenum and selenium were found to be soluble under quasi-neutral pH test conditions of the selected reject samples.	

Table 1: Summary of geochemical investigations conducted on current and planned coal mines in the Gunnedah Basin. CONTINUED

Project	Target Seams	Samples		Analyses	Findings and Recommendations	Reference
Vickery Coal Project	Maules Creek Formation	34	Overburden	pH & EC Acid-Base NAG Test Multi-Elements	The overburden ranges from pH neutral to moderately alkaline and from non-saline to slightly saline. Apart from one sample of uneconomic coal and one sample of carbonaceous mudstone, the overburden is considered to be NAF. The overburden is expected to be enriched in silver, arsenic, boron, antimony and selenium, and arsenic, molybdenum and selenium are expected to be relatively soluble under the near neutral test pH conditions.	Vickery Extension Project – Geochemistry Assessment of Overburden, Interburden and Coal Rejects (Apr'18). Geo-Environmental Management Pty Ltd
		10	Coal & Coal Rejects	pH & EC Acid-Base NAG Test Multi-Elements	The coal and coal rejects range from acidic to slightly alkaline. The coal is expected to be highly saline and the coal rejects to range from low to high salinity. The rejects are NAF, while the coal seam material comprises both NAF and PAF material. The coal and coal reject samples were found to be enriched in silver, and selenium, and mercury was found to be slightly enriched in some of the samples. Arsenic, molybdenum and selenium were found to be relatively soluble under near-neutral test pH conditions.	
Maules Creek Project	Maules Creek Formation	40 98	Overburden Roof & Floor Rock	pH & EC Acid-Base Sodicity Multi-Elements	The overburden typically has low S and moderate ANC indicating an significant excess in acid neutralisation over acid generation. For this assessment the geochemical characteristics of the coal seam roof and floor were considered to be representative of the coal reject that would be produced and the results indicated that, although the bulk of this material is considered to be low S and relatively barren in terms of acid generation and neutralisation, some material with an excess in acid generation over neutralisation was identified. The overburden and roof and floor rock samples were found to have no enriched or readily soluble elements.	Maules Creek Project - Geochemical Assessment of Overburden and Potential Coal Reject Materials (Jan'11). RGS Environmental Pty Ltd

Source: Orthophoto: NCOPL (2019)

WHITEHAVEN COAL

NARRABRI STAGE 3 PROJECT

Existing Pit Top Layout

Figure 4

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3.2 Water Quality Investigations

Surface water monitoring at the Narrabri Mine is conducted in accordance with the approved Water Management Plan (Whitehaven, 2017).

A Surface Water Assessment has been prepared by WRM (2020) in support of the Project which includes an assessment of water quality at existing storages at the Narrabri Mine. Table 2 summarises the existing water quality of the following water storages at the Narrabri Mine:

- Storages SB1 and SB2 – collect runoff from the product coal stockpile; and
- Storage SB3 – collects runoff from the Reject Emplacement Area.

Table 2: Water Quality of Relevant Storages at the Narrabri Mine Pit Top Area. Source: WRM, 2020.

Water Quality Parameter		SB1	SB2	SB3
pH	20th Percentile	9.0	9.1	9.2
	Median	9.3	9.5	9.5
	80th Percentile	9.6	9.8	9.9
	Number of Samples	114	90	86
Electrical Conductivity (EC) (µs/cm)	20th Percentile	2,548	1,356	3,540
	Median	6,710	2,655	7,390
	80th Percentile	8,618	4,136	10,500
	Number of Samples	114	90	86

Note: µs/cm = micro Siemens per centimetre

Table 2 indicates that the water quality in storages SB1, SB2 and SB3 are relatively alkaline with median values ranging between 9.3 and 9.5. SB1, SB2 and SB3 are generally saline with median EC values ranging from 2,655 to 7,390.

WRM (2020) also conducted a review of watercourses draining the Narrabri Mine and concluded that there appears to be no significant difference in water quality between undisturbed monitoring locations and those located downstream of the Narrabri Mine.

The presented surface water quality monitoring data indicate that the management strategies adopted for the product coal stockpile and Reject Emplacement Area during active disposal for the current operations have been successful in negating any potential off-site water quality impacts.

Further information regarding existing water storages and surface water monitoring can be found in the Surface Water Assessment (WRM, 2020).

4 Existing and Approved Management Measures

A summary of the existing/approved management strategies implemented at the Narrabri Mine for the key mine material types and the relevant site water management programs are provided below.

4.1 Coal Stockpiles

Run of mine (ROM) and product coal from the underground operations are stored in the ROM and product coal stockpiles, and located in the Pit Top Area (Figure 4) which is within the existing water management system (Section 4.4).

There are no specific management measures implemented for the product and ROM coal stockpiles.

4.2 Development Waste

Development waste is removed from the underground and disposed of in the Reject Emplacement Area or consolidated with excavated soil to construct sumps (SLR Consulting Pty Ltd [SLR], 2019).

There are no specific management measures implemented for the development waste.

4.3 Reject Emplacement Area

Coarse rejects at the Narrabri Mine are disposed of in the Reject Emplacement Area (Figure 4) in accordance with the Mining Operations Plan (MOP) (SLR, 2019), the Water Management Plan (Whitehaven, 2017) and the Waste Management Plan (Whitehaven, 2015) (or their latest approved versions).

The Reject Emplacement Area has been constructed with a compacted floor that has a permeability of less than $1x10^{-9}$ metres per second (m/s) and a surface water runoff management system (SLR, 2019).

In accordance with the MOP (SLR, 2019), disposal of coarse rejects within the Reject Emplacement Area occurs in “cells”, with cells being formed contiguously, generally in an anti-clockwise direction. Each cell is planned to be constructed to a nominated height of 15 m and capped with approximately 400 millimetres (mm) of clay capping material (ATC Williams, 2019).

Each cell has sufficient capacity to provide an operational life of approximately 2 years.

4.4 Site Water Management

Site water management at the Narrabri Mine is conducted in accordance with the Water Management Plan (Whitehaven, 2017) (or the latest approved version). The site water management strategy for the Narrabri Mine is based on the containment and re-use of mine water and diversion of upstream water around the Pit Top Area.

Storages SB1 and SB2 have been designed to collect runoff from the product coal stockpile, Storage SB4 collects runoff from the ROM coal stockpile and SB3 collects runoff from the Reject Emplacement Area (Figure 4).

5 Geochemical Assessment Program

The geochemical assessment program involved a range of static geochemical tests performed on samples of the development waste, coal seam roof and floor rock (i.e. mine rock), and the raw and product coal and coarse rejects.

5.1 Sample Selection and Preparation

The samples for this assessment included 36 drill hole samples representing the development waste (2 samples) and coal seam roof and floor rock, collectively known as mine rock (34 samples), 5 composite samples produced using materials from the coal quality and washability trials, representing the raw and product coal, and the coarse rejects, and 1 sample collected as a slurry representing the exploration waste material from a recently completed exploration drill hole.

5.1.1 Mine Rock and Development Waste Samples

The drill hole samples were collected to represent development waste and coal seam roof and floor rock. The samples were collected by NCOPL site personnel and prepared by Indicium Labs under instruction from GEM. A total of 18 drill holes were sampled from across the Project area (Figure 2). The sample details, including the drill holes and intervals sampled, are provided in Attachment A (Table A-1). Depending on the interval thickness, the sample weights typically ranged from 1 to 5 kilograms (kg). Each sample was crushed to <4 mm and a 500 gram (g) sub-sample pulverised to minus 75 micrometres (µm) for analysis.

5.1.2 Coal and Coarse Reject Samples

Five composite samples representing the raw coal, product coal and coarse rejects were prepared by Australian Laboratory Services Pty Ltd (Mayfield West Laboratory). Table 3 provides the relevant details for the prepared samples. The < 25 mm fraction of the coal was used to produce the raw coal samples representing the Hoskissons Seam and the ‘other’ seams. The 106 mm > 25 mm fraction was used to prepare samples of the product coal and coarse rejects. The overflow with a density of <1.4 specific gravity (SG) represents the PCI coal, the underflow with a density of 1.7 to 1.4SG represents the thermal coal, and the sinks with a density of >1.7SG represents the coarse rejects.

The composite samples were prepared by combining equal portions of the individual samples sourced from a number of drill holes across the mine area. A nominal 300 g sub-sample of the composites was pulverised to minus 75 µm for analysis.

Table 3: Details of the composite coal and coarse reject samples.

Material Type	Sample ID	Description	Sizing	Density
Raw Coal	Raw HSK2 Raw Other	Hoskissons Seam Coal Other Seams Coal	<25mm <25mm	- -
Product Coal	PCI Thermal	PCI Coal Thermal Coal	>25mm >25mm	Overflow (<1.4SG) Underflow (1.7 - 1.4SG)
Rejects	Reject	Coarse Reject	>25mm	Sinks (>1.7SG)

5.2 Testing Program

The laboratory program for this assessment included the following tests and procedures:

- pH and EC determination;
- total sulfur (S) assay;
- acid neutralising capacity (ANC) determination;
- net acid producing potential (NAPP) calculation;
- single addition net acid generation (NAG) test;
- extended boil NAG test;
- sulfide S analysis (chromium reducible sulfur [CRS]); and
- multi-element scans on solids and water extracts.

The total S assays were performed by Indicium Labs, the CRS analyses were performed by Australian Laboratory Services Pty Ltd (Brisbane Laboratory), the ANC determinations and NAG tests were performed by Environmental Geochemistry International Pty Ltd (EGi), and the multi-element analyses were performed by Genalysis Laboratories Pty Ltd.

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

5.2.1 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 (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 = deci-siemens per metre

5.2.2 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 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 kg of 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 CRS analysis method is used to determine the proportion of total S within a sample that occurs as sulfide.

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/t.

Determination of the ANC using the Modified Sobek method (Sobek *et al.*, 1978) 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, acid buffering characteristic curves (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 ABCCs 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 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.

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 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 5 also shows the plotted lines corresponding to ANC/MPA ratios of 2 and 3.

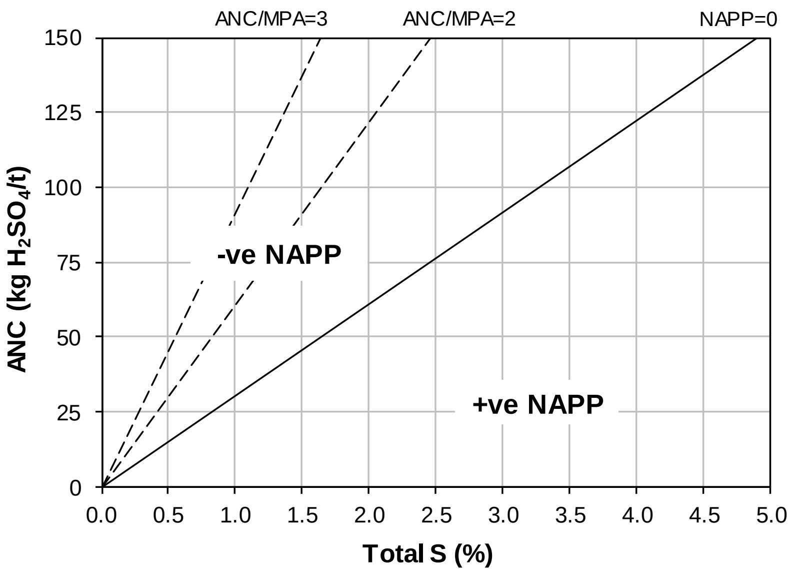

Figure 5: Typical acid-base account plot.

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 and aluminium. The titration value at pH 7 also includes metallic ions that precipitate in the form of hydroxides.

When subjected to the NAG test, samples containing carbonaceous material may generate organic acids potentially producing misleading low NAGpH values and acidities. To overcome this effect an extended boil NAG test has been developed by EGi, where the organic acids are fully decomposed with boiling in order to ensure that the measured NAGpH and acidity of the NAG solution are due solely to sulfide oxidation.

5.2.3 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 (GAI). 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.

5.3 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;
- 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/t.

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 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 $\geq$ 4.5.

Potentially Acid Forming

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 usually defined as PAF when it has a positive NAPP and a final NAGpH < 4.5. Typically, if a PAF sample has a NAPP and/or NAG capacity when titrated to pH 4.5, of ≤ 5 kg H_2SO_4/t, 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 ≤ 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.

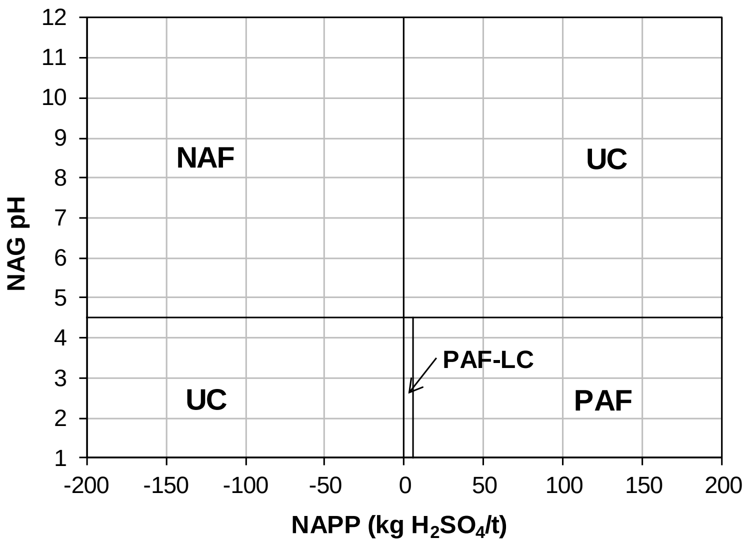

Figure 6: Typical geochemical classification plot.

6 Mine Rock and Development Waste Geochemistry

The geochemical test results for the mine rock (coal seam roof and floor rock) samples and development waste, including the $pH_{1:2}$ and $EC_{1:2}$, acid forming characteristics, and element enrichment and solubility, are provided in Attachment B (Tables B-1, B-2, B-3 and B-4). A summary of the $pH_{1:2}$ and $EC_{1:2}$, ABA and NAG test results for the different materials is provided in Table 5.

Table 5: Summary of the pH, EC, acid-base account and NAG test results for the mine rock and development waste samples.

Material Type		$pH_{1:2}$ *	$EC_{1:2}$ (dS/m)	Total S	Sulfide S	MPA	ANC	NAPP	$NAPP_{sulf.}$
				(%S)		(kg H_2SO_4/t)			
All	*Average*	8.2	0.174	0.09	0.02	3	6	-3	-5
36 Samples	*Min*	7.0	0.082	0.01	0.01	0	1	-63	-65
	Max	8.9	0.475	0.54	0.05	16	65	10	0
Roof	*Average*	8.6	0.299	0.13	0.02	4	16	-12	-15
8 Samples	*Min*	8.1	0.183	0.04	0.01	1	4	-63	-65
	Max	8.9	0.475	0.27	0.04	8	65	1	-4
Floor	*Average*	8.0	0.138	0.03	0.02	1	3	-2	-2
25 Samples	*Min*	7.2	0.093	0.01	0.01	0	1	-18	-18
	Max	8.8	0.391	0.13	0.05	4	19	2	0
Waste	*Average*	7.4	0.167	0.06	0.02	2	4	-2	-3
2 Samples	*Min*	7.0	0.155	0.01	0.01	0	1	-18	-18
	Max	7.7	0.178	0.46	0.05	14	19	9	0
Coal		7.2	0.082	0.54	0.05	16	6	10	-4

* Average pH values reported are median values.

6.1 pH and Salinity

The mine rock and development waste samples are all relatively alkaline with $pH_{1:2}$ values ranging from 7.0 to 8.9. The $EC_{1:2}$ values range from 0.082 to 0.475 dS/m, indicating that these materials are expected to be non-saline.

6.2 Acid Forming Characteristics

The total S content of these samples is typically low ranging from 0.01 to 0.54%S with an average of only 0.09%S. The majority of the samples (78%) have a total S content of less than 0.1%S, and only 3 samples (8%) have a total S content greater than 0.3%S. The sample with the highest total S content (0.54%S) is that of the mine rock coal sample collected from above the Hoskissons Seam. The sulfide S analyses, ranging from 0.02 to 0.05%S, indicating that the proportion of the total S that occurs as reactive sulfide ranges from a low of 2.5% to a high of 130%S. The mine rock coal seam sample has a sulfide S content of only 0.049%S (Attachment B; Table B-1).

The ANC of the mine rock and development waste samples generally ranges from 1 to 20 kg H_2SO_4/t with an average of 4 kg H_2SO_4/t excluding the mine rock coal seam sample with a significantly higher ANC of 65 kg H_2SO_4/t. Figure 7 is an ABA plot for the mine rock and development waste samples where the sulfide S content is plotted against the ANC. This plot shows that all of the samples plot above the NAPP = 0 (ANC/MPA = 1) line and are NAPP negative, indicating an excess in acid buffering capacity over potential acidity. The majority of these samples are also considered to be barren in terms of acid generation and neutralisation.

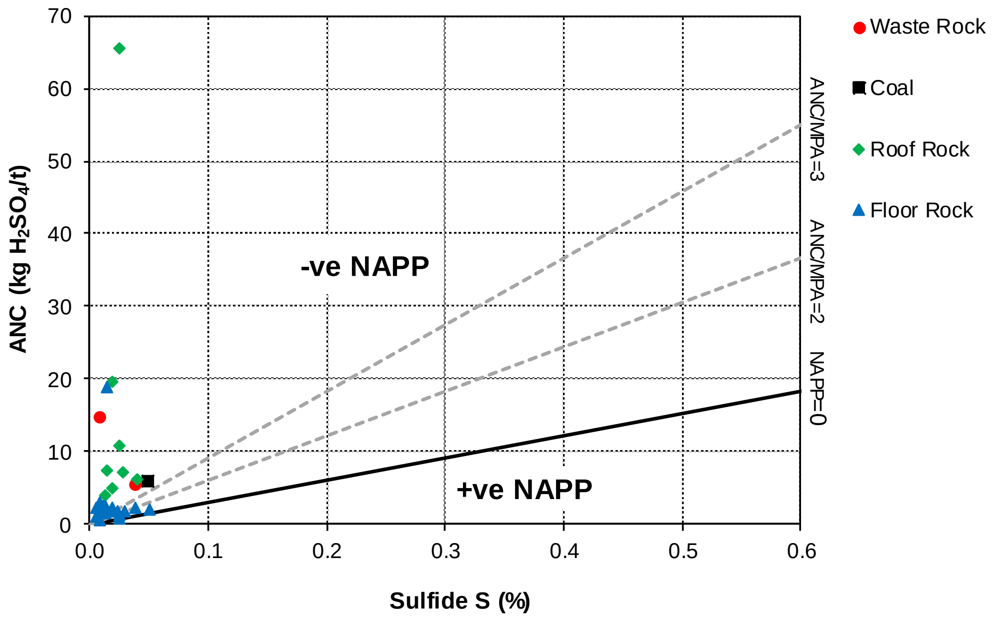

Figure 7: Acid-base account plot for the mine rock and development waste samples.

The results of the standard NAG test indicate that the NAGpH values range from 2.0 to 7.9 and that 21 of the samples (58%) have a NAGpH < 4.5. Figure 8 is a geochemical classification plot using the sulfide S content to calculate the NAPP. This plot shows that a number of the mine rock (roof and floor rock) samples have a NAGpH ≥ 4.5 with a negative NAPP and are classified as NAF. However, a number of the mine rock samples, and the coal seam and the development waste samples, have a NAGpH < 4.5 with a negative NAPP and these samples have an uncertain (UC) classification.

The UC samples were selected for extended boil NAG testing in order to fully decompose any organic acids that may be present and responsible for producing misleading low NAGpH values. These results produced a NAGpH > 4.5 for all of the selected samples. Figure 9 is the geochemical classification plot incorporating the extended boil NAGpH values showing that all of the samples are classified as NAF.

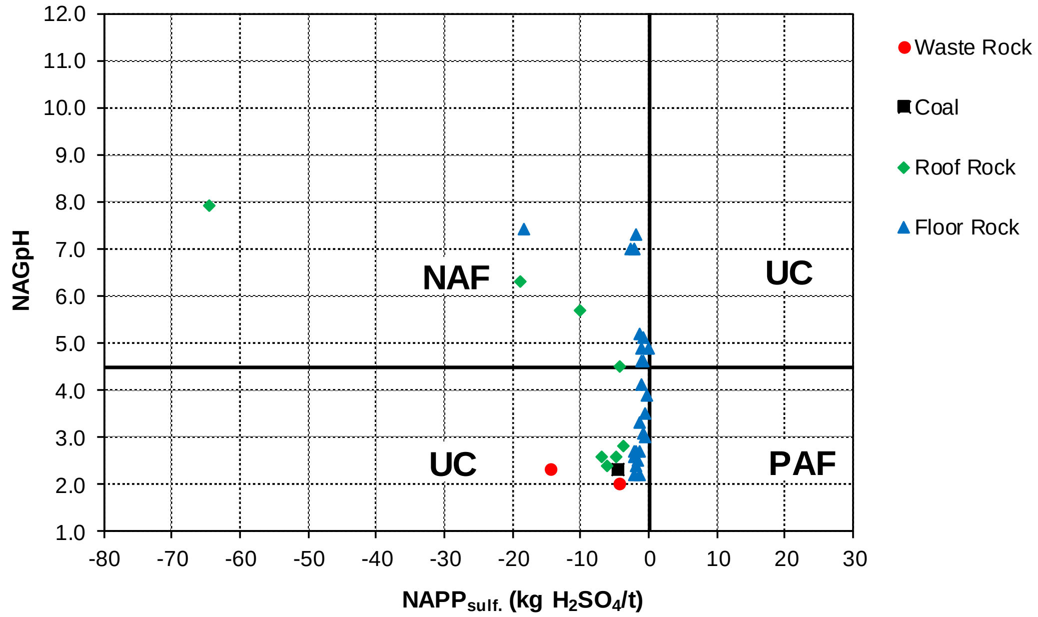

Figure 8: Geochemical classification plot for the mine rock and development waste samples using the standard NAG test.

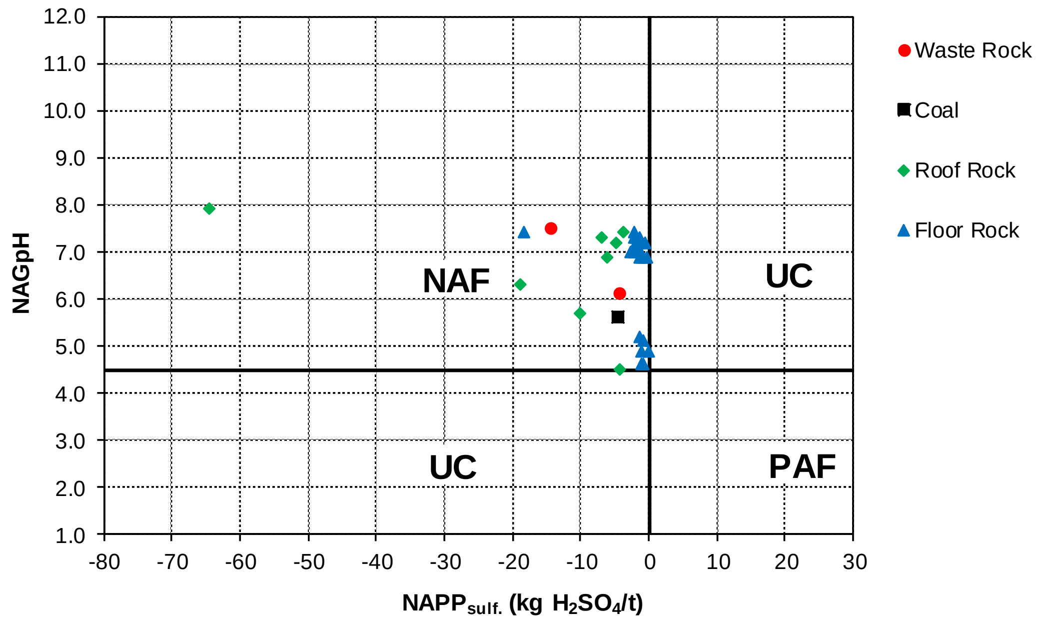

Figure 9: Geochemical classification plot for the mine rock and development waste samples using the extended boil NAG test.

6.3 Metal Enrichment and Solubility

Fourteen samples representing the mine rock (roof and floor rock) and development waste were selected for multi-element analyses. The results from these analyses and their geochemical abundances indices are provided in Attachment B (Tables B-2 and B-3). These results indicate the slight enrichment of As, Sb and Se in some of the samples and significant enrichment of Sb in one of the development waste samples.

The results of multi-element scans performed on the water extracts (1 part sample/ 2 parts deionised water) from these samples are presented in Attachment B (Table B-4). These results indicate that, under the prevailing neutral to slightly alkaline test pH conditions, high concentrations of dissolved As and Se are consistently found in the mine rock and development waste samples, and that high concentrations of dissolved Mo are found in some of these samples. In order to provide an indication of the relative solubility of these metals, the dissolved concentration ranges are compared to the Australian and New Zealand Environment Conservation Council (ANZECC) irrigation water quality guidelines (ANZECC, 2000) in Table 6 in order to provide an indication of the relative solubility of these metals.

Table 6: Concentration ranges and ANZECC (2000) irrigation water quality guidelines for the readily soluble elements in selected mine rock and development waste samples.

Element	Units	Concentration Range	Water Quality Guideline	
			Short-Term Exposure*	Long-Term Exposure**
As	µg/L	2.7 - 788.8	2,000	100
Mo	µg/L	4.86 - 345.21	50	10
Se	µg/L	18.3 - 121.9	50	20

*Short-term Exposure (up to 20 years)
**Long-term Exposure (up to 100 years)
µg/L = micrograms per litre

These results indicate that the dissolved As concentrations do not exceed the short-term exposure guidelines, but exceed the long-term guidelines in two samples. The dissolved Mo concentrations exceed both the short- and long-term exposure guidelines in some of the samples, and the dissolved Se concentrations exceed both the short- and long-term exposure guidelines in most of the samples. Recommendations for water quality monitoring and management of the underground workings and development waste in regard to these findings are provided in Section 9.0.

7 Coal and Coarse Reject Geochemistry

The geochemical test results for the coal and coarse reject samples, including the $pH_{1:2}$ and $EC_{1:2}$, acid forming characteristics, and element enrichment and solubility, are provided in Attachment C (Tables C-1, C-2 and C-3) and a summary of the acid forming characteristics is provided in Table 7.

Table 7: Summary of the acid forming characteristics for the composited coal and coarse reject samples.

Material Type		$pH_{1:2}$ *	$EC_{1:2}$ (dS/m)	Total S (%S)	Sulfide S (%S)	ANC (kg H_2SO_4/t)	$NAPP_{sulf.}$ (kg H_2SO_4/t)	NAGpH**
Raw Coal	HSK2 Seam	7.3	0.143	0.33	0.02	7	-6	7.1
	Other Seams	8.3	0.360	0.34	0.06	9	-7	7.2
Product Coal	PCI	6.9	0.087	0.37	0.01	1	-1	6.5
	Thermal	7.1	0.161	0.38	0.06	8	-6	7.2
Coarse Reject		6.2	1.050	3.74	3.48	50	56	3.9

* Average pH values reported are median values.
** NAGpH derived from the Extended Boil NAG Test.

7.1 pH and Salinity

The raw coal samples are both relatively alkaline and non-saline with $pH_{1:2}$ values of 7.3 and 8.3, and $EC_{1:2}$ values of 0.143 and 0.360 dS/m for the Hoskissons Seam (HSK2) and other seams, respectively. The product coal samples are both pH neutral and non-saline with $pH_{1:2}$ values of 6.9 and 7.1, and $EC_{1:2}$ values of 0.087 and 0.161 dS/m for the PCI and thermal coal samples, respectively. The coarse reject sample is slightly acidic and slightly saline with a $pH_{1:2}$ value of 6.2 and an $EC_{1:2}$ value of 1.050 dS/m.

7.2 Acid Forming Characteristics

The acid forming characteristics of the composited raw and product coal samples are relatively similar with total S contents ranging from 0.33 to 0.38%S and ANC values ranging from 1 to 9 kg H_2SO_4/t. The sulfide S contents range from only 0.014 to 0.057%S indicating that the reactive sulfide S content only makes up 4 to 16% of the contained total S. These results indicate that the S contained in these materials occurs predominantly as sulfate and/or other organic or native S forms. Differing from these characteristics, the composite coarse reject sample has a total S content of 3.74%S and a sulfide S content of 3.48%S indicating that 93% of the contained S in this sample occurs as reactive sulfide. This sample has an ANC of 50 kg H_2SO_4/t.

Figure 10 is an ABA plot for the coal and coarse reject samples where the sulfide S content is plotted against the ANC. This plot shows that all of the coal samples are NAPP negative and considered to be barren in terms of acid generation and neutralisation. However, with a sulfide S content of 3.48%S and an ANC of 50 kg H_2SO_4/t, the coarse reject sample is NAPP positive with a NAPP value of 56 kg H_2SO_4/t.

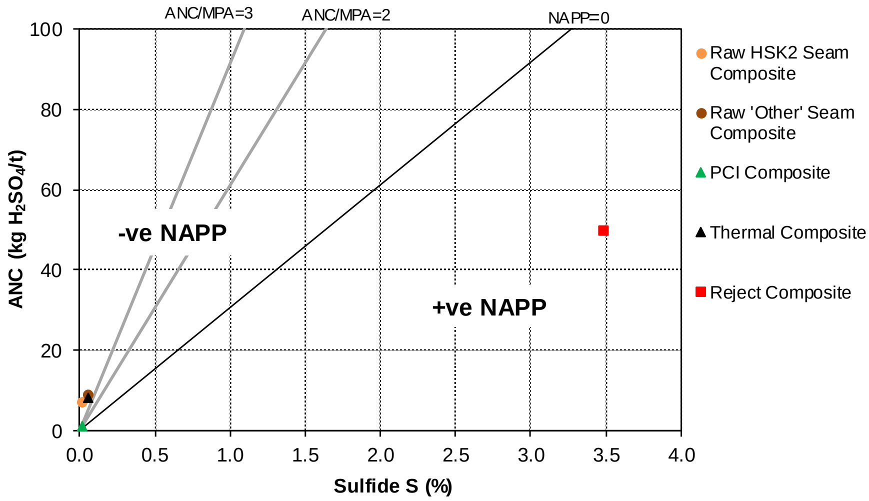

Figure 10: Acid-base account plot for coal and coarse reject samples.

The standard NAG test results for these samples indicate that all of the composited coal and coarse reject samples have a NAGpH < 4.5, ranging from 2.4 to 2.6 for the coal samples and being 3.0 for the coarse reject sample. Figure 11 is the geochemical classification plot for these samples using the NAGpH from the standard NAG test. This plot shows that, being NAPP positive with a NAGpH < 4.5, the coarse reject sample is classified as PAF. However, being NAPP negative with a NAGpH < 4.5, all of the various coal samples have a UC classification.

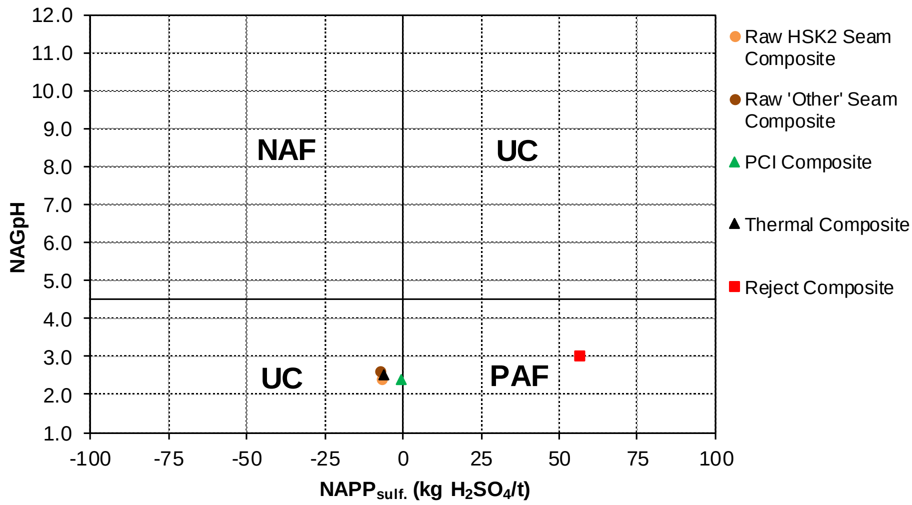

Figure 11: Geochemical classification plot for the coal and coarse reject samples using the standard NAG test.

When subjected to the extended boil NAG test, due to their carbonaceous nature, the NAGpH values for the coal samples increased to > 4.5 with a range of 6.5 to 7.2, and for the coarse reject sample the NAGpH remained < 4.5 at a value of 3.9. Figure 12 is a geochemical classification plot for the coal and coarse reject samples using the NAGpH from the extended boil NAG test. This plot shows that, with a negative NAPP value and a NAGpH > 4.5, the coal samples are classified as NAF, and that with a negative NAPP and a NAGpH of 3.9, the coarse reject sample is classified as PAF.

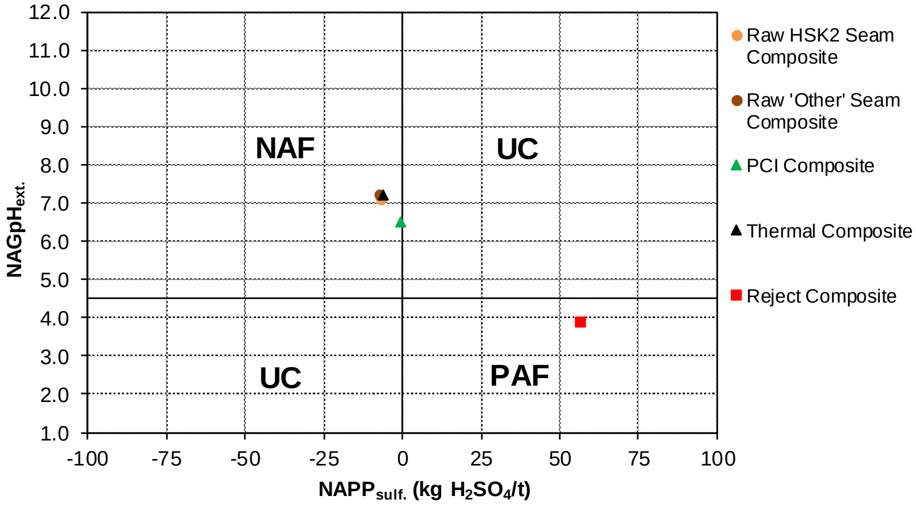

Figure 12: Geochemical classification plot for the coal and coarse reject samples using the extended boil NAG test.

The coarse reject sample has a NAPP value of 56 kg H_2SO_4/t when the sulfide S content is used to calculate the NAPP. However, this sample only has a NAG capacity of 1 kg H_2SO_4/t when titrated to pH 4.5, indicating that the material represented by this sample is only expected to have a low capacity to generate acid (PAF-LC).

7.3 Metal Enrichment and Solubility

Multi-element scans were performed on the 4 raw and product coal samples and the coarse reject sample and the results of these scans and the geochemical abundance indices are provided in Attachment C (Table C-2). These results indicate that Se is significantly enriched in all of the samples and that additional to this, As and Mo are significantly enriched in the coarse reject sample.

The results of multi-element scans performed on the water extracts (1 part sample/2 parts deionised water) from these samples are presented in Attachment C (Table C-3). These results indicate that Se is readily soluble in all of the composited coal and coarse reject samples and that Mo is readily soluble in the coal samples only. The concentrations of Se and Mo in these samples are compared to the ANZECC irrigation and general use water quality guidelines (ANZECC, 2000) in Table 8 in order to provide an indication of the relative solubility of these metals. A stated goal of the ANZECC irrigation and general use water quality guidelines (ANZECC, 2000) is to maintain the productivity of irrigated agricultural land and associated water resources, in accordance with the principles of ecologically sustainable development and integrated catchment management. The ANZECC irrigation and general use water quality guidelines (ANZECC, 2000) are therefore considered appropriate for the Project.

Table 8: Concentration ranges and ANZECC (2000) irrigation water quality guidelines for the readily soluble elements in the composited coal and coarse reject samples.

Element	Chemical Composition					Water Quality Guideline	
	Raw Coal		Product Coal		Coal	Short Term Exposure*	Long Term Exposure**
	HSK2 Seam	Other Seams	PCI	Thermal	Reject		
Mo (ug/l)	51.39	178.17	43.13	54.65	10.35	50	10
Se (ug/l)	164.7	170.6	81.3	108.8	138.4	50	20

*Short-term Exposure (up to 20 years)

**Long-term Exposure (up to 100 years)

These results indicate that the dissolved Se concentrations exceed the long-term and short-term exposure guidelines in all of the coal and coarse reject samples, and that the dissolved Mo concentrations exceed the long-term and short-term exposure guidelines in the coal samples only. Recommendations for water quality monitoring and management of the ROM and product coal stockpiles, and the coarse rejects in regard to these findings are provided in Section 9.0.

8 Exploration Drill Hole Waste Geochemistry

The acid forming characteristics of the exploration drill hole sample are provided below in Table 9 and the element composition of the sample solid, water extract and decant, are provided in Attachment C (Tables C-2 and C-3).

Table 9: Acid forming characteristics of exploration drill hole waste material.

Material Type	ACID-BASE ANALYSIS				NAG TEST			Geochem. Class.
	Tot.S	MPA	ANC	NAPP	NAGpH	$NAG_{pH4.5}$	$NAG_{pH7.0}$	
	(%S)	(kgH_2SO_4/t)				(kgH_2SO_4/t)		
Drill Waste	0.17	5.3	11.7	-6.4	7.1	0	0	NAF

With a total S content of 0.17%S and an ANC of 12 kg H_2SO_4/t, resulting in a NAPP of minus 6 kg H_2SO_4/t, this sample is considered to be barren in terms of acid generation and neutralisation. The NAGpH of 7.1 confirms that the material represented by this sample is expected to be NAF.

The solids from the exploration drill hole waste slurry sample is significantly enriched with Se and less so with As. The water extract from the solid fraction is relatively alkaline, with a $pH_{1:2}$ of 8.9, and slightly saline, with an $EC_{1:2}$ of 0.693 dS/m. This salinity is due to the presence, in equal proportion, of SO_4 and Cl salts. Relatively high concentrations of dissolved As, Mo and Se indicate that these metals are likely to be readily soluble in the exploration drilling wastes represented by this sample.

The decant collected from the exploration drill hole waste slurry sample is pH neutral with a $pH_{1:2}$ of 7.6 and has high salinity with an $EC_{1:2}$ of 3.59 dS/m. The high salinity is primarily due to the presence of NaCl salt. Differing from the water extract collected from this sample, the decant, although having high concentrations of dissolved Se, also has relatively high concentrations of dissolved Co.

9 Conclusions and Recommendations

The following sections provide the conclusions and recommendations for the key mine material types and facilities for the Project.

9.1 Development Waste

Based on the geochemical characteristics of the development waste from the current investigation and the overburden from previous investigations, the material that would be excavated during development of the underground operations at the Project is expected to be non- to slightly saline and NAF. Typical for the overburden in this region, the development waste is expected to be enriched with As, Sb and Se, and the As and Se are expected to be readily soluble. The identified high concentrations of dissolved As and Se are most likely due to the flushing of these readily soluble metals.

Geochemical Characteristics

- Non- to slightly saline.
- NAF.
- Enriched As, Sb and Se.
- Soluble As and Se.

Recommendations
Based on these findings the following recommendations are made:

- No specific management measures for this material would be required for ongoing geochemical security of this material.
- This material is expected to be geochemically suitable for use on-site for construction and/or earthworks, as required.

9.2 Underground Mine Workings

Current investigations indicate that the roof and floor rock (i.e. the mine rock) for the Project would be NAF and that no PAF material is expected to be encountered.

Geochemical Characteristics
- Non-saline.
- NAF.
- Enriched As and Se.
- Soluble As and Se.

Recommendations
Based on these findings the following recommendations are made:

- No specific measures would be required in regard to the control of acid generation within the underground workings.

9.3 Coal Stockpiles

The ROM and product coal would continue to be stockpiled on-site at the ROM and product stockpiles within the Pit Top Area for the Project. The geochemical characteristics of these materials indicate that both the ROM and product coal would be non-saline and NAF. However, these materials are expected to be enriched with Se and that readily soluble Mo and Se would be flushed from the coal when stockpiled if left exposed to water infiltration and leaching.

Geochemical Characteristics
- Non-saline.
- NAF.
- Enriched Se.
- Soluble Mo and Se.

Recommendations
Based on these findings the following recommendations are made:

- No specific measures would be required for the control of acid generation within the ROM and product coal stockpiles.

9.4 Coarse Rejects

The rejects produced during coal processing would comprise the coarse fraction (>25mm) with a SG >1.7 (i.e. sinks). A composite sample of the coarse rejects was found to be slightly acidic, with a relatively high total S content (3.74%S) and moderate ANC (50 kg H_2SO_4/t). This material is considered reactive and based on the NAG test results is classified as PAF-LC. The coarse rejects are expected to be enriched with As, Mo and Se, and Se is expected to be readily soluble.

Geochemical Characteristics
- Slightly saline and acidic.
- PAF-LC.
- Enriched As, Mo and Se.
- Soluble Se.

Recommendations

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

- Coarse rejects should continue to be deposited within the Reject Emplacement Area in accordance with existing management measures (Section 4.3). However, due to the risk of developing saline or low pH conditions (refer to below regarding PAF risk) if the rejects are left exposed for extended periods, it is recommended that an interim cap is placed on the surface of the rejects if they are not overdumped within a suitable timeframe. Additional to this, it is recommended that the final layer of each cell is capped with the clay capping material as soon as practical in order to minimise exposure of the rejects.
- If highly saline and/or acidic conditions are allowed to develop in the exposed rejects prior to capping, the stored salts and/or acidity are likely to migrate to the surface of the capping, therefore potentially impacting revegetation and surface water drainage.
- Based on the previous and current test results the bulk of the coarse reject is expected to be NAF and that a relatively small amount of PAF-LC material may occur. Although mixing during disposal is expected to produce an overall NAF material, it is recommended that NCOPL undertake a confirmatory testing program when suitable materials are available to further evaluate the presence of PAF-LC material identified in the Project area.
- The recommended testing program should include leach column tests on selected representative samples of the coarse reject in order to evaluate the leaching behaviour of this material and determine the maximum period of exposure prior to saline and/or acidic conditions being developed, as applicable.
- The samples required for the recommended confirmatory testing should be collected from the surface of the Reject Emplacement Area and/or during active disposal of the coarse rejects, prior to capping.
- The need for ongoing periodic confirmatory testing should be assessed after a suitable period of operation (e.g. 12 months).

9.5 Exploration Drill Hole Waste Material

The sample representing the exploration drill hole waste is slightly saline and NAF. This material is enriched with Se and, to a lesser extent, As and Mo. In addition to this, the contained As, Mo and Se are expected to be readily soluble under the relatively alkaline pH conditions. The decant is pH neutral with high salinity due primarily to the presence of NaCl salts.

Geochemical Characteristics
Solids

- Slightly saline.
- NAF.
- Enriched As, Mo and Se.
- Soluble As, Mo and Se.

Decant

- Highly saline.
- High dissolved Co and Se.

Recommendations
Based on these findings the following recommendations are provided for managing the exploration drilling waste:

- The exploration drill hole waste slurry (solids and decant) should be co-disposed with the coarse rejects in the Reject Emplacement Area, and the existing Reject Emplacement Area management measures (Section 4.3) should be adopted.

9.6 Water Quality Monitoring and Management

Due to the enrichment and/or expected solubility of the identified elements, it is recommended that they, along with the general water quality parameters, are included in the site water quality monitoring program/s:

- pH, EC, total alkalinity, acidity and SO_4, As, Co, Mo, Sb and Se.

The data generated from the site water quality monitoring program should be periodically reviewed and it is recommended that this review be carried out annually. The primary objective of this review is to determine if the Project is impacting the site water quality and to assess if the release of this water would be likely to adversely impact the quality of water in the receiving environment. This program should also include a review of the water quality monitoring parameters and the modification of these parameters, as required

The potential impacts on the surface water quality for the Project are assessed in the Surface Water Assessment (WRM, 2020).

10 References

ATC Williams Pty Ltd (2019) *Narrabri Mine Rejects Emplacement Area Capping Assessment & Closure Design.* Narrabri Coal Operations Pty Ltd.

Australian and New Zealand Environment Conservation Council (2000) *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*. Canberra, October.

Australasian Groundwater and Environmental Consultants (2020) *Narrabri Underground Mine Stage 3 Extension Project – Groundwater Impact Assessment.* Narrabri Coal Operations Pty Ltd.

Bowen H.J.M. (1979) *Environmental Chemistry of the Elements*. Academic Press, London.

Ditton Geotechnical Services Pty Ltd (2020) *Mine Subsidence Assessment for the Narrabri Underground Mine Stage 3 Extension Project*.

Geo-Environmental Management Pty Ltd (2010) *Geochemistry Assessment of Tarrawonga Coal Mine Modification, New South Wales*. Tarrawonga Coal Pty Ltd.

Geo-Environmental Management Pty Ltd (2011) *Tarrawonga Coal Project – Geochemistry Assessment of Overburden, Interburden and Coarse Rejects*. Tarrawonga Coal Pty Ltd.

Geo-Environmental Management Pty Ltd (2012a) *Environmental Geochemistry Assessment of Coarse Rejects from the Narrabri Mine, New South Wales*. Narrabri Coal Operations Pty Ltd.

Geo-Environmental Management Pty Ltd (2012b) *Vickery Coal Project – Geochemistry Assessment of Overburden, Interburden and Coal Rejects*. Whitehaven Coal Limited.

Geo-Environmental Management Pty Ltd (2018) *Vickery Extension Project – Geochemistry Assessment of Overburden, Interburden and Coal Rejects*. Whitehaven Coal Limited.

Geo-Environmental Management Pty Ltd (2019) *Environmental Geochemistry Assessment for the Reject Emplacement Area, Narrabri Coal Mine, Update Report*. Narrabri Coal Operations Pty Ltd.

RGS Environmental Pty Ltd (2009) *Continuation of Boggabri Coal Mine Geochemical Assessment*. Boggabri Coal Pty Ltd.

RGS Environmental Pty Ltd (2011) *Maules Creek Project Geochemical Assessment of Overburden and Potential Coal Reject Materials.* Ashton Resources Limited.

Rhoades J.D., Chanduvi F. and Lesch S.M. (1999) *Soil Salinity Assessment: Methods and Interpretation of Electrical Conductivity Measurements.* FAO Irrigation and Drainage Paper No. 57, Food and Agriculture Organisation of the United Nations, Rome, Italy.

SLR Consulting Australia Pty Ltd (2019) *Narrabri Mine Mining Operations Plan (MOP) Amendment A*. Narrabri Coal Operations Pty Ltd.

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.

Whitehaven Coal Limited (2015) *Narrabri Mine Waste Management Plan*. Narrabri Coal Operations Pty Ltd.

Whitehaven Coal Limited (2017) *Narrabri Mine Water Management Plan*. Narrabri Coal Operations Pty Ltd.

WRM Water & Environment Pty Ltd (2020) *Narrabri Underground Mine Stage 3 Extension Project Surface Water Assessment*. Narrabri Coal Operations Pty Ltd.

Attachment A

Drill Hole Sample Details

Table A-1: Drill hole sample details.

Table A-1: Drill hole sample details for the Narrabri Underground (Stage 3) Project.

Drill-Hole ID	Sample ID	Depth (m)			Material Type
		From	To	Interval	
NC731C	NC731C_CH01	269.96	270.71	0.75	Waste
	NC731C_CH02	277.36	277.89	0.53	Waste
	NC731C_CH03	300.85	301.43	0.58	Floor
	NC731C_CH04	300.69	300.85	0.16	Floor
NC714C	NC714C_CH01	400.21	400.53	0.32	Floor
NC739C	NC739C_CH01	276.01	276.70	0.69	Floor
NC674CR	NC674CR_CH01	354.57	355.13	0.56	Floor
NC732C	NC732C_CH01	304.43	304.67	0.24	Floor
NC733C	NC733C_CH01	337.75	338.70	0.95	Floor
NC720C	NC720C_CH01	264.67	265.49	0.82	Floor
NC738C	NC738C_CH01	280.60	281.45	0.85	Roof
	NC738C_CH02	290.29	290.47	0.18	Floor
	NC738C_CH03	290.69	290.89	0.20	Floor
NC734C	NC734C_CH01	370.83	371.81	0.98	Floor
NC741C	NC741C_CH01	342.72	343.31	0.59	Roof
	NC741C_CH02	343.55	343.68	0.13	Roof
	NC741C_CH03	350.25	351.20	0.95	Floor
	NC741C_CH04	342.28	342.72	0.44	Coal
NC717C	NC717C_CH01	346.99	347.95	0.96	Floor
NC735C	NC735C_CH01	300.40	300.51	0.11	Floor
	NC735C_CH02	300.59	301.33	0.74	Floor
NC736C	NC736C_CH01	374.10	374.19	0.09	Floor
	NC736C_CH02	374.25	375.24	0.99	Floor
NC742C	NC742C_CH01	333.80	334.62	0.82	Roof
	NC742C_CH02	343.22	343.66	0.44	Floor
	NC742C_CH03	343.90	344.09	0.19	Floor
NC740C	NC740C_CH01	350.08	351.08	1.00	Roof
	NC740C_CH02	359.74	359.94	0.20	Floor
	NC740C_CH03	360.21	360.78	0.57	Floor
NC743C	NC743C_CH01	351.77	352.78	1.01	Roof
	NC743C_CH02	360.99	361.13	0.14	Floor
	NC743C_CH03	362.11	363.10	0.99	Floor
NC835C	NC835C_CH01	235.42	236.38	0.96	Roof
	NC835C_CH02	245.41	246.37	0.96	Floor
NC821C	NC821C_CH01	338.48	339.61	1.13	Roof
	NC821C_CH02	347.44	348.40	0.96	Floor

Attachment B

Mine Rock and Development Waste

Geochemical Test Results

Table B-1: Acid forming characteristics of the mine rock and development waste samples.

Sample Code	Depth (m)			Sample Type	$pH_{1:2}$	$EC_{1:2}$	ACID-BASE ANALYSIS							NAG (Standard)			NAG (Extended Boil)			Geochem. Class.
	From	To	Interv.				Total %S	Sulfide %S	MPA	ANC	NAPP	$NAPP_{sulf.}$	ANC/MPA	NAGpH	$NAG_{pH4.5}$	$NAG_{pH7.0}$	NAGpH	$NAG_{pH4.5}$	$NAG_{pH7.0}$	
NC731C_CH01	269.96	270.71	0.75	Waste	7.0	0.178	0.456	0.038	14	5	9	-4	0.4	2.0	105	152	6.1	0	3	NAF
NC731C_CH02	277.36	277.89	0.53	Waste	7.7	0.155	0.353	0.009	11	15	-4	-14	1.4	2.3	49	78	7.5	0	0	NAF
NC731C_CH03	300.85	301.43	0.58	Floor	7.9	0.133	0.063	0.05	2	2	0	0	1.0	3.0	6	15	7.2	0	0	NAF
NC731C_CH04	300.69	300.85	0.16	Floor	7.2	0.095	0.130	0.019	4	2	2	-2	0.6	2.4	28	50	7.1	0	0	NAF
NC714C_CH01	400.21	400.53	0.32	Floor	7.9	0.101	0.026	0.011	1	2	-1	-1	2.2	2.7	8	25	7.3	0	0	NAF
NC739C_CH01	276.01	276.70	0.69	Floor	7.8	0.097	0.032	0.029	1	2	-1	-1	1.7	5.1	0	1				NAF
NC674CR_CH01	354.57	355.13	0.56	Floor	8.8	0.391	0.018	0.014	1	19	-18	-18	34.1	7.4	0	0				NAF
NC732C_CH01	304.43	304.67	0.24	Floor	7.9	0.099	0.040	0.01	1	2	-1	-2	1.6	2.5	16	33	7.1	0	0	NAF
NC733C_CH01	337.75	338.70	0.95	Floor	8.1	0.124	0.022	0.025	1	1	-1	-1	2.0	3.5	2	7	7.2	0	0	NAF
NC720C_CH01	264.67	265.49	0.82	Floor	8.0	0.139	0.029	0.038	1	2	-1	-1	2	4.1	0	5	6.9	0	0	NAF
NC738C_CH01	280.60	281.45	0.85	Roof	8.1	0.231	0.171	0.015	5	7	-2	-7	1.4	2.6	33	57	7.3	0	0	NAF
NC738C_CH02	290.29	290.47	0.18	Floor	7.7	0.100	0.026	0.01	1	3	-2	-2	3.2	7.0	0	0				NAF
NC738C_CH03	290.69	290.89	0.20	Floor	8.0	0.093	0.013	0.009	0	1	0	0	1.5	3.9	1	9	6.9	0	0	NAF
NC734C_CH01	370.83	371.81	0.98	Floor	8.0	0.100	0.012	0.009	0	1	-1	-1	4.0	4.6	0	6				NAF
NC741C_CH01	342.72	343.31	0.59	Roof	8.9	0.475	0.086	0.025	3	65	-63	-65	24.8	7.9	0	0				NAF
NC741C_CH02	343.55	343.68	0.13	Roof	8.6	0.329	0.057	0.013	2	4	-2	-4	2.4	2.8	13	28	7.4	0	0	NAF
NC731C_CH05	350.25	351.20	0.95	Floor	8.8	0.190	0.014	0.005	0	1	0	-1	2.2	4.6	0	6				NAF
NC731C_CH06	342.28	342.72	0.44	Coal	7.2	0.082	0.536	0.049	16	6	10	-4	0.4	2.3	79	135	5.6	0	3	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)

Geochemical Classification Key

NAF = Non-Acid Forming

PAF = Potentially Acid Forming

PAF-LC = PAF Low Capacity

UC = Uncertain (expected classification)

Table B-1: Acid forming characteristics of the mine rock and development waste samples. CONTINUED

Sample Code	Depth (m)			Sample Type	$pH_{1:2}$	$EC_{1:2}$	ACID-BASE ANALYSIS							NAG (Standard)			NAG (Extended Boil)			Geochem. Class.
	From	To	Interv.				Total %S	Sulfide %S	MPA	ANC	NAPP	$NAPP_{sulf.}$	ANC/MPA	NAGpH	$NAG_{pH4.5}$	$NAG_{pH7.0}$	NAGpH	$NAG_{pH4.5}$	$NAG_{pH7.0}$	
NC731C_CH07	346.99	347.95	0.96	Floor	8.2	0.136	0.050	0.01	2	2	0	-1	1.1	2.2	23	44	7.2	0	0	NAF
NC731C_CH08	300.40	300.51	0.11	Floor	7.8	0.110	0.091	0.01	3	3	0	-2	0.9	2.2	29	50	7.1	0	0	NAF
NC714C_CH02	300.59	301.33	0.74	Floor	7.9	0.107	0.020	0.009	1	2	-1	-1	2.6	3.3	3	15	6.9	0	0	NAF
NC739C_CH02	374.10	374.19	0.09	Floor	7.8	0.134	0.053	0.011	2	3	-1	-2	2	2.6	18	36	7.4	0	0	NAF
NC674CR_CH02	374.25	375.24	0.99	Floor	8.6	0.196	0.015	0.013	0	2	-2	-2	5.3	7.0	0	0				NAF
NC732C_CH02	333.80	334.62	0.82	Roof	8.5	0.250	0.267	0.028	8	7	1	-6	0.9	2.4	55	89	6.9	0	0	NAF
NC733C_CH02	343.22	343.66	0.44	Floor	8.2	0.134	0.023	0.025	1	1	0	0	1.3	4.9	0	3				NAF
NC720C_CH02	343.90	344.09	0.19	Floor	8.5	0.181	0.017	0.006	1	2	-2	-2	4.1	7.3	0	0				NAF
NC738C_CH04	350.08	351.08	1.00	Roof	8.5	0.250	0.227	0.04	7	6	1	-5	0.9	2.6	38	63	7.2	0	0	NAF
NC738C_CH05	359.74	359.94	0.20	Floor	8.2	0.138	0.038	0.013	1	3	-1	-2	2.2	2.7	13	29	7.3	0	0	NAF
NC738C_CH06	360.21	360.78	0.57	Floor	8.5	0.164	0.016	0.017	0	2	-1	-1	3.7	5.2	0	3				NAF
NC734C_CH02	351.77	352.78	1.01	Roof	8.6	0.334	0.174	0.019	5	20	-14	-19	3.7	6.3	0	1				NAF
NC741C_CH03	360.99	361.13	0.14	Floor	7.9	0.095	0.029	0.011	1	2	-1	-2	2.5	2.7	12	28	7.1	0	0	NAF
NC741C_CH04	362.11	363.10	0.99	Floor	8.2	0.117	0.016	0.013	0	1	-1	-1	2.9	4.9	0	5				NAF
NC731C_CH09	235.42	236.38	0.96	Roof	8.6	0.337	0.058	0.025	2	11	-9	-10	6.2	5.7	0	3				NAF
NC731C_CH10	245.41	246.37	0.96	Floor	8.5	0.170	0.037	0.024	1	2	-1	-1	1.5	3.1	5	19	6.9	0	0	NAF
NC731C_CH11	338.48	339.61	1.13	Roof	8.4	0.183	0.037	0.019	1	5	-4	-4	4.4	4.5	0	6				NAF
NC731C_CH12	347.44	348.40	0.96	Floor	8.6	0.106	0.021	0.009	1	3	-2	-3	4.6	7.0	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 (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)

Geochemical Classification Key

NAF = Non-Acid Forming

PAF = Potentially Acid Forming

PAF-LC = PAF Low Capacity

UC = Uncertain (expected classification)

Table B-2: Multi-element composition of selected mine rock and development waste samples.

Element	Unit	Detect. Limit	Element Concentration													
			731-1	731-2	731-4	738-1	738-2	742-1	742-2	740-1	740-2	835-1	835-2	821-1	821-2	741-4
			Waste	Waste	Floor	Roof	Floor	Roof	Floor	Roof	Floor	Roof	Floor	Roof	Floor	Coal
Ag	mg/kg	0.05	<	<	<	<	<	<	0.06	0.2	<	<	0.05	<	<	<
Al	%	0.005%	3.175%	2.205%	4.365%	6.528%	8.151%	7.070%	7.313%	7.280%	9.839%	9.924%	7.331%	8.766%	6.470%	1.722%
As	mg/kg	0.5	4.7	2.4	0.6	2.8	0.8	1.2	1.3	2.0	1.1	8.6	1.9	8.7	1.2	3.9
B	mg/kg	50	<	<	<	<	<	<	<	<	<	<	<	<	<	<
Ba	mg/kg	0.1	92.6	174.8	195.7	405.8	287.9	235.6	384.2	362.4	470.5	508.6	410.2	571.1	361.6	83.6
Be	mg/kg	0.05	5.37	5.40	1.74	1.31	1.28	1.35	1.63	2.11	3.09	1.57	1.42	1.48	1.16	1.79
Ca	%	0.005%	0.077%	0.251%	0.024%	0.089%	0.044%	0.114%	0.029%	0.108%	0.039%	0.098%	0.014%	0.103%	0.047%	0.106%
Cd	mg/kg	0.02	0.11	0.08	0.07	0.12	0.06	0.20	0.07	0.15	0.12	0.16	0.08	0.13	0.06	<
Co	mg/kg	0.1	6.3	10.8	2.3	3.7	1.5	4.8	2.7	6.3	1.6	4.5	3.4	3.3	1.3	9.9
Cr	mg/kg	5	<	22	51	21	49	12	57	16	69	32	63	32	54	7
Cu	mg/kg	1	8	17	20	21	25	19	16	16	30	23	11	19	10	9
Fe	%	0.01%	0.17%	0.09%	0.27%	1.04%	0.99%	0.86%	0.52%	0.88%	0.46%	1.36%	0.34%	0.99%	1.31%	0.85%
Hg	mg/kg	0.2	0.010	0.044	0.018	0.038	0.016	0.066	0.016	0.091	0.044	0.044	0.051	0.046	0.021	0.007
K	%	0.002%	0.102%	0.137%	0.736%	1.759%	1.077%	0.869%	1.577%	1.723%	1.817%	2.369%	1.712%	2.363%	1.457%	0.173%
Mg	%	0.002%	0.045%	0.088%	0.112%	0.289%	0.152%	0.160%	0.102%	0.192%	0.188%	0.319%	0.098%	0.201%	0.088%	0.089%
Mn	mg/kg	1	16	10	17	59	213	30	151	49	22	99	29	108	428	179
Mo	mg/kg	0.1	3.0	2.5	0.4	1.8	0.2	1.6	0.3	1.8	0.3	1.0	0.3	1.0	0.2	3.1
Na	%	0.002%	0.055%	0.063%	0.095%	0.172%	0.114%	0.113%	0.123%	0.206%	0.183%	0.494%	0.137%	0.207%	0.104%	0.040%
Ni	mg/kg	1	9	13	10	8	10	8	11	9	9	10	7	9	5	10
P	mg/kg	50	<	63	60	72	70	75	75	73	140	103	75	127	<	<
Pb	mg/kg	0.5	20.2	11.5	18.3	17.4	20.8	17.8	23.7	23.1	28.7	23.9	26.5	22.1	17.7	7.2
Sb	mg/kg	0.05	7.04	1.49	0.91	0.98	0.49	0.46	0.39	0.84	0.51	1.01	0.34	0.84	0.37	0.58
Se	mg/kg	0.01	0.11	0.28	0.29	0.24	0.27	0.42	0.19	0.31	0.33	0.23	0.09	0.25	0.05	0.14
Si	%	0.001	0.03	0.13	0.27	0.23	0.32	0.17	0.34	0.20	0.30	0.30	0.35	0.31	0.36	0.07
Sn	mg/kg	0.1	2.9	1.5	3.2	2.5	3.8	3.1	3.1	3.6	4.4	3.6	3.5	3.1	2.3	0.6
Th	mg/kg	0.01	12.17	8.17	11.24	11.89	13.54	12.34	13.10	15.24	17.75	15.54	11.21	14.31	8.00	3.21
U	mg/kg	0.01	3.65	2.73	2.58	3.48	2.65	3.11	3.20	3.98	3.41	4.56	2.66	4.14	2.00	1.41
V	mg/kg	1	15	58	90	89	62	52	72	62	146	101	71	90	28	31
Zn	mg/kg	1	50	38	36	21	15	82	49	47	49	74	89	66	17	7

< element at or below analytical detection limit.

Table B-3: Geochemical abundance indices for selected mine rock and development waste samples.

Element	***Mean Crustal Abund.**	**Geochemical Abundance Indicies (GAI)**													
		731-1	731-2	731-4	738-1	738-2	742-1	742-2	740-1	740-2	835-1	835-2	821-1	821-2	741-4
		Waste	Waste	Floor	Roof	Floor	Roof	Floor	Roof	Floor	Roof	Floor	Roof	Floor	Coal
Ag	0.07	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Al	8.2%	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As	1.5	1	-	-	-	-	-	-	-	-	2	-	2	-	1
B	10	<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	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Co	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cr	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cu	50	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe	4.1%	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hg	0.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
K	2.1%	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mg	2.3%	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn	950	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mo	1.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Na	2.3%	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ni	80	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P	1000	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pb	14	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sb	0.2	**5**	2	2	2	1	1	-	1	1	2	-	1	-	1
Se	0.05	1	2	2	2	2	2	1	2	2	2	-	2	-	1
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-4: Chemical composition of water extracts from selected mine rock and development waste samples.

Parameter	Unit	Detection Limit	Chemical Compostion													
			731-1	731-2	731-4	738-1	738-2	742-1	742-2	740-1	740-2	835-1	835-2	821-1	821-2	741-4
			Waste	Waste	Floor	Roof	Floor	Roof	Floor	Roof	Floor	Roof	Floor	Roof	Floor	Coal
pH		0.1	7.0	7.7	7.2	8.1	7.7	8.5	8.2	8.5	8.2	8.6	8.5	8.4	8.6	7.2
EC	dS/m	0.001	0.178	0.155	0.095	0.231	0.100	0.250	0.134	0.250	0.138	0.337	0.170	0.183	0.106	0.082
SO4	mg/l	0.3	32.3	14.7	12.2	8.4	10.6	11.2	26.2	12.0	15.9	32.4	42.3	23.6	13.5	5.2
Cl	mg/l	2.0	6	2	3	2	2	2	2	2	2	5	6	2	3	6
Major Constituents																
Al	mg/l	0.01	0.06	0.18	0.10	0.71	0.27	2.17	0.21	2.21	1.07	3.71	0.63	2.57	1.39	0.10
B	mg/l	0.01	0.06	0.05	0.05	0.03	0.04	0.05	0.02	0.04	0.06	0.1	0.05	0.04	0.03	0.09
Ca	mg/l	0.01	1.34	1.53	0.21	0.25	0.14	0.50	0.13	0.40	0.15	0.24	0.09	0.27	0.22	0.27
Cr	mg/l	0.01	<	<	<	<	<	<	<	<	<	<	<	<	<	<
Cu	mg/l	0.01	<	<	<	<	<	<	<	<	<	<	<	<	<	<
Fe	mg/l	0.01	0.02	0.02	<	0.08	0.03	0.21	0.03	0.19	0.25	0.22	0.04	0.17	0.09	0.04
K	mg/l	0.1	1.7	2.1	0.9	3.8	1.4	4.1	1.3	4.8	1.7	9.6	3.1	4.6	2.4	1.8
Mg	mg/l	0.01	0.61	0.27	0.03	0.07	0.03	0.15	0.02	0.14	0.04	0.22	0.05	0.14	0.07	0.05
Mn	mg/l	0.01	<	<	<	<	<	<	<	<	<	<	<	<	<	<
Na	mg/l	0.1	54.5	53.6	29.3	69.8	35.4	96.0	46.9	94.0	60.9	154.7	77.2	86.0	56.5	34.7
Ni	mg/l	0.01	<	<	<	<	<	<	<	<	<	<	<	0.01	<	<
P	mg/l	0.1	<	<	<	<	<	<	<	<	<	<	<	<	<	<
Si	mg/l	0.05	1.13	1.45	3.07	4.14	3.58	5.40	3.34	5.62	5.72	5.49	2.80	7.30	5.87	2.13
V	mg/l	0.01	<	0.01	0.01	0.02	<	<	<	0.01	0.03	0.02	<	0.02	<	<
Zn	mg/l	0.01	0.01	0.01	0.05	0.01	0.01	0.01	0.02	0.01	0.18	0.01	<	0.04	0.01	<
Minor Constituents																
Ag	ug/l	0.01	0.09	0.02	0.07	0.03	0.02	0.02	0.01	<	0.16	0.06	0.04	0.01	<	0.02
As	ug/l	0.1	6.6	52.4	4.9	99.3	20.7	6.1	37.9	26.7	11.9	174.7	63.5	788.8	27.9	2.7
Ba	ug/l	0.05	78.85	59.37	7.91	18.22	7.34	27.72	6.43	39.14	14.61	17.73	5.05	21.41	15.62	10.43
Be	ug/l	0.1	<	<	<	<	<	0.2	<	0.3	0.2	0.2	<	0.3	0.2	<
Cd	ug/l	0.50	<	<	<	<	<	<	<	<	<	<	<	<	<	0.60
Co	ug/l	0.1	0.9	0.4	0.1	0.1	<	0.4	0.2	0.4	<	0.8	0.3	3.4	0.6	0.3
Hg	ug/l	0.1	<	<	<	<	<	<	<	<	<	<	<	<	<	<
Mo	ug/l	0.05	126.97	168.36	4.86	249.05	7.15	199.69	18.58	127.97	11.36	235.83	49.88	345.21	18.35	67.52
Pb	ug/l	2.0	3.0	<	<	<	<	<	<	<	3.0	<	<	3.0	<	3.0
Sb	ug/l	0.01	4.86	2.16	0.93	1.10	1.37	0.47	2.26	1.20	1.77	3.74	2.40	5.78	1.68	0.41
Se	ug/l	0.5	59.0	64.7	46.4	61.2	51.1	108.7	75.0	121.9	71.5	85.6	28.3	85.8	18.3	23.9
Sn	ug/l	0.1	<	<	<	<	<	<	<	0.1	<	0.1	<	<	<	<
Th	ug/l	0.005	0.044	0.041	0.020	0.385	0.086	0.271	0.013	0.758	0.566	0.632	0.186	0.777	0.267	0.029
U	ug/l	0.005	0.899	1.215	0.050	0.337	0.031	0.736	0.065	1.255	0.105	0.341	0.074	0.211	0.063	0.177

< element at or below analytical detection limit.

Attachment C

Coal, Coarse Reject and Exploration Drill Hole Waste

Geochemical Test Results

Table C-1: Acid forming characteristics of the raw coal, product coal and coarse reject composite samples.

Material Type	Composite Sample ID	$pH_{1:2}$	$EC_{1:2}$	ACID-BASE ANALYSIS							NAG (Standard)			NAG (Extended Boil)			Geochem Class.
				Total %S	Sulfide %S	MPA	ANC	NAPP	$NAPP_{sulf.}$	ANC/ MPA	NAGpH	$NAG_{pH4.5}$	$NAG_{pH7.0}$	NAGpH	$NAG_{pH4.5}$	$NAG_{pH7.0}$	
Raw Coal	HSK2 Seam	7.3	0.143	0.33	0.018	10	7	3	-6	0.7	2.4	121	199	7.1	0	0	NAF
	Other Seams	8.3	0.360	0.34	0.055	10	9	1	-7	0.9	2.6	78	133	7.2	0	0	NAF
Product Coal	PCI	6.9	0.087	0.37	0.014	11	1	10	-1	0.1	2.4	128	209	6.5	0	1	NAF
	Thermal	7.1	0.161	0.38	0.057	12	8	4	-6	0.7	2.5	102	168	7.2	0	0	NAF
Coarse Reject	Rejects	6.2	1.050	3.74	3.48	114	50	64	56	0.4	3.0	37	54	3.9	1	3	PAF

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)

Geochemical Classification Key

NAF = Non-Acid Forming

PAF = Potentially Acid Forming

PAF-LC = PAF Low Capacity

UC = Uncertain (expected class.)

Table C-2: Multi-element composition and geochemical abundance indices for the coal and coarse reject composites, and the exploration drill hole waste.

Element	Unit	Detect. Limit	Element Concentration						Element	*Mean Crustal Abund.	Geochemical Abundance Indicies (GAI)					
			Raw Coal		Product Coal		Coarse Reject	Drill Waste			Raw Coal		Product Coal		Coarse Reject	Drill Waste
			HSK2 Seam	Other Seams	PCI Coal	Thermal Coal					HSK2 Seam	Other Seams	PCI Coal	Thermal Coal		
Ag	mg/kg	0.05	<	<	<	<	<	<	Ag	0.07	-	-	-	-	-	-
Al	%	0.005%	1.197%	6.664%	0.156%	0.287%	4.673%	8.720%	Al	8.2%	-	-	-	-	-	-
As	mg/kg	0.5	<	2.8	<	0.7	143.0	9.0	As	1.5	-	-	-	-	**6**	2
B	mg/kg	50	<	<	<	<	<	<	B	10	<2	<2	<2	<2	<2	<2
Ba	mg/kg	0.1	34.5	126.6	16.3	13.4	162.8	362.2	Ba	500	-	-	-	-	-	-
Be	mg/kg	0.05	1.14	1.83	0.40	0.33	1.15	1.86	Be	2.6	-	-	-	-	-	-
Ca	%	0.005%	0.127%	0.265%	0.012%	0.055%	0.875%	0.581%	Ca	4.0%	-	-	-	-	-	-
Cd	mg/kg	0.02	0.07	0.18	0.05	0.04	0.33	0.44	Cd	0.11	-	-	-	-	1	1
Co	mg/kg	0.1	2.2	3.9	1.4	0.6	4.6	40.5	Co	20	-	-	-	-	-	-
Cr	mg/kg	5	9	12	<	<	18	188	Cr	100	-	-	-	-	-	-
Cu	mg/kg	1	5	20	4	2	14	37	Cu	50	-	-	-	-	-	-
Fe	%	0.01%	0.49%	0.92%	0.27%	0.88%	11.30%	15.70%	Fe	4.1%	-	-	-	-	1	1
Hg	mg/kg	0.2	0.033	0.063	0.006	0.042	1.124	0.173	Hg	0.2	-	-	-	-	2	-
K	%	0.002%	0.029%	0.274%	0.010%	0.011%	0.359%	0.504%	K	2.1%	-	-	-	-	-	-
Mg	%	0.002%	0.056%	0.108%	0.004%	0.019%	0.518%	0.261%	Mg	2.3%	-	-	-	-	-	-
Mn	mg/kg	1	110	196	55	74	2842	5929	Mn	950	-	-	-	-	1	2
Mo	mg/kg	0.1	0.3	1.9	0.2	0.2	19.3	1.6	Mo	1.5	-	-	-	-	**3**	-
Na	%	0.002%	0.026%	0.085%	0.013%	0.012%	0.071%	0.206%	Na	2.3%	-	-	-	-	-	-
Ni	mg/kg	1	9	6	6	3	15	115	Ni	80	-	-	-	-	-	-
P	mg/kg	50	<	57	<	<	60	1050	P	1000	-	-	-	-	-	-
Pb	mg/kg	0.5	4.3	17.6	3.1	2.7	14.6	13.9	Pb	14	-	-	-	-	-	-
Sb	mg/kg	0.05	0.13	0.52	<	<	1.53	0.38	Sb	0.2	-	1	-	-	2	-
Se	mg/kg	0.01	0.56	0.67	0.43	0.71	1.84	0.91	Se	0.05	**3**	**3**	**3**	**3**	**5**	**4**
Si	%	0.001	0.05	0.11	0.03	0.05	0.11	0.16	Si	27.7%	-	-	-	-	-	-
Sn	mg/kg	0.1	0.5	2.8	0.2	0.2	3.3	2.4	Sn	2.2	-	-	-	-	-	-
Th	mg/kg	0.01	2.76	10.32	0.60	0.81	5.11	7.43	Th	12	-	-	-	-	-	-
U	mg/kg	0.01	0.89	2.80	0.26	0.30	2.66	2.05	U	2.4	-	-	-	-	-	-
V	mg/kg	1	16	51	5	4	34	173	V	160	-	-	-	-	-	-
Zn	mg/kg	1	19	43	7	7	63	91	Zn	75	-	-	-	-	-	-

< element at or below analytical detection limit.

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

Table C-3: Chemical composition of water extracts from coal and coarse reject composites, and of the water extract and decant from the exploration drill hole waste.

Parameter	**Unit**	**Detect. Limit**	**Chemical Compostion**						
			Raw Coal		Product Coal		Coarse Reject	Drill Waste	
			HSK2 Seam	Other Seams	PCI	Thermal		Extract	Decant
pH		0.1	7.3	8.3	6.9	7.1	6.2	8.9	7.3
EC	dS/m	0.001	0.143	0.360	0.087	0.161	1.050	0.693	3.590
SO4	mg/l	0.3	15.5	90.2	8.8	33.0	890.7	132.0	188.0
Cl	mg/l	2.0	7	4	10	21	21	108	470
Major Constituents									
Al	mg/l	0.01	0.19	0.81	0.04	0.08	0.04	0.35	0.37
B	mg/l	0.01	0.08	0.05	0.05	0.07	0.02	0.08	0.17
Ca	mg/l	0.01	9.28	2.87	3.74	15.66	131.11	2.83	7.53
Cr	mg/l	0.01	<	<	<	<	<	<	<
Cu	mg/l	0.01	<	<	<	<	<	0.01	0.01
Fe	mg/l	0.01	0.02	0.13	0.01	0.03	0.02	0.37	0.06
K	mg/l	0.1	3.5	7.1	2.4	5.7	20.9	6.6	15.6
Mg	mg/l	0.01	1.72	0.38	1.15	3.59	33.68	0.74	6.51
Mn	mg/l	0.01	<	<	<	<	0.1	0.0	0.0
Na	mg/l	0.1	66.4	159.9	45.1	73.7	294.4	276.1	1072.6
Ni	mg/l	0.01	<	<	<	<	<	0.06	0.16
P	mg/l	0.1	<	<	<	<	<	<	<
Si	mg/l	0.05	0.96	3.12	1.64	2.74	2.31	2.35	2.89
V	mg/l	0.01	<	<	<	<	<	0.02	<
Zn	mg/l	0.01	0.01	0.01	<	0.02	0.01	0.03	0.04
Minor Constituents									
Ag	ug/l	0.01	<	<	<	0.01	0.02	0.01	<
As	ug/l	0.1	1.0	3.4	0.6	1.2	1.4	27.6	5.8
Ba	ug/l	0.05	82.62	66.04	32.18	128.25	54.05	147.12	144.88
Be	ug/l	0.1	<	<	<	<	<	<	<
Cd	ug/l	0.50	<	<	<	<	<	0.60	<
Co	ug/l	0.1	0.2	0.4	0.2	0.2	6.4	21.4	165.2
Hg	ug/l	0.1	<	<	<	<	<	<	<
Mo	ug/l	0.05	51.39	178.17	43.13	54.65	10.35	434.43	365.78
Pb	ug/l	2.0	3.0	<	4.0	<	<	<	<
Sb	ug/l	0.01	0.42	0.93	0.45	0.43	0.44	4.19	2.48
Se	ug/l	0.5	164.7	170.6	81.3	108.8	138.4	57.1	4.5
Sn	ug/l	0.1	<	<	<	0.2	<	<	<
Th	ug/l	0.005	0.006	0.243	0.011	<	0.009	0.029	0.028
U	ug/l	0.005	0.317	1.089	0.046	0.659	3.026	0.986	1.586

< element at or below analytical detection limit.