APPENDIX V: WASTE ASSESSMENT STUDY

MELMOTH IRON ORE PROJECT WASTE ROCK WASTE ASSESSMENT AND GEOCHEMICAL CHARACTERISATION STUDY

Jindal Melmoth

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EXECUTIVE SUMMARY

The proposed Melmoth Iron Ore project mining site is located 25 km southeast of Melmoth, within the Mthonjaneni Local Municipality in the KwaZulu-Natal Province. In January 2021, Jindal Iron Ore (Pty) Ltd appointed SLR Consulting South Africa (Pty) Ltd (SLR) as the independent environmental assessment practitioner (EAP) to undertake a new environmental and social impact assessment (ESIA), public participation process (PP) and prepare all documentation for a mining right application (MRA). As part of the many specialist investigations for the Melmoth Iron Ore project MRA and Environmental Impact Assessment (EIA) Scoping report, a geochemistry study was undertaken to assess the risks for Acid Rock Drainage (ARD) and Metal Leaching Potential (MLP) and classify the Melmoth waste rock materials to determine the proposed waste rock dump (WRD) facility liner requirements and ultimately inform mine site design and closure planning.

Thirty-two exploration core samples were collected and made up into six composites that represent the main Melmoth waste rock (WR) lithologies and subjected to comprehensive suite of geochemical analysis.

The WR samples are dominated by Quartz, Biotite and Plagioclase, with major to minor Actinolite, Grunerite, Microcline and various clay minerals. According to the NEMWA GN R. 635 and 636 of 2013, all the WR lithologies are assessed to be Type 3 waste that require incorporation into a waste facility that has a Class C liner or similar constructed barrier.

Acid Based Accounting (ABA) and Net Acid Generation (NAG) tests assessed the Melmoth WR materials to all be non-PAG. The SPLP results returned minor Aluminium (J-QMS), Iron (J-MDOL and J-QMS) and Manganese (J-QTVN) exceedances of SANS 241: Operations and Aesthetic guidelines. The modelled source terms for the individual WR lithologies and WRD predicts no leachate constituents of concern (CoCs).

On assessment of WR geochemical results, we can conclude that the Melmoth WR materials present a low risk for ARD and MLP to the surrounding environment and downstream receptors.

Notwithstanding the report's findings, SLR would like to make the following recommendations:

- Results of the geochemical modelling of the effluent mix should not be evaluated in isolation but together with numerical or reactive groundwater modelling risk assessment. The complete source, pathway and receptor should be considered when evaluating the overall potential risks to groundwater.
- Once the mine is operational and the WR is reporting to the WRD, regular testing of the exposed WR material should be undertaken to document changes in its geochemical characterisation, most especially when operations transition into different stratigraphies. If the geochemistry is found to be evolving significantly, the groundwater model should be updated with the new source terms.
- To regularly document the performance of the WRD and its liner, an extensive network of monitoring boreholes should be put in place to monitor change in the groundwater chemistry in the vicinity of the facility.

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ACRONYMS AND ABBREVIATIONS

Acronym / Abbreviation	Definition
ABA	Acid Base Accounting
AMP	Amphibolite
AP	Acid Potential
AQMcS	Amphibole-Quartz-Mica Schist
ARD	Acid Rock Drainage
BIF	Banded Iron Formation
BPG	Best Practice Guidelines
CBE	Charge Balance Equilibrium
CoC	Constituents of Concern
DMR EDTEA	Department of Economic Development, Tourism and Environmental Affairs
DWS	Department of Water and Sanitation
EAP	Environmental Application Practitioner
EPA	Environmental Protection Agency
ESIA	Environmental and Social Impact Assessment
I&APs	Interested and Affected Parties
IFC	International Finance Corporation Guidelines for Mining Effluents
LC	Leachable Concentrations
LCT	Leachable Concentrations Threshold
MDOL	Meta-Dolerite
MLP	Metal Leaching Potential
MRA	Mining Right Application
Mtpa	Million tonnes per annum
NAG	Net Acid Generation
NEMWA	National Environmental Management: Waste Act
NNP	Net Neutralisation Potential
Non-PAG	Non-Potentially Acid Generating
NP	Neutralisation Potential
NPR	Neutralising Potential Ratio
PAG	Potentially Acid Generating
PHREEQC	pH, Redox, Equilibrium Code

Acronym / Abbreviation	Definition
PP	Public Participation
QAG	Quartz-amphibolite gneiss
QMS	Quartz-Mica Schist
QTVN	Quartz Vein
QTZT	Quartzite
ROM	Run of Mine
SANS 241	South African National Standards 241 Drinking Water
SLR	SLR Consulting South Africa
SNPR	Sulphur Neutralisation Potential Ratio
SPLP	Synthetic Precipitation Leaching Procedure
TC	Total Concentrations
TCT	Total Concentrations Threshold
TNPR	Total Neutralisation Potential Ratio
TSF	Tailings Storage Facility
WA	Waste Assessment
WR	Waste Rock
WRD	Waste Rock Dump
WHO, 2017	World Health Organisation Guidelines for drinking water quality
XRD	X-Ray Diffraction

Melmoth Iron ore Waste Rock Waste Assessment and Geochemical Characterisation Study

1. INTRODUCTION

The Melmoth Iron Ore Project (the Project) site is located 25 km southeast of Melmoth, within the Mthonjaneni Local Municipality in the KwaZulu-Natal Province. Jindal Iron Ore (Pty) Ltd (Jindal), is owned by Jindal Steel and Power (Mauritius) Limited (74%) and South African BEE partner Mr. Thabang Khomo (Pty) Ltd (26%). Jindal holds two Prospecting Rights over the project site. The prospecting rights are referred to as North Block (PR 10644) and South Block (PR 10652) and have a total combined area of 20 170 ha.

The areas of interest contain banded iron formations (BIF) and were investigated by Premier Zululand Zinc in 1908 followed by Union Carbide Prospecting SA in 1969 and Iscor (Pty) Ltd in the 1980's. The investigations indicated that iron ore was present as magnetite, a magnetically recoverable mineral of high iron content, and as amphibole grunerite, a mineral of low iron content that is not recoverable. These early investigations did not result in project development because the magnetite content was too low to compete with the more attractive hematite iron mineralisation in the Northern Cape and the prevailing iron ore price could not support feasible mining of the magnetite BIF.

The iron ore price started increasing in 2007 generating renewed interest in iron ore in the Melmoth district. In 2011 Sungu Sungu (Pty) Ltd, (later renamed to Jindal Iron Ore (Pty) Ltd.) was issued prospecting rights for the two concessions which are the subject of this report.

In 2013 Jindal appointed Golder Associates Africa (Pty) Ltd. (Golder) as the independent Environmental Assessment Practitioner (EAP) responsible for managing the Environment and Social Impact Assessment (ESIA) and the supporting Public Participation (PP) process. Golder submitted a Final Scoping Report to the Department of Economic Development, Tourism and Environmental Affairs (DMR EDTEA) under both Jindal Iron Ore (for the mining ESIA) and Jindal Processing KZN (for the Processing Plant ESIA) in March 2015. In June 2015 both Scoping Reports (mining and processing) were returned to Jindal with comments from the EDTEA requesting more clarity on various aspects of the project, company structure and further engagement with Interested and Affected Parties (I&APs).

In the interim the iron ore price declined from a high of $130 per tonne in January 2014 to a low of $47 per tonne in December 2015. The decline in the iron ore and steel prices worldwide resulted in reduced funding from Jindal for the project and it was not possible to complete an amended Scoping Report. In 2019 through 2020 the iron ore price steadily recovered and the first quarter of 2021 averaged $160 per tonne. The improved iron ore price has encouraged Jindal to increase the rate of development of the Melmoth Iron Ore Project. In January 2021 Jindal appointed SLR Consulting South Africa (SLR) as the independent EAP to undertake a new ESIA and public participation process and prepare all documentation for a Mining Right Application (MRA). Jindal has also appointed consultants to produce a Bankable Feasibility Study for the envisioned Melmoth Iron Ore Mine.

As part of the many specialist investigations for the Melmoth Iron Ore MRA and EIA Scoping Report, a specialist geochemistry study was undertaken to assess the Acid Rock Drainage (ARD) and Metal Leaching Potential (MLP) risk and classify the waste rock (WR) materials to determine the waste rock dump (WRD) facility liner requirements which will inform mine site design and closure planning.

2. OBJECTIVE AND SCOPE OF WORK

The main objective of this report is to produce a waste assessment and geochemical characterisation specialist study of the proposed waste rock materials to assess their risk for ARD and MLP. The scope of work includes:

- Desktop study to delineate baseline conditions, data gaps and understanding of the proposed mining processes,
- Using the knowledge gained from the desktop study to formulate a sampling protocol,
- Analyse waste rock composite samples for a suite of geochemical indicators to include:
  - Sample preparation
  - Total concentrations on solids – NEMWA GN R. 635
  - Leachate concentrations on solids – NEMWA GN R. 635
  - Acid based accounting (ABA), Net acid generation (NAG), S and C speciation and Paste pH
  - X-Ray Diffraction (XRD) Minerology
  - Synthetic Precipitation Leachate Procedure (SPLP) and ICP metal and major ion analysis for source terms,
- Waste assessment,
- Source term modelling, and
- Reporting.

3. BACKGROUND

3.1 SITE LOCATION AND TOPOGRAPHY

The proposed Melmoth mining site falls within a Greenfields zone which is classed as rural with a mixture of formal and informal agricultural land use. The topography of the area is determined by the type of bedrock underlying the soils, the geology of the area and the dissection of the streams flowing in the area. Melmoth is 800m above sea level and is surrounded by low sandstone mountains and mudstone valleys. The regional geology of the area has given rise to a considerable diversity of relief, from gently rolling slopes to hilly and severely incised slopes found along drainage ways and stream valleys. This topography gives the area its aesthetic appeal and also makes it conducive for agricultural practises. The soils are formed from weathering of regional quartzites, tillites and granite rocks and vary considerably in texture from stony / sandy to clay loams with a topsoil ranging in depth from 0 - 300 mm. (Golder, 2013).

3.2 GEOLOGY

The regional geology has been discussed in detail in the Golder (2015) report, herewith summarized to include information relevant to this study.

The study area lies within the Ilangwe Greenstone Belt, which is separated from various granitoids to the north and south by major tectonic contacts (Mathe, 1997). The rocks of Ilangwe Greenstone Belt belong to the Nondweni Group, which is divided into the lower Umhlathuze Subgroup (a suite of mafic-ultramafic meta-volcanic rocks) and upper Nkandla Subgroup, a meta-sedimentary suite. Both units host BIF, which is the iron ore resource at Melmoth.

The greenstone sequence is strongly deformed and was subjected to at least three major deformation events. This resulted in intense transpositional layering, complex folding and shearing, thrusting and structural repetition of greenstone lithologies (Mathe, 1997). The repetition of lithologies is evident from exploration borehole logging data. Quartz veins and dolerite dykes of Karoo age intruded the granite-greenstone sequence in the area (Figure 3-1).

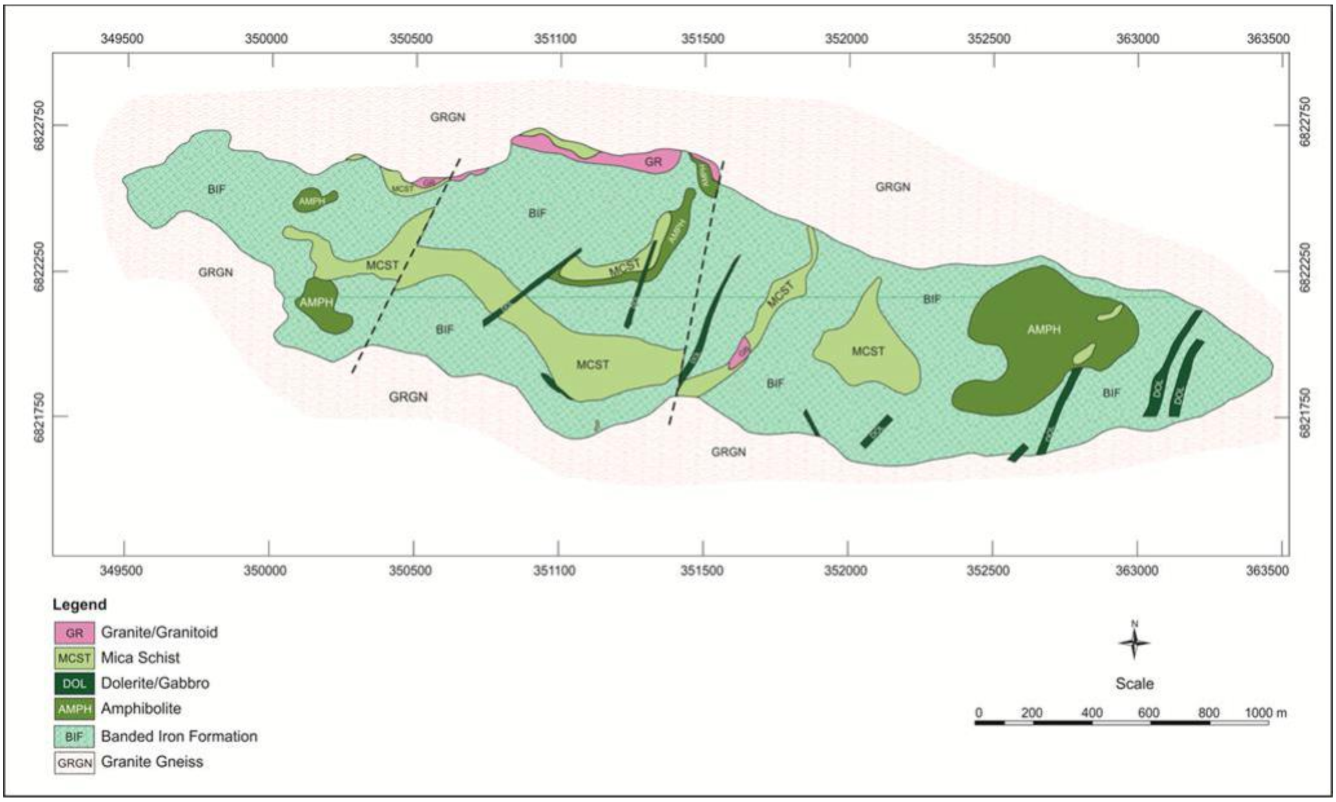

Figure 3-1: Surface Geology of the SE Block (adapted from Jindal 2014)

The mineralisation is hosted in the Matshansundu Formation of the Umhlatuze Subgroup and Entembeni Formation of the Nkandla Subgroup (Jindal, 2014). The ore body occurs as BIF, which consists of alternating bands (on a millimetre scale) of magnetite and cherty quartz. Hematite and minor K-feldspar, stilpnomelane, grunerite and chlorite are also present. The mineralogical composition of the amphibolite, which is associated with the BIF includes actinolite and tremolite; minor hornblende and plagioclase; varying amounts of quartz; and rare cordierite, pyroxene, biotite and garnet. Alteration minerals include hematite, talc, chlorite, sericite, epidote and calcite. Pyrite is also present in the ore and associated rocks in small amounts as fracture infill, disseminations and nodules. The mineralisation is considered to be most likely of an Algoma-type deposit due to its association with an Archaean greenstone belt metavolcanics (Mathe, 1997).

3.3 CLIMATE

The project area region is typified by a sub-tropical climate with warm, very humid, wet summers and moderately cold and dry winters. The average annual temperature in the Mthonjaneni Municipality is 16°C. On average, the town of Melmoth receives approximately 838mm of rain per year. Most of the rain falls during summer months from November to March and the highest rainfall is usually recorded in January and February. The lowest rainfall is received in the winter season with about 10mm of rain recorded in July. The average mid-day temperatures for Melmoth range from 20.3˚C in June to 26.5˚C in January. Melmoth is coldest in June when the temperatures drop below 7˚C during the night.

3.4 HYDROLOGY

There are no major water bodies in and around Melmoth. However, the Mfulezane or 'small Mfule' river runs through Melmoth and there are several seasonal streams in the surrounding area. Ntunja River flows through the North Block and Kwamazula River runs through the South Block. Mhlathuze river, which runs along the southern boundary of the South Block, and the White Mfolozi rivers are also found in the greater Mthonjaneni Municipality.

To the southeast of the South Block is Goedertrou Dam, a 1 194ha dam constructed on the Mhlathuze River in 1980 with a capacity of 304 000 000 m³. Water quality studies conducted in the Mhlathuze Catchment from 1998 - 2002 found that water quality in the catchment was consistently within the recommended limits specified in the South African Water Quality Guidelines. The quality of water in local area rivers is generally affected by increased nutrients from both commercial forestry and the farming of sugarcane, sediment runoff, seasonally reduced flow volumes, and increased pressure from rural domestic users.

There is no specific geohydrology data available for the project area as there has been very little groundwater testing or monitoring in the area. The regional groundwater is suggested to have a medium to low or very low level of vulnerability to contamination (DWS / CPH Water, 2002).

4. METHODOLOGY

4.1 SAMPLING

A SLR representative visited the Melmoth core store in Melmoth on 20 October 2022 to collect a selection of WR samples which represent the six main waste rock lithologies (Table 4-1). Thirty-two (32) core samples were sampled from a variety of exploration cores and core depths located within the proposed Melmoth pit outline (Figure 4-1 and Table 4-2) and combined into six composite samples for testing. Estimates of the WR unit proportions, that will report to the proposed WRD during mining operations, was supplied by Jindal.

Table 4-1: Melmoth waste rock lithologies and estimated WRD proportions

Sl.No.	Lithocode	Revised Name	Mineral Assemblages (In increasing order)	Estimated WRD proportions (%)
3	MDOL	Meta-dolerite	Plagioclase + Amphibole	2
4	QTZT	Quartzite	Quartz ± Mica ± Chlorite	2
5	QMS	Quatz-Mica Schist	Quartz + Mica ± Garnet	4
6	AQMcS	Amphibole-Quartz-Mica Schist	Amphibole + Quartz + Mica ± Plagioclase ± Garnet	55
7	AMP	Amphibolite	Chlorite + Mica + Plagioclase + Amphibole ± Quartz	35
10	QTVN	Quartz Vein	Quartz	2
			Total	100

4.2 LABORATORY TESTING

The WR samples were submitted to Waterlab (Pty) Ltd, Pretoria, South Africa for the following comprehensive geochemical analysis:

- Acid Base Accounting (ABA) and Paste pH,
- Sulphur and Carbon Speciation,
- Net Acid Generation (NAG),
- X-Ray Diffraction (XRD) minerology,
- Total element concentration by HNO_3:HF digestion, and
- Total leachable concentrations with deionized water.

4.2.1 Minerology: X-Ray Diffraction

Minerals are the building blocks of rocks. Mine drainage quality is generally a function of mineral dissolution (or precipitation) during interaction of rocks with water. XRD analysis identifies the main crystalline mineral phases in each sample. XRD is conducted on whole rock samples that have been crushed and ground to a powder. The powdered sample is placed on a flat holder, which faces the X-ray beam. The X-rays are diffracted by the crystal planes in the minerals, with diffraction peaks at characteristic angles. The phases are identified by comparing the locations and intensities of the diffraction peak with the peaks of mineral reference standards (Price, 2009). Limitations of XRD are that it is not easy to identify non-crystalline minerals, and minerals present in low concentrations may not be detected.

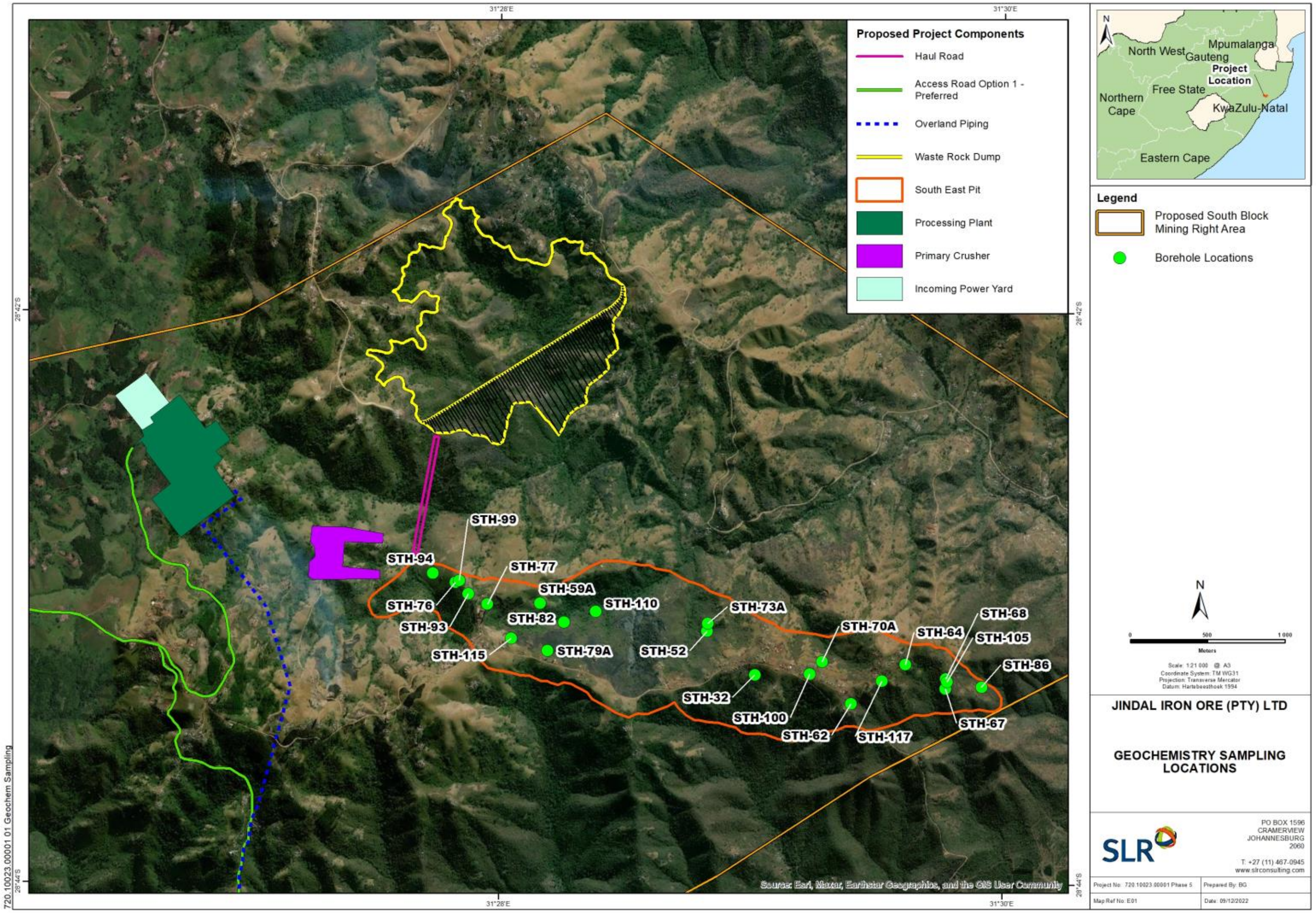

Figure 4-1: Melmoth exploration core locations from which WR lithology samples were collected

Table 4-2: Melmoth WR lithology sampled from exploration cores

Sample ID	BH ID	Easting	Northing	Depth (m)
J-AMP-01	STH-67	353128.22	6821896.32	29.53 -32.13
J-AMP-02	STH-77	350158.171	6822397.38	47.46 - 51.46
J-AMP-03	STH-52	351582.001	6822243.23	142.99 - 145.99
J-AMP-04	STH-93	350032.182	6822459.67	8.47 - 14.47
J-AMP-05	STH-52	351582.001	6822243.23	47.79 -50.39
J-AMP-06	STH-62	352519.045	6821790.91	164.08 - 166.08
J-AMP-07	STH-94	352519.045	6821790.91	38.90 -39.90
J-AQMcS-01	STH-62	352519.045	352519.045	171.48 - 175.08
J-AQMcS-02	STH-64	352866.763	6822049.75	43.34 -47.14
J-AQMcS-03	STH-73A	351585.792	6822295.96	137.34 - 139.77
J-AQMcS-04	STH-79A	350550.737	6822101	156.33 -158.55
J-AQMcS-05	STH-93	350032.182	6822459.67	502.30 -505.76
J-AQMcS-06	STH-115	350315.659	6822176.01	74.80 -75.60
J-AQMcS-07	STH-117	352715.99	6821940.9	19.85 -22.85
J-MDOL-01	STH-62	352519.045	6821790.91	159.28 -161.88
J-MDOL-02	STH-59A	350499.625	6822407.49	414.19 -416.11
J-MDOL-03	STH-73A	351585.792	6822295.96	21.69 -22.49
J-MDOL-04	STH-105	353138.89	6821941.75	822.45 -824.80
J-MDOL-05	STH-117	352715.99	6821940.9	123.90 -125.05
J-MDOL-06	STH-100	352249.69	6821978.78	394.00 -397.00
J-MDOL-07	STH-105	353138.89	6821941.75	21.69 -22.49
J-QTVN-01	STH-76	349950.291	6822535.19	437.01 - 437.90
J-QTVN-02	STH-110	350859.814	6822360.1	247.80 -248.80
J-QTVN-03	STH-79A	350550.737	6822101	184.42 -185.25
J-QTVN-04	STH-99	349972.79	6822545.81	218.07 -218.60
J-QTVN-05	STH-70A	352329.851	6822059.85	238.18 - 239.18
J-QTVN-06	STH-68	353129.841	6821959.35	75.21 - 76.41
J-QTVN-07	STH-86	353362.014	6821910.71	222.16 -222.96
J-QMS-01	STH-82	350656.192	6822287.68	45.43 - 46.63
J-QMS-02	STH-86	353362.014	6821910.71	200.16 - 204.96
J-QMS-03	STH-86	353362.014	6821910.71	475.36 - 476.76
J-QTZT-01	STH-32	351895.06	6821966.9	485.0 - 485.60

4.2.2 Waste Assessment

The objective is underpinned by the legal provisions of the National Environmental Management: Waste Act (NEMWA) 59 of 2008 which prescribes the following in terms of waste streams:

- Undertake a waste type assessment in terms of GN R. 635 (23 August 2013); and
- Determine the liner requirements as per GN R. 636. (23 August 2013).

The South African waste classification regulations provide norms and standards for assessing/classifying (GN Regulation 635) waste material. Although the Norms and Standards refer to landfills, the definition of waste in South Africa includes mine residues such as tailings and waste rock and therefore the norms and standards apply to mine residue classification. In terms of the regulations, the total concentration (TC) of chemical substances specified in Section 6 of GN R. 635 that are known to occur, likely to occur or can reasonably be expected to occur are determined. The TC of the chemical substances is compared to the total concentration threshold (TCT) limits specified in Section 6 of GN R. 635.

The leachable concentrations (LC) of the chemical substances must be determined and compared to the leachable concentration threshold (LCT) limits specified in Section 6 of GN R. 635. The TC and LC limits of elements and chemical substances in the waste material exceeding the corresponding TCT and LCT limits determine the specific waste type according to Section 7 of GN R. 635.

The waste type and related risk-based assessment approach is used to inform the potential liner requirements. Figure 4-2 illustrates the flow diagram of the general processes to be followed to determine the waste type and then associated liner requirements.

4.2.3 Acid Based Accounting and Paste pH

Acid Base Accounting (ABA) provides an industry-recognized assessment of the acid generation or acid neutralisation potential of materials. The ABA method used for the characterisation of the samples is the Modified Sobek ABA method (EPA 600), which includes both laboratory analysis and empirical calculations based on acid generating potential (AP) and neutralising potential (NP). The classification of each material in terms of its potential to generate acid is based on the criteria shown in Table 4-3.

Paste pH analysis is undertaken in conjunction with the ABA test. The test is a simple, rapid, and inexpensive screening tool that indicates the presence of readily available NP (generally from carbonate) or stored acidity and involves the placement of 'crushed' sample with distilled water at a low solid to liquid ratio (to produce a paste) and the pH measured after approximately two minutes. Paste pH values of less than 5 indicate the presence of stored acidity, whereas higher paste pH values suggest the presence of reactive neutralising minerals.

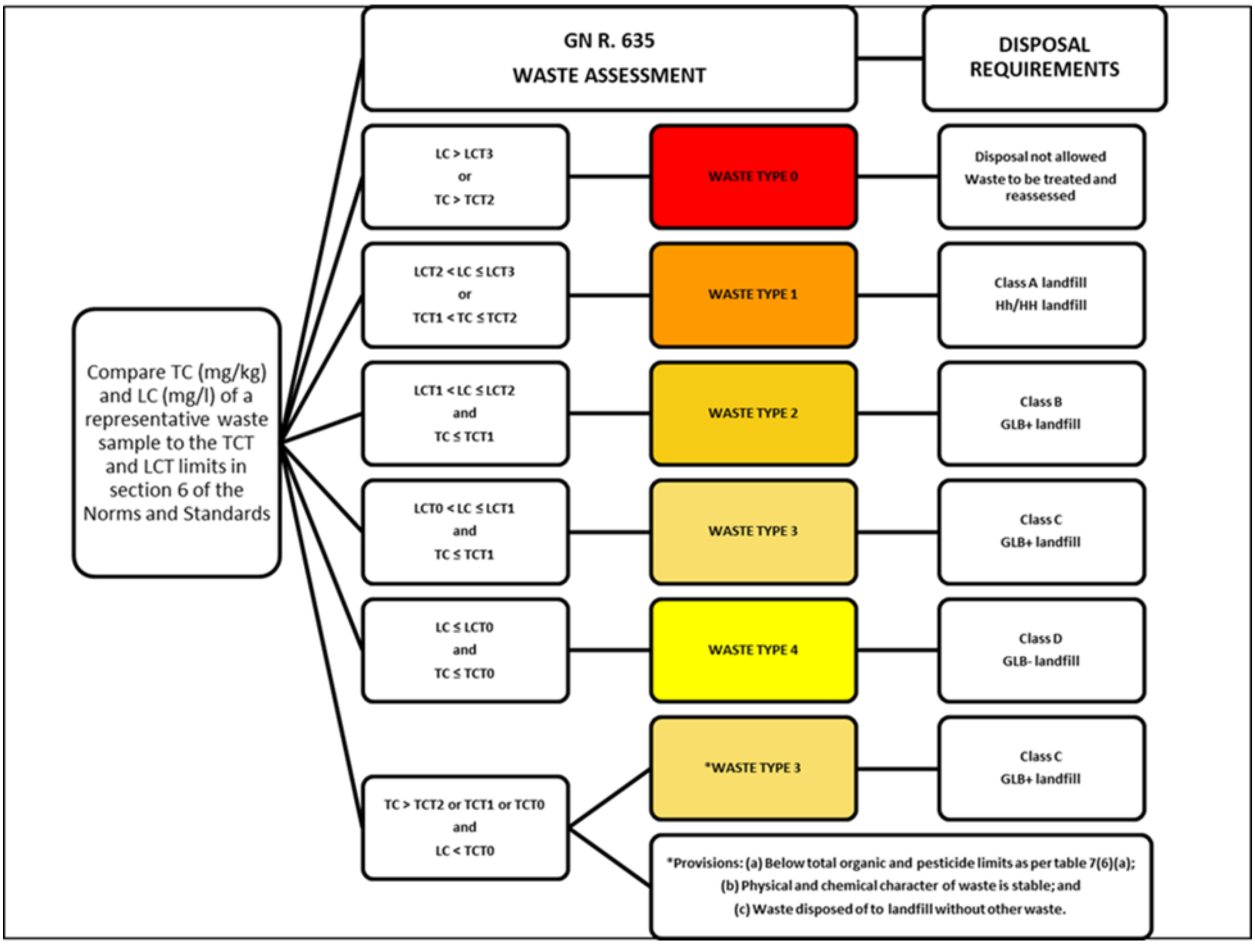

Figure 4-2: Flow Diagram for Assessing Waste in Terms of South African Waste Assessment Regulations (GN R. 635 of 2013)

The outcome of the test is governed by the surficial properties of the solid material being tested, and more particularly, the extent of soluble minerals, which may provide useful information regarding anticipated mine water quality. It represents more closely the water to solid ratio of pore waters in wastes than other analysis procedures. It should be noted that the paste pH may vary depending on the degree of weathering of the material.

Table 4-3: Acid Mine Drainage Classification

Parameter	Potentially Acid Generating (PAG)	Uncertain/Marginal	Non-Potentially Acid Generating (non-PAG)	Reference
Paste pH	<3.5	3.5 - 5.5	>5.5	Price and Errington, 1995
NNP	<-20	-20 – 20	>20	Roberson and Broughton, 1992
NPR	<1	1:1 – 2:1 = Possibly 2:1 – 4:1 = Low	>4	Price *et al.*, 1997
Sulphide %	> 0.3%	-	< 0.3%	Soregaroli and Lawrence, 1998

4.2.4 Sulphur and Carbon Speciation

The ABA tests assume that all sulphide minerals in a rock sample are acid generating. Some of the sulphur in the rock may be present in non-acid producing sulphates. If a significant part of the total sulphur occurs as sulphate sulphur instead of sulphide sulphur, the overall risk of acid generation is reduced. NAG pH can be artificially influenced by organic acids, therefore the proportion of organic carbon to total carbon in the rock samples is an important indicator of the accuracy of the NAG results.

4.2.5 Acid Potential and Neutralisation Potential

An estimate of acid generation is made by assuming complete reaction between all minerals with acid generating potential and all of the minerals with neutralising potential (essentially dissolution of carbonate minerals and to very limited extent silicate minerals as the latter have very slow reaction kinetics). The Acid NP is a measure of the total acid a material is capable of neutralising and is predominantly a result of neutralising bases, mostly carbonates and exchangeable alkali and alkali earth cations. The AP values are calculated from sulphide sulphur concentrations and reported as kilogram calcium carbonate ($CaCO_3$) per ton of rock (kg $CaCO_3$/ton).

4.2.6 Net Neutralisation Potential

The difference between the acid generating mineral phases and acid neutralising mineral phases is referred to as the net neutralisation potential (NNP). The NNP allows classification of the samples as potentially acid consuming or acid producing. The NNP is calculated by subtracting the AP from the Acid NP:

$$NNP = NP – AP$$

4.2.7 Neutralisation Potential Ratio

Acid Base Accounting data is also described using the neutralisation potential ratio (NPR). The NPR can be used to identify potentially acid producing rocks. The NPR is calculated by dividing the NP by the AP:

$$NPR = NP/AP$$

4.2.8 Net Acid Generation

Static Net Acid Generation (NAG) test work is carried out in order to determine the maximum potential for acid generation from the samples. The static NAG test differs from the ABA test in that it provides a direct empirical estimate of the overall sample reactivity, including any acid generated by semi-soluble sulphate minerals as well as potentially acid generating sulphide minerals. As such, the NAG test may provide a better estimate of field acid generation than the more widely used ABA method, which defines acid potential based solely on sulphide content independent of the site mineralogy and geology.

The guidelines used for assessing the acid generation potential based on NAG results are summarised in Table 4-4.Error! Reference source not found.

Table 4-4: Acid generation criteria for NAG results (Price, 2009)

Acid Generation Capacity	Final NAG pH
Potentially Acid Generating	<3.5
Intermediate	3.5 < pH < 5.5
Non-Potentially Acid Generating	≥5.5

4.3 SYNTHETIC PRECIPITATION LEACHING PROCEDURE

Synthetic precipitation leaching procedure (SPLP) is a quick and inexpensive method to determine:

- The mobility/leachability of low volatility organic and inorganic analytes in liquids, soils, and wastes,
- The measure of desorption of contaminants from soil (rather than adsorption),
- The possibility of leaching metals into ground and surface waters, and
- A site-specific impact to groundwater soil remediation standard.

Since the test uses custom pH levels to simulate rainfall in a particular geographic region, this test is often recommended over other methods when predicting leachate quality and risk to ground water.

Many factors can affect the leaching potential of constituents of concern (CoC): pH, redox conditions, liquid-to-solid ratio, solubility, partitioning, presence of organic carbon, and non-aqueous phase extraction. Therefore, SPLP concentrations are used as input concentrations to geochemical models to simulate realistic field conditions and produce more accurate source terms. As part of this assessment, the SPLP results and source terms were subject to preliminary screening to identify potential CoCs by comparing the results to the following relevant water quality and effluent standards:

- Department of Water and Forestry (Now Department of Water and Sanitation) livestock watering guidelines (DWAF TWQG),
- International Finance Corporation (IFC) Guidelines for Mining Effluents (IFC, 2007), and
- South African National Standards (SANS) 241 Drinking Water (SANS 241:2015).

4.4 GEOCHEMICAL SOURCE TERMS

The SPLP results will be used as input concentrations to generate leachate source terms for the site. Laboratory leachate results are only an indicator of site drainage water quality, due to the test conditions not fully representing field conditions, most especially the liquid to solid ratio and varying redox settings. PHREEQC geochemical software can be used to perform geochemical calculations to predict mineral speciation, surface complexation, ion exchange equilibria and kinetic reactions. PREEEQC includes thermodynamic databases for a wide range of inorganic parameters relevant to industrial water quality and the field conditions they are subject to. The generated geochemical source terms (predicted analyte concentrations) can then be input into a groundwater model to predict the significance and extent of contamination. A comprehensive geochemical and geohydrological assessment will assist SLR in gaining a better understanding of potential risks to better advise the client how to minimise those risks in the context of the site.

4.4.1 Model Code

This assessment applies the pH, Redox, Equilibrium Code (PHREEQC) for hydrogeochemical modelling (Parkhurst and Appelo, 2013).

PHREEQC is a versatile geochemical model initially developed in 1995 by the United States Geological Survey. It has undergone extensive use, testing and validation by third parties with version 3 released in January 2015. This assessment used version 3.4.0.12927 (released 9th November 2017). PHREEQC can perform low-temperature aqueous geochemical calculations, including speciation, saturation indices, batch reaction and 1-dimensional transport calculations. PHREEQC can account for aqueous, mineral, gas, solid solution, surface complexation and ion exchange equilibria, as well as kinetic reactions.

PHREEQC is widely used for environmental geochemical modelling because it is freely available, open source, and flexible. It includes thermodynamic databases for a wide range of inorganic parameters relevant to mine water quality.

4.4.2 Model inputs

The key model inputs are the contact water quality determined from laboratory leach tests (Appendix A). The input data concentrations were adjusted to achieve a charge balance equilibrium (CBE) < 10%. Concentrations indicated as below detection limit were entered as one-half of the detection limit or omitted where practical.
It is assumed that the sediment materials have a field moisture capacity of about 20%. The column of waste material can only generate seepage if the water content exceeds this value. No analysis was conducted to confirm this.

4.4.3 Boundary Conditions

The model boundary conditions are summarised in Table 4-5.

Table 4-5: Model boundary conditions

Boundary Conditions	Description
Gas phase	It is assumed that there is little biological activity in the material and the CO_2(g) pressure was set to $10^{-3.5}$ atm.
Minerals	Based on the mineralogical analysis the pure phase that can react reversibly with the aqueous phase is Calcite, Phlogopite, Tremolite (Actinolite), Albite or Anorthite (Plagioclase), Anthophyllite (Cummingtonite). Mineral phases to simulate only precipitation reactions were added for each sample modelled if they were over saturated in the solution.
Adsorption surface	Metal cations can sorb to charged surfaces. In this simulation no such sorption was simulated.

4.4.4 Model Algorithm

The algorithm comprised the following:

- For simulations were mixing of different solutions was required the solutions were proportioned according to the determined ratios.
- Determine pore water quality by adjusting solid-liquid ratio of the leach test to the expected ratio at field capacity. This was done by modelling the removal of water from the solution.
- Establish equilibrium composition of pore water in sediments, allowing relevant minerals to dissolve/precipitate.

4.4.5 Model Limitations

Predicting water qualities from an evaporation and settling setting, requires some assumptions and has limitations. The statistician George Box said: all models are wrong, but some models are useful (Box, 1976). This statement captures the essential truth that all model's approximate reality in that they reduce complex systems to a limited number of significant processes. How "useful" a model is depends on how closely the selected processes approximate reality.

Predicting the water qualities of complex systems demands assumptions. Even a rigorous sampling and analysis programme cannot precisely determine the physical and geochemical characteristics of the system. Nor can they precisely indicate how these characteristics may change over time.

Table 4-6 summarises the key limitations of the input data and the hydrogeochemical model used for this assessment.

Table 4-6: Model Limitations

No	Limitations	Description
1	Predicting field scale water quality from lab scale test results is an approximation	Leaching of salts and metals at the field scale is variable in time and controlled by factors not fully applied at the lab scale. Amongst others, these factors include temperature, evaporation, nature of the leaching solution, the solution to solid ratio, solution-solid contact time and particle size of the solid. The modelled quality of water due to interaction with tailings or waste is an informed estimate.
2	The geochemical database is relevant to the system being modelled	Hydrogeochemical modelling uses the inherently uncertain laboratory results and water qualities as inputs. These are processed using thermodynamic data determined in the laboratory on ideal materials and solutions. The laboratory determined constants may not be directly applicable to the materials, solutions, and chemical context of the waste material. The llnl.dat database was used for the model.
3	The modelling assumes thermodynamic equilibrium in the model system	In the field, all chemical components are subject to kinetic variation and the system might, at best be in a state of quasi equilibrium. This may suggest that attempts to simulate or predict the state of these complex systems have questionable value. However, geochemical evaluations of natural and mine waters over the last few decades have shown that the equilibrium assumption is a powerful tool that in many circumstances produces results that accurately describe the general chemistry of such waters.

No	Limitations	Description
4	Adsorption surface	Metal cations can sorb to charged surfaces. There is no data to quantify either these surfaces, or their effect on water quality. Cation sorption linked to the amount of ferrihydrite precipitating was not modelled.

Considering the uncertainties outlined above, the available information is sufficient to provide the preliminary estimated sediments seepage quality presented in this report. However, even though this report presents deterministic concentration values, these should be viewed as first-order approximations[1]. As such, the predicted concentrations in this report indicate the likely order of magnitude of concentrations.

5. GEOCHEMISTRY RESULTS AND INTERPRETATIONS

5.1 MINEROLAGY

There are six main WR lithologies present at Melmoth Iron Ore Project site, namely Meta-Dolerite (MDOL), Quartzite (QTZT), Quartz-Mica Schist (QMS), Amphibole-Quartz-Mica Schist (AQMcS), Amphibolite (AMP) and Quartz Vein (QTVN). The main minerology of each lithology is listed below (Table 5-1).

AMP: Major Quartz, Plagioclase, Biotite, Grunerite, Microcline, Actinolite and Smectite with minor Kaolinite and trace Magnetite.

AQMcS: Dominant Quartz and Biotite, major Plagioclase, Grunerite and Actinolite, with minor Microcline and Smectite, and trace Magnetite and Kaolinite.

MDOL: Dominant Plagioclase and Actinolite, major Biotite and Microcline with minor Quartz, Kaolinite and Smectite.

QTVN: Dominant Quartz with minor Plagioclase and minor Calcite.

QMS: Dominant Quartz and Plagioclase, major Biotite with minor Magnetite, Grunerite, Microcline, Actinolite, Kaolinite.

QTZT: Dominant Quartz, major Plagioclase and Microcline with minor Kaolinite, Smectite, Calcite and Muscovite.

[1] A first-order approximation is an estimated value of a quantity, often preliminary to more precise determination. Mathematically, it is a linear approximation of a polynomial function.

Table 5-1: Mineralogy of the Melmoth Iron ore WR composites samples

Analyses		Sample Identification					
		J-AMP	J-AQMcS	J-MDOL	J-QTVN	J-QMS	J-QTZT
Sample No		176214	176215	176216	176217	176218	176219
Mineral	Formula	Composition (%)					
Quartz	SiO_2	12.31	24.29	1.75	85.93	32.84	49.12
Magnetite	Fe_3O_4	0.5	0.37	0	0	1.44	0
Plagioclase	$(Na,Ca)(Si,Al)_4O_8$	10.97	12.16	23.67	12.57	39.91	28.72
Biotite	$K(Mg,Fe)_3 ((OH)_2 Al Si_3 O_{10})$	15.09	29.08	17.51	0	14.03	0
Grunerite	$Mg_2Fe_5Si_8O_{22}(OH)_2$	13.32	12.72	0	0	2.21	0
Microcline	$KAlSi_3O_8$	17.13	5.07	19.61	0	2.8	17.15
Actinolite	$Ca_2(Mg,Fe)_5Si_8O_{22}(OH)$	15.59	14.66	21.59	0	6.29	0
Kaolinite	$Al_2Si_2O_5(OH)_4$	2.56	0.59	2.57	0	0.48	0.92
Smectite	$CaMg_2AlSi_4(OH)_2 \cdot H_2O$	12.55	1.08	13.3	0	0	0.65
Calcite	$Ca(CO_3)$	0	0	0	1.5	0	2.07
Muscovite	$KAl_3Si_3O_{10}(OH)_2$	0	0	0	0	0	1.37

5.2 MELMOTH IRON ORE WASTE ROCK WASTE ASSESSMENT

5.2.1 Total and Leachable Concentrations

The waste assessment (WA) according to total and leachable concentrations for Melmoth WR composite samples is presented in Table 5-2 and Table 5-3. A summary of the waste type classification and liner requirements is presented in Table 5-4.

Based on the WA results, all six WR samples are assessed to be a Type 3 waste in terms of the total concentration and leachable concentrations. In accordance with GN R. 635 of 2013, for a waste to be Type 3 results should meet the following criteria:

- Leachable concentrations of ALL elements are below or equal to LCT0, AND
- Total concentrations of ALL elements below or equal to TCT1.

Therefore, for waste to be a Type 3, in addition to the total concentrations being below TCT1, the leachable concentrations of elements need to be "below or equal to LCT0".

Table 5-2: Melmoth Iron Ore Waste Rock total concentrations and screening

Analyses	Units	TCT0	TCT1	TCT2	J-AMP	J-AQMcS	J-MDOL	J-QTVN	J-QMS	J-QTZT
As, Arsenic	mg/kg	5.8	500	2000	74.8	8.4	8.8	8.4	34.4	3.2
B, Boron	mg/kg	150	15000	6000	95.2	<10	371.2	94.4	198.8	77.6
Ba, Barium	mg/kg	62.5	6250	25000	590.8	1077.6	718.8	48.8	1119.2	309.2
Cd, Cadmium	mg/kg	7.5	260	1040	<0.400	<0.400	<0.400	<0.400	<0.400	<0.400
Co, Cobalt	mg/kg	50	5000	20000	37.6	<10	57.6	<10	<10	<10
CrTotal, Chromium Total	mg/kg	46000	800000	N/A	431.6	534.8	251.6	144.8	283.2	417.6
Cu, Copper	mg/kg	16	19500	78000	29.6	37.2	36.0	<4.00	6.0	<4.00
Hg, Mercury	mg/kg	0.93	160	640	<0.400	<0.400	<0.400	<0.400	<0.400	<0.400
Mn, Manganese	mg/kg	1000	25000	100000	3344	4568	1956.4	567.6	1728.4	451.2
Mo, Molybdenum	mg/kg	40	1000	4000	<10	19.2	<10	<10	<10	31.2
Ni, Nickel	mg/kg	91	10600	42400	14	65.6	122	18.8	78.8	16.8
Pb, Lead	mg/kg	20	1900	7600	15.2	23.6	19.6	7.2	28.0	24.0
Sb, Antimony	mg/kg	10	75	300	0.8	0.4	0.4	0.4	0.4	<0.400
Se, Selenium	mg/kg	10	50	200	4.8	<0.400	<0.400	<0.400	<0.400	<0.400
V, Vanadium	mg/kg	150	2680	10720	104.4	<10	229.6	<10	<10	<10
Zn, Zinc	mg/kg	240	160000	640000	106.0	<10	96.0	<10	42.0	14.4
Cr(VI), Chromium (VI) Total [o]	mg/kg	6.5	500	2000	<2	<2	<2	<2	<2	<2
Total Fluoride [o]	mg/kg	100	10000	40000	3.2	15.5	4.9	64.4	17.7	13.2
Total Cyanide as CN [o]	mg/kg	14	10500	42000	<1.55	<1.55	<1.55	<1.55	<1.55	<1.55

Table 5-3: Melmoth Iron Ore Waste Rock leachable concentrations and screening

Analyses	Units	LCT0	LCT1	LCT2	LCT3	J-AMP	J-AQMcS	J-MDOL	J-QTVN	J-QMS	J-QTZT
As, Arsenic	mg/l	0.01	0.5	1	4	0.003	0.003	0.003	0.003	0.011	0.001
B, Boron	mg/l	0.5	25	50	200	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Ba, Barium	mg/l	0.7	35	70	280	0.055	<0.025	0.038	0.025	0.13	<0.025
Cd, Cadmium	mg/l	0.003	0.15	0.3	1.2	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Co, Cobalt	mg/l	0.5	25	50	200	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
CrTotal, Chromium Total	mg/l	0.1	5	10	40	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Cr(VI), Chromium (VI)	mg/l	0.05	2.5	5	20	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Cu, Copper	mg/l	2.0	100	200	800	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Hg, Mercury	mg/l	0.006	0.3	0.6	2.4	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Mn, Manganese	mg/l	0.5	25	50	200	<0.025	<0.025	<0.025	0.034	<0.025	<0.025
Mo, Molybdenum	mg/l	0.07	3.5	7	28	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Ni, Nickel	mg/l	0.07	3.5	7	28	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Pb, Lead	mg/l	0.01	0.5	1	4	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Sb, Antimony	mg/l	0.02	1.0	2	8	0.001	0.001	0.001	0.001	0.001	0.001
Se, Selenium	mg/l	0.01	0.5	1	4	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
V, Vanadium	mg/l	0.2	10	20	80	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Zn, Zinc	mg/l	5.0	250	500	2000	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Total Dissolved Solids*	mg/l	1000	12 500	25 000	100 000	38	28	28	28	28	26
Chloride as Cl	mg/l	300	15 000	30 000	120 000	<2	<2	<2	<2	<2	<2
Sulphate as SO4	mg/l	250	12 500	25 000	100 000	<2	<2	<2	<2	<2	<2
Nitrate as N	mg/l	11	550	1100	4400	<0.1	<0.1	<0.1	<0.1	<0.1	0.4
Nitrite as N	mg/l					<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Fluoride as F	mg/l	1.5	75	150	600	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Total Cyanide as CN [o]	mg/l	0.07	3.5	7	28	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07
pH	mg/l					9.1	9.3	9.3	9.2	9.4	9.2

Table 5-4: Waste type determination for Melmoth Iron Ore Waste Rock

Sample Name	Waste Type	Reason for Classification	Landfill Class
AMP	Type 3	As, Ba, Cu, Mn >TCT0, All LC < LCT0	Class C
AQMcS	Type 3	As, Ba, Cu, Mn, Pb > TCT0; All LC < LCT0	Class C
MDOL	Type 3	As, Ba, Co, Cu, Mn, Ni, V > TCT0; All LC < LCT0	Class C
QTVN	Type 3	As, Ba > TCT0; All LC < LCT0	Class C
QMS	Type 3	As, B, Ba, Mn, Pb > TCT0; As = LCT0	Class C
QTZT	Type 3	Ba, Pb > TCT0; All LC < LCT0	Class C

5.2.2 Determining Landfill Class (Liner requirements)

The Melmoth WR materials have all been classified as a Type 3 waste and therefore disposal or incorporation into a storage facility will require a Class C landfill liner or similar constructed barrier. Figure 5-1 depicts an example of a Class C liner requirement.

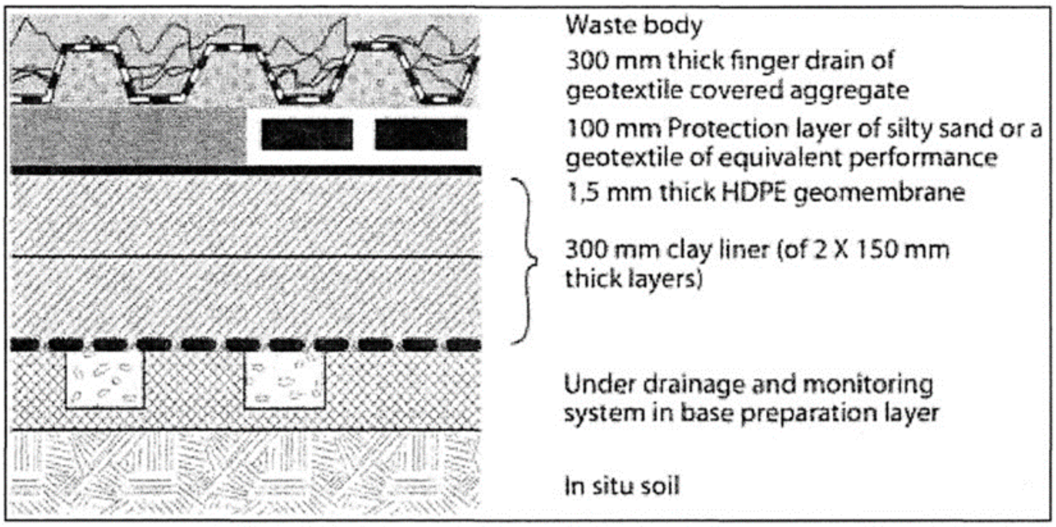

Figure 5-1: Class C landfill prescribed liner

5.3 ACID BASE ACCOUNTING AND NET ACID GENERATION

ABA, NAG, sulphur, and carbon speciation analysis was undertaken on Melmoth WR materials. The results are presented in Table 5-5 and Table 5-6 with laboratory certificates included in Appendix A. The total sulphur results returned values ranging from 0.08 to 0.17 % for the WR lithologies, with varying proportions of the total sulphur consisting of sulphides S. The total carbon proportions were reported between 0.21 and 0.39 % for the WR materials, the majority of which is inorganic carbon (> 90%).

Table 5-5: Melmoth Iron Ore WR Sulphur and Carbon speciation results

Sample Description	Lab Number	Total Sulphur	Sulphide S	Sulphate Sulphur as S	Total Carbon (LECO)[s]	Organic Carbon	Inorganic Carbon
		%	%	%	%	%	%
J-AMP	176214	0.14	0.14	<0.01	0.219	0.020	0.199
J-AQMcS	176215	0.17	0.12	0.05	0.213	0.012	0.201
J-MDOL	176216	0.11	0.08	0.03	0.257	0.007	0.25
J-QTVN	176217	0.16	0.08	0.08	0.337	0.008	0.329
J-QMS	176218	0.08	0.02	0.06	0.299	0.009	0.29
J-QTZT	176219	0.15	0.07	0.08	0.391	0.014	0.377

The paste pH recorded alkaline values for all WR samples. This is consistent with the XRD minerology results (Table 5-1) where acid generating sulphides are absent and major neutralizing minerals Plagioclase, Actinolite and Grunerite are recorded in most of the WR samples. The neutralisation potential ratio (NPR), recorded > 4 values for all WR samples, indicating they are non-potential acid generating (non-PAG) materials. The nett neutralisation potential (NNP), net acid generation (NAG) @pH 4.5 and NAG pH @ pH 7 classified all the WR samples as non-PAG materials. On the other hand, NAG @ pH 7 values fall within the intermediate ranges (0 < NAG < 10). The inconsistent ABA and NAG classifications are not uncommon when determining acid generation potential of extractive materials due to the contradictions between complex in field conditions versus laboratory test conditions.

Therefore, Geochemists often employ phase diagrams where sample data is plotted on Paste pH vs NPR charts to graphically classify otherwise inconclusive results. In the paste pH v NPR chart (Figure 5-2), all the WR lithologies are classified as Non-PAG materials.

Table 5-6: ABA and NAG results for Melmoth Iron Ore WR lithologies

Sample	Lab number	Paste pH	Total S	Sulphide Acid Potential (AP)	Neutralization Potential (NP)	Neutralisation potential ratio (NPR)	Nett Neutralization Potential (NNP)	NAG pH (H_2O_2)	NAG (kg H_2SO_4)	NAG pH (H_2O_2)	NAG (kg H_2SO_4)	Classification NPR vs Paste pH
		-	%	kg/t $CaCO_3$	kg/t $CaCO_3$		Kg/t $CaCO_3$	pH 4.5		pH 7		
Non-PAG		>5.5	<0.3			>4	>20	≥5.5	NAG = 0	≥5.5	NAG = 0	
Intermediate		3.5-5.5				04-Jan	-20 to 20	3.5 < pH <5.5	0 <NAG<10	3.5 < pH <5.5	0 <NAG<10	
PAG		<3.5	>0.3			<1	<-20	<3.5	NAG> 10	<3.5	NAG> 10	
J-AMP	176214	8.1	0.14	4.40	44	9.99	39.5	6.5	<0.01	6.5	0.588	Non-PAG
J-AQMcS	176215	8.2	0.17	5.16	26	4.98	20.5	6.4	<0.01	6.4	1.176	Non-PAG
J-MDOL	176216	8.4	0.11	3.37	30	8.76	26.2	6.5	<0.01	6.5	0.588	Non-PAG
J-QTVN	176217	8.3	0.16	4.90	26	5.36	21.4	6.0	<0.01	6.0	2.744	Non-PAG
J-QMS	176218	8.9	0.08	2.55	24	9.36	21.3	6.2	<0.01	6.2	1.568	Non-PAG
J-QTZT	176219	8.6	0.15	4.83	33	6.74	27.7	6.1	<0.01	6.1	2.156	Non-PAG

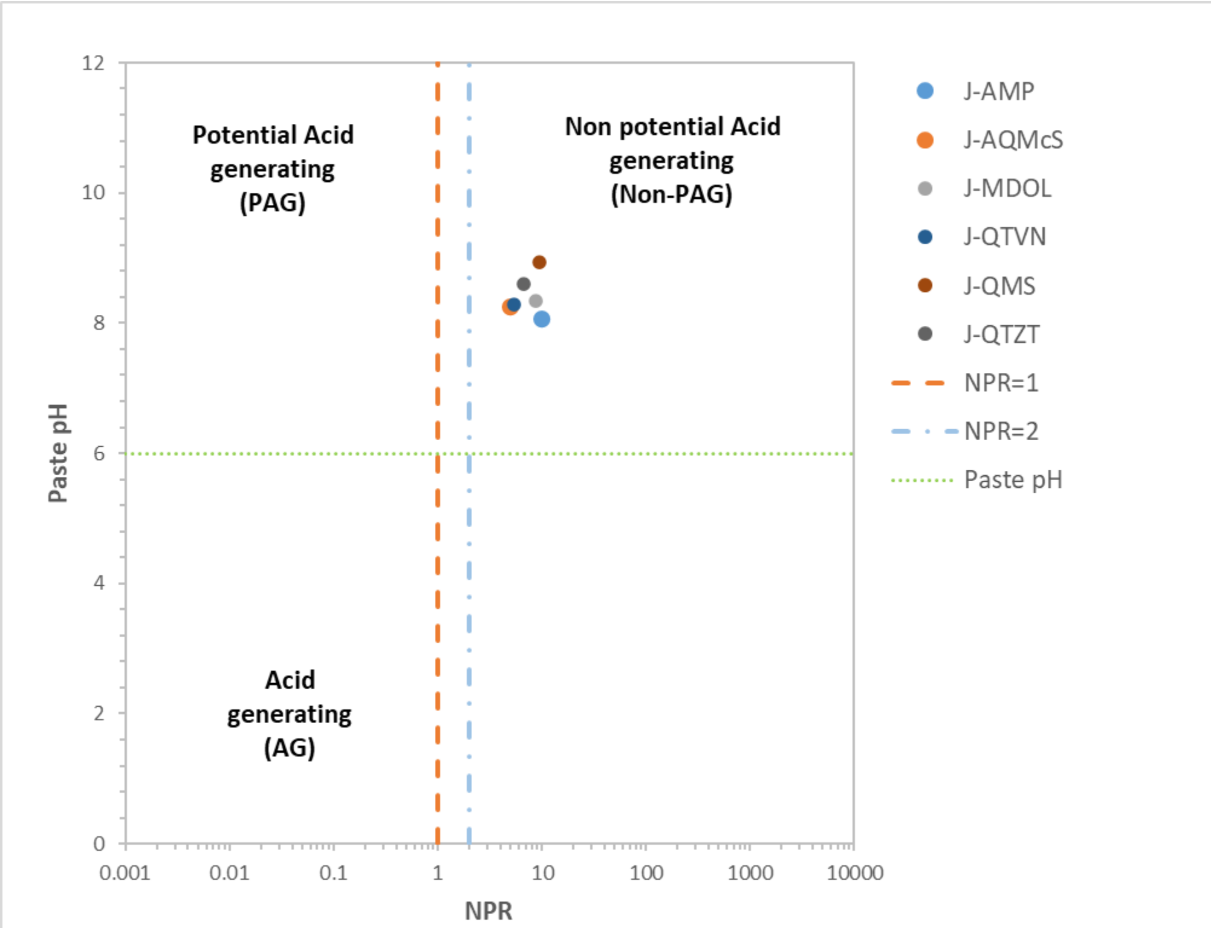

Figure 5-2: Acid generating potential classification for Melmoth WR lithologies - NPR vs Paste pH chart

5.4 SYNTHETIC PRECIPITATION LEACHING PROCEDURE LEACHATE QUALITY SCREENING

The SPLP results (Table 5-7) for the Melmoth WR materials returned SANS 241: Operational and Aesthetic exceedances for Aluminium (J-QMS), Iron (J-MDOL and J-QMS) and Manganese (J-QTVN). The SPLP results were used as input for geochemical modelling to produce leachate quality source terms for the individual WR lithologies and a proportional mix to produce a single source term for the proposed WRD.

5.5 GEOCHEMICAL SOURCE TERMS

To assess or predict impacts to groundwater and surface water resources from any facility that may be a significant source of water contamination, a source term must be developed. Evaporation was not modelled due to the limits of PHREEQC to concentrating mixtures over time steps. The source term results are summarised in Table 5-8 . Half detection limits were used for those common major and trace elements that reported below detection limits.

The WR lithologies and WRD modelled source terms predict no CoCs with the expectation of Mercury that exceeds the IFC guidelines, however, Mercury was reported below detection limits for the SPLP and input into the modal as half the detection limit, therefore this predicted value is based on a theoretical input concentration and should be disregarded.

Table 5-7: Melmoth Iron Ore WR lithologies SPLP quality results and screening

Analytes	Ag	Al*	As	Au	B	Ba	Be	Bi	Ca*	Cd	Ce	Co	Cr (total)	Cs	Cu	Dy	Er	Eu	Fe*	Ga
Unit	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*
1. DWAF TWQG		5	1		5				1000	10		1			5				10	
2. IFC: Mining effluent			0.1							0.05					0.3				2.0	
3. SANS 241: Operational		0.3																		
4. SANS 241: Aesthetic																			0.3	
5. SANS 241: Acute Health																				
6. SANS 241: Chronic Health					2.4	0.7				0.003					2.0				2.0	
J-AMP	<0.010	<0.100	<0.010	<0.010	<0.025	0.083	<0.010	<0.010	6	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.033	0.011
J-AQMcS	<0.010	<0.100	<0.010	<0.010	<0.025	0.033	<0.010	<0.010	6	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.077	<0.010
J-MDOL	<0.010	0.298	<0.010	<0.010	<0.025	0.049	<0.010	<0.010	6	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.335	<0.010
J-QTVN	<0.010	<0.100	<0.010	<0.010	<0.025	0.038	<0.010	<0.010	14	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.025	<0.010
J-QMS	<0.010	0.441	0.02	<0.010	<0.025	0.08	<0.010	<0.010	6	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.436	<0.010
J-QTZT	<0.010	0.273	<0.010	<0.010	<0.025	0.022	<0.010	<0.010	10	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.191	<0.010

Analytes	Gd	Ge	Hf	Hg	Ho	In	Ir	K*	La	Li	Lu	Mg*	Mn*	Mo	Na*	Nb	Nd	Ni	Os	P
Unit	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*
1. DWAF TWQG				1.0								500	10	0.01	2000			1		
2. IFC: Mining effluent				0.002														0.5		
3. SANS 241: Operational																				
4. SANS 241: Aesthetic													0.1		200					
5. SANS 241: Acute Health																				
6. SANS 241: Chronic Health				0.006									0.4					0.07		
J-AMP	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	8.214	<0.010	0.011	<0.010	4	<0.025	<0.010	15	<0.010	<0.010	<0.010	<0.010	0.097
J-AQMcS	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	14.603	<0.010	0.028	<0.010	4	<0.025	<0.010	4	<0.010	<0.010	<0.010	<0.010	0.036
J-MDOL	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	5.955	<0.010	<0.010	<0.010	3	<0.025	<0.010	8	<0.010	<0.010	<0.010	<0.010	0.099
J-QTVN	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	1.994	<0.010	<0.010	<0.010	2	0.362	<0.010	2	<0.010	<0.010	<0.010	<0.010	0.051
J-QMS	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	7.998	<0.010	<0.010	<0.010	1	0.037	<0.010	4	<0.010	<0.010	<0.010	<0.010	<0.010
J-QTZT	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	2.658	<0.010	<0.010	<0.010	1	0.087	<0.010	5	<0.010	<0.010	<0.010	<0.010	0.073

Analytes	Pb	Pd	Pr	Pt	Rb	Rh	Ru	Sb	Sc	Se	Si*	Sm	Sn	Sr	Ta	Tb	Te	Th	Ti	Tl
Unit	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*
1. DWAF TWQG	0.5									50										
2. IFC: Mining effluent	0.2																			
3. SANS 241: Operational																				
4. SANS 241: Aesthetic																				
5. SANS 241: Acute Health																				
6. SANS 241: Chronic Health	0.01							0.02		0.04										
J-AMP	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	5.662	<0.010	<0.010	0.025	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
J-AQMcS	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	3.747	<0.010	<0.010	0.033	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
J-MDOL	<0.010	<0.010	<0.010	<0.010	0.013	<0.010	<0.010	<0.010	<0.010	<0.010	2.057	<0.010	<0.010	0.028	<0.010	<0.010	<0.010	<0.010	0.016	<0.010
J-QTVN	<0.010	<0.010	<0.010	<0.010	0.011	<0.010	<0.010	<0.010	<0.010	<0.010	<0.2	<0.010	<0.010	0.05	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
J-QMS	<0.010	<0.010	<0.010	<0.010	0.019	<0.010	<0.010	<0.010	<0.010	<0.010	0.29	<0.010	<0.010	0.063	<0.010	<0.010	<0.010	<0.010	0.02	<0.010
J-QTZT	<0.010	<0.010	<0.010	<0.010	0.013	<0.010	<0.010	<0.010	<0.010	<0.010	<0.2	<0.010	<0.010	0.071	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010

Analytes	Tm	U	V	W	Y	Yb	Zn	Zr	pH	EC	TDS	Tot Alk	Cl	SO4	NO3	NO2	F	Free NH3	Ortho-P
Unit	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*		*mS/m*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*
1. DWAF TWQG			1				20				3000		3000	1000	100	10	6		
2. IFC: Mining effluent							0.5		6-9										
3. SANS 241: Operational									5 -9.7										
4. SANS 241: Aesthetic							5			170	1200		300	250				1.5	
5. SANS 241: Acute Health														500	11	0.9			
6. SANS 241: Chronic Health		0.03															1.5		
J-AMP	<0.010	<0.010	<0.010	0.012	<0.010	<0.010	<0.010	<0.010	8.1	16.0	80	60	<2	2	<0.1	<0.05	0.3	<0.1	<0.1
J-AQMcS	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	8.2	13.5	62	56	3	8	<0.1	<0.05	0.2	<0.1	<0.1
J-MDOL	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	8.3	11.6	52	52	<2	3	<0.1	<0.05	0.2	<0.1	<0.1
J-QTVN	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	7.7	13.2	74	32	2	31	0.1	<0.05	<0.2	<0.1	<0.1
J-QMS	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	8.6	8.9	44	36	<2	4	<0.1	<0.05	<0.2	<0.1	<0.1
J-QTZT	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	8.1	10.7	66	32	6	4	1.9	<0.05	<0.2	<0.1	<0.1

Table 5-8: Geochemical source terms for Melmoth WR Lithologies and WRD

Element	Units	SANS 241 / DWAF*	IFC	WR J-AMP	WR J-AQMcS	WR J-MDOL	WR J-QTVN	WR J-QMS	WR J-QTZT	WRD Mix
Al	mg/L	5*		0.694	1.055	1.155	3.373	4.018	3.589	1.146
As	mg/L	1*	0.1	0.005	0.005	0.005	0.005	0.020	0.005	0.006
B	mg/L	2.4		0.012	0.012	0.012	0.012	0.012	0.012	0.012
Ba	mg/L	0.7		0.083	0.033	0.049	0.038	0.080	0.022	0.053
Be	mg/L			0.005	0.005	0.005	0.005	0.005	0.005	0.005
Alkalinity as HCO_3^-	mg/L			60.028	56.026	52.023	27.964	36.012	30.362	55.470
Ca	mg/L	1000*		5.058	0.017	5.487	13.811	8.549	11.378	2.735
Cd	mg/L	10	0.05	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Cl (-1)	mg/L	300		1.000	3.000	1.000	2.000	1.000	6.002	2.220
Co	mg/L	1*		0.005	0.005	0.005	0.005	0.005	0.005	0.005
Cr	mg/L	0.05		0.002	0.002	0.002	0.002	0.002	0.002	0.002
Cs	mg/L			0.005	0.005	0.005	0.005	0.005	0.005	0.005
Cu	mg/L	2	0.3	0.005	0.005	0.005	0.005	0.005	0.005	0.005
F	mg/L	1.5		0.300	0.200	0.200	0.100	0.100	0.100	0.227
Fe	mg/L	2	2	0.033	0.077	0.335	0.013	0.436	0.191	0.082
Hg	mg/L	0.006	0.002	0.005	0.005	0.005	0.005	0.005	0.005	0.005
K	mg/L			8.214	14.607	5.955	1.994	7.999	2.658	11.440
Li	mg/L			0.011	0.028	0.005	0.005	0.005	0.005	0.020
Mg	mg/L	500*		2.569	5.964	2.223	2.000	0.833	1.000	4.319
Mn	mg/L	10*		0.013	0.013	0.013	0.362	0.037	0.087	0.022
Mo	mg/L	0,01*		0.005	0.005	0.005	0.005	0.005	0.005	0.005
N as NO_3	mg/L	22*		0.332	0.332	0.332	0.553	0.332	8.519	0.500
Na	mg/L	200		15.590	4.895	8.732	2.000	4.000	5.000	8.624
Ni	mg/L	0.07	0.5	0.005	0.005	0.005	0.005	0.005	0.005	0.005
P	mg/L			0.097	0.036	0.099	0.051	0.005	0.073	0.058
Pb	mg/L	0,1*	0.2	0.005	0.005	0.005	0.005	0.005	0.005	0.005
S as SO_4^{2-}	mg/L	500		2.001	8.002	3.001	31.007	4.001	4.001	6.022
Sb	mg/L	0.02		0.015	0.015	0.005	0.005	0.005	0.005	0.014
Se	mg/L	0,05*		0.005	0.005	0.005	0.005	0.005	0.005	0.005
Si	mg/L			2.155	2.834	2.202	3.463	3.550	3.497	2.637
Sn	mg/L			0.005	0.005	0.005	0.005	0.005	0.005	0.005
Sr	mg/L			0.025	0.033	0.028	0.050	0.063	0.071	0.032
Ti	mg/L			0.005	0.005	0.016	0.005	0.005	0.005	0.005
U	mg/L	0.03		0.005	0.005	0.005	0.005	0.005	0.005	0.005
V	mg/L	1*		0.005	0.005	0.005	0.005	0.005	0.005	0.005
W	mg/L			0.012	0.005	0.005	0.005	0.005	0.005	0.007
Zn	mg/L	5	0.5	0.005	0.005	0.005	0.005	0.005	0.005	0.005
pH		6 - 9	6 - 9	8.742	8.907	8.751	8.778	8.754	8.820	8.838

6. CONCLUSIONS

A WA and geochemical characterisation study of the WR materials that will report to the WRD at the proposed Melmoth Iron Ore project mine was undertaken as part of the many specialist reports for input into the MRA and ESIA for the project.

Thirty-two exploration cores samples were collected and made up into 6 composite samples that represent the main Melmoth WR lithologies. The WR composites are dominated by Quartz, Biotite and Plagioclase, with major to minor Actinolite, Grunerite, Microcline and various clay minerals. According to the NEMWA GN R. 635 and 636 of 2013, all the WR lithologies are assessed to be Type 3 waste that require incorporation into a waste facility that has a Class C liner or similar constructed barrier.

ABA and NAG tests assessed the Melmoth WR materials to all be non-PAG. The SPLP results returned minor Aluminium (J-QMS), Iron (J-MDOL and J-QMS) and Manganese (J-QTVN) exceedances of SANS 241: Operations and Aesthetic guidelines. The modelled source terms for the individual WR lithologies and WRD predicts no leachate CoCs that could negatively influence the local water resources. Therefore, we can conclude that the Melmoth WR materials present a low risk for ARD and MLP to the surrounding environment and downstream receptors.

6.1 RECOMMENDATIONS

Notwithstanding the report conclusions, SLR would like to make the following recommendations:

- Results of the geochemical modelling of the effluent mix should not be evaluated in isolation but together with numerical or reactive groundwater modelling risk assessment. The complete source, pathway and receptor should be considered when evaluating the overall potential risks to groundwater.
- Once the mine is operational and the WR is reporting to the WRD, regular testing of the exposed WR material should be undertaken to document changes in its geochemical characterisation, most especially when operations transition into different stratigraphies. If the geochemistry is found to be evolving significantly, the groundwater model should be updated with the new source terms.
- To regularly document the performance of the WRD and its liner, an extensive network of monitoring boreholes should be put in place to monitor change in the groundwater chemistry in the vicinity of the WRD.

Yours sincerely,

Dr Andrea Baker
Senior Geochemist
(Report Author)

Stephen Weber
Africa Land & Water Operations Manager
(Reviewer)

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APPENDIX A: LABORATORY CERTIFICATES

WATERLAB (PTY) LTD

Reg. No.: 1983/009165/07 V.A.T. No.: 4130107891

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CERTIFICATE OF ANALYSES

Index

Date received:	**2022/10/24**		**Date completed:**	**2022/11/24**
Project number:	**139**	**Report number: 114784**	**Order number:**	**JBAB20-44855.4703855324**

Client name:	**SLR Consulting (South Africa) Ltd**	**Contact person:**	**Andrea Baker**
Address:	**PO Box 1596, Cramerview, South Africa, 2060**	**Email:**	**abaker@slrconsulting.com**
Telephone:	**011 467 0945**	**Cell:**	**072 100 8173**

Analyses
Leachable
Distilled Water
SPLP
Total
Acid Digestion
Outsourced analysis
Acid Base Accounting
Net Acid Generation
Sulphur Speciation
X-Ray Diffraction [o]
Total, Organic & Inorganic Carbon [o]

S. Laubscher
Assistant Geochemistry Project Manager

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CERTIFICATE OF ANALYSES
EXTRACTIONS AS 4439.3

Date received:	**2022/10/24**		**Date completed:**	**2022/11/21**
Project number:	**139**	**Report number: 114784**	**Order number:**	**JBAB20-44855.4703855324**

Client name:	**SLR Consulting (South Africa) (Pty) Ltd**	**Contact person:**	**Andrea Baker**
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Telephone:	**011 467 0945**	**Cell:**	**072 100 8173**

Analyses										
	J-AMP	J-AQMcS	J-MDOL	J-QTVN	J-QMS	J-QTZT				
Sample Number	176214	176215	176216	176217	176218	176219				
TCLP / Borax / Distilled Water	**Distilled Water**	**Distilled Water**	**Distilled Water**	**Distilled Water**	**Distilled Water**	**Distilled Water**				
Ratio*	**1:20**	**1:20**	**1:20**	**1:20**	**1:20**	**1:20**				
Units	**mg/ℓ**	**mg/ℓ**	**mg/ℓ**	**mg/ℓ**	**mg/ℓ**	**mg/ℓ**	**LCT0 mg/l**	**LCT1 mg/l**	**LCT2 mg/l**	**LCT3 mg/l**
As, Arsenic	0.003	0.003	0.003	0.003	0.011	0.001	0.01	0.5	1	4
B, Boron	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	0.5	25	50	200
Ba, Barium	0.055	<0.025	0.038	0.025	0.130	<0.025	0.7	35	70	280
Cd, Cadmium	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	0.15	0.3	1.2
Co, Cobalt	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	0.5	25	50	200
$Cr_{Total,}$ Chromium Total	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	0.1	5	10	40
Cr(VI), Chromium (VI)	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.05	2.5	5	20
Cu, Copper	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	2.0	100	200	800
Hg, Mercury	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.006	0.3	0.6	2.4
Mn, Manganese	<0.025	<0.025	<0.025	0.034	<0.025	<0.025	0.5	25	50	200
Mo, Molybdenum	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	0.07	3.5	7	28
Ni, Nickel	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	0.07	3.5	7	28
Pb, Lead	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.01	0.5	1	4
Sb, Antimony	0.001	0.001	0.001	0.001	0.001	0.001	0.02	1.0	2	8
Se, Selenium	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.01	0.5	1	4
V, Vanadium	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	0.2	10	20	80
Zn, Zinc	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	5.0	250	500	2000
Inorganic Anions	**mg/ℓ**	**mg/ℓ**	**mg/ℓ**	**mg/ℓ**	**mg/ℓ**	**mg/ℓ**				
Total Dissolved Solids*	38	28	28	28	28	26	1000	12 500	25 000	100 000
Chloride as Cl	<2	<2	<2	<2	<2	<2	300	15 000	30 000	120 000
Sulphate as SO4	<2	<2	<2	<2	<2	<2	250	12 500	25 000	100 000
Nitrate as N	<0.1	<0.1	<0.1	<0.1	<0.1	0.4	11	550	1100	4400
Nitrite as N	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05				
Fluoride as F	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	1.5	75	150	600
Total Cyanide as CN [o]	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	0.07	3.5	7	28
pH	9.1	9.3	9.3	9.2	9.4	9.2				

[o] = Outsourced

***Please note:**

1. The samples were used as received.
2. A moisture content were determined for wet or moist samples.
3. In cases where the sample were a slurry, a solid to liquid ratio were done (reported).
   Moisture content were determined after filtration
4. The results are reported as received. The moisture content were not taken into account.

S. Laubscher ____________________
Assistant Geochemistry Project Manager

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CERTIFICATE OF ANALYSES
SPLP EXTRACTION

Date received:	**2022/10/24**	**Date completed:**	**2022/11/21**
Project number:	**139**	**Order number:**	**JBAB20-44855.4703855324**
Report number:	**114784**		

Client name:	**SLR Consulting (South Africa) Ltd**	**Contact person:**	**Andrea Baker**
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Telephone:	**011 467 0945**	**Cell:**	**072 100 8173**

Analyses	**Sample Identification**					
	J-AMP		**J-AQMcS**		**J-MDOL**	
Sample Number	**176214**		**176215**		**176216**	
TCLP / Acid Rain / Distilled Water / H_2O_2	**SPLP**		**SPLP**		**SPLP**	
Dry Mass Used (g)	**100**		**100**		**100**	
Volume Used (mℓ)	**400**		**400**		**400**	
pH Value at 25˚C	8.1		8.2		8.3	
Electrical Conductivity in mS/m at 25˚C	16.0		13.5		11.6	
Inorganic Anions	**mg/ℓ**	**mg/kg**	**mg/ℓ**	**mg/kg**	**mg/ℓ**	**mg/kg**
Total Dissolved Solids at 180 ˚C	80	320	62	248	52	208
Total Alkalinity as CaCO3	60	240	56	224	52	208
Chloride as Cl	<2	<8	3	12	<2	<8
Sulphate as SO_4	2	8	8	32	3	12
Nitrate as N	<0.1	<0.4	<0.1	<0.4	<0.1	<0.4
Nitrite as N	<0.05	<0.2	<0.05	<0.2	<0.05	<0.2
Fluoride as F	0.3	1.2	0.2	0.8	0.2	0.8
Free & Saline Ammonia as N	<0.1	<0.4	<0.1	<0.4	<0.1	<0.4
Ortho Phosphate as P	<0.1	<0.4	<0.1	<0.4	<0.1	<0.4
ICP-MS Scan	See ICP SPLP tab					

Analyses	**Sample Identification**					
	J-QTVN		**J-QMS**		**J-QTZT**	
Sample Number	**176217**		**176218**		**176219**	
TCLP / Acid Rain / Distilled Water / H_2O_2	**SPLP**		**SPLP**		**SPLP**	
Dry Mass Used (g)	**100**		**100**		**100**	
Volume Used (mℓ)	**400**		**400**		**400**	
pH Value at 25˚C	7.7		8.6		8.1	
Electrical Conductivity in mS/m at 25˚C	13.2		8.9		10.7	
Inorganic Anions	**mg/ℓ**	**mg/kg**	**mg/ℓ**	**mg/kg**	**mg/ℓ**	**mg/kg**
Total Dissolved Solids at 180 ˚C	74	296	44	176	66	264
Total Alkalinity as CaCO3	32	128	36	144	32	128
Chloride as Cl	2	8	<2	<8	6	24
Sulphate as SO_4	31	124	4	16	4	16
Nitrate as N	0.1	0.4	<0.1	<0.4	1.9	7.6
Nitrite as N	<0.05	<0.2	<0.05	<0.2	<0.05	<0.2
Fluoride as F	<0.2	<0.8	<0.2	<0.8	<0.2	<0.8
Free & Saline Ammonia as N	<0.1	<0.4	<0.1	<0.4	<0.1	<0.4
Ortho Phosphate as P	<0.1	<0.4	<0.1	<0.4	<0.1	<0.4
ICP-MS Scan	See ICP SPLP tab					

S. Laubscher
Assistant Geochemistry Project Manager

WATERLAB (PTY) LTD
CERTIFICATE OF ANALYSES
ICP-MS SCAN ANALYSIS

Date received:	2022/10/24	**Date Completed:**	2022/11/21
Project number:	139	**Report number:**	114784

Client name:	SLR Consulting (South Africa) (Pty) Ltd	**Contact person:**	Andrea Baker
Address:	P.O. Box 1596, Cramerview, 2060	**Email:**	abaker@slrconsulting.com

Extract	Sample Mass (g)	Volume (ml)	Factor
SPLP	100	400	4

Sample Id	Sample Number	Ag	Ag	Al*	Al*	As	As
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.010	<0.040	<0.100	<0.400	<0.010	<0.040
J-AMP	176214	<0.010	<0.040	<0.100	<0.400	<0.010	<0.040
J-AQMcS	176215	<0.010	<0.040	<0.100	<0.400	<0.010	<0.040
J-MDOL	176216	<0.010	<0.040	0.298	1.19	<0.010	<0.040
J-QTVN	176217	<0.010	<0.040	<0.100	<0.400	<0.010	<0.040
J-QMS	176218	<0.010	<0.040	0.441	1.76	0.020	0.080
J-QTZT	176219	<0.010	<0.040	0.273	1.09	<0.010	<0.040

Sample Id	Sample Number	Au	Au	B	B	Ba	Ba
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.010	<0.040	<0.025	<0.100	<0.010	<0.040
J-AMP	176214	<0.010	<0.040	<0.025	<0.100	0.083	0.332
J-AQMcS	176215	<0.010	<0.040	<0.025	<0.100	0.033	0.132
J-MDOL	176216	<0.010	<0.040	<0.025	<0.100	0.049	0.196
J-QTVN	176217	<0.010	<0.040	<0.025	<0.100	0.038	0.152
J-QMS	176218	<0.010	<0.040	<0.025	<0.100	0.080	0.320
J-QTZT	176219	<0.010	<0.040	<0.025	<0.100	0.022	0.088

Sample Id	Sample Number	Be	Be	Bi	Bi	Ca*	Ca*
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.010	<0.040	<0.010	<0.040	<1	<4
J-AMP	176214	<0.010	<0.040	<0.010	<0.040	6	24
J-AQMcS	176215	<0.010	<0.040	<0.010	<0.040	6	24
J-MDOL	176216	<0.010	<0.040	<0.010	<0.040	6	24
J-QTVN	176217	<0.010	<0.040	<0.010	<0.040	14	56
J-QMS	176218	<0.010	<0.040	<0.010	<0.040	6	24
J-QTZT	176219	<0.010	<0.040	<0.010	<0.040	10	40

Sample Id	Sample Number	Cd	Cd	Ce	Ce	Co	Co
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-AMP	176214	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-AQMcS	176215	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-MDOL	176216	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-QTVN	176217	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-QMS	176218	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-QTZT	176219	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040

Sample Id	Sample Number	Cr	Cr	Cs	Cs	Cu	Cu
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-AMP	176214	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-AQMcS	176215	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-MDOL	176216	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-QTVN	176217	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-QMS	176218	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-QTZT	176219	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040

Sample Id	Sample Number	Dy	Dy	Er	Er	Eu	Eu
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-AMP	176214	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-AQMcS	176215	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-MDOL	176216	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-QTVN	176217	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040

J-QMS	176218	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-QTZT	176219	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040

Sample Id	Sample Number	Fe*	Fe*	Ga	Ga	Gd	Gd
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<0.100	<0.010	<0.040	<0.010	<0.040
J-AMP	176214	0.033	0.132	0.011	0.044	<0.010	<0.040
J-AQMcS	176215	0.077	0.308	<0.010	<0.040	<0.010	<0.040
J-MDOL	176216	0.335	1.34	<0.010	<0.040	<0.010	<0.040
J-QTVN	176217	<0.025	<0.100	<0.010	<0.040	<0.010	<0.040
J-QMS	176218	0.436	1.74	<0.010	<0.040	<0.010	<0.040
J-QTZT	176219	0.191	0.764	<0.010	<0.040	<0.010	<0.040

Sample Id	Sample Number	Ge	Ge	Hf	Hf	Hg	Hg
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-AMP	176214	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-AQMcS	176215	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-MDOL	176216	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-QTVN	176217	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-QMS	176218	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-QTZT	176219	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040

Sample Id	Sample Number	Ho	Ho	In	In	Ir	Ir
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-AMP	176214	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-AQMcS	176215	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-MDOL	176216	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-QTVN	176217	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-QMS	176218	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-QTZT	176219	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040

Sample Id	Sample Number	K*	K*	La	La	Li	Li
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.5	<2.0	<0.010	<0.040	<0.010	<0.040
J-AMP	176214	8.2	33	<0.010	<0.040	0.011	0.044
J-AQMcS	176215	14.6	58	<0.010	<0.040	0.028	0.112
J-MDOL	176216	6.0	24	<0.010	<0.040	<0.010	<0.040
J-QTVN	176217	2.0	8.0	<0.010	<0.040	<0.010	<0.040
J-QMS	176218	8.0	32	<0.010	<0.040	<0.010	<0.040
J-QTZT	176219	2.7	10.6	<0.010	<0.040	<0.010	<0.040

Sample Id	Sample Number	Lu	Lu	Mg*	Mg*	Mn*	Mn*
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.010	<0.040	<1	<4	<0.025	<0.100
J-AMP	176214	<0.010	<0.040	4	16	<0.025	<0.100
J-AQMcS	176215	<0.010	<0.040	4	16	<0.025	<0.100
J-MDOL	176216	<0.010	<0.040	3	12	<0.025	<0.100
J-QTVN	176217	<0.010	<0.040	2	8	0.362	1.45
J-QMS	176218	<0.010	<0.040	1	4	0.037	0.148
J-QTZT	176219	<0.010	<0.040	1	4	0.087	0.348

Sample Id	Sample Number	Mo	Mo	Na*	Na*	Nb	Nb
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.010	<0.040	<1	<4	<0.010	<0.040
J-AMP	176214	<0.010	<0.040	15	60	<0.010	<0.040
J-AQMcS	176215	<0.010	<0.040	4	16	<0.010	<0.040
J-MDOL	176216	<0.010	<0.040	8	32	<0.010	<0.040
J-QTVN	176217	<0.010	<0.040	2	8	<0.010	<0.040
J-QMS	176218	<0.010	<0.040	4	16	<0.010	<0.040
J-QTZT	176219	<0.010	<0.040	5	20	<0.010	<0.040

Sample Id	Sample Number	Nd	Nd	Ni	Ni	Os	Os
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-AMP	176214	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-AQMcS	176215	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-MDOL	176216	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-QTVN	176217	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-QMS	176218	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-QTZT	176219	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040

Sample Id	Sample Number	P	P	Pb	Pb	Pd	Pd
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-AMP	176214	0.097	0.388	<0.010	<0.040	<0.010	<0.040
J-AQMcS	176215	0.036	0.144	<0.010	<0.040	<0.010	<0.040
J-MDOL	176216	0.099	0.396	<0.010	<0.040	<0.010	<0.040
J-QTVN	176217	0.051	0.204	<0.010	<0.040	<0.010	<0.040
J-QMS	176218	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-QTZT	176219	0.073	0.292	<0.010	<0.040	<0.010	<0.040

Sample Id	Sample Number	Pr	Pr	Pt	Pt	Rb	Rb
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-AMP	176214	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-AQMcS	176215	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-MDOL	176216	<0.010	<0.040	<0.010	<0.040	0.013	0.052
J-QTVN	176217	<0.010	<0.040	<0.010	<0.040	0.011	0.044
J-QMS	176218	<0.010	<0.040	<0.010	<0.040	0.019	0.076
J-QTZT	176219	<0.010	<0.040	<0.010	<0.040	0.013	0.052

Sample Id	Sample Number	Rh	Rh	Ru	Ru	Sb	Sb
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-AMP	176214	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-AQMcS	176215	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-MDOL	176216	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-QTVN	176217	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-QMS	176218	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-QTZT	176219	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040

Sample Id	Sample Number	Sc	Sc	Se	Se	Si*	Si*
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.010	<0.040	<0.010	<0.040	<0.2	<0.8
J-AMP	176214	<0.010	<0.040	<0.010	<0.040	5.7	23
J-AQMcS	176215	<0.010	<0.040	<0.010	<0.040	3.7	15.0
J-MDOL	176216	<0.010	<0.040	<0.010	<0.040	2.1	8.2
J-QTVN	176217	<0.010	<0.040	<0.010	<0.040	<0.2	<0.8
J-QMS	176218	<0.010	<0.040	<0.010	<0.040	0.3	1.2
J-QTZT	176219	<0.010	<0.040	<0.010	<0.040	<0.2	<0.8

Sample Id	Sample Number	Sm	Sm	Sn	Sn	Sr	Sr
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-AMP	176214	<0.010	<0.040	<0.010	<0.040	0.025	0.100
J-AQMcS	176215	<0.010	<0.040	<0.010	<0.040	0.033	0.132
J-MDOL	176216	<0.010	<0.040	<0.010	<0.040	0.028	0.112
J-QTVN	176217	<0.010	<0.040	<0.010	<0.040	0.050	0.200
J-QMS	176218	<0.010	<0.040	<0.010	<0.040	0.063	0.252
J-QTZT	176219	<0.010	<0.040	<0.010	<0.040	0.071	0.284

Sample Id	Sample Number	Ta	Ta	Tb	Tb	Te	Te
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-AMP	176214	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-AQMcS	176215	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-MDOL	176216	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-QTVN	176217	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-QMS	176218	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-QTZT	176219	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040

Sample Id	Sample Number	Th	Th	Ti	Ti	Tl	Tl
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-AMP	176214	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-AQMcS	176215	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-MDOL	176216	<0.010	<0.040	0.016	0.064	<0.010	<0.040
J-QTVN	176217	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-QMS	176218	<0.010	<0.040	0.020	0.080	<0.010	<0.040
J-QTZT	176219	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040

Sample Id	Sample Number	Tm	Tm	U	U	V	V
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-AMP	176214	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-AQMcS	176215	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-MDOL	176216	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-QTVN	176217	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-QMS	176218	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-QTZT	176219	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040

Sample Id	Sample Number	W	W	Y	Y	Yb	Yb
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-AMP	176214	0.012	0.048	<0.010	<0.040	<0.010	<0.040
J-AQMcS	176215	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-MDOL	176216	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-QTVN	176217	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-QMS	176218	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040
J-QTZT	176219	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040

Sample Id	Sample Number	Zn	Zn	Zr	Zr
		mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.010	<0.040	<0.010	<0.040
J-AMP	176214	<0.010	<0.040	<0.010	<0.040
J-AQMcS	176215	<0.010	<0.040	<0.010	<0.040
J-MDOL	176216	<0.010	<0.040	<0.010	<0.040
J-QTVN	176217	<0.010	<0.040	<0.010	<0.040
J-QMS	176218	<0.010	<0.040	<0.010	<0.040
J-QTZT	176219	<0.010	<0.040	<0.010	<0.040

[*] = Element analysed on ICP-OES Instrument

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CERTIFICATE OF ANALYSES

Digestion AS 4439.3

Date received:	**2022/10/24**		**Date completed:**	**2022/11/24**
Project number:	**139**	**Report number: 114784**	**Order number:**	**JBAB20-44855.4703855324**

Client name:	**SLR Consulting (South Africa) (Pty) Ltd**	**Contact person:**	**Andrea Baker**
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Analyses	J-AMP		J-AQMcS		J-MDOL		J-QTVN		J-QMS		J-QTZT				
Sample Number	176214		176215		176216		176217		176218		176219		TCT0 mg/kg	TCT1 mg/kg	TCT2 mg/kg
Digestion	HNO3 : HF		HNO3 : HF		HNO3 : HF		HNO3 : HF		HNO3 : HF		HNO3 : HF				
Dry Mass Used (g)	0.25		0.25		0.25		0.25		0.25		0.25				
Volume Used (mℓ)	100		100		100		100		100		100				
Units	**mg/ℓ**	**mg/kg**	**mg/ℓ**	**mg/kg**	**mg/ℓ**	**mg/kg**	**mg/ℓ**	**mg/kg**	**mg/ℓ**	**mg/kg**	**mg/ℓ**	**mg/kg**			
As, Arsenic	0.187	75	0.021	8	0.022	8.80	0.021	8.40	0.086	34	0.008	3.20	5.8	500	2000
B, Boron	0.238	95	<0.025	<10	0.928	371	0.236	94	0.497	199	0.194	78	150	15000	6000
Ba, Barium	1.48	591	2.69	1078	1.80	719	0.122	49	2.80	1119	0.773	309	62.5	6250	25000
Cd, Cadmium	<0.001	<0.400	<0.001	<0.400	<0.001	<0.400	<0.001	<0.400	<0.001	<0.400	<0.001	<0.400	7.5	260	1040
Co, Cobalt	0.094	38	<0.025	<10	0.144	58	<0.025	<10	<0.025	<10	<0.025	<10	50	5000	20000
$Cr_{Total,}$ Chromium Total	1.08	432	1.34	535	0.629	252	0.362	145	0.708	283	1.04	418	46000	800000	N/A
Cu, Copper	0.074	30	0.093	37	0.090	36	<0.010	<4.00	0.015	6.00	<0.010	<4.00	16	19500	78000
Hg, Mercury	<0.001	<0.400	<0.001	<0.400	<0.001	<0.400	<0.001	<0.400	<0.001	<0.400	<0.001	<0.400	0.93	160	640
Mn, Manganese	8.36	3344	11.42	4568	4.89	1956	1.42	568	4.32	1728	1.13	451	1000	25000	100000
Mo, Molybdenum	<0.025	<10	0.048	19	<0.025	<10	<0.025	<10	<0.025	<10	0.078	31	40	1000	4000
Ni, Nickel	0.035	14	0.164	66	0.305	122	0.047	19	0.197	79	0.042	17	91	10600	42400
Pb, Lead	0.038	15	0.059	24	0.049	20	0.018	7.20	0.070	28	0.060	24	20	1900	7600
Sb, Antimony	0.002	0.800	0.001	0.400	0.001	0.400	0.001	0.400	0.001	0.400	<0.001	<0.400	10	75	300
Se, Selenium	0.012	4.80	<0.001	<0.400	<0.001	<0.400	<0.001	<0.400	<0.001	<0.400	<0.001	<0.400	10	50	200
V, Vanadium	0.261	104	<0.025	<10	0.574	230	<0.025	<10	<0.025	<10	<0.025	<10	150	2680	10720
Zn, Zinc	0.265	106	<0.025	<10	0.240	96	<0.025	<10	0.105	42	0.036	14.4	240	160000	640000
Inorganic Anions	**mg/ℓ**	**mg/kg**	**mg/ℓ**	**mg/kg**	**mg/ℓ**	**mg/kg**	**mg/ℓ**	**mg/kg**	**mg/ℓ**	**mg/kg**	**mg/ℓ**	**mg/kg**			
Cr(VI), Chromium (VI) Total [o]	---	<2	---	<2	---	<2	---	<2	---	<2	---	<2	6.5	500	2000
Total Fluoride [o]	---	3.24	---	15.45	---	4.86	---	64.37	---	17.65	---	13.17	100	10000	40000
Total Cyanide as CN [o]	---	<1.55	---	<1.55	---	<1.55	---	<1.55	---	<1.55	---	<1.55	14	10500	42000

[o] = Outsourced

UTD = Unable to determine

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CERTIFICATE OF ANALYSES
ACID – BASE ACCOUNTING
EPA-600 MODIFIED SOBEK METHOD

Date received:	**2022/10/24**		**Date completed:**	**2022/11/21**
Project number:	**139**	**Report number: 114784**	**Order number:**	**JBAB20-44855.4703855324**

Client name:	**SLR Consulting (South Africa) (Pty) Ltd**	**Contact person:**	**Andrea Baker**
Address:	**P.O. Box 1596, Cramerview, 2060**	**Email:**	**abaker@slrconsulting.com**
Telephone:	**011 467 0945**	**Cell:**	**072 100 8173**

Acid – Base Accounting	Sample Identification						
Modified Sobek (EPA-600)	**J-AMP**	**J-AQMcS**	**J-MDOL**	**J-QTVN**	**J-QMS**	**J-QTZT**	**J-QTZT**
Sample Number	**176214**	**176215**	**176216**	**176217**	**176218**	**176219**	**176219 D**
Paste pH	8.1	8.2	8.4	8.3	8.9	8.6	8.6
Total Sulphur (%) (LECO)	0.14	0.17	0.11	0.16	0.08	0.15	0.15
Acid Potential (AP) (kg/t)	4.40	5.16	3.37	4.90	2.55	4.83	4.74
Neutralization Potential (NP)	44	26	30	26	24	33	33
Nett Neutralization Potential (NNP)	40	21	26	21	21	28	28
Neutralising Potential Ratio (NPR) (NP : AP)	9.99	4.98	8.76	5.36	9.36	6.74	6.88
Rock Type	III	III	III	III	III	III	III

*** Negative NP values are obtained when the volume of NaOH (0.1N) titrated (pH: 8.3) is greater than the volume of HCl (1N) to reduce the pH of the sample to 2.0 – 2.5 Any negative NP values are corrected to 0.00.**

APPENDIX: TERMINOLOGY AND ROCK CLASSIFICATION

TERMINOLOGY (SYNONYMS)

➢ Acid Potential (AP) ; *Synonyms* : Maximum Potential Acidity (MPA)	**Method**: Total S(%) (Leco Analyzer) x 31.25
➢ Neutralization Potential (NP) ; *Synonyms:* Gross Neutralization Potential (GNP) ; *Syn* : Acid Neutralization Capacity (ANC) (The capacity of a sample to consume acid)	**Method**: Fizz Test ; Acid-Base Titration (Sobek & Modified Sobek (Lawrence) Methods)
➢ Nett Neutralization Potential (NNP) ; *Synonyms:* Nett Acid Production Potential (NAPP)	**Calculation:** NNP = NP – AP ; NAPP = ANC – MPA
➢ Neutralising Potential Ratio (NPR)	**Calculation:** NPR = NP : AP

CLASSIFICATION ACCORDING TO NETT NEUTRALISING POTENTIAL (NNP)

If NNP (NP – AP) < 0, the sample has the potential to generate acid
If NNP (NP – AP) > 0, the sample has the potential to neutralise acid produced
Any sample with NNP < 20 is potentiall acid-generating, and any sample with NNP > -20 might not generate acid (Usher *et al* ., 2003)

ROCK CLASSIFICATION

TYPE I	Potentially Acid Forming	Total S(%) > 0.25% and NP:AP ratio 1:1 or less
TYPE II	Intermediate	Total S(%) > 0.25% and NP:AP ratio 1:3 or less
TYPE III	Non-Acid Forming	Total S(%) < 0.25% and NP:AP ratio 1:3 or greater

CLASSIFICATION ACCORDING TO NEUTRALISING POTENTIAL RATIO (NPR)

Guidelines for screening criteria based on ABA (Price *et al* ., 1997 ; Usher *et al* ., 2003)

Potential for ARD	Initial NPR Screening Criteria	Comments
Likely	**< 1:1**	Likely AMD generating
Possibly	**1:1 – 2:1**	Possibly AMD generating if NP is insufficiently reactive or is depleted at a faster rate than sulphides
Low	**2:1 – 4:1**	Not potentially AMD generating unless significant preferential exposure of sulphides along fracture planes, or extremely reactive sulphides in combination with insufficiently reactive NP
None	**>4:1**	No further AMD testing required unless materials are to be used as a source of alkalinity

CLASSIFICATION ACCORDING TO SULPHUR CONTENT (%S) AND NEUTRALISING POTENTIAL RATIO (NPR)

For sustainable long-term acid generation, at least 0.3% Sulphide-S is needed. Values below this can yield acidity but it is likely to be only of short-term significance. From these facts, and using the NPR values, a number of rules can be derived:

1) Samples with less than 0.3% Sulphide-S are regarded as having insufficient oxidisable Sulphide-S to sustain acid generation.
2) NPR ratios of >4:1 are considered to have enough neutralising capacity.
3) NPR ratios of 3:1 to 1:1 are consider inconclusive.
4) NPR ratios below 1:1 with Sulphide-S above 3% are potentially acid-generating. (Soregaroli & Lawrence, 1998 ; Usher *et al* ., 2003)

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CERTIFICATE OF ANALYSES
NET ACID GENERATION

Date received:	**2022/10/24**		**Date completed:**	**2022/11/21**
Project number:	**139**	**Report number: 114784**	**Order number:**	**JBAB20-44855.4703855324**

Client name:	**SLR Consulting (South Africa) (Pty) Ltd**	**Contact person:**	**Andrea Baker**
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Net Acid Generation	Sample Identification: pH 4.5						
	J-AMP	J-AQMcS	J-MDOL	J-QTVN	J-QMS	J-QTZT	J-QTZT
Sample Number	**176214**	**176215**	**176216**	**176217**	**176218**	**176219**	**176219 D**
NAG pH: (H_2O_2)	6.5	6.4	6.5	6.0	6.2	6.1	6.1
NAG (kg H_2SO_4 / t)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Net Acid Generation	Sample Identification: pH 7.0						
	J-AMP	J-AQMcS	J-MDOL	J-QTVN	J-QMS	J-QTZT	J-QTZT
Sample Number	**176214**	**176215**	**176216**	**176217**	**176218**	**176219**	**176219 D**
NAG pH: (H_2O_2)	6.5	6.4	6.5	6.0	6.2	6.1	6.1
NAG (kg H_2SO_4 / t)	0.588	1.18	0.588	2.74	1.57	2.16	2.16

Notes:

- Samples analysed with Single Addition NAG test as per Prediction Manual For Drainage Chemistry from Sulphidic Geological Materials MEND Report 1.20.1.
- Please let me know if results do not correspond to other data.

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CERTIFICATE OF ANALYSES
SULPHUR SPECIATION

Methods from: Prediction Manual For Drainage Chemistry from Sulphidic Geological Materials MEND Report 1.20.1

Date received: 2022/10/24
Project number: 139
Report number: 114784
Date completed: 2022/11/21
Order number: JBAB20-44855.4703855324

Client name: SLR Consulting (South Africa) (Pty) Ltd
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Contact person: Andrea Baker
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Cell: 072 100 8173

Analyses	Sample Identification:						
	J-AMP	J-AQMcS	J-MDOL	J-QTVN	J-QMS	J-QTZT	J-QTZT
Sample Number	176214	176215	176216	176217	176218	176219	176219 D
Total Sulphur (%) (ELTRA)	0.14	0.17	0.11	0.16	0.08	0.15	0.15
Sulphate Sulphur as S (%)	<0.01	0.05	0.03	0.08	0.06	0.08	0.09
Sulphide Sulphur (%)	0.14	0.12	0.08	0.08	0.02	0.07	0.06

Notes:

- Samples analysed with Pyrolysis at 550°C as per Prediction Manual For Drainage Chemistry from Sulphidic Geological Materials MEND Report 1.20.1.
  Multiply Sulphate Sulphur to calculate SO4 % by 2.996. Please see the method for interferences.
- Organic Sulphur is not taken into account and may be included in the results.
- Please let me know if results do not correspond to other data.

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Ass lanager

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CERTIFICATE OF ANALYSES
X-RAY DIFFRACTION

Date received:	**2022/10/24**		**Date completed:**	**2022/11/21**
Project number:	**139**	**Report number: 114784**	**Order number:**	**JBAB20-44855.4703855324**

Client name:	**SLR Consulting (South Africa) (Pty) Ltd**	**Contact person:**	**Andrea Baker**
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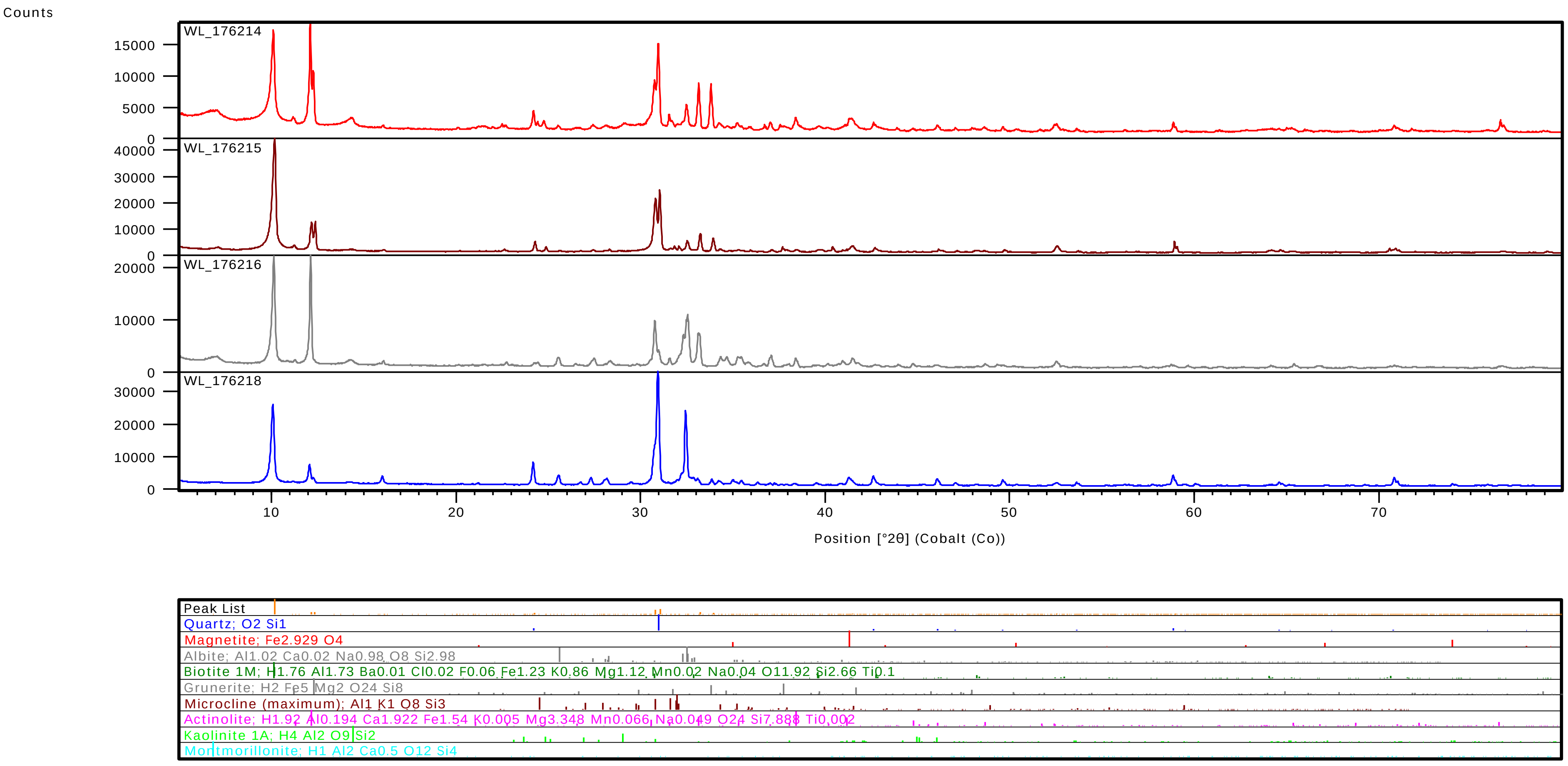
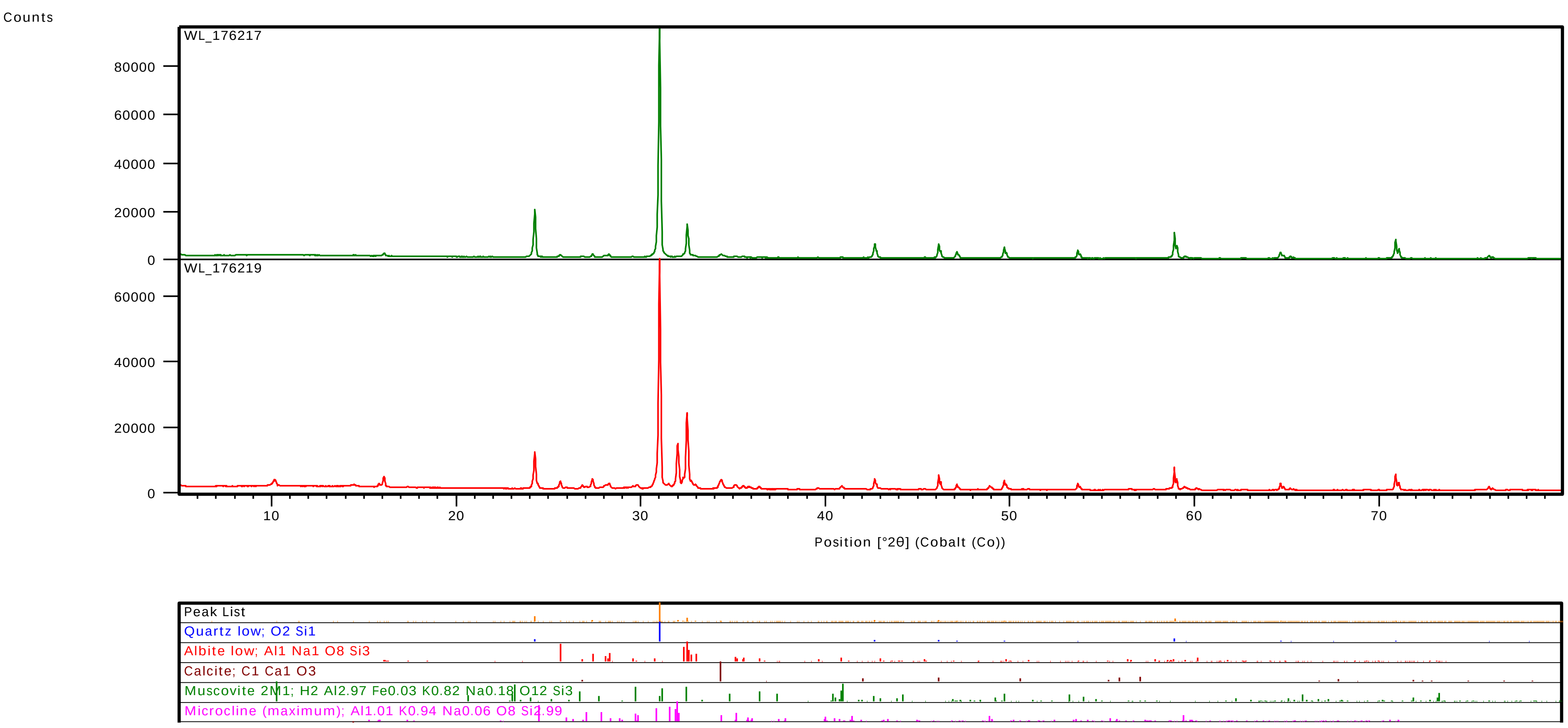
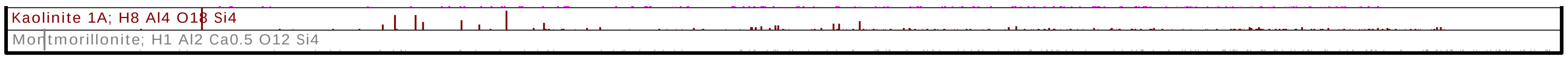
Analyses	**Sample Identification**					
	J-AMP	**J-AQMcS**	**J-MDOL**	**J-QTVN**	**J-QMS**	**J-QTZT**
Sample Number	**176214**	**176215**	**176216**	**176217**	**176218**	**176219**
Mineral Amount (weight %)	**Composition (%) [o]**					
Quartz	12.31	24.29	1.75	85.93	32.84	49.12
Magnetite	0.5	0.37	0	0	1.44	0
Plagioclase	10.97	12.16	23.67	12.57	39.91	28.72
Biotite	15.09	29.08	17.51	0	14.03	0
Grunerite	13.32	12.72	0	0	2.21	0
Microcline	17.13	5.07	19.61	0	2.8	17.15
Actinolite	15.59	14.66	21.59	0	6.29	0
Kaolinite	2.56	0.59	2.57	0	0.48	0.92
Smectite	12.55	1.08	13.3	0	0	0.65
Calcite	0	0	0	1.5	0	2.07
Muscovite	0	0	0	0	0	1.37

[o] = Outsourced







Note:

The material was prepared for XRD analysis using a back loading preparation method.
Diffractograms were obtained using a Malvern Panalytical Aeris diffractometer with PIXcel detector and fixed slits with Fe filtered Co-Kα radiation.
The phases were identified using X'Pert Highscore plus software.

The relative phase amounts (weight %) were estimated using the Rietveld method.

Comment:

- In case the results do not correspond to results of other analytical techniques, please let me know for further fine tuning of XRD results.
- Mineral names may not reflect the actual compositions of minerals identified, but rather the mineral group.
- Smectite, lizardite (serpentine), vermiculite, chlorite and kaolinite peaks overlap and further test would be necessary to distinguish. Identification is largely based on peak shapes and positions.
- Due to preferred orientation and crystallite size effects, results may not be as accurate as shown.
- Traces of additional phases may be present. Amounts below 0.5 weight % may be unreliable.
- Amorphous phases, if present, were not taken into consideration during quantification.

Ideal Mineral compositions:

Compound Name	Chemical Formula
Actinolite	$Ca_2(Mg,Fe)_5Si_8O_{22}(OH)$
Biotite	$K(Mg,Fe)_3((OH)_2 Al Si_3 O_{10})$
Calcite	$Ca(CO_3)$
Grunerite	$Mg_2Fe_5Si_8O_{22}(OH)_2$
Kaolinite	$Al_2Si_2O_5(OH)_4$
Magnetite	Fe_3O_4
Microcline	$KAlSi_3O_8$
Muscovite	$KAl_3Si_3O_{10}(OH)_2$
Plagioclase	$(Na,Ca)(Si,Al)_4O_8$
Quartz	SiO_2
Smectite	$CaMg_2AlSi_4(OH)_2 \cdot H_2O$

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CERTIFICATE OF ANALYSES

CARBON

Date received:	**2022/10/24**		**Date completed:**	**2022/11/24**
Project number:	**139**	**Report number: 114784**	**Order number:**	**JBAB20-44855.4703855324**

Client name:	**SLR Consulting (South Africa) (Pty) Ltd**	**Contact person:**	**Andrea Baker**
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Analyses	**Sample Identification**						
	J-AMP	**J-AMP**	**J-AQMcS**	**J-MDOL**	**J-QTVN**	**J-QMS**	**J-QTZT**
Sample Number	**176214**	**176214 D**	**176215**	**176216**	**176217**	**176218**	**176219**
Total Carbon (%) (LECO)[o]	0.219	0.223	0.213	0.257	0.337	0.299	0.391
Organic Carbon (%) (LECO) [o]	0.020	0.016	0.012	0.007	0.008	0.009	0.014
Inorganic Carbon (%) (LECO) [o]	0.199	0.207	0.201	0.25	0.329	0.29	0.377

[o] = Outsourced

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RECORD OF REPORT DISTRIBUTION

SLR Reference:	720.10023.00001
Title:	Melmoth Iron ore project Waste Rock Waste Assessment and Geochemical Characterisation Study
Report Number:	0002
Client:	Jindal Iron Ore (Pty) Ltd

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