PROPOSED LEHATING MINE - MN48 MR CONSOLIDATION & EMP AMENDMENT

SPECIALIST STUDY: UPDATED GEOCHEMISTRY AND WASTE TYPE ASSESSMENT

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EXECUTIVE SUMMARY

Mn48 (Pty) Ltd (Mn48) is developing a new underground manganese mining operation near Black Rock in the John Taolo Gaetsewe District Municipality, Northern Cape Province. The Lehating Mine is a prospective manganese mine looking to exploit the Kalahari Manganese Field (KMF) in the Northern Cape Province of South Africa.

An acid rock drainage and geochemical investigation was conducted on the proposed Lehating mine by SLR in 2012 in support of the Integrated Water Use License Applications (IWULA), followed by a waste assessment of residues, in accordance with Regulation 634 and 635 and determination of the appropriate barrier systems for residue facilities in accordance with Regulation 636 completed in 2017.

Subsequent to these reports, Mn48 and Khwara Manganese (Pty) Ltd, who hold an approved EMPr for underground mining of manganese immediately adjacent and to the south of Lehating Mine, entered into an agreement to combine the two adjacent mineral resources and surface rights comprising the Khwara and Lehating Mines into a single, high-grade manganese mining company that will be known as Mn48 (Pty) Ltd (Mn48). Since this new agreement is proposing the consolidation of Mn48 and Khwara mining right areas, an updated geochemistry and waste assessment report that takes into account the new Lehating mine layout is required, notwithstanding the geochemical and waste assessment investigation results remaining the same.

To summaries, the objectives of the investigation are to assess the material to be stockpiled at the proposed waste rock dump (WRD) facility. The assessment includes:

- Evaluation of the acid forming potential of the materials;
- Estimation of the contamination potential the proposed WRD have to the water resources;
- A waste classification in terms of GN R. 634 (23 August 2013);
- A waste type assessment in terms of GN R. 635 (23 August 2013); and
- Determination of the liner requirements as per GN R. 636. (23 August 2013).

Samples tested comprised sections of diamond-drill core obtained from a borehole drilled at the adjacent Wessels property and grab samples from the Tshipi Mine, which is approximately 40 km to the south and has a similar geology to Lehating. Since similar geology was sampled in each case, the composite waste rock sample is likely to be indicative of the geochemical character of the Lehating waste rock until suitably representative site-specific samples are available.

With respect to the objectives of this study, the following conclusions apply:

- To determine if potentially acid forming material is present: The Lehating Composite proxy waste rock sample is not potentially acid generating.
- To assess the potential risk to water resources: considering the remote location, semi-arid climate, and low leachable concentrations associated with the proxy Lehating waste rock, the potential risk to water resources appears to be low. However, monitoring of local water resources downstream of waste rock dumps and stockpiles is required to confirm this.

The results of this investigation are generally consistent with the geochemical investigation conducted by SLR in 2012.

The waste classification (GN R. 634) and waste type assessment (GN R. 635) has been undertaken for the Lehating composite proxy sample.

The Lehating composite sample was classified as non-hazardous in terms of GN R. 634. In terms of GN R. 635, the Lehating composite waste rock sample assessment indicated a Type 3 waste based on the TC for Ba, Cd, Cu,

Mn, Sb and F exceeding TCT0 and Type 4 wastes based on their LC (no exceedances of LCT). This sample thus does not satisfy the complete criteria for a Type 3 waste (LCT0<LC≤LCT1 and TC≤TCT1) or the complete criteria for Type 4 waste (LC≤LCT0 and TC≤TCT0).

Risk Based Approach

The DWS accepted a proposal by the Chamber of Mines of South Africa to follow a risk-based approach on a case-by-case basis to allow for representations on alternative barrier systems for Mine Residue Deposits and Stockpiles based on a risk assessment (29 June 2016). The risk assessment will enable an evaluation of the efficacy of the alternative barrier system to prevent pollution as required in terms of Section 19 (1) and (2) of the NEM:WA (Singh, 2016). Since the purpose of the Norms and Standards is to protect water resources it may be appropriate to consider the potential water quality risk associated with existing facilities, rather than retroactively applying the legislated liner requirements.

The DWS, in its 3rd March 2016 response to the Water Use Licence Application (WULA) for Kudumane Mine which is located approximately 15km from the UMK Mine suggest that the waste type (Type 3) for samples may have been 'over-estimated'.

The DWS stated that "…the classification is based on the principle of assessing what is leachable and if it is leachable then what is the total concentration which will influence decisions on the total polluting period". In the case of Kudumane the leachable concentrations are reported to not exceed LCT0 values for any of the samples and hence a Class D barrier of only stripping of topsoil and foundation preparation is the requirement...".

SLR recommends a risk-based approach for protection of the water resource quality from the proposed Lehating WRD rather than a formulaic application of the Norms and Standards for the following reasons:

- The material was classified as non-hazardous;
- The leachable concentrations of all the constituents are below the LCT0 limit which indicates a low seepage risk;
- The material will be placed dry and not contain wastewater;
- From the geochemical study conducted by SLR it was concluded that the materials are non-PAG;
- The area has low rainfall and high evaporation that would limit recharge from the dumps;
- A class C liner is impractical for a WRD due to the possibility of failure; and
- A similar set of circumstances has been encountered at the nearby Kudumane mine. In that instance it was determined by the relevant authorities (including DWS) that a Class D barrier (including stripping topsoil and base preparation) will be adequate.
- Due to proxy composite samples being used to run the geochemical analysis, the reported results are to be considered preliminary and subject to confirmation once representative samples become available.

It is anticipated that the Class D barrier with topsoil stripping and base preparation will be adequate for the Lehating WRD. A meeting with the authorities is recommended to establish the acceptability of the risk-based approach for this material.

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ACRONYMS AND ABBREVIATIONS

Acronym / Abbreviation	Definition
ABA	Acid base accounting
Al	Aluminium
As	Arsenic
ASLP	Australian standard leaching procedure
Ba	Barium
BFS	Bankable feasibility study
BIF	Banded Iron Formation
Cd	Cadmium
Cr	Chromium
DEA	Department of Environmental Affairs
DWS	Department of Water and Sanitation
Fe	Iron
GARD	Global Acid Rock Drainage
GN R.	Government Notice Regulation
ICP	Inductively coupled plasma
IFC	International Financial Corporation
INAP	International Network for Acid Prevention
IPAG	Indicate potential acid generation
IWULA	Integrated Water Use Licence Application
KMF	Kalahari Manganese Field
KMF	Kalahari Manganese Field
LC	Leachable Concentrations
LCT	Leachable Concentration Threshold
LMO	Lower Manganese Ore Body
MMO	Middle Manganese Ore Body
Mn	Manganese
Mo	Molybdenum
MPRDA	Mineral & Petroleum Resources Development Act

Acronym / Abbreviation	Definition
NEM:WA	National Environmental Management: Waste Act
Ni	Nickel
NPR	Neutralising potential ratio
ROM	Run of mine
SANS	South African National Standards
Sb	Antimony
Se	Selenium
SPLP	Synthetic precipitation leaching procedure
TC	Total Concentration
TCT	Total Concentration Threshold
TSF	Tailings Storage Facility
TWPP	TWP Projects (Pty) Ltd
UMO	Upper Manganese Ore Body
WCMR	Waste Classification and Management Regulations
WHO	World Health Organisation
WRD	Waste Rock Dumps

1. INTRODUCTION

Mn48 (Pty) Ltd (Mn48) is developing a new underground manganese mining operation near Black Rock in the John Taolo Gaetsewe District Municipality, Northern Cape Province. The local setting is presented in Figure 1-1.

The Lehating Mine is a prospective manganese mine looking to exploit the Kalahari Manganese Field (KMF) in the Northern Cape Province of South Africa. The KMF is a large land-based manganese deposit and consists of low grade sedimentary Mamatwan-type ore (constitutes about 97% of the ore reserves) and high grade Wessels-type ore (constitutes about 3% of the known reserves). Lehating is located in the north-western part of the KMF. The ore body is contained in a graben structure which houses the Wessels-type high grade ore.

An acid rock drainage and geochemical investigation was conducted by SLR in 2012 in support of the Integrated Water Use License Applications (IWULA). Since 2014 the Department of Water and Sanitation (DWS) imposed new requirements for IWULAs. As part of these new requirements a waste assessment of residues, in accordance with Regulation 634 and 635, and determination of the appropriate barrier systems for residue facilities in accordance with Regulation 636 was completed in 2017.

Subsequent to these reports, Khwara Manganese (Pty) Ltd, who holds an approved EMPr for underground mining of manganese immediately adjacent and to the south of Lehating Mine and Mn48, entered into an agreement to combine the two adjacent mineral resources and surface rights comprising the Khwara and Lehating Mines into a single, high-grade manganese mining company that will be known as Mn48 (Pty) Ltd. Khwara Manganese (Pty) Ltd (Khwara) holds an approved EMPr for underground mining of manganese on Portion 2 of the farm Wessels 227 and the Remaining Extent and Portions 3 and 4 of the farm Dibiaghomo 226, while Mn48 has approval for a mine located on a portion of Portion 1 of the farm Lehating 741. The Khwara underground resource will be accessed via the Lehating mine, using Mn48's approved surface infrastructure. In this regard, no surface infrastructure will be established as part of the Khwara Mine.

Since this new agreement is proposing the consolidation of Mn48 and Khwara mining right areas, an updated geochemistry and waste assessment report that takes into account the new Lehating mine layout is required, notwithstanding that the geochemical and waste assessment investigation results will not change.

1.1 OBJECTIVES

The objectives of the waste assessment investigation were to assess the material to be stockpiled at the proposed waste rock dumps (WRD).

The assessment included:

- Evaluation of the acid forming potential of the materials;
- Estimation of the contamination potential the proposed WRD have to the water resources;
- A waste classification in terms of GN R. 634 (23 August 2013);
- A waste type assessment in terms of GN R. 635 (23 August 2013); and
- Determination of the liner requirements as per GN R. 636. (23 August 2013).

1.2 SCOPE

The scope of work was to:

- Conduct a data review;
- Analyse samples collected by Mn48; and

- Interpret the results in accordance with the required regulations.

The collection of the samples required for the assessment was not included in the scope of work. SLR provided Mn48 with a sampling and analysis strategy for the collection of waste rock samples representative of the Lehating site geochemistry. The samples were collected by the Mn48 and delivered to the SLR offices in Fourways. The samples comprised sections of diamond-drill core obtained from a borehole drilled at the adjacent Wessels property and grab samples from the Tshipi Mine which is approximately 40 km to the south with a similar geology to Lehating site. Since similar geology was sampled in each case, the composite waste rock sample is likely to be indicative of the geochemical character of the Lehating waste rock until suitably representative site-specific samples are available.

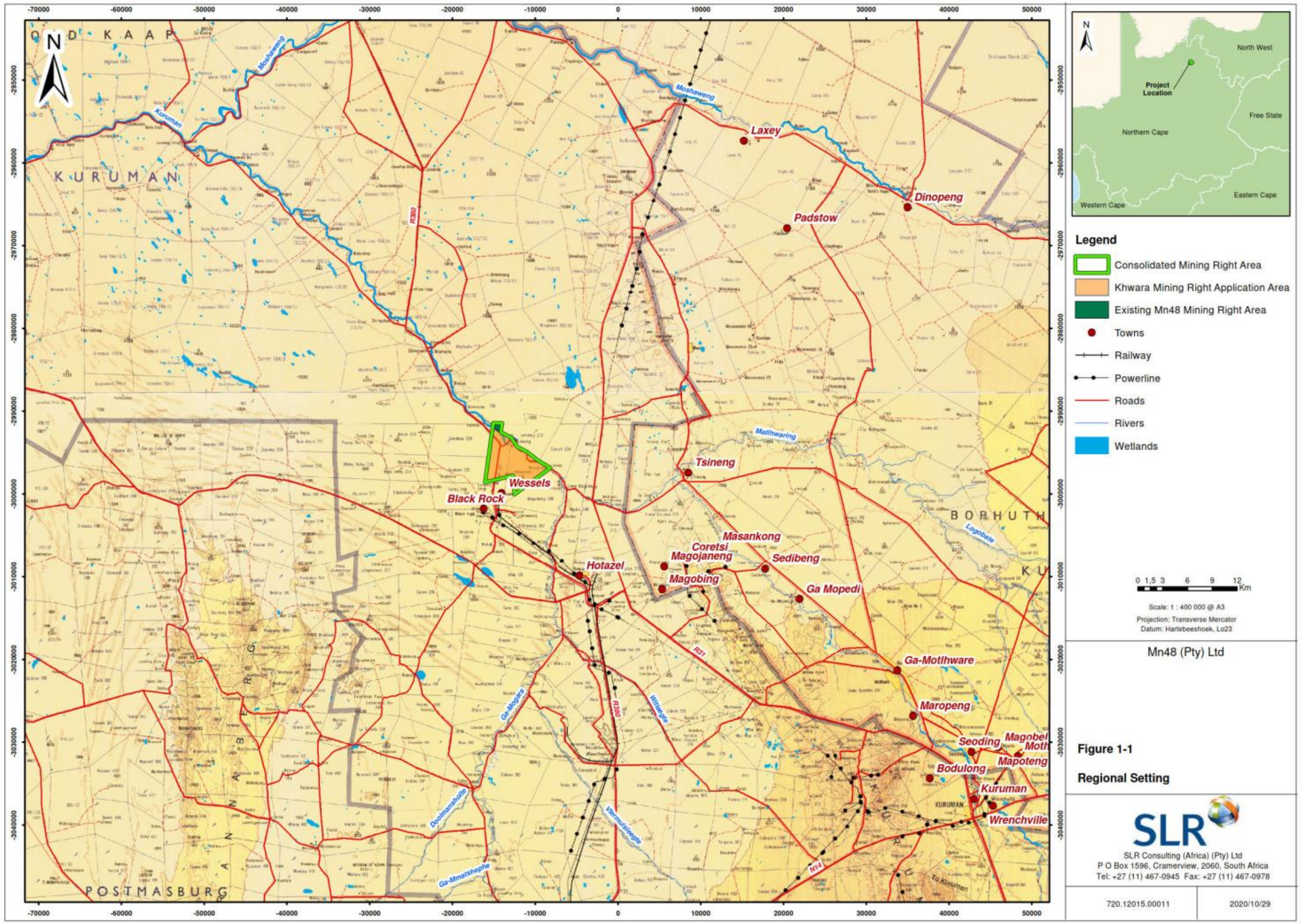

Figure 1-1: Site location for consolidated Lehating Mine

2. LEGISTLATION

The ambit of the National Environmental Management: Waste Act, 2008 (Act 59 of 2008) (NEM:WA) was amended as of 2 September 2014 and residue deposits and residue stockpiles from mining related activities are regarded as hazardous waste under the definitions in the NEM:WA. As such the requirements of the NEM:WA, its regulations and Norms and Standards apply to residue deposits and residue stockpiles. The definition of residue deposits and residue stockpiles in the NEM:WA is as assigned in the Mineral & Petroleum Resources Development Act.

The Department of Environmental Affairs (DEA) has revised the South African waste classification and assessment system under the NEM:WA. The Waste Classification and Management Regulations (WCMR) (GN R. 634 of 2013) were published in August 2013 and set out the requirements for the classification of waste and the assessment of waste for disposal. The WCMR references the following Norms and Standards with regards to waste assessment and classification:

- Waste Classification and Management Regulations (GN R. 634 of 2013);
- National Norms and Standards for the assessment of waste for landfill disposal (GN R.635 of 2013); and
- National Norms and Standards for disposal of waste to landfill (GN R.636 of 2013).

3. APPROACH

3.1 ACID GENERATION POTENTIAL REGULATORY REQUIREMENT

The International Network for Acid Prevention (INAP) (2009) sponsored the development of the Global Acid Rock Drainage (GARD) Guide, which outlines current international best practice for the prediction, prevention and management of acid rock drainage. This report follows this guideline.

3.2 WASTE ASSESSMENT AND CLASSIFICATION

This section aims to resolve the following objectives of this investigation:

- Classify the waste according to South African National Standards (SANS) 10234 as per GN R. 634 (23 August 2013);
- Undertake a waste type assessment in terms of GN R. 635 (23 August 2013);
- Determine the liner requirements as per GN R. 636. (23 August 2013);
- Planning and Management of Residue Stockpiles and Residue Deposits (GN R. 632 of 2015).

3.2.1 Legislation

The ambit of the National Environmental Management: Waste Act, 2008 (Act 59 of 2008) (NEM:WA) was amended as of 2 September 2014 and residue deposits and residue stockpiles from mining related activities are regarded as hazardous waste under the definitions in the NEM:WA. As such the requirements of the NEM:WA, its regulations and Norms and Standards apply to residue deposits and residue stockpiles. The definition of residue deposits and residue stockpiles in the NEM:WA is as assigned in the Mineral and Petroleum Resources Development Act, 2002 (MPRDA, Act No. 28 of 2002).

The Department of Environmental Affairs (DEA) has revised the South African waste classification and assessment system under the NEM:WA. The Waste Classification and Management Regulations (WCMR) (GN R. 634 of 2013) were published in August 2013 and set out the requirements for the classification of waste and the assessment of waste for disposal. The WCMR references the following Norms and Standards with regards to waste assessment and classification:

- Waste Classification and Management Regulations (GN R. 634 of 2013);
- National Norms and Standards for the assessment of waste for landfill disposal (GN R. 635 of 2013); and
- National Norms and Standards for disposal of waste to landfill (GN R. 636 of 2013).

3.2.2 Approach

3.2.2..1 Waste Classification in accordance with GN R. 634 SANS 10234

All waste generators must ensure that their waste is classified in accordance with the Global Harmonized System (GHS) of Classification of Chemicals and Labelling (SANS 10234:2008) within 180 days of generation in accordance with section 4(2) of GN R.634 of 2013, except if it is listed in Annexure 1 (Wastes that do not require Classification and Assessment). Waste must be kept separate for the purposes of classification and must not be mixed before classification. Furthermore, waste must be re-classified every 5 years.

The SANS 10234:2008 standard covers the harmonized criteria for the classification of hazardous substances according to their health, environmental and physical hazards. The GHS does not require testing where testing has been done previously. Information or data that has been published in journals or any credible source can be utilised to classify the waste stream.

Chemical test results as well as the intrinsic properties of the waste streams were used for the SANS10234:2008 classification. Concentrations of total and leachable constituents exceeding 1% (Table 3 1) were used for classification in terms of the health and environmental hazards, except where constituents are known to be toxic at lower concentrations based on the International Agency for Research on Cancer (IARC) Monographs (WHO-IARC, 2016) in which case concentrations of constituents exceeding 0.1% were noted.

Table 3-1: Cut-off/concentration limits for hazard classes

Hazard class	Cut-off value (concentration limit) %
Acute toxicity	> 1.0
Skin corrosion	> 1.0
Skin irritation	> 1.0
Serious damage to eyes	> 1.0
Eye irritation	> 1.0
Respiratory sensitisation	> 1.0
Skin sensitisation	> 1.0
Mutagenicity: Category 1	> 0.1 > 1.0

Hazard class	Cut-off value (concentration limit) %
Category 2	
Carcinogenicity	> 0.1
Reproductive toxicity	> 0.1
Target organ systemic toxicity	> 1.0
Hazardous to the aquatic environment	> 1.0

3.2.2..2 Waste Assessment in accordance with GN R.635 of 2013

In terms of Regulation 8 (1)(a) of the WCMR, waste generators must ensure that their waste is assessed in accordance with the Norms and Standards for Assessment of Waste for Landfill Disposal (GN R. 635) prior to the disposal of the waste to landfill.

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 must be 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 will determine the specific waste type according to Section 7 of GN R. 635.

3.2.2.3 Assessment of Waste for Landfill Disposal in Accordance with GN R.636 of 2013

In terms of Regulation 8 (1)(b) of the WCMR, waste generators must ensure that the disposal of their waste to landfill is undertaken in accordance with the Norms and Standards for Disposal of Waste to Landfill (GN R. 636).

Government notice regulation 636 sets out the landfill classification (Class A to D) and containment barrier design for each waste type as determined by the waste type assessment in accordance with GN R. 635. Figure 3-1 illustrates the flow diagram of the general processes to be followed to determine the waste type and liner requirements.

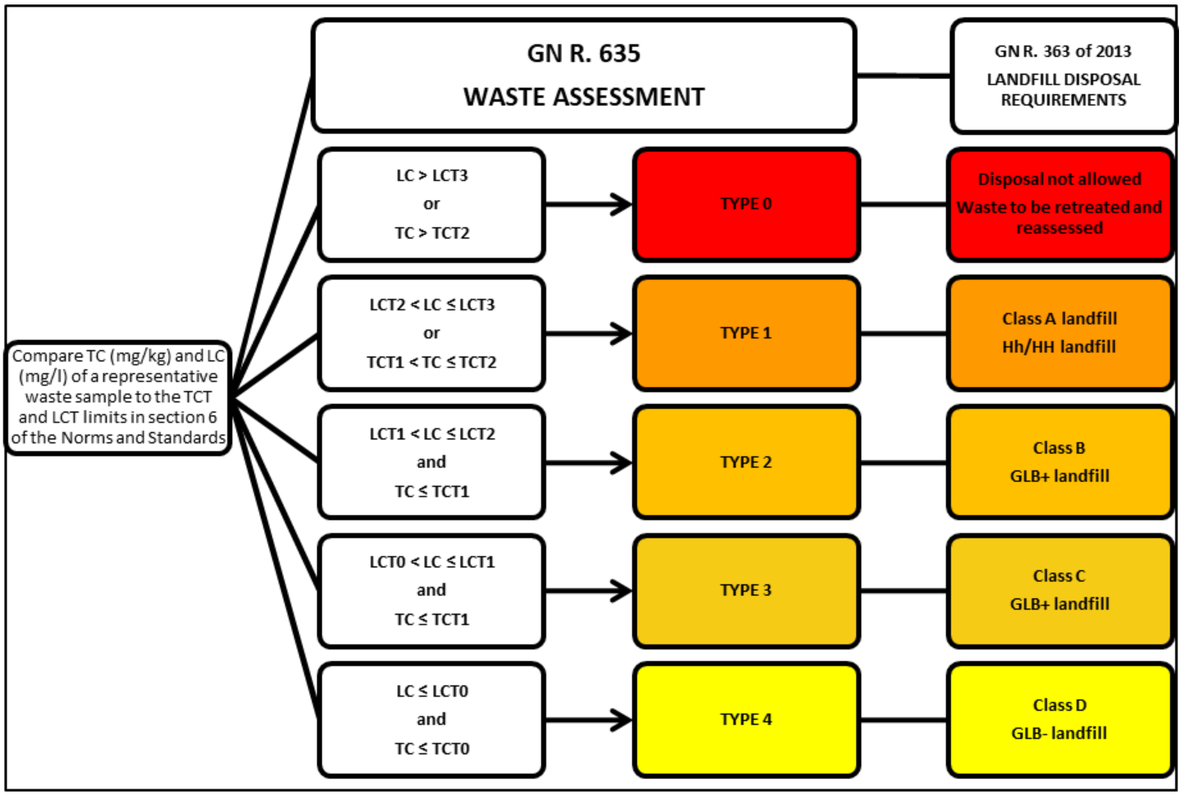

Figure 3-1: Flow diagram for assessing waste in terms of GN R. 635 of 2013 and GN R636 of 2013

4. DATA REVIEW

4.1 DATA INVENTROY

The available information examined which was applicable to the study is listed in Table 4-1.

Table 4-1: Sources of data

Author	Document Title	Reference	Document Date
Metago	Groundwater report – Lehating 741	WL 005-01	Apr-11
Metago	Groundwater report – Addendum Packer Tests	WL 005-01	Aug-11
SLR	Acid rock drainage and geochemical report	710.20011.00002	Feb-12
SLR	Desktop groundwater assessment – Lehating 741	WL 005-01	Apr-12
Mining Plus	Lehating Mining Pty Ltd Mineral Resource Estimation	MCLEHW21-MRE-003	Jun-13
SLR	Groundwater flow and contaminate transport modelling	710.12015.00001_R01	Aug-13
SLR	Environmental impact assessment and environmental management programme report for the proposed Lehating Mine	710.12015.00001	Jan-14
L. C. Blignaut	A petrographical and geochemical analysis of the upper and Lower Manganese Ore Bodies from the Kalahari Manganese deposit, Northern Cape, South Africa- control on hydrothermal metasomatism and metal upgrading	PhD thesis	2017
SLR	Lehating Environmental Authorisation Specialist Study: Geochemistry and Waste Type Assessment	720.12015.00006	Nov 2017

The information in these sources is summarised in the following sections.

4.2 GEOLOGY

The proposed project is located on the south western outer rim of the Kalahari Manganese Field (KMF). The general stratigraphic column of the Kalahari Manganese Field is presented in Table 4-2.

Three beds of manganese ore are interbedded with the Banded Iron Formation (BIF) of the Hotazel Formation (Transvaal Supergroup).

The BIF of the Hotazel Formation typically consists of repeated thin layers of black iron oxides (magnetite or hematite) alternating with bands of iron-poor shales and cherts.

The surface geology at Lehating is predominantly of Cenozoic deposits (Kalahari Formation). The Kalahari Formation is approximately 80 m thick and overlies the Dwyka Formation which forms the basal part of the Karoo Supergroup. The Dwyka Formation is approximately 200 m thick and overlies the Hotazel Formation which forms park of the Transvaal Supergroup.

Table 4-2: General stratigraphic column for the Kalahari Manganese Field

Supergroup / Group / Subgroup / Formation				Geological Description
Kalahari Group				Kalahari sands, calcrete, clays & gravel beds
Kalahari unconformity				
Karoo Supergroup				Dwyka tillite
Dwyka unconformity				
Olifantshoek Supergroup			Lucknow Formation	White ortho-quartzite
			Mapedi Formation	Green, maroon and black shales and quartzites
Olifantshoek unconformity				
Transvaal Supergroup	Postmansburg Group	Voelwater Subgroup	Mooidraai Formation	Dolomite, chert
			Hotazel Formation	Banded ironstone (upper)
				Upper Mn Ore Body
				Banded ironstone (middle)
				Middle manganese body
				Banded ironstone (middle)
				Lower manganese body
				Banded ironstone (lower)
		Ongeluk Formation		Andesitic Lava

4.3 GROUNDWATER FLOW AND CONTAMINATE TRANSPORT

In 2014 SLR was contracted to provide specialist groundwater input as part of the EIA during the development of the Lehating Mine. A regional groundwater flow model was developed based on the available and site-specific aquifer parameters to evaluate the potential impacts of mining activities on groundwater flow and quality. The numerical model was used to predict the spreading of potential contaminants within the groundwater system based on a worst-case scenario assuming conservative, non-retarded contaminant transport behaviour. The potential contaminant sources contained within the model included the unlined tailings storage facility (TSF), WRD and other stockpiles. No specific source concentration was modelled, and the plumes were illustrated as a percentages of a relative source concentration. Table 4 3 shows the seepage rates and source concentrations for the TSF and WRD used in the groundwater flow model conducted in 2014 (SLR).

Table 4-3: Seepage rate and source concentrations used in the groundwater flow model conducted in 2014

Scenario	Seepage rate (m/d)	Source concentration (%)
TSF[1]	0.000432 (unlined)	100
WRD	Natural recharge	100
Other Stockpiles	Natural recharge	100

The contaminant transport model estimated the dispersion of the contaminant plume. The dominant spreading of the potential contaminants/pollutants associated with the modelled sources occurred in a radial manner and towards the north-west. The potential pollutant spread occurred within the mining boundary.

The model showed localised pollutant spreading might occur towards the Kuruman River. However, from the predicted spreading plume no potential pollutants reached the Kuruman River within the first 100 years. The model indicated that the simulated pollution plume spread (up to 100 years) will impact the groundwater as resource, however no indication of third-party groundwater users or surface water will be impacted. Impact is highly likely to occur and will affect both the groundwater flow and groundwater quality on a local scale. Localised but widespread impact may occur if the contaminated groundwater daylights into highly conductive alluvial systems and rivers.

4.1 GEOCHEMISTRY

In 2012 SLR conducted a geochemical assessment to provide technical input to the preparation of an Acid Rock Drainage (ARD) Management plan for the proposed Lehating Mine. Four samples of material likely to be encountered during the mining operation were collected from site and geochemical test work undertaken. The test work included acid base accounting (ABA), net acid generation (NAG), and leach tests. The results obtained during this investigation are summarized in Table 4-4.

[1] The approved EMPr for Mn48 specified the need for a TSF, however, the client has since made a fundamental change to the mineral processing methodology whereby a dry screening process will be used, instead of a wet process which does away with the need for a TSF.

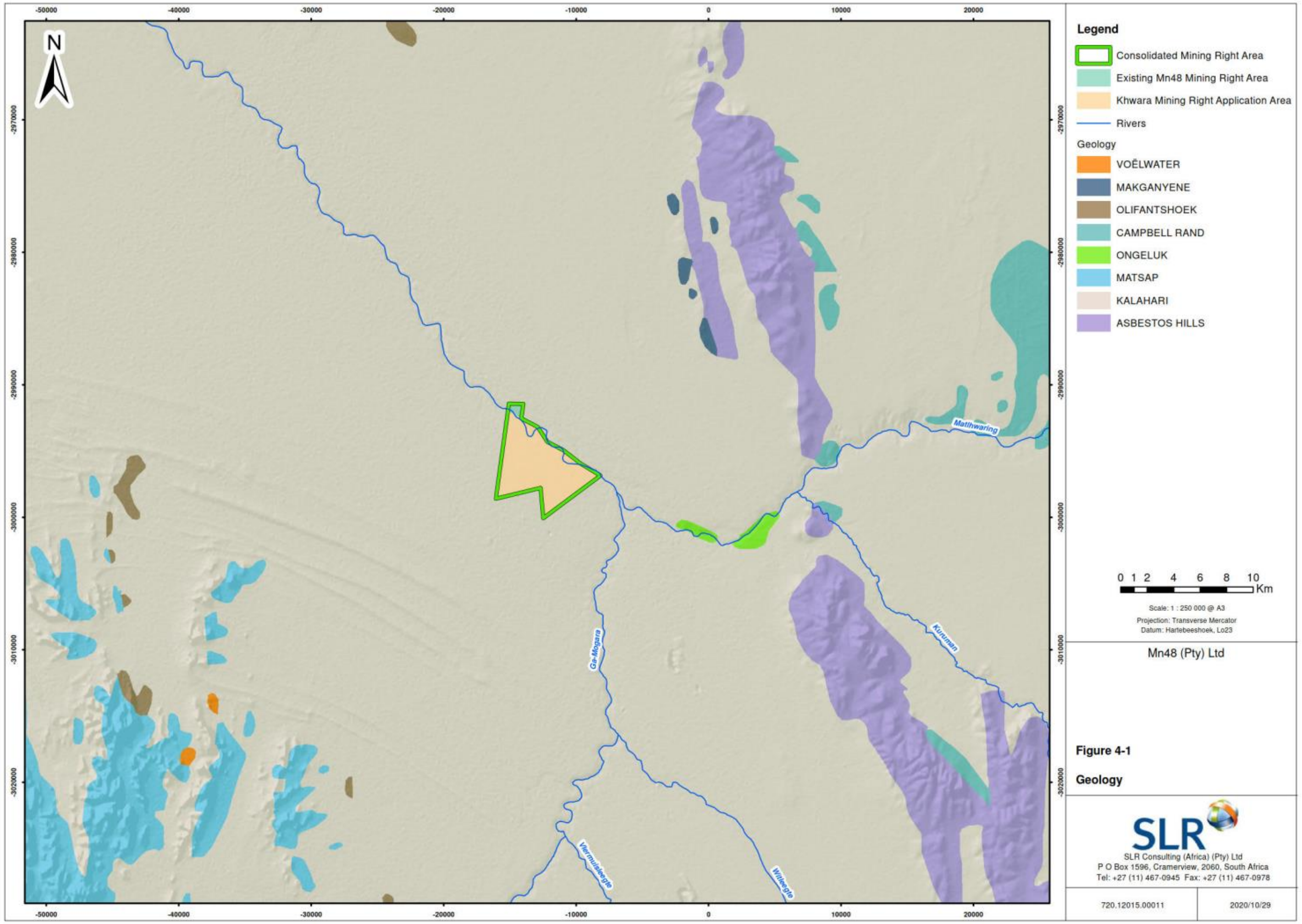

Figure 4-1: Surface geology of the proposed Lehating Mine and surrounding mines

Table 4-4: Analytical results obtained from geochemical analysis of Lehating geological material (SLR, 2012)

Laboratory Test	Kalahari Formation	Dwyka	Ongeluk Lava	Mn Ore
Acid base accounting				
NAG pH	6.7	6.8	4.2	6.5
NAG (kg H_2SO_4/t)	<0.01	<0.01	1.18	<0.01
Paste pH	7.2	7.7	8.0	6.9
Total Sulphur (%)	<0.01	-	<0.01	0.05
Sulphate (SO_4^{2-}) Sulphur (%)	<0.01	-	<0.01	0.04
Sulphide (S^{2-}) Sulphur (%)	0.01	-	<0.01	<0.01
Acid Potential (AP) [kg $CaCO_3$/t]	0.31	8.46	0.31	1.44
Total Carbon (%)	1.94	1.55	0.03	0.12
Organic Carbon (%)	0.05	0.46	0.01	<0.01
Inorganic Carbon (%)]	1.89	1.09	0.02	0.11
Neutralizing Potential (NP) [kg $CaCO_3$/t]	85.8	39.2	5.59	23.5
Net Neutralizing Potential NNP (=NP-AP)	85.5	30.7	5.28	22.1
Neutralizing Potential Ratio NPR (=NP/AP)	275	4.63	17.9	16.3
Assessment	Non-Acid Forming	Non-Acid Forming	Non-Acid Forming	Non-Acid Forming
SPLP Leachate analysis Exceedances with regards to relevant quality criteria				
Leachate at pH 7	none	Al, As, B, Cr, Fe, Mn, Mo, Ni,	Al, Fe, Mn	B, Ba, Mn
Leachate at pH 3	Ba, Mn, Sb	B, Mn	Mn	B, Ba, Mn

Based on the laboratory results, it was concluded that all four samples were not potentially acid generating (non-PAG) with sufficient neutralising potential to compensate any potentially generated acidity. The results from the assessment can be summarised as follows:

- Based on ABA testing all four samples are classified as non-PAG.
- When compared to the WHO drinking water standards (see Table 4-4), the leaching procedure results suggest that a number of constituents in leachate from waste material could exceed the standard:
  - The SPLP results under neutral conditions (pH 7) identified the following constituents of concern: aluminium (Al), arsenic (As), boron (B), barium (Ba), chromium (Cr), iron (Fe), manganese (Mn), molybdenum (Mo) and nickel (Ni).
  - The SPLP results under acidic conditions (pH 3) identified the following constituents of concern: antimony (Sb), B, Ba and Mn.

Based on the available data, the quality of the leachate produced was found to be unacceptable for discharge (when compared to relevant chemical water quality standards) into the environment without treatment. However, it is noted that these conclusions were based on four samples and it was recommended that further test work be undertaken (specifically on waste rock) to confirm the results and to better understand the potential for acid generation and metal leaching at the proposed Lehating Mine. This recommendation led to the additional geochemical test work described in this report.

5. SAMPLING AND ANALYSIS

Previous geochemical work from Lehating assessed four waste rock lithologies individually. The combined water quality impact of all lithologies in the proposed Lehating WRD is required for the Water Use Licence (WUL). Therefore, this assessment was directed at obtaining a composite waste rock sample.

5.1 SAMPING SELECTION AND COLLECTION

Lehating provided the waste rock samples. As no fresh geological core material was available from the Lehating property, material was sourced from the neighbouring Wessels property and the Tshipi Borwa mine (located approximately 40 km to the south-southeast of Lehating). Based on a review of the available data for the site and communication with Jeff Leader[2], SLR prepared a sampling and analysis strategy for the collection of waste rock samples. The samples were obtained from exploration drill cores from the Wessels property and grab samples from the Tshipi Borwa open pit.

It was established that the material to be deposited on the Lehating WRD will consist of material from the main shaft (borehole LEX14) and the ventilation shaft (borehole LEX27). Borehole logs for the shafts were provided by Nico Hager from Lehating. The location of the boreholes are indicated in Figure 5-1 along with the location of the borehole from which samples from the Wessels property were sourced (TN17). The remainder of the samples were collected from the open pit of the Tshipi Borwa mine.

Lithology samples were selected based on the relative length of intersections in drill cores (LEX14 and LEX27). Table 5-1 presents the proportion of each lithology based on the length of intersections in drill cores LEX14 and LEX27. Table 5-1 also presents the location from where each lithology was sourced.

As indicated in Table 5-1 two samples (representing approximately 58% of the Lehating overburden lithology) were obtained from Wessels property. Six samples (representing approximately 42% of the Lehating overburden lithology) were obtained from the Tshipi Mine. The geology at both locations is similar.

A composite waste rock sample combining the eight lithology samples in proportions indicated from Lehating overburden boreholes was developed for geochemical testing. The composite sample developed from these samples is a proxy of Lehating overburden. The proxy composite indicates the likely Lehating waste rock geochemistry until suitably representative site-specific samples are available.

[2] Jeff Leader is the project manager for Ntsimbintle on the Wessels site and has worked on the project since 2008. His experience in manganese dates back to 2004.

Table 5-1: Percentage of different lithologies found in the main and ventilation shafts at Wessels based on two borehole logs including source of samples

Lithology	Total length of lithology (m)	Percentage of lithology (%)	Source of lithology sample collected
Sand	24	4.6	Tshipi Borwa - Pit
Gravel	14	2.7	Tshipi Borwa - Pit
Clay	89	17.0	Tshipi Borwa - Pit
Calcrete	17	3.2	Tshipi Borwa - Pit
Dwyka	157.51	30.1	Wessels - Borehole (TN17)
Lava	148.29	28.3	Wessels - Borehole (TN17)
Gravel - Coarse	69	13.2	Tshipi Borwa - Pit
Red Clay	5	1.0	Tshipi Borwa - Pit
TOTAL	**523.8**	**100**	

5.2 LABORATORY ANALYSIS

The lithology samples provided by Lehating through Jeff Leader were submitted to Waterlab (Pty) Ltd (Waterlab) in South Africa. The lab developed a 1 kg proxy sample, Lehating Composite, using the percentages of each lithology as specified in Table 5-1.

SLR instructed Waterlab to analyse the Lehating Composite proxy waste rock sample per the following tests:

- Acid Base Accounting (ABA);
- Sulphur Speciation;
- Total elemental concentrations by Aqua regia digestion; and
- Synthetic Precipitation Leaching Procedure (SPLP) test at a solid to solution ratio of 1:4.

Appendix A presents a brief description of the analytical methods.

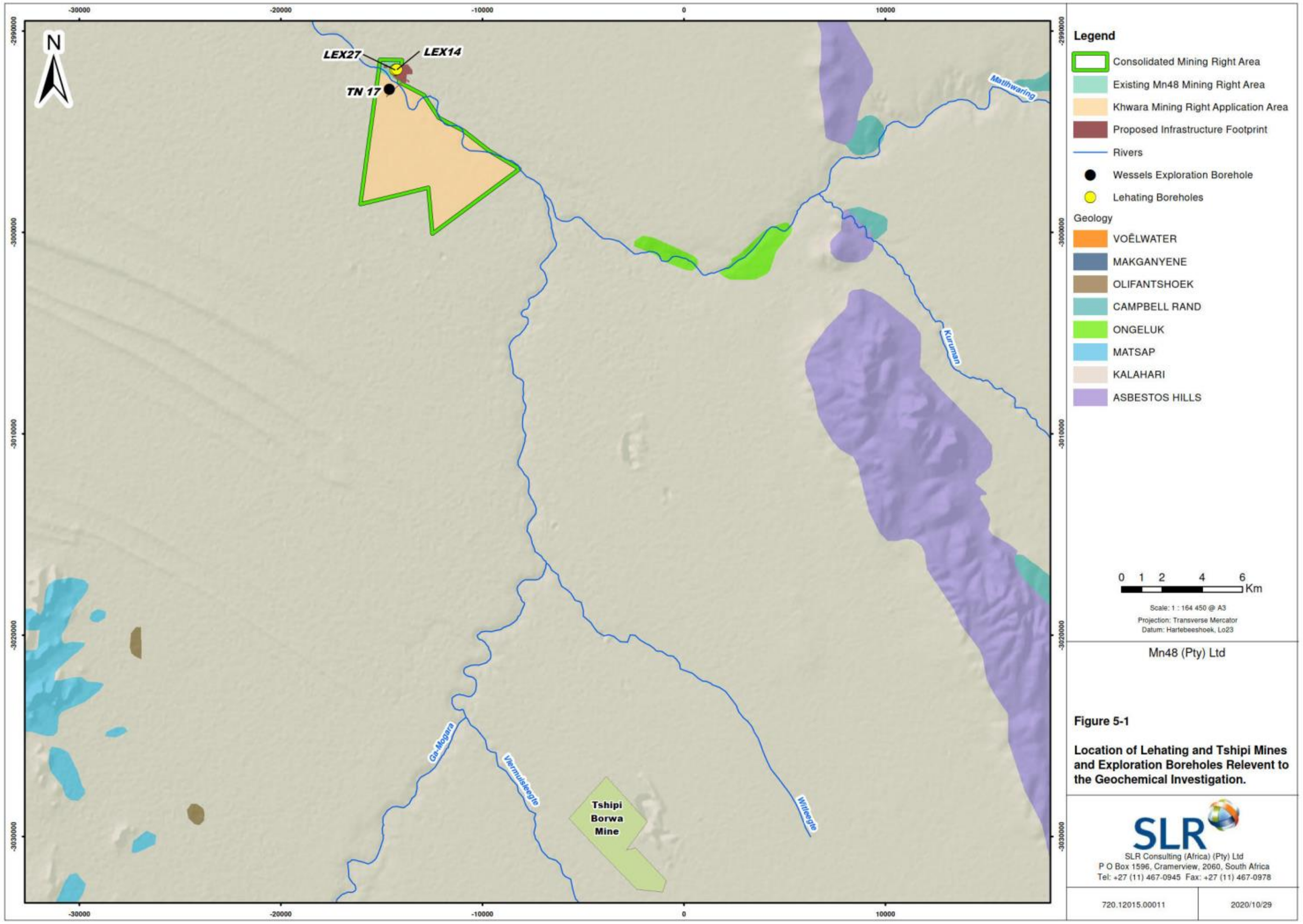

Figure 5-1: Location of Lehating and Tshipi Mines and exploration borehole relevant to the geochemical investigation

6. RESULTS

The results of test work undertaken as part of this assessment are provided in the following section. Appendix B presents copies of the laboratory reports.

6.1 GEOCHEMISTRY

6.1.1 ACID-BASE ACCOUNTING

The ABA results are presented in Table 6-1. The ABA results show that the total sulphur, sulphide and sulphur content is below the reporting limit (<0.01 %) for all the samples assessed. For sustainable long-term acid generation at least 0.3% Sulphide-S is needed (Price and Errington, 1994).

The neutralising potential ratio (NPR) is significantly above two (Figure 6-1), which implies the material has sufficient neutralising potential to offset the low acid potential. Therefore, the Lehating Composite waste sample is classed as Non-PAG according to the methodology of Price (2009).

The paste pH was alkaline and indicates that there is little potential for the generation of short-term acidity from the proposed Lehating WRD.

Table 6-1: Acid-base accounting results for Lehating proxy waste rock sample

Sample ID	*Criteria*	Lehating composite
Paste pH	*> 5.5 (Non-PAG)*	8.3
Total Sulphur (%) (LECO)		<0.01
Sulphate Sulphur as S (%)		<0.01
Sulphide Sulphur (%)	*Sulphide-S > 0.3* *Short-term PAG*	<0.01
Acid Potential (AP) (kg/t)		0.313
Neutralization Potential (NP)		90.0
Nett Neutralization Potential (NNP)	*NNP>0 (Non-PAG)*	89.7
Neutralising Potential Ratio (NPR) (NP : AP)	*NPR>2 (Non-PAG)*	288
Classification		Non-PAG

Non-PAG: Non-Potentially acid generating

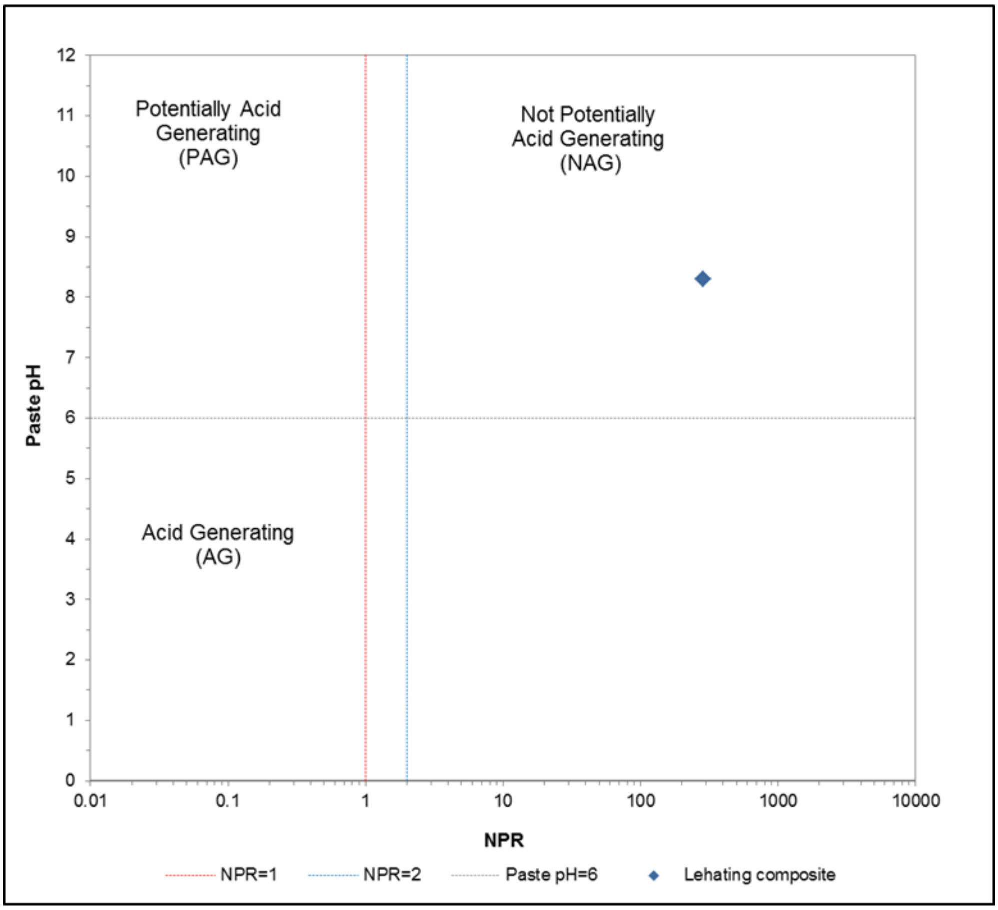

Figure 6-1: Neutralising potential ration (NPR) and paste pH

6.1.2 TOTAL ELEMENT CONCENTRATIONS

A measure of enrichment of elements in whole rock samples is the Geochemical Abundance Index (GAI) (INAP, 2009). The GAI for an element is calculated as follows:

GAI = log2 [Concentration of element in sample/(1.5 x median crustal abundance)]

As a general guide, a GAI of 3 or more is considered significant and indicates that enrichment may have occurred and thus further examination may be required (INAP, 2009). The total concentrations of trace elements were compared to the average (median) crustal abundance (Fortescue, 1992). Where values were below the detection limit, half the detection limit was used. The only trace elements with GAI greater than three in the Aqua Regia digest are cadmium (Cd), antimony (Sb) and selenium (Se). The results suggest that Cd, Sb and Se may be leachable in significant concentrations and could lead to environmental risk. This was further assessed from leach tests as discussed in the following section.

6.1.3 LEACHING POTENTIAL

The leach test results for the waste rock material are presented in Table 6-2.

Leach test results are not an indicator of drainage quality as the conditions of the test, especially the liquid-to-solid ratio, do not represent actual field conditions. Therefore, leachate concentrations are not representative of seepage or run-off that could emanate from site. However, the results may indicate chemicals of concern (CoCs) in mine drainage.

As a preliminary screening to identify potential CoCs, the leachates were compared to the following water quality and effluent standards:

- World Health Organisation (WHO) Guidelines for drinking-water quality (WHO, 2011);
- International Finance Corporation (IFC) Guidelines for Mining Effluents (IFC, 2007); and
- South African National Standards (SANS) 241 (2011) Drinking Water (SANS 241:2011).

Use of drinking water guidelines does not suggest that leachates and drainage from mine activities will be used for drinking purposes. Use of these guidelines is purely intended as a preliminary indicator of potential environmental risk.

The majority of the trace metal concentrations were below the detection limit, including Cd, Sb, and Se. The elements boron (B), barium (Ba), molybdenum (Mo), strontium (Sr) were detected. However, none of the values reported exceeded the screening criteria listed above.

6.1 WASTE CLASSIFICATION ACCORDING TO GN R.634

The Lehating proxy sample was classified in terms of its intrinsic properties/hazards. The classification criteria include:

- Physical hazards (flammability, corrosiveness, etc.);
- Health hazards (toxicity, carcinogenicity, etc.); and
- Environmental hazards (aquatic toxicity, bioaccumulation, etc.).

6.1.1 PHYSICAL HAZARDS

The Lehating composite sample is not considered flammable, explosive, or oxidising and is not expected to release significant volumes of toxic gases when in contact with water or acid. Therefore, it is not hazardous in terms of physical characteristics.

6.1.2 HEALTH HAZARDS

The percentage concentration of chemical elements obtained from the Aqua regia digestion and SPLP results were compared to the cut-off values/concentration limits for hazard classes (Table 3-1). None of the total or leachable concentrations of chemical elements (Table 6-3) exceeded the 1.0%. Considering the total and leachable (soluble) concentrations of chemical elements, the Lehating composite sample does not pose a significant risk to human health.

Table 6-2: SPLP results for samples supplied by Lehating

Relevant Water Quality Standards	Ag	Al	As	B	Ba	Be	Bi	Ca	Cd	Co	Cr	Cu	Fe	K	Li	Mg	Mn	Mo	Na	Ni
WHO Standard for Drinking Water (2011)	N/A	N/A	0.01	2.4	0.7	N/A	N/A	N/A	0.003	N/A	0.05	2.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.07
IFC Mining Effluent (2007)	N/A	N/A	0.1	N/A	N/A	N/A	N/A	N/A	0.05	N/A	0.1	0.3	2	N/A	N/A	N/A	N/A	N/A	N/A	0.5
SANS 241 (2011) Operational	N/A	0.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SANS 241 (2011) Aesthetic	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.3	N/A	N/A	N/A	0.1	N/A	200	N/A
SANS 241 (2011) Acute Heath	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SANS 241 (2011) Chronic Health	N/A	N/A	0.01	N/A	N/A	N/A	N/A	N/A	0.003	0.5	0.05	2	2	N/A	N/A	N/A	0.5	N/A	N/A	0.07
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
Lehating Composite	<0.010	<0.100	<0.010	0.072	0.021	<0.010	<0.010	8	<0.010	<0.010	<0.010	<0.010	<0.025	2.3	<0.010	4	<0.025	0.028	21	<0.010

Relevant Water Quality Standards	P	Pb	Sb	Se	Si	Sn	Sr	Ti	V	W	Zn	Zr	pH	EC	TDS	Alkalinity	Cl	SO4	NO3 (N)	F
WHO Standard for Drinking Water (2011)	N/A	0.01	0.02	0.04	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	11	1.5
IFC Mining Effluent (2007)	N/A	0.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SANS 241 (2011) Operational	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	5 - 9.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SANS 241 (2011) Aesthetic	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	5	N/A	N/A	170	N/A	N/A	300	250	N/A	N/A
SANS 241 (2011) Acute Heath	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	500	11	N/A
SANS 241 (2011) Chronic Health	N/A	0.01	0.02	0.01	N/A	N/A	N/A	N/A	0.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.5
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	-	mS/m	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Lehating Composite	<0.010	<0.010	<0.010	<0.010	5.8	<0.010	0.052	<0.010	<0.010	<0.010	<0.010	<0.010	7.5	19.4	100	24	7	15	2.4	0.6

Note: Values that were below the laboratory reporting limit is shown in grey

6.1.3 ENVIRONMENTAL HAZARDS

The leachable concentrations of all major chemical elements were below 1.0% and in some cases, below the laboratory detection limits. Due to these low leachable concentrations of all chemical elements, in all the samples, the Lehating composite sample is unlikely to pose unacceptable risk to the environment.

6.2 WASTE ASSESSMENT ACCORDING TO GN. R 635

The full laboratory certificates for the waste samples can be found in Appendix A.

6.2.1 TOTAL CONCENTRATION

The analytical results of the total (*aqua regia)* concentrations of chemical elements in the waste rock for which TCT limits are available is presented in **Error! Reference source not found.**.

Shaded values indicated in grey, yellow or red show where TCs exceeded the TCT0 threshold levels but were still lower than TCT1, or exceed TCT1 but lower than TCT2 and exceeded TCT2 respectively. The results showed that the total barium (Ba), cadmium (Cd), copper (Cu), manganese (Mn), antimony (Sb) and fluoride (F) concentrations exceeded the TCT0 limit but remained below the TCT1 limit.

Table 6-3: Total concentration of COC in waste rock samples compared to TCT limits

Analysis	Unit	TCT0	TCT1	TCT2	Lehating Composite
Metal Ions					
As, Arsenic	mg/kg	5.8	500	2000	<4.00
B, Boron	mg/kg	150	15000	6000	<10
Ba, Barium	mg/kg	62.5	6250	25000	306
Cd, Cadmium	mg/kg	7.5	260	1040	12
Co, Cobalt	mg/kg	50	5000	20000	<10
Cr_{Total}, Chromium	mg/kg	46000	800000	N/A	95
Cu, Copper	mg/kg	16	19500	78000	26
Hg, Mercury	mg/kg	0.93	160	640	<0.400
Mn, Manganese	mg/kg	1000	25000	100000	1480
Mo, Molybdenum	mg/kg	40	1000	4000	<10
Ni, Nickel	mg/kg	91	10600	42400	55
Pb, Lead	mg/kg	20	1900	7600	<4.00
Sb, Antimony	mg/kg	10	75	300	11
Se, Selenium	mg/kg	10	50	200	<4.00
V, Vanadium	mg/kg	150	2680	10720	57
Zn, Zinc	mg/kg	240	160000	640000	44
Inorganic Anions					
Cr(VI), Chromium (VI) Total	mg/kg	6.5	500	2000	<5
Total Fluoride	mg/kg	100	10000	40000	287
Total Cyanide as CN	mg/kg	14	10500	42000	<0.01

Note: Grey: TCT0 < TC < TCT1; **Yellow**: TCT1 < TC < TCT2; **Red**: TC > TCT2. Values that were below the laboratory reporting limit is shown in grey.

6.2.2 LEACHABLE CONCENTRATIONS

The analytical results of the leachable concentrations of the rock samples according to the ASLP method (Appendix A) are presented in Table 6-4.

The results indicated that none of the constituents assessed exceeded the LCT0 limit.

Table 6-4: Leachable concentrations of waste samples compared to leachable concentrations threshold limits

Analysis	Unit	LCT0	LCT1	LCT2	LCT3	Lehating Composite	
						1:4 dilution	1:20 calculated
Electrical Conductivity	mS/m					19.4	3.88
pH	-					7.5	7.5
Metal ions							
As, Arsenic	mg/l	0.01	0.5	1	4	<0.010	brl
B, Boron	mg/l	0.5	25	50	200	0.072	0.014
Ba, Barium	mg/l	0.7	35	70	280	0.021	0.004
Cd, Cadmium	mg/l	0.003	0.15	0.3	1.2	<0.010	brl
Co, Cobalt	mg/l	0.5	25	50	200	<0.010	brl
Cr, Chromium	mg/l	0.1	5	10	40	<0.010	brl
Cr(VI), Hexavalent Chromium	mg/l	0.07	3.5	7	28	<0.010	brl
Cu, Copper	mg/l	2	100	200	800	<0.010	brl
Hg, Mercury	mg/l	0.006	0.3	0.6	2.4	<0.010	brl
Mn, Manganese	mg/l	0.5	25	50	200	<0.025	brl
Mo, Molybdenum	mg/l	0.07	3.5	7	28	0.028	0.006
Ni, Nickel	mg/l	0.07	3.5	7	28	<0.010	brl
Pb, Lead	mg/l	0.01	0.5	1	4	<0.010	brl
Sb, Antimony	mg/l	0.02	1	2	8	<0.010	brl
Se, Selenium	mg/l	0.01	0.5	1	4	<0.010	brl
V, Vanadium	mg/l	0.2	10	20	80	<0.010	brl
Zn, Zinc	mg/l	5	250	500	2000	<0.010	brl
Inorganic Anions							
Nitrate as N	mg/l	11	550	1100	4400	2.4	0.48
Sulphate as SO4	mg/l	250	12500	25000	100000	15	3
Chloride as Cl	mg/l	300	15000	30000	120000	7	1.4
TDS	mg/l	1000	12500	25000	100000	100	20
Fluoride as F	mg/l	1.5	75	150	600	0.6	0.12

Note: Values that were below the laboratory reporting limit is shown in grey.

6.2.3 Determining Waste Type

The waste type for the Lehating composite sample, determined through the waste type assessment, as presented in Table 6-3 and are presented in Table 6-5. The reason for the classification along with the required landfill based on the classification is also provided in Table 6 5.

Table 6-5: Waste types determined from wate rock proxy samples for Lehating mine

Sample Name	Lithology	Waste Type	Reason for classification	Landfill Class
Lehating composite	Sand Gravel Clay Calcrete Dwyka Lava Gravel - Coarse Red Clay	**Type 3**	Ba, Cd, Cu, Mn, Sb and F exceed TCT0	Class C
		Type4	No exceedance of LCT0	Class D

6.2.4 Determining Landfill Class (Liner Requirements)

Figure 6-2 depicts the prescribed liner requirements for a Class C liner and Figure 6-3 shows the liner requirements for a Class D liner.

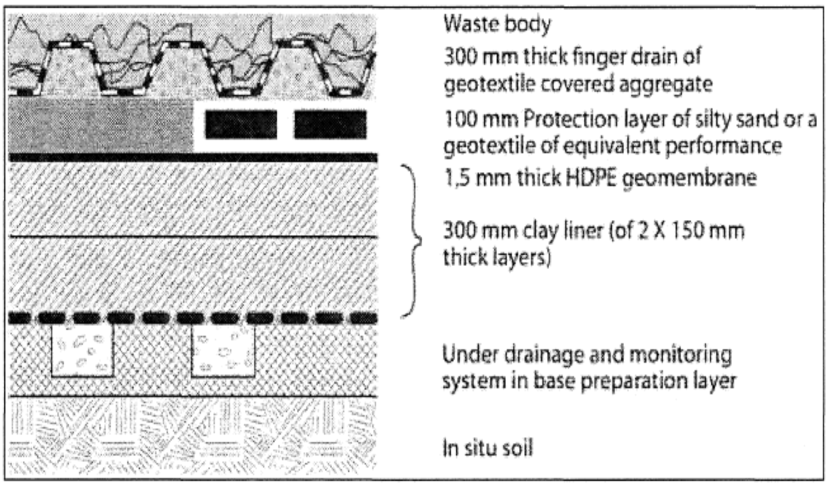

Figure 6-2: Class C prescribed lining requirements

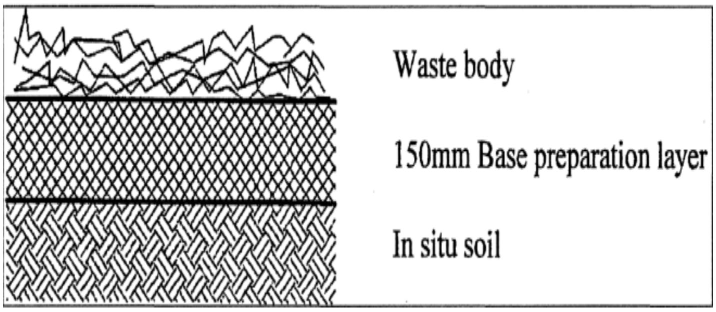

Figure 6-3: Class D prescribed lining requirements

7. ASSUMPTIONS AND LIMITATIONS

The following assumptions and limitations are pertinent to the investigation:

- The relevant WRD material could not be sampled directly from Lehating and a proxy sample was developed using lithology samples from the Wessels property and Tshipi Borwa mine.
- The Lehating composite concentration used for the waste assessment and classification was based on the percentage contribution of each lithology based on lithology logs received from Lehating.
- It is assumed that the geological setting at the Kudumane mine is comparable to that of Lehating (refer to Conclusion).
- Toxicity tests were not performed on the composite sample.

8. CONCLUSIONS

The objective of this investigation was to undertake geochemical characterisation of mineral material to be stockpiled at Lehating in the proposed WRD. This is to fulfil requirements of the IWULA.

The relevant WRD material could not be sampled directly from Lehating. However, a proxy sample of waste rock was developed using lithology samples selected from the Wessels property and Tshipi Borwa mine. These were combined into a composite sample ("Lehating composite") in the proportions determined from Lehating borehole profiles.

Due to the lack of site-specific samples, the conclusions from this study must be considered preliminary and subject to confirmation once representative samples are available.

8.1 GEOCHEMISTRY

With respect to the objectives of this study, the following conclusions apply:

- To determine if potentially acid forming material is present: The Lehating Composite proxy waste rock sample is not potentially acid generating.
- To assess the potential risk to water resources: Considering the remote location, semi-arid climate, and low leachable concentrations associated with the proxy Lehating waste rock, the potential risk to water resources appears to be low. However, monitoring of local water resources downstream of waste rock dumps and stockpiles is required to confirm this.

The results of this investigation are generally consistent with the geochemical investigation conducted by SLR in 2012.

8.2 WASTE CLASSIFICATION AND ASSESSEMENT

The waste classification (GN R. 634) and waste type assessment (GN R. 635) has been undertaken for the Lehating composite proxy sample.

The Lehating composite sample was classified as non-hazardous in terms of GN. R. 634. In terms of GN R. 635, the Lehating composite waste rock sample assessment indicated a **Type 3** waste based on the TC for Ba, Cd, Cu, Mn, Sb and F exceeding TCT0 and Type 4 wastes based on their LC (no exceedances of LCT). This sample thus do not satisfy the complete criteria for a **Type 3** waste (LCT0<LC≤LCT1 **and** TC≤TCT1) or the complete criteria for Type 4 waste (LC≤LCT0 **and** TC≤TCT0).

Risk Based Approach

The DWS accepted a proposal by the Chamber of Mines of South Africa to follow a risk-based approach on a case-by-case basis to allow for representations on alternative barrier systems for Mine Residue Deposits and Stockpiles based on a risk assessment (29 June 2016). The risk assessment will enable an evaluation of the efficacy of the alternative barrier system to prevent pollution as required in terms of Section 19 (1) and (2) of the NEM:WA (Singh, 2016). Since the purpose of the Norms and Standards is to protect water resources it may be appropriate to consider the potential water quality risk associated with existing facilities, rather than retroactively applying the legislated liner requirements.

The DWS, in its 3rd March 2016 response to the Water Use Licence Application (WULA) for Kudumane Mine which is located approximately 15km from the UMK Mine suggest that the waste type (Type 3) for samples may have been 'over-estimated'.

The DWS stated that "…the classification is based on the principle of assessing what is leachable and if it is leachable then what is the total concentration which will influence decisions on the total polluting period". In the case of Kudumane the leachable concentrations are reported to not exceed LCT0 values for any of the samples and hence a Class D barrier of only stripping of topsoil and foundation preparation is the requirement...".

9. RECOMMENDATIONS

SLR recommends a risk-based approach for protection of the water resource quality from the proposed Lehating WRD rather than a formulaic application of the Norms and Standards for the following reasons:

- The material was classified as non-hazardous;
- The leachable concentrations of all the constituents are below the LCT0 limit which indicates a low seepage risk;
- The material will be placed dry and not contain wastewater;
- From the geochemical study conducted by SLR it was concluded that the materials are non-PAG;
- The area has low rainfall and high evaporation that would limit recharge from the dumps;
- A class C liner is impractical for a WRD due to the possibility of failure; and
- A similar set of circumstances has been encountered at the nearby Kudumane mine. In that instance it was determined by the relevant authorities (including DWS) that a Class D barrier (including stripping topsoil and base preparation) will be adequate.
- Due to proxy composite samples being used to run the geochemical analysis, the reported results are to be considered preliminary and subject to confirmation once representative samples become available.

It is anticipated that the Class D barrier with topsoil stripping and base preparation will be adequate for the Lehating WRD. A meeting with the authorities is recommended to establish the acceptability of the risk-based approach for this material.

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Andrea Baker	**Natasha Smyth**	**Reviewer**
(Report Author)	(Project Manager)	(Reviewer)

10.REFERENCES

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APPENDIX A: ANALYTICAL MEHTODOLOGY

ACID BASE ACCOUNTING

Acid Potential and Neutralising Potential

Acid–Base Accounting (ABA) is an internationally accepted analytical procedure that was developed to screen the acid-producing and acid-neutralizing potential of rocks.

The Acid Generating Potential (AP) is due to the oxidation of sulphide minerals in a rock sample and is calculated as the total sulphide sulphur content in % multiplied by 31.25.

The Acid Neutralising Potential (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.

Net Neutralising Potential (NNP)

The Net Neutralisation Potential (NNP) is calculated by subtracting the Acid Generating Potential (AP) from the Acid Neutralising Potential (NP):

NNP = NP – AP

Results are reported in kg of calcium carbonate per tonne of overburden (or parts per thousand). For a sample:

- Negative NNP indicates potential to generate acid.
- Positive NNP indicates excess acid-neutralising potential.

Neutralising Potential Ratio (NPR)

The Neutralising Potential Ratio is calculated by dividing the Neutralising Potential (NP) by the acid potential (AP):

NPR = NP/AP

In the assessment:

- NPR ratios larger than 2 indicate non-potentially acid generation (Non-PAG);
- ratios between 1 and 2 are considered inconclusive / possibly acid generating; and
- NPR ratios below 1 indicate potential acid generation (PAG).

PASTE PH

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.

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.

CHEMICAL COMPOSITION COMPARED TO CRUSTAL ABUNDANCE

The chemical composition of a sample is determined by an Aqua Regia analysis. The relative proportions of the total elements as determined with the acid digestion procedure for each lithology analysed is therefore identified. In addition, the composition is compared to the average (median) crustal abundance (abundance of elements in Earth's crust as a percentage) to identify which elements the samples are enriched in which may indicate which elements may be leachable in significant concentrations.

METAL LEACHING

Synthetic Precipitation Leaching Procedure is a laboratory extraction method designed to determine the leachability of both organic and inorganic elements present in liquids, soils, and wastes under certain conditions. The solid phase is extracted over with an extraction fluid, and liquid-to-solid ratio of 4:1 (Price, 2009). Following extraction, the liquid extract is separated from the solid phase by filtration and analysed.

The leachate underwent the following laboratory test work:

- Inductively coupled plasma (ICP) Scan.
- Major anion and cations.
- General parameters.

APPENDIX B: LABORATORY CERTIFICATES

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

Date received: 2017-05-12
Project number: 139
Report number: 66926
Date completed: 2017-06-08
Order number: TBC

Client name: SLR Consulting (South Africa) (Pty) Ltd
Address: Block 7, Fourways Manor Office Park, Fourways, Johannesburg, 2060
Telephone: 011 467 0945
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Contact person: M. Papenfus
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Cell: ---

Acid – Base Accounting Modified Sobek (EPA-600)	Sample Identification Lehating Waste Dump (Composite)
Sample Number	**4839**
Paste pH	8.3
Total Sulphur (%) (LECO)	11
Acid Potential (AP) (kg/t)	352
Neutralization Potential (NP)	90
Nett Neutralization Potential (NNP)	-261
Neutralising Potential Ratio (NPR) (NP : AP)	0.257
Rock Type	I

*** 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.**

Please refer to Appendix (p.2) for a Terminology of terms and guidelines for rock classification

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

Date received: 2017-05-12
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Date completed: 2017-06-08
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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

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

Date received: 2017-05-12 **Date completed: 2017-06-08**
Project number: 139 **Report number: 66926** **Order number: TBC**

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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
ACID – BASE ACCOUNTING
EPA-600 MODIFIED SOBEK METHOD

Date received: 2017-05-12
Project number: 139
Report number: 66926
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Order number: TBC

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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: 2017-05-12
Project number: 139
Report number: 66926
Date completed: 2017-06-15
Order number: TBC

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Sulphur Speciation*	**Sample Identification**
	Lehating Waste Dump (Composite)
Sample Number	**4839**
Total Sulphur (%) (LECO)	<0.01
Sulphate Sulphur as S (%)	<0.01
Sulphide Sulphur (%)	<0.01

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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CERTIFICATE OF ANALYSES

TCLP / ACID RAIN / DISTILLED WATER EXTRACTIONS

Date received:	2017/05/12		**Date completed:**	2017/06/08
Project number:	139	**Report number: 66926**	**Order number:**	**TBC**

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Telephone:	**011 467 0945**	**Cell:**	---

Analyses	Lehating Waste Dump (Composite)	
Sample Number	**4839**	
TCLP / Acid Rain / Distilled Water / H_2O_2	**Distilled Water**	
Dry Mass Used (g)	**250**	
Volume Used (mℓ)	**1000**	
pH Value at 25°C	7,5	
Electrical Conductivity in mS/m at 25°C	19,4	
Inorganic Anions	**mg/ℓ**	**mg/kg**
Total Dissolved Solids at 180 °C	100	400
Total Alkalinity as CaCO3	24	96
Chloride as Cl	7	28
Sulphate as SO4	15	60
Nitrate as N	2,4	9,6
Fluoride as F	0,6	2,4
Hexavalent Chromium as Cr6+	<0.010	<0.04
Total Cyanide as CN		0,0
ICP-MS Scan	See tab ICP DW	
Acid Base Accounting	See attached Report 66926 ABA	

[s]=subcontracted

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CERTIFICATE OF ANALYSES

ICP-MS SCAN ANALYSIS

Date received:	2017/05/12	Date Completed:	2017/06/08
Project number:	139	Report number:	66926

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Extract	Sample Mass (g)	Volume (ml)	Factor
Distilled Water	250	1000	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
Lehating Waste Dump (Composite)	4839	<0.010	<0.040	<0.100	<0.400	<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	<0.010	<0.040	<0.010	<0.040
Lehating Waste Dump (Composite)	4839	<0.010	<0.040	0,072	0,289	0,021	0,084

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
Lehating Waste Dump (Composite)	4839	<0.010	<0.040	<0.010	<0.040	8	32

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
Lehating Waste Dump (Composite)	4839	<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
Lehating Waste Dump (Composite)	4839	<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
Lehating Waste Dump (Composite)	4839	<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
Lehating Waste Dump (Composite)	4839	<0.025	<0.100	<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
Lehating Waste Dump (Composite)	4839	<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
Lehating Waste Dump (Composite)	4839	<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
Lehating Waste Dump (Composite)	4839	2,3	9,3	<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
Lehating Waste Dump (Composite)	4839	<0.010	<0.040	4	16	<0.025	<0.100

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
Lehating Waste Dump (Composite)	4839	0,028	0,111	21	84	<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
Lehating Waste Dump (Composite)	4839	<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
Lehating Waste Dump (Composite)	4839	<0.010	<0.040	<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
Lehating Waste Dump (Composite)	4839	<0.010	<0.040	<0.010	<0.040	<0.010	<0.040

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
Lehating Waste Dump (Composite)	4839	<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
Lehating Waste Dump (Composite)	4839	<0.010	<0.040	<0.010	<0.040	5,8	23

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
Lehating Waste Dump (Composite)	4839	<0.010	<0.040	<0.010	<0.040	0,052	0,208

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
Lehating Waste Dump (Composite)	4839	<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
Lehating Waste Dump (Composite)	4839	<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
Lehating Waste Dump (Composite)	4839	<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
Lehating Waste Dump (Composite)	4839	<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
Lehating Waste Dump (Composite)	4839	<0.010	<0.040	<0.010	<0.040

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CERTIFICATE OF ANALYSES

Digestion AS 4439.3

Date received:	**2017/05/12**		**Date completed:**	**2017/06/08**
Project number:	**139**	**Report number: 66926**	**Order number:**	**TBC**

Client name:	**SLR Consulting (South Africa) (Pty) Ltd**	**Contact person:**	**M. Papenfus**
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Analyses	Lehating Waste Dump (Composite)				
Sample Number	4839		TCT0 mg/kg	TCT1 mg/kg	TCT2 mg/kg
Digestion	HNO3 : HF				
Dry Mass Used (g)	**0,25**				
Volume Used (mℓ)	**100**				
Units	**mg/ℓ**	**mg/kg**			
As, Arsenic	<0.010	<4.00	5,8	500	2000
B, Boron	<0.025	<10	150	15000	6000
Ba, Barium	0,766	306	62,5	6250	25000
Cd, Cadmium	0,029	12	7,5	260	1040
Co, Cobalt	<0.025	<10	50	5000	20000
Cr_{Total}, Chromium Total	0,238	95	46000	800000	N/A
Cu, Copper	0,066	26	16	19500	78000
Hg, Mercury	<0.001	<0.400	0,93	160	640
Mn, Manganese	3,70	1480	1000	25000	100000
Mo, Molybdenum	<0.025	<10	40	1000	4000
Ni, Nickel	0,138	55	91	10600	42400
Pb, Lead	<0.010	<4.00	20	1900	7600
Sb, Antimony	0,027	11	10	75	300
Se, Selenium	<0.010	<4.00	10	50	200
V, Vanadium	0,142	57	150	2680	10720
Zn, Zinc	0,110	44	240	160000	640000
Inorganic Anions	**mg/ℓ**	**mg/kg**			
Cr(VI), Chromium (VI) Total [s]	---	<5	6,5	500	2000
Total Fluoride [s] mg/kg	---	287	100	10000	40000
Total Cyanide as CN mg/kg	---	<0.01	14	10500	42000

[s] = subcontracted

UTD = Unable to determine

E. Botha ________________

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