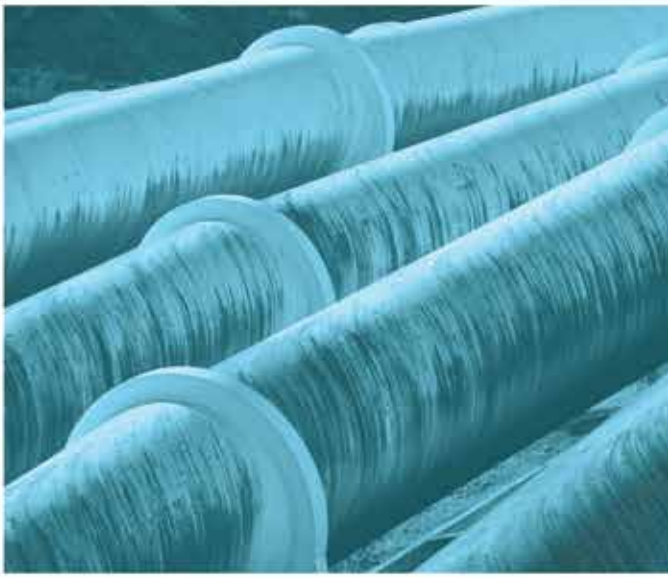
Appendix G

Charbon Colliery - Geochemistry assessment


Charbon Colliery - Modification 2

Geochemistry assessment

Prepared for Centennial Coal Company Limited
August 2020

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Charbon Colliery - Modification 2

Geochemistry assessment

Report Number

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Client

Charbon Coal Pty Limited

Date

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Version

Final

Prepared by	Approved by
	
James Tuff Associate Geochemist 31 August 2020	**Phil Towler** Associate Director 31 August 2020

Executive Summary

Charbon Colliery (Charbon) is an underground and open cut coal mine owned and operated by Charbon Coal Pty Limited (Charbon Coal), a joint venture between Centennial Coal Company Limited (Centennial) and SK Networks Resources Australia Pty Ltd. Charbon has been in operation since the 1920s.

In 2015, mining operations ceased following the depletion of Charbon's approved coal reserves. Since the cessation of mining, Charbon Coal has been progressively rehabilitating the site. Charbon Coal undertakes rehabilitation and mine closure activities at the site pursuant to SSD 08_0211.

It is proposed to use coarse coal reject (CCR) material from Centennial's Clarence Colliery (Clarence) to enhance rehabilitation at Charbon. As nominated in Charbon's *Mining Operations Plan* (MOP), Charbon Coal proposes to import CCR from Clarence by train to backfill historical mining areas requiring rehabilitation. The transfer of CCR from Clarence to Charbon will assist Charbon Coal to better develop a final landform that is representative of existing landforms within and adjacent to site.

Charbon Coal is seeking to modify SSD 08_0211 to allow for the transfer of CCR from Clarence to Charbon and the use of this material on-site during rehabilitation activities. If approved, the proposed modification will authorise:

- the importation of CCR from Clarence to Charbon by rail;
- use of CCR for ongoing rehabilitation at Charbon; and
- an extension of the time permitted to undertake water transfers between Charbon and Airly Mine.

This geochemistry assessment evaluates whether CCR from Clarence is suitable for use during ongoing rehabilitation at Charbon. It investigates the geochemical properties of reject emplacement area (REA) 6 CCR and compares these with waste material on-site at Charbon. The assessment includes a review of Charbon's rehabilitation plans to determine whether provisions have been made to adequately mitigate the potential geochemical impacts arising from use of imported CCR material in rehabilitation at Charbon.

Based on the geochemical characterisation of Clarence and Charbon waste material, REA6 CCR material has similar or lower acid and metalliferous drainage (AMD) risks to the other waste material at Clarence and waste material currently in the Main REA and Northern REA at Charbon.

Water chemistry collected from the Clarence and Charbon REA leachate dams and from laboratory leach testing on waste samples was assessed to provide an indication of the longer-term weathering and leaching characteristics of the coarse coal rejects.

Given the results of the solid sample geochemistry and the leachate water quality, it is recommended that Clarence CCR to be used in rehabilitation activities at Charbon is treated as potentially acid forming (PAF) material, with the capacity to generate AMD if exposed. Field testing of the AMD potential of CCR from Clarence (eg as it is excavated or collected from the production stream) could be used to provide an indication of the buffering capacity required (eg limestone addition rates), which could be used as an additional method to mitigate AMD risk at Charbon.

The final landform at Charbon will be representative of existing landforms within and adjacent to the site. The areas proposed to receive Clarence CCR will be 'water shedding' as they are all hillside rehabilitation landforms. A 3-metre-thick multi-layer moderate hydraulic conductivity cover will be developed on the sloping landforms with store-and-release characteristics. This will allow plant establishment and growth, while minimising deep drainage (potential AMD seepage) and mitigating upward migration of soluble salts.

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1 Introduction

1.1 Overview

Charbon Colliery (Charbon) is an underground and open cut coal mine owned and operated by Charbon Coal Pty Limited (Charbon Coal), a joint venture between Centennial Coal Company Limited (Centennial) and SK Networks Resources Australia Pty Ltd. Charbon is approximately 87 kilometres (km) north-west of Lithgow and 3 km south of Kandos in the Western Coalfields of New South Wales (NSW) within the Mid-Western Regional local government area (LGA) (Figure 1.1). The project site boundary shown on Figure 1.1 covers an area of 2,692 hectares (ha) (the site) and comprises historical underground workings and open cut areas.

Charbon was approved as a Major Project under the now repealed Section 75J Part 3A of the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act) on 7 September 2010 (PA 08_0211). PA 08_0211 has since been declared a State significant development (SSD) under Clause 6 of Schedule 2 of NSW Environmental Planning and Assessment (Savings, Transitional and Other Provisions) Regulation 2017 (SSD 08_0211).

Charbon has been in operation since the 1920s and has been owned and operated by Charbon Coal since 1994. In 2015, mining operations ceased following the depletion of Charbon's approved coal reserves. Since the cessation of mining, Charbon Coal has been progressively rehabilitating the site.

Charbon Coal undertakes rehabilitation and mine closure activities at the site pursuant to SSD 08_0211. While mining is permitted to continue until 31 August 2025, only rehabilitation and mine closure activities are currently being undertaken and these activities are approved to continue beyond 31 August 2025. In addition to rehabilitation activities, water is currently transferred from Charbon's existing surface water dams via rail to Centennial Airly Pty Limited's (Centennial Airly's) Airly Mine (Figure 1.1) in accordance with the relevant conditions of SSD 08_0211 and Airly's development consent (SSD-5581). Under SSD-5581, this activity is approved until 31 January 2037.

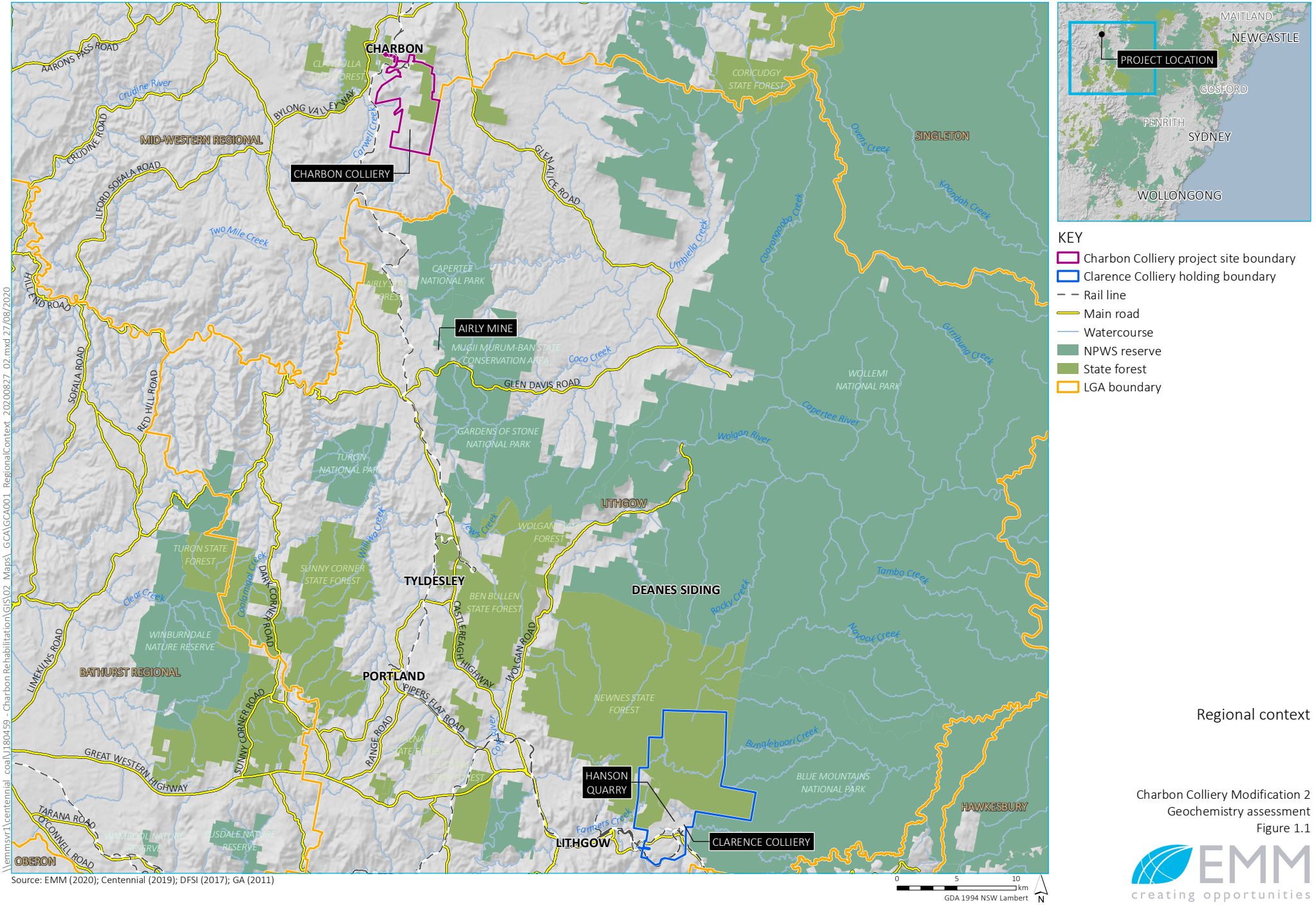
It is proposed to use coarse coal reject (CCR) material from Centennial's Clarence Colliery (Clarence) to enhance rehabilitation at Charbon. Clarence is an underground coal mining operation utilising bord and pillar mining and partial extraction techniques. It is situated in the Western Coalfields of NSW, approximately 10 km east of Lithgow in the Lithgow LGA (Figure 1.1). Clarence operates under DA 504-00 which was granted in 2005 by the NSW Department of Infrastructure, Planning and Natural Resources (now NSW Department of Planning, Industry and Environment (DPIE)). Clarence is managed by Centennial.

As nominated in Charbon's *Mining Operations Plan* (MOP), Charbon Coal proposes to import CCR from Clarence by train to backfill historical mining areas requiring rehabilitation. The transfer of CCR from Clarence to Charbon will assist Charbon Coal in developing a final landform that is representative of existing landforms within and adjacent to the site.

Charbon Coal is seeking to modify SSD 08_0211, pursuant to Section 4.55(2) of the EP&A Act, to allow for the transfer of CCR from Clarence to Charbon and the use of this material on-site during rehabilitation activities. If approved, the proposed modification will authorise:

- the importation of CCR from Clarence to Charbon by rail;
- use of CCR for ongoing rehabilitation at Charbon; and
- an extension of the time permitted to undertake water transfers between Charbon and Airly Mine.

At the same time Charbon Coal is seeking to modify SSD 08_0211, Centennial will submit a modification application for DA 504-00 to allow for the exportation of CCR from Clarence to Charbon by rail.



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Source: EMM (2020); Centennial (2019); DFSI (2017); GA (2011)

Regional context

Charbon Colliery Modification 2
Geochemistry assessment
Figure 1.1

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1.2 Site description

The project site boundary (Figure 1.2) is the existing development consent boundary applicable to SSD 08_0211 and includes all areas of disturbance requiring rehabilitation. The majority of the site is owned by Centennial. Forestry Corporation of NSW owns Kandos State Forest and Clandulla State Forest, both of which intersect with the project site boundary (Figure 1.2). Various small private landholdings occur in the southern and western portions of the site and several small areas of Crown land (mostly Crown road reserves) also occur.

Land uses surrounding the site include rural residences, agriculture, transport infrastructure and commercial forestry. To the north, the site is bounded by bushland, Charbon Lime Works, and the village of Charbon (Figure 1.2). To the east is bushland (Kandos State Forest) and escarpment (Great Dividing Range). The south and west of the site is dominated by bushland and agricultural land.

There are a number of non-mine owned residences in the area surrounding the project site boundary (Figure 1.2). The closest non-mine owned residence is Residence H, approximately 80 m from the project site boundary. The closest non-mine owned residence to the rail loop and proposed rail unloading activities is Residence P, approximately 1,500 m south-west of the rail loop.

1.3 Assessment guidelines and requirements

This geochemistry assessment has been prepared by EMM Consulting Pty Limited (EMM) to accompany the modification report and assesses the geochemical impacts of the proposed modification on environmental values in the surrounding area.

This assessment has been completed with reference to the following guidelines and policies:

- *Acid Rock Drainage (ARD) Test Handbook* (AMIRA 2002); and
- *Global Acid Rock Drainage (GARD) Guide* (INAP 2009).

NSW Department of Planning, Industry and Environment (DPIE) requested that the modification report include an assessment of the geochemical properties of CCR in order to:

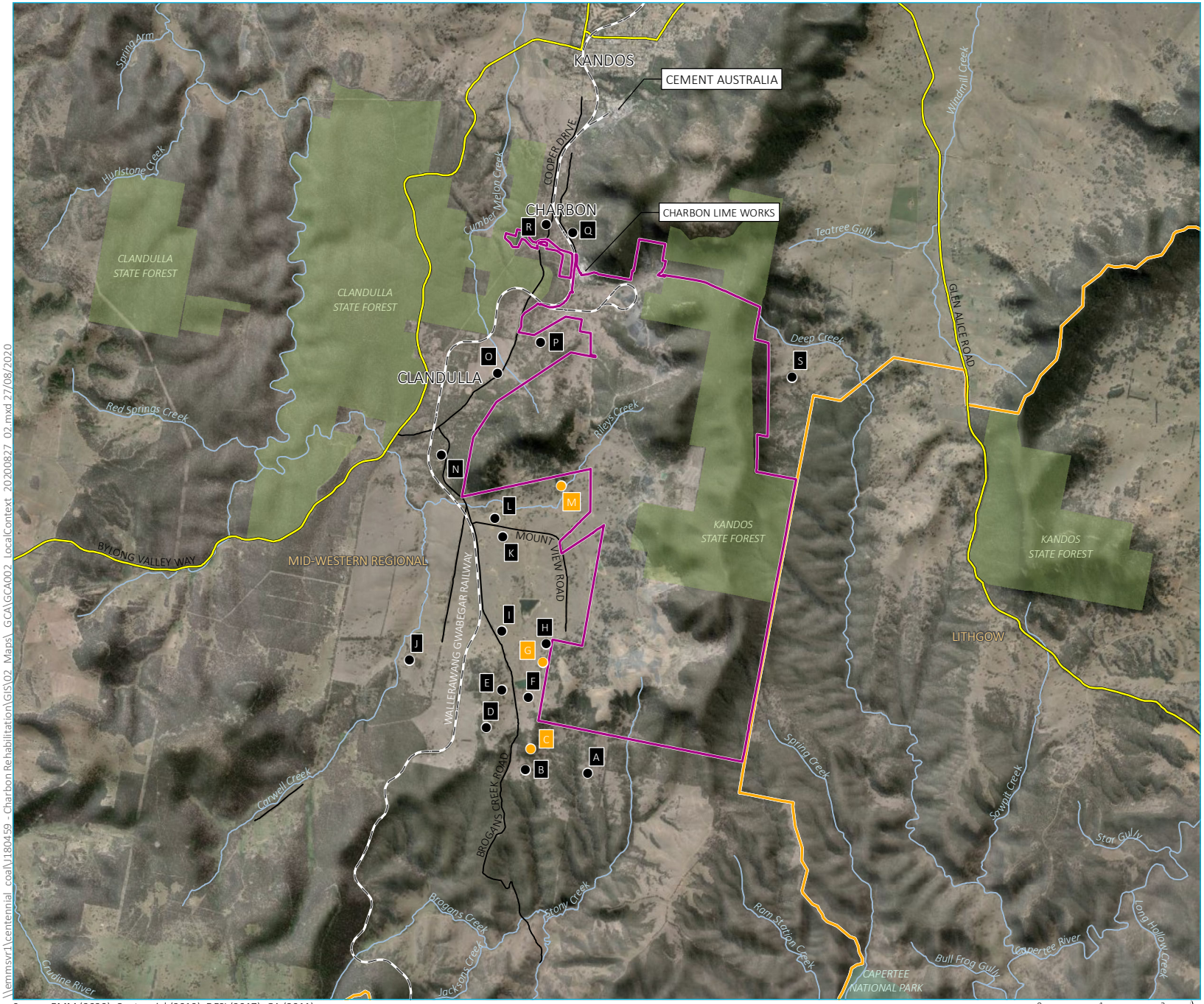
> …demonstrate that the coal reject material is suitable for rehabilitation, with consideration of statutory requirements for transport and disposal of coal reject waste, and potential for land and water pollution due to the geochemical nature of the coal reject material.[1]

This report outlines a geochemical characterisation study of REA6 CCR to determine the potential geochemical risks associated with placement of REA6 CCR at Charbon. REA6 CCR is then compared to waste rock and rejects from other emplacement facilities at both Clarence and Charbon to assess the suitability of REA6 CCR (and CCR from Clarence's production stream more generally) as backfill at Charbon.

This assessment also considers the limits within the Environment Protection Licence (EPL) for Clarence (EPL 726) and Charbon (EPL 528).

The study methodology is described in Chapter 2.

[1] Charbon Coal Project (08-0211) – Proposed Modification 2 (PMA-594). Letter from DPIE to Iain Hornshaw, Approvals Coordinator, 29 April 2020



KEY

- Charbon Colliery project site boundary
- Sensitive receiver
- Centennial-owned property
- Rail line
- Watercourse
- NPWS reserve
- State forest
- LGA boundary

Source: EMM (2020); Centennial (2019); DFSI (2017); GA (2011)

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Local context

Charbon Colliery Modification 2
Geochemistry assessment
Figure 1.2

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1.4 Proposed modification

Charbon Coal is seeking to modify SSD 08_0211, pursuant to Section 4.55(2) of the EP&A Act, to allow for the transfer of CCR from Clarence to Charbon and the use of this material on-site during rehabilitation activities. The transfer of CCR from Clarence to Charbon will assist Charbon Coal in developing a final landform that is representative of existing landforms within and adjacent to the site. The proposed modification includes:

- Construction of a 3,000 square metre (m^2) hardstand pad adjacent to Charbon's existing rail loop (Figure 1.3). During unloading activities, a forklift and other machinery will be operated on this hardstand. Containers used to transport CCR to Charbon may also be stored on this hardstand. Some minor vegetation clearance is required to construct the proposed hardstand.

- Construction of a link road to facilitate vehicle movements between the proposed hardstand and Charbon's existing haul roads (Figure 1.3). The link road will be constructed within the existing disturbance footprint for Charbon's reject emplacement area (REA) complex.

- Widening of Charbon's existing haul roads in some areas to ensure a minimum width of 8.8 m is maintained. Widening activities will remain within Charbon's existing approved disturbance footprint.

- Importation of CCR from Clarence to Charbon by rail (one loaded train per day).

- Unloading of CCR containers at Charbon's existing rail loop using a forklift truck. Containers will either be moved directly onto waiting trucks for transfer to the active rehabilitation areas or placed on the proposed hardstand for temporary storage. A fleet of three or four trucks will be used to transport the containers from the proposed hardstand to the active rehabilitation areas.

- Use of CCR for ongoing rehabilitation at Charbon (including establishment of management measures to mitigate the risk of acid and metalliferous drainage (AMD) and potential impacts on the surrounding environment).

- Construction of powerline poles and an additional 11-kV transmission line for Charbon's existing pump shed.

- An extension to the approved water transfer activities from Charbon to Airly Mine from 31 August 2025 to 31 January 2037 to align with Airly Mine's Development Consent (SSD-5581).

As part of the proposed modification, CCR material will be sourced from Clarence's REA6, the mine's production stream or from other REAs where the geochemical properties of the material are suitable for use in Charbon rehabilitation.

1.5 Coarse coal reject material

Clarence has primarily mined the Katoomba coal seam of the Permian Illawarra coal measures. Clarence has six approved REAs that accept CCR. The rehabilitation of the REAs is progressive and is undertaken in accordance with Clarence's MOP. Of the REAs, 1, 2 and 3 are partially rehabilitated and in care and maintenance. REA6 is currently operational and available as a source of material for placement at Charbon.

Geochemical assessments of CCR material in REA2, REA3 and REA4 at Clarence have previously been commissioned by Centennial (GHD 2013; GHD 2018). These assessments provide information on the geochemical behaviour of 'fresh' CCR and the behaviour of CCR after it has been placed in a REA. EMM was engaged by Centennial to characterise CCR sampled from REA6 (EMM 2020a). The results indicated that the geochemical characteristics of CCR from REA6 are broadly similar to the characteristics of the other REAs. This is expected given the consistency of mining the Katoomba coal seam throughout mining operations at Clarence.

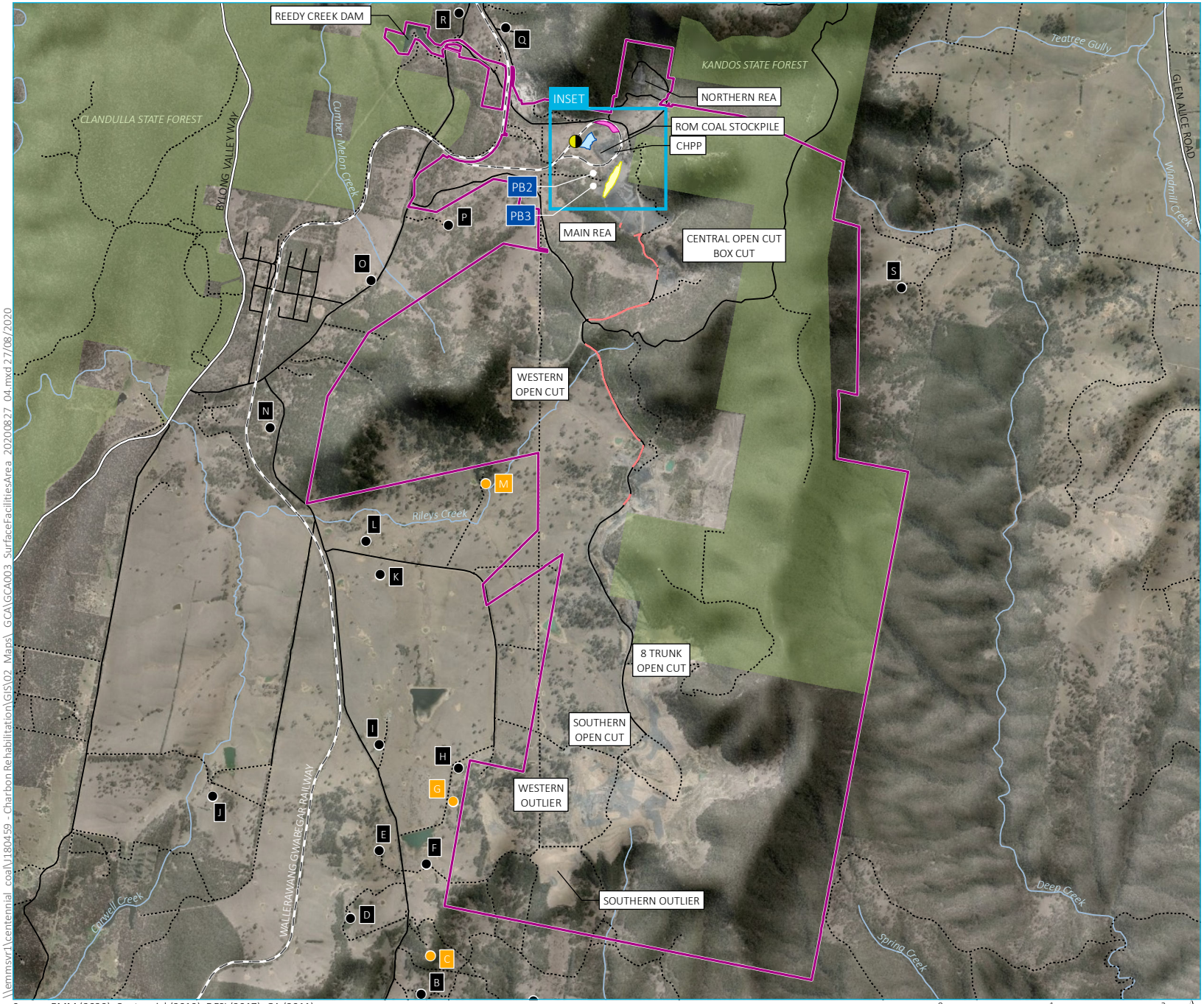
Charbon also mined the Permian Illawarra coal measures. During mining operations, waste material was handled in two REAs (Main REA (MREA) and Northern REA (NREA) - Figure 1.3). Both MREA and NREA contain CCR and fine tailings.

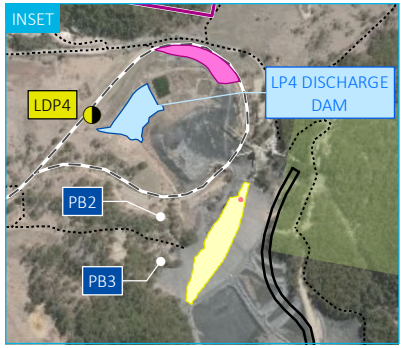
As part of closure design studies, a number of investigations have characterised Charbon's waste material (EGi 2018; LAMAC 2018). The results of these investigations are used in this report to compare the geochemical properties and placed behaviour between material present at Charbon and material sourced from Clarence.

To demonstrate that CCR from Clarence can be used during rehabilitation at Charbon, this assessment:

- reviews the geochemical properties of CCR from the REAs at Clarence and compares it with the characteristics of the waste material (rejects and overburden) available at Charbon; and

- reviews existing material management and rehabilitation plans at Charbon to assess whether provisions have been made to adequately mitigate potential geochemical impacts arising from the use of CCR from Clarence during on-site rehabilitation at Charbon.





KEY

- Charbon Colliery project site boundary
- Surface water storage
- Sensitive receiver
- Centennial-owned property
- Licensed Discharge Point (LDP)
- Rail line
- Main road
- Local road
- Vehicular track
- Watercourse
- State forest

Proposed modification elements

- Hardstand
- Link road
- Haul road widening

Source: EMM (2020); Centennial (2019); DFSI (2017); GA (2011)

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Mine layout at Charbon Colliery

Clarence Colliery and Charbon Colliery
Geochemistry assessment
Figure 1.3

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Source: EMM (2020); Centennial (2019); DFSI (2017); GA (2011)

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KEY

- Clarence Colliery holding boundary
- Clarence Colliery surface facilities
- Sensitive receiver
- Rail line
- Main road
- Local road
- Watercourse/drainage line
- Waterbody

Existing surface facilities at Clarence Colliery

Charbon Colliery Modification 2
Geochemistry assessment
Figure 1.4

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2 Methodology

The aim of this assessment is to confirm (or otherwise) that CCR material from Clarence is suitable to be used during ongoing rehabilitation at Charbon and that any potential impacts can be managed.

Charbon's approved rehabilitation plans included in the MOP assume that all material will be sourced from within the project site boundary. To satisfy DPIE's requirements (Section 1.3), EMM has reviewed the approved MOP rehabilitation plans alongside geochemical information available for both Charbon and Clarence mineral waste and CCR material. The following sections outline the approach taken.

2.1 Geochemical risks of coarse coal reject emplacement

The potential geochemical impact of placement of Clarence CCR at Charbon has been assessed to provide an indication of whether placement of Clarence CCR will have an adverse impact on Charbon's receiving environment and, if Clarence CCR is shown to have a higher impact on Charbon's receiving environment, to provide input for the rehabilitation design to minimise potential geochemical impacts. This has been assessed by examining the following information:

- Geochemical characterisation data from Clarence CCR at REA6 (EMM 2020a).
- Geochemical characterisation and Australian Standard Leaching Procedure (ASLP) leachate data from Clarence's REA2, REA3 and REA4 and mineral waste (GHD 2013; GHD 2018) to confirm the geochemical properties of this material and compare leaching behaviour for this material under laboratory-controlled conditions and on-site at Clarence.
- REA6 seepage water quality data using Leachate Dam 3 (LD3) at Clarence (EMM 2020a). Centennial regularly monitor seepage collected from REA6. This monitoring data has been used to determine the potential level of reactivity of Clarence CCR if exposed to conditions on-site (eg water and oxygen). This information can be used to assess the potential for AMD and geochemical parameters that may be of concern.
- Water quality data from Leachate Dam 1 and 2 (LD1 and LD2) at Clarence, which collect seepage from the other REAs and are regularly monitored by Centennial (GHD 2013). This data has been compared with the water quality characteristics of REA6 LD3.

The locations of LD1, LD2 and LD3 at Clarence are shown on Figure 1.4.

2.2 Requirement for additional mitigation and management

This assessment also considers whether placement of CCR from Clarence at Charbon triggers a requirement for modifications to approved rehabilitation design at Charbon (ie to mitigate potential impacts to the receiving environment as a result of the use of this material). Charbon's approved MOP rehabilitation plans assume that all material will be sourced from within the project site boundary and that this material will be capped to provide geochemical isolation (EGi 2018; LAMAC 2018). This has been assessed by:

- Comparing the geochemical characteristics of the REA6 CCR with rock and water quality information available at Charbon to determine whether placement of Clarence CCR at Charbon presents a higher, lower or similar risk to the receiving environment than the previously approved design. Available information on Charbon's waste material geochemistry includes:

- geochemical characterisation and leachate geochemistry of Charbon rejects and overburden (EGi 2018; LAMAC 2018);

- leachate water quality from licensed discharge point (LDP) 4 (Figure 1.3), which is at the outlet of the LDP4 Discharge Dam and captures drainage from MREA and NREA (EGi 2018); and

- groundwater quality from monitoring bores (PB2 and PB3 - Figure 1.3) adjacent to MREA (EGi 2018).

- Assessing the approved rehabilitation design at Charbon to determine whether any potential adverse impacts from importation of Clarence CCR would be adequately addressed through the current site management measures. This involved a review of Charbon's void capping plans (supplied by Centennial) and a comparison of these with Charbon's approved rehabilitation plans for MREA and NREA (EGi 2018; LAMAC 2018).

- Recommending amendments to the approved rehabilitation design and/or waste management and monitoring plans if:

  - placement of Clarence CCR is found to present an increased risk of adverse impacts to the receiving environment at Charbon when compared with the existing approved plans; or

  - the approved rehabilitation design is not adequate to mitigate potential impacts.

3 Impact assessment

3.1 Overview

Emplacement of CCR at Charbon may require management of geochemical issues associated with CCR, including:

- AMD;
- soil contamination; and
- impacts to groundwater and sensitive receptors (eg landholder bores, surface water bodies or groundwater dependent ecosystems (GDEs)).

This chapter summarises the potential geochemical risk that Clarence CCR may pose to the receiving environment at Charbon and reviews Charbon's approved waste management and mitigation plans.

3.2 Geochemical risks of coarse coal reject emplacement

EMM (2020a) completed a geochemical characterisation assessment of CCR from REA6 at Clarence. As part of this assessment, 15 samples were collected for laboratory analysis across the top of REA6 and at depths ranging from the REA6 upper surface to 2.4 m below the surface. The results of this assessment are summarised in Section 3.2.1. The geochemical characteristics of the REA6 samples are compared to those from REAs 2, 3 and 4 in Section 3.2.2.

3.2.1 Coarse coal reject from REA6

CCR samples from REA6 underwent the following laboratory analyses:

- pH and electrical conductivity (EC) (saturated paste);
- total sulfur concentration as S;
- total carbon and organic carbon content;
- maximum potential acidity (MPA) in kg H_2SO_4/t (calculated);
- acid neutralising capacity (ANC) in kg H_2SO_4/t;
- net acid producing potential (NAPP) in kg H_2SO_4/t (calculated); and
- major and trace element whole-sample concentrations, including metals and metalloids.

The results were used to assess the acid-base and metals/metalloids characteristics of the samples.

i Acid-base accounting

The initial assessment of the AMD potential of the samples was undertaken via acid-base accounting, which evaluates the balance between acid generation processes and acid neutralising processes (AMIRA 2002).

MPA is a measure of the highest acidity that a sample will generate assuming all sulfur within the sample is oxidised and available to form sulfuric acid. A sample containing 1% S has the potential to generate 30.6 kg of H_2SO_4 per tonne of sample (30.6 kg H_2SO_4/t). This is a conservative indication of the maximum acid generating capacity within each sample.

The ANC of a sample is a measure of the capacity of the material within the sample (eg carbonates) to buffer the acidity produced. ANC is generally expressed in units of kg H_2SO_4/t (ie equivalent to MPA units).

The NAPP is also reported in kg H_2SO_4/t and records the balance within the sample of the acidity generated versus its intrinsic buffering capacity and provides an indication of the potential for a sample to generate acidity.

Where MPA is less than ANC, NAPP is negative, indicating that the sample may have sufficient buffering capacity to prevent AMD. A positive NAPP (MPA is greater than ANC) indicates that the material may potentially generate net acidity under appropriate conditions.

In addition, the neutralisation potential ratio (NPR) is used to provide an indication of the acidity versus buffering of a sample, where:

- NPR greater than 2 is considered non-acid forming (NAF);
- NPR less than 1 is considered potentially acid forming (PAF); and
- NPR of greater than or equal to 1 and less than or equal to 2 is uncertain (UC).

Results from the REA6 acid-base accounting are shown in Table 3.1.

Of the 15 samples analysed:

- 4 samples are NAF;
- 9 samples are PAF; and
- 2 samples are UC.

Total sulfur content within the samples is low, with the maximum concentration recorded in CLR REA6 Surface #4 (0.109%). Sulfur concentrations record a degree of spatial heterogeneity, which may be expected from rejects in a waste emplacement facility; however, sulfur contents are generally consistent with depth across REA6.

Saturated paste pH values range from 3.6 (CLR REA6 Auger #5) to 7.4 (CLR REA6 Excavation #2) and reflect the presence/absence of potentially readily-leachable acid-generating material in each sample. Most samples reporting low saturated paste pH values are PAF and have little to no ANC (Figure 3.1). Samples reported as NAF that also report low saturated paste pH values are likely to contain ANC in non-readily available or less reactive forms (ie non-calcium carbonate ANC), which is consistent with the low calcium contents reported.

MPA has been calculated assuming that all sulfur analysed is in the form of reactive sulfide. This approach provides a conservative (worst case) estimate of the potential for each REA6 sample to generate acidity and much of the sulfur may be present as sulfate, which will further limit the MPA.

REA6 saturated paste EC values range between 32 and 414 µS/cm and are consistent with Clarence's EPL 726 discharge compliance limit of 350 µS/cm.

As may be expected in rejects associated with coal seams, the REA6 CCR samples record high total carbon contents (12.8–55.1%), with most carbon present as organic carbon (Table 3.1).

Almost all REA6 CCR samples have NAPP values that classify them as low capacity PAF (PAF-LC) material (ie 0–5 kg H_2SO_4/t), with the exception of CLR REA6 Surface #2, which has a NAPP value of 9.2 kg H_2SO_4/t. This is more a reflection of the lack of ANC within this sample, rather than a high MPA.

Table 3.1 Laboratory acid-base accounting results for CCR samples from REA6

Sample ID	Date	Depth	Sat. paste pH	Sat. paste EC	Moisture content	Total carbon	Total organic carbon	Sulfur	MPA	ANC	NAPP	NPR	Classification (Price 2009)
		m	-	µS/cm	%	%	%	%	kg H_2SO_4/t	kg H_2SO_4/t	kg H_2SO_4/t	-	
CLR REA6 Surface #1	23/04/2020	0.0	5.8	63	2.4	14.6	14.0	0.045	1.38	0.00	4.0	0.0	PAF
CLR REA6 Surface #2	23/04/2020	0.0	4.4	32	3.8	17.3	16.6	0.057	1.74	0.00	9.2	0.0	PAF
CLR REA6 Surface #3	23/04/2020	0.0	4.7	49	3.1	14.4	13.9	0.016	0.49	1.89	-1.4	3.9	NAF
CLR REA6 Surface #4	23/04/2020	0.0	4.3	106	2.7	20.4	19.6	0.109	3.34	1.64	1.7	0.5	PAF
CLR REA6 Surface #5	23/04/2020	0.0	4.2	126	2.5	12.8	12.4	0.037	1.13	0.00	1.2	0.0	PAF
CLR REA6 Auger #1	23/04/2020	1.0	7.4	414	3.2	14.5	13.5	0.074	2.26	4.06	-1.8	1.8	UC
CLR REA6 Auger #2	23/04/2020	1.0	4.5	109	3.4	17.6	16.5	0.067	2.05	0.65	1.4	0.3	PAF
CLR REA6 Auger #3	23/04/2020	1.0	6.4	180	3.1	16.4	15.3	0.022	0.67	2.77	-2.1	4.1	NAF
CLR REA6 Auger #4	23/04/2020	1.0	4.5	168	3.6	13.6	12.7	0.020	0.61	0.11	0.5	0.2	PAF
CLR REA6 Auger #5	23/04/2020	1.0	3.6	183	17.9	12.2	11.7	0.031	0.95	0.00	1.2	0.0	PAF
CLR REA6 Excavation #1	23/04/2020	2.3	4.2	356	3.4	15.3	14.1	0.037	1.13	2.93	-1.8	2.6	NAF
CLR REA6 Excavation #2	23/04/2020	2.2	7.4	244	3.8	14.7	14.1	0.034	1.04	3.24	-2.2	3.1	NAF
CLR REA6 Excavation #3	23/04/2020	2.4	5.0	111	3.3	13.2	12.9	0.022	0.67	0.00	0.7	0.0	PAF
CLR REA6 Excavation #4	23/04/2020	2.1	6.9	124	7.2	55.1	55.1	0.030	0.92	0.00	3.1	0.0	PAF
CLR REA6 Excavation #5	23/04/2020	2.3	4.4	120	4.2	13.9	13.6	0.067	2.05	2.85	-0.8	1.4	UC

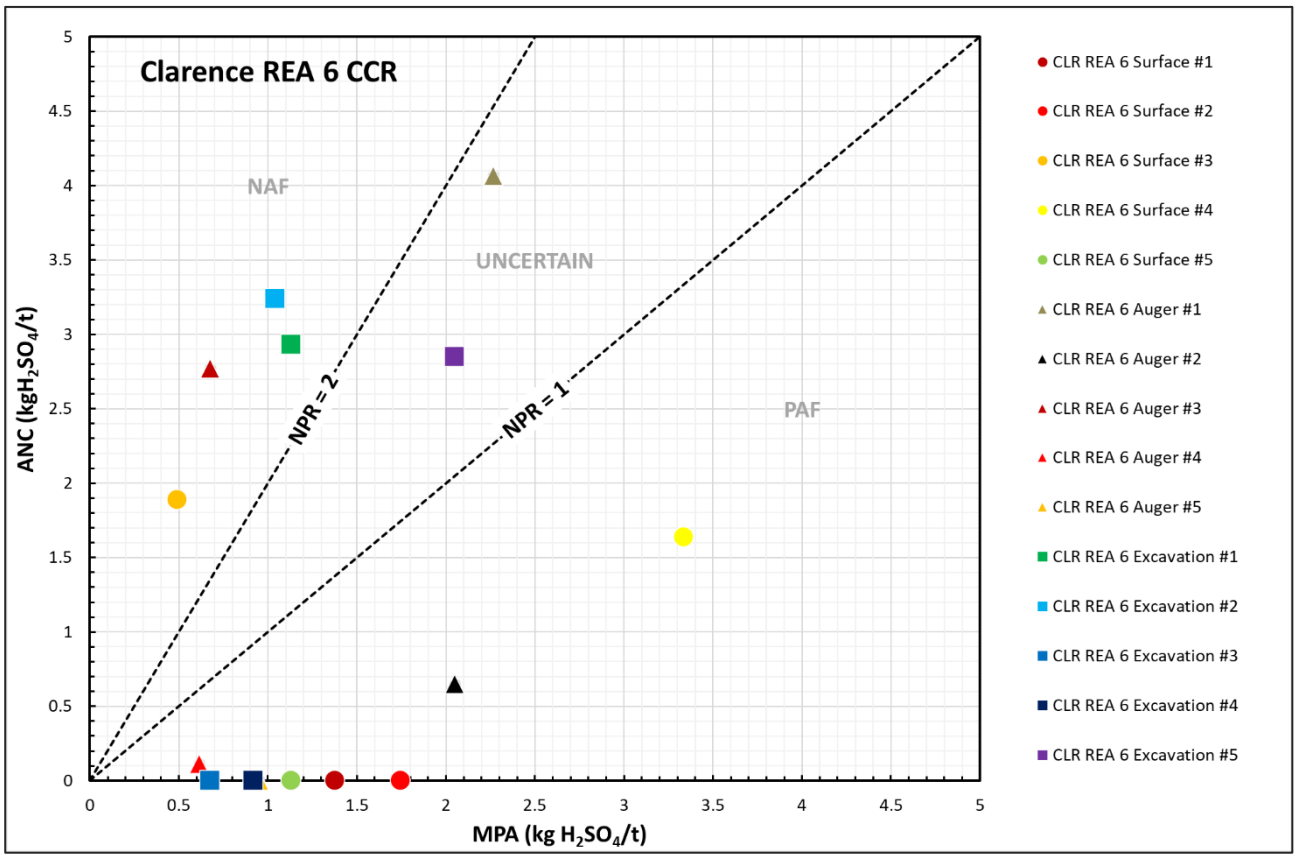

Figure 3.1 Maximum potential acidity versus acid neutralisation capacity for REA6 CCR samples

ii Metal and metalloid analysis

The REA6 CCR samples were analysed for whole-sample metal and metalloid concentrations. Metal and metalloid contents were assessed with reference to the geochemical abundance index (GAI). The GAI compares the concentration of an analyte in a sample with a reference value to determine the level of enrichment in the sample and thus to highlight analytes that may act as sources of contamination in AMD. Global median soil concentrations were used following the standard convention (GARD 2009; Bowen 1979; Berkman 1976). GAI values are reported as integers and range between 0 (the sample analyte concentration is similar to or less than the reference concentration) and 6 (the sample analyte concentration is enriched to approximately 100 times the reference content).

Metal and metalloid concentrations within the samples from REA6 were at or below the laboratory limit of reporting (LOR) for the majority of the analytes measured (Table 3.2). These values are presented in this report at the LOR to provide a conservative estimate. Actual concentrations may be lower than the LOR.

Calculated GAIs are zero for almost all measured analytes, indicating that the REA6 CCR samples have similar or lower metal and metalloid concentrations compared to global median soil contents. Two analytes show possible enrichment:

- cobalt - GAI value of 1–2 (enrichment of approximately 2–4 times the global median soil concentration); and
- selenium – GAI value of 3 (enrichment of approximately 8 times the global median soil concentration), which is likely to be an artifact of the analysis, as selenium values for all samples have been reported at a LOR of 5 mg/kg and may actually be present at lower concentrations.

Table 3.2 REA6 laboratory whole-sample metals/metalloids concentrations

Sample ID	Analyte concentration (mg/kg)																												
	Ag	Al	As	Au	B	Ba	Ca	Cd	Co	Cr	Cu	Fe	Hg	K	Mg	Mn	Mo	Na	Ni	Pb	Sb	Se	Sr	Th	Ti	Tl	U	V	W	Zn
CLR REA6 Surface #1	2	1,630	5	0.1	50	20	10	1	11	2	5	3,870	0.1	10	10	83	2	10	57	14	5	5	4	3.8	10	5	1	5	0.1	16
CLR REA6 Surface #2	2	1,530	5	0.1	50	100	10	1	24	2	10	3,600	0.1	10	10	73	2	10	68	44	5	5	48	3.4	10	5	2	6	0.1	21
CLR REA6 Surface #3	2	640	5	0.1	50	20	10	1	15	2	6	2,340	0.1	10	10	47	2	10	32	10	5	5	4	2.4	10	5	0.6	5	0.1	23
CLR REA6 Surface #4	2	1,290	5	0.1	50	30	10	1	42	2	10	2,510	0.1	10	10	36	2	10	127	17	5	5	7	2.6	10	5	1.2	5	0.1	21
CLR REA6 Surface #5	2	890	5	0.1	50	20	10	1	30	2	6	1,810	0.1	10	10	54	2	10	102	16	5	5	6	2.8	10	5	0.7	5	0.1	29
CLR REA6 Auger #1	2	1,040	5	0.1	50	40	40	1	15	2	13	4,050	0.1	10	10	119	2	10	39	19	5	5	8	5.1	10	5	0.7	5	0.1	51
CLR REA6 Auger #2	2	1,310	5	0.1	50	50	10	1	57	2	10	3,150	0.1	10	10	122	2	10	137	16	5	5	18	3.1	10	5	0.8	5	0.1	71
CLR REA6 Auger #3	2	1,430	5	0.1	50	40	10	1	20	2	13	20,100	0.1	10	10	349	2	20	48	18	5	5	10	4.6	10	5	0.7	8	0.1	60
CLR REA6 Auger #4	2	1,070	5	0.1	50	60	10	1	17	2	14	480	0.1	10	10	31	2	10	48	22	5	5	8	1.4	10	5	0.6	5	0.1	30
CLR REA6 Auger #5	2	9,090	6	0.1	50	80	10	1	18	42	17	22,300	0.1	20	20	260	2	10	32	28	5	5	25	1.4	180	5	0.2	45	0.1	80
CLR REA6 Excavation #1	2	710	5	0.1	50	30	10	1	17	2	5	4,640	0.1	10	10	119	2	10	46	9	5	5	6	1.7	10	5	0.4	5	0.1	29
CLR REA6 Excavation #2	2	1,080	5	0.1	50	40	40	1	29	2	12	29,400	0.1	10	10	692	2	10	70	26	5	5	2	4.3	10	5	0.8	7	0.1	68
CLR REA6 Excavation #3	2	690	5	0.1	50	40	10	1	23	2	7	880	0.1	10	10	51	2	10	71	9	5	5	7	3.4	10	5	0.4	5	0.1	15
CLR REA6 Excavation #4	2	1,020	5	0.1	50	220	50	1	28	2	8	2,190	0.1	10	10	144	2	10	70	8	5	5	58	1.7	10	5	0.5	5	0.1	175
CLR REA6 Excavation #5	2	1,540	5	0.1	50	70	10	1	26	2	17	20,800	0.1	10	10	355	2	10	69	26	5	5	16	6.2	10	5	1.1	10	0.1	51

Note: Values reported at or below laboratory LORs are shown in red.

3.2.2 Comparison of material at Clarence

REA6 CCR geochemistry has been compared to the geochemical characteristics of samples from REAs 2, 3 and 4 to evaluate the Clarence waste material as a whole and to determine how representative of Katoomba coal seam waste the recently analysed REA6 samples are. The data sets for REAs 2, 3 and 4 consist of:

- 12 samples from REAs 2, 3 and 4 (GHD 2013); and
- 8 samples from REA3 (mean only) (GHD 2018).

REA6 CCR acid-base characteristics fall within the range of those from the other REAs at Clarence (Figure 3.2).

REA6 CCR samples have among the lowest MPA values (and lowest sulfur contents) of all of the samples. REA6 CCR samples have MPA values between those estimated for REA3 based on total sulfur (labelled as 'Total S' in Figure 3.2) and those estimated for REA3 based on chromium reducible sulfur (labelled as 'SCr' in Figure 3.2) (GHD 2018).

Although eight REA6 CCR samples report zero ANC, the remaining seven samples have the highest ANC of the Clarence samples.

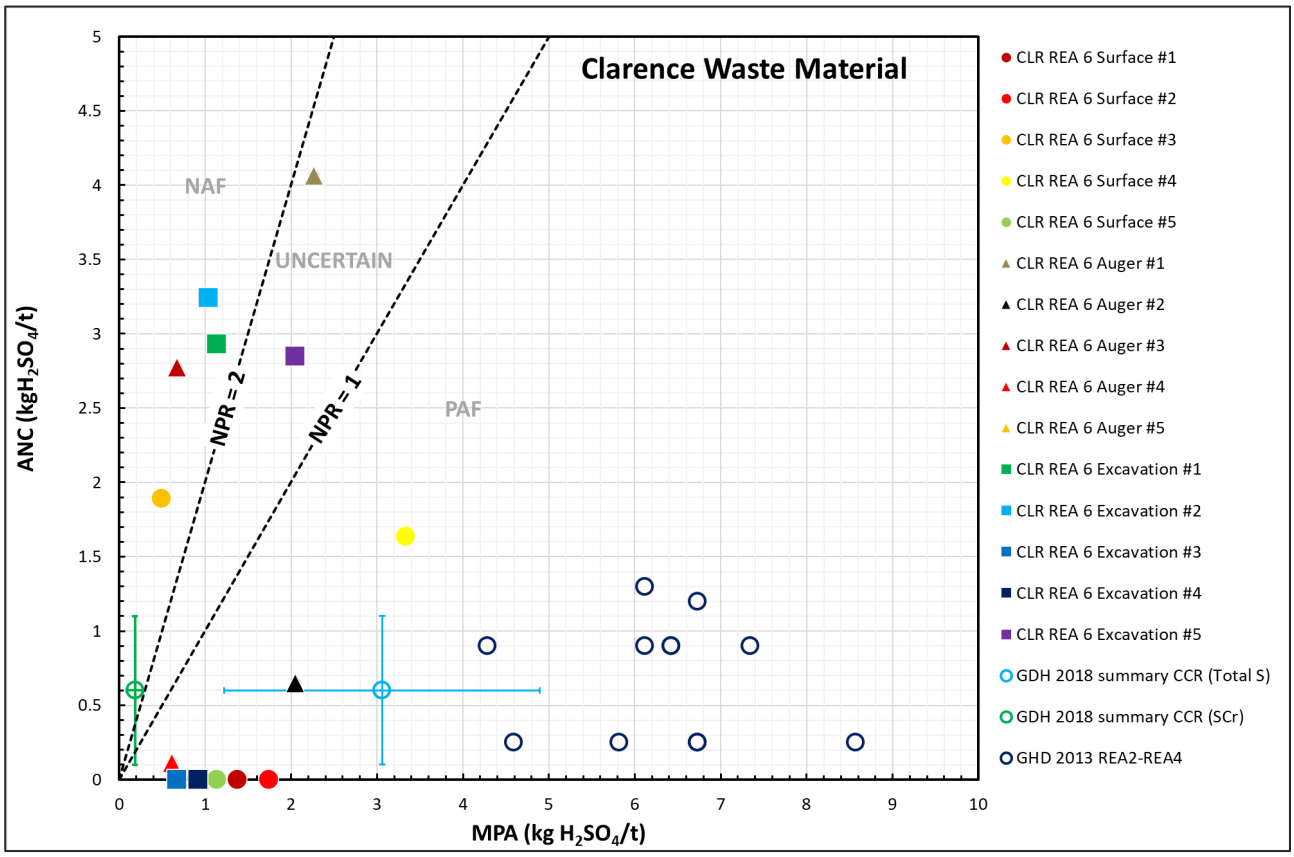

Figure 3.2 Comparison of maximum potential acidity and acid neutralisation capacity for Clarence

Note: GHD (2018) samples are summarised based on estimates of MPA using total sulfur (blue) and chromium reducible sulfur (green).

REA6 CCR metal and metalloid concentrations are similar to those in other Clarence REA material, with many analytes recorded at or below LORs (Figure 3.3; Figure 3.4).

REA6 CCR cobalt concentrations, reported as enriched compared to global median soil concentrations, are comparable to those in other Clarence REA material, indicating that this is likely a feature of Clarence's lithology.

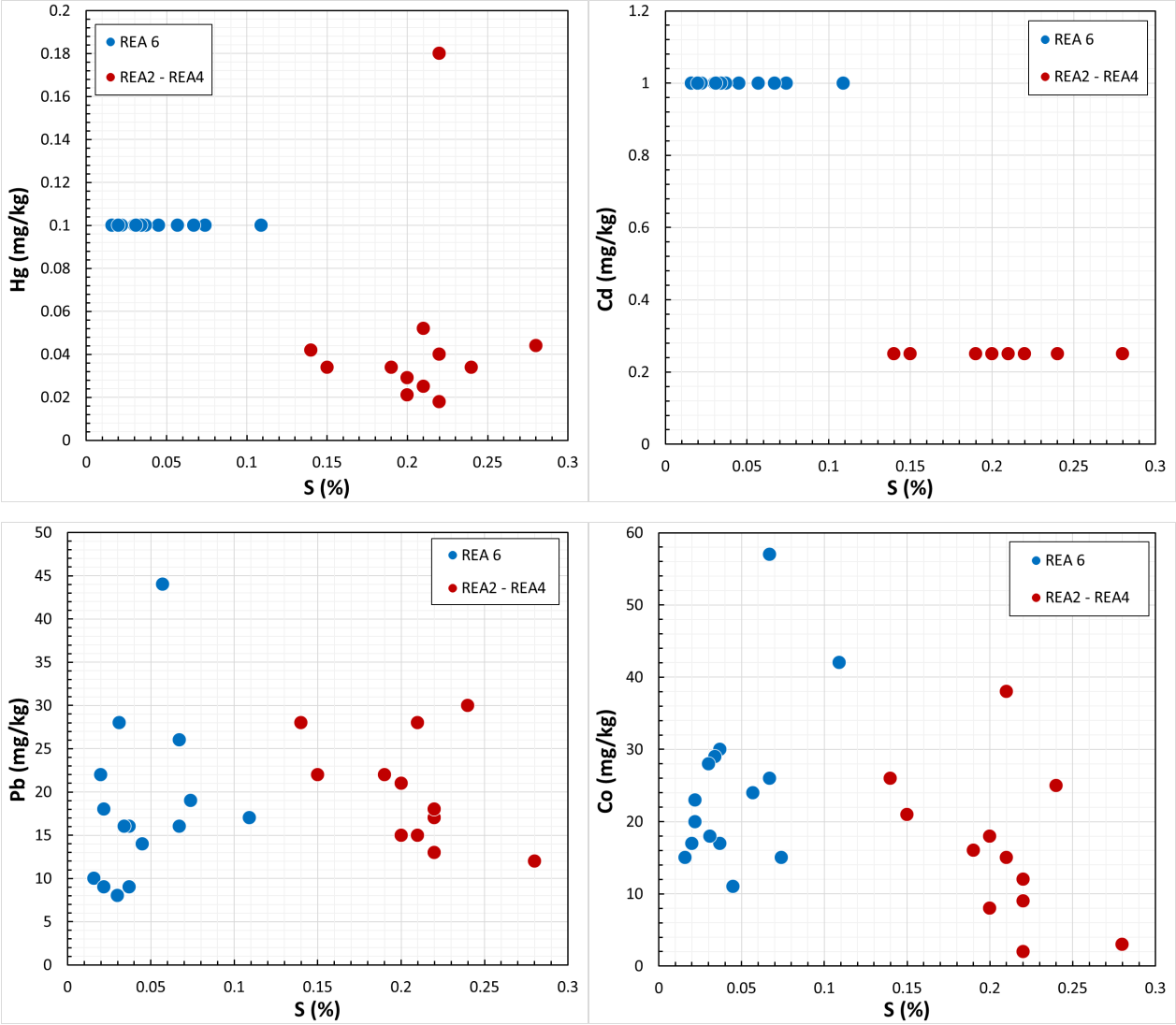

Figure 3.3 **Comparison between whole-sample sulfur and metal (mercury, cadmium, lead and cobalt) contents of REA6 CCR samples and those from REAs 2, 3 and 4**

Note: Mercury concentrations for REAs 2, 3 and 4 and cadmium concentrations for REAs 2, 3, 4 and 6 were recorded in the laboratory analysis to be less than LORs. Values have been shown at LORs in Figure 3.3; however, these are likely to be present at lower concentrations.

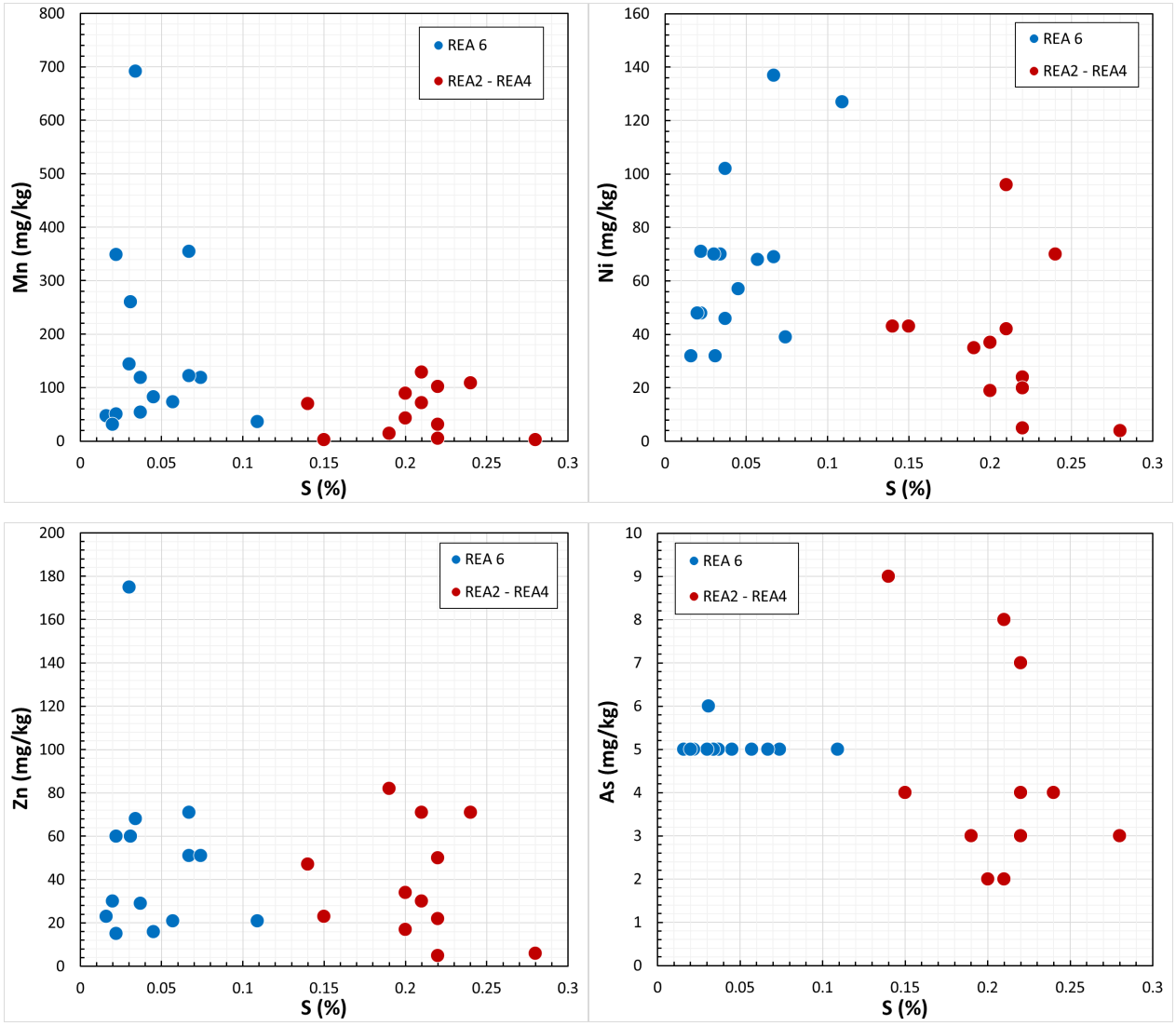

Figure 3.4 **Comparison between whole-sample sulfur and metal (manganese, nickel and zinc) and metalloid (arsenic) contents of REA6 CCR samples and those from REAs 2, 3 and 4**

3.2.3 Leachate water quality at Clarence

Centennial regularly monitors leachate collected in dams downslope of the REAs, providing an indication of the long-term reactivity and weathering characteristics of the waste material to inform waste management.

REA6 leachate water quality (from LD3) was compared to leachate water quality from the other Clarence REA leachate dams (LD1 and LD2) and leachate from ASLP testing on REA 2, 3 and 4 CCR and waste rock (as outlined in Section 2.1) to assess the similarities in geochemistry between REA6 and the other REAs.

The leachate water quality comparisons are shown in Figure 3.5 for pH and concentrations of chloride, mercury, cadmium, lead and arsenic against sulfate contents[2].

Leachate water quality was also compared to Clarence's EPL 726 discharge compliance limit values, which are largely based on ANZECC (2000) values[3].

Figure 3.5 shows that the ASLP concentrations of chloride, cobalt, nickel, lead and arsenic are at or below LORs. Most of the parameters analysed in the laboratory ASLP tests on REAs 2, 3 and 4 CCR and waste rock are lower than the same parameters monitored in leachate from LD1, LD2 and LD3. This may be due to:

- differences in scale between the laboratory-controlled conditions and those on-site (eg crushed laboratory samples versus waste material in-situ);
- differences in timescale between laboratory tests (typically approximately 18 hours) and long-term observations taken on-site (months and years); and
- differences in dilution factors between controlled laboratory testing (known and consistent dilution) and on-site conditions, which are subject to seasonal variations.

The leachate dam sulfate concentrations are also consistently higher than those recorded from laboratory leach testing. This reflects long-term loading of oxidised sulfur into the leachate dams.

Despite the limitations of comparing laboratory and field data, the ASLP test results were included in this study to account for gaps in the geochemical information base in parameters that have not been monitored in the REA leachate dams. Both the laboratory leachate results and the observed REA 2, 3, 4 and 6 leachate water quality indicate the following general characteristics:

- Leachate pH is generally acidic (ie less than 6.5), which may be because:
    - Clarence waste rock material contains limited buffering capacity for acidity that may result from sulfide oxidation (ie the maximum ANC recorded in the samples collected at Clarence is approximately 4 kg H_2SO_4/t whereas the highest MPA is approximately 8.5 kg H_2SO_4/t - Figure 3.2). Although Clarence CCR samples report low sulfur concentrations, the lack of adequate ANC results in limited buffering of AMD. Following emplacement of CCR, weathering and infiltration of rainfall may load acidity in the leachate dams;

[2] Sulfate is a conservative parameter because it is not attenuated by sorption onto substrates. It provides a direct indicator of analyte load from leached waste material.

[3] Australian and New Zealand Environment Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) (2000). Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Now referred to as Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2018).

- the REAs may contain ‘pockets’ of acidity, which are yet to be sampled. Such pockets may have been subjected to preferential seepage and weathering resulting in AMD reporting to the leachate dams; or

- as yet undiscovered sources of AMD that may contribute to leachate dam acidity.

This is discussed in more detail in Section 3.3.2.

- Leachate metal and metalloid concentrations are generally low and are reported at or below LORs for many analytes. Cobalt, nickel and lead concentrations exceed Clarence’s EPL 726 limits for offsite discharge, noting that it has not been assessed whether discharge has occurred.

REA6 leachate water quality from LD3 (Figure 3.5) is geochemically similar to water quality reported from LD1 and LD2 at Clarence (locations shown on Figure 1.4). This is consistent with the similarities in the whole-sample geochemistry of REA6 and material from the other REAs.

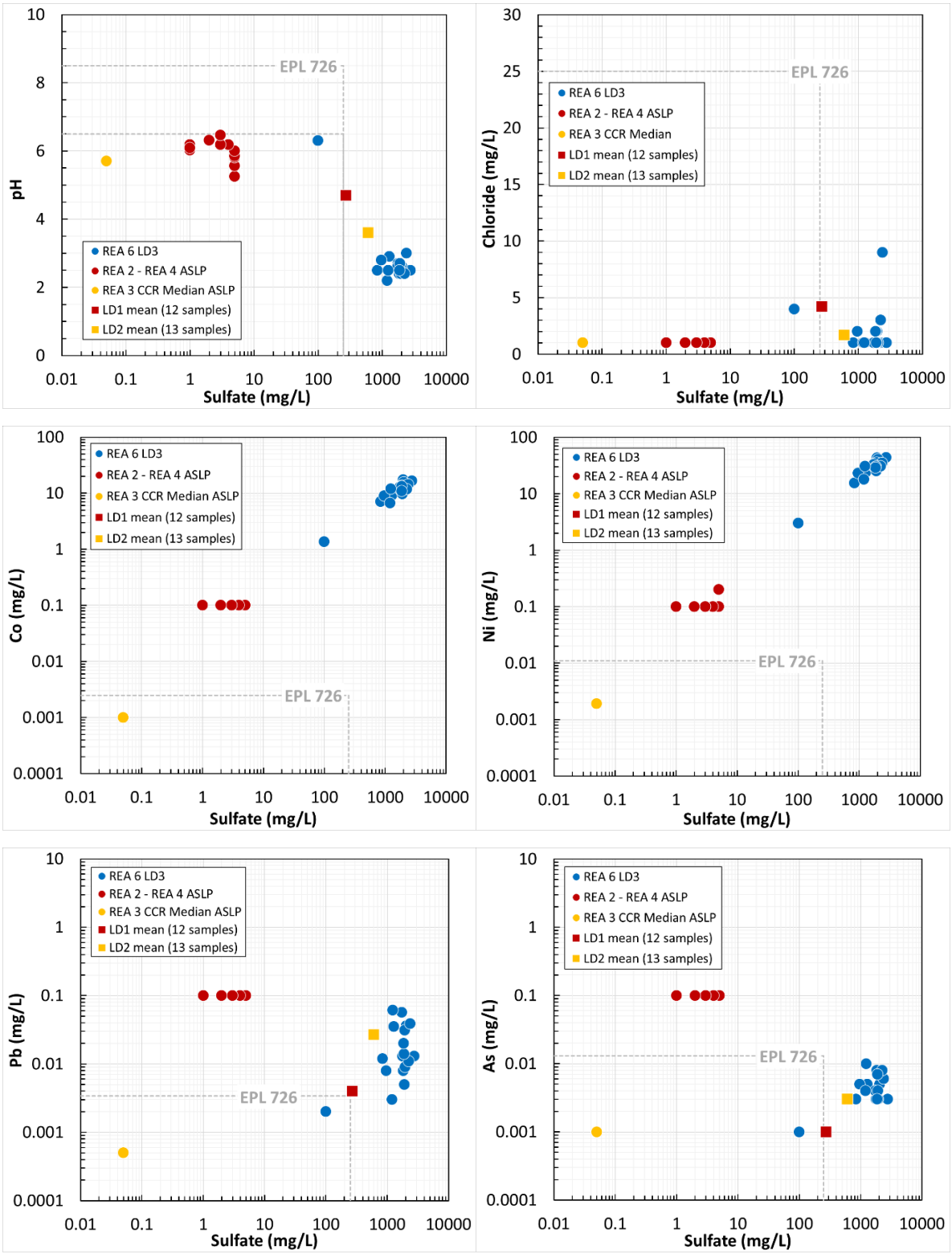

Figure 3.5 Variations in leachate pH, chloride, mercury, cadmium, lead and arsenic versus sulfate at Clarence

3.3 Requirement for additional mitigation and management

The current rehabilitation design for the three areas likely to receive CCR material from Clarence (ie Western Open Cut, 8 Trunk Open Cut and Central Open Cut Box Cut) is based on managing and mitigating the potential geochemical impacts following placement of on-site waste material available at Charbon.

To assess whether use of CCR from Clarence will result in higher, lower, or similar geochemical impacts, the results presented in Section 3.2, have been compared to the geochemical characteristics assessed in previous studies of on-site waste material at Charbon.

3.3.1 Comparison of waste characteristics

Clarence REA samples are compared with Charbon waste material sampled at the MREA and NREA (Figure 3.6).

While some Clarence REA6 CCR samples are characterised as PAF, they have low metal and metalloid contents and low sulfur (Table 3.1). This is comparable to waste material from Clarence REAs 2, 3 and 4, which have sulfur contents generally less than 0.3% (Section 3.2.2). In contrast, Charbon MREA and NREA samples have sulfur contents generally less than 8.5% and most Charbon samples are classified as PAF.

Given that PAF material is present, it is the presence or absence of ANC that largely governs whether AMD will be generated.

A number of samples from Clarence REA6 CCR, other Clarence REAs and Charbon MREA and NREA have zero ANC and it is likely that acidity may be produced in the absence of buffering capacity.

Contrastingly, some of the Charbon samples have high sulfur concentrations which may result in acid generation because, as for many coal-associated samples, they also lack significant buffering capacity).

In contrast to REA6 CCR, Charbon MREA and NREA material generally records higher metal and metalloid concentrations, with enrichment relative to global median soil concentrations and GAIs greater than 2 for beryllium, mercury, thallium and tungsten (EGi 2018).

Charbon metal and metalloid concentrations are generally among the highest across the range of samples investigated (Figure 3.7 and Figure 3.8). The exception is cobalt, which is generally reported in higher concentrations in Clarence samples, although these are comparable to Charbon samples from 8 Trunk Open Cut and Southern Open Cut (LAMAC 2018).

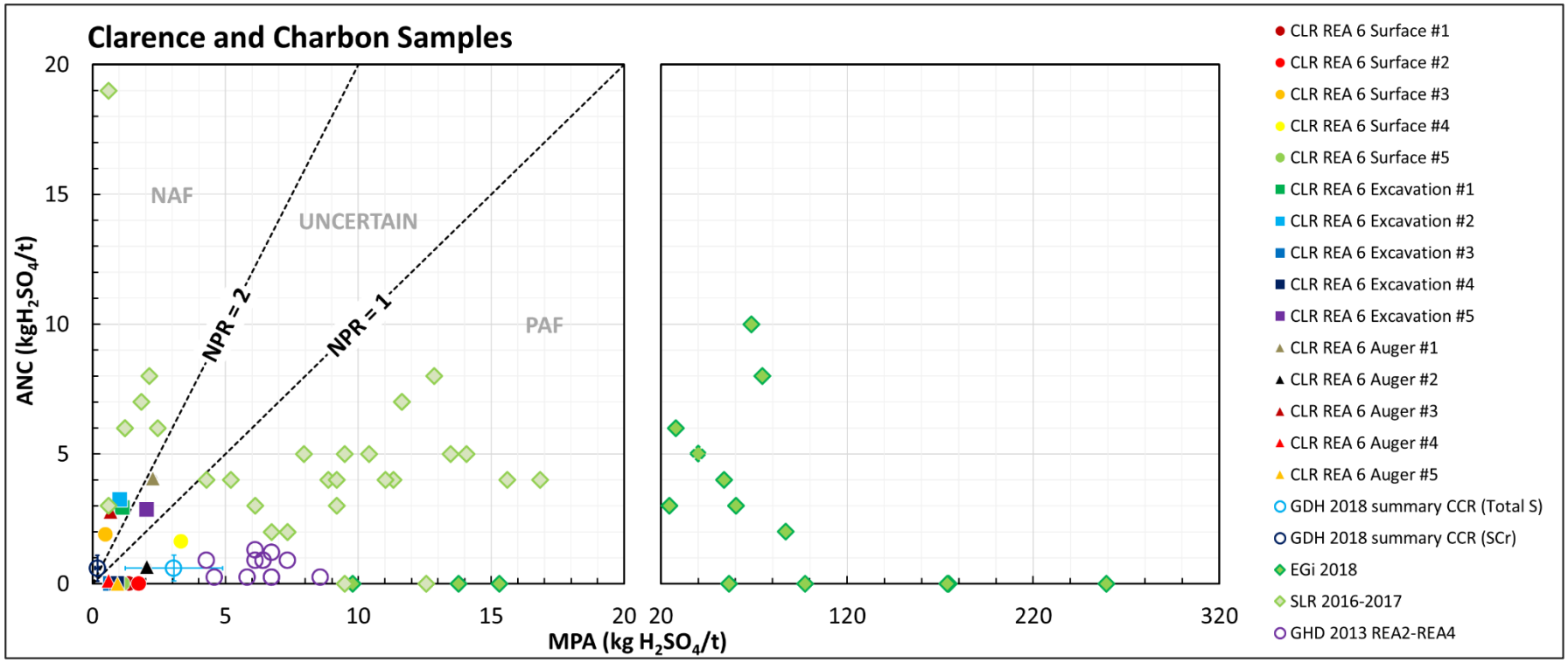

Figure 3.6 Comparison of maximum potential acidity and acid neutralisation capacity from Charbon and Clarence waste materials

Note: Samples from Charbon (diamond symbols) are labelled as EGi 2018 and LAMAC 2018 (consistent with the sources of this data). All other samples are from Clarence. High MPA Charbon samples are shown on a larger scale on the right-hand side plot and are in the PAF domain.

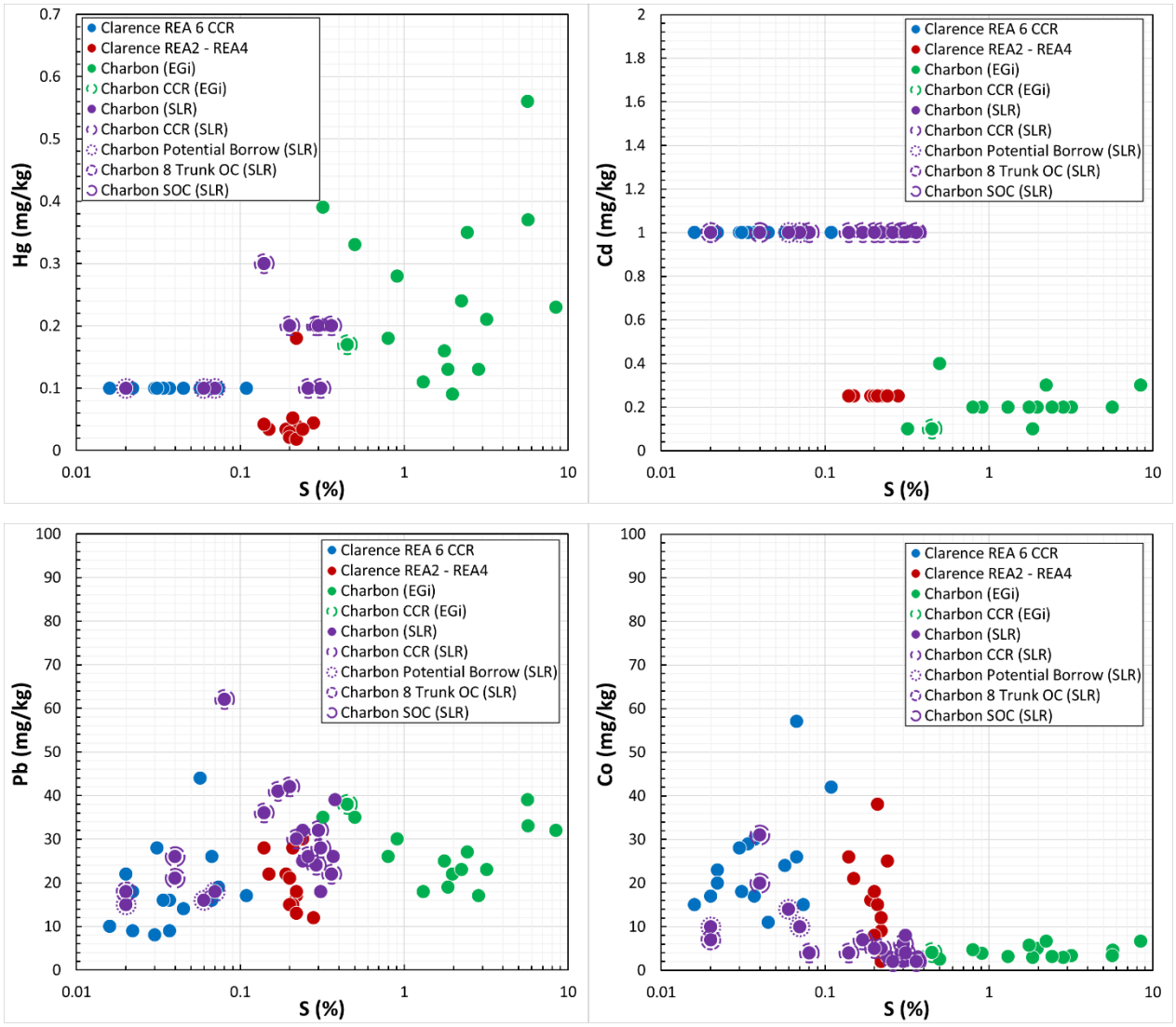

Figure 3.7 **Comparison of sulfur, mercury, cadmium, lead and cobalt concentrations in Clarence and Charbon waste material**

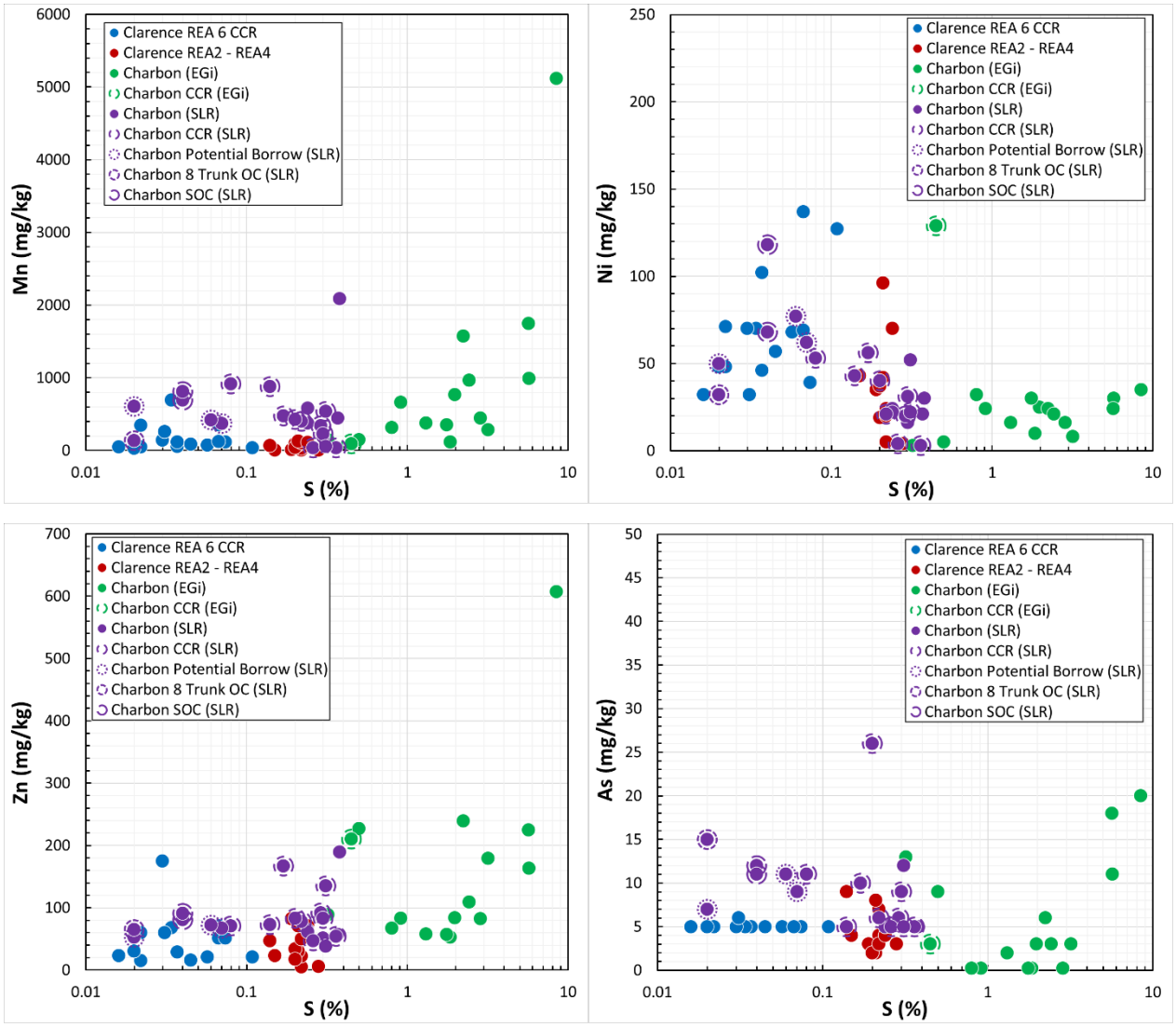

Figure 3.8 **Comparison of sulfur, manganese, nickel, zinc and arsenic concentrations in Clarence and Charbon waste material**

3.3.2 Comparison of leachate water quality

Clarence and Charbon leachate water quality was compared using the following information:

- leachate dam water quality:
  - LD3, which collects REA6 leachate at Clarence;
  - LD1 and LD2, which collect leachate from REAs 2, 3 and 4 at Clarence; and
  - LDP 4, which collects leachate from MREA and NREA at Charbon;
- Charbon groundwater monitoring water quality in the vicinity of the MREA and NREA (PB2 and PB3); and
- laboratory leach testing data:
  - leachate testing (using a 1:5 soil to water ratio) on Charbon samples from MREA and NREA by EGi (2018) and LAMAC (2018) (ie labelled 'Charbon 1:5' and 'Charbon CCR 1:5' to distinguish Charbon CCR leachate from the other Charbon waste material leachate in Figure 3.9 to Figure 3.20); and
  - leachate testing on Clarence samples from REAs 2, 3 and 4 by GHD (2013; 2018) (ie REA2-REA4 ASLP and REA3 CCR Median ASLP in Figure 3.9 to Figure 3.20).

In addition, Clarence's EPL 726 and Charbon's EPL 528 have been used to provide a comparison of the leachate water quality with each site's prescribed discharge values.

The results of this comparison are shown in Figure 3.9 to Figure 3.20 and are summarised as follows:

- REA6 leachate collected at LD3 has among the lowest (ie more acidic) pH values considered in this assessment (Figure 3.9). REAs 2, 3 and 4 leachate collected at LD1 and LD2 is moderately acidic to acidic. All Clarence leachate pH values are below the lower limits of EPL 528 and EPL 726. In contrast, Charbon LDP 4 leachate is mildly alkaline and is comparable to groundwater samples collected within the vicinity of REAs at Charbon. Although differences in scale (see Section 3.2.3) limit potential for direct comparisons of laboratory and field data, Charbon MREA and NREA leachate testing records low pH values (comparable to those reported from LD3) for some samples.
- Sulfate concentrations and EC generally correlate in all samples (Figure 3.9 and Figure 3.10). REA6 LD3 leachate has relatively high sulfate concentrations and EC, similar to Charbon groundwater quality.
- REA6 leachate collected at LD3 has among the highest metal and metalloid concentrations of the samples monitored and tested and exceed EPL 726 criteria (Figure 3.11 to Figure 3.20). However, REA6 LD3 metal and metalloid contents are comparable to concentrations from laboratory leach testing on Clarence REAs 2, 3 and 4 and Charbon leachate samples. Cobalt and nickel concentrations are generally higher in Clarence leachate compared to those in Charbon leachate.

The results indicate that Charbon waste samples generally have a higher capacity for acid generation (Figure 3.6) and higher metal and metalloid concentrations than those at Clarence (Figure 3.7 and Figure 3.8). In contrast, in situ (in field) measurements of leachate from the waste emplacement facilities (MREA and NREA at Charbon; REAs 2, 3, 4 and 6 at Clarence) indicate that Charbon leachate is neutral to mildly alkaline but Clarence leachate is mildly acidic to acidic (Figure 3.9 and Figure 3.10). Possible reasons for this discrepancy are outlined below.

EGi (2018) noted that the highest risk of AMD at Charbon was likely to be close to tailings spigot points within the MREA, which represented 'hot spots' of potential acidity and that the bulk of the leachate arising from Charbon waste material was likely to be neutral/saline.

In contrast, sampling of REA6 CCR found no evidence for acidity hot spots, with samples reporting low sulfur concentrations (low MPA) and low metal and metalloid contents (EMM 2020a). However, the acidic leachate recorded at LD3 requires some source of AMD input, which may include:

- similar pockets of acidity at REA6 as at the MREA (albeit in waste rock rather than tailings), which were not encountered during sampling (such pockets may have been subjected to preferential seepage and weathering); and/or

- due to the low ANC of REA6 CCR, limited buffering of the (low) acidity resulting from sulfide oxidation may result in a build-up of acidity over time; and/or

- alternatively, as yet undiscovered sources of AMD may contribute to LD3 acidity.

A build-up of acidity over time in REA6 leachate is consistent with the conclusions of GHD (2018), which included a geochemical characterisation of Clarence's REA3:

> Due to the relatively large volume of CCR contained within REA3, and despite its low potential to form acid, there remains a significant cumulative potential acidity load within the material should it continue to be exposed to atmospheric and/or aqueous oxygen (based on SCR [chromium reducible sulfur] and calculated NAG [net acid generation] data).

Although leachate monitoring of LD3 suggests that REA6 material may pose an additional risk of AMD if emplaced at Charbon, aside from pH it is generally within the range of what may be expected at Charbon based on monitoring and laboratory leach testing data.

In addition, if the geochemistry of the samples collected at REA6 are representative of the REA6 geochemistry as a whole, the low MPA values will require moderate addition of buffering capacity to reduce the risk of AMD.

Comparison of the geochemical characteristics of materials at Charbon and Clarence supports the requirement for the rehabilitation strategies at Charbon to contain adequate mitigation and management measures to manage AMD in order to prevent potential adverse impacts on the receiving environment.

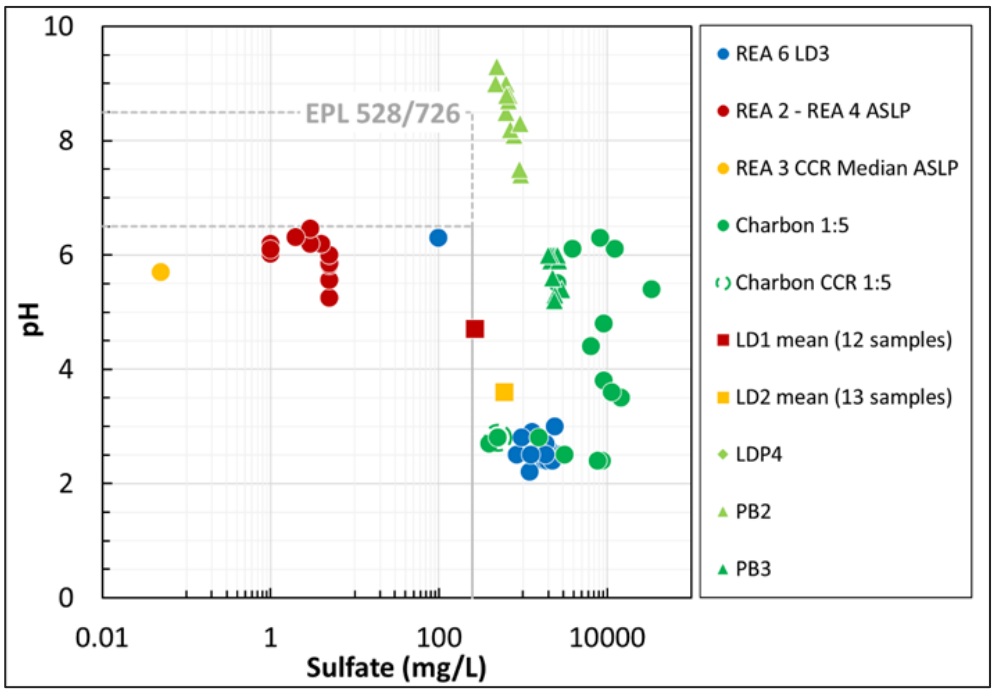

Figure 3.9 Sulfate versus pH for Clarence and Charbon waste material leachate

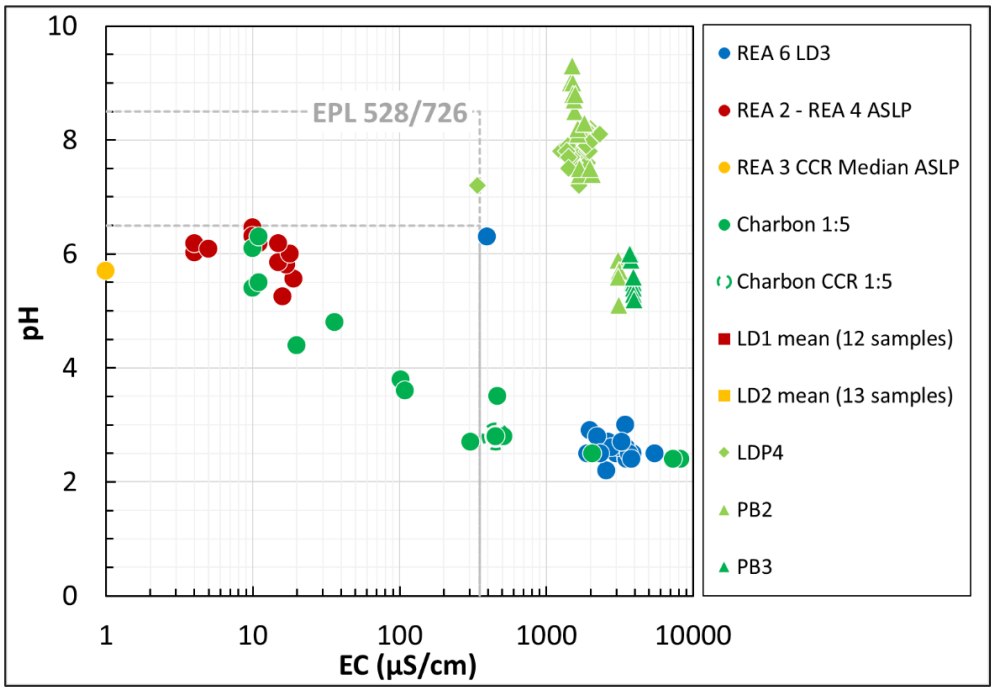

Figure 3.10 Electrical conductivity versus pH for Clarence and Charbon waste material leachate

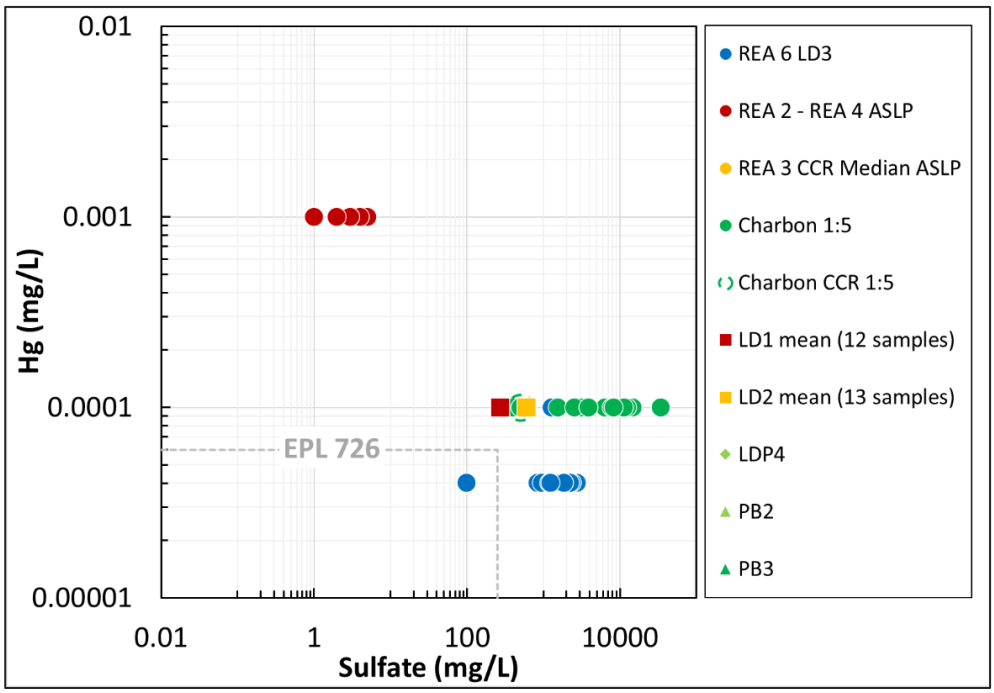

Figure 3.11 Sulfate versus mercury for Clarence and Charbon waste material leachate[4]

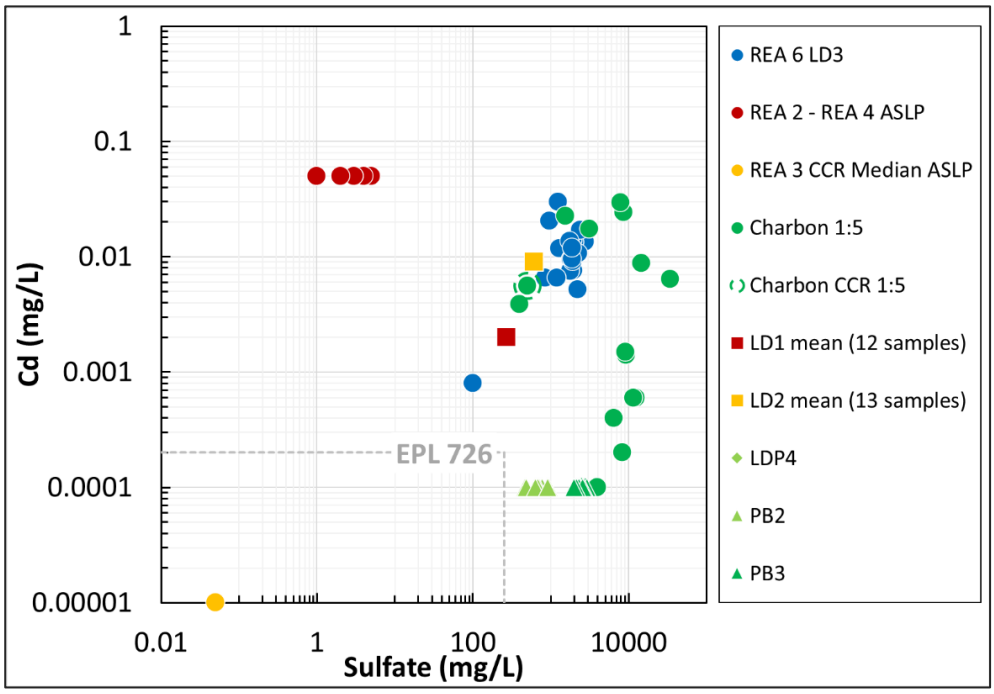

Figure 3.12 Sulfate versus cadmium for Clarence and Charbon waste material leachate

[4] Many of the analytes are in concentrations at or below the laboratory limit of reporting (LOR). In Figures 3.11 to 3.20 these concentrations are shown at the LORs for each analyte. Note that LORs may change depending on the laboratory conditions at the time of analysis. In Figure 3.11, for example, the REA 3 – REA 4 ASLP mercury concentrations are 0.001 mg/L, which was the LOR at the time of analysis; in contrast, REA 6 LD3 mercury concentrations are 0.00004 mg/L, which was the LOR at the time of leachate analysis.

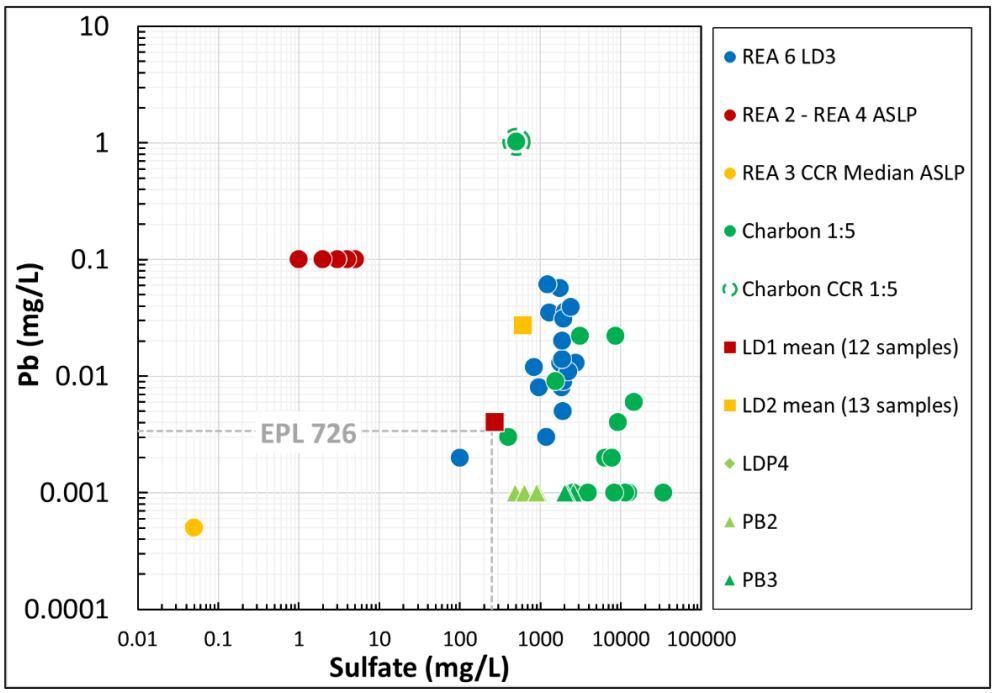

Figure 3.13 Sulfate versus lead for Clarence and Charbon waste material leachate

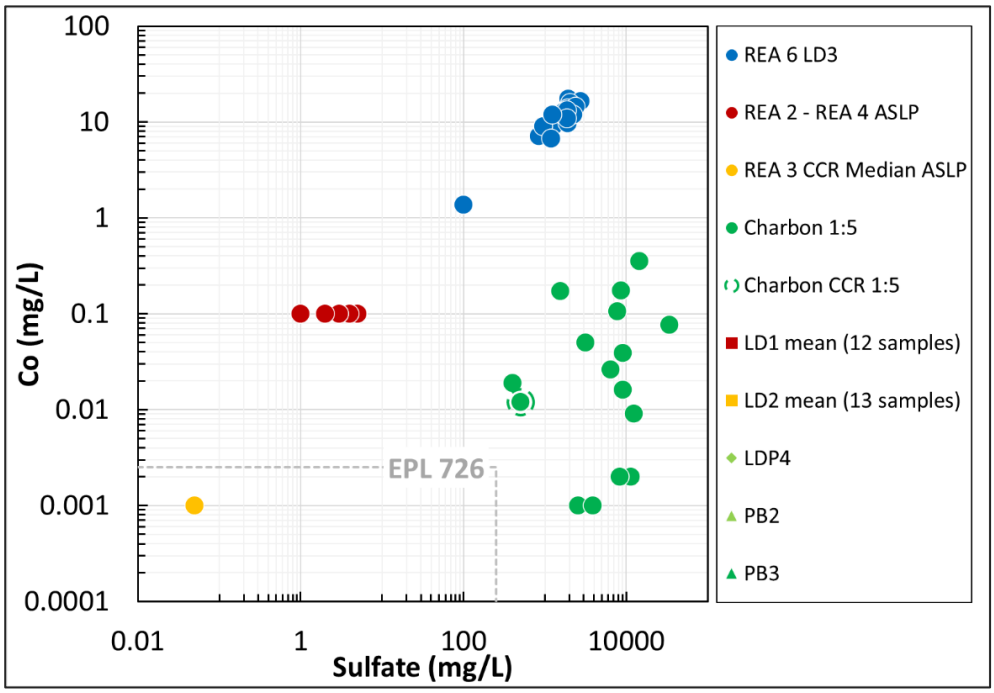

Figure 3.14 Sulfate versus cobalt for Clarence and Charbon waste material leachate

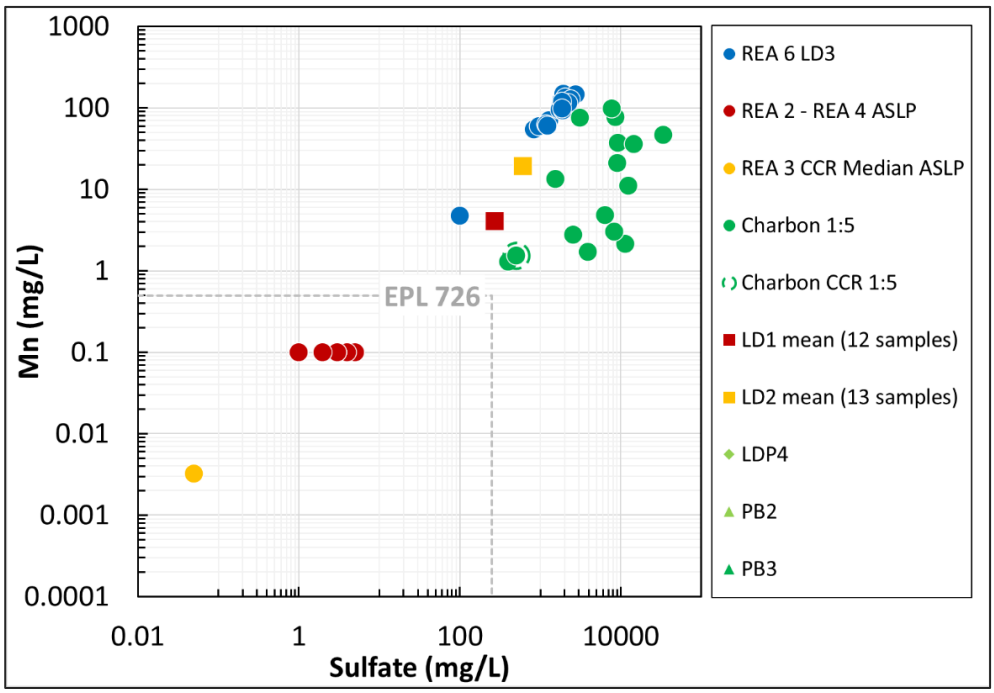

Figure 3.15 Sulfate versus manganese for Clarence and Charbon waste material leachate

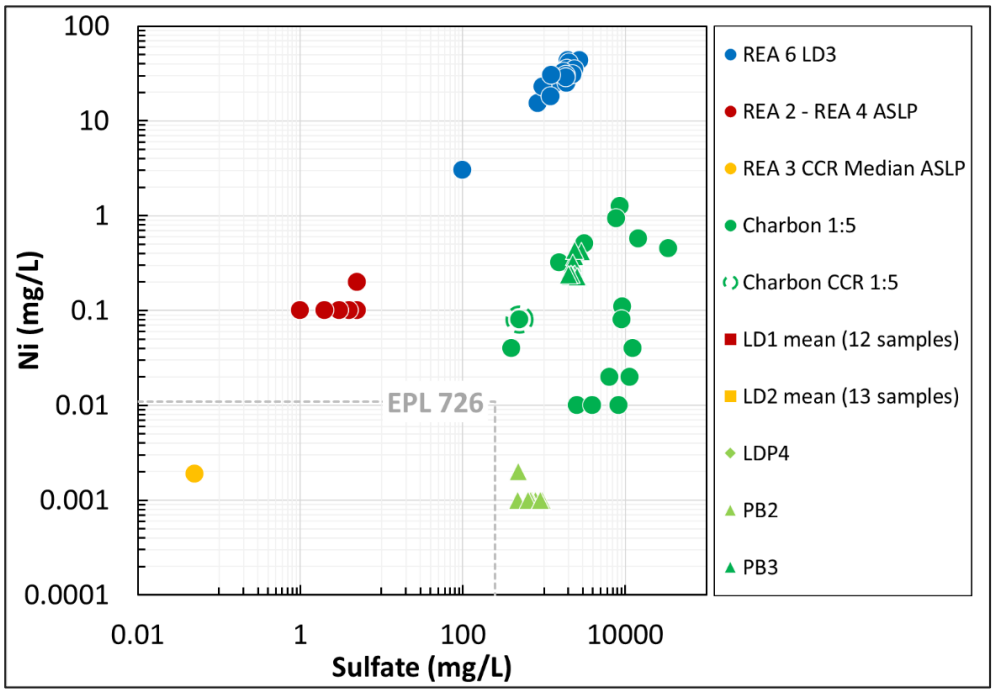

Figure 3.16 Sulfate versus nickel for Clarence and Charbon waste material leachate

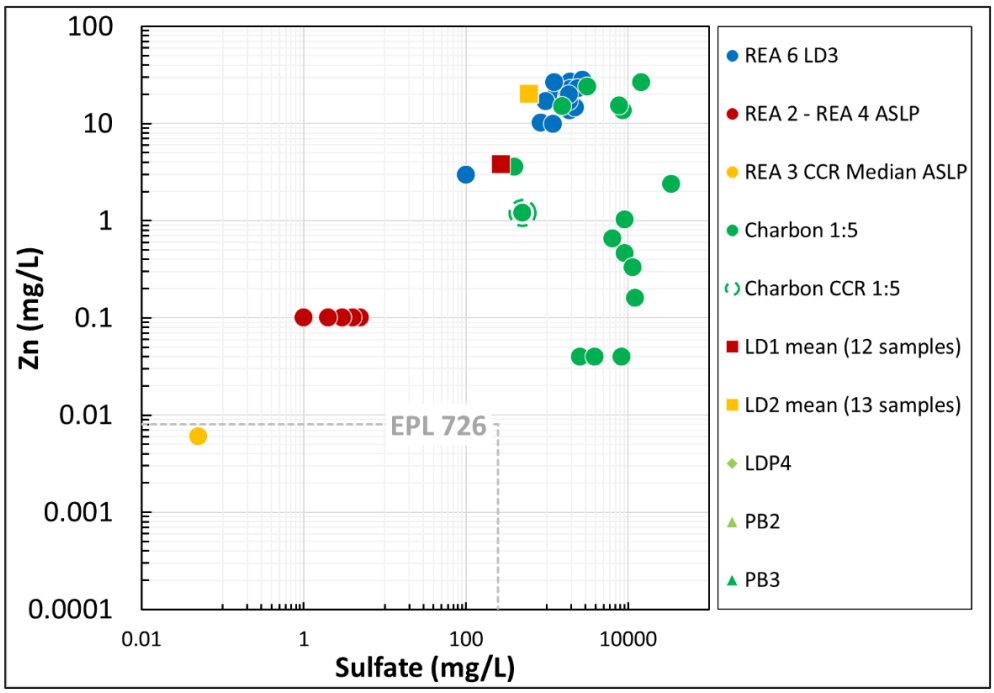

Figure 3.17 Sulfate versus zinc for Clarence and Charbon waste material leachate

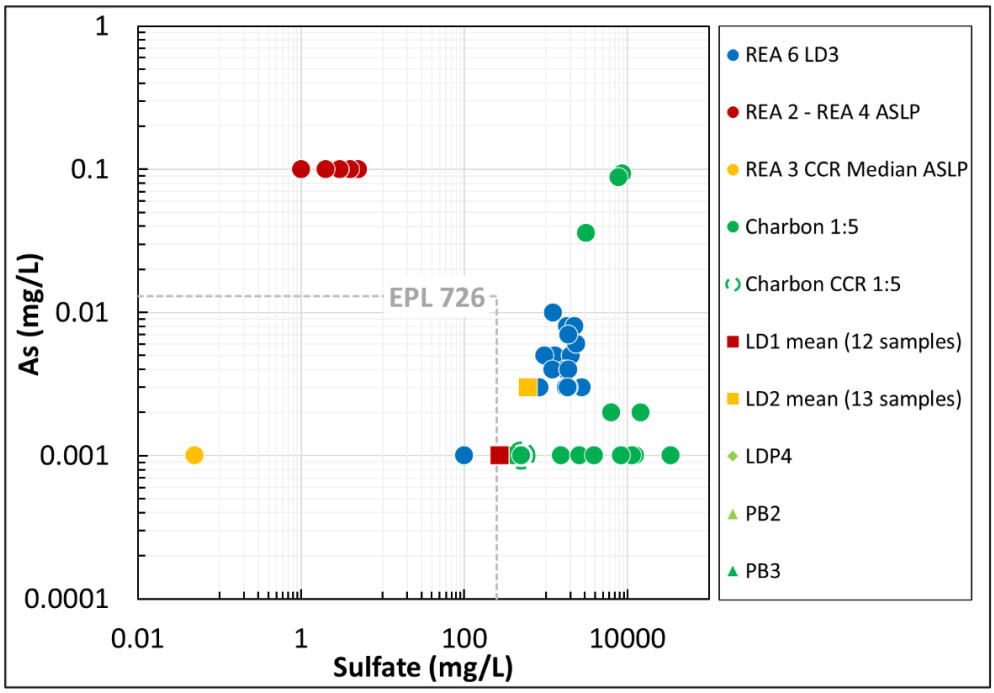

Figure 3.18 Sulfate versus arsenic for Clarence and Charbon waste material leachate

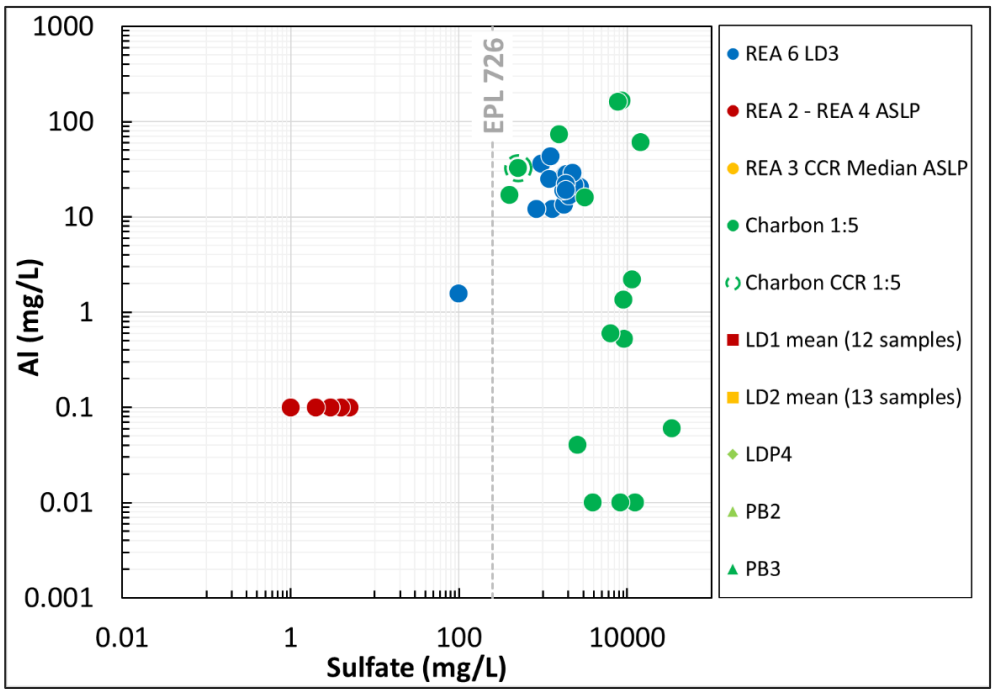

Figure 3.19 Sulfate versus aluminium for Clarence and Charbon waste material leachate

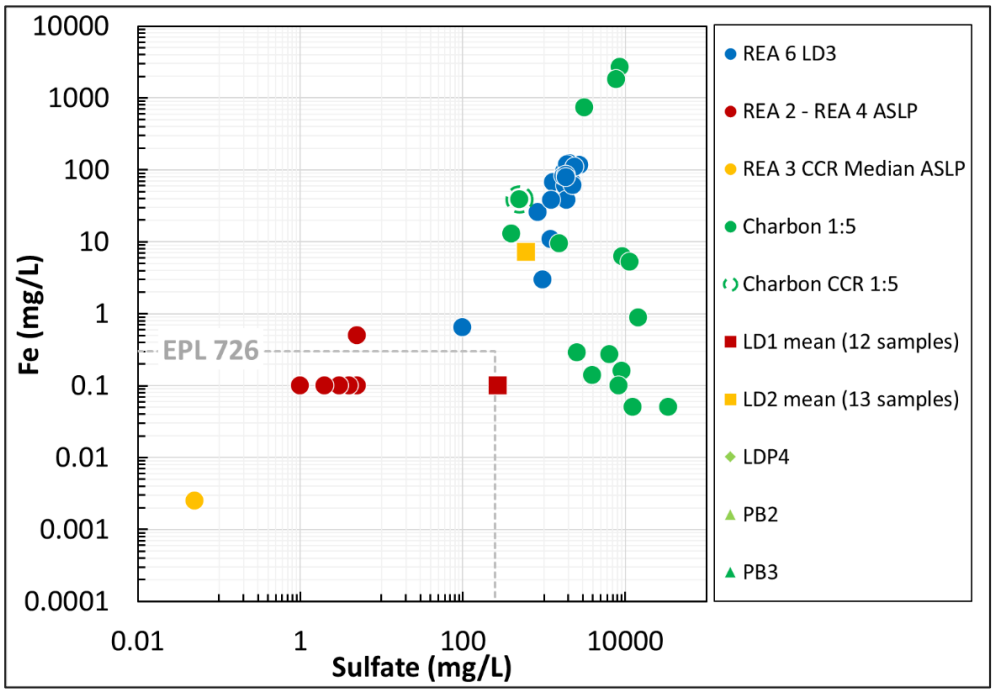

Figure 3.20 Sulfate versus iron for Clarence and Charbon waste material leachate

3.3.3 Rehabilitation design for Charbon

Charbon's waste management and rehabilitation plans are described in LAMAC (2018). Note that the designs in the LAMAC report primarily focus on rehabilitation of MREA and NREA (including existing tailings placement); however, the MREA and NREA rehabilitation design principles have been evaluated for their appropriateness for use in rehabilitating the other void spaces at Charbon (ie Western Open Cut, 8 Trunk Open Cut and Central Open Cut Box Cut voids).

The LAMAC (2018) report evaluated two rehabilitation designs:

- Option A - multi-layer low hydraulic conductivity cover; and
- Option B - single layer store and release cover.

i Multi-layer low hydraulic conductivity cover (Option A)

LAMAC (2018) described the multi-layer low hydraulic conductivity cover (Option A) as follows:

> Multi-layer, low hydraulic conductivity compacted barrier cover systems are designed to limit the infiltration of both water and oxygen into the underlying tailings. The multi-layer cover that has been considered here is a 2m thick cover that comprises 0.5 m low hydraulic conductivity clay, overlain by 1.25m of well graded erosion resistant growth material, and 0.25m of coarse surface cover. The growth material is soil that can support plant life and provide erosion resistance. The growth medium layer serves as a means of integrating the cover system into the ecosystem and protecting the underlying low hydraulic conductivity layer from weathering processes such as erosion and wet/dry cycling (i.e. cracking). The thickness of the cover layers are typical industry accepted values, and are based on:
>
> - Storage volume – ensuring that the material covering the low hydraulic conductivity clay is capable of storing a sufficient quantity of moisture to maintain plant life and prevent cracking of the clay layer. The 1.5m of material overlying the low hydraulic conductivity layer provides sufficient depth to prevent complete loss of soil moisture to evapotranspiration when water is scarce.
> - Physical barrier – the coarse surface material provides a physical barrier in reducing/preventing excessive erosion, particularly prior to the establishment of vegetation. The thickness of the cover material also provides sufficient material to establish root systems without damaging underlying low hydraulic conductivity layers. The 0.5m of low hydraulic conductivity material reduces the net infiltration of water into the underlying tailings, less clay material reduces the pathway distance to the underlying material, which increases the net infiltration. A thickness of 0.5m of material is considered industry standard, as it optimises the hydraulic conductivity properties of the clay as the return on increasing clay thickness is considered to have diminishing returns in relation to both cost and performance.
> - Chemical barrier – the presence of the low hydraulic conductivity layer aids in the reduction of oxygen ingress to the underlying material, and also restricts the upward capillary rise of salts. The coarse surface material also provides a capillary break for the underlying materials. The low hydraulic conductivity layer is assumed to be sourced from the old stockpile material and the growth medium material from the overburden stockpile with coarse material mixed in from the existing box cut. The coarse surface cover is assumed to be sourced from the overburden stockpile with some coarse material sourced from the box cut to provide erosion protection in the upper 0.25m.

ii Single layer store and release cover (Option B)

LAMAC (2018) described the single layer store and release cover (Option B) as follows:

The store and release cover is designed to reduce the infiltration of water to the underlying tailings. This cover type utilises a well graded material to store moisture during periods of wet and for evapotranspiration during dry periods. Moisture store and release covers are not designed to reduce oxygen ingress.

The single layer cover that has been considered is a 2 m thick well graded moderate hydraulic conductivity layer. The material has been assumed to be sourced from the potential borrow site - overburden stockpile, with some coarse material sourced from the box cut to provide erosion protection in the upper 0.25m.

The thickness of the cover layers are typical industry accepted values and are based on:

- Storage volume – ensuring that the material covering the tailings is capable of storing a sufficient quantity of moisture to maintain plant life and preventing cracking and fissures. Store and release covers function by storing infiltration for a sufficient length of time so that the moisture can be removed by evapotranspiration. The moisture storage capacity of the cover is critical in meeting infiltration requirement. The maximum storage capacity is the volume of water that the cover can hold between the driest and wettest conditions that may arise. The 2m of material overlying the tailings layer provides sufficient depth to prevent complete loss of soil moisture to evapotranspiration when water is scarce and prevent the material from reaching critical wilting point for vegetation.

- Physical barrier – the coarse surface material provides a physical barrier in reducing/preventing excessive erosion of the cover and landform, particularly prior to the establishment of vegetation. The thickness of the cover material also provides sufficient material to establish root systems.

- Chemical barrier – the store-and-release cover does not provide the same level of chemical barrier as the low hydraulic conductivity system; however, it does provide some in the form of reducing the net percolation of water into the underlying materials.

iii Recommendations from previous studies

LAMAC (2018) recommended the following option:

> From the two cover designs presented in this report the multi-layer low hydraulic conductivity cover system (Option A) is most likely to provide reduced oxygen ingress and lower net percolation values. Option B would not likely provide sufficient net percolation reduction or oxygen ingress reduction. Both options provide adequate moisture storage to support native grass species if a minimum thickness of 1.5m if provided for growth. Additionally, the plant material aids in removing excess soil moisture and provides erosional support for the plant life and landform.
>
> The geochemical analysis of the tailings material showed that there was PAF material present in the tailings material. To further refine and prove the capping needs of this field tests are recommended to further assess the PAF material properties. If the material is PAF with/without metal leaching, additional cover material additives could be applied (such as lime for neutralisation potential). Consideration of oxygen ingress into the landform maybe required if it is established that the material is acid forming, as the reduction of the oxygen ingress decreases the ability of sulphides to oxidise and release.

EGi (2018) reviewed these designs, based on two studies undertaken by SLR Consulting, noting:

> In the first SLR report, a variety of cover designs were assessed based on the assumption that all rejects materials were potentially acid forming (PAF), and a multi-layer low hydraulic conductivity cover was recommended as the preferred option. The PAF classification of the samples was due to a misinterpretation of the 2016 geochemical testing results. This was corrected somewhat in the second SLR report in which samples were described as likely to be NAF, but no revised cover design recommendation was made.

The current conceptual cover system for the REAs is understood to comprise a draining landform of on average 1.5 to 2.0 m cover of clean overburden. This cover configuration should largely control the upward migration of acid and salts through capillary effects into the growth horizon. This assumption could be confirmed by better defining the physical/hydrological properties of the capping materials to be used (visually may be sufficient), and it is suggested that water flux modelling of cover system options also be carried out. This cover is also expected to significantly reduce the salinity reporting to LDP4 by restricting contact water with surface rejects.

Results of this investigation have the following management implications for Charbon REA closure:

The final cover system will need to control upward migration of localised ARD and surface salts into the growth horizon, but infiltration control does not appear to be a major concern in terms of geochemical effects on receiving surface water and groundwater quality. The cover materials selected will require contrasting hydrological properties to the fine rejects and be NAF.

Prior to placement of the final cover system, incorporate (rip) crushed limestone (or equivalent) into the surface 200mm of the fine rejects hot spots at a rate of 40 tonnes $CaCO_3$/ha in a zone radiating approximately 20m from the spigot point to ensure neutralisation of any existing acidity. It is understood that a suitable limestone source is available, which would comprise a local quarry product called limestone gravel crusher dust (-7mm) combined with "kiln ash ring" waste product high in lime from the nearby Sibelco lime-works. This would provide some short term and longer term neutralisation of the acidic hotspots.

iv Proposed rehabilitation design

Despite the revisions in the Charbon waste characterisation, the LD3 water quality monitoring suggests that REA6 CCR should be treated as PAF material and may be treated as recommended by LAMAC (2018) and EGi (2018). Comparison of the geochemical characteristics of materials at Charbon and Clarence supports the requirement for the rehabilitation strategies at Charbon to contain adequate mitigation and management measures to manage AMD in order to prevent potential adverse impacts on the receiving environment.

The rehabilitation design proposed by Centennial (2020) is a combination of the design principles for MREA and NREA and the characteristics of the void spaces at Charbon (ie Western Open Cut, 8 Trunk Open Cut and Central Open Cut Box Cut). It also considers the geochemical characteristics of Clarence CCR material to be placed in the voids. The final landform at Charbon will be representative of existing landforms within and adjacent to the site. The areas proposed to receive Clarence CCR will be 'water shedding' as they are all hillside rehabilitation landforms.

A deep multi-layer moderate hydraulic conductivity cover will be developed on the sloping landforms with store-and-release characteristics, that will allow plant establishment and growth, while minimising deep-drainage (potential AMD seepage) and mitigating upward migration of soluble salts. The deep multi-layer cover will be 3-m-thick and will consist of a 2.5 m benign overburden layer (average thickness) followed by approximately 0.5 m of Southern Open Cut resistant overburden cladding. This cover will be adopted at areas to be rehabilitated with Clarence CCR (Centennial 2020).

Rehabilitation plans for the Western Open Cut, 8 Trunk Open Cut and Central Open Cut Box Cut voids will:

- maintain drainage between the landform areas and sediment basins and maintain the integrity of the sediment basins and surface water management infrastructure to ensure they do not overtop;
- implement the approved final landform design, with 2.5 m of benign overburden and 0.5 m of Southern Open Cut resistant overburden cladding on top Centennial (2020)[5];

[5] The LAMAC designs follow industry practice (LAMAC 2018), which Centennial has further developed following industry consultation.

- ensure emplacement areas are designed to reduce water infiltration and keep material dry if waste material is PAF; and
- include:
    - ongoing monitoring of groundwater quality at PB2 and PB3;
    - ongoing monitoring of landform emplacement areas to identify any seepage areas and quantify volumes; and
    - installation of monitoring bores down-gradient of emplacement areas and up-gradient of receptors and ongoing monitoring of groundwater quality at these locations[6].

[6] Three additional groundwater monitoring bores are proposed to be installed as detailed in the water resources assessment (EMM 2020b).

4 Management approach

Due to the potential AMD risk of the Clarence CCR material (as described in Section 3.2), the following waste management methods are being / will be implemented by Centennial:

- Clarence CCR will be sampled and tested prior to and during excavation or from the production stream to verify the material geochemical characteristics for placement at Charbon. This may be conducted in the field and/or using rapid turn-around laboratory analysis.

- As noted by LAMAC (2018) and EGi (2018) (Charbon) and also recommended by GHD (2018) (Clarence), field trials of the cover designs should be set up prior to start of the rehabilitation works to allow the performance of the design to be assessed.

- PAF material may be mitigated following addition of buffering capacity, in the form of limestone, as outlined by LAMAC (2018) and EGi (2018). Limestone addition may be estimated in situ as follows:

    - Field testing of pH (pH_f), hydrogen peroxide pH (pH_{fox}) and field analysis of sulfur concentrations using X-ray fluorescence spectroscopy (XRF) to provide field geochemical verification of CCR material.

    - Samples recording acidity (low pH_f), the potential for acidity if exposed to oxygen and water (low pH_{fox}) and high sulfur contents (greater than 0.1% S as recorded by XRF) should be sent for laboratory analysis to determine dosing factors[7].

    - CCR may then be dosed with limestone prior to use in rehabilitation at Charbon.

- Water quality monitoring and wastewater treatment should continue at Charbon and Clarence. In addition, groundwater monitoring should be undertaken down gradient of the proposed CCR emplacement areas at Charbon (Section 3.3.3).

[7] This field testing method is similar to methods employed in acid sulfate soil investigations, which are often carried out concurrently with construction activities. As such, the field testing provides a rapid means of verifying the geochemical properties of the REA CCR during excavation. Samples exhibiting the potential for AMD may be sent for laboratory analysis and calculation of addition of limestone, with most laboratories ensuring a 24-hour turn-around time for results.

5 Conclusion

This report has assessed whether CCR from Clarence (including REA6 and the mine's production stream) can be used during ongoing rehabilitation at Charbon by investigating the geochemical properties of REA6 CCR and comparing these with waste material on-site at Charbon.

The rehabilitation plans were also reviewed to determine whether provisions had been made to adequately mitigate the potential geochemical impacts arising from use of imported CCR material in rehabilitation at Charbon.

The primary findings of this assessment are:

- From a geochemical perspective and based on the geochemical characterisation of Clarence and Charbon waste material, REA6 CCR has a similar or lower AMD risk to the other waste material at Clarence and waste material currently in MREA and NREA Charbon:
    - While some REA6 samples are classified as PAF, they have low metal and metalloid contents and low sulfur concentrations (0.109% sulfur was the maximum content recorded in REA6 CCR). Waste material from the other Clarence REAs recorded sulfur contents less than or equal to 0.3% and waste material from Charbon's MREA and NREA recorded sulfur concentrations of less than or equal to 8.5%.
    - The presence or absence of ANC governs whether AMD will be buffered. Some REA6 CCR samples have zero ANC and lack the capacity to buffer low levels of acidity that may be generated if the material is left exposed. In contrast, some of the Charbon waste material samples have a high capacity to generate acidity and as for many coal-associated waste samples, lack significant buffering capacity.
- In terms of water chemistry:
    - LD3, which collects seepage from Clarence REA6, has consistently low pH. This is similar to LD1 and LD2 (which collect seepage from the other Clarence REAs) but is lower than the mildly alkaline leachate recorded at Charbon's LDP4.
    - Laboratory leachate testing of Charbon's waste material, in contrast, indicates potential for some AMD. This may be explained by 'pockets' of acidity associated with tailings spigot points at MREA. Similar 'pockets' (albeit in waste rock) may exist in Clarence's REAs. The acidic leachate at LD3 may also be explained by the build-up of acidity over time and the lack of buffering capacity in the REA6 CCR. Alternatively, an as yet unknown source may be responsible for the acidic leachate at Clarence.
- Given the results for the solid sample and leachate water quality, it is recommended that Clarence CCR is treated as PAF material with the capacity to generate AMD if exposed if it is to be used in rehabilitation activities at Charbon.
- The final landform at Charbon will be representative of existing landforms within and adjacent to the site. The areas proposed to receive Clarence CCR will be 'water shedding' as they are all hillside rehabilitation landforms. A 3-metre-thick multi-layer moderate hydraulic conductivity cover will be developed on the sloping landforms with store-and-release characteristics (Centennial 2020). This will allow plant establishment and growth, while minimising deep drainage (potential AMD seepage) and mitigating upward migration of soluble salts.

Field testing of the AMD potential of CCR from Clarence (eg as it is being excavated or collected from the production stream) could be used to provide limestone addition rates, which can be used as an additional method to mitigate AMD risk at Charbon.

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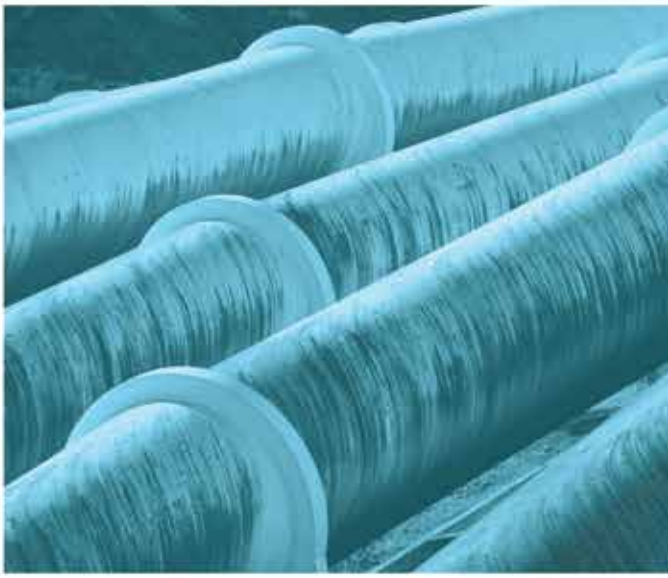
Appendix A

Clarence Colliery - REA6 geochemical verification


Clarence Colliery - Modification 6

REA 6 geochemical verification

Prepared for Centennial Coal Company Limited
August 2020

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Clarence Colliery - Modification 6

REA 6 geochemical verification

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Client

Centennial Coal Company Limited

Date

31 August 2020

Version

Final

Prepared by	**Approved by**
	
James Tuff Associate Geochemist 31 August 2020	**Phil Towler** Associate Director 31 August 2020

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1 Introduction

EMM Consulting Pty Limited (EMM) has been engaged by Centennial Coal Company Limited (Centennial) to prepare a characterisation verification report in support of a proposed modification to the development consents for Clarence Colliery (Clarence) and Charbon Colliery (Charbon).

Clarence is an underground coal mining operation within the Western Coalfield of New South Wales (NSW) approximately 10 kilometres (km) east of Lithgow in the Lithgow local government area (LGA). Clarence has been in operation since the 1980s and is currently owned by Centennial Coal Company Limited (Centennial) and SK Networks Resources Australia Pty Ltd as participants in the Clarence Colliery Joint Venture. Centennial has been appointed as the management entity for the Clarence Colliery Joint Venture.

Clarence operates under three separate development consents:

- an interim development consent issued in 1976 by Blaxland Shire Council (now Lithgow City Council) for the construction of surface facilities (IRM.GE.76);
- a development consent issued in 1994 by Lithgow City Council for the extension of underground coal mining, surface reject emplacement areas (REAs) and water management and ancillary structures (174/93); and
- development consent issued in 2005 (DA 504-00) by the NSW Department of Infrastructure, Planning and Natural Resources (now the NSW Department of Planning, Industry and Environment (DPIE)) to expand site operations into Mining Lease (ML) 1583.

Clarence extracts coal from the Katoomba Seam and has the facilities on-site to wash run-of-mine (ROM) coal in order to maximise coal quality. A by-product of the washing process is coarse coal reject (CCR), which is approved under the aforementioned development consents to be emplaced in six REAs at Clarence's pit top, including:

- REA1, REA2 and REA4, which are rehabilitated but not closed;
- REA3, which is in care and maintenance;
- REA5, which is currently being constructed within the rail loop; and
- REA6, which is operational.

Centennial has identified an opportunity to use CCR material from Clarence to enhance rehabilitation at Charbon. Charbon is an underground and open cut coal mine owned and operated by Charbon Coal Pty Limited (Charbon Coal). In 2015, mining operations at Charbon ceased following the depletion of the mine's approved coal reserves. Since the cessation of mining, Charbon Coal has been progressively rehabilitating the site. Charbon Coal undertakes rehabilitation and mine closure activities at the site pursuant to SSD 08_0211.

Centennial is seeking to modify DA 504-00 pursuant to Section 4.55(2) of the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act) to allow for the transportation of CCR from REA6 and Clarence's production stream to Charbon via rail. If approved, the modification will authorise:

- extraction of CCR from REA6;
- transfer of CCR from REA6 and Clarence's production stream to the existing train load out (TLO);
- loading of CCR into train-based containers via the existing TLO; and

- export of CCR off-site to Charbon via rail.

At the same time Centennial is seeking to modify DA 504-00, Charbon Coal will submit a modification application for SSD 08_0211 to allow for the importation of CCR from Clarence by rail and its use in ongoing rehabilitation activities at Charbon.

Emplacement of CCR from Clarence at Charbon will require management of geochemical issues associated with the CCR, including potential:

- for acid and metalliferous drainage (AMD);
- to cause soil contamination; and
- impacts to groundwater and sensitive receptors (eg landholder bores, surface water bodies or groundwater dependent ecosystems (GDEs)).

Clarence has six approved REAs that accept CCR. Rehabilitation of these REAs is progressive and is undertaken in accordance with Clarence's Rehabilitation Plan and Mining Operations Plan (MOP). REA6 is currently operational and available as a source of CCR material for Charbon.

Geochemical assessments of CCR placed in REA2, REA3 and REA4 at Clarence have previously been commissioned by Centennial (GHD 2013; GHD 2018). These assessments provide information on the geochemical behaviour of 'fresh' CCR and the behaviour of CCR after it has been placed in a REA (REA2, REA3 and REA4). Clarence has primarily mined the Katoomba coal seam and CCR currently emplaced in REA6 is expected to have similar geochemical properties to the historic CCR emplaced in the older REAs.

Establishing similar geochemical behaviour between historic and currently worked CCR at Clarence will provide Centennial with the opportunity to use the extensive geochemical dataset that is already available at Clarence in the environmental assessment and approval documentation for the proposed modifications.

To confirm the geochemical similarities between historic CCR and REA6 CCR, Centennial and EMM undertook a program of sampling and analysis to characterise REA6 CCR and verify the similarities of this material with those in the other REAs.

2 Methodology

2.1 Overview

Successful design and implementation of waste material management relies on a comprehensive understanding of the geochemical characteristics of the material involved. This includes:

- The potential for the material to generate undesirable drainage, which may be acidic (ARD; AMD), saline (SD), or neutral (ND)[1]. Essential information includes knowledge of the inherent acidic potential versus the intrinsic acid buffering capacity and the leachability of ions of the existing material and material scheduled for emplacement.

- The behaviour of the material in the designed landform if/when it is exposed to water and oxygen, which includes understanding the generation of potential acidic, saline and neutral drainage, the composition of the drainage (eg heavy metal concentrations) and the potential impact of the drainage if released, which may be assessed against appropriate guidelines for sensitive environmental values.

- Assessment of the appropriateness of available material to be used in methods to counter adverse impacts, such as encapsulation or cover of potentially deleterious waste.

For successful rehabilitation, the closure design must be informed by geochemical characterisation of the material present and/or of material designated for use in the rehabilitation designs to provide an indication of the mitigation steps that may be required. To support collection of this information, the following steps were undertaken:

- In accordance with industry practice (eg AMIRA 2002[2]; GARD Guide 2009[3]) (Figure 2.1), a staged laboratory testing program was designed to initiate the geochemical characterisation of material within REA6. For Phase 1 of the testing program, samples were collected from the REA6 surface, at 1 m depth below the surface and at 2.1-2.4 m depths below the surface (Section 2.2). These samples underwent acid-base and whole-sample metals/metalloids analysis (Section 2.3).

- All sampling and laboratory testing of primary samples and intra-laboratory duplicate samples was performed by Australian Laboratory Services (ALS), which is accredited by the National Association of Testing Authorities (NATA). Sampling was undertaken following the Sampling and Analysis Plan (SAP) developed by Centennial and EMM (2020a). Certificates of analysis are provided in Appendix A.

- Results from the initial Phase 1 characterisation program were evaluated to determine whether additional detail would be required as part of a Phase 2 testing program (Chapter 4).

- Leachate water quality collected at the toe of REA6 (Leachate Dam 3) was examined to provide an indication of the behaviour of REA6 CCR following emplacement and its potential for weathering.

[1] These terms follow the GARD-Guide approximate thresholds of drainage as being acid rock drainage (ARD) if reporting a pH of less than 6, saline drainage (SD) if reporting a pH greater than 6 and a sulphate concentration above 1,000 mg/L and neutral drainage (ND) if reporting a pH greater than 6 and sulphate concentration below 1,000 mg/L. Acid and metalliferous drainage (AMD) is used as a synonym of ARD in Australia and is referred to in this report.

[2] http://www.amira.com.au.

[3] http://www.inap.com.au/gard-guide.

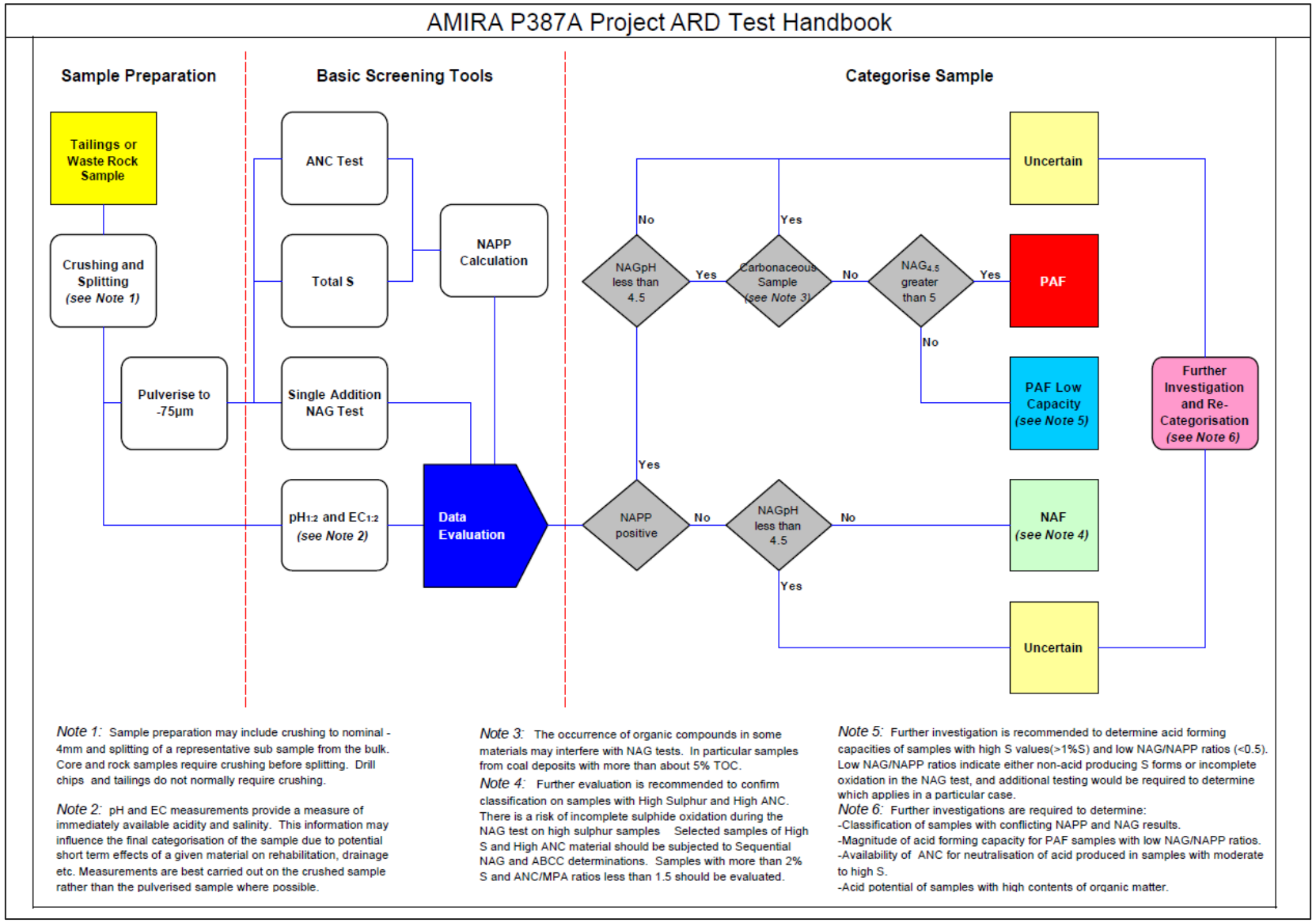

Figure 2.1 Flow chart of decision-making process regarding geochemical testing for acid rock drainage (ARD; AMIRA 2002)

The information obtained on REA6 whole-sample results and leachate chemistry was then compared to the existing (historical) geochemical dataset of material from the older Clarence REA samples and leachate water quality to determine the geochemical similarities between the REA materials.

Details of the sampling and analysis program are provided in the following sections.

2.2 Sampling

Sampling was conducted by ALS in accordance with the REA6 SAP and used the following approach:

- While no consensus exists as to the minimum number of samples that should be investigated to adequately constrain the potential AMD risk of a particular material type, a number of guidelines draw on industry experience to provide overall sampling methods. The approach recommended by the New South Wales (NSW) Government guidelines, which are broadly consistent with the Queensland Department of Natural Resources, Mines and Energy (DNRME) and the United States Environment Protection Agency (USEPA) guidelines and are widely accepted as good practice, is to collect approximately 20–80 samples for waste rock tonnages of approximately 1–10 Mt (Kentwell, Garvie, & Chapman 2012; Department of Mines and Petroleum 2009).

- It is key that the samples are representative of the main material types of concern.

- Different degrees of weathering will affect the reactivity of the material of concern and must be taken into account during sampling to provide an adequate representation of different material behaviour. It is noted that historical sampling has included both weathered and fresh CCR.

Since mining is primarily focussed on the Katoomba coal seam, the additional CCR samples were anticipated to have broadly similar geochemical characteristics to the historically mined material. The additional samples were selected to enhance the existing dataset and follow the recommended practice.

Samples were collected in a grid pattern on the top of REA6 to provide an adequate spatial distribution. To increase sample variation, and to provide material representative of different levels of exposure and stages of weathering, samples were collected over a range of depths:

- grab samples from the REA6 surface;

- 1 m depth samples using augurs; and

- >2 m depth samples using an excavator.

The REA6 CCR sample details are summarised in Table 2.1 and examples of REA6 sampling are shown in Photograph 2.1 and Photograph 2.2. The REA6 field campaign, conducted on the 23 April, provided 15 CCR samples for initial (Phase 1) laboratory analysis.

Table 2.1 Clarence REA6 CCR sample details

Sample name	GPS coordinate	Depth[1]
Surface grab samples		
Surface #1	S 33° 27.946 - E 150° 14.669	Surface
Surface #2	S 33° 27.962 - E 150° 14.644	Surface
Surface #3	S 33° 27.952 - E 150° 14.614	Surface
Surface #4	S 33° 27.952 - E 150° 14.594	Surface
Surface #5	S 33° 27.933 - E 150° 14.624	Surface
Sub-surface samples		
Augur #1	S 33° 27.946 - E 150° 14.669	1 m
Augur #2	S 33° 27.962 - E 150° 14.644	1 m
Augur #3	S 33° 27.952 - E 150° 14.614	1 m
Augur #4	S 33° 27.952 - E 150° 14.594	1 m
Augur #5	S 33° 27.933 - E 150° 14.624	1 m
Deeper sub-surface samples		
Excavation #1	S 33° 27.946 - E 150° 14.669	2.3 m
Excavation #2	S 33° 27.962 - E 150° 14.644	2.2 m
Excavation #3	S 33° 27.952 - E 150° 14.614	2.4 m
Excavation #4	S 33° 27.952 - E 150° 14.594	2.1 m
Excavation #5	S 33° 27.933 - E 150° 14.624	2.3 m

1. Total sample mass per location approximately 3 kg.

Photograph 2.1 REA6 sampling - surface grab samples

Photograph 2.2 REA6 sampling – sample excavation

2.3 Laboratory analysis

Verification of the REA6 CCR geochemical characteristics involved the implementation of a staged testing approach consisting of:

- determining initial geochemical characteristics using static acid-base accounting and whole-sample geochemistry (Phase 1);
- using the results of the Phase 1 testing to determine whether REA6 CCR samples should undergo more detailed geochemical testing (Phase 2); and
- comparing the geochemical data with historic information to assess whether longer-term geochemical testing (eg kinetic testing) would be required (Phase 3).

To provide an initial verification of the REA6 CCR geochemical characteristics and potential for AMD, the following Phase 1 analysis was undertaken:

- pH and electrical conductivity (saturated paste);
- total sulfur concentration as S;
- total carbon and organic carbon content;
- maximum potential acidity (MPA) in kg H_2SO_4/t (calculated, see below);
- acid neutralising capacity (ANC) in kg H_2SO_4/t;
- net acid producing potential (NAPP) in kg H_2SO_4/t (calculated, see below); and
- major and trace element whole-sample concentrations, including metals and metalloids.

Phase 1 testing interpretation is described in Sections 2.3.1 and 2.3.2.

2.3.1 Acid-base accounting

The initial assessment of the AMD potential of the samples was undertaken via acid-base accounting, which evaluates the balance between acid generation processes and acid neutralising processes (AMIRA 2002). The MPA (in kg H_2SO_4/t) is a measure of the highest acidity that a sample will generate assuming all sulfur within the sample is oxidised and available to form sulfuric acid. It is defined from the stoichiometry of pyrite (sulfide) oxidation and is calculated as:

MPA=S% x 30.6 (AMIRA 2002)

A sample containing 1% S has the potential to generate 30.6 kg of H_2SO_4 per tonne of sample (30.6 kg H_2SO_4/t). This is a conservative indication of the maximum acid generating capacity within each sample.

The ANC of a sample is a measure of the capacity of the material within the sample (eg carbonates) to buffer the acidity produced. ANC is generally expressed in units of kg H_2SO_4/t (ie equivalent to MPA units).

The net acid production potential (NAPP, reported in kg H_2SO_4/t) records the balance within the sample of the acidity generated versus its intrinsic buffering capacity and provides an indication of the potential for a sample to generate acidity. It is defined as:

NAPP=MPA-ANC (AMIRA 2002)

Where MPA is less than ANC, NAPP is negative, indicating that the sample may have sufficient buffering capacity to prevent AMD. A positive NAPP (MPA>ANC) indicates that the material may potentially generate net acidity under the appropriate conditions. In addition, the neutralisation potential ratio (NPR) is used to provide an indication of the acidity versus buffering of a sample. NPR is calculated as:

$$NPR=ANC/MPA$$

Classifications in this verification report adhere to the conventions in Price (2009) with the following divisions:

- NPR>2 = Non-acid forming (NAF).
- NPR<1 = Potentially acid forming (PAF).
- 1≤NPR≤2 = Uncertain (UC).

2.3.2 Metals/metalloids analysis

The REA6 CCR samples were analysed for whole-sample metals/metalloids concentrations. The Phase 1 metals/metalloids were assessed with reference to the geochemical abundance index (GAI). The GAI compares the concentration of an analyte in a sample with a reference value to determine the level of enrichment in the sample and thus to highlight analytes that may act as sources of contamination in AMD. For this verification exercise, global median soil concentrations were used following the standard convention (GARD Guide 2009; Bowen 1979; Berkman 1976). The GAI is calculated as follows:

$$GAI=\log_2[Conc_{Sample}/1.5Conc_{Median\ Soil}]$$

GAI values are reported as integers and range between 0 (the sample analyte concentration is similar to or less than the reference concentration) to 6 (the sample analyte concentration is enriched to approximately 100 times the reference content).

3 Results

3.1 Acid-base characteristics

Results from the Phase 1 acid-base accounting are shown in Table 3.1. Of the 15 samples analysed:

- 4 samples are recorded as NAF;
- 9 samples are recorded as PAF; and
- 2 samples are recorded as UNCERTAIN.

REA6 CCR total sulfur contents are low, with the maximum concentration recorded in sample CLR REA6 Surface #4 (0.109%). Sulfur concentrations record a degree of spatial heterogeneity, which may be expected from rejects in a waste emplacement facility (Figure 3.1); however, sulfur contents are generally consistent with depth across REA6 (Figure 3.2).

Saturated paste pH values range from 3.6 (CLR REA6 Auger #5) to 7.4 (CLR REA6 Excavation #2) and reflect the presence/absence of potentially readily-leachable acid-generating material in each sample. Most samples reporting low saturated paste pH values are PAF and have little to no ANC (Table 3.1). Samples reported as NAF that also report low saturated paste pH values are likely to contain ANC in non-readily available or less reactive forms (ie non-calcium carbonate ANC), which is consistent with the low calcium contents reported (Section 3.2). It should also be noted that MPA has been calculated assuming that all sulfur analysed is in the form of reactive sulfide. This approach was taken to provide a conservative (worst case) estimate of the potential for each REA6 sample to generate acidity and much of the sulfur may be present as sulfate, which will further limit the MPA.

REA6 saturated paste EC values range between 32 and 414 µS/cm and compare favourably with the Clarence Environmental Protection Licence (EPL) 726 discharge compliance limit of 350 µS/cm.

As expected, the REA6 CCR samples record high total carbon contents (12.8–55.1%), with most carbon present as organic carbon (Table 3.1).

Table 3.1 REA6 laboratory acid-base accounting results

Sample	Date	Depth	Sat. paste pH	Sat. paste EC	Moisture content	Total carbon	Total organic carbon	Sulfur	MPA	ANC	NAPP	NPR	Price (2009) classification
		m	-	µS/cm	%	%	%	%	Kg H_2SO_4/t	Kg H_2SO_4/t	Kg H_2SO_4/t	-	
CLR REA6 Surface #1	23/04/2020	0.0	5.8	63	2.4	14.6	14.0	0.045	1.38	0.00	4.0	0.0	PAF
CLR REA6 Surface #2	23/04/2020	0.0	4.4	32	3.8	17.3	16.6	0.057	1.74	0.00	9.2	0.0	PAF
CLR REA6 Surface #3	23/04/2020	0.0	4.7	49	3.1	14.4	13.9	0.016	0.49	1.89	-1.4	3.9	NAF
CLR REA6 Surface #4	23/04/2020	0.0	4.3	106	2.7	20.4	19.6	0.109	3.34	1.64	1.7	0.5	PAF
CLR REA6 Surface #5	23/04/2020	0.0	4.2	126	2.5	12.8	12.4	0.037	1.13	0.00	1.2	0.0	PAF
CLR REA6 Auger #1	23/04/2020	1.0	7.4	414	3.2	14.5	13.5	0.074	2.26	4.06	-1.8	1.8	UNCERTAIN
CLR REA6 Auger #2	23/04/2020	1.0	4.5	109	3.4	17.6	16.5	0.067	2.05	0.65	1.4	0.3	PAF
CLR REA6 Auger #3	23/04/2020	1.0	6.4	180	3.1	16.4	15.3	0.022	0.67	2.77	-2.1	4.1	NAF
CLR REA6 Auger #4	23/04/2020	1.0	4.5	168	3.6	13.6	12.7	0.020	0.61	0.11	0.5	0.2	PAF
CLR REA6 Auger #5	23/04/2020	1.0	3.6	183	17.9	12.2	11.7	0.031	0.95	0.00	1.2	0.0	PAF
CLR REA6 Excavation #1	23/04/2020	2.3	4.2	356	3.4	15.3	14.1	0.037	1.13	2.93	-1.8	2.6	NAF
CLR REA6 Excavation #2	23/04/2020	2.2	7.4	244	3.8	14.7	14.1	0.034	1.04	3.24	-2.2	3.1	NAF
CLR REA6 Excavation #3	23/04/2020	2.4	5.0	111	3.3	13.2	12.9	0.022	0.67	0.00	0.7	0.0	PAF
CLR REA6 Excavation #4	23/04/2020	2.1	6.9	124	7.2	55.1	55.1	0.030	0.92	0.00	3.1	0.0	PAF
CLR REA6 Excavation #5	23/04/2020	2.3	4.4	120	4.2	13.9	13.6	0.067	2.05	2.85	-0.8	1.4	UNCERTAIN

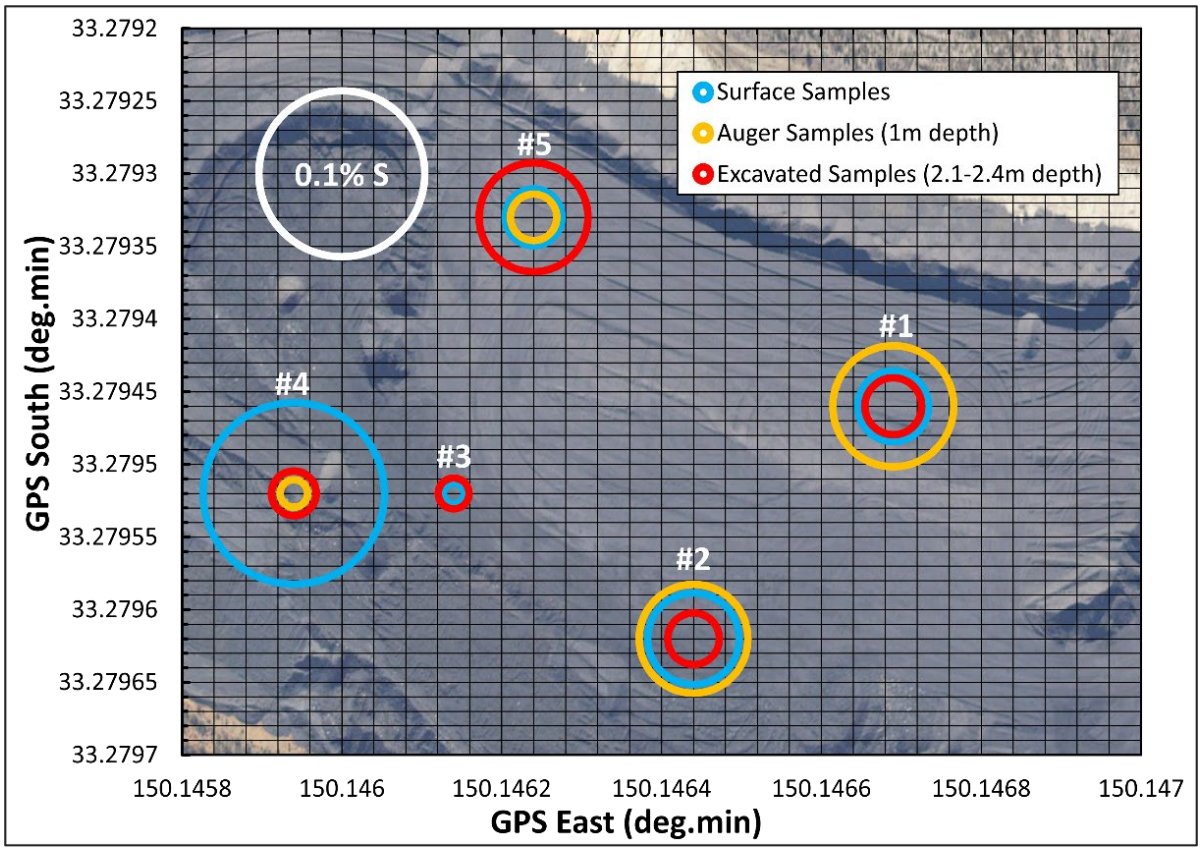

Figure 3.1 **Approximate locations of REA6 CCR samples**

Note: Circle diameters represent sulfur concentrations; the upper left circle represents a concentration of 0.1% sulfur.

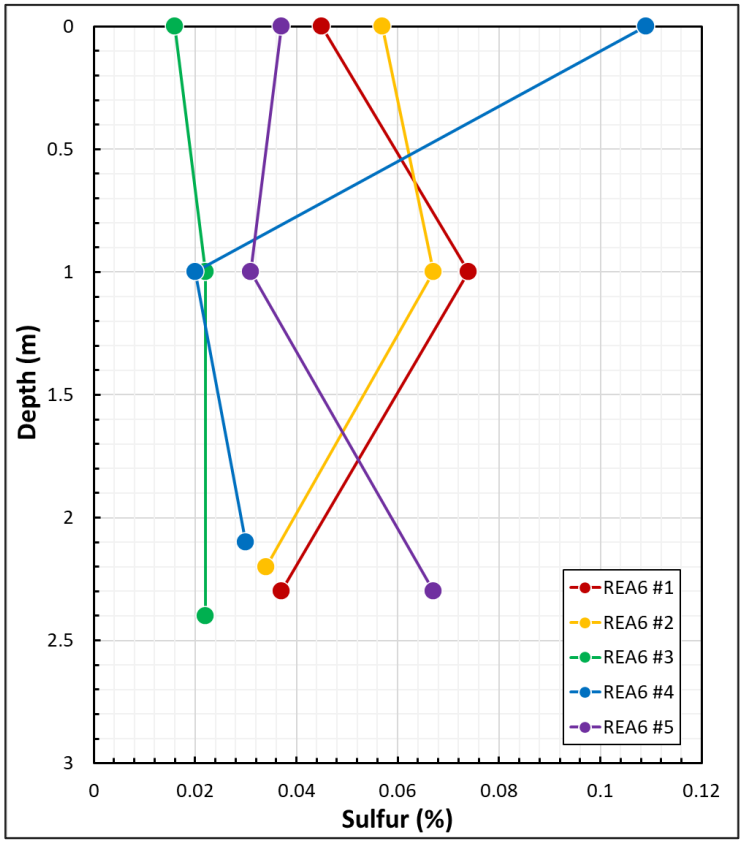

Figure 3.2 **Variation in sulfur concentrations with depth at the five sample locations**

The acid-base characteristics of the REA6 CCR samples are reflected in the relative proportions of MPA and ANC (ie acid generation potential versus acid buffering capacity). Samples identified as PAF generally contain little to no available ANC for buffering (Figure 3.3). Almost all REA6 CCR samples record NAPP values that classify them as low capacity PAF (PAF-LC) material (NAPP values of 0–5 kg H_2SO_4/t). The exception is sample CLR REA6 Surface #2, which reports a NAPP value of 9.2 kg H_2SO_4/t; however, this is more of a reflection of the lack of ANC within this sample, rather than a high MPA (resulting from a high sulfur content; Figure 3.3).

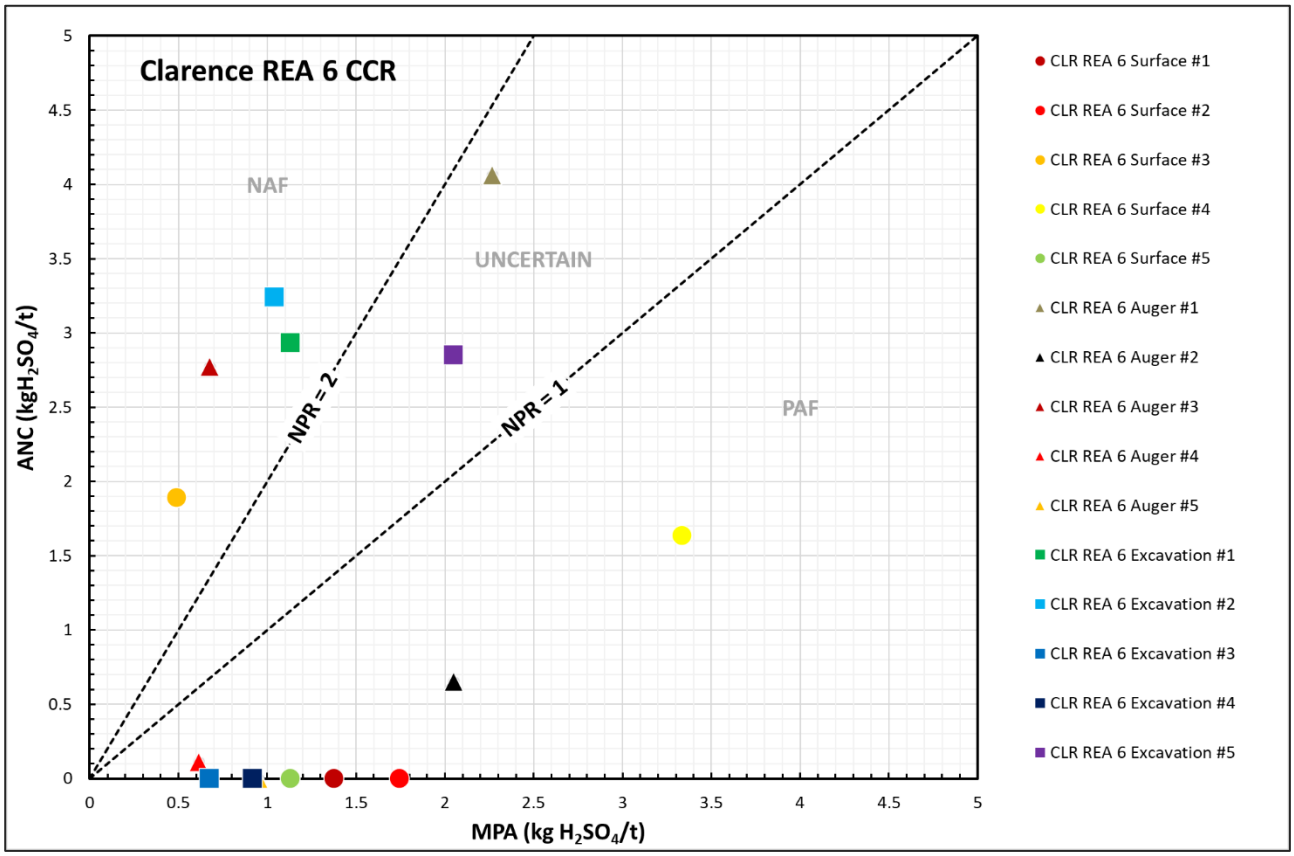

Figure 3.3 MPA versus ANC for REA6 CCR samples

Note: Following the Price (2009) convention, samples are categorised by ANC/MPA (NPR): NPR > 2 = NAF; 2≥NPR≥1 = UNCERTAIN; NPR<1 = PAF

3.2 Metals/metalloids analysis

REA6 CCR metals/metalloids concentrations are recorded at or below the laboratory limit of reporting (LOR) for the majority of the analytes measured (Table 3.2). These values are presented in this verification report at the LOR to provide a conservative estimate and actual concentrations may be lower than the LOR.

Calculated GAIs are zero for almost all measured analytes, indicating that the REA6 CCR samples have similar or lower metals/metalloids concentrations compared to global median soil contents. Two analytes record possible enrichment:

- GAIs for cobalt range between 1 and 2 (enrichment of approximately 2–4 times the global median soil concentration); and
- GAIs for selenium indicate approximately 8 times the enrichment of global median soil content. This is likely to be an artifact of the analysis, since selenium values are reported at a LOR of 5 mg/kg and may actually be present at lower concentrations.

Table 3.2 REA6 laboratory whole-sample metals/metalloids concentrations

Sample ID	Analyte concentration (mg/kg)																											
	Ag	Al	As	Au	B	Ba	Ca	Cd	Co	Cr	Cu	Fe	Hg	K	Mg	Mn	Mo	Na	Ni	Pb	Sb	Se	Sr	Th	Ti	Tl	U	V	W	Zn
CLR REA6 Surface #1	2	1,630	5	0.1	50	20	10	1	11	2	5	3,870	0.1	10	10	83	2	10	57	14	5	5	4	3.8	10	5	1	5	0.1	16
CLR REA6 Surface #2	2	1,530	5	0.1	50	100	10	1	24	2	10	3,600	0.1	10	10	73	2	10	68	44	5	5	48	3.4	10	5	2	6	0.1	21
CLR REA6 Surface #3	2	640	5	0.1	50	20	10	1	15	2	6	2,340	0.1	10	10	47	2	10	32	10	5	5	4	2.4	10	5	0.6	5	0.1	23
CLR REA6 Surface #4	2	1,290	5	0.1	50	30	10	1	42	2	10	2,510	0.1	10	10	36	2	10	127	17	5	5	7	2.6	10	5	1.2	5	0.1	21
CLR REA6 Surface #5	2	890	5	0.1	50	20	10	1	30	2	6	1,810	0.1	10	10	54	2	10	102	16	5	5	6	2.8	10	5	0.7	5	0.1	29
CLR REA6 Auger #1	2	1,040	5	0.1	50	40	40	1	15	2	13	4,050	0.1	10	10	119	2	10	39	19	5	5	8	5.1	10	5	0.7	5	0.1	51
CLR REA6 Auger #2	2	1,310	5	0.1	50	50	10	1	57	2	10	3,150	0.1	10	10	122	2	10	137	16	5	5	18	3.1	10	5	0.8	5	0.1	71
CLR REA6 Auger #3	2	1,430	5	0.1	50	40	10	1	20	2	13	20,100	0.1	10	10	349	2	20	48	18	5	5	10	4.6	10	5	0.7	8	0.1	60
CLR REA6 Auger #4	2	1,070	5	0.1	50	60	10	1	17	2	14	480	0.1	10	10	31	2	10	48	22	5	5	8	1.4	10	5	0.6	5	0.1	30
CLR REA6 Auger #5	2	9,090	6	0.1	50	80	10	1	18	42	17	22,300	0.1	20	20	260	2	10	32	28	5	5	25	1.4	180	5	0.2	45	0.1	80
CLR REA6 Excavation #1	2	710	5	0.1	50	30	10	1	17	2	5	4,640	0.1	10	10	119	2	10	46	9	5	5	6	1.7	10	5	0.4	5	0.1	29
CLR REA6 Excavation #2	2	1,080	5	0.1	50	40	40	1	29	2	12	29,400	0.1	10	10	692	2	10	70	26	5	5	2	4.3	10	5	0.8	7	0.1	68
CLR REA6 Excavation #3	2	690	5	0.1	50	40	10	1	23	2	7	880	0.1	10	10	51	2	10	71	9	5	5	7	3.4	10	5	0.4	5	0.1	15
CLR REA6 Excavation #4	2	1,020	5	0.1	50	220	50	1	28	2	8	2,190	0.1	10	10	144	2	10	70	8	5	5	58	1.7	10	5	0.5	5	0.1	175
CLR REA6 Excavation #5	2	1,540	5	0.1	50	70	10	1	26	2	17	20,800	0.1	10	10	355	2	10	69	26	5	5	16	6.2	10	5	1.1	10	0.1	51

Note: Values reported at or below laboratory LORs are shown in red.

3.3 Comparison of REA6 to REAs 2-4

To assess the similarities of REA6 CCR material to material in the older Clarence REAs, the Phase 1 REA6 CCR geochemical characteristics were compared to the following samples:

- 12 waste samples from REAs 2, 3 and 4 (GHD 2013); and
- The mean of 8 CCR samples from REA 3 (GHD 2018).

REA6 CCR acid-base characteristics fall within the range of those from the other REAs (Figure 3.4).

REA6 CCR record among the lowest MPA values (and lowest sulfur contents) of the Clarence data set. REA6 CCR samples have MPA values between those estimated for REA 3 based on total sulfur and chromium reducible sulfur (GHD 2018).

Although eight REA6 CCR samples report zero ANC, the remaining seven samples record the highest ANC of the Clarence samples.

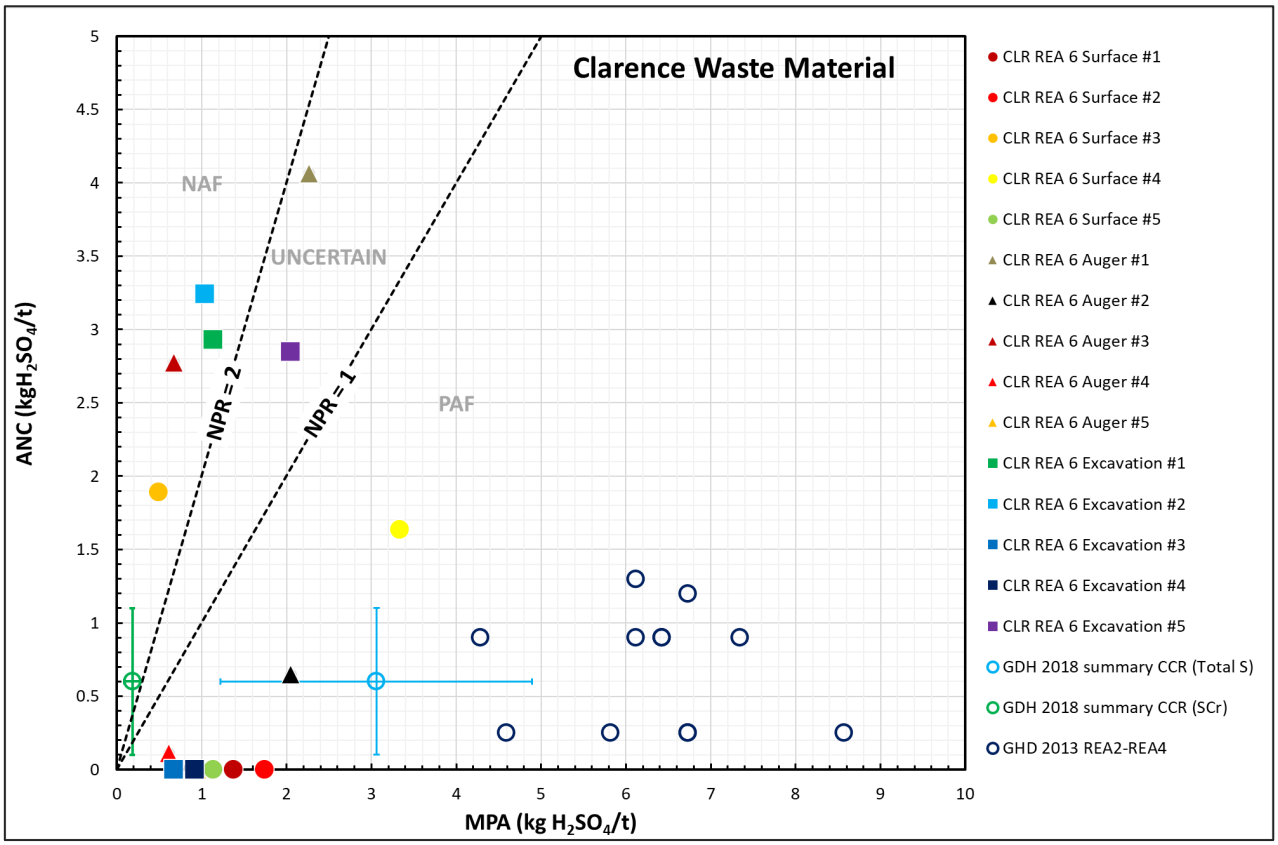

Figure 3.4 MPA versus ANC for Clarence waste material

Note: Following the Price (2009) convention, samples are categorised by ANC/MPA (NPR): NPR>2 = NAF; 2≥NPR≥1 = UNCERTAIN; NPR<1 = PAF. GHD (2018) CCR samples are summarised based on estimates of MPA using total sulfur (blue) and chromium reducible sulfur (green).

REA6 CCR metal/metalloid concentrations are also similar to those in the older Clarence REA material, with many analytes recorded at or below LORs (Figure 3.5 and Figure 3.6).

REA6 CCR cobalt concentrations, reported as enriched compared to global median soil concentrations, are nevertheless comparable to those from the older REAs at Clarence, indicating that this is likely to be a natural feature of the Clarence lithology.

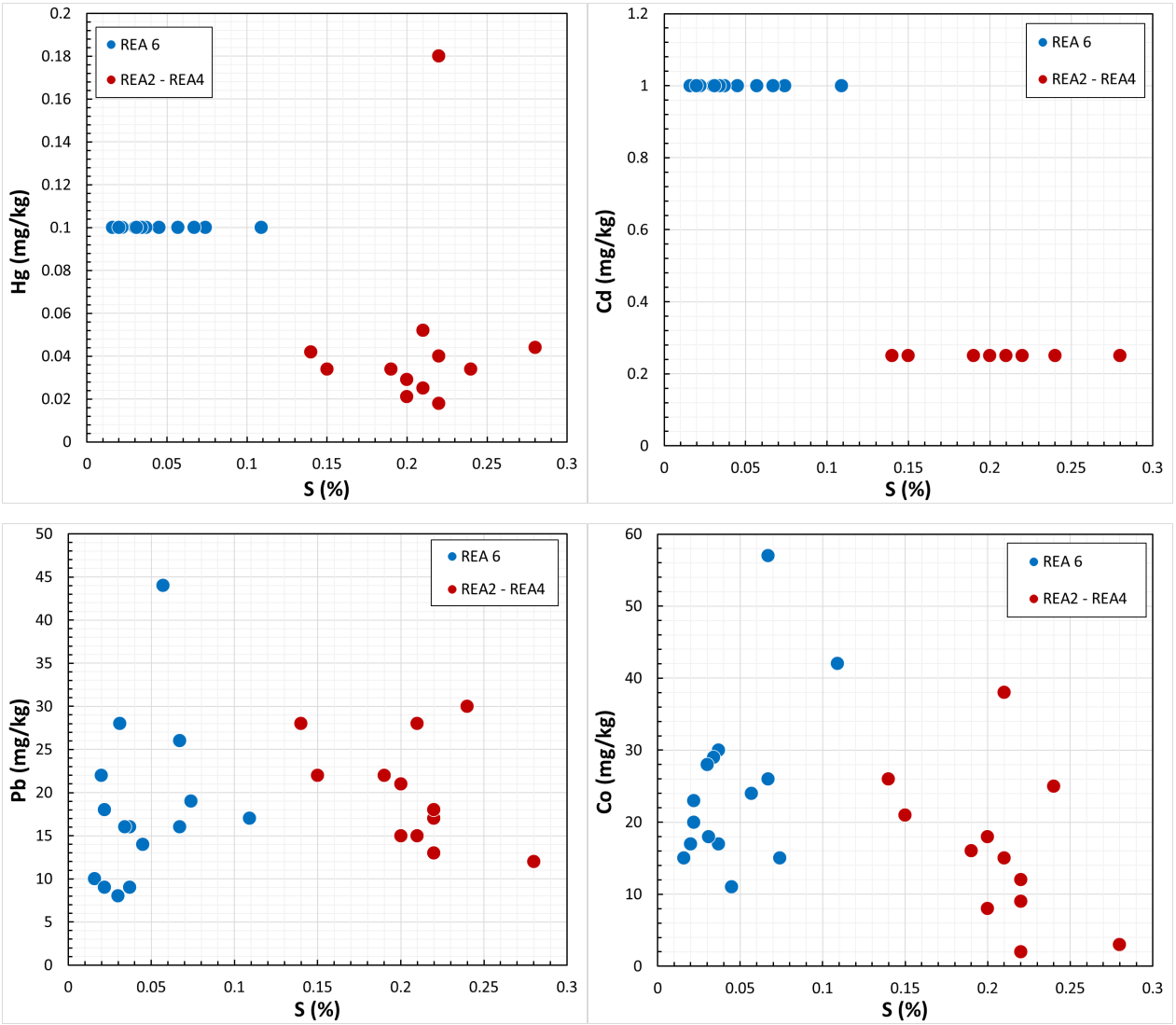

Figure 3.5 **Variations in whole-sample sulfur and metal contents for REA6 CCR samples compared to those from waste material at REAs 2, 3 and 4**

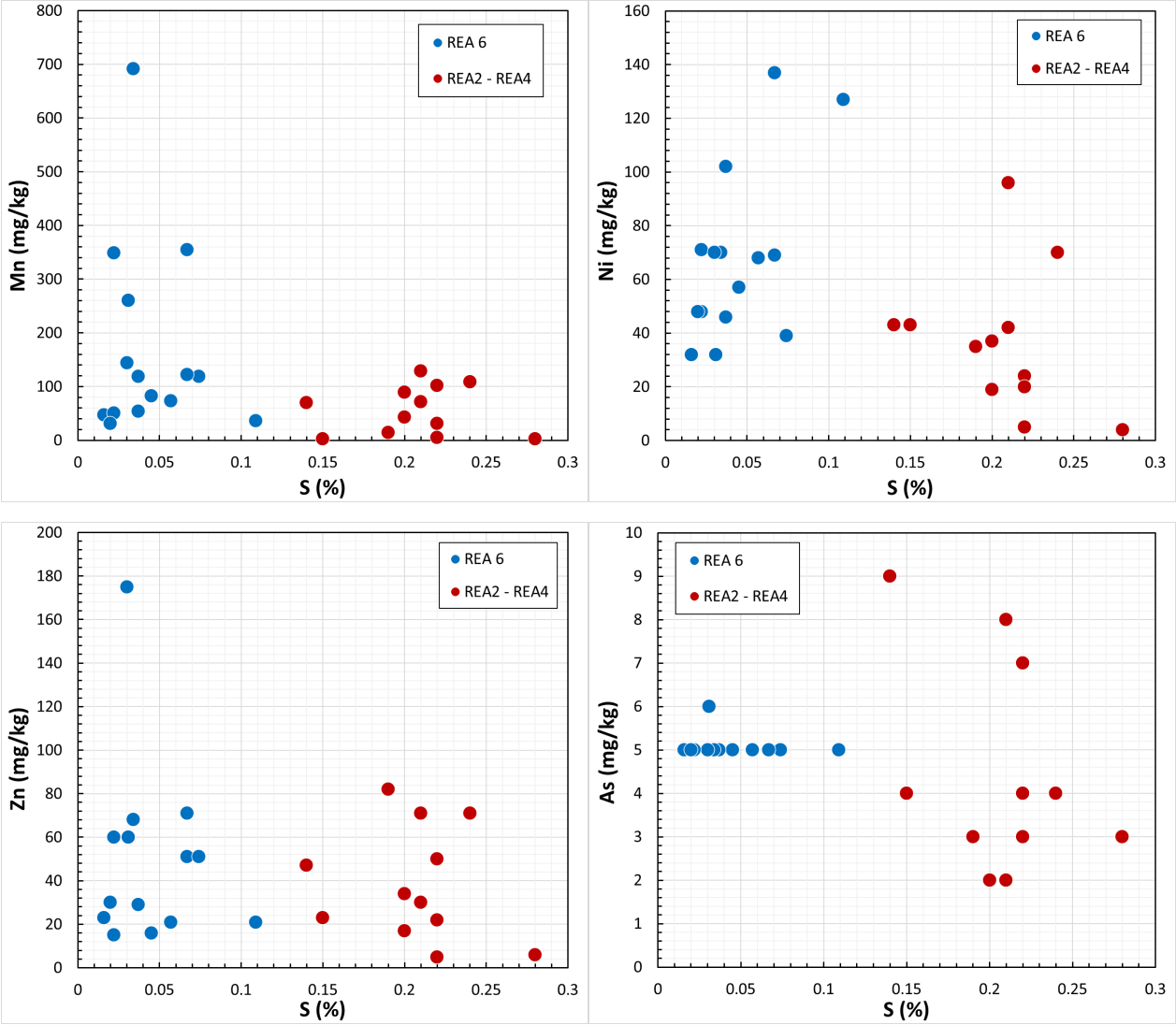

Figure 3.6 **Variations in whole-sample sulfur and metal (Mn, Ni and Zn) and metalloid (As) contents for REA6 CCR samples compared to those from waste material at REAs 2, 3 and 4**

3.4 Leachate concentrations

Centennial regularly monitor leachate collected in dams at the REAs, allowing for an assessment of the long-term reactivity and weathering characteristics of the waste material for waste management. REA6 leachate water quality (from Leachate Dam 3) was compared to the following data sources to assess the similarities in geochemistry between REA6 and the older REAs:

- Mean water quality recorded in Leachate Dam 1 and Leachate Dam 2, collected from the older REAs (GHD 2013), to provide a direct comparison of REA6 CCR reactivity and mobility of contaminants of potential concern with those of waste material from the older REAs.

- Median REA CCR 3 CCR water chemistry following leach testing using the Australian Standard Leaching Procedure (ASLP) at 10 times dilution (GHD 2018) to provide a comparison between leaching under site conditions (REA6) and leaching under laboratory-controlled conditions (REA 3).

- REA 2, REA 3 and REA 4 waste material water chemistry following leach testing using the ASLP (GHD 2013) to provide additional laboratory information on samples from the other REAs.

Leachate water quality was also compared to Clarence's EPL 726 discharge compliance limit values, which are largely based on ANZECC (2000) values[4] for Clarence water quality.

Leachate water quality comparisons are shown in Figure 3.7 for values of pH and concentrations of chloride, mercury, cadmium, lead and arsenic against contents of the conservative parameter sulfate[5].

The comparisons indicate that the laboratory leachate concentrations generally underestimate the pH and metals/metalloids concentrations observed in the leachate dams. This is to be expected due to:

- differences in scale between the laboratory-controlled conditions and those on-site (eg crushed laboratory samples versus waste material in-situ);
- differences in timescale between laboratory tests (typically approximately 18 hours) and long-term observations taken on-site (months and years); and
- differences in dilution factors between controlled laboratory testing (known and consistent dilution) and on-site conditions, which are subject to seasonal variations.

In addition, the leachate dam sulfate concentrations are consistently higher than those recorded from laboratory leach testing, which reflects long-term loading of oxidised sulfur into the leachate dams. Nevertheless, both the Clarence laboratory leachate results and the observed REA 2-4 and REA6 leachate water quality indicate the following general characteristics:

- Leachate pH is generally acidic (pH <6.5), which is likely to be a reflection of the Clarence CCR and other waste material lacking the buffering capacity to neutralise acidity generated from oxidation of the moderate to low sulfur (sulfide) concentrations in the source waste material (as noted by GHD 2018). Although Clarence CCR samples report low sulfur concentrations, the lack of adequate ANC results in limited buffering of AMD. Following emplacement of CCR, weathering and infiltration of rainfall may load acidity in the leachate dams.
- Leachate metals/metalloids concentrations are generally low and are reported at or below LORs for many analytes. For lead and cadmium, these concentrations exceed Clarence's EPL 726 limits.

REA6 leachate water quality from Leachate Dam 3 is geochemically similar to water quality reported from Leachate Dam 1 and Leachate Dam 2. This is consistent with the similarities in the whole-sample geochemistry of REA6 and material from the older REAs.

Although REA6 Leachate Dam 3 water quality is generally acidic, it is comparable to pH values reported from leachate testing of Charbon waste material (EGi 2018). Furthermore, acid-base accounting of Charbon waste material records a greater potential for acid generation, which may contribute to AMD following placement and exposure (EGi 2018). This will be described in detail in a follow-up study comparing the geochemical characteristics of Charbon and Clarence waste material.

[4] Australian and New Zealand Environment Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) (2000). Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Now referred to as Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2018).

[5] Sulfate is a conservative parameter because it is not attenuated by sorption onto substrates. It provides a direct indicator of analyte load from leached water material.

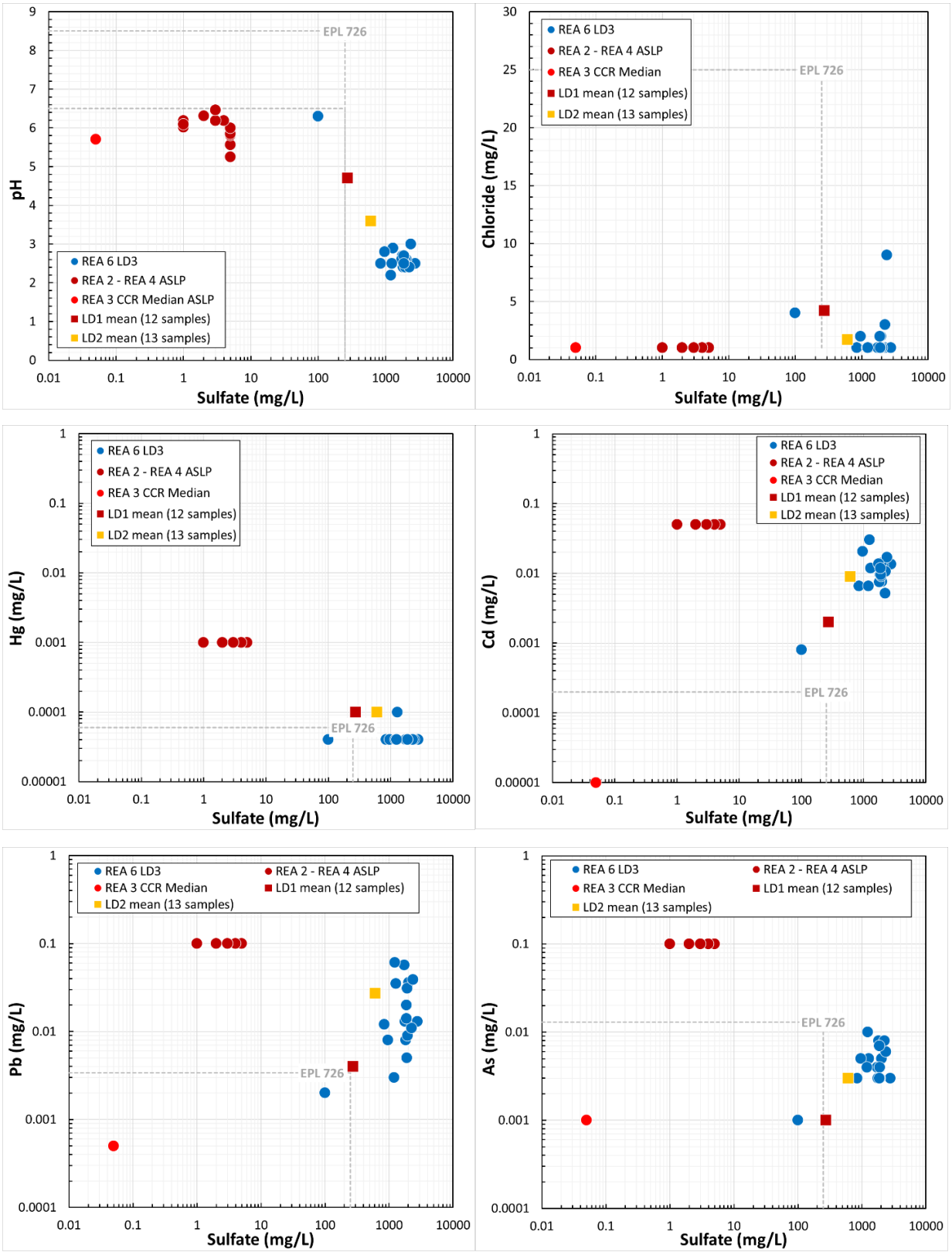

Figure 3.7 Variations in leachate pH, chloride, mercury, cadmium, lead and arsenic versus sulfate at Clarence

4 Recommendations

The requirement for additional (Phase 2) geochemical testing was evaluated based on the following:

- the results from the REA6 CCR Phase 1 testing program;
- comparison of the REA6 results to those from the older REAs; and
- characteristics of the REA6 Leachate Dam 3 and older REA Leachate Dams 1 and 2.

This evaluation indicates that Phase 2 testing is not required because:

- The REA6 CCR samples record low sulfur contents (low MPA) and low metals/metalloids concentrations, which fall within the range of concentrations reported in waste material sampled from the older REAs. Even when considering a conservative estimate of REA6 CCR MPA, this is within the values estimated in the older REAs (GHD 2018).
- Although REA6 Leachate Dam 3 water quality records low pH values (approximately 2.2–2.5), these are comparable to water quality from the older REAs in Leachate Dams 1 and 2 (mean values of 3.6 and 4.7) and are within the range of values reported at Charbon (EGi 2018)[6].
- With REA6 CCR verified as geochemically similar to material from the older REAs, the geochemical database now consists of 35 samples, which is within industry practice guidelines for sample numbers, namely:
    - 8 samples of REA 3 CCR (GHD 2018);
    - 12 samples of REAs 2 – 4 waste material (GHD 2013); and
    - 15 samples of REA6 CCR (this report).
- Additionally, water quality from REA6 Leachate Dam 3 and Leachate Dams 1 and 2 from the older REAs preclude the requirement to conduct Phase 2 leach testing, as the dam leachate water qualities are more representative of the reactivity and weathering characteristics of the Clarence waste than laboratory testing.
- Verification of the REA6 CCR samples allows use of the Phase 2 test results conducted on the older REA waste material (GHD 2018; GHD 2013). This precludes the need for Phase 2 testing on the REA6 CCR samples.

[6]Note that pH values less than 4.5 generally indicate a lack of readily available buffering capacity in the leachate and pH may only be recovered using treatment methods. Although water at a pH of 2 will require higher levels of treatment than water at a pH of 3, both are essentially acidic and are unlikely to experience a natural recovery of pH unless buffering capacity is added. The Australian Department of Foreign Affairs and Trade (DFAT) classify pH less than 4.5 as very low, hence the leachate dams record similar acidic water quality (DFAT 2016).

5 Conclusion

Phase 1 geochemical testing, consisting of acid-base accounting and whole-sample metal/metalloid analysis, was undertaken on 15 CCR samples collected from the top of REA6. The testing was conducted to:

- evaluate the geochemical characteristics of the REA6 CCR; and
- verify that the REA6 CCR was geochemically similar to CCR at the older Clarence REAs.

Results from the verification exercise indicate:

- REA6 CCR samples are geochemically similar to those from the older Clarence REAs and record sulfur concentrations (low MPA) and metals/metalloids contents that fall within the range of concentrations reported in material from the older REAs;
- leachate from REA6 is acidic but is generally similar in composition to leachate collected at the other REAs, which are also acidic, and within the range of leachate testing water quality of Charbon waste material;
- the sampling exercise has increased the Clarence geochemical dataset to 35 samples, which is a reasonable representation of the waste material on-site and is within industry recommendations; and
- the increased dataset and use of REA leachate water quality precludes the requirement for additional (Phase 2) geochemical testing on the REA6 CCR samples.

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Price, WA 2009, *Prediction Manual of Drainage Chemistry from Sulphic Geologic Materials,* MEND Report 1.20.1.

Appendix A

Laboratory certificates of analysis

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **ES2014226**	Page	: 1 of 8
Amendment	: **1**		
Client	: **ACIRL PTY LTD**	Laboratory	: Environmental Division Sydney
Contact	: LITHGOW ENVIRO	Contact	: Customer Services ES
Address	: UNIT 3/16 DONALD STREET LITHGOW NSW, AUSTRALIA 2790	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
Telephone	: 02 6350 7400	Telephone	: +61-2-8784 8555
Project	: Clarence Colliery - Phase 1	Date Samples Received	: 28-Apr-2020 09:00
Order number	: ----	Date Analysis Commenced	: 28-Apr-2020
C-O-C number	: ----	Issue Date	: 15-May-2020 17:42
Sampler	: ----		
Site	: ACIRL Lithgow		
Quote number	: EN/222		
No. of samples received	: 15		
No. of samples analysed	: 15		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Ankit Joshi	Inorganic Chemist	Sydney Inorganics, Smithfield, NSW
Ben Felgendrejeris	Senior Acid Sulfate Soil Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD
Celine Conceicao	Senior Spectroscopist	Sydney Inorganics, Smithfield, NSW
Ivan Taylor	Analyst	Sydney Inorganics, Smithfield, NSW

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- EA031 (Saturated Paste pH): NATA accreditation does not cover the performance of this service.
- EA032 (Saturated Paste EC): NATA accreditation does not cover the performance of this service.
- EG005: Poor precision was obtained for Nickel and Manganese on sample ES2014226-#011. Results have been confirmed by re-extraction and reanalysis.
- EA031 : Duplicate has not been conducted due to insufficient samples.
- Amendment (12/05/2020): This report has been amended and re-released to allow the reporting of additional analytical data.
- ASS: EA013 (ANC) Fizz Rating: 0- None; 1- Slight; 2- Moderate; 3- Strong; 4- Very Strong; 5- Lime.

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	CLR REA 6 Surface #1	CLR REA 6 Surface #2	CLR REA 6 Surface #3	CLR REA 6 Surface #4	CLR REA 6 Surface #5
			Client sampling date / time	23-Apr-2020 00:00	23-Apr-2020 00:00	23-Apr-2020 00:00	23-Apr-2020 00:00	23-Apr-2020 00:00
Compound	CAS Number	LOR	Unit	ES2014226-001	ES2014226-002	ES2014226-003	ES2014226-004	ES2014226-005
				Result	Result	Result	Result	Result
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	4.0	9.2	-1.4	1.7	1.2
EA031: pH (saturated paste)								
ø pH (Saturated Paste)	----	0.1	pH Unit	5.8	4.4	4.7	4.3	4.2
EA032: Electrical Conductivity (saturated paste)								
ø Electrical Conductivity (Saturated Paste)	----	1	µS/cm	63	32	49	106	126
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	2.4	3.8	3.1	2.7	2.5
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	<10	<10	<10	<10	<10
Magnesium	7439-95-4	10	mg/kg	<10	<10	<10	<10	<10
Sodium	7440-23-5	10	mg/kg	<10	<10	<10	<10	<10
Potassium	7440-09-7	10	mg/kg	10	<10	<10	<10	<10
EG005(ED093)T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	1630	1530	640	1290	890
Antimony	7440-36-0	5	mg/kg	<5	<5	<5	<5	<5
Barium	7440-39-3	10	mg/kg	20	100	20	30	20
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Cobalt	7440-48-4	2	mg/kg	11	24	15	42	30
Iron	7439-89-6	50	mg/kg	3870	3600	2340	2510	1810
Manganese	7439-96-5	5	mg/kg	83	73	47	36	54
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2
Selenium	7782-49-2	5	mg/kg	<5	<5	<5	<5	<5
Silver	7440-22-4	2	mg/kg	<2	<2	<2	<2	<2
Strontium	7440-24-6	2	mg/kg	4	48	4	7	6
Vanadium	7440-62-2	5	mg/kg	<5	6	<5	5	<5
Sulfur as S	63705-05-5	50	mg/kg	450	570	160	1090	370
Titanium	7440-32-6	10	mg/kg	<10	10	<10	<10	<10
Thallium	7440-28-0	5	mg/kg	<5	<5	<5	<5	<5
Arsenic	7440-38-2	5	mg/kg	<5	<5	<5	5	<5
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	<1	<1
Chromium	7440-47-3	2	mg/kg	<2	2	<2	<2	<2
Copper	7440-50-8	5	mg/kg	5	10	6	10	6
Lead	7439-92-1	5	mg/kg	14	44	10	17	16
Nickel	7440-02-0	2	mg/kg	57	68	32	127	102

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	CLR REA 6 Surface #1	CLR REA 6 Surface #2	CLR REA 6 Surface #3	CLR REA 6 Surface #4	CLR REA 6 Surface #5
				Client sampling date / time	23-Apr-2020 00:00	23-Apr-2020 00:00	23-Apr-2020 00:00	23-Apr-2020 00:00	23-Apr-2020 00:00
Compound	CAS Number	LOR	Unit		ES2014226-001	ES2014226-002	ES2014226-003	ES2014226-004	ES2014226-005
					Result	Result	Result	Result	Result
EG005(ED093)T: Total Metals by ICP-AES - Continued									
Zinc	7440-66-6	5	mg/kg		**16**	**21**	**23**	**21**	**29**
EG020T: Total Metals by ICP-MS									
Gold	7440-57-5	0.1	mg/kg		<0.1	<0.1	<0.1	<0.1	<0.1
Thorium	7440-29-1	0.1	mg/kg		**3.8**	**3.4**	**2.4**	**2.6**	**2.8**
Tungsten	7440-33-7	0.1	mg/kg		<0.1	<0.1	<0.1	<0.1	<0.1
Uranium	7440-61-1	0.1	mg/kg		**1.0**	**2.0**	**0.6**	**1.2**	**0.7**
EG035T: Total Recoverable Mercury by FIMS									
Mercury	7439-97-6	0.1	mg/kg		<0.1	<0.1	<0.1	<0.1	<0.1
EP003: Total Organic Carbon (TOC) in Soil									
Total Organic Carbon	----	0.02	%		**14.0**	**16.6**	**13.9**	**19.6**	**12.4**
EP003TC: Total Carbon (TC) in Soil									
Total Carbon	TC	0.02	%		**14.6**	**17.3**	**14.4**	**20.4**	**12.8**

Analytical Results

Sub-Matrix: **SOIL**
(Matrix: **SOIL**)

Compound	CAS Number	LOR	Unit	Client sample ID	CLR REA 6 Excavation #1	CLR REA 6 Excavation #2	CLR REA 6 Excavation #3	CLR REA 6 Excavation #4	CLR REA 6 Excavation #5
				Client sampling date / time	23-Apr-2020 00:00	23-Apr-2020 00:00	23-Apr-2020 00:00	23-Apr-2020 00:00	23-Apr-2020 00:00
					ES2014226-006	ES2014226-007	ES2014226-008	ES2014226-009	ES2014226-010
					Result	Result	Result	Result	Result
EA009: Net Acid Production Potential									
Net Acid Production Potential	----	0.5	kg H2SO4/t		**-1.8**	**-2.2**	**0.7**	**3.1**	**-0.8**
EA031: pH (saturated paste)									
ø pH (Saturated Paste)	----	0.1	pH Unit		**4.2**	**7.4**	**5.0**	**6.9**	**4.4**
EA032: Electrical Conductivity (saturated paste)									
ø Electrical Conductivity (Saturated Paste)	----	1	µS/cm		**356**	**244**	**111**	**124**	**120**
EA055: Moisture Content (Dried @ 105-110°C)									
Moisture Content	----	1.0	%		**3.4**	**3.8**	**3.3**	**7.2**	**4.2**
ED093S: Soluble Major Cations									
Calcium	7440-70-2	10	mg/kg		<10	**40**	<10	**50**	<10
Magnesium	7439-95-4	10	mg/kg		<10	**20**	<10	<10	<10
Sodium	7440-23-5	10	mg/kg		<10	<10	<10	<10	<10
Potassium	7440-09-7	10	mg/kg		<10	<10	<10	<10	**10**
EG005(ED093)T: Total Metals by ICP-AES									
Aluminium	7429-90-5	50	mg/kg		**710**	**1080**	**690**	**1020**	**1540**
Antimony	7440-36-0	5	mg/kg		<5	<5	<5	<5	<5
Barium	7440-39-3	10	mg/kg		**30**	**40**	**40**	**220**	**70**
Boron	7440-42-8	50	mg/kg		<50	<50	<50	<50	<50
Cobalt	7440-48-4	2	mg/kg		**17**	**29**	**23**	**28**	**26**
Iron	7439-89-6	50	mg/kg		**4640**	**29400**	**880**	**2190**	**20800**
Manganese	7439-96-5	5	mg/kg		**119**	**692**	**51**	**144**	**355**
Molybdenum	7439-98-7	2	mg/kg		<2	<2	<2	<2	<2
Selenium	7782-49-2	5	mg/kg		<5	<5	<5	<5	<5
Silver	7440-22-4	2	mg/kg		<2	<2	<2	<2	<2
Strontium	7440-24-6	2	mg/kg		**6**	<2	**7**	**58**	**16**
Vanadium	7440-62-2	5	mg/kg		<5	**7**	<5	**5**	**10**
Sulfur as S	63705-05-5	50	mg/kg		**370**	**340**	**220**	**300**	**670**
Titanium	7440-32-6	10	mg/kg		<10	**10**	<10	**10**	**10**
Thallium	7440-28-0	5	mg/kg		<5	<5	<5	<5	<5
Arsenic	7440-38-2	5	mg/kg		<5	<5	<5	<5	<5
Cadmium	7440-43-9	1	mg/kg		<1	<1	<1	<1	<1
Chromium	7440-47-3	2	mg/kg		<2	<2	<2	<2	**2**
Copper	7440-50-8	5	mg/kg		**5**	**12**	**7**	**8**	**17**
Lead	7439-92-1	5	mg/kg		**9**	**16**	**9**	**8**	**26**
Nickel	7440-02-0	2	mg/kg		**46**	**70**	**71**	**70**	**69**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	CLR REA 6 Excavation #1	CLR REA 6 Excavation #2	CLR REA 6 Excavation #3	CLR REA 6 Excavation #4	CLR REA 6 Excavation #5
				Client sampling date / time	23-Apr-2020 00:00	23-Apr-2020 00:00	23-Apr-2020 00:00	23-Apr-2020 00:00	23-Apr-2020 00:00
Compound	CAS Number	LOR	Unit		ES2014226-006	ES2014226-007	ES2014226-008	ES2014226-009	ES2014226-010
					Result	Result	Result	Result	Result
EG005(ED093)T: Total Metals by ICP-AES - Continued									
Zinc	7440-66-6	5	mg/kg		**29**	**68**	**15**	**175**	**51**
EG020T: Total Metals by ICP-MS									
Gold	7440-57-5	0.1	mg/kg		<0.1	<0.1	<0.1	<0.1	<0.1
Thorium	7440-29-1	0.1	mg/kg		**1.7**	**4.3**	**3.4**	**1.7**	**6.2**
Tungsten	7440-33-7	0.1	mg/kg		<0.1	<0.1	<0.1	<0.1	<0.1
Uranium	7440-61-1	0.1	mg/kg		**0.4**	**0.8**	**0.4**	**0.5**	**1.1**
EG035T: Total Recoverable Mercury by FIMS									
Mercury	7439-97-6	0.1	mg/kg		<0.1	<0.1	<0.1	<0.1	<0.1
EP003: Total Organic Carbon (TOC) in Soil									
Total Organic Carbon	----	0.02	%		**14.1**	**14.1**	**12.9**	**55.1**	**13.6**
EP003TC: Total Carbon (TC) in Soil									
Total Carbon	TC	0.02	%		**15.3**	**14.7**	**13.2**	**55.1**	**13.9**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	CLR REA 6 Auger #1	CLR REA 6 Auger #2	CLR REA 6 Auger #3	CLR REA 6 Auger #4	CLR REA 6 Auger #5
			Client sampling date / time	23-Apr-2020 00:00	23-Apr-2020 00:00	23-Apr-2020 00:00	23-Apr-2020 00:00	23-Apr-2020 00:00
Compound	CAS Number	LOR	Unit	ES2014226-011	ES2014226-012	ES2014226-013	ES2014226-014	ES2014226-015
				Result	Result	Result	Result	Result
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	-1.8	1.4	-2.1	<0.5	1.2
EA031: pH (saturated paste)								
ø pH (Saturated Paste)	----	0.1	pH Unit	7.4	4.5	6.4	4.5	3.6
EA032: Electrical Conductivity (saturated paste)								
ø Electrical Conductivity (Saturated Paste)	----	1	µS/cm	414	109	180	168	183
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	3.2	3.4	3.1	3.6	17.9
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	40	<10	<10	<10	10
Magnesium	7439-95-4	10	mg/kg	10	<10	<10	<10	20
Sodium	7440-23-5	10	mg/kg	<10	<10	20	<10	<10
Potassium	7440-09-7	10	mg/kg	<10	<10	<10	<10	20
EG005(ED093)T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	1040	1310	1430	1070	9090
Antimony	7440-36-0	5	mg/kg	<5	<5	<5	<5	<5
Barium	7440-39-3	10	mg/kg	40	50	40	60	80
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Cobalt	7440-48-4	2	mg/kg	15	57	20	17	18
Iron	7439-89-6	50	mg/kg	4050	3150	20100	480	22300
Manganese	7439-96-5	5	mg/kg	119	122	349	31	260
Molybdenum	7439-98-7	2	mg/kg	<2	<2	<2	<2	<2
Selenium	7782-49-2	5	mg/kg	<5	<5	<5	<5	<5
Silver	7440-22-4	2	mg/kg	<2	<2	<2	<2	<2
Strontium	7440-24-6	2	mg/kg	8	18	10	8	25
Vanadium	7440-62-2	5	mg/kg	5	<5	8	<5	45
Sulfur as S	63705-05-5	50	mg/kg	740	670	220	200	310
Titanium	7440-32-6	10	mg/kg	<10	<10	10	<10	180
Thallium	7440-28-0	5	mg/kg	<5	<5	<5	<5	<5
Arsenic	7440-38-2	5	mg/kg	<5	<5	<5	<5	6
Cadmium	7440-43-9	1	mg/kg	<1	<1	<1	<1	<1
Chromium	7440-47-3	2	mg/kg	<2	<2	2	<2	42
Copper	7440-50-8	5	mg/kg	13	10	13	14	17
Lead	7439-92-1	5	mg/kg	19	16	18	22	28
Nickel	7440-02-0	2	mg/kg	39	137	48	48	32

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	CLR REA 6 Auger #1	CLR REA 6 Auger #2	CLR REA 6 Auger #3	CLR REA 6 Auger #4	CLR REA 6 Auger #5
				Client sampling date / time	23-Apr-2020 00:00	23-Apr-2020 00:00	23-Apr-2020 00:00	23-Apr-2020 00:00	23-Apr-2020 00:00
Compound	CAS Number	LOR	Unit		ES2014226-011	ES2014226-012	ES2014226-013	ES2014226-014	ES2014226-015
					Result	Result	Result	Result	Result
EG005(ED093)T: Total Metals by ICP-AES - Continued									
Zinc	7440-66-6	5	mg/kg		**51**	**71**	**60**	**30**	**60**
EG020T: Total Metals by ICP-MS									
Gold	7440-57-5	0.1	mg/kg		<0.1	<0.1	<0.1	<0.1	<0.1
Thorium	7440-29-1	0.1	mg/kg		**5.1**	**3.1**	**4.6**	**1.4**	**1.4**
Tungsten	7440-33-7	0.1	mg/kg		<0.1	<0.1	<0.1	<0.1	<0.1
Uranium	7440-61-1	0.1	mg/kg		**0.7**	**0.8**	**0.7**	**0.6**	**0.2**
EG035T: Total Recoverable Mercury by FIMS									
Mercury	7439-97-6	0.1	mg/kg		<0.1	<0.1	<0.1	<0.1	<0.1
EP003: Total Organic Carbon (TOC) in Soil									
Total Organic Carbon	----	0.02	%		**13.5**	**16.5**	**15.3**	**12.7**	**11.7**
EP003TC: Total Carbon (TC) in Soil									
Total Carbon	TC	0.02	%		**14.5**	**17.6**	**16.4**	**13.6**	**12.2**