# Rasp Mine

## Waste Rock Classification

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**Prepared For:** Broken Hill Operations Pty Ltd

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Table 1-1. *Document Control*

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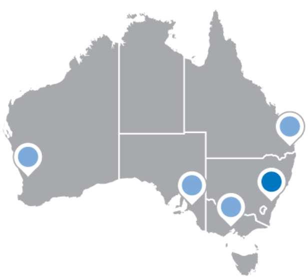

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# 1. Executive Summary

Pacific Environment undertook an assessment of waste rock from a stockpile present within the Kintore Pit of the Rasp Mine located at Broken Hill, NSW. The assessment was required to support an application ('MOD 4') to use the waste rock for the construction of embankments at the Blackwood Pit Tailings Storage Facility ('TSF2') and for construction of a noise abatement bund around the perimeter of the concrete batching plant to the north, east and west.

More generally, BHOP intend to use the waste rock for other dust suppression applications as part of its rehabilitation process for the mine site. This will include cover for existing areas that may otherwise have a potential to generate dust containing elevated lead concentrations. The rock is known to contain potentially elevated lead concentrations due to the ore bodies being mined.

To minimise any potential health affects for the local community the original EA for the Rasp Mine (BHOP, July 2010) stipulated that any waste rock material used for rehabilitation, or other site surface purposes, will be 'inert'. What constitutes 'inert' material has not been defined in the EA. No directly applicable criteria are available for assessing the potential for hazardous dusts generated from the weathering of waste rock at the site, potentially resulting in exposure scenarios for inhalation/ingestion by residents outside the site, or for site users post-rehabilitation.

The study utilised a 'multiple lines of evidence approach', in accordance with guidance provided in the NEPM 2013. This is used for evaluating and integrating information from different sources of data and uses best professional judgement to assess the consistency and plausibility of the conclusions which can be drawn.

This approach studied the following parameters:

- rock type (geological description);
- moisture content;
- particle size distribution (PSD); and
- metals content.

In addition to these studies, additional consideration was given to the prior Human Health Risk Assessment work undertaken by Toxikos (2010, 2015), background soil/dust data, air quality modelling and recent Confined Air Burst Chamber (CABC) testing undertaken by Pacific Environment on-site for the purposes of quantifying dust control.

**Results and Conclusions**

The results of the waste rock assessment, and in consideration of associated studies, identified that;

- The rock type varies, however all rock types identified are competent and mostly hard, with good resistance to weathering;
- The rock comprises only approximately 1% fines capable of producing dust;

- This was qualified by Confined Air Burst Chamber tests, which identified a 99.7% reduction in dust generation from the waste rock, compared to disturbed dry tailings.
- Lead concentrations averaged 2,371.5 mg/kg (0.24%), and were taken from crushed samples (and therefore conservative). This is approximately 4 x the NEPM HIL-C criterion (600 mg/kg), but significantly below surface dust averages (15,640 mg/kg, or 1.56%). Whilst the NEPM criteria are not directly applicable, they do represent a level below which soils would not be considered a risk to human health.
- Bioaccessibility is very low (7.3% on average). This is much lower (6.8 x) than the 50% (bioavailability) assumed for the calculation of HIL's. This would suggest that results, if adjusted for bioaccessibility, would meet HIL-C criteria;
- Air quality modelling conducted by PE (2017), assumed a waste rock concentration of 0.5% (5,000 mg/kg). Results demonstrate compliance with all the NSW EPA impact assessment criteria for all air quality parameters assessed.

In conclusion, the results support the use of the waste rock for dust suppression for the TSF and 'free areas', and are considered unlikely to cause an unacceptable risk to human health based upon the site's final land use as a proposed tourist/recreational site.

Air quality modelling has assumed lead concentrations above those identified in the waste rock on site (0.5% compared to 0.24%), and therefore the waste rock is likely to meet NSW EPA impact assessment criteria, and is unlikely to impact further upon surface soil lead concentrations within local communities. The very low dusting potential of the rock supports this conclusion.

**In consideration of all other lines of evidence, the 0.5% lead concentration adopted by the air quality model is considered to be a suitable criterion for waste rock placement on-site.**

It is therefore considered that the waste rock meets the criteria of being 'inert' material, based upon the multiple lines of evidence approach.

**Recommendations**

The waste rock, when placed, is considered to be suitable as a means of reducing, to an acceptable level, the potential for dust generation from the TSF and 'free areas' of the site. To reduce potential risks during placement, we recommend that dust suppression spraying is carried out during capping material (waste rock) placement. A final spray is recommended to ensure that finer particles are washed between the larger rocks. This will greatly reduce the future potential for the rock to create dust.

This assessment has been partially based upon a limited number of waste rock samples, which were analysed for lead composition. For the conclusions of this assessment to maintain validity, it is recommended that field screening of the waste rock is undertaken during placement to confirm that median lead concentrations do not exceed 0.5%. PE recommends that this is undertaken by use of a calibrated x-ray fluorescence (XRF) field meter. It is noted that:

- laboratory results were considered to be conservative due to the crushing and leaching processes used as part of the analysis methodology;

- XRF results are therefore unlikely to be comparable to laboratory results (they may be lower), however they would be considered to be representative for the reasons above; and
- use of an XRF provides a practical and timely characterisation of field material. Many more samples may be screened in comparison to laboratory analysis.

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# 1. Introduction

The Land and Water group of Pacific Environment was commissioned by Broken Hill Operations Pty Ltd (BHOP) to carry out classification of the waste rock stockpile present within the Kintore Pit of the Rasp Mine located at Broken Hill, NSW. The site has mined for lead, zinc and silver for approximately 130 years. This study is in support of an application for the modification of the site ('MOD 4'), to include a purpose built concrete batching plant and modifications to the Blackwood Pit Tailings Storage Facility ('TSF2').

A noise abatement bund will be constructed around the perimeter of the concrete batching plant to the north, east and west, utilising the waste rock. The TSF2 modifications will include installation of embankments and a retaining wall along low points in the perimeter utilising the waste rock. More generally, BHOP intend to use the waste rock for other dust suppression applications as part of its rehabilitation process for the mine site. This will include cover for existing areas that may otherwise have a potential to generate dust containing elevated lead concentrations. Due to the historical growth of the City of Broken Hill, many residential structures are located within close proximity to the mine workings. The protection of human health is of the greatest importance.

## 1.1 Project Description

The project involves the classification of the waste rock, which is intended to be utilised for placement within the site. Currently a large waste rock stockpile, believed to exceed 700,000 tonnes, is contained within Kintore Pit. If suitable, the waste rock will be used for general rehabilitation within the site. Proposed uses include:

- Supporting the batter sides of the Tailings Storage Facility (TSF) to allow a vertical extension of the TSF, and;
- Noise abatement bunding.
- Placement on the 'free areas' (non-active areas of the mine site) of the site to mitigate against wind erosion of any loose material.

Although there are many more years of extractive operation remaining under the current Project Approval (PA07_0018), the final use of the site, as outlined in the original Environment Assessment Report (EA), is to return the facility to a condition suitable for continuing tourist operations, with some historical buildings and mine workings preserved for tourism activities post closure of the mine. Tourist operations were conducted on-site prior to BHOP's acquisition of the lease in 2001, including a walking tour and underground tour. Current tourism activities on site include interpretive signage and a miner's memorial and café.

With the final use in mind and the proximity of the residential population to the mine site, the assessment of the waste rock material must consider potential human health effects.

To minimise any potential health affects for the local community the original EA for the Rasp Mine (BHOP, July 2010) stipulated that any waste rock material used for rehabilitation, or other site surface purposes, must be 'inert'. What constitutes 'inert' material has not been defined in the EA. This study will recommend criteria for this term as part of this assessment considering that the material should not cause, or have the potential to cause air pollutant concentrations (metals in dust) that would exceed relevant ambient air quality limits.

A definition of 'solid inert waste' found in the Victorian EPA Publication 448, Classification of Wastes, states: "hard waste which has negligible activity or effect on the environment". No specific directly applicable criteria are available for dust generation from waste rock. Other available criteria are discussed in Sections 3.2.3, 3.2.4 and 3.2.5 .

## 1.2 Objectives

The objectives of this study are:

1. To characterise the physical and chemical attributes of the waste rock, with respect to its potential to generate lead bearing dusts post-placement;
2. To determine a suitable criteria for the use of the waste rock so as to minimise any health effects on the local community, in particular the potential impact of lead exposure to children, and;
3. To assess if the waste rock meets the identified suitability criteria for use as rehabilitation material in open areas of the Rasp Mine site. This will include;
    a. Comparison against applicable criteria (if any), and
    b. Defining the term 'inert' and evaluation of the waste rock against these definitions

## 1.3 Reference documents

In order to complete a desktop assessment of the waste rock material, information from the following documents has been incorporated into this report:

- Rasp Mine Environmental Assessment Report (EAR), Chapter 5 – Existing Environment;
- Rasp Mine EAR, Chapter 8 – Air Quality and Greenhouse Gases;
- Rasp Mine EAR, Chapter 17 – Rehabilitation and Final Landform;
- Rasp Mine EAR – Annexure F – Tailings Scoping Study and Preliminary Design;
- Rasp Mine EAR – Annexure I (Part B) – Chemical Dust Suppression Agent HRA;
- NSW Government, Department of Planning, Rasp Mine Project (07_0018) Director Generals Requirements (dated 29 March 2009);
- CBH Resources Limited, Broken Hill Operations Pty Ltd, Rasp Mining Project: *Project Application* (dated February 2007);
- Vic EPA 448.3 Waste Classification, Publication 448.3* May 2007 available from http://www.esdat.com.au/Environmental%20Standards/Australia/448.3%20Waste%20Classification.pdf;
- Lyle DM, Phillips AR, Balding WA, Burke H, Stokes D, Corbett S, Hall J. (2006) Dealing with lead in Broken Hill – trends in blood lead levels in young children 1991 – 2003. Science of the Total Environment 2006, 359:111-119.
- National Environment Protection (Assessment of Site Contamination) Amendment Measure 2013 (No.1) – Volume 2: Schedule B1. National Environment Protection Council (NEPC) (1999).
- National Environment Protection (Assessment of Site Contamination) Amendment Measure 2013 (No.1) – Volume 10: Schedule B7 – Appendix A1, The Derivation of HILs for Metals and Inorganics. National Environment Protection Council (NEPC) (1999).

- Toxikos Pty Ltd (2010), *Health Risk Assessment for Rasp Mine Proposal, Broken Hill*, Toxikos document TR200510-RF (Volume 1, V2), June 2010.
- Pacific Environment Ltd, *Re: Air Quality Assessment for the Rasp Mine Modification 4*, March 2017
- Pacific Environment Ltd, '*Re: Rasp Mine Wind Erosion Field Testing*', March 2017
- AP 42, Fifth Edition, Volume I Chapter 13: Miscellaneous Sources, Prepared for U. S. Environmental Protection Agency Office of Air Quality Planning and Standards Emission Measurement Center Research Triangle Park, NC 27711, published January 1995, last updated November 2006.
- Boreland, F. and Lyle, D. (2009a) Using performance indicators to monitor attendance at the Broken Hill blood screening clinic. Environmental Research. 109 (3): 267-272.

# 2. Site Description

Mining operations commenced on the site in 1885. Historically both open pit and underground mining methods have been used at the site. Today mining is conducted underground to extract zinc, lead and silver ore. The site consists of a series of open cut pits along the Line of Lode, which is in an approximate north-east to south-west alignment. The remaining hill is made up of tailings storage and ore waste rock emplacement, and there is little evidence of the original ore outcropping. There is little buffer distance between the site and the town, with residential encroachment to the north-west and south-east of the mine.

Underground mining access is via a portal 70m from surface located in Kintore Pit. A processing plant takes the ore and through a flotation and filtering process produces two separate concentrates zinc and lead with silver reporting to the lead concentrate. A rail load out area is located to the north east of the site for rail dispatch of concentrates. Tailings are currently stored in an historic open pit, Blackwood Pit ('TSF2') and stormwater retention and evaporation basins are located across the site. Internal roads (sealed or compacted surfaces) are present between the various buildings and facilities within the site.  Historic buildings and structures are located across the site together with old stockpiles of mine overburden, waste rock from both open pit and underground mining operations and old tailings. BHOP purchased the site from Normandy Mining Investments in 2001, and has therefore inherited the condition of the site from the previous operators of the site.

## 2.1 Site Location/Setting

Broken Hill is located in far west New South Wales; the local environment is classed as semi-arid with a low annual rainfall in the range of 200 – 300mm and high evaporation rates (2,614mm/yr). The Rasp Mine was founded after the discovery of lead bearing galena on the surface, which had been exposed by weathering of a ridge of the main ore body. Although exposed at the point of discovery, the ore body then dips to the north and south.

With the development of the mine, the area went from rural grazing land with few permanent occupants to mining and residential, with workers' accommodation established in close proximity to the mine. As was common in the late 1800's, private transport was limited and people lived close to their places of work. The mine has operated over an unusually extended time due to the quantity and quality of the ore, with the town gradually developing around the mine.

## 2.2 Site Layout

The site is approximately rectangular and lies in a north-east to south-west orientation as can be seen in Figure 2-1 below. The ore body was discovered in an outcrop in the approximate centre of the site, but dips both to the north-east and south-west. Open cut pits were originally established for extraction of the ore, followed by both the continuation of open cut operations and underground operations occurring concurrently by various mining companies. The Kintore Pit was a former open-cut pit located in the south-western end of the site (Figure 2-1), and now provides access to the underground operations.

Historical buildings and structures, some of which date from the 1890s, have been retained at various locations across the site. A large number of these are listed as heritage items on the BHCC Local Environment Plan 2013 (LEP). In 2015 the City of Broken Hill was included on the National Heritage List primarily for its contributions to mining and ore processing developments.

During current underground mine operations, waste rock material has been stockpiled in the Kintore Pit at the southern end; the waste rock stockpile is estimated to comprise more than 700,000 tonnes of material.

Tailings are stored in an historic open-cut pit (Blackwood Pit) (TSF2), which is located towards the north-east end of the site as shown in Figure 1 below.

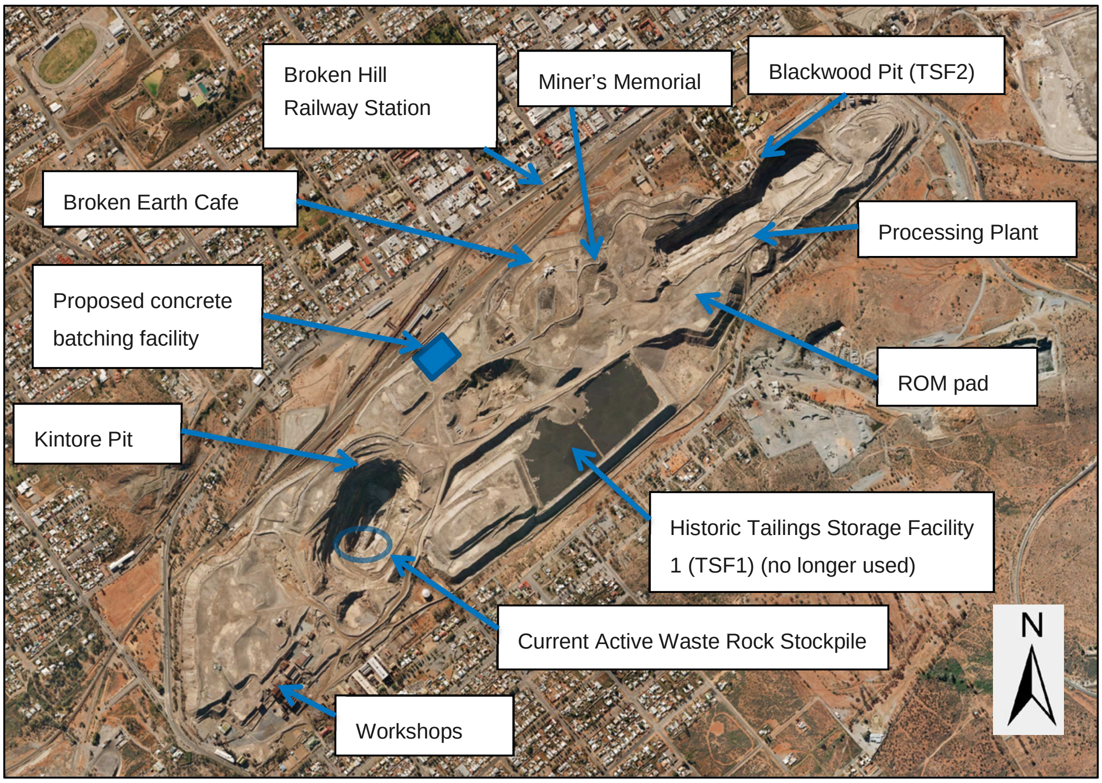



Figure 2-1: Aerial view of the Rasp Mine site – Mine Features

## 2.3 Current and Proposed Land Use

The current use of the site is for mining activities, the current development consent (PA07_0018) allows for the mining to continue until 2026. Further extensions may be sought after that date providing it is economic to continue production.

The end use of the site, as presented in the site's EA, is for tourism. Guided tours of the old processing plant and heritage buildings were conducted by the then Line of Lode Association and another tourism operator conducted underground tours via the Delprat Shaft, prior to the current mining operation. Several historical buildings and mining related structures have been preserved within the site and the potential for tourism has been noted as a potential post closure use option.

## 2.4 Stockpile Material Origin

The current active waste rock stockpile in the Kintore Pit is composed of material obtained from the creation of the Rasp Decline with portal access at the base of the Pit, which commenced development in 2007. It includes some fines, and may contain limited volumes of low grade ore from areas adjacent to the ore body   The vast majority of the stockpile is either very low grade ore, or material deficient in the minerals extracted at the Rasp Mine. All of the waste rock was derived from within the site and is therefore comprised of material natural to this region.

The waste rock stockpile is placed on the southern end of the Kintore Pit and has a depth of approximately forty metres. The most recent waste rock material has originated from the development of the zinc lode decline, as well as material from stope development adjacent to the ore body. Due to the nature of the construction of the stockpile, some recent material will have flowed down the outside face of the stockpile, although the majority of the recently extracted waste rock material will have remained at the top of the stockpile, where a flat area is maintained.

# 3. Methodology

To use the waste rock material for rehabilitation and other surface activities the waste rock is required to meet the following requirements:

1. Be 'inert' as stipulated in the original EAR. What constitutes 'inert' material has not been defined in the EAR.
2. The material should not cause, or have the potential to cause air pollutant concentrations (metals in dust) that would exceed relevant ambient air quality limits; and
3. Any dusts created by the waste rock material should not result in metals in soils concentrations off-site that exceed relevant criteria, or present unacceptable risks to human health based upon the final land use.

This report will provide a characterisation of the physical and chemical attributes of the waste rock in comparison with the above requirements and provide a recommendation on the suitability for use of this material.

Our evaluation of this issue utilises a multiple lines of evidence approach. The multiple-lines-of-evidence approach is the process for evaluating and integrating information from different sources of data and uses best professional judgement to assess the consistency and plausibility of the conclusions which can be drawn (NEPM 2013 definition).

The following parameters were deemed critical parameters for use in assessing the waste rock material:

- rock type (geological description);
- moisture content;
- particle size distribution (PSD); and
- metals content.

In order to obtain data on the waste rock material, several representative samples were collected from the upper levels of the Kintore Pit stockpile by Rasp Mine staff and forwarded to testing facilities NATA accredited for the appropriate range of analysis. These were ALS (moisture content and metals content) and GHD (PSD).

An initial sample was taken by BHOP staff and submitted for analysis. Based upon the treatment and analysis of this sample, a revised methodology was as developed to obtain more relevant characterisation data for the upper strata of the waste rock stockpile. Specifically, this included moisture content analysis prior to PSD analysis (which requires a drying stage), and PSD prior to crushing to identify the relevant proportions of fine material. Further discussion of these methods is provided in sections 3.2.1 and 3.2.2.

# 3.1 Identification of potential exposure pathways

The NEPM determines risk to human health via a 'source-pathway-receptor' concept, and that a complete linkage must be present for risks to be realised. For the Rasp Mine the current source is the open areas of the site containing fine, loose material, which is naturally impacted by heavy metals. Of these metals, lead is the primary concern. Studies have proven that there is a positive link between the lead levels in the environment and those in the blood of children living in areas with high environmental concentrations of lead present.

The potential pathway for exposure is wind driven dust generated from these open areas of the site and deposited among the residential and recreational spaces of the town and mine site. The potential human health receptors are the Broken Hill residents, and in the case of the final land use, tourists and site users.

The pathways are therefore, potentially, dust (inhalation and ingestion) and direct contact/ingestion on site at final land use. A Human Health Risk Assessment (HHRA) has already been carried out for the site (Toxikos, 2010, and 2015) where the dust pathway was assessed under several scenarios, including mitigation by 80% using chemical dust suppressant. The capping of exposed areas of the site by coarse waste rock with extremely low fines content is also expected to mitigate against the generation of wind driven dust.

Where a pathway can be blocked or restricted, the risk to the receptors is therefore removed or reduced. Providing that the waste rock is deemed suitable for use in mitigating wind driven dust at the mine site, then the risk from this pathway may be reduced to an acceptable level. The potential for dust generation from the waste rock after placement is therefore the primary concern regarding the use of this material.

# 3.2 Characterisation of Waste Rock

A total of six waste rock samples were submitted for laboratory analysis;

- one initial sample for characterisation; and
- a further five subsequent samples based upon a revised analysis suite

Samples were submitted for moisture content, particle size distribution (PSD) and metals content. Samples were analysed by ALS and GHD, who are NATA accredited for the analyses specified.

The transect along which samples were taken is shown in **Figure 1, Appendix A**. Laboratory results are provided in **Appendix B**, and a photographic log is presented as **Appendix C**.

locations are

## 3.2.1 Initial sample

The results of a single waste rock sample ('Waste Rock Tipple') obtained by BHOP site staff were initially provided for review. The sample was composited from material collected from the surface layer of the waste rock stockpile and analysed by ALS in Sydney. The weight of the sample was almost 10kg and it was crushed by the laboratory prior to analysis. The analytical suite included total metals and water leaching tests to replicate conditions when exposed to weather on the site. The full laboratory report may be viewed in **Appendix B**. A summary table is provided below.

The sample results were reviewed by Pacific Environment and the following information/limitations were noted:

- The exact weight of material from each individual collection point that comprised the composite sample was not noted;

- The sample was crushed prior to leaching, which exposes a far greater surface area to leaching than would otherwise be available when the rock is placed at the mine site; and
- Photographs of the upper surface of the waste rock stockpile indicated that some fines are present. It was not noted if fines were included in the sample material.

Figure 3-1: Material form the Waste Rock Stockpile

In order to obtain more representative data, a process was devised to obtain more relevant characterisation data for the upper strata of the waste rock stockpile. Specifically, this included PSD analysis prior to crushing to identify the relevant proportions of fine material.

### 3.2.2 Additional samples

Another five (5) discrete samples were collected by BHOP site staff and forwarded to NATA accredited laboratories (ALS and GHD) for analysis for a revised suite of analytical parameters (moisture content and PSD (prior to crushing) and metals content (post-crushing). The transect of these samples is shown in **Figure 1** in **Appendix A**.

Moisture content was determined by ALS prior to the waste rock being forwarded to a geological testing facility (GHD) for particle size distribution (PSD) in its natural state. Following the sizing process, the waste rock material was returned to the chemical analytical facility for the determination of concentrations of potential contaminants of concern (heavy metals).

The following information is relevant to the sampling and analysis process:

- The waste rock samples were washed (as standard) as part of the PSD analysis,
- The waste rock samples were crushed by the laboratory for the extraction of the metals and,

- The waste rock samples were obtained from the near surface of the Kintore Pit stockpile.

The types of rock present in the Kintore Pit waste rock stockpile are described and illustrated in Section 4.1**Error! Reference source not found.**. There is significant variation between these rock types and some ore grade material may be present where it was uneconomic to separate this ore for processing. The results of the laboratory analysis are therefore expected to vary

### 3.2.3 Applicable Criteria

No directly applicable criteria are available to assess the potential for hazardous dusts generated from the weathering of waste rock at the site, potentially resulting in exposure scenarios for inhalation/ingestion by residents outside the site, or for site users post-rehabilitation. An assessment of the 'dusting potential' of the rock, and therefore potential risks posed via this pathway can only be quantified by site testing that is beyond the scope of this assessment.

### 3.2.4 Other criteria and guidance

The primary national guidance for criteria relating to human health risks from metals is from the National Environmental Protection (Assessment of Site Contamination) Measure (NEPM) Health Based Investigation Levels (HILS). These include criteria for total concentrations of heavy metals in soil media based upon exposure estimates and toxicity reference values.

These HIL's are to be used in the first stage ('Tier 1' or 'screening') of an assessment of potential risks to human health and are intentionally conservative. They are levels at which more investigation is required to assess human health risks, and have been derived from the NHRMC Blood Lead Goal for Australia[1].

The NEPM guideline criteria are not directly applicable to the use of waste rock for rehabilitation works. This is primarily because soils are more readily available (for ingestion) than rock (generally having a smaller particle size), and are more accessible to children (the most sensitive receptors) as a part of gardens, playgrounds or other urban spaces. However, the NEPM criteria do provide a basic level below which no adverse human health risks are expected. For this reason, they have been adopted as a basic trigger level for further investigation.

The NEPM criteria listed in Table 2 below are for the following land use categories;

- Residential (HIL A) - for low density residential use with access to the soil, assumes that less than 10% of food intake will be grown in the soil;
- Recreational (HIL C) - open public space (parks, playgrounds, playing fields, secondary schools and footpaths); and
- Commercial/Industrial (HIL D) – includes premises such as shops, offices, factories and industrial sites.

The most relevant criteria for the site's intended post mining use are **HIL C** (Recreational).

It must be noted that Broken Hill has a naturally occurring exposed ore body with a high lead content which has been exposed to weathering for centuries, if not longer. This natural process could be expected to have elevated the background concentrations of lead in the residential areas of the city without the advent of the mining operations.

[1] National Health and Medical Research Council, *Evidence on the Effects of Lead on Human Health* (2015)

Table 3-1 - *NEPM Guideline Criteria*

| Analyte | NEPM HIL A Guidelines (Residential) (mg/kg) | NEPM HIL C Guidelines (Recreational) (mg/kg) | NEPM HIL D Guidelines (Commercial/industrial) (mg/kg) |
|---|---|---|---|
| Arsenic | 100 | 300 | 3,0000 |
| Barium | ND | ND | ND |
| Beryllium | 60 | 90 | 500 |
| Boron | 4,500 | 20,000 | 300,000 |
| Cadmium | 20 | 90 | 900 |
| Chromium (VI) | 100 | 300 | 3,600 |
| Cobalt | 100 | 300 | 4,000 |
| Copper | 6,000 | 17,000 | 240,000 |
| **Lead** | **300** | **600** | **1,500** |
| Manganese | 3,800 | 19,000 | 60,000 |
| Nickel | 400 | 1,200 | 6,000 |
| Selenium | 200 | 700 | 10,000 |
| Vanadium | ND | ND | ND |
| Zinc | 7,400 | 30,000 | 400,000 |
| Mercury (methyl) | 10 | 13 | 180 |

*ND: Not Defined* ** Total Mercury* *^ Arsenic (V) – lowest criterion*

The NEPM also contains criteria for metals in surface waters, however; these levels relate to drinking water and fresh (recreational) waters. These water criteria do not directly apply to rainwater detained within the mine site via storm water retention basins and therefore the rainwater/runoff retained within the site has not been included in these discussions. The retained mine site water is understood not to be in continuity with surface water or groundwater resources.

## 3.2.5 Background data

### *3.2.5.1 Broken Hill – Town Soils*

While 'baseline' or background lead levels in the town's soil have not been assessed as part of this report, it should be noted that several reports into the natural and anthropogenic deposition of dust within Broken Hill have been carried out for health assessment purposes. Soil lead and indoor dust levels measured in 1992 were reported by Lyle et al. (2006), for five zones covering the residential area of Broken Hill. The reported concentrations of lead in soil ranged from 262mg/kg (less than the NEPM HIL A residential criteria of 300mg/kg) to 1,967mg/kg (greater than the NEPM HIL D commercial /industrial criteria of 1,500mg/kg).

Since the soil lead analysis was undertaken more than a century after the commencement of mining operations at Broken Hill, it is most likely a product of a combination of both anthropogenic and natural processes relating to the ore body. It should also be noted that some soil remediation of highly impacted areas was carried out in Broken Hill in the late 1990's.

A Human Health Risk Assessment carried out by Toxikos (2010) used later soil concentrations and the Lyle et al. data and found that the five previous zones had most likely merged into three zones with the following assumed soil lead concentrations:

- Zone 1 – 2,000mg/kg
- Zones 2 & 3 – 1,000mg/kg
- Zones 4 & 5 – 500mg/kg

The zones are depicted in Figure 2 below.

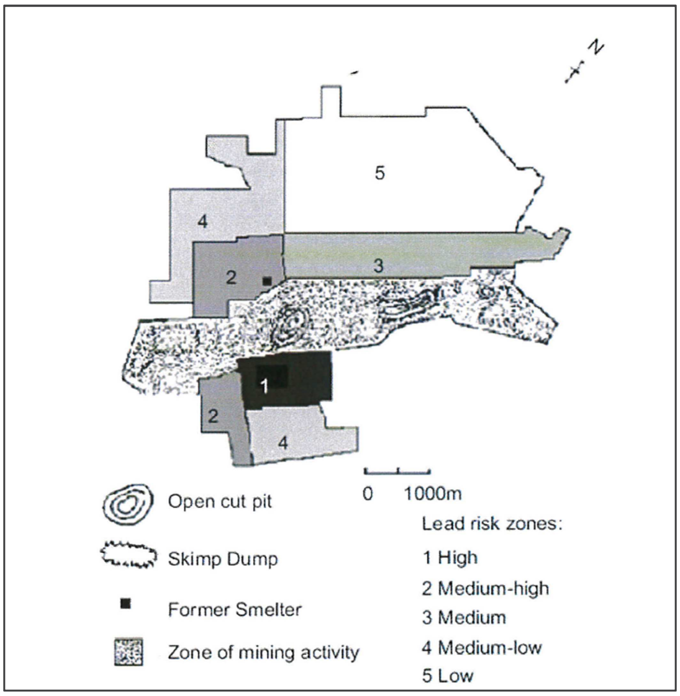



Figure 3-2: Lead Risk Zones (Figure from Boreland et al. (2009a))

### *3.2.5.2 Rasp Mine Soils*

Further to the Broken Hill town soil lead concentrations adopted as part of the Human Health Risk Assessment (HHRA) (Toxikos, 2010), this assessment also considered lead concentrations in surface dust (composite) samples taken from five site locations representing operational and non-operational ('free') areas. The results are provided in Table 3-2, below

Table 3-2 - *Lead concentrations in surface dusts – Rasp Mine*

| Sampling Point | Lead Concentration (mg/g) | Lead Concentration (mg/kg) | Lead Concentration (%) |
|---|---|---|---|
| 1 | 31 | 31,000 | 3.1 |
| 2 | 8.8 | 8,800 | 0.88 |
| 3 | 7.1 | 7,100 | 0.71 |
| 4 | 11.8 | 11,800 | 1.18 |
| 5 | 18.7 | 18,700 | 1.87 |

*ND: Not Defined* ** Total Mercury* *^ Arsenic (V) – lowest criterion*

### *3.2.5.3 Bioavailability and Bioaccessibility*

In addition to lead concentrations in dust, the HHRA also considered bioavailability. Bioavailability is a function of;

- bioaccessibility – the amount of contaminant released from the media (e.g. soil/dust) during digestion within the body that is available to be absorbed; and
- absorption – the part of the bioaccessible fraction that is actually absorbed into systemic circulation within the body

The HHRA used the physiologically based extraction test (PBET) for determining the bioaccessibility of metals from surface dusts at the mine site. This involved simulating the leaching of a solid matrix in the human stomach and small intestine under feed and fasting conditions. This test was conducted by enTox at Queensland University (2009) on the same samples as those submitted for lead concentration (refer Table 3-2)

Results were as follows:

Table 3-3 – *Bioaccessibility of lead in surface dusts – Rasp Mine*

| Sampling Point | Lead Concentration (mg/g) | Lead Concentration (mg/kg) | Lead Concentration (%) | Bioaccessibility (Bac) (%) |
|---|---|---|---|---|
| 1 | 31 | 31,000 | 3.1 | **14.6** |
| 2 | 8.8 | 8,800 | 0.88 | **3.6** |
| 3 | 7.1 | 7,100 | 0.71 | **8.5** |
| 4 | 11.8 | 11,800 | 1.18 | **6.1** |
| 5 | 18.7 | 18,700 | 1.87 | **3.7** |
| | | | Average bioaccessibility | **7.3** |

For comparison, NEPM HILs have been derived based upon assumed bioavailability for lead (from soil/dust, food and water) of **50%**[2]. This was considered to be 'sufficiently conservative', based upon the wide range of values and factors that have the potential to affect absorption.

[2] NEPM Schedule B7 – Appendix A1, The Derivation of HILs for Metals and Organics

# 4. Results

## 4.1 Physical and geotechnical characteristics

BHOP provided PE with geological descriptions of the potential waste rock types, based upon geological studies of the ore body and surrounds, and overburden material. These are as follows:

The bulk of the waste rock is composed of **Garnet Pelite (GPE)** and **Psammopelite (PM)** then Garnet Spotted Psammopelite (SPM). Only very minor quantities of DOL and GQ will be present. All of these rock types are described as hard and competent units with the exception of GPE1 and GPE2, which is noted as a softer rock type that has been more susceptible to accommodating shearing. Conversely, DOL1 and DOL2 is rated as extremely hard rock with very high UCS.

An explanation of these geological rock description terms is contained below.

**GPE1 and GPE2**: Garnet pelite. Strongly foliated to slightly sheared granulite facies metamorphic pelite. Composition dominated by large garnet porphyroblasts within a strongly foliated biotite and sillimanite matrix with regular quartz and feldspar leucocratic melt veins. Softer rock type that has been more susceptible to accommodating shearing with the lithological sequence and as a result may have more chloritic retrograde alteration associated within.

Figure 4-1: Image of Garnet Pelite (GPE) Sample

**PM1 and PM2**: Psammopelite. Rock type characterised by a moderately banded, interbedded sequence of pelite and psammite layers on an approximate 10cm scale. Quartz garnet biotite sillimanite pelite interbedded with Quartz garnet psammite. Some psammite layers have been subjected to minor hydrothermal garnet dominant alteration. Generally a strong and competent rock unit.

Figure 4-2: Image of Psammopelite Sample

**SPM1 and SPM2**: Garnet spotted psammopelite. Moderately foliated siliceous rock characterised by 0.5-1cm garnet porphyroblast aggregations. Quartz garnet gneiss. Gneissic banding dominated by quartz melt veins with lesser feldspar leucocratic melt veins. This rock type is strong and competent and has been observed to produce extremely good ground conditions in the underground mine with few defects in the rock mass.

Figure 4-3: Image of  Garnet Spotted Psammopelite Sample

**DOL1 and DOL2**: Massive I type igneous intrusion with minor assimilation of S type country rock. Dolerites form minor cross cutting dyke structures occasionally encountered in mine development. Extremely hard rock with very high Uniaxial Compressive Strength (UCS).

Figure 4-4: Image of Dolerite Sample

**GQ1 and GQ2**: Garnet quartzite. Hard quartzite rock with massive texture subjected to granulite facies pressure temperature conditions with hydrothermal garnet dominated alteration. Composition dominated by quartz with minor garnet, lesser biotite and irregular minor chlorite alteration. This rock type is rated as a strong competent rock unit.

Figure 4-5: Image of Garnet Quartzite Sample

## 4.2 PSD and Moisture Content

The waste rock composition was analysed for moisture content and PSD by ALS and GHD laboratories respectively. Results are presented in Table 4.1 below.

Table 4-1: Size and Moisture Characterisation

| Sample ID | Moisture Content | Sieve sizes - Percentage Passing | | | | |
|---|---|---|---|---|---|---|
| | | 75mm | 53mm | 19mm | 2.36mm | 75µm (silt and clay) |
| 1 | 3.1% | 100% | 52% | 23% | 8% | **2%** |
| 2 | 1.6% | 68% | 49% | 14% | 3% | **1%** |
| 3 | 3.1% | 85% | 47% | 15% | 5% | **1%** |
| 4 | 3.4% | 70% | 47% | 16% | 5% | **1%** |
| 5 | 3.4% | 71% | 49% | 11% | 3% | **1%** |

Results in **bold** represent particle sizes that are potentially 'dust producing'

The moisture content of all samples is very low. Moisture content has a significant effect on rock strength, lower moisture contents are typically linked to increased rock strength.

The waste rock samples (1-5) that were sent for PSD analysis at the GHD laboratory showed a consistent trend with a low proportion of small particle sizes. Laboratory reports showed that 4 of the 5 samples had 1% of the sample passing a 75µm sieve; while the last sample had 2% passing the 75µm sieve. Significant volumes of dust are unlikely to be generated from particle sizes greater than 75µm.

Furthermore, the greatest percentage of any sample passing a 2.36mm sieve was only 8%. 2.36mm is considered to be the geotechnical cut-off point for fine grained soils, i.e. particles with a diameter less than 2.36mm are classed as fine grained. Silt is classed as particles of less than 75µm, but greater than 2µm; particles of less than 2µm are classed as clay.

Therefore, the average silt content of the five samples is 1.2%, which may include some proportion of clay particles.

Importantly, it is also noted that the proportion of small or fine grained material in the waste rock pile is likely strongly influenced by the method of mining (blasting) rather than being reflective of the rock's natural degradation and erosion (which will be slow).

## 4.3 Metals Content

It is known that the waste rock comprises a number of different rock types, in varying quantities (refer section 4.1. Crushing of the samples prior to metals analysis was undertaken in order to homogenise the sample and eliminate or reduce the possibility that sampling of the finer material, that may constitute a particular rock type, may bias analytical results.

The analytical results have been summarised in Table 4-2 below. The full laboratory reports may be viewed in **Appendix B**.

Table 4-2: *Summary of Laboratory Analysis Results, Moisture and Heavy Metals*

| Analyte | Units | Sample ID | | | | | |
|---|---|---|---|---|---|---|---|
| | | Waste Rock Tipple | 1 | 2 | 3 | 4 | 5 |
| **Sample Date** | -- | 25.08.16 | 15.09.16 | 15.09.16 | 15.09.16 | 15.09.16 | 15.09.16 |
| **Moisture Content** | % | 1.3 | 3.1 | 1.6 | 3.1 | 3.4 | 3.4 |
| Arsenic | mg/kg | 13 | 9 | 241 | 34 | 26 | 75 |
| Barium | mg/kg | 40 | 30 | 30 | 30 | 30 | 20 |
| Beryllium | mg/kg | <1 | <1 | <1 | <1 | <1 | <1 |
| Boron | mg/kg | <50 | <50 | <50 | <50 | <50 | <50 |
| Cadmium | mg/kg | 6 | <1 | 5 | 57 | 4 | 17 |
| Chromium | mg/kg | 17 | 22 | 13 | 10 | 20 | 17 |
| Cobalt | mg/kg | 8 | 9 | 16 | 14 | 10 | 11 |
| Copper | mg/kg | 93 | 15 | 55 | 240 | 45 | 141 |
| **Lead** | mg/kg | 543 | 57 | **905** | **9010** | **684** | **3030** |
| Manganese | mg/kg | 78 | 91 | 258 | 405 | 174 | 188 |
| Nickel | mg/kg | 12 | 18 | 18 | 12 | 19 | 18 |
| Selenium | mg/kg | <5 | <5 | <5 | <5 | <5 | <5 |
| Vanadium | mg/kg | 15 | 22 | 18 | 14 | 28 | 22 |
| Zinc | mg/kg | 1780 | 222 | 1420 | 21500 | 973 | 4060 |
| Mercury | mg/kg | <0.1 | <0.1 | <0.1 | 0.1 | <0.1 | <0.1 |

The concentrations of all metals analysed other than lead are within the NEPM HIL-C (recreational) and HIL-D (industrial/commercial) guideline criteria. Exceedances of the HIL-C criterion are highlighted in bold in Table 4-2.

Four of the six samples exceed the NEPM HIL-C (recreational) criteria for lead in soil, and two of the samples (samples 3 and 5) exceed HIL-D (industrial/commercial) criteria. The mean lead concentration of all six samples in Table 4-2 was calculated as being 2,371.5 mg/kg. This mean also exceeds the NEPM HIL-C guideline value of 600 mg/kg and the HIL-D guideline value of 1,500 mg/kg.

## 4.4 Dust generation potential

Typically, we would use the US emission factor documentation (AP-42) to derive site-specific emissions from wind erosion, specifically chapter 13.2.5 – Industrial Wind Erosion.  The General statement from this document is copied below -

"*Dust emissions may be generated by wind erosion of open aggregate storage piles and exposed areas within an industrial facility. These sources typically are characterized by nonhomogeneous surfaces impregnated with non-erodible elements (particles larger than approximately 1 centimetre [cm] in diameter). Field testing of coal piles and other exposed materials using a portable wind tunnel has shown that (a) threshold wind speeds exceed 5 meters per second (m/s) (11 miles per hour [mph]) at 15 cm above the surface or 10 m/s (22 mph) at 7 m above the surface, and (b) particulate* *emission rates tend to decay rapidly (half-life of a few minutes) during an erosion event. In other words, these aggregate material surfaces are characterized by finite availability of erodible material (mass/area) referred to as the erosion potential. Any natural crusting of the surface binds the erodible material, thereby reducing the erosion potential*"

From the review of the geological test data (PSD) of the waste rock stockpile material discussed in Section 4.2 above, it is likely that this material will have a very low potential for dust generation. This is partially due to the low percentage of particles sized below 0.75µm as well as the rock type.

The hardness of the rock types and low rainfall conditions at the site indicate that weathering of the rock types present will be particularly slow, requiring geological time frames to decompose significantly.

### 4.4.1 Confined air burst chamber (CABC) testing

Additional field testing was undertaken by Pacific Environment staff in December 2016 to determine the wind erosion/dust generating potential of the waste rock (as well as other areas of the site). The field tests undertaken were 'Confined Air Burst Chamber (CABC)' tests. This is a semi-quantitative method developed in the US to measure relative wind erosion potential, comprising:

- Pressurised air jet released onto the test surface within the chamber
- Peak particulate matter (PM) concentrations within the chamber recorded as a measure of surface erodibility
- Test conducted on uncontrolled surface and repeated on other (controlled) surfaces allowing estimation of relative control efficiency (% control)

A total of 52 CABC tests were conducted on:

- Dry tailings (Crusted and Disturbed).
- Wet tailings
- **Waste rock trial areas**
- Uncontrolled free areas (Crusted and Disturbed)
- Dust suppressant application area (applied June 2016)
- Fresh dust suppressant application

Table 4-3 – *CABC Results*

| Material Type | % control |
|---|---|
| Base Case – Dry Tailings - Disturbed | **0.0%** |
| Dry Tailings – Crusted | **99.7%** |
| Wet Tailings | **100%** |
| **Waste Rock Trial** | **99.7%** |
| Base Case – Dry Tailings - Disturbed | **0.0%** |
| Uncontrolled Free Areas – Crusted | **96.6%** |
| Uncontrolled Free Areas – 5 mo old RST Total Ground Control | **98.9%** |
| Base Case – Dry Tailings - Disturbed | **0.0%** |
| Unsealed Areas - Crusted | **90%** |
| Unsealed Areas – Fresh RST Total Ground Control | **99.2%** |

The results of the CABC tests on the waste rock showed a 99.7% level of control, when compared to the control site (disturbed, dry tailings).

The full report on this work is presented as a letter report to BHOP, *Air Quality Assessment for the Rasp Mine Modification 4***,** Pacific Environment Limited, March 2017 and can be viewed at Appendix I of the *Rasp Mine Environment Assessment Modification 4 Concrete Batching Plant Blackwood Pit TSF2 Extension*, BHOP, March 2017.

# 5. Discussion

The multiple lines of evidence used to assess the “inert’ properties of the Kintore Pit waste rock stockpile were:

- rock type
- moisture content;
- particle size distribution (PSD), and
- metals concentration.

In addition to these studies, additional consideration was given to the prior Human Health Risk Assessment work undertaken by Toxikos (2010, 2015), background soil/dust data and recent Confined Air Burst Chamber (CABC) testing undertaken on site for the purposes of quantifying dust control.

**Rock type** – Studies and observations undertaken by BHOP have identified that the bulk of the waste rock is composed of Garnet Pelite and Psammopelite then Garnet Spotted Psammopelite. Only very minor quantities of Dolerite and Garnet Quartzile will be present. Psammopelite is generally a strong and competent rock unit. Garnet pelite is less strong, but is nonetheless a competent, metamorphic rock type.

**Moisture content** - The moisture content of the samples is quite low, with the upper level being 3.4% and the lower level being 1.3%. These figures fit with the known rainfall and evaporation conditions at the site, even in the wettest months; evaporation exceeds rainfall by greater than a factor of ten. Low moisture content is typical of harder rock types.

**Particle Size Distribution** - The silt content of the waste rock make-up in its unprocessed state is considered low, being an average of 1.2% of material <0.75µm in the samples subjected to PSD. The potential for dust generation is therefore ranked as low. If the waste rock is subjected to rainfall, this will wash the fines deep into the lower strata, where it will not be subject to wind scour, therefore reducing the potential for dust generation even further.

**Metals concentration** - No directly applicable criteria are available for are available for dust generation from waste rock. The metals concentrations in the waste rock were found to be below NEPM HIL-C (recreational) soil trigger values for the protection of human health for all metals with the exception of lead. Lead concentrations in the samples ranged from 57 mg/kg to 9,010 mg/kg. Four of the six samples exceed the NEPM HIL-C criteria for lead in soil (600 mg/kg), and two of the samples (samples 3 and 5) exceed HIL-D (industrial/commercial) criteria for lead in soil (1,500 mg/kg)

The mean lead concentration of all six (waste rock) samples was **2,371.5 mg/kg (0.23 %)**.

It should be noted that:

- The waste rock, as physically characterised, presents a reduced risk to potential sensitive receptors on-site when compared to soils with similar concentrations of metals. This is based upon its strength/competency and particle size;
- The analysis process involves crushing the samples prior to extracting the metals. The crushing process exposes a greater surface area to the laboratory’s extraction fluid, releasing metals that may otherwise have remained within the rock over geological time periods. It is therefore considered to be a highly conservative analysis.

**Comparison of waste rock lead content to other available criteria/data**

The mean lead concentration of the waste rock samples (2,371.5 mg/kg or 0.23 %) can be compared to surface dust concentrations

Table 5-1 – *Comparison of lead concentration and bioaccessibility data*

| Sample ID | Median Lead Concentration (mg/kg) | Median Lead Concentration (%) | Median Bioaccessibility (Bac) (%) |
|---|---|---|---|
| Surface dust samples (Toxikos, 2010) | 15,640 | 1.56 | **7.3** |
| Waste Rock (PE, 2017) | 2,371.5 | 0.24 | **7.3^** |
| Broken Hill Town soils (Lyle, et al, 2006) | 500 – 2,000 | 0.05 – 0.2 | UK* |
| HIL-C Criteria (recreational) | 600 | 0.06 | **50** |
| HIL-D Criteria (industrial/commercial) | 1,500 | 0.15 | **50** |

**unknown*

*^assumed, based upon Toxikos prior studies on-site*

The comparison identifies that:

- Waste rock has a significantly lower median concentration of lead compared to existing site surfaces (both processing and 'free areas');
- Waste rock has a marginally higher concentration of lead than soils in the Broken Hill Town;
- Waste rock exceeds HIL-C criteria and HIL-D criteria for soils, however;
    a. These criteria are based upon soils concentrations and are not directly applicable. This is because soils are more readily available (for ingestion) than rock (generally having a smaller particle size), and are more accessible to children (the most sensitive receptors) as a part of gardens, playgrounds or other urban spaces.
    b. HILs assume a bioaccessibility of 50%. Site dusts have been shown to have a median bioaccesibility of 7.3%.

**Confined Air Burst Chamber (CABC) Tests**

CABC tests identified that waste rock provided a 99.7% level of control (reduction, compared to the base case) when compared to dust emissions from existing dry tailings.

**Comparison to modelling data**

Pacific Environment has assessed particulate matter and lead impacts associated with MOD 4 activities as part of an air quality modelling exercise. The model used assumed concentrations of 0.5% lead in waste rock. This is higher than the median of 0.24% identified from limited field sampling. The results demonstrate compliance with all the NSW EPA impact assessment criteria for all air quality parameters assessed.

# 6. Conclusions

PE have considered numerous physical and chemical attributes of the waste rock in assessing it's potential to impact the identified receptors (on-site visitors/tourists and off-site residents (children)).

The results of the waste rock assessment, and in consideration of associated studies, identified that;

- The rock type varies, however all rock types identified are competent and mostly hard, with good resistance to weathering;
- The rock comprises only approximately 1% fines capable of producing dust;
- This was qualified by Confined Air Burst Chamber tests, which identified a 99.7% reduction in dust generation compared to disturbed dry tailings.
- Lead concentrations averaged 2,371.5 mg/kg (0.24%). This is above NEPM HIL-C and HIL-D criteria (600 mg/kg and 1,500 mg/kg respectively), but significantly below surface dust averages (15,640 mg/kg, or 1.56%).
- Bioaccessibility is very low (7.3% on average). This is much lower (6.8 x) than the 50% (bioavailability) assumed for the calculation of HIL's. This would suggest that results, if adjusted for bioaccessibility, would meet HIL-C criteria;
- Air quality modelling conducted by PE (2017), assumed a waste rock concentration of 0.5% (5,000 mg/kg). Results demonstrate compliance with all the NSW EPA impact assessment criteria for all air quality parameters assessed.

In conclusion, the results support the use of the waste rock for dust suppression for the TSF and 'free areas', and are considered unlikely to cause an unacceptable risk to human health based upon the site's final land use as a proposed tourist/recreational site.

Air quality modelling has assumed lead concentrations above those identified in the waste rock on site (0.5% compared to 0.24%), and therefore the waste rock is likely to meet NSW EPA impact assessment criteria, and is unlikely to impact further upon surface soil lead concentrations within local communities. The very low dusting potential of the rock supports this conclusion.

**In consideration of all other lines of evidence, the 0.5% lead concentration adopted by the air quality model is considered to be a suitable criterion for waste rock placement on-site.**

It is therefore considered that the waste rock meets the criteria of being 'inert' material, based upon the multiple lines of evidence approach.

# 7. Recommendations

The waste rock, when placed, is considered to be suitable as a means of reducing, to an acceptable level, the potential for dust generation from the TSF and 'free areas' of the site. To reduce potential risks during placement, we recommend that dust suppression spraying is carried out during capping material (waste rock) placement. A final spray is recommended to ensure that finer particles are washed between the larger rocks. This will greatly reduce the future potential for the rock to create dust.

This assessment has been partially based upon a limited number of waste rock samples, which were analysed for lead composition. For the conclusions of this assessment to maintain validity, it is recommended that field screening of the waste rock is undertaken during placement to confirm that median concentrations do not exceed 0.5%. PE recommends that this is undertaken by use of a calibrated x-ray fluorescence (XRF) field meter. It is noted that:

- laboratory results were considered to be conservative due to the crushing and leaching processes used as part of the analysis methodology;
- XRF results are therefore unlikely to be comparable to laboratory results (they may be lower), however they would be considered to be representative for the reasons above; and
- use of an XRF provides a practical and timely characterisation of field material. Many more samples may be screened in comparison to laboratory analysis.

# 8. Limitations

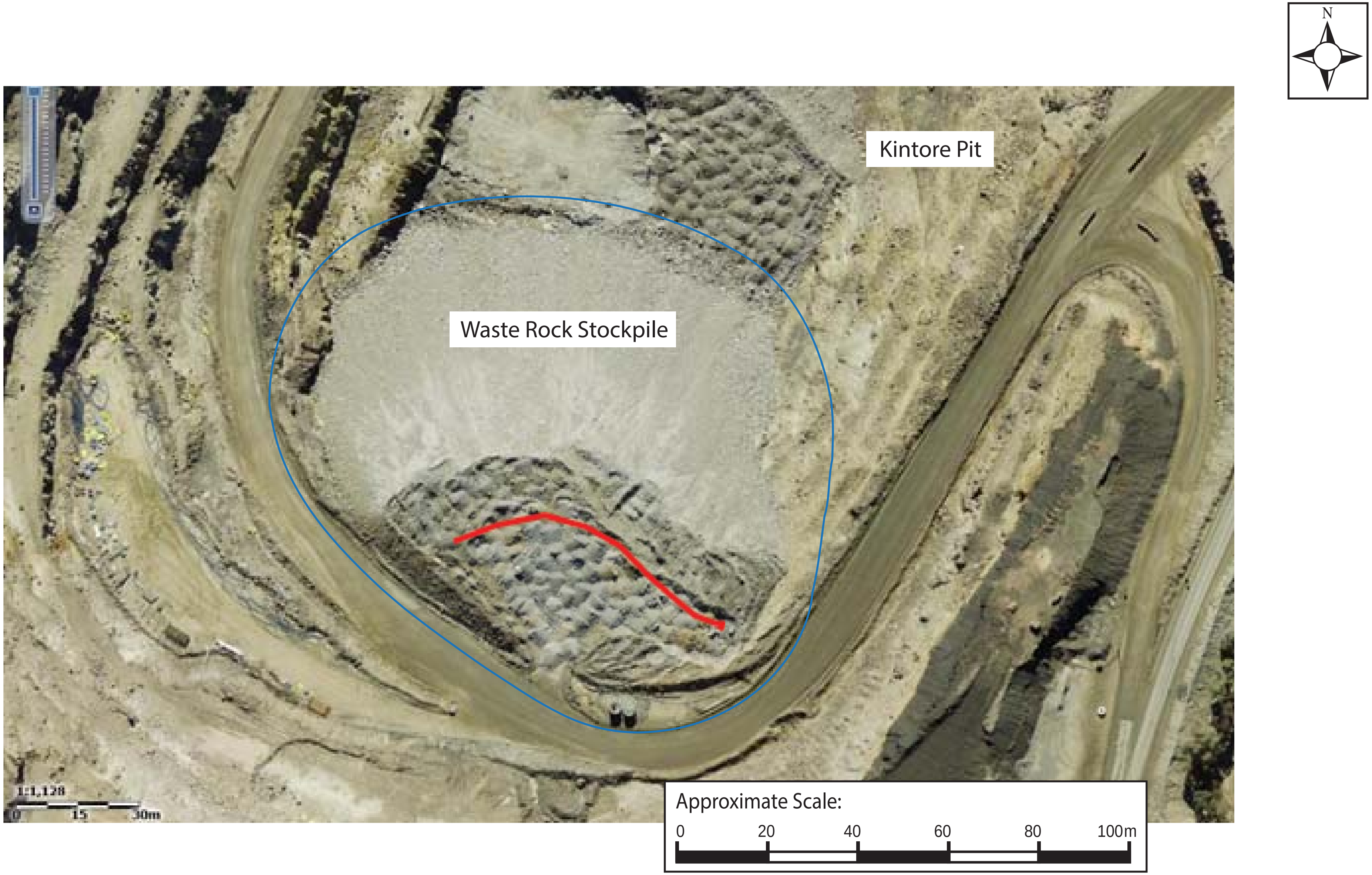
This report has been prepared, in part, from materials provided by third parties and from the analysis of samples collected by third parties. These third parties were not under the direct supervision of Pacific Environment at the time these activities were carried out. Pacific Environment cannot guarantee the data and other information gained from these sources is entirely accurate although we have not been given reason to think that it is not accurate. The validity and comprehensiveness of supplied information has not been independently verified and, for the purposes of this report, it is assumed that the information provided to Pacific Environment is both complete and accurate.

Errors made where Pacific Environment was reliant on third party data or other information obtained from sources outside the control of Pacific Environment will not constitute a failure of Pacific Environment in their duty to their client.

# 9. Signatories

| Drafted by: | Approved By: |
| --- | --- |
| Ross Lawrence | |
| Ross Lawrence<br>B. Env Tech, CEnvP<br>Senior Consultant<br>Pacific Environment Limited | Brian Fainton<br>BSc (Hons), MSc<br>Principal & Team Lead, Contaminated Land<br>Pacific Environment Limited |

# Appendix A - Figures




LEGEND

FIGURE 001

Approximate outline of waste rock stockpile

Sampling transect

Sampling Transect - Kintore Pit Stockpile

Rasp Mine
Broken Hill Operations Pty Ltd
Broken Hill, New South Wales

| JOB ID: 21544B | DRAWN BY: RL | APPROVED BY: BF | March 2017 |
|---|---|---|---|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# Appendix B - Laboratory Reports

ALS Environmental

# CHAIN OF CUSTODY

ALS Laboratory: please tick →

☐ADELAIDE 21 Burma Road Pooraka SA 5095 Ph: 08 8359 0890 E: adelaide@alsglobal.com
☐BRISBANE 32 Shand Street Stafford QLD 4053 Ph: 07 3243 7222 E: samples.brisbane@alsglobal.com
☐GLADSTONE 46 Callemondah Drive Clinton QLD 4680 Ph: 07 7471 5600 E: gladstone@alsglobal.com
☐MACKAY 78 Harbour Road Mackay QLD 4740 Ph: 07 4944 0177 E: mackay@alsglobal.com
☐MELBOURNE 2-4 Westall Road Springvale VIC 3171 Ph: 03 8549 9600 E: samples.melbourne@alsglobal.com
☐MUDGEE 27 Sydney Road Mudgee NSW 2850 Ph: 02 6372 6735 E: mudgee.mail@alsglobal.com
☐NEWCASTLE 5 Rose Gum Road Warabrook NSW 2304 Ph: 02 4968 9433 E: samples.newcastle@alsglobal.com
☐NOWRA 4/13 Geary Place North Nowra NSW 2541 Ph: 024423 2063 E: nowra@alsglobal.com
☐PERTH 10 Hod Way Malaga WA 6090 Ph: 08 9209 7655 E: samples.perth@alsglobal.com
☐SYDNEY 277-289 Woodpark Road Smithfield NSW 2164 Ph: 02 8784 8555 E: samples.sydney@alsglobal.com
☐TOWNSVILLE 14-15 Desma Court Bohle QLD 4818 Ph: 07 4796 0600 E: townsville.environmental@alsglobal.com
☐WOLLONGONG 99 Kenny Street Wollongong NSW 2500 Ph: 02 4225 3125 E: portkembla@alsglobal.com

| | |
|---|---|
| Broken Hill Operations (ALS shortcode: BROHIL) | TURNAROUND REQUIREMENTS : ☑ Standard TAT (List due date): |
| : PO BOX 5073, BROKEN HILL NSW 2880 | (Standard TAT may be longer for some tests e.g.. Ultra Trace Organics) ☐ Non Standard or urgent TAT (List due date): |
| CT: RASP MINE | ALS QUOTE NO.: SY/127/13 |
| NUMBER: PO 37241 | GROUNDWATER SAMPLES |
| CT MANAGER: Leonard Sharp | CONTACT PH: (08) 8088 9111 |
| ER: L.Sharp | SAMPLER MOBILE: 0414 347 125 |
| ailed to ALS? ( YES / NO) | EDD FORMAT (or default): |
| eports to (will default to PM if no other addresses are listed): leonardsharp@cbhresources.com.au | |
| voice to (will default to PM if no other addresses are listed): travisbow@cbhresources.com.au | |

COC SEQUENCE NUMBER (Circle)

COC: 1 2 3 4 5 6 7

OF: 1 2 3 4 5 6 7

FOR LABORATORY USE ONLY (Circle)

Custody Seal Intact? Yes No N/A

Free ice / frozen ice bricks present upon receipt? Yes No N/A

Random Sample Temperature on Receipt: 15.7 °C

Other comment:

| RELINQUISHED BY: | RECEIVED BY: | RELINQUISHED BY: | RECEIVED BY: |
|---|---|---|---|
| *Len Sharp* | Jessie | | |
| DATE/TIME: 25/08/16 2.00pm | DATE/TIME: 26/8/16 12:35 | DATE/TIME: | DATE/TIME: |

NTS/SPECIAL HANDLING/STORAGE OR DISPOSAL:

SAMPLE DETAILS MATRIX: SOLID (S) WATER (W)

CONTAINER INFORMATION

ANALYSIS REQUIRED including SUITES (NB. Suite Codes must be listed to attract suite price) Where Metals are required, specify Total (unfiltered bottle required) or Dissolved (field filtered bottle required).

| SAMPLE ID | DATE / TIME | MATRIX | TYPE & PRESERVATIVE (refer to codes below) | TOTAL CONTAINERS | Deionised water leach | W-30 | S-3 | Jaw crush/pulverise (sample already crushed as per Len.) | Size fractioning | | Hydrometer + Sieve in order to get silt, sand + clay | As discussed with Len. D.W. 29/8/16 | Additional Information: Comments on likely contaminant levels, dilutions, or samples requiring specific QC analysis etc. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Waste Rock Tipple | 25/08/2016 | soil | snaplock bag | 1 | X | X | X | X | | | | | possible high Pb and Zn |
| Mill Material | 25/08/2016 | soil | snaplock bag | 1 | X | X | X | | | | | | possible high Pb and Zn |
| Mill Material 2 | 25/08/2016 | soil | snaplock bag | 1 | | | | | X | | | | possible high Pb and Zn |
| Spillway | 25/08/2016 | soil | snaplock bag | 1 | X | X | X | | | | | | possible high Pb and Zn |
| | | | TOTAL | 4 | | | | | | | | | |

Subcon / Forward Lab / Split WO
Lab / Analysis: Newcastle
Organised By / Date:
Relinquished By / Date: ASD
Connote / Courier:
WO No:
Attach By PO / Internal Sheet:

Environmental Division
Sydney
Work Order Reference
ES1618999

Telephone : + 61-2-8784 8555

ntainer Codes: P = Unpreserved Plastic; N = Nitric Preserved Plastic; ORC = Nitric Preserved ORC; SH = Sodium Hydroxide/Cd Preserved; S = Sodium Hydroxide Preserved Plastic; AG = Amber Glass Unpreserved; AP - Airfreight Unpreserved Plastic
ial HCl Preserved; VB = VOA Vial Sodium Bisulphate Preserved; VS = VOA Vial Sulfuric Preserved; AV = Airfreight Unpreserved Vial SG = Sulfuric Preserved Amber Glass; H = HCl preserved Plastic; HS = HCl preserved Speciation bottle; SP = Sulfuric Preserved Plastic; F = Formaldehyde Preserved Glass;
cetate Preserved Bottle; E = EDTA Preserved Bottles; ST = Sterile Bottle; ASS = Plastic Bag for Acid Sulphate Soils; B = Unpreserved Bag.

# CERTIFICATE OF ANALYSIS



| | | | |
|---|---|---|---|
| **Work Order** | : **ES1618999** | Laboratory | : Environmental Division Sydney |
| Client | : **BROKEN HILL OPERATIONS PTY LTD** | Contact | : |
| Contact | : MR LEONARD SHARP | Address | : 277-289 Woodpark Road Smithfield NSW Australia 2164 |
| Address | : PO BOX 5073<br>BROKEN HILL NSW 2880 | | |
| Telephone | : +61 08 8088 9104 | Telephone | : +61-2-8784 8555 |
| Project | : RASP MINE | Date Samples Received | : 26-Aug-2016 12:35 |
| Order number | : 37241 | Date Analysis Commenced | : 30-Aug-2016 |
| C-O-C number | : ---- | Issue Date | : 02-Sep-2016 11:13 |
| Sampler | : LEONARD SHARP | | |
| Site | : ---- | | |
| Quote number | : ---- | | |
| No. of samples received | : 4 | | |
| No. of samples analysed | : 4 | | |

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* |
|---|---|---|
| Celine Conceicao | Senior Spectroscopist | Sydney Inorganics, Smithfield, NSW |
| Dianne Blane | Laboratory Coordinator (2IC) | Newcastle - Inorganics, Mayfield West, NSW |
| Edwandy Fadjar | Organic Coordinator | Sydney Inorganics, Smithfield, NSW |
| RICHARD TEA | Lab technician | Sydney Inorganics, Smithfield, NSW |

## General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by 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.

## Analytical Results

| Sub-Matrix: **DI WATER LEACHATE** (Matrix: **WATER**) | | | Client sample ID | **WASTE ROCK TIPPLE** | **MILL MATERIAL** | **SPILLWAY** | ---- | ---- |
|---|---|---|---|---|---|---|---|---|
| | | | Client sampling date / time | [25-Aug-2016] | [25-Aug-2016] | [25-Aug-2016] | ---- | ---- |
| *Compound* | *CAS Number* | *LOR* | *Unit* | **ES1618999-001** | **ES1618999-002** | **ES1618999-004** | -------- | -------- |
| | | | | Result | Result | Result | ---- | ---- |
| **EG020W: Water Leachable Metals by ICP-MS** | | | | | | | | |
| **Aluminium** | 7429-90-5 | 0.01 | mg/L | **3.76** | **1.76** | **0.02** | ---- | ---- |
| **Arsenic** | 7440-38-2 | 0.001 | mg/L | **0.002** | **0.005** | <0.001 | ---- | ---- |
| **Cadmium** | 7440-43-9 | 0.0001 | mg/L | **0.0002** | **0.0149** | **0.197** | ---- | ---- |
| **Chromium** | 7440-47-3 | 0.001 | mg/L | **0.004** | **0.002** | <0.001 | ---- | ---- |
| **Copper** | 7440-50-8 | 0.001 | mg/L | **0.008** | **0.016** | **0.002** | ---- | ---- |
| **Lead** | 7439-92-1 | 0.001 | mg/L | **0.054** | **0.491** | **3.56** | ---- | ---- |
| **Nickel** | 7440-02-0 | 0.001 | mg/L | **0.002** | **0.002** | **0.011** | ---- | ---- |
| **Selenium** | 7782-49-2 | 0.01 | mg/L | <0.01 | <0.01 | <0.01 | ---- | ---- |
| **Zinc** | 7440-66-6 | 0.005 | mg/L | **0.121** | **0.950** | **6.20** | ---- | ---- |
| **Iron** | 7439-89-6 | 0.05 | mg/L | **1.74** | **0.93** | <0.05 | ---- | ---- |
| **EG035W: Water Leachable Mercury by FIMS** | | | | | | | | |
| **Mercury** | 7439-97-6 | 0.0001 | mg/L | <0.0001 | <0.0001 | <0.0001 | ---- | ---- |

## Analytical Results

| Sub-Matrix: SOIL (Matrix: SOIL) | | | Client sample ID | WASTE ROCK TIPPLE | MILL MATERIAL | MILL MATERIAL 2 | SPILLWAY | ---- |
|---|---|---|---|---|---|---|---|---|
| | | | Client sampling date / time | [25-Aug-2016] | [25-Aug-2016] | [25-Aug-2016] | [25-Aug-2016] | ---- |
| Compound | CAS Number | LOR | Unit | ES1618999-001 | ES1618999-002 | ES1618999-003 | ES1618999-004 | -------- |
| | | | | Result | Result | Result | Result | ---- |
| **EA055: Moisture Content** | | | | | | | | |
| Moisture Content (dried @ 103°C) | ---- | 1 | % | 1.3 | 5.5 | ---- | 6.5 | ---- |
| **EA150: Particle Sizing** | | | | | | | | |
| +75µm | ---- | 1 | % | ---- | ---- | 81 | ---- | ---- |
| +150µm | ---- | 1 | % | ---- | ---- | 76 | ---- | ---- |
| +300µm | ---- | 1 | % | ---- | ---- | 71 | ---- | ---- |
| +425µm | ---- | 1 | % | ---- | ---- | 68 | ---- | ---- |
| +600µm | ---- | 1 | % | ---- | ---- | 65 | ---- | ---- |
| +1180µm | ---- | 1 | % | ---- | ---- | 59 | ---- | ---- |
| +2.36mm | ---- | 1 | % | ---- | ---- | 50 | ---- | ---- |
| +4.75mm | ---- | 1 | % | ---- | ---- | 42 | ---- | ---- |
| +9.5mm | ---- | 1 | % | ---- | ---- | 32 | ---- | ---- |
| +19.0mm | ---- | 1 | % | ---- | ---- | 28 | ---- | ---- |
| +37.5mm | ---- | 1 | % | ---- | ---- | 14 | ---- | ---- |
| +75.0mm | ---- | 1 | % | ---- | ---- | <1 | ---- | ---- |
| **EA150: Soil Classification based on Particle Size** | | | | | | | | |
| Clay (<2 µm) | ---- | 1 | % | ---- | ---- | 6 | ---- | ---- |
| Silt (2-60 µm) | ---- | 1 | % | ---- | ---- | 12 | ---- | ---- |
| Sand (0.06-2.00 mm) | ---- | 1 | % | ---- | ---- | 29 | ---- | ---- |
| Gravel (>2mm) | ---- | 1 | % | ---- | ---- | 41 | ---- | ---- |
| Cobbles (>6cm) | ---- | 1 | % | ---- | ---- | 12 | ---- | ---- |
| **EA152: Soil Particle Density** | | | | | | | | |
| ø Soil Particle Density (Clay/Silt/Sand) | ---- | 0.01 | g/cm3 | ---- | ---- | 2.77 | ---- | ---- |
| **EG005T: Total Metals by ICP-AES** | | | | | | | | |
| Arsenic | 7440-38-2 | 5 | mg/kg | 13 | 86 | ---- | 97 | ---- |
| Barium | 7440-39-3 | 10 | mg/kg | 40 | 30 | ---- | 60 | ---- |
| Beryllium | 7440-41-7 | 1 | mg/kg | <1 | <1 | ---- | <1 | ---- |
| Boron | 7440-42-8 | 50 | mg/kg | <50 | <50 | ---- | <50 | ---- |
| Cadmium | 7440-43-9 | 1 | mg/kg | 6 | 43 | ---- | 13 | ---- |
| Chromium | 7440-47-3 | 2 | mg/kg | 17 | 12 | ---- | 15 | ---- |
| Cobalt | 7440-48-4 | 2 | mg/kg | 8 | 10 | ---- | 12 | ---- |
| Copper | 7440-50-8 | 5 | mg/kg | 93 | 108 | ---- | 216 | ---- |
| Lead | 7439-92-1 | 5 | mg/kg | 543 | 3190 | ---- | 15800 | ---- |
| Manganese | 7439-96-5 | 5 | mg/kg | 78 | 2160 | ---- | 5500 | ---- |
| Nickel | 7440-02-0 | 2 | mg/kg | 12 | 13 | ---- | 16 | ---- |

## Analytical Results

| Sub-Matrix: SOIL (Matrix: SOIL) | | | Client sample ID | WASTE ROCK TIPPLE | MILL MATERIAL | MILL MATERIAL 2 | SPILLWAY | ---- |
|---|---|---|---|---|---|---|---|---|
| | | | Client sampling date / time | [25-Aug-2016] | [25-Aug-2016] | [25-Aug-2016] | [25-Aug-2016] | ---- |
| Compound | CAS Number | LOR | Unit | ES1618999-001 | ES1618999-002 | ES1618999-003 | ES1618999-004 | -------- |
| | | | | Result | Result | Result | Result | ---- |
| **EG005T: Total Metals by ICP-AES - Continued** | | | | | | | | |
| **Selenium** | 7782-49-2 | 5 | mg/kg | <5 | <5 | ---- | <5 | ---- |
| **Vanadium** | 7440-62-2 | 5 | mg/kg | **15** | **15** | ---- | **18** | ---- |
| **Zinc** | 7440-66-6 | 5 | mg/kg | **1780** | **2600** | ---- | **3130** | ---- |
| **EG035T: Total Recoverable Mercury by FIMS** | | | | | | | | |
| **Mercury** | 7439-97-6 | 0.1 | mg/kg | <0.1 | <0.1 | ---- | **0.3** | ---- |
| **EN60: Bottle Leaching Procedure** | | | | | | | | |
| **Final pH** | ---- | 0.1 | pH Unit | **8.0** | **7.5** | ---- | **5.8** | ---- |

ALS Environmental

# QUALITY CONTROL REPORT

| | | | |
|---|---|---|---|
| **Work Order** | : **ES1618999** | Page | : 1 of 5 |
| Client | : **BROKEN HILL OPERATIONS PTY LTD** | Laboratory | : Environmental Division Sydney |
| Contact | : MR LEONARD SHARP | Contact | : |
| Address | : PO BOX 5073<br>BROKEN HILL NSW 2880 | Address | : 277-289 Woodpark Road Smithfield NSW Australia 2164 |
| Telephone | : +61 08 8088 9104 | Telephone | : +61-2-8784 8555 |
| Project | : RASP MINE | Date Samples Received | : 26-Aug-2016 |
| Order number | : 37241 | Date Analysis Commenced | : 30-Aug-2016 |
| C-O-C number | : ---- | Issue Date | : 02-Sep-2016 |
| Sampler | : LEONARD SHARP | | |
| Site | : ---- | | |
| Quote number | : ---- | | |
| No. of samples received | : 4 | | |
| No. of samples analysed | : 4 | | |

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 Quality Control Report contains the following information:

- Laboratory Duplicate (DUP) Report; Relative Percentage Difference (RPD) and Acceptance Limits
- Method Blank (MB) and Laboratory Control Spike (LCS) Report; Recovery and Acceptance Limits
- Matrix Spike (MS) Report; Recovery and Acceptance Limits

## *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* |
|---|---|---|
| Celine Conceicao | Senior Spectroscopist | Sydney Inorganics, Smithfield, NSW |
| Dianne Blane | Laboratory Coordinator (2IC) | Newcastle - Inorganics, Mayfield West, NSW |
| Edwandy Fadjar | Organic Coordinator | Sydney Inorganics, Smithfield, NSW |
| RICHARD TEA | Lab technician | Sydney Inorganics, Smithfield, NSW |

## General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by 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

Key : Anonymous = Refers to samples which are not specifically part of this work order but formed part of the QC process lot
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
RPD = Relative Percentage Difference
# = Indicates failed QC

## Laboratory Duplicate (DUP) Report

The quality control term Laboratory Duplicate refers to a randomly selected intralaboratory split. Laboratory duplicates provide information regarding method precision and sample heterogeneity. The permitted ranges for the Relative Percent Deviation (RPD) of Laboratory Duplicates are specified in ALS Method QWI-EN/38 and are dependent on the magnitude of results in comparison to the level of reporting: Result < 10 times LOR: No Limit; Result between 10 and 20 times LOR: 0% - 50%; Result > 20 times LOR: 0% - 20%.

Sub-Matrix: **SOIL**

| | | | | Laboratory Duplicate (DUP) Report | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| *Laboratory sample ID* | *Client sample ID* | *Method: Compound* | *CAS Number* | *LOR* | *Unit* | *Original Result* | *Duplicate Result* | *RPD (%)* | *Recovery Limits (%)* |
| **EA055: Moisture Content (QC Lot: 567254)** | | | | | | | | | |
| ES1618999-002 | MILL MATERIAL | EA055-103: Moisture Content (dried @ 103°C) | ---- | 1 | % | 5.5 | 5.7 | 3.71 | No Limit |
| ES1619032-016 | Anonymous | EA055-103: Moisture Content (dried @ 103°C) | ---- | 1 | % | 70.7 | 70.3 | 0.576 | 0% - 20% |
| **EG005T: Total Metals by ICP-AES (QC Lot: 567185)** | | | | | | | | | |
| ES1618941-002 | Anonymous | EG005T: Beryllium | 7440-41-7 | 1 | mg/kg | <1 | <1 | 0.00 | No Limit |
| | | EG005T: Cadmium | 7440-43-9 | 1 | mg/kg | <1 | <1 | 0.00 | No Limit |
| | | EG005T: Barium | 7440-39-3 | 10 | mg/kg | <10 | <10 | 0.00 | No Limit |
| | | EG005T: Chromium | 7440-47-3 | 2 | mg/kg | 3 | 3 | 0.00 | No Limit |
| | | EG005T: Cobalt | 7440-48-4 | 2 | mg/kg | <2 | <2 | 0.00 | No Limit |
| | | EG005T: Nickel | 7440-02-0 | 2 | mg/kg | <2 | <2 | 0.00 | No Limit |
| | | EG005T: Arsenic | 7440-38-2 | 5 | mg/kg | 5 | 5 | 0.00 | No Limit |
| | | EG005T: Copper | 7440-50-8 | 5 | mg/kg | 6 | 6 | 0.00 | No Limit |
| | | EG005T: Lead | 7439-92-1 | 5 | mg/kg | 19 | 18 | 0.00 | No Limit |
| | | EG005T: Manganese | 7439-96-5 | 5 | mg/kg | 14 | 20 | 35.1 | No Limit |
| | | EG005T: Selenium | 7782-49-2 | 5 | mg/kg | <5 | <5 | 0.00 | No Limit |
| | | EG005T: Vanadium | 7440-62-2 | 5 | mg/kg | 5 | 7 | 24.4 | No Limit |
| | | EG005T: Zinc | 7440-66-6 | 5 | mg/kg | 15 | 14 | 6.87 | No Limit |
| | | EG005T: Boron | 7440-42-8 | 50 | mg/kg | <50 | <50 | 0.00 | No Limit |
| ES1619096-002 | Anonymous | EG005T: Beryllium | 7440-41-7 | 1 | mg/kg | <1 | <1 | 0.00 | No Limit |
| | | EG005T: Cadmium | 7440-43-9 | 1 | mg/kg | <1 | <1 | 0.00 | No Limit |
| | | EG005T: Barium | 7440-39-3 | 10 | mg/kg | <10 | <10 | 0.00 | No Limit |
| | | EG005T: Chromium | 7440-47-3 | 2 | mg/kg | <2 | <2 | 0.00 | No Limit |
| | | EG005T: Cobalt | 7440-48-4 | 2 | mg/kg | <2 | <2 | 0.00 | No Limit |
| | | EG005T: Nickel | 7440-02-0 | 2 | mg/kg | <2 | <2 | 0.00 | No Limit |
| | | EG005T: Arsenic | 7440-38-2 | 5 | mg/kg | <5 | <5 | 0.00 | No Limit |
| | | EG005T: Copper | 7440-50-8 | 5 | mg/kg | <5 | <5 | 0.00 | No Limit |

Sub-Matrix: **SOIL**

| Laboratory sample ID | Client sample ID | Method: Compound | CAS Number | LOR | Unit | Original Result | Duplicate Result | RPD (%) | Recovery Limits (%) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Laboratory Duplicate (DUP) Report | | | | | |
| **EG005T: Total Metals by ICP-AES (QC Lot: 567185) - continued** | | | | | | | | | |
| ES1619096-002 | Anonymous | EG005T: Lead | 7439-92-1 | 5 | mg/kg | <5 | <5 | 0.00 | No Limit |
| | | EG005T: Manganese | 7439-96-5 | 5 | mg/kg | 7 | 8 | 13.1 | No Limit |
| | | EG005T: Selenium | 7782-49-2 | 5 | mg/kg | <5 | <5 | 0.00 | No Limit |
| | | EG005T: Vanadium | 7440-62-2 | 5 | mg/kg | <5 | <5 | 0.00 | No Limit |
| | | EG005T: Zinc | 7440-66-6 | 5 | mg/kg | <5 | <5 | 0.00 | No Limit |
| | | EG005T: Boron | 7440-42-8 | 50 | mg/kg | <50 | <50 | 0.00 | No Limit |
| **EG035T: Total Recoverable Mercury by FIMS (QC Lot: 567186)** | | | | | | | | | |
| ES1618941-002 | Anonymous | EG035T: Mercury | 7439-97-6 | 0.1 | mg/kg | 0.2 | 0.2 | 0.00 | No Limit |
| ES1619096-002 | Anonymous | EG035T: Mercury | 7439-97-6 | 0.1 | mg/kg | <0.1 | <0.1 | 0.00 | No Limit |

Sub-Matrix: **WATER**

| Laboratory sample ID | Client sample ID | Method: Compound | CAS Number | LOR | Unit | Original Result | Duplicate Result | RPD (%) | Recovery Limits (%) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Laboratory Duplicate (DUP) Report | | | | | |
| **EG020W: Water Leachable Metals by ICP-MS (QC Lot: 569454)** | | | | | | | | | |
| ES1618999-001 | WASTE ROCK TIPPLE | EG020A-W: Cadmium | 7440-43-9 | 0.0001 | mg/L | 0.0002 | 0.0002 | 0.00 | No Limit |
| | | EG020A-W: Arsenic | 7440-38-2 | 0.001 | mg/L | 0.002 | 0.002 | 0.00 | No Limit |
| | | EG020A-W: Chromium | 7440-47-3 | 0.001 | mg/L | 0.004 | 0.003 | 0.00 | No Limit |
| | | EG020A-W: Copper | 7440-50-8 | 0.001 | mg/L | 0.008 | 0.008 | 0.00 | No Limit |
| | | EG020A-W: Lead | 7439-92-1 | 0.001 | mg/L | 0.054 | 0.055 | 0.00 | 0% - 20% |
| | | EG020A-W: Nickel | 7440-02-0 | 0.001 | mg/L | 0.002 | 0.001 | 0.00 | No Limit |
| | | EG020A-W: Zinc | 7440-66-6 | 0.005 | mg/L | 0.121 | 0.123 | 2.08 | 0% - 20% |
| | | EG020A-W: Aluminium | 7429-90-5 | 0.01 | mg/L | 3.76 | 3.51 | 6.97 | 0% - 20% |
| | | EG020A-W: Selenium | 7782-49-2 | 0.01 | mg/L | <0.01 | <0.01 | 0.00 | No Limit |
| | | EG020A-W: Iron | 7439-89-6 | 0.05 | mg/L | 1.74 | 1.84 | 5.70 | 0% - 20% |
| ES1619038-019 | Anonymous | EG020A-W: Cadmium | 7440-43-9 | 0.0001 | mg/L | <0.0001 | <0.0001 | 0.00 | No Limit |
| | | EG020A-W: Arsenic | 7440-38-2 | 0.001 | mg/L | 0.002 | 0.003 | 0.00 | No Limit |
| | | EG020A-W: Chromium | 7440-47-3 | 0.001 | mg/L | 0.003 | 0.003 | 0.00 | No Limit |
| | | EG020A-W: Copper | 7440-50-8 | 0.001 | mg/L | 0.074 | 0.076 | 3.04 | 0% - 20% |
| | | EG020A-W: Lead | 7439-92-1 | 0.001 | mg/L | 2.19 | 2.17 | 1.09 | 0% - 20% |
| | | EG020A-W: Nickel | 7440-02-0 | 0.001 | mg/L | <0.001 | <0.001 | 0.00 | No Limit |
| | | EG020A-W: Zinc | 7440-66-6 | 0.005 | mg/L | 0.037 | 0.037 | 0.00 | No Limit |
| | | EG020A-W: Aluminium | 7429-90-5 | 0.01 | mg/L | 1.84 | 1.92 | 4.20 | 0% - 20% |
| | | EG020A-W: Selenium | 7782-49-2 | 0.01 | mg/L | <0.01 | <0.01 | 0.00 | No Limit |
| | | EG020A-W: Iron | 7439-89-6 | 0.05 | mg/L | 1.94 | 1.86 | 4.24 | 0% - 20% |
| **EG035W: Water Leachable Mercury by FIMS (QC Lot: 569492)** | | | | | | | | | |
| ES1618999-001 | WASTE ROCK TIPPLE | EG035W: Mercury | 7439-97-6 | 0.0001 | mg/L | <0.0001 | <0.0001 | 0.00 | No Limit |

## Method Blank (MB) and Laboratory Control Spike (LCS) Report

The quality control term Method / Laboratory Blank refers to an analyte free matrix to which all reagents are added in the same volumes or proportions as used in standard sample preparation. The purpose of this QC parameter is to monitor potential laboratory contamination. The quality control term Laboratory Control Spike (LCS) refers to a certified reference material, or a known interference free matrix spiked with target analytes. The purpose of this QC parameter is to monitor method precision and accuracy independent of sample matrix. Dynamic Recovery Limits are based on statistical evaluation of processed LCS.

Sub-Matrix: **SOIL**

| | | | | Method Blank (MB) Report | Laboratory Control Spike (LCS) Report | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Spike | Spike Recovery (%) | Recovery Limits (%) | |
| Method: Compound | CAS Number | LOR | Unit | Result | Concentration | LCS | Low | High |
| **EG005T: Total Metals by ICP-AES (QCLot: 567185)** | | | | | | | | |
| EG005T: Arsenic | 7440-38-2 | 5 | mg/kg | <5 | 21.7 mg/kg | 100 | 86 | 126 |
| EG005T: Barium | 7440-39-3 | 10 | mg/kg | <10 | 143 mg/kg | 97.9 | 85 | 115 |
| EG005T: Beryllium | 7440-41-7 | 1 | mg/kg | <1 | 5.63 mg/kg | 111 | 90 | 112628 |
| EG005T: Boron | 7440-42-8 | 50 | mg/kg | <50 | ---- | ---- | ---- | ---- |
| EG005T: Cadmium | 7440-43-9 | 1 | mg/kg | <1 | 4.64 mg/kg | 99.2 | 83 | 113 |
| EG005T: Chromium | 7440-47-3 | 2 | mg/kg | <2 | 43.9 mg/kg | 88.9 | 76 | 128 |
| EG005T: Cobalt | 7440-48-4 | 2 | mg/kg | <2 | 16 mg/kg | 102 | 88 | 120 |
| EG005T: Copper | 7440-50-8 | 5 | mg/kg | <5 | 32 mg/kg | 108 | 86 | 120 |
| EG005T: Lead | 7439-92-1 | 5 | mg/kg | <5 | 40 mg/kg | 96.4 | 80 | 114 |
| EG005T: Manganese | 7439-96-5 | 5 | mg/kg | <5 | 130 mg/kg | 97.4 | 85 | 117 |
| EG005T: Nickel | 7440-02-0 | 2 | mg/kg | <2 | 55 mg/kg | 99.7 | 87 | 123 |
| EG005T: Selenium | 7782-49-2 | 5 | mg/kg | <5 | 5.37 mg/kg | 103 | 75 | 131 |
| EG005T: Vanadium | 7440-62-2 | 5 | mg/kg | <5 | 29.6 mg/kg | 106 | 92 | 122 |
| EG005T: Zinc | 7440-66-6 | 5 | mg/kg | <5 | 60.8 mg/kg | 108 | 80 | 122 |
| **EG035T: Total Recoverable Mercury by FIMS (QCLot: 567186)** | | | | | | | | |
| EG035T: Mercury | 7439-97-6 | 0.1 | mg/kg | <0.1 | 2.57 mg/kg | 87.2 | 70 | 105 |

Sub-Matrix: **WATER**

| | | | | Method Blank (MB) Report | Laboratory Control Spike (LCS) Report | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Spike | Spike Recovery (%) | Recovery Limits (%) | |
| Method: Compound | CAS Number | LOR | Unit | Result | Concentration | LCS | Low | High |
| **EG020W: Water Leachable Metals by ICP-MS (QCLot: 569454)** | | | | | | | | |
| EG020A-W: Aluminium | 7429-90-5 | 0.01 | mg/L | <0.01 | 0.5 mg/L | 101 | 81 | 121 |
| EG020A-W: Arsenic | 7440-38-2 | 0.001 | mg/L | <0.001 | 0.1 mg/L | 104 | 79 | 119 |
| EG020A-W: Cadmium | 7440-43-9 | 0.0001 | mg/L | <0.0001 | 0.1 mg/L | 102 | 84 | 108 |
| EG020A-W: Chromium | 7440-47-3 | 0.001 | mg/L | <0.001 | 0.1 mg/L | 97.6 | 84 | 114 |
| EG020A-W: Copper | 7440-50-8 | 0.001 | mg/L | <0.001 | 0.1 mg/L | 104 | 81 | 117 |
| EG020A-W: Lead | 7439-92-1 | 0.001 | mg/L | <0.001 | 0.1 mg/L | 102 | 83 | 115 |
| EG020A-W: Nickel | 7440-02-0 | 0.001 | mg/L | <0.001 | 0.1 mg/L | 98.2 | 80 | 116 |
| EG020A-W: Selenium | 7782-49-2 | 0.01 | mg/L | <0.01 | 0.1 mg/L | 96.6 | 74 | 122 |
| EG020A-W: Zinc | 7440-66-6 | 0.005 | mg/L | <0.005 | 0.1 mg/L | 96.7 | 80 | 114 |
| EG020A-W: Iron | 7439-89-6 | 0.05 | mg/L | <0.05 | 0.5 mg/L | 97.8 | 83 | 117 |
| **EG035W: Water Leachable Mercury by FIMS (QCLot: 569492)** | | | | | | | | |
| EG035W: Mercury | 7439-97-6 | 0.0001 | mg/L | <0.0001 | 0.01 mg/L | 87.5 | 82 | 106 |

## Matrix Spike (MS) Report

The quality control term Matrix Spike (MS) refers to an intralaboratory split sample spiked with a representative set of target analytes. The purpose of this QC parameter is to monitor potential matrix effects on analyte recoveries. Static Recovery Limits as per laboratory Data Quality Objectives (DQOs). Ideal recovery ranges stated may be waived in the event of sample matrix interference.

Sub-Matrix: **SOIL**

| | | | | Matrix Spike (MS) Report | | | |
|---|---|---|---|---|---|---|---|
| | | | | Spike | SpikeRecovery(%) | Recovery Limits (%) | |
| Laboratory sample ID | Client sample ID | Method: Compound | CAS Number | Concentration | MS | Low | High |
| **EG005T: Total Metals by ICP-AES (QCLot: 567185)** | | | | | | | |
| ES1618876-012 | Anonymous | EG005T: Arsenic | 7440-38-2 | 50 mg/kg | 98.2 | 70 | 130 |
| | | EG005T: Cadmium | 7440-43-9 | 50 mg/kg | 99.0 | 70 | 130 |
| | | EG005T: Chromium | 7440-47-3 | 50 mg/kg | 90.4 | 70 | 130 |
| | | EG005T: Copper | 7440-50-8 | 250 mg/kg | 100 | 70 | 130 |
| | | EG005T: Lead | 7439-92-1 | 250 mg/kg | 94.9 | 70 | 130 |
| | | EG005T: Nickel | 7440-02-0 | 50 mg/kg | 98.0 | 70 | 130 |
| | | EG005T: Zinc | 7440-66-6 | 250 mg/kg | 99.6 | 70 | 130 |
| **EG035T: Total Recoverable Mercury by FIMS (QCLot: 567186)** | | | | | | | |
| ES1618941-002 | Anonymous | EG035T: Mercury | 7439-97-6 | 5 mg/kg | 89.9 | 70 | 130 |

Sub-Matrix: **WATER**

| | | | | Matrix Spike (MS) Report | | | |
|---|---|---|---|---|---|---|---|
| | | | | Spike | SpikeRecovery(%) | Recovery Limits (%) | |
| Laboratory sample ID | Client sample ID | Method: Compound | CAS Number | Concentration | MS | Low | High |
| **EG020W: Water Leachable Metals by ICP-MS (QCLot: 569454)** | | | | | | | |
| ES1618999-001 | WASTE ROCK TIPPLE | EG020A-W: Arsenic | 7440-38-2 | 1 mg/L | 97.6 | 70 | 130 |
| | | EG020A-W: Cadmium | 7440-43-9 | 0.25 mg/L | 97.3 | 70 | 130 |
| | | EG020A-W: Chromium | 7440-47-3 | 1 mg/L | 98.2 | 70 | 130 |
| | | EG020A-W: Copper | 7440-50-8 | 1 mg/L | 94.1 | 70 | 130 |
| | | EG020A-W: Lead | 7439-92-1 | 1 mg/L | 94.4 | 70 | 130 |
| | | EG020A-W: Nickel | 7440-02-0 | 1 mg/L | 95.3 | 70 | 130 |
| | | EG020A-W: Zinc | 7440-66-6 | 1 mg/L | 96.7 | 70 | 130 |
| **EG035W: Water Leachable Mercury by FIMS (QCLot: 569492)** | | | | | | | |
| ES1618999-004 | SPILLWAY | EG035W: Mercury | 7439-97-6 | 0.01 mg/L | 89.7 | 70 | 130 |

ALS Environmental

# QA/QC Compliance Assessment to assist with Quality Review

| | | | |
|---|---|---|---|
| **Work Order** | : **ES1618999** | Page | : 1 of 5 |
| Client | : **BROKEN HILL OPERATIONS PTY LTD** | Laboratory | : Environmental Division Sydney |
| Contact | : MR LEONARD SHARP | Telephone | : +61-2-8784 8555 |
| Project | : RASP MINE | Date Samples Received | : 26-Aug-2016 |
| Site | : ---- | Issue Date | : 02-Sep-2016 |
| Sampler | : LEONARD SHARP | No. of samples received | : 4 |
| Order number | : 37241 | No. of samples analysed | : 4 |

**This report is automatically generated by the ALS LIMS through interpretation of the ALS Quality Control Report and several Quality Assurance parameters measured by ALS. This automated reporting highlights any non-conformances, facilitates faster and more accurate data validation and is designed to assist internal expert and external Auditor review. Many components of this report contribute to the overall DQO assessment and reporting for guideline compliance.**

Brief method summaries and references are also provided to assist in traceability.

## *Summary of Outliers*

### *Outliers : Quality Control Samples*

This report highlights outliers flagged in the Quality Control (QC) Report.

- **NO Method Blank value outliers occur.**
- **NO Duplicate outliers occur.**
- **NO Laboratory Control outliers occur.**
- **NO Matrix Spike outliers occur.**
- **For all regular sample matrices, NO surrogate recovery outliers occur.**

### *Outliers : Analysis Holding Time Compliance*

- **NO Analysis Holding Time Outliers exist.**

### *Outliers : Frequency of Quality Control Samples*

- **NO Quality Control Sample Frequency Outliers exist.**

## Analysis Holding Time Compliance

If samples are identified below as having been analysed or extracted outside of recommended holding times, this should be taken into consideration when interpreting results.

This report summarizes extraction / preparation and analysis times and compares each with ALS recommended holding times (referencing USEPA SW 846, APHA, AS and NEPM) based on the sample container provided. Dates reported represent first date of extraction or analysis and preclude subsequent dilutions and reruns. A listing of breaches (if any) is provided herein.

Holding time for leachate methods (e.g. TCLP) vary according to the analytes reported. Assessment compares the leach date with the shortest analyte holding time for the equivalent soil method. These are: organics 14 days, mercury 28 days & other metals 180 days. A recorded breach does not guarantee a breach for all non-volatile parameters.

Holding times for ***VOC in soils*** vary according to analytes of interest. Vinyl Chloride and Styrene holding time is 7 days; others 14 days. A recorded breach does not guarantee a breach for all VOC analytes and should be verified in case the reported breach is a false positive or Vinyl Chloride and Styrene are not key analytes of interest/concern.

Matrix: **SOIL**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

| Method | Sample Date | Extraction / Preparation | | | Analysis | | |
|---|---|---|---|---|---|---|---|
| Container / Client Sample ID(s) | | Date extracted | Due for extraction | Evaluation | Date analysed | Due for analysis | Evaluation |
| **EA055: Moisture Content** | | | | | | | |
| **Snap Lock Bag (EA055-103)**<br>WASTE ROCK TIPPLE, MILL MATERIAL,<br>SPILLWAY | **25-Aug-2016** | **----** | ---- | ---- | **30-Aug-2016** | 08-Sep-2016 | ✓ |
| **EA150: Particle Sizing** | | | | | | | |
| **Snap Lock Bag (EA150H)**<br>MILL MATERIAL 2 | **25-Aug-2016** | **----** | ---- | ---- | **31-Aug-2016** | 21-Feb-2017 | ✓ |
| **EA150: Soil Classification based on Particle Size** | | | | | | | |
| **Snap Lock Bag (EA150H)**<br>MILL MATERIAL 2 | **25-Aug-2016** | **----** | ---- | ---- | **31-Aug-2016** | 21-Feb-2017 | ✓ |
| **EA152: Soil Particle Density** | | | | | | | |
| **Snap Lock Bag (EA152)**<br>MILL MATERIAL 2 | **25-Aug-2016** | **----** | ---- | ---- | **31-Aug-2016** | 21-Feb-2017 | ✓ |
| **EG005T: Total Metals by ICP-AES** | | | | | | | |
| **Snap Lock Bag (EG005T)**<br>WASTE ROCK TIPPLE, MILL MATERIAL,<br>SPILLWAY | **25-Aug-2016** | **30-Aug-2016** | 21-Feb-2017 | ✓ | **31-Aug-2016** | 21-Feb-2017 | ✓ |
| **EG035T: Total Recoverable Mercury by FIMS** | | | | | | | |
| **Snap Lock Bag (EG035T)**<br>WASTE ROCK TIPPLE, MILL MATERIAL,<br>SPILLWAY | **25-Aug-2016** | **30-Aug-2016** | 22-Sep-2016 | ✓ | **31-Aug-2016** | 22-Sep-2016 | ✓ |
| **EN60: Bottle Leaching Procedure** | | | | | | | |
| **Non-Volatile Leach: 28 day HT(e.g. Hg, CrVI) (EN60-Dla)**<br>WASTE ROCK TIPPLE, MILL MATERIAL,<br>SPILLWAY | **25-Aug-2016** | **31-Aug-2016** | 22-Sep-2016 | ✓ | **----** | ---- | ---- |

Matrix: **WATER**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

| Method | Sample Date | Extraction / Preparation | | | Analysis | | |
|---|---|---|---|---|---|---|---|
| Container / Client Sample ID(s) | | Date extracted | Due for extraction | Evaluation | Date analysed | Due for analysis | Evaluation |

Matrix: **WATER**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

| Method / Container / Client Sample ID(s) | | Sample Date | Extraction / Preparation | | | Analysis | | |
|---|---|---|---|---|---|---|---|---|
| | | | Date extracted | Due for extraction | Evaluation | Date analysed | Due for analysis | Evaluation |
| **EG020W: Water Leachable Metals by ICP-MS** | | | | | | | | |
| **Clear Plastic Bottle - Nitric Acid; Unfiltered (EG020A-W)** | | | | | | | | |
| WASTE ROCK TIPPLE, SPILLWAY | MILL MATERIAL, | **31-Aug-2016** | **01-Sep-2016** | 27-Feb-2017 | ✓ | **01-Sep-2016** | 27-Feb-2017 | ✓ |
| **EG035W: Water Leachable Mercury by FIMS** | | | | | | | | |
| **Clear Plastic Bottle - Nitric Acid; Unfiltered (EG035W)** | | | | | | | | |
| WASTE ROCK TIPPLE, SPILLWAY | MILL MATERIAL, | **31-Aug-2016** | **----** | ---- | ---- | **01-Sep-2016** | 28-Sep-2016 | ✓ |

## Quality Control Parameter Frequency Compliance

The following report summarises the frequency of laboratory QC samples analysed within the analytical lot(s) in which the submitted sample(s) was(were) processed. Actual rate should be greater than or equal to the expected rate. A listing of breaches is provided in the Summary of Outliers.

Matrix: **SOIL**

Evaluation: × = Quality Control frequency not within specification ; ✓ = Quality Control frequency within specification.

| Quality Control Sample Type | | Count | | Rate (%) | | | Quality Control Specification |
|---|---|---|---|---|---|---|---|
| *Analytical Methods* | *Method* | *QC* | *Regular* | ***Actual*** | ***Expected*** | *Evaluation* | |
| Laboratory Duplicates (DUP) | | | | | | | |
| Moisture Content | EA055-103 | 2 | 15 | **13.33** | **10.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Total Mercury by FIMS | EG035T | 2 | 18 | **11.11** | **10.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Total Metals by ICP-AES | EG005T | 2 | 20 | **10.00** | **10.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Laboratory Control Samples (LCS) | | | | | | | |
| Total Mercury by FIMS | EG035T | 1 | 18 | **5.56** | **5.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Total Metals by ICP-AES | EG005T | 1 | 20 | **5.00** | **5.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Method Blanks (MB) | | | | | | | |
| Total Mercury by FIMS | EG035T | 1 | 18 | **5.56** | **5.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Total Metals by ICP-AES | EG005T | 1 | 20 | **5.00** | **5.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Matrix Spikes (MS) | | | | | | | |
| Total Mercury by FIMS | EG035T | 1 | 18 | **5.56** | **5.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Total Metals by ICP-AES | EG005T | 1 | 20 | **5.00** | **5.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |

Matrix: **WATER**

Evaluation: × = Quality Control frequency not within specification ; ✓ = Quality Control frequency within specification.

| Quality Control Sample Type | | Count | | Rate (%) | | | Quality Control Specification |
|---|---|---|---|---|---|---|---|
| *Analytical Methods* | *Method* | *QC* | *Regular* | ***Actual*** | ***Expected*** | *Evaluation* | |
| Laboratory Duplicates (DUP) | | | | | | | |
| Water Leachable Mercury by FIMS | EG035W | 1 | 3 | **33.33** | **10.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Water Leachable Metals by ICP-MS - Suite A | EG020A-W | 2 | 20 | **10.00** | **10.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Laboratory Control Samples (LCS) | | | | | | | |
| Water Leachable Mercury by FIMS | EG035W | 1 | 3 | **33.33** | **5.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Water Leachable Metals by ICP-MS - Suite A | EG020A-W | 1 | 20 | **5.00** | **5.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Method Blanks (MB) | | | | | | | |
| Water Leachable Mercury by FIMS | EG035W | 1 | 3 | **33.33** | **5.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Water Leachable Metals by ICP-MS - Suite A | EG020A-W | 1 | 20 | **5.00** | **5.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Matrix Spikes (MS) | | | | | | | |
| Water Leachable Mercury by FIMS | EG035W | 1 | 3 | **33.33** | **5.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Water Leachable Metals by ICP-MS - Suite A | EG020A-W | 1 | 20 | **5.00** | **5.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |

## Brief Method Summaries

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the US EPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request. The following report provides brief descriptions of the analytical procedures employed for results reported in the Certificate of Analysis. Sources from which ALS methods have been developed are provided within the Method Descriptions.

| *Analytical Methods* | *Method* | *Matrix* | *Method Descriptions* |
|---|---|---|---|
| Moisture Content | EA055-103 | SOIL | In house: A gravimetric procedure based on weight loss over a 12 hour drying period at 103-105 degrees C. This method is compliant with NEPM (2013) Schedule B(3) Section 7.1 and Table 1 (14 day holding time). |
| Particle Size Analysis by Hydrometer | EA150H | SOIL | Particle Size Analysis by Hydrometer according to AS1289.3.6.3 - 2003 |
| Soil Particle Density | * EA152 | SOIL | Soil Particle Density by AS 1289.3.5.1-2006 : Methods of testing soils for engineering purposes - Soil classification tests - Determination of the soil particle density of a soil - Standard method |
| Total Metals by ICP-AES | EG005T | SOIL | In house: Referenced to APHA 3120; USEPA SW 846 - 6010. Metals are determined following an appropriate acid digestion of the soil. The ICPAES technique ionises samples in a plasma, emitting a characteristic spectrum based on metals present. Intensities at selected wavelengths are compared against those of matrix matched standards. This method is compliant with NEPM (2013) Schedule B(3) |
| Water Leachable Metals by ICP-MS - Suite A | EG020A-W | SOIL | In house: Referenced to APHA 3125; USEPA SW846 - 6020, AS 4439.3, ALS QWI-EN/EG020. The ICPMS technique utilizes a highly efficient argon plasma to ionize selected elements. Ions are then passed into a high vacuum mass spectrometer, which separates the analytes based on their distinct mass to charge ratios prior to their measurement by a discrete dynode ion detector. |
| Total Mercury by FIMS | EG035T | SOIL | In house: Referenced to AS 3550, APHA 3112 Hg - B (Flow-injection (SnCl2)(Cold Vapour generation) AAS) FIM-AAS is an automated flameless atomic absorption technique. Mercury in solids are determined following an appropriate acid digestion. Ionic mercury is reduced online to atomic mercury vapour by SnCl2 which is then purged into a heated quartz cell. Quantification is by comparing absorbance against a calibration curve. This method is compliant with NEPM (2013) Schedule B(3) |
| Water Leachable Mercury by FIMS | EG035W | SOIL | In house: Referenced to AS 3550, APHA 3112 Hg - B (Flow-injection (SnCl2)(Cold Vapour generation) AAS) FIM-AAS is an automated flameless atomic absorption technique. A bromate/bromide reagent is used to oxidise any organic mercury compounds in the TCLP solution. The ionic mercury is reduced online to atomic mercury vapour by SnCl2 which is then purged into a heated quartz cell. Quantification is by comparing absorbance against a calibration curve. This method is compliant with NEPM (2013) Schedule B(3) |

| *Preparation Methods* | *Method* | *Matrix* | *Method Descriptions* |
|---|---|---|---|
| Digestion for Total Recoverable Metals in DI Water Leachate | EN25W | SOIL | In house: Referenced to USEPA SW846-3005. Method 3005 is a Nitric/Hydrochloric acid digestion procedure used to prepare surface and ground water samples for analysis by ICPAES or ICPMS. This method is compliant with NEPM (2013) Schedule B(3) |
| Deionised Water Leach | EN60-DIa | SOIL | In house QWI-EN/60 referenced to AS4439.3 Preparation of Leachates |
| Hot Block Digest for metals in soils sediments and sludges | EN69 | SOIL | In house: Referenced to USEPA 200.2. Hot Block Acid Digestion 1.0g of sample is heated with Nitric and Hydrochloric acids, then cooled. Peroxide is added and samples heated and cooled again before being filtered and bulked to volume for analysis. Digest is appropriate for determination of selected metals in sludge, sediments, and soils. This method is compliant with NEPM (2013) Schedule B(3) (Method 202) |

# CHAIN OF CUSTODY

ALS Laboratory: please tick →

☐ADELAIDE 21 Burma Road Pooraka SA 5095 Ph 08 8359 0890 E adelaide@alsglobal.com
☐BRISBANE 32 Shand Street Stafford QLD 4053 Ph 07 3243 7222 E samples.brisbane@alsglobal.com
☐GLADSTONE 46 Callemondah Drive Clinton QLD 4680 Ph 07 7471 5600 E gladstone@alsglobal.com
☐MACKAY 78 Harbour Road Mackay QLD 4740 Ph 07 4944 0177 E mackay@alsglobal.com
☐MELBOURNE 2-4 Westall Road Springvale VIC 3171 Ph 03 8549 9600 E samples.melbourne@alsglobal.com
☐MUDGEE 27 Sydney Road Mudgee NSW 2850 Ph 02 6372 6735 E mudgee.mail@alsglobal.com
☐NEWCASTLE 5 Rose Gum Road Warabrook NSW 2304 Ph 02 4968 9433 E samples.newcastle@alsglobal.com
☐NOWRA 4/13 Geary Place North Nowra NSW 2541 Ph 024423 2063 E nowra@alsglobal.com
☐PERTH 10 Hod Way Malaga WA 6090 Ph 08 9209 7655 E samples.perth@alsglobal.com
☐SYDNEY 277-289 Woodpark Road Smithfield NSW 2164 Ph 02 8784 8555 E samples.sydney@alsglobal.com
☐TOWNSVILLE 14-15 Desma Court Bohle QLD 4818 Ph 07 4796 0600 E townsville.environmental@alsglobal.com
☐WOLLONGONG 99 Kenny Street Wollongong NSW 2500 Ph 02 4225 3125 E portkembla@alsglobal.com

| | | |
|---|---|---|
| CLIENT: Broken Hill Operations (ALS shortcode: BROHIL) | TURNAROUND REQUIREMENTS : (Standard TAT may be longer for some tests e.g Ultra Trace Organics) | ☑ Standard TAT (List due date): ☐ Non Standard or urgent TAT (List due date): |
| OFFICE: PO BOX 5073, BROKEN HILL NSW 2880 | | |
| PROJECT: RASP MINE | ALS QUOTE NO.: SY/127/13 | COC SEQUENCE NUMBER (Circle) |
| ORDER NUMBER: 41541 | Waste rock samples | COC: 1 2 3 4 5 6 7 |
| PROJECT MANAGER: Leonard Sharp | CONTACT PH: (08) 8088 9111 | OF: 1 2 3 4 5 6 7 |
| SAMPLER: L.Sharp | SAMPLER MOBILE: 0414 347 125 | |
| COC emailed to ALS? ( YES / NO) | EDD FORMAT (or default): | |
| Email Reports to (will default to PM if no other addresses are listed): leonardsharp@cbhresources.com.au | | |
| Email Invoice to (will default to PM if no other addresses are listed): travisbow@cbhresources.com.au | | |

| RELINQUISHED BY: | RECEIVED BY: | RELINQUISHED BY: | RECEIVED BY: |
|---|---|---|---|
| Len Sharp | FADI | | |
| DATE/TIME: 15/09/16 4.00pm | DATE/TIME: 10/09/16 12:30 | DATE/TIME: | DATE/TIME: |

COMMENTS/SPECIAL HANDLING/STORAGE OR DISPOSAL:

ANALYSIS REQUIRED including SUITES (NB. Suite Codes must be listed to attract suite price) Where Metals are required, specify Total (unfiltered bottle required) or Dissolved (field filtered bottle required)

| LAB ID | SAMPLE ID | DATE / TIME | MATRIX | TYPE & PRESERVATIVE (refer to codes below) | TOTAL CONTAINERS | S-3 | Jaw crush | Size fractioning | Moisture content | | | | | Additional Information: Comments on likely contaminant levels, dilutions, or samples requiring specific QC analysis etc. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 15/09/2016 | ~~soil~~ / rock | 10L bucket | 1 | X | X | X | X | | | | | possible high Pb and Zn |
| 2 | 2 | 15/09/2016 | ~~soil~~ / rock | 10L bucket | 1 | X | X | X | X | | | | | possible high Pb and Zn |
| 3 | 3 | 15/09/2016 | ~~soil~~ / rock | 10L bucket | 1 | X | X | X | X | | | | | possible high Pb and Zn |
| 4 | 4 | 15/09/2016 | ~~soil~~ / rock | 10L bucket | 1 | X | X | X | X | | | | | possible high Pb and Zn |
| 5 | 5 | 15/09/2016 | ~~soil~~ / rock | 10L bucket | 1 | X | X | X | X | | | | | possible high Pb and Zn |
| | | | | TOTAL | 5 | | | | | | | | | |

please ensure moisture content is measured before crushing sample

~~Turnaround~~ ASAP will accept surcharge

Environmental Division
Sydney
Work Order Reference
ES1622679

Telephone : + 61-2-8784 8555

Subcon / Forward Lab / Split WO
Lab / Analysis: Orange: crushing
Organised By / Date: ____________
Relinquished By / Date: ____________
Connote / Courier: ____________
WO No: ES1622679
Attach By PO / Internal Sheet: ______

Water Container Codes: P = Unpreserved Plastic; N = Nitric Preserved Plastic; ORC = Nitric Preserved ORC; SH = Sodium Hydroxide/Cd Preserved; S = Sodium Hydroxide Preserved Plastic; AG = Amber Glass Unpreserved; AP - Airfreight Unpreserved Plastic
V = VOA Vial HCl Preserved; VB = VOA Vial Sodium Bisulphate Preserved; VS = VOA Vial Sulfuric Preserved; AV = Airfreight Unpreserved Vial SG = Sulfuric Preserved Amber Glass; H = HCl preserved Plastic; HS = HCl preserved Speciation bottle; SP = Sulfuric Preserved Plastic; F = Formaldehyde Preserved Glass;
Z = Zinc Acetate Preserved Bottle; E = EDTA Preserved Bottles; ST = Sterile Bottle; ASS = Plastic Bag for Acid Sulphate Soils; B = Unpreserved Bag.

# CERTIFICATE OF ANALYSIS

| | | | |
|---|---|---|---|
| **Work Order** | : **ES1622679** | Page | : 1 of 2 |
| Client | : **BROKEN HILL OPERATIONS PTY LTD** | Laboratory | : Environmental Division Sydney |
| Contact | : MR LEONARD SHARP | Contact | : |
| Address | : PO BOX 5073<br>BROKEN HILL NSW 2880 | Address | : 277-289 Woodpark Road Smithfield NSW Australia 2164 |
| Telephone | : +61 08 8088 9104 | Telephone | : +61-2-8784 8555 |
| Project | : RASP MINE | Date Samples Received | : 10-Oct-2016 12:30 |
| Order number | : 41541 | Date Analysis Commenced | : 14-Oct-2016 |
| C-O-C number | : ---- | Issue Date | : 18-Oct-2016 14:38 |
| Sampler | : LEONARD SHARP | | |
| Site | : ---- | | |
| Quote number | : ---- | | |
| No. of samples received | : 5 | | |
| No. of samples analysed | : 5 | | |

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* |
|---|---|---|
| Edwandy Fadjar | Organic Coordinator | Sydney Inorganics, Smithfield, NSW |
| RICHARD TEA | Lab technician | Sydney Inorganics, Smithfield, NSW |

## General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by 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.

## Analytical Results

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

| | | | Client sample ID | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|---|
| | | | *Client sampling date / time* | [15-Sep-2016] | [15-Sep-2016] | [15-Sep-2016] | [15-Sep-2016] | [15-Sep-2016] |
| *Compound* | *CAS Number* | *LOR* | *Unit* | **ES1622679-001** | **ES1622679-002** | **ES1622679-003** | **ES1622679-004** | **ES1622679-005** |
| | | | | Result | Result | Result | Result | Result |
| **EA055: Moisture Content** | | | | | | | | |
| **Moisture Content (dried @ 103°C)** | ---- | 1 | % | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 |
| **EG005T: Total Metals by ICP-AES** | | | | | | | | |
| **Arsenic** | 7440-38-2 | 5 | mg/kg | **9** | **241** | **34** | **26** | **75** |
| **Barium** | 7440-39-3 | 10 | mg/kg | **30** | **30** | **30** | **30** | **20** |
| **Beryllium** | 7440-41-7 | 1 | mg/kg | <1 | <1 | <1 | <1 | <1 |
| **Boron** | 7440-42-8 | 50 | mg/kg | <50 | <50 | <50 | <50 | <50 |
| **Cadmium** | 7440-43-9 | 1 | mg/kg | <1 | **5** | **57** | **4** | **17** |
| **Chromium** | 7440-47-3 | 2 | mg/kg | **22** | **13** | **10** | **20** | **17** |
| **Cobalt** | 7440-48-4 | 2 | mg/kg | **9** | **16** | **14** | **10** | **11** |
| **Copper** | 7440-50-8 | 5 | mg/kg | **15** | **55** | **240** | **45** | **141** |
| **Lead** | 7439-92-1 | 5 | mg/kg | **57** | **905** | **9010** | **684** | **3030** |
| **Manganese** | 7439-96-5 | 5 | mg/kg | **91** | **258** | **405** | **174** | **188** |
| **Nickel** | 7440-02-0 | 2 | mg/kg | **18** | **18** | **12** | **19** | **18** |
| **Selenium** | 7782-49-2 | 5 | mg/kg | <5 | <5 | <5 | <5 | <5 |
| **Vanadium** | 7440-62-2 | 5 | mg/kg | **22** | **18** | **14** | **28** | **22** |
| **Zinc** | 7440-66-6 | 5 | mg/kg | **222** | **1420** | **21500** | **973** | **4060** |
| **EG035T: Total Recoverable Mercury by FIMS** | | | | | | | | |
| **Mercury** | 7439-97-6 | 0.1 | mg/kg | <0.1 | <0.1 | **0.1** | <0.1 | <0.1 |

ALS Environmental

# QUALITY CONTROL REPORT

| | | | |
|---|---|---|---|
| **Work Order** | : **ES1622679** | Page | : 1 of 4 |
| Client | : **BROKEN HILL OPERATIONS PTY LTD** | Laboratory | : Environmental Division Sydney |
| Contact | : MR LEONARD SHARP | Contact | : |
| Address | : PO BOX 5073<br>BROKEN HILL NSW 2880 | Address | : 277-289 Woodpark Road Smithfield NSW Australia 2164 |
| Telephone | : +61 08 8088 9104 | Telephone | : +61-2-8784 8555 |
| Project | : RASP MINE | Date Samples Received | : 10-Oct-2016 |
| Order number | : 41541 | Date Analysis Commenced | : 14-Oct-2016 |
| C-O-C number | : ---- | Issue Date | : 18-Oct-2016 |
| Sampler | : LEONARD SHARP | | |
| Site | : ---- | | |
| Quote number | : ---- | | |
| No. of samples received | : 5 | | |
| No. of samples analysed | : 5 | | |

ilac-MRA NATA

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 Quality Control Report contains the following information:

- Laboratory Duplicate (DUP) Report; Relative Percentage Difference (RPD) and Acceptance Limits
- Method Blank (MB) and Laboratory Control Spike (LCS) Report; Recovery and Acceptance Limits
- Matrix Spike (MS) Report; Recovery and Acceptance Limits

## *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* |
|---|---|---|
| Edwandy Fadjar | Organic Coordinator | Sydney Inorganics, Smithfield, NSW |
| RICHARD TEA | Lab technician | Sydney Inorganics, Smithfield, NSW |

## General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by 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

Key : Anonymous = Refers to samples which are not specifically part of this work order but formed part of the QC process lot
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
RPD = Relative Percentage Difference
# = Indicates failed QC

## Laboratory Duplicate (DUP) Report

The quality control term Laboratory Duplicate refers to a randomly selected intralaboratory split. Laboratory duplicates provide information regarding method precision and sample heterogeneity. The permitted ranges for the Relative Percent Deviation (RPD) of Laboratory Duplicates are specified in ALS Method QWI-EN/38 and are dependent on the magnitude of results in comparison to the level of reporting: Result < 10 times LOR: No Limit; Result between 10 and 20 times LOR: 0% - 50%; Result > 20 times LOR: 0% - 20%.

Sub-Matrix: **SOIL**

| | | | | Laboratory Duplicate (DUP) Report | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| *Laboratory sample ID* | *Client sample ID* | *Method: Compound* | *CAS Number* | *LOR* | *Unit* | *Original Result* | *Duplicate Result* | *RPD (%)* | *Recovery Limits (%)* |
| **EA055: Moisture Content (QC Lot: 617477)** | | | | | | | | | |
| ES1622679-003 | 3 | EA055-103: Moisture Content (dried @ 103°C) | ---- | 1 | % | <1.0 | <1.0 | 0.00 | No Limit |
| **EG005T: Total Metals by ICP-AES (QC Lot: 618866)** | | | | | | | | | |
| ES1622679-001 | 1 | EG005T: Beryllium | 7440-41-7 | 1 | mg/kg | <1 | <1 | 0.00 | No Limit |
| | | EG005T: Cadmium | 7440-43-9 | 1 | mg/kg | <1 | <1 | 0.00 | No Limit |
| | | EG005T: Barium | 7440-39-3 | 10 | mg/kg | 30 | 30 | 0.00 | No Limit |
| | | EG005T: Chromium | 7440-47-3 | 2 | mg/kg | 22 | 20 | 7.61 | 0% - 50% |
| | | EG005T: Cobalt | 7440-48-4 | 2 | mg/kg | 9 | 8 | 0.00 | No Limit |
| | | EG005T: Nickel | 7440-02-0 | 2 | mg/kg | 18 | 17 | 0.00 | No Limit |
| | | EG005T: Arsenic | 7440-38-2 | 5 | mg/kg | 9 | 6 | 33.0 | No Limit |
| | | EG005T: Copper | 7440-50-8 | 5 | mg/kg | 15 | 18 | 16.5 | No Limit |
| | | EG005T: Lead | 7439-92-1 | 5 | mg/kg | 57 | 55 | 3.52 | 0% - 50% |
| | | EG005T: Manganese | 7439-96-5 | 5 | mg/kg | 91 | 88 | 3.04 | 0% - 50% |
| | | EG005T: Selenium | 7782-49-2 | 5 | mg/kg | <5 | <5 | 0.00 | No Limit |
| | | EG005T: Vanadium | 7440-62-2 | 5 | mg/kg | 22 | 22 | 0.00 | No Limit |
| | | EG005T: Zinc | 7440-66-6 | 5 | mg/kg | 222 | 205 | 8.24 | 0% - 20% |
| | | EG005T: Boron | 7440-42-8 | 50 | mg/kg | <50 | <50 | 0.00 | No Limit |
| **EG035T: Total Recoverable Mercury by FIMS (QC Lot: 618867)** | | | | | | | | | |
| ES1622679-001 | 1 | EG035T: Mercury | 7439-97-6 | 0.1 | mg/kg | <0.1 | <0.1 | 0.00 | No Limit |

## Method Blank (MB) and Laboratory Control Spike (LCS) Report

The quality control term Method / Laboratory Blank refers to an analyte free matrix to which all reagents are added in the same volumes or proportions as used in standard sample preparation. The purpose of this QC parameter is to monitor potential laboratory contamination. The quality control term Laboratory Control Spike (LCS) refers to a certified reference material, or a known interference free matrix spiked with target analytes. The purpose of this QC parameter is to monitor method precision and accuracy independent of sample matrix. Dynamic Recovery Limits are based on statistical evaluation of processed LCS.

Sub-Matrix: **SOIL**

| | | | | Method Blank (MB) Report | Laboratory Control Spike (LCS) Report | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Spike | Spike Recovery (%) | Recovery Limits (%) | |
| Method: Compound | CAS Number | LOR | Unit | Result | Concentration | LCS | Low | High |
| **EG005T: Total Metals by ICP-AES (QCLot: 618866)** | | | | | | | | |
| EG005T: Arsenic | 7440-38-2 | 5 | mg/kg | <5 | 21.7 mg/kg | 96.9 | 86 | 126 |
| EG005T: Barium | 7440-39-3 | 10 | mg/kg | <10 | 143 mg/kg | 95.0 | 85 | 115 |
| EG005T: Beryllium | 7440-41-7 | 1 | mg/kg | <1 | 5.63 mg/kg | 106 | 90 | 112628 |
| EG005T: Boron | 7440-42-8 | 50 | mg/kg | <50 | ---- | ---- | ---- | ---- |
| EG005T: Cadmium | 7440-43-9 | 1 | mg/kg | <1 | 4.64 mg/kg | 92.8 | 83 | 113 |
| EG005T: Chromium | 7440-47-3 | 2 | mg/kg | <2 | 43.9 mg/kg | 90.5 | 76 | 128 |
| EG005T: Cobalt | 7440-48-4 | 2 | mg/kg | <2 | 16 mg/kg | 99.3 | 88 | 120 |
| EG005T: Copper | 7440-50-8 | 5 | mg/kg | <5 | 32 mg/kg | 97.4 | 86 | 120 |
| EG005T: Lead | 7439-92-1 | 5 | mg/kg | <5 | 40 mg/kg | 91.5 | 80 | 114 |
| EG005T: Manganese | 7439-96-5 | 5 | mg/kg | <5 | 130 mg/kg | 95.7 | 85 | 117 |
| EG005T: Nickel | 7440-02-0 | 2 | mg/kg | <2 | 55 mg/kg | 95.8 | 87 | 123 |
| EG005T: Selenium | 7782-49-2 | 5 | mg/kg | <5 | 5.37 mg/kg | 98.2 | 75 | 131 |
| EG005T: Vanadium | 7440-62-2 | 5 | mg/kg | <5 | 29.6 mg/kg | 102 | 92 | 122 |
| EG005T: Zinc | 7440-66-6 | 5 | mg/kg | <5 | 60.8 mg/kg | 97.4 | 80 | 122 |
| **EG035T: Total Recoverable Mercury by FIMS (QCLot: 618867)** | | | | | | | | |
| EG035T: Mercury | 7439-97-6 | 0.1 | mg/kg | <0.1 | 2.57 mg/kg | 76.2 | 70 | 105 |

## Matrix Spike (MS) Report

The quality control term Matrix Spike (MS) refers to an intralaboratory split sample spiked with a representative set of target analytes. The purpose of this QC parameter is to monitor potential matrix effects on analyte recoveries. Static Recovery Limits as per laboratory Data Quality Objectives (DQOs). Ideal recovery ranges stated may be waived in the event of sample matrix interference.

Sub-Matrix: **SOIL**

| | | | | Matrix Spike (MS) Report | | | |
|---|---|---|---|---|---|---|---|
| | | | | Spike | SpikeRecovery(%) | Recovery Limits (%) | |
| Laboratory sample ID | Client sample ID | Method: Compound | CAS Number | Concentration | MS | Low | High |
| **EG005T: Total Metals by ICP-AES (QCLot: 618866)** | | | | | | | |
| ES1622679-001 | 1 | EG005T: Arsenic | 7440-38-2 | 50 mg/kg | 97.0 | 70 | 130 |
| | | EG005T: Cadmium | 7440-43-9 | 50 mg/kg | 92.8 | 70 | 130 |
| | | EG005T: Chromium | 7440-47-3 | 50 mg/kg | 90.7 | 70 | 130 |
| | | EG005T: Copper | 7440-50-8 | 250 mg/kg | 93.1 | 70 | 130 |
| | | EG005T: Lead | 7439-92-1 | 250 mg/kg | 97.4 | 70 | 130 |
| | | EG005T: Nickel | 7440-02-0 | 50 mg/kg | 91.5 | 70 | 130 |
| | | EG005T: Zinc | 7440-66-6 | 250 mg/kg | 103 | 70 | 130 |
| **EG035T: Total Recoverable Mercury by FIMS (QCLot: 618867)** | | | | | | | |
| ES1622679-001 | 1 | EG035T: Mercury | 7439-97-6 | 5 mg/kg | 71.6 | 70 | 130 |

# QA/QC Compliance Assessment to assist with Quality Review

| | | | |
|---|---|---|---|
| **Work Order** | : **ES1622679** | Page | : 1 of 4 |
| Client | : **BROKEN HILL OPERATIONS PTY LTD** | Laboratory | : Environmental Division Sydney |
| Contact | : MR LEONARD SHARP | Telephone | : +61-2-8784 8555 |
| Project | : RASP MINE | Date Samples Received | : 10-Oct-2016 |
| Site | : ---- | Issue Date | : 18-Oct-2016 |
| Sampler | : LEONARD SHARP | No. of samples received | : 5 |
| Order number | : 41541 | No. of samples analysed | : 5 |

**This report is automatically generated by the ALS LIMS through interpretation of the ALS Quality Control Report and several Quality Assurance parameters measured by ALS. This automated reporting highlights any non-conformances, facilitates faster and more accurate data validation and is designed to assist internal expert and external Auditor review. Many components of this report contribute to the overall DQO assessment and reporting for guideline compliance.**

Brief method summaries and references are also provided to assist in traceability.

## *Summary of Outliers*

### *Outliers : Quality Control Samples*

This report highlights outliers flagged in the Quality Control (QC) Report.

- **NO Method Blank value outliers occur.**
- **NO Duplicate outliers occur.**
- **NO Laboratory Control outliers occur.**
- **NO Matrix Spike outliers occur.**
- **For all regular sample matrices, NO surrogate recovery outliers occur.**

### *Outliers : Analysis Holding Time Compliance*

- **Analysis Holding Time Outliers exist - please see following pages for full details.**

### *Outliers : Frequency of Quality Control Samples*

- **NO Quality Control Sample Frequency Outliers exist.**

## Outliers : Analysis Holding Time Compliance

Matrix: **SOIL**

| Method / Container / Client Sample ID(s) | | Extraction / Preparation: Date extracted | Due for extraction | Days overdue | Analysis: Date analysed | Due for analysis | Days overdue |
|---|---|---|---|---|---|---|---|
| **EA055: Moisture Content** | | | | | | | |
| **Plastic bucket** | | | | | | | |
| 1, | 2, | ---- | ---- | ---- | 14-Oct-2016 | 29-Sep-2016 | **15** |
| 3, | 4, | | | | | | |
| 5 | | | | | | | |
| **EG035T: Total Recoverable Mercury by FIMS** | | | | | | | |
| **Plastic bucket** | | | | | | | |
| 1, | 2, | 17-Oct-2016 | 13-Oct-2016 | **4** | 17-Oct-2016 | 13-Oct-2016 | **4** |
| 3, | 4, | | | | | | |
| 5 | | | | | | | |

## Analysis Holding Time Compliance

If samples are identified below as having been analysed or extracted outside of recommended holding times, this should be taken into consideration when interpreting results.

This report summarizes extraction / preparation and analysis times and compares each with ALS recommended holding times (referencing USEPA SW 846, APHA, AS and NEPM) based on the sample container provided. Dates reported represent first date of extraction or analysis and preclude subsequent dilutions and reruns. A listing of breaches (if any) is provided herein.

Holding time for leachate methods (e.g. TCLP) vary according to the analytes reported. Assessment compares the leach date with the shortest analyte holding time for the equivalent soil method. These are: organics 14 days, mercury 28 days & other metals 180 days. A recorded breach does not guarantee a breach for all non-volatile parameters.

Holding times for ***VOC in soils*** vary according to analytes of interest. Vinyl Chloride and Styrene holding time is 7 days; others 14 days. A recorded breach does not guarantee a breach for all VOC analytes and should be verified in case the reported breach is a false positive or Vinyl Chloride and Styrene are not key analytes of interest/concern.

Matrix: **SOIL**

Evaluation: ✘ = Holding time breach ; ✓ = Within holding time.

| Method / Container / Client Sample ID(s) | | Sample Date | Extraction / Preparation: Date extracted | Due for extraction | Evaluation | Analysis: Date analysed | Due for analysis | Evaluation |
|---|---|---|---|---|---|---|---|---|
| **EA055: Moisture Content** | | | | | | | | |
| **Plastic bucket (EA055-103)** | | | | | | | | |
| 1, | 2, | **15-Sep-2016** | **----** | ---- | ---- | **14-Oct-2016** | 29-Sep-2016 | ✘ |
| 3, | 4, | | | | | | | |
| 5 | | | | | | | | |
| **EG005T: Total Metals by ICP-AES** | | | | | | | | |
| **Plastic bucket (EG005T)** | | | | | | | | |
| 1, | 2, | **15-Sep-2016** | **17-Oct-2016** | 14-Mar-2017 | ✓ | **17-Oct-2016** | 14-Mar-2017 | ✓ |
| 3, | 4, | | | | | | | |
| 5 | | | | | | | | |
| **EG035T: Total Recoverable Mercury by FIMS** | | | | | | | | |
| **Plastic bucket (EG035T)** | | | | | | | | |
| 1, | 2, | **15-Sep-2016** | **17-Oct-2016** | 13-Oct-2016 | ✘ | **17-Oct-2016** | 13-Oct-2016 | ✘ |
| 3, | 4, | | | | | | | |
| 5 | | | | | | | | |

## Quality Control Parameter Frequency Compliance

The following report summarises the frequency of laboratory QC samples analysed within the analytical lot(s) in which the submitted sample(s) was(were) processed. Actual rate should be greater than or equal to the expected rate. A listing of breaches is provided in the Summary of Outliers.

Matrix: **SOIL**

Evaluation: × = Quality Control frequency not within specification ; ✓ = Quality Control frequency within specification.

| Quality Control Sample Type | | Count | | Rate (%) | | | Quality Control Specification |
|---|---|---|---|---|---|---|---|
| *Analytical Methods* | *Method* | *QC* | *Regular* | ***Actual*** | ***Expected*** | *Evaluation* | |
| Laboratory Duplicates (DUP) | | | | | | | |
| Moisture Content | EA055-103 | 1 | 5 | **20.00** | **10.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Total Mercury by FIMS | EG035T | 1 | 5 | **20.00** | **10.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Total Metals by ICP-AES | EG005T | 1 | 7 | **14.29** | **10.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Laboratory Control Samples (LCS) | | | | | | | |
| Total Mercury by FIMS | EG035T | 1 | 5 | **20.00** | **5.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Total Metals by ICP-AES | EG005T | 1 | 7 | **14.29** | **5.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Method Blanks (MB) | | | | | | | |
| Total Mercury by FIMS | EG035T | 1 | 5 | **20.00** | **5.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Total Metals by ICP-AES | EG005T | 1 | 7 | **14.29** | **5.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Matrix Spikes (MS) | | | | | | | |
| Total Mercury by FIMS | EG035T | 1 | 5 | **20.00** | **5.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |
| Total Metals by ICP-AES | EG005T | 1 | 7 | **14.29** | **5.00** | ✓ | NEPM 2013 B3 & ALS QC Standard |

## Brief Method Summaries

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the US EPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request. The following report provides brief descriptions of the analytical procedures employed for results reported in the Certificate of Analysis. Sources from which ALS methods have been developed are provided within the Method Descriptions.

| *Analytical Methods* | *Method* | *Matrix* | *Method Descriptions* |
|---|---|---|---|
| Moisture Content | EA055-103 | SOIL | In house: A gravimetric procedure based on weight loss over a 12 hour drying period at 103-105 degrees C. This method is compliant with NEPM (2013) Schedule B(3) Section 7.1 and Table 1 (14 day holding time). |
| Total Metals by ICP-AES | EG005T | SOIL | In house: Referenced to APHA 3120; USEPA SW 846 - 6010. Metals are determined following an appropriate acid digestion of the soil. The ICPAES technique ionises samples in a plasma, emitting a characteristic spectrum based on metals present. Intensities at selected wavelengths are compared against those of matrix matched standards. This method is compliant with NEPM (2013) Schedule B(3) |
| Total Mercury by FIMS | EG035T | SOIL | In house: Referenced to AS 3550, APHA 3112 Hg - B (Flow-injection (SnCl2)(Cold Vapour generation) AAS) FIM-AAS is an automated flameless atomic absorption technique. Mercury in solids are determined following an appropriate acid digestion. Ionic mercury is reduced online to atomic mercury vapour by SnCl2 which is then purged into a heated quartz cell. Quantification is by comparing absorbance against a calibration curve. This method is compliant with NEPM (2013) Schedule B(3) |

| *Preparation Methods* | *Method* | *Matrix* | *Method Descriptions* |
|---|---|---|---|
| Hot Block Digest for metals in soils sediments and sludges | EN69 | SOIL | In house: Referenced to USEPA 200.2. Hot Block Acid Digestion 1.0g of sample is heated with Nitric and Hydrochloric acids, then cooled. Peroxide is added and samples heated and cooled again before being filtered and bulked to volume for analysis. Digest is appropriate for determination of selected metals in sludge, sediments, and soils. This method is compliant with NEPM (2013) Schedule B(3) (Method 202) |

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# Aggregate/Soil Test Report

Report No: SYD1601652
Issue No: 1
*This report replaces all previous issues of report no 'SYD1601652'.*

Client:
Broken Hill Operations Pty Ltd
130 Eyre Street
Broken Hill NSW 2880

Project: 2125880

Accredited for compliance with ISO / IEC 17025

NATA Accredited Laboratory Number: 679

Approved Signatory: D.P Brooke (Sydney Laboratory Manager)

Date of Issue: 5/10/2016



## Sample Details

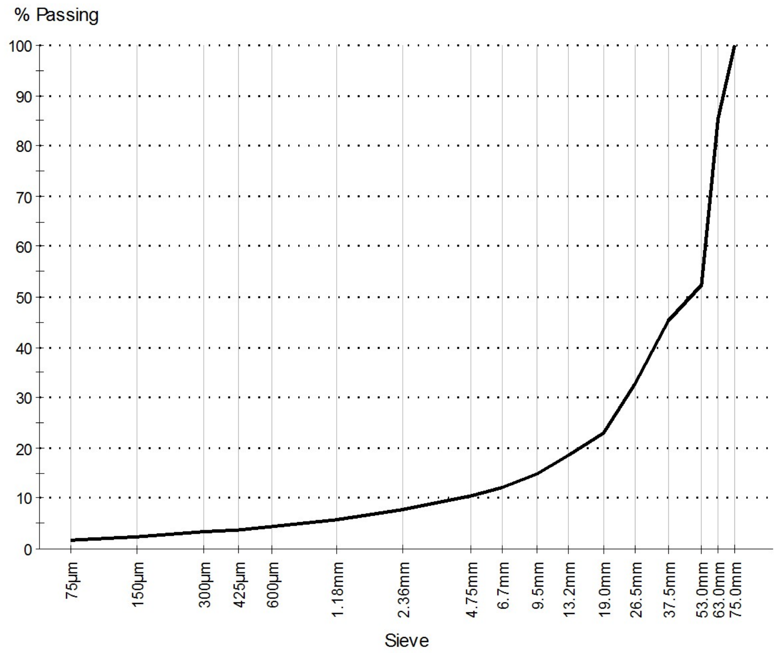
| | |
|---|---|
| GHD Sample No | SYD16-0360-01 |
| Client Sample ID | 1 |
| Date Sampled | 22/09/2016 |
| Sampled By | Supplied by Client |
| Location | CBH Resources Rasp Mine |

## Other Test Results

| Description | Method | Result | Limits |
|---|---|---|---|

## Particle Size Distribution

Method: AS 1289.3.6.1
Drying by: Oven
Date Tested: 29/09/2016
Note: Sample Washed




| Sieve Size | % Passing | Limits |
|---|---|---|
| 75.0mm | 100 | |
| 63.0mm | 85 | |
| 53.0mm | 52 | |
| 37.5mm | 45 | |
| 26.5mm | 33 | |
| 19.0mm | 23 | |
| 13.2mm | 18 | |
| 9.5mm | 15 | |
| 6.7mm | 12 | |
| 4.75mm | 10 | |
| 2.36mm | 8 | |
| 1.18mm | 6 | |
| 600µm | 4 | |
| 425µm | 4 | |
| 300µm | 3 | |
| 150µm | 2 | |
| 75µm | 2 | |

## Comments

N/A

Sydney Laboratory
57 Herbert St
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# Aggregate/Soil Test Report

Report No: SYD1601653
Issue No: 1
This report replaces all previous issues of report no 'SYD1601653'.

Client:
Broken Hill Operations Pty Ltd
130 Eyre Street
Broken Hill NSW 2880

Project: 2125880

Accredited for compliance with ISO / IEC 17025

NATA Accredited Laboratory Number: 679

Approved Signatory: D.P Brooke (Sydney Laboratory Manager)

Date of Issue: 5/10/2016

THIS DOCUMENT SHALL NOT BE REPRODUCED EXCEPT IN FULL

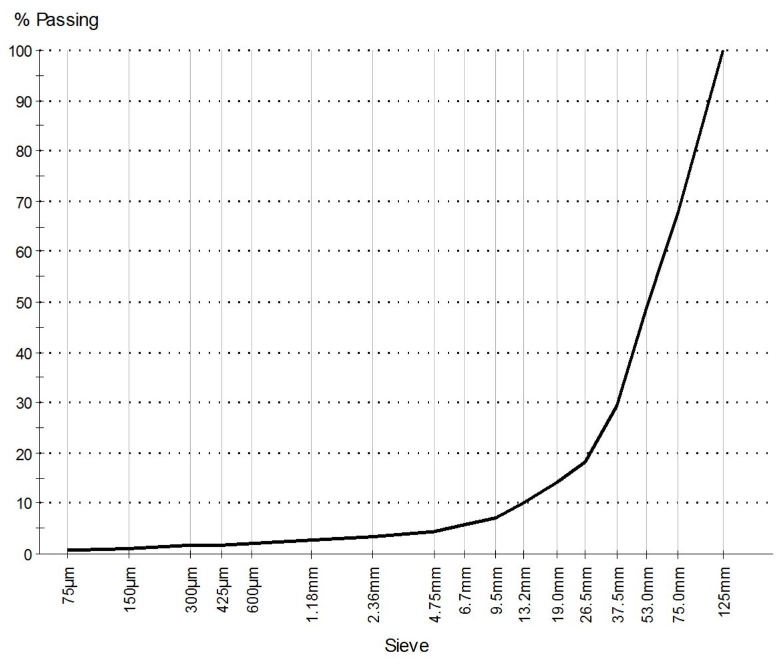
## Sample Details

| | |
|---|---|
| GHD Sample No | SYD16-0360-02 |
| Client Sample ID | Sample 2 |
| Date Sampled | 22/09/2016 |
| Sampled By | Supplied by Client |
| Location | CBH Resources Rasp Mine |

## Other Test Results

| Description | Method | Result | Limits |
|---|---|---|---|

## Particle Size Distribution




Method: AS 1289.3.6.1
Drying by: Oven
Date Tested: 29/09/2016
Note: Sample Washed

| Sieve Size | % Passing | Limits |
|---|---|---|
| 125mm | 100 | |
| 75.0mm | 68 | |
| 53.0mm | 49 | |
| 37.5mm | 30 | |
| 26.5mm | 18 | |
| 19.0mm | 14 | |
| 13.2mm | 10 | |
| 9.5mm | 7 | |
| 6.7mm | 6 | |
| 4.75mm | 4 | |
| 2.36mm | 3 | |
| 1.18mm | 3 | |
| 600µm | 2 | |
| 425µm | 2 | |
| 300µm | 2 | |
| 150µm | 1 | |
| 75µm | 1 | |

## Comments

N/A

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# Aggregate/Soil Test Report

Report No: SYD1601654
Issue No: 1
This report replaces all previous issues of report no 'SYD1601654'.

Client:
Broken Hill Operations Pty Ltd
130 Eyre Street
Broken Hill NSW 2880

Project: 2125880

Accredited for compliance with ISO / IEC 17025

NATA Accredited Laboratory Number: 679

Approved Signatory: D.P Brooke (Sydney Laboratory Manager)

Date of Issue: 5/10/2016



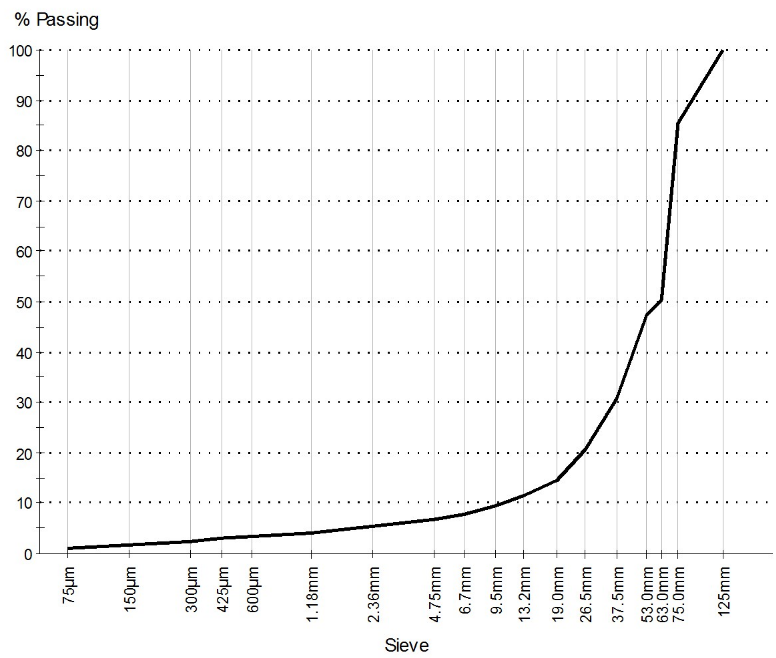
## Sample Details

| | |
|---|---|
| GHD Sample No | SYD16-0360-03 |
| Client Sample ID | Sample 3 |
| Date Sampled | 22/09/2016 |
| Sampled By | Supplied by Client |
| Location | CBH Resources Rasp Mine |

## Other Test Results

| Description | Method | Result | Limits |
|---|---|---|---|

## Particle Size Distribution




Method: AS 1289.3.6.1
Drying by: Oven
Date Tested: 29/09/2016
Note: Sample Washed

| Sieve Size | % Passing | Limits |
|---|---|---|
| 125mm | 100 | |
| 75.0mm | 85 | |
| 63.0mm | 50 | |
| 53.0mm | 47 | |
| 37.5mm | 31 | |
| 26.5mm | 21 | |
| 19.0mm | 15 | |
| 13.2mm | 12 | |
| 9.5mm | 9 | |
| 6.7mm | 8 | |
| 4.75mm | 7 | |
| 2.36mm | 5 | |
| 1.18mm | 4 | |
| 600µm | 3 | |
| 425µm | 3 | |
| 300µm | 2 | |
| 150µm | 2 | |
| 75µm | 1 | |

## Comments

N/A

Sydney Laboratory
57 Herbert St
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# Aggregate/Soil Test Report

Report No: SYD1601655
Issue No: 1
This report replaces all previous issues of report no 'SYD1601655'.

Client:
Broken Hill Operations Pty Ltd
130 Eyre Street
Broken Hill NSW 2880

Project: 2125880

Accredited for compliance with ISO / IEC 17025

NATA Accredited Laboratory Number: 679

Approved Signatory: D.P Brooke (Sydney Laboratory Manager)

Date of Issue: 5/10/2016

THIS DOCUMENT SHALL NOT BE REPRODUCED EXCEPT IN FULL

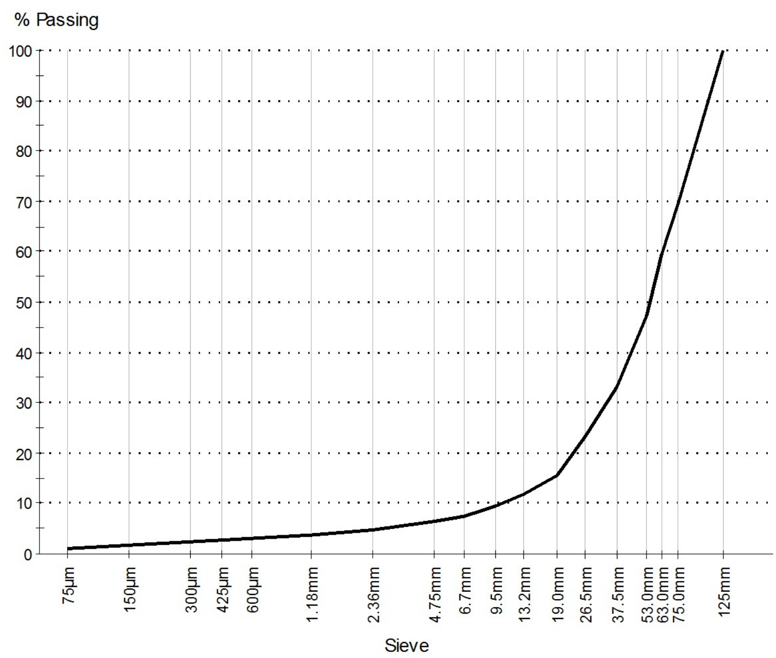
## Sample Details

| | |
|---|---|
| GHD Sample No | SYD16-0360-04 |
| Client Sample ID | Sample 4 |
| Date Sampled | 22/09/2016 |
| Sampled By | Supplied by Client |
| Location | CBH Resources Rasp Mine |

## Other Test Results

| Description | Method | Result | Limits |
|---|---|---|---|

## Particle Size Distribution




Method: AS 1289.3.6.1
Drying by: Oven
Date Tested: 29/09/2016
Note: Sample Washed

| Sieve Size | % Passing | Limits |
|---|---|---|
| 125mm | 100 | |
| 75.0mm | 70 | |
| 63.0mm | 60 | |
| 53.0mm | 47 | |
| 37.5mm | 33 | |
| 26.5mm | 23 | |
| 19.0mm | 16 | |
| 13.2mm | 12 | |
| 9.5mm | 9 | |
| 6.7mm | 7 | |
| 4.75mm | 6 | |
| 2.36mm | 5 | |
| 1.18mm | 4 | |
| 600µm | 3 | |
| 425µm | 3 | |
| 300µm | 2 | |
| 150µm | 2 | |
| 75µm | 1 | |

## Comments

N/A

Sydney Laboratory
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# Aggregate/Soil Test Report

Report No: SYD1601656
Issue No: 1
This report replaces all previous issues of report no 'SYD1601656'.

Accredited for compliance with ISO / IEC 17025

NATA Accredited Laboratory Number: 679

Approved Signatory: D.P Brooke (Sydney Laboratory Manager)

Date of Issue: 5/10/2016

THIS DOCUMENT SHALL NOT BE REPRODUCED EXCEPT IN FULL

Client:
Broken Hill Operations Pty Ltd
130 Eyre Street
Broken Hill NSW 2880

Project: 2125880

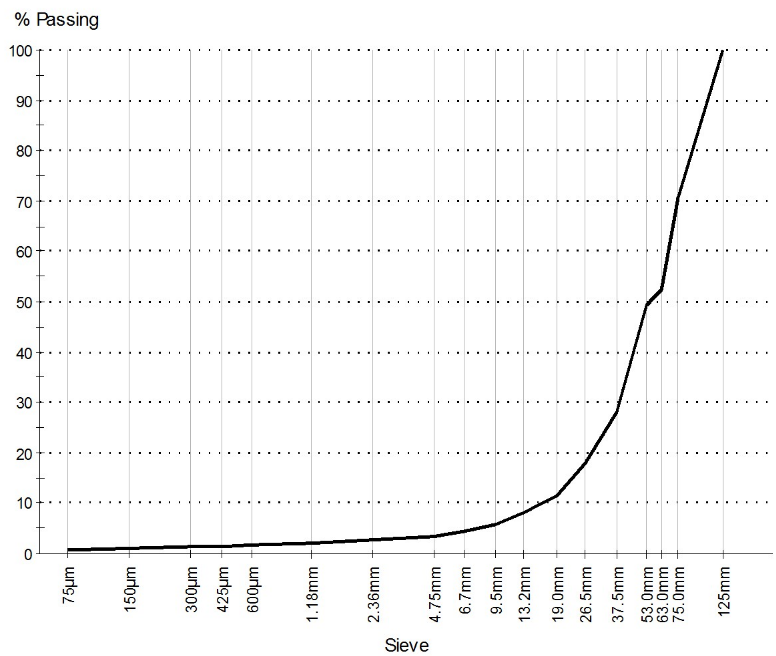
## Sample Details

| | |
|---|---|
| GHD Sample No | SYD16-0360-05 |
| Client Sample ID | Sample 5 |
| Date Sampled | 22/09/2016 |
| Sampled By | Supplied by Client |
| Location | CBH Resources Rasp Mine |

## Other Test Results

| Description | Method | Result | Limits |
|---|---|---|---|

## Particle Size Distribution




Method: AS 1289.3.6.1
Drying by: Oven
Date Tested: 29/09/2016
Note: Sample Washed

| Sieve Size | % Passing | Limits |
|---|---|---|
| 125mm | 100 | |
| 75.0mm | 71 | |
| 63.0mm | 52 | |
| 53.0mm | 49 | |
| 37.5mm | 28 | |
| 26.5mm | 18 | |
| 19.0mm | 11 | |
| 13.2mm | 8 | |
| 9.5mm | 6 | |
| 6.7mm | 4 | |
| 4.75mm | 4 | |
| 2.36mm | 3 | |
| 1.18mm | 2 | |
| 600µm | 2 | |
| 425µm | 1 | |
| 300µm | 1 | |
| 150µm | 1 | |
| 75µm | 1 | |

## Comments

N/A

# Appendix C - Photographic Log

Photo 1: Part of the waste rock stockpile showing hard hat for rock size reference

Photo 2: Another area of the waste rock stockpile with hard hat for rock size reference

Photo 3: View of Kintore pit waste rock stockpile from west

Photo 4: Closer view of waste rock stockpile

Photo 5: Flat area on top of waste rock stockpile, mine vehicle for size reference

Photo 6: View from top of waste rock stockpile looking north at far wall of Kintore pit

| | |
|---|---|
|  |  |
| Photo 7: Close up view of waste rock material, note: large degree of variation in sizes | Photo 8: Close up view of another area of the waste rock stockpile, note: size variation |