Proposed Open Pit Magnetite Mine and Concentrator Plant, Mokopane, Limpopo Province

Geochemistry and Waste Classification Assessment

Project Number:

VMC3049

Prepared for:

Pamish Investments No. 39 (Pty) Ltd

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This document has been prepared by Digby Wells Environmental.

Report Type:	**Geochemistry and Waste Classification Assessment**
Project Name:	**Proposed Open Pit Magnetite Mine and Concentrator Plant, Mokopane, Limpopo Province**
Project Code:	**VMC3049**

Name	**Responsibility**	**Signature**	**Date**
André van Coller	Senior Hydro-Geochemist: Geochemistry and Reporting		18 June 2015
Lucas Smith	1st Review		19 May 2015

EXECUTIVE SUMMARY

Digby Wells Environmental (hereafter Digby Wells) has been requested by Pamish Investments (hereafter PI) to undertake a geochemical waste classification as part of an environmental assessment for a proposed Vanadium Opencast Project near Mokopane in the Limpopo Province.

The results and discussions detailed in this report focus on the geochemical and waste classification process followed as per NEM: WA and DWS guidelines for classifying and identifying potential risks associated with the storage of waste material on site. This report will form part of the application and motivation for a waste licence to be submitted to the DEA to advice on the liner requirements for waste storage facilities.

The following deliverables are delivered in this document:

- Laboratory results and interpretations;
- Waste classification and liner requirements;
- Technical report with recommendations.

All samples were sent to the Waterlab (Pty) Ltd where standardised methods were used to prepare and analyse the samples. Samples FS7520, FS7508 and FS7481 were hanging wall samples representing the waste rock material to be temporarily stored on site with samples MMLA and MMLB being two samples compiled from a tailings material sample. All material were sampled by the client and delivered to Digby Wells for processing and test work. The following tests were performed on the five (5) samples:

- Acid-Base Accounting (ABA);
- Nett Acid Generation (NAG);
- X-ray diffraction (XRD);
- X-ray florescence (XRF); and
- Reagent/Distilled Water leachate tests.

The project will include both low and lower grade stockpiles on site. However, only waste rock and tailings samples were tested and the assumption is made that the low and lower grade material will be made up of the waste rock material tested. The geochemical interpretations and waste classification of the tailings and waste rock material can be summarised and concluded with the following main points.

Waste Rock Material

- Only waste rock samples were tested and the assumption is made that the low and lower grade material will be made up of the waste rock material tested;

- The waste rock material showed a high neutralising potential in both the mineralogical and acid rock drainage (ARD) assessments and tests, and both ARD and metal leach (ML) potential is low;
- The neutralising nature of the waste rock material was confirmed in the paste pH of the ABA results and also the pH of the resultant leachate quality abstracted from the distilled water leachate tests;
- The waste rock material was classed as a Type 3 waste according to the NEM: WA guidelines due to total concentrations of some elements being above the recommended TCT0 values; however
- No elements leached out in concentrations above the LCT0 values and in most cases were below the detection limits with a very low risk of contamination or seepage based on the conservative methods followed as per NEM: WA regulations; and
- Overall from the available data and test results the waste rock material is deemed to be a low environmental contamination risk and the Type 3 classification of the waste rock is too conservative and not a true reflection of the low risk nature of the material.

Tailings Material

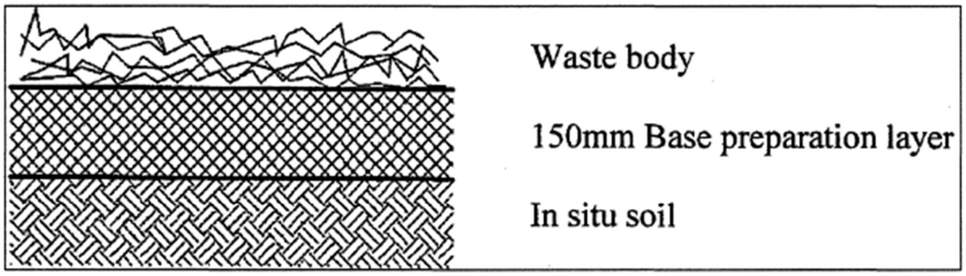
- The tailings material showed a marginal potential for ARD, but the ARD potential is uncertain based on the current available data;
- The neutralising nature of the tailings material was confirmed in the paste pH of the ABA results and also the pH of the resultant leachate quality abstracted from the distilled water leachate tests; however
- The remaining parameters tested for and evaluated does show a marginal potential for ARD development that can lead to a potential for contaminants to leach out of the material;
- The acid producing potential of the tailings material is most probably caused by the siderite mineralogy;
- The tailings material was classed as a Type 3 waste according to the NEM: WA guidelines due to total concentrations of some elements being above the recommended TCT0 values; and
- Overall from the available data and test results keeping in mind the potential acid forming nature of the tailings material, the Type 3 classification of the tailings material is an accurate classification.

From the above conclusions Digby Wells recommends the following:

- The waste rock material is a low environmental risk and it is recommended that the client apply for a waste licence to allow the waste rock material to be declassified to a

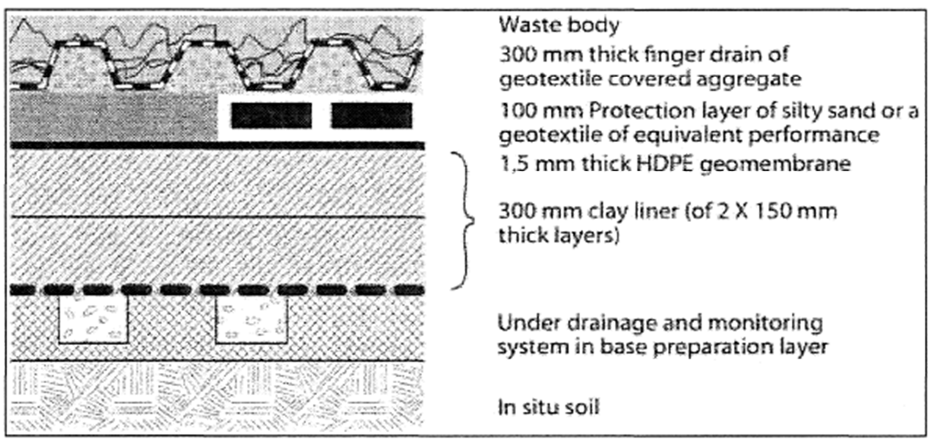
Type 4 waste and disposed of at a facility with the liner design in accordance with a Class D disposal facility as shown below.

(d) Class D Landfill:



- The tailings material is a Type 3 waste and should be should be disposed of at a Class C waste facility or a disposal facility with the liner designed in accordance with the NEM: WA guidelines for a Class C landfill as shown below.

(c) Class C Landfill:



- Monitoring of the receiving environment in the vicinity of the waste facilities should be planned and implemented to act as an early warning system and to evaluate any potential environmental impacts over time.
- Digby Wells recommends that future work include a larger amount of tailings samples to be tested to increase certainty on both the ARD and seepage potential of the material.
- More detailed mineralogical work on waste material (e.g. QEMSCAN) can also aid in understanding the trace element make-up of the material.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

Abbreviation	Description
ABA	Acid Base Accounting
AP	Acid Potential
ARD	acid rock drainage
CoC	constituents of concern
DEA	Department of Environmental Affairs
DW	distilled water
DWS	Department of Water and Sanitation
Ga	billion years
LC	leachable concentrations
LCT	Leachable concentration threshold
Ma	million years
ML	metal leach
NAF	Non-Acid Forming
NAG	Net Acid Generation
NEM: WA	National Environmental Management: Waste Act
NNP	Net Neutralising Potential
NP	Neutralising Potential
NPR	Neutralising Potential Ratio
PAF	Potentially Acid Forming
TC	total concentrations
TCT	Total concentration threshold
US EPA	United States Environmental Protection Agency
VMIC	VM Investment Company
WHO	World Health Organisation
XRD	X-Ray Diffraction
XRF	X-Ray Fluorescence

1 Introduction

Digby Wells Environmental (hereafter Digby Wells) has been appointed by Pamish Investments No. 39 (hereafter PI) to undertake a geochemical waste classification as part of an environmental impact assessment for the proposed Magnetite Project near Mokopane in the Limpopo Province.

The results and discussions detailed in this report focus on the geochemical and waste classification process followed as per National Environmental Management: Waste Act (NEM: WA) and Department of Water and Sanitation (DWS) guidelines for classifying and identifying potential risks associated with the storage of waste material on site. This report will form part of the application and motivation for a waste licence to be submitted to the Department of Environmental Affairs (DEA) to advice on the liner requirements for waste storage facilities.

1.1 Deliverables

The following deliverables are summarised in this document:

- Laboratory results and interpretations;
- Waste classification and liner requirements; and
- Technical report with recommendations.

2 Methodology and Scope of Work

2.1 Sampling and Laboratory Tests

All samples were sent to Waterlab (Pty) Ltd where standardised methods were used to prepare and analyse the samples. Samples FS7520, FS7508 and FS7481 were hanging wall samples representing the waste rock material to be temporarily stored on site. Samples MMLA and MMLB are two samples compiled from tailings material samples. All material were sampled by the client and delivered to Digby Wells for processing and submission to the laboratory. The project will include both low and lower grade stockpiles on site. However, only waste rock and tailings samples were tested and the assumption is made that the low and lower grade material will be made up of the waste rock material tested. The following tests were performed on the five (5) samples:

- Acid-Base Accounting (ABA);
- Nett Acid Generation (NAG);
- X-ray diffraction (XRD);
- X-ray florescence (XRF); and
- Reagent/Distilled Water leachate tests.

2.2 Results Interpretation

The laboratory results were assessed against various guidelines from the United States Environmental Protection Agency (US EPA), World Health Organisation (WHO), and the guidelines as set out in the National Environmental Management Waste Act, 2008 (ACT No. 59 of 2008) to determine the potential environmental and human risks, as well as to determine the waste type and classification of the tailings and waste rock material.

Along with the evaluation of the results against various standards, the mineralogy and chemical composition of the samples were interpreted to understand where any possible contamination can originate from.

3 Project Area Description

3.1 Project Location

The proposed Project area is located on the farms Vogelstruisfontein 765 LR, Vriesland 781 LR, Vleigekraal 783 LR, Schoonoord 786 LR and portions Re/1, Re/2, 3, 4, 5 and 6 of the farm Bellevue 808 LR.

The proposed Project is situated approximately 35 kilometres (km) north-west of Mokopane and 65 km west of Polokwane. The villages of Ditlotswana, Malokong, Mosate and Sepharane fall within the project area. Villages within 5 km of the project area include, but are not limited to: Eckstein, Eseldrift, Ga-Mabuela, Ga-Masipa, Ga-Masoge, Ga-Modipana, Ga-Mokwena, Ga-Ramurulane, Goede Hoop, Haakdoring, Kaditshwene, Kwakwalata Mesopotamia, Lyden, Mabuladihlare, Mmahlogo, Phafola, and Rooivaal.

3.2 Geology

The basement rock in the regional study area comprises magmatic, Archaean Granite and Gneiss, which are Neo-archaean in age dating from *c.* 2 800 Ma to 2 500 Ma. These Neo-archaean granitoids are associated with the linear Pietersburg and Giyani Greenstone belts (Robb, Brandl, Anhaeusser, & Puojol, 2006, p. 75).

The Bushveld Complex comprises of felsic and mafic igneous rocks, containing the largest platinum-group elements ore reserves globally within the mafic units of the complex. The lithostratigraphy of the Bushveld Complex underlying the project area is dominated by the Lower, Critical, Main and Upper Zones of the Rustenburg Layered Suite that date from c. 2 050 Ma to around 2 000 Ma of the Eoproterozioc Era. The predominant rocks that comprise the Rustenburg Layered Suite include gabbro and gabbro-norite.

The Rustenburg Layered Suite is overlain by the Lebowa Granite Suite (c. 1 790 Ma to 1 604 Ma) comprising Nebo Granite, representing the final stratigraphic unit of the Bushveld Complex in the project area.

The Waterberg Group overlying the Lebowa Granite Suite in the western parts of the project area are considered to be between 1 700 Ma and 2 000 Ma old, and of Kheisian period of the Palaeoproterizoic era. The typical rocks associated with this group are arenite and rudite – sedimentary rocks deposited by large braided rivers (Barker, Brandl, Callaghan, Erikson, & van der Neut, 2006, p. 314). Rudite includes sedimentary rocks composed of conglomerate rounded or angular granules, pebbles, cobbles and boulders.

4 Laboratory Results and Interpretations

All laboratory results and certificates are presented in Appendix A.

4.1 Laboratory Test Description

The laboratory tests applied to determine the potential for rock samples to produce acid rock drainage (ARD) and to determine waste classifications are generally grouped into two categories; static and kinetic tests. Static tests are relatively simple, inexpensive and rapid and enable initial screening of waste material in terms of the potential to produce ARD.

Static testing provides an indication of whether a particular sample has the potential to generate ARD and the elements that may leach from sample, whereas kinetic testing provides more confidence in the static test findings, as well as providing an indication of the time scale of the ARD and metal leaching.

4.1.1 XRD and XRF

XRF is an X-ray method used to determine the elemental composition of a material that allows for the evaluation of a material's chemical compound distribution, as well as the various trace element concentrations. XRD allows for the measurement of the crystal structures within a sample to determine the mineralogical composition of the material that allows the specialist to determine whether any reactive solids will lead to environmental risks through the study of the various minerals.

4.1.2 ABA and NAG

Acid-Base Accounting (ABA) is a first order classification procedure whereby the acid-neutralising potential and acid-generating potential of rock samples are determined and the difference (Net Neutralising Potential) is calculated. This procedure includes NAG tests that evaluate the Net Acid Generation and neutralising potential of the material to evaluate the potential of the material to counter acid production. The Net Neutralising Potential and/or the ratio of neutralising potential to acid-generation potential is compared with a predetermined value, or set of values to divide samples into categories that either require, or do not require further determinative acid potential generation test work. Table 1 shows the criteria to determine ARD potential from ABA and NAG results.

Table 1: ARD Classification Criteria

	Potentially Acid generating	Uncertain/Marginal	Non-Acid Generating
Paste pH	<5.5	-	>5.5
NNP	<-20	-20 to 20	>20
NPR	<1	1 to 3	>3
S%	>0.3%	-	<0.3%
NAG	>0.1	-	<0.1

4.1.3 Leachate Tests and Total Element Analysis

Distilled/Reagent water (DW) leachate tests are done to simulate the heavy metal and anion leachate potential of soils, waste material and waste water left in-situ under normal conditions, with only neutral water allowing leaching to occur. These tests will simulate and evaluate the potential of any heavy metal or ion contamination from the waste material that will be produced. The distilled/reagent water tests are used to evaluate the leachability of material that will be mono-disposed.

4.2 Sample Identification

The following samples (Table 2) were provided by the client and submitted for the tests discussed in sections 2.1 and 4.1.

Table 2: Sample Description

<table>
<tr><th colspan="2">Sample ID</th><th>Type</th><th>Tests</th><th>Comments</th></tr>
<tr><td colspan="2">FS7520</td><td>Hanging wall material</td><td rowspan="5">XRD, XRF, ABA, NAG and DW leachate (Total and leachable concentrations)</td><td>Waste Rock</td></tr>
<tr><td colspan="2">FS7508</td><td>Hanging wall material</td><td>Waste Rock</td></tr>
<tr><td colspan="2">FS7481</td><td>Hanging wall material</td><td>Waste Rock</td></tr>
<tr><td rowspan="2">MML Composite fresh</td><td>MML A</td><td>Tailings</td><td rowspan="2">Split MML Composite into 2 separate samples</td></tr>
<tr><td>MML B</td><td>Tailings</td></tr>
</table>

4.3 XRF and XRD Tests

XRF and XRD tests are performed to evaluate the general mineralogy of the samples and help predict the potential origin of any contaminants that is found to leach into solution from the samples.

The XRD results are shown in Table 3.

Table 3: XRD Results

Mineral	Weight %				
	FS7520	FS7508	FS7481	MML A	MML B
Plagioclase	84.58	89.67	93.63	90.89	90.23
Chlorite	0.46	0.39	0.23	2.6	2.54
Magnetite	11.46	7.17	1.62	4.7	4.76
Muscovite	3.06	2.77	4.29	0.6	0.61
Siderite	0.44	trace	trace	1.21	1.86
Hornblende	trace	trace	trace	-	-
Calcite	trace	trace	0.22	-	-

Trace elements are difficult to quantify and pick-up in XRD tests and in some cases more work with other methods is needed to accurately determine the trace lement make-up of rocks. The mineralogical make-up of the waste rock samples (hanging wall) are typical of the Bushveld complex with high plagioclase content along with the accessory minerals mostly dominated by the chain silicate or clay minerals, chlorite and muscovite with high magnetite content as would be expected. Siderite is also present in both the waste rock and tailings. The presence of siderite in the samples indicate that the original oxidation state is still stable with the main iron phase being ferrous iron (Fe(II)). Siderite is uncommon in the Bushveld rock but does exist in the tailings material as the concentration of the mineral could have increased in ratios due to the removal of other elements/minerals in the processing. Siderite can potentially act as a neutraliser under certain conditions, but with higher alkaline conditions and pH levels being elevated the weathering reaction of siderite can lead to acid production. The dissolution of siderite produces Fe^{2+} and HCO_3^- and combined with ferrous iron oxidation under elevated pH levels gives of protons in conditions where bicarbonate is stable. More acidic environments give aqueous conditions where carbonic acid is stable and no net acid production will occur (Dold 2005).

Hornblende and calcite are picked up in trace amounts in the waste rock material with hornblende a mineral associated with igneous and metamorphic formations with high metal content. The calcite, plagioclase and muscovite content can add significantly to the buffering potential of the material to counter any potential acid production. The potential ARD formation will be further discussed in Section 4.4.

The general formulas for the minerals are given below:

- Calcite $CaCO_3$
- Muscovite $KAl_2(Si_3Al)O_{10}(OH,F)_2$
- Siderite $FeCO_3$
- Chlorite $(Mg,Fe)_5Al(AlSi_3O_{10})(OH)_8$

- Plagioclase $(Na,Ca)(Si,Al)_4O_8$
- Hornblende $Ca_2(Mg, Fe, Al)_5(Al, Si)_8O_{22}(OH)_2$
- Magnetite Fe_3O_4

The mineralogical content of the samples can be sub-divided into oxide content showing the distribution of the minerals in a simpler form, shown in Table 4. Before the XRF and XRD tests are performed to determine the mineralogical and elemental content of the samples, the samples are dried to evaluate the moisture content and then burned at 1000˚C to remove any impurities and/or unwanted material that can potentially produce mineralogical results not part of the material make-up. The samples had moisture content (H_2O) between 0.04 and 0.14% with a loss of material at ignition (LOI) of between 0.32 and 2.48%.

Table 4: Oxide Distribution

Major Oxides	Major Element Concentration (weight %)				
	FS7520	FS7508	FS7481	MML A	MML B
SiO_2	41.25	45.24	52.37	37.97	38.68
TiO_2	2.41	1.8	0.23	3.71	3.82
Al_2O_3	20.52	22.86	25.07	23.6	23.86
Fe_2O_3	18.05	13.99	3.26	16.55	16.69
MnO	0.1	0.06	0.03	0.08	0.09
MgO	1.7	0.6	0.43	2.74	2.52
CaO	11.25	10.06	10.86	8.99	9
Na_2O	3.04	3.88	5.26	2.66	2.58
K_2O	0.37	0.41	0.57	0.26	0.24
P_2O_5	<0.01	<0.01	0.01	<0.01	<0.01
Cr_2O_3	0.03	0.02	<0.01	0.02	0.02
SO_3	0.1	0.1	0.1	0.13	0.14
LOI	0.39	0.32	1.03	2.48	2.35
Total	99.29	99.38	99.32	99.32	100.1
H_2O-	0.06	0.04	0.1	0.14	0.13

As would be expected from the metal rich formations along with the plagioclase dominant geology the oxide distribution is mainly made up of SiO_2, Al_2O_3, Fe_2O_3, CaO, Na_2O and K_2O. Along with the main mineralogical distribution, some trace elements are also present and shown in Table 5. The overall mineralogy of the waste rock and tailings material is similar and shows that alteration of the material in the mining and processing methods of the ore and material does not alter the general mineralogical make-up. The mineralogy is generally neutralising with no acid formation expected, this will however be evaluated in the ABA and NAG results.

Table 5: Trace Element Distribution

Trace Elements	Trace Element Concentration (ppm) [s]				
	FS7520	FS7508	FS7481	MML A	MML B
As	<0.43	<0.43	<0.43	<0.43	<0.43
Ba	87	104	98.4	76.8	79.5
Bi	1.51	1.29	1.51	1.54	2.12
Cd	7.19	4.05	7.16	3.61	7.18
Ce	182	116	43.8	<3.08	<3.08
Cl	165	167	178	133	132
Co	<0.56	<0.56	<0.56	<0.56	<0.56
Cs	1.31	2	2.15	<0.49	2.97
Cu	256	304	31.6	1,023	1,045
Ga	28.5	25.3	17.3	28.1	29.4
Ge	<0.50	<0.50	<0.50	<0.50	<0.50
Hf	28.2	20.3	<0.38	36.6	41.2
Hg	<1.00	<1.00	<1.00	<1.00	<1.00
La	12.3	67.8	99.8	43.5	33.4
Lu	3.8	3.14	2.05	4.05	3.72
Mo	1.61	1.9	1.64	1.91	1.94
Nb	3.95	4.49	3.88	4.99	5.18
Nd	<2.39	14.1	49.8	<2.39	<2.39
Ni	120	97.2	<5.14	404	413
Pb	<2.03	<2.03	<2.03	<2.03	<2.03
Rb	8.03	7.14	7.59	7.57	7.84
Sb	<1.48	<1.48	<1.48	5.42	<1.48
Sc	36.5	36	45.3	39.4	33.9
Se	<0.36	<0.36	<0.36	<0.36	<0.36
Sm	69.3	48	13.1	59.5	74.9
Sn	21.2	14.2	9.02	15.1	16.1

Trace Elements	Trace Element Concentration (ppm) [s]				
	FS7520	FS7508	FS7481	MML A	MML B
Sr	239	276	321	221	226
Ta	2.64	1.99	1.73	2.97	2.49
Te	10.3	13.6	11.7	9.04	10.5
Th	<0.88	<0.88	<0.88	<0.88	<0.88
Tl	0.83	0.57	0.28	0.81	0.92
U	1.28	2.1	3.31	<0.74	1.34
V	<7.60	<7.60	<7.60	<7.60	<7.60
W	1.66	1.51	1.04	1.76	1.84
Y	<0.97	<0.97	3.98	<0.97	<0.97
Yb	20.2	16.6	6.45	19.4	22.2
Zn	43.8	41.6	42.6	75.3	78.1
Zr	16.6	12.6	16.2	14	12.3

4.4 ABA and NAG Tests

From the ABA and NAG results the potential for ARD is assessed. Table 6 and Table 7 shows the lab results with the main outcome and classification shown in Table 8.

Table 6: ABA Results

Acid Base Accounting						
Sample Number	**FS7520**	**FS7508**	**FS7481**	**MML A**	**MML B**	**MML B**
Paste pH	9	9	9.3	8.1	8.2	---
Total Sulphur (%) (LECO)	0.09	0.13	0.02	0.51	0.49	0.49
Acid Potential (AP) (kg/t)	2.81	4.06	0.625	16	15	15
Neutralization Potential (NP)	26	26	30	34	34	34
Nett Neutralization Potential (NNP)	23	22	30	18	18	19
Neutralising Potential Ratio (NPR) (NP : AP)	9.27	6.36	49	2.1	2.19	2.24
Rock Type	III	III	III	II	II	II

Table 7: NAG Results

NAG Test	Test pH 4.5					
	FS7520	FS7508	FS7481	FS7481	MML A	MML B
NAG pH: (H_2O_2)	6	5.8	5.7	5.6	6.1	6.1
NAG (kg H_2SO_4 / t)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Table 8: ARD Classification

Sample ID	Paste pH	Sulphur content	NNP	NPR	NAG (kg H_2SO_4 / t)	Verdict
FS7520	Low Acid Generating Risk	Low Acid Generating Risk	Non-Acid Generating	Non-Acid Generating	Non-Acid Generating/ Acid Neutralising	NAF
FS7508	Low Acid Generating Risk	Low Acid Generating Risk	Non-Acid Generating	Non-Acid Generating	Non-Acid Generating/ Acid Neutralising	NAF
FS7481	Low Acid Generating Risk	Low Acid Generating Risk	Non-Acid Generating	Non-Acid Generating	Non-Acid Generating/ Acid Neutralising	NAF
MML A	Low Acid Generating Risk	Potential Acid Generating Risk	Low Acid Generating Risk	Low Acid Generating Risk	Non-Acid Generating/ Acid Neutralising	Inconclusive /Uncertain (Rock type II)
MML B	Low Acid Generating Risk	Potential Acid Generating Risk	Low Acid Generating Risk	Low Acid Generating Risk	Non-Acid Generating/ Acid Neutralising	Inconclusive /Uncertain (Rock type II)

Based on the ABA and NAG results (Table 8) the following can be concluded:

- The waste rock samples show no potential for acid generation with a high neutralising potential and thus ARD formation is not a risk and high metal leach or seepage of contaminants due to an acidic environment is not seen as a potential environmental impact;
- The two tailings material samples show a low risk for acid forming potential. However, a neutralising capacity is also observed due to the mineralogy discussed in section 4.3. The ARD potential of the material is however uncertain and a larger

amount of samples is recommended to be tested to allow a statistical distribution and a higher level of certainty; and

- The acid generating potential in the tailings material is most likely due to the siderite content being exposed to alkaline conditions that can potentially lead to siderite forming small amounts of acid.

4.5 Static Leachate Tests

As part of this assessment, leach tests were undertaken by performing a 1:20 aqueous extraction with deionised water as per NEM: WA guidelines for classification of waste (DEA 2013; DEA 2014) to be mono-disposed. Although the leach test can determine the leachability of determinants, the liquid-to-solid ratio does not represent actual field conditions; therefore resultant concentrations should not be considered representative of run-off that could emanate from site. The tests are commonly used as a preliminary screening process to identify potential constituents of concern (CoC).

The total concentrations (TC) and leachable concentrations (LC) results are shown in Table 9 and Table 10 and compared to the various thresholds as will be discussed in section 5 of this report.

Table 9: Total Concentrations as determined through Aqua Regia Acid Digestion Methods

Sample	TCT0	TCT1	TCT2	FS7520	FS7508	FS7481	MML A	MML B
Units	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
As	5.8	500	2000	<4.00	<4.00	<4.00	<4.00	<4.00
B	150	15000	60000	<10	<10	<10	<10	<10
Ba	62.5	6250	25000	115.2	123.2	90.8	85.2	99.6
Cd	7.5	260	1040	13.2	6.4	<2.00	6.4	7.6
Co	50	5000	20000	84	60.4	<10	292	300
Cr (total)	46000	800000	N/A	223.6	107.6	<10	208.8	219.2
Cu	16	19500	78000	412	484	16.4	1792	1844
Hg	0.93	160	640	<0.4	<0.4	<0.4	<0.4	<0.4
Mn	1000	25000	100000	480	340.8	161.6	552	632
Mo	40	1000	4000	<10	<10	<10	<10	<10
Ni	91	10600	42400	169.6	138.8	<10	576	596
Pb	20	1900	7600	<8.00	<8.00	<8.00	<8.00	<8.00
Sb	10	75	300	10.4	13.2	<4.00	10	12.8
Se	10	50	200	<8.00	<8.00	<8.00	<8.00	<8.00

Sample	TCT0	TCT1	TCT2	FS7520	FS7508	FS7481	MML A	MML B
Units	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
V	150	2680	10720	1688	1052	<10	900	912
Zn	240	160000	640000	111.2	56	13.2	110.4	115.6
Cr (VI)	6.5	500	2000	<5	<5	<5	<5	<5
F	100	10000	40000	117	112	143	112	103
CN	14	10500	42000	<0.01	<0.01	<0.01	<0.01	<0.01

Table 10: Leachable Concentrations as determined through Distilled Water Abstraction

Sample	LCT0	LCT1	LCT2	LCT3	FS7520	FS7508	FS7481	MML A	MML B
Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
pH	N/A	N/A	N/A	N/A	7.8	7.7	7.7	7.3	7.4
EC	N/A	N/A	N/A	N/A	5.4	4.4	5.1	10.2	10.2
As	0.01	0.5	1	4	<0.010	<0.010	<0.010	<0.010	<0.010
B	0.5	25	50	200	<0.025	<0.025	<0.025	<0.025	<0.025
Ba	0.7	35	70	280	<0.025	<0.025	<0.025	<0.025	<0.025
Cd	0.003	0.15	0.3	1.2	<0.003	<0.003	<0.003	<0.003	<0.003
Co	0.5	25	50	200	<0.025	<0.025	<0.025	<0.025	<0.025
Cr (total)	0.1	5	10	40	<0.025	<0.025	<0.025	<0.025	<0.025
Cr (VI)	0.05	2.5	5	20	<0.010	<0.010	<0.010	<0.010	<0.010
Cu	2	100	200	800	<0.025	<0.025	<0.025	<0.025	<0.025
Hg	0.006	0.3	0.6	2.4	<0.001	<0.001	<0.001	<0.001	<0.001
Mn	0.5	25	50	200	<0.025	<0.025	<0.025	<0.025	<0.025
Mo	0.07	3.5	7	28	<0.025	<0.025	<0.025	<0.025	<0.025
Ni	0.07	3.5	7	28	<0.025	<0.025	<0.025	<0.025	<0.025
Pb	0.01	0.5	1	4	<0.010	<0.010	<0.010	<0.010	<0.010
Sb	0.02	1	2	8	<0.010	<0.010	<0.010	<0.010	<0.010
Se	0.01	0.5	1	4	<0.010	<0.010	<0.010	<0.010	<0.010
V	0.2	10	20	80	<0.025	<0.025	<0.025	<0.025	<0.025
Zn	5	250	500	2000	<0.025	<0.025	<0.025	<0.025	<0.025
TDS	1000	12500	25000	100000	52	38	38	76	60

Sample	LCT0	LCT1	LCT2	LCT3	FS7520	FS7508	FS7481	MML A	MML B
Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Cl	300	15000	30000	120000	<5	<5	<5	<5	<5
SO4	250	12500	25000	100000	<5	<5	<5	18	18
NO3 as N	11	550	1100	4400	<0.2	<0.2	<0.2	<0.2	<0.2
F	1.5	75	150	600	<0.2	<0.2	<0.2	<0.2	<0.2
CN	0.07	3.5	7	28	<0.01	<0.01	<0.01	<0.01	<0.01

5 Waste Classification

5.1 Legislation

On 2 June 2014, the National Environmental Management: Waste Amendment Act (NEMWA), 2014 (Act No. 26 of 2014) was published, which for the first time included “residue deposits” and “residue stockpiles” under the environmental waste legislation (previously mining residue was covered under the MPRDA). Mine wastes are listed under Schedule 3, under the category “Hazardous Waste”, therefore the understanding is that mine wastes are considered to be hazardous unless the applicant can prove that the waste is non-hazardous.

As residue deposits and residue stockpiles are considered to be waste, they are regulated by the following regulations, both promulgated on 23 August 2013 in the amended NEM: WA guidelines:

- R635 – National norms and standards for assessment of waste for landfill disposal; and
- R636 – National norms and standards for disposal of waste to landfill.

According to these regulations, waste that is generated must be classified in accordance with SANS 10234 within 180 days of generation. Waste that has already been generated, but not previously classified must be classified within 18 months of the date of commencement of the regulations. The norms and standards specify the waste classification methodologies for determining the waste category, and the specifications for pollution control barrier systems (liners) for each of the waste categories.

The Department of Environmental Affairs (DEA) has published the following draft regulations (DEA 2014):

- Notice 1005 of 2014 (14 November 2014): Proposed regulations regarding the planning and management of residue stockpiles and residue deposits from a prospecting, mining, exploration or production operation.

In terms of waste classification, these regulations state that residue stockpiles and residue deposits must be characterised to identify any potential risk to health or safety and environmental impact in terms of physical characteristics, chemical characteristics (toxicity, propensity to oxidise and decompose, propensity to undergo spontaneous combustion, pH and chemical composition of the water separated from the solids, stability and reactivity and the rate thereof, neutralising potential and concentration of volatile organic compounds), and mineral content.

In addition, the quality of seepage from residue facilities needs to be predicted:

- Notice 1006 of 2014 (14 November 2014): Proposed regulations to exclude a waste stream or a portion of a waste stream from the definition of waste.

These regulations state that waste generated from a source listed in Category A of Schedule 3 of NEMWA may be excluded from being defined as hazardous on demonstration that the waste is non-hazardous in accordance with the Waste Management and Classification regulations. Exclusion of a waste stream from the definition of waste may be considered if it can be demonstrated that any contaminant of concern originating from the waste reaching the receptor will not exceed the acceptable environmental limits for any contaminant of concern for such a receptor. The acceptable environmental limits have not been defined.

5.2 Waste Classification Methodology

Five (5) samples were analysed in order to classify the anticipated waste rock material in accordance with the NEM: WA Regulations (2014), by comparison with total and leachable concentration thresholds.

Total Concentration (TC) values were determined by *aqua regia* digestion (Table 9) and analysis with ICP methods by Waterlab (Pty) Ltd, Gauteng Province.

Total Concentration Threshold (TCT) limits are subdivided into three categories as follows:

- TCT0 limits based on screening values for the protection of water resources, as contained in the Framework for the Management of Contaminated Land (DEA, March 2010);
- TCT1 limits derived from land remediation values for commercial/industrial land (DEA, March 2010); and
- TCT2 limits derived by multiplying the TCT1 values by a factor of 4, as used by the Environmental Protection Agency, Australian State of Victoria.

Leachable concentrations (LC) were determined by following the Australian Standard Leaching Procedure for Wastes, Sediments and Contaminated Soils (AS 4439.3-1997), as specified in the NEMWA Regulations (2013). The procedure recommends the use of reagent/distilled water for leaching of non-putrescible material that will be mono-filled. A leachate of 1:20 solids per reagent water was prepared and analysed by Waterlab (Pty) Ltd.

Leachable Concentration Threshold (LCT) limits are subdivided into four categories as follows:

- LCT0 limits derived from human health effect values for drinking water, as published by the Department of Water and Sanitation (DWS), South African National Standards (SANS), World Health Organization (WHO) or the United States Environmental Protection Agency (USEPA);
- LCT1 limits derived by multiplying LCT0 values by a Dilution Attenuation Factor (DAF) of 50, as proposed by the Australian State of Victoria;
- LCT2 limits derived by multiplying LCT1 values by a factor of 2; and
- LCT3 limits derived by multiplying the LCT2 values by a factor of 4.

Waste is classified by comparison of the total and leachable concentration of elements and chemical substances in the waste material to TCT and LCT limits as specified in the National Norms and Standards for Waste Classification and the National Norms and Standards for Disposal to Landfill as per Table 11.

Table 11: Waste Classification Criteria

Waste Type	Total Concentrations	Leachable Concentrations	Disposal
0	>TCT2	>LCT3	Not allowed
1	Between TCT1 and TCT2	Between LCT2 and LCT3	Class A or Hh:HH landfill
2	<TCT1	Between LCT1 and LCT2	Class B or GLB+ landfill
3	<TCT1	Between LCT0 and LCT1	Class C or GLB- landfill
4	<TCT0	<LCT0	Class D or GLB- landfill

5.3 Classification

Based on the criteria discussed in section 5.2and the classification of the results as shown in Table 9 and Table 10, the following classification summary is given (Table 12).

Table 12: Waste Classification Summary

Material		Waste rock (Hanging wall)			Tailings	
Sample ID		**FS7520**	**FS7508**	**FS7481**	**MML A**	**MML B**
TC	**Range**	TCT0 < TC ≤ TCT1	TCT0 < TC ≤ TCT1	TCT0 < TC ≤ TCT1	TCT0 < TC ≤ TCT1	TCT0 < TC ≤ TCT1
	Elements showing potential risk	Ba, Cd, Co, Cu, Ni, Sb, V, F	Ba, Co, Cu, Ni, Sb, V, F	Ba, Cu, F	Ba, Co, Cu, Ni, V, F	Ba, Cd, Co, Cu, Ni, Sb, V, F
LC	**Range**	LC ≤ LCT0	LC ≤ LCT0	LC ≤ LCT0	LC ≤ LCT0	LC ≤ LCT0
	Elements showing potential risk	None	None	None	None	None
Waste Type		Type 3 (Moderately Hazardous)	Type 3 (Moderately Hazardous)	Type 3 (Moderately Hazardous)	Type 3 (Moderately Hazardous)	Type 3 (Moderately Hazardous)
Disposal facility		Class C (GLB+ landfill)	Class C (GLB+ landfill)	Class C (GLB+ landfill)	Class C (GLB+ landfill)	Class C (GLB+ landfill)

Based on the classification in Table 12 the following can be concluded:

- The pH of all samples show a neutral range with low electrical conductivity values confirming the low metal leach (ML) potential from the waste material;
- The outcome of the sample classification is a Type 3 waste for all samples (Moderate risk/hazard) due to some elements (listed in Table 12) being above the ideal TCT0 concentrations and if disposed, the facility should be designed in accordance with the specifications for a Class C landfill site (Old GLB+ landfill facilities); and
- The liner requirements for a Type 3 waste and Class C facility is summarized in Figure 1 and is a guideline for the design of liners if no exemption is given by the DEA and/or DWS in the waste license issued to the client/mine..

(c) Class C Landfill:

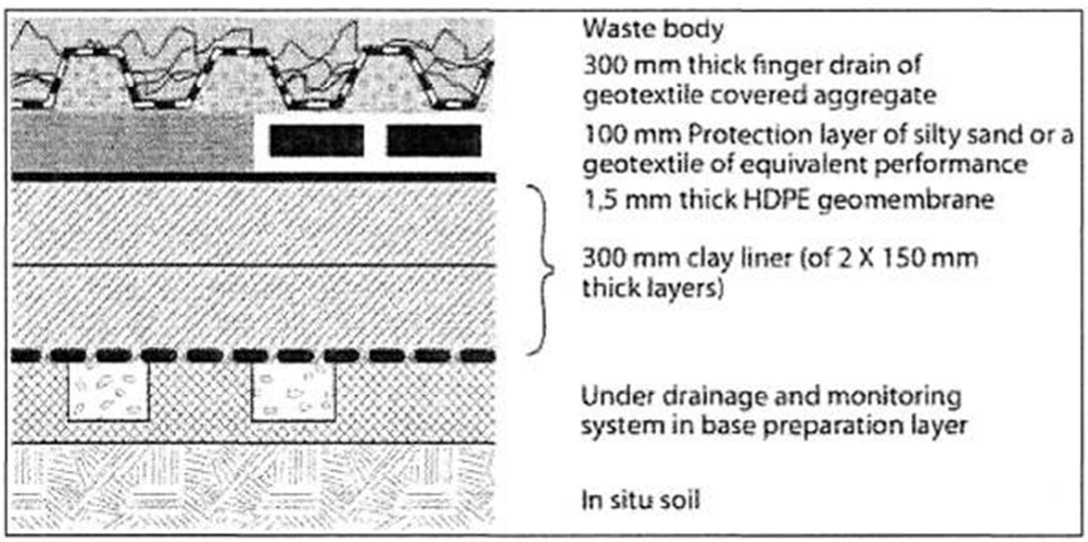


Figure 1: Class C landfill site liner design requirements (DEA 2014)

6 Conclusions

The following conclusions can be reached from the geochemical waste classification study and laboratory analysis.

Based on the ABA and NAG results (Table 8) the following can be concluded:

- The waste rock samples show no potential for acid generation with a high neutralising potential and thus ARD formation is not a risk and high metal leach or seepage of contaminants due to an acidic environment is not seen as a potential environmental impact;
- The two tailings material samples show a low risk for acid forming potential. However, a neutralising capacity is also observed due to the mineralogy discussed in section 4.3. The ARD potential of the material is however uncertain and a larger amount of samples is recommended to be tested to allow a statistical distribution and a higher level of certainty; and
- The acid generating potential in the tailings material is most likely due to the siderite content being exposed to alkaline conditions that can potentially lead to siderite forming small amounts of acid.

Based on the waste classification the following can be concluded:

- The pH of all samples are within the neutral range with low electrical conductivity values confirming the low metal leach (ML) potential from the waste material; and
- The outcome of all the sample is a Type 3 waste (Moderate risk/hazard) due to some elements (Table 12) being above the ideal TCT0 concentrations and if disposed of the facility it should be designed in accordance with the specifications for a Class C landfill site (Old GLB+ landfill facilities).

7 Final Discussion and Recommendations

The geochemical interpretations and waste classification of the tailings and waste rock material can be summarised and concluded with the following main points.

7.1 Waste Rock Material

- The waste rock material showed a high neutralising potential in both the mineralogical and ARD assessments and tests, and both ARD and ML potential is low;
- The neutralising nature of the waste rock material was confirmed in the paste pH of the ABA results and also the pH of the resultant leachate quality abstracted from the distilled water leachate tests;

- The waste rock material was classed as a Type 3 waste according to the NEM: WA guidelines due to total concentrations of some elements being above the recommended TCT0 values; however
- No elements leached out in concentrations above the LCT0 values and in most cases were below the detection limits with a very low risk of contamination or seepage based on the conservative methods followed as per NEM: WA regulations; and
- Overall from the available data and test results the waste rock material is deemed to be a low environmental contamination risk and the Type 3 classification of the waste rock is too conservative and not a true reflection of the low risk nature of the material.

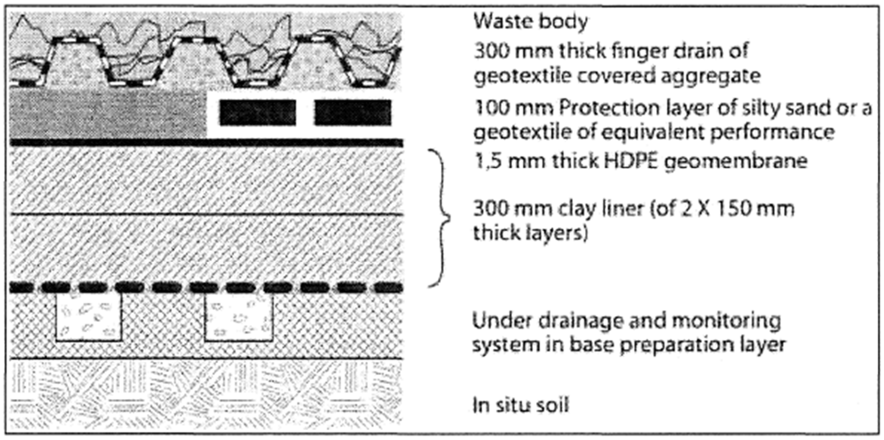
7.2 Tailings Material

- The tailings material showed a marginal potential for ARD, but the ARD potential is uncertain based on the current available data;
- The neutralising nature of the tailings material was confirmed in the paste pH of the ABA results and also the pH of the resultant leachate quality abstracted from the distilled water leachate tests; however
- The remaining parameters tested for and evaluated does show a marginal potential for ARD development that can lead to a potential for contaminants to leach out of the material;
- The acid producing potential of the tailings material is most probably caused by the siderite mineralogy;
- The tailings material was classed as a Type 3 waste according to the NEM: WA guidelines due to total concentrations of some elements being above the recommended TCT0 values; and
- Overall from the available data and test results keeping in mind the potential acid forming nature of the tailings material, the Type 3 classification of the tailings material is an accurate classification.

From the above conclusions Digby Wells recommends the following:

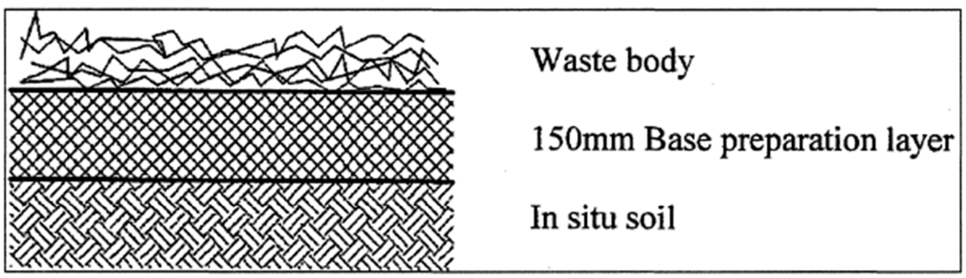
- The waste rock material is a low environmental risk and it is recommended that the client apply for a waste licence to allow the waste rock material to be declassified to a Type 4 waste and disposed of at a facility with the liner design in accordance with a Class D disposal facility as shown below.

(c) Class C Landfill:



- The tailings material is a Type 3 waste and should be disposed of at a Class C waste facility or a disposal facility with the liner designed in accordance with the NEM: WA guidelines for a Class C landfill as shown below.

(d) Class D Landfill:



- Monitoring of the receiving environment in the vicinity of the waste facilities should be planned and implemented to act as an early warning system and to evaluate any potential environmental impacts over time.
- Digby Wells recommends that future work include a larger amount of tailings samples to be tested to increase certainty on both the ARD and seepage potential of the material.
- More detailed mineralogical work on waste material (e.g. QEMSCAN) can also aid in understanding the trace element make-up of the material.

8 References

DEA, 2014. *National Environmental Management: Waste Act 59 of 2008*,

DEA, 2013. *National Norms and Standards for the Assessment of Waste for Landfill Disposal*, Department of Environmental Affairs.

Dold, B., 2005. Basic Concepts of Environmental Geochemistry of Sulfide Mine-Waste. *Society of Economic Geologists*.

Appendix A: Laboratory Certificates

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CERTIFICATE OF ANALYSES
NETT ACID GENERATION

Date received: 2015-04-01 **Date completed: 2015-05-11**
Project number: 1000 **Report number: 51396** **Order number: VMC3049**

Client name: Digby Wells Environmetal **Contact person: Andre van Coller**
Address: Private Bag X 10046, Randburg, 2125 **Email: andre.van.coller@digbywells.com**
Telephone: 011 789 9495 **Facsimile: 011 789 9498** **Cell: 076 076 9443**

Nett Acid Generation	Sample Identification: pH 4.5			
	FS7520	FS7508	FS7481	FS7481
Sample Number	2807	2808	2809	2809D
NAG pH: (H_2O_2)	6.0	5.8	5.7	5.6
NAG (kg H_2SO_4 / t)	<0.01	<0.01	<0.01	<0.01

Nett Acid Generation	Sample Identification: pH 7			
	FS7520	FS7508	FS7481	FS7481
Sample Number	2807	2808	2809	2809D
NAG pH: (H_2O_2)	6.0	5.8	5.7	5.6
NAG (kg H_2SO_4 / t)	3.53	3.92	6.47	6.86

Nett Acid Generation	Sample Identification: pH 4.5	
	MML A	MML B
Sample Number	2810	2811
NAG pH: (H_2O_2)	6.1	6.1
NAG (kg H_2SO_4 / t)	<0.01	<0.01

Nett Acid Generation	Sample Identification: pH 7	
	MML A	MML B
Sample Number	2810	2811
NAG pH: (H_2O_2)	6.1	6.1
NAG (kg H_2SO_4 / t)	2.16	1.96

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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
ACID – BASE ACCOUNTING
EPA-600 MODIFIED SOBEK METHOD

Date received: 2015-04-01 | **Date completed:** 2015-05-11

Project number: 1000 | **Report number:** 51396 | **Order number:** VMC3049

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Acid – Base Accounting Modified Sobek (EPA-600)	Sample Identification		
	FS7520	FS7508	FS7481
Sample Number	**2807**	**2808**	**2809**
Paste pH	9.0	9.0	9.3
Total Sulphur (%) (LECO)	0.09	0.13	0.02
Acid Potential (AP) (kg/t)	2.81	4.06	0.625
Neutralization Potential (NP)	26	26	30
Nett Neutralization Potential (NNP)	23	22	30
Neutralising Potential Ratio (NPR) (NP : AP)	9.27	6.36	49
Rock Type	III	III	III

Acid – Base Accounting Modified Sobek (EPA-600)	Sample Identification		
	MML A	MML B	MML B
Sample Number	**2810**	**2811**	**2811 D**
Paste pH	8.1	8.2	---
Total Sulphur (%) (LECO)	0.51	0.49	0.49
Acid Potential (AP) (kg/t)	16	15	15
Neutralization Potential (NP)	34	34	34
Nett Neutralization Potential (NNP)	18	18	19
Neutralising Potential Ratio (NPR) (NP : AP)	2.10	2.19	2.24
Rock Type	II	II	II

*** 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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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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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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REFERENCES

LAWRENCE, R.W. & WANG, Y. 1997. **Determination of Neutralization Potential in the Prediction of Acid Rock Drainage**. Proc. 4th International Conference on Acid Rock Drainage. Vancouver. BC. pp. 449 – 464.

PRICE, W.A., MORIN, K. & HUTT, N. 1997. **Guidelines for the prediction of Acid Rock Drainage and Metal leaching for mines in British Columbia** : Part 11. Recommended procedures for static and kinetic testing. In: Proceedings of the Fourth International Conference on Acid Rock Drainage. Vol 1. May 31 – June 6. Vancouver, BC., pp. 15 – 30.

SOBEK, A.A., SCHULLER, W.A., FREEMAN, J.R. & SMITH, R.M. 1978. **Field and laboratory methods applicable to overburdens and minesoils**. EPA-600/2-78-054. USEPA. Cincinnati. Ohio.

SOREGAROLI, B.A. & LAWRENCE, R.W. 1998. Update on waste Characterisation Studies. Proc. Mine Design, Operations and Closure Conference. Polson, Montana.

USHER, B.H., CRUYWAGEN, L-M., DE NECKER, E. & HODGSON, F.D.I. 2003. **Acid-Base : Accounting, Techniques and Evaluation (ABATE): Recommended Methods for Conducting and Interpreting Analytical Geochemical Assessments at Opencast Collieries in South Africa.** Water Research Commission Report No 1055/2/03. Pretoria.

ENVIRONMENT AUSTRALIA. 1997. **Managing Sulphidic Mine Wastes and Acid Drainage**.

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CERTIFICATE OF ANALYSES
X-RAY DIFFRACTION

Date received: 2015-04-01 **Date completed: 2015-04-24**
Project number: 1000 **Report number: 51396** **Order number: VMC3049**

Client name: Digby Wells Environmetal **Contact person: Andre van Coller**
Address: Private Bag X 10046, Randburg, 2125 **Email: andre.van.coller@digbywells.com**
Telephone: 011 789 9495 **Facsimile: 011 789 9498** **Cell: 076 076 9443**

Composition (%) [s]					
FS7520		**FS7508**		**FS7481**	
2807		**2808**		**2809**	
Mineral	Amount (weight %)	**Mineral**	Amount (weight %)	**Mineral**	Amount (weight %r
Plagioclase	84.58	**Plagioclase**	89.67	**Plagioclase**	93.63
Chlorite	0.46	**Chlorite**	0.39	**Chlorite**	0.23
Magnetite	11.46	**Magnetite**	7.17	**Magnetite**	1.62
Muscovite	3.06	**Muscovite**	2.77	**Muscovite**	4.29
Siderite	0.44	**Siderite**	trace	**Siderite**	trace
Hornblende	trace	**Hornblende**	trace	**Hornblende**	trace
Calcite	trace	**Calcite**	trace	**Calcite**	0.22

Composition (%) [s]			
MML A		**MML B**	
2810		**2811**	
Mineral	Amount (weight %)	**Mineral**	Amount (weight %)
Plagioclase	90.89	**Plagioclase**	90.23
Chlorite	2.6	**Chlorite**	2.54
Magnetite	4.7	**Magnetite**	4.76
Muscovite	0.6	**Muscovite**	0.61
Siderite	1.21	**Siderite**	1.86

[s] Results obtained from sub-contracted laboratory

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X-RAY DIFFRACTION

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Note:

Tthe material was prepared for XRD analysis using a backloading preparation method.

It was analysed with a PANalytical Empyrean 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.
- Due to preferred orientation effects results may not be as accurate as shown in the table.
- Amorphous phases, if present, were not taken into consideration during quantification
- Traces of additional phases may be present

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CERTIFICATE OF ANALYSES
X-RAY FLUORESENCE

Date received: 2015-04-01
Date completed: 2015-04-24
Project number: 1000
Report number: 51396
Order number: VMC3049

Client name: Digby Wells Environmetal
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Major Elements	Major Element Concentration (wt %)[s]				
	FS7520	FS7508	FS7481	MML A	MML B
	2807	2808	2809	2810	2811
SiO_2	41.25	45.24	52.37	37.97	38.68
TiO_2	2.41	1.8	0.23	3.71	3.82
Al_2O_3	20.52	22.86	25.07	23.6	23.86
Fe_2O_3	18.05	13.99	3.26	16.55	16.69
MnO	0.1	0.06	0.03	0.08	0.09
MgO	1.7	0.6	0.43	2.74	2.52
CaO	11.25	10.06	10.86	8.99	9
Na_2O	3.04	3.88	5.26	2.66	2.58
K_2O	0.37	0.41	0.57	0.26	0.24
P_2O_5	<0.01	<0.01	0.01	<0.01	<0.01
Cr_2O_3	0.03	0.02	<0.01	0.02	0.02
SO_3	0.1	0.1	0.1	0.13	0.14
LOI	0.39	0.32	1.03	2.48	2.35
Total	99.29	99.38	99.32	99.32	100.1
H_2O-	0.06	0.04	0.1	0.14	0.13

[s] =Results obtained from sub-contracted laboratory

Notes: % g/g is equivalent to wt %; mg/kg is equivalent to ppm; n.d. = not determined; bold italicised font represents semi-quantitative data; * represents measurements reported in % g/g or wt%.

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Trace Elements	Trace Element Concentration (ppm) [s]				
	FS7520	FS7508	FS7481	MML A	MML B
	2807	2808	2809	2810	2811
As	<0.43	<0.43	<0.43	<0.43	<0.43
Ba	87	104	98.4	76.8	79.5
Bi	1.51	1.29	1.51	1.54	2.12
Cd	7.19	4.05	7.16	3.61	7.18
Ce	182	116	43.8	<3.08	<3.08
Cl	165	167	178	133	132
Co	<0.56	<0.56	<0.56	<0.56	<0.56
Cs	1.31	2	2.15	<0.49	2.97
Cu	256	304	31.6	1,023	1,045
Ga	28.5	25.3	17.3	28.1	29.4
Ge	<0.50	<0.50	<0.50	<0.50	<0.50
Hf	28.2	20.3	<0.38	36.6	41.2
Hg	<1.00	<1.00	<1.00	<1.00	<1.00
La	12.3	67.8	99.8	43.5	33.4
Lu	3.8	3.14	2.05	4.05	3.72
Mo	1.61	1.9	1.64	1.91	1.94
Nb	3.95	4.49	3.88	4.99	5.18
Nd	<2.39	14.1	49.8	<2.39	<2.39
Ni	120	97.2	<5.14	404	413
Pb	<2.03	<2.03	<2.03	<2.03	<2.03
Rb	8.03	7.14	7.59	7.57	7.84
Sb	<1.48	<1.48	<1.48	5.42	<1.48
Sc	36.5	36	45.3	39.4	33.9
Se	<0.36	<0.36	<0.36	<0.36	<0.36
Sm	69.3	48	13.1	59.5	74.9
Sn	21.2	14.2	9.02	15.1	16.1
Sr	239	276	321	221	226
Ta	2.64	1.99	1.73	2.97	2.49
Te	10.3	13.6	11.7	9.04	10.5
Th	<0.88	<0.88	<0.88	<0.88	<0.88
Tl	0.83	0.57	0.28	0.81	0.92
Results continued on next page					

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CERTIFICATE OF ANALYSES
X-RAY FLUORESENCE

Date received: 2015-04-01 **Date completed: 2015-04-24**
Project number: 1000 **Report number: 51396** **Order number: VMC3049**

Client name: Digby Wells Environmetal **Contact person: Andre van Coller**
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Trace Elements	Trace Element Concentration (ppm) [s]				
	FS7520	FS7508	FS7481	MML A	MML B
	2807	2808	2809	2810	2811
U	1.28	2.1	3.31	<0.74	1.34
V	<7.60	<7.60	<7.60	<7.60	<7.60
W	1.66	1.51	1.04	1.76	1.84
Y	<0.97	<0.97	3.98	<0.97	<0.97
Yb	20.2	16.6	6.45	19.4	22.2
Zn	43.8	41.6	42.6	75.3	78.1
Zr	16.6	12.6	16.2	14	12.3

[s] =Results obtained from sub-contracted laboratory

XRF: Major Element Analysis (Geological)

The samples were prepared by first drying the samples at 100$_o$C for ~3 hours in order to determine loss of moisture content (H_2O-), followed by ashing of the sample at 1000$_o$C until completely ashed, to determine the loss on ignition (LOI). XRF analyses were performed using a PANalytical Epsilon 3 XL ED-XRF spectrometer, equipped with a 50kV Ag-anode X-ray tube, 6 filters, a helium purge facility and a high resolution silicon drift detector, calibrated using a number of international and national certified reference materials (CRMs).

XRF: Trace Element Analysis (Geological)

XRF analyses were performed using a PANalytical Epsilon 3 XL ED-XRF spectrometer, equipped with a 50kV Ag-anode X-ray tube, 6 filters, a helium purge facility and a high resolution silicon drift detector, calibrated using international and national certified reference materials (CRMs).

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CERTIFICATE OF ANALYSES

Digestion AS 4439.3

Date received:	**2015/04/01**			**Date completed:**	**2015/05/11**	
Project number:	**1000**	**Report number:**	**51396**	**Order number:**	**VMC3049**	

Client name:	**Digby Wells Environmetal**	**Contact person:**	**Andre van Coller**
Address:	**Private Bag X 10046, Randburg, 2125**	**Email:**	**andre.van.coller@digbywells.com**
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Analyses	FS7520		FS7508		FS7481		MML A		MML B		
Sample Number	2807		2808		2809		2810		2811		TCT0 mg/kg
Digestion	Aqua Regia		Aqua Regia		Aqua Regia		Aqua Regia		Aqua Regia		
Dry Mass Used (g)	0.25		0.25		0.25		0.25		0.25		
Volume Used (mℓ)	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	
As, Arsenic	<0.010	<4.00	<0.010	<4.00	<0.010	<4.00	<0.010	<4.00	<0.010	<4.00	5.8
B, Boron	<0.025	<10	<0.025	<10	<0.025	<10	<0.025	<10	<0.025	<10	150
Ba, Barium	0.288	115	0.308	123	0.227	91	0.213	85	0.249	100	62.5
Cd, Cadmium	0.033	13	0.016	6.40	<0.005	<2.00	0.016	6.40	0.019	7.60	7.5
Co, Cobalt	0.210	84	0.151	60	<0.025	<10	0.730	292	0.750	300	50
$Cr_{Total,}$ Chromium Total	0.559	224	0.269	108	<0.025	<10	0.522	209	0.548	219	46000
Cu, Copper	1.03	412	1.21	484	0.041	16	4.48	1792	4.61	1844	16
Hg, Mercury	<0.001	<0.4	<0.001	<0.4	<0.001	<0.4	<0.001	<0.4	<0.001	<0.4	0.93
Mn, Manganese	1.20	480	0.852	341	0.404	162	1.38	552	1.58	632	1000
Mo, Molybdenum	<0.025	<10	<0.025	<10	<0.025	<10	<0.025	<10	<0.025	<10	40
Ni, Nickel	0.424	170	0.347	139	<0.025	<10	1.44	576	1.49	596	91
Pb, Lead	<0.020	<8.00	<0.020	<8.00	<0.020	<8.00	<0.020	<8.00	<0.020	<8.00	20
Sb, Antimony	0.026	10	0.033	13	<0.010	<4.00	0.025	10	0.032	13	10
Se, Selenium	<0.020	<8.00	<0.020	<8.00	<0.020	<8.00	<0.020	<8.00	<0.020	<8.00	10
V, Vanadium	4.22	1688	2.63	1052	<0.025	<10	2.25	900	2.28	912	150
Zn, Zinc	0.278	111	0.140	56	0.033	13	0.276	110	0.289	116	240
Inorganic Anions	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 [s]	---	<5	---	<5	---	<5	---	<5	---	<5	6.5
Total Fluoride [s] mg/kg	---	117	---	112	---	143	---	112	---	103	100
Total Cyanide as CN mg/kg	---	<0.01	---	<0.01	---	<0.01	---	<0.01	---	<0.01	14

[s] = subcontracted

UTD = Unable to determine

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CERTIFICATE OF ANALYSES
EXTRACTIONS AS 4439.3

Date received:	**2015/04/01**		
Project number:	**1000**	**Report number:**	**51396**

Client name:	**Digby Wells Environmetal**
Address:	**Private Bag X 10046, Randburg, 2125**
Telephone:	**011 789 9495**

Analyses	FS7520	FS7508	FS7481	MML A	MML B
Sample Number	**2807**	**2808**	**2809**	**2810**	**2811**
TCLP / Borax / Distilled Water	**Distilled Water**	**Distilled Water**	**Distilled Water**	**Distilled Water**	**Distilled Water**
Ratio*	**1:20**	**1:20**	**1:20**	**1:20**	**1:20**
Units	**mg/ℓ**	**mg/ℓ**	**mg/ℓ**	**mg/ℓ**	**mg/ℓ**
As, Arsenic	<0.010	<0.010	<0.010	<0.010	<0.010
B, Boron	<0.025	<0.025	<0.025	<0.025	<0.025
Ba, Barium	<0.025	<0.025	<0.025	<0.025	<0.025
Cd, Cadmium	<0.003	<0.003	<0.003	<0.003	<0.003
Co, Cobalt	<0.025	<0.025	<0.025	<0.025	<0.025
$Cr_{Total,}$ Chromium Total	<0.025	<0.025	<0.025	<0.025	<0.025
Cr(VI), Chromium (VI)	<0.010	<0.010	<0.010	<0.010	<0.010
Cu, Copper	<0.025	<0.025	<0.025	<0.025	<0.025
Hg, Mercury	<0.001	<0.001	<0.001	<0.001	<0.001
Mn, Manganese	<0.025	<0.025	<0.025	<0.025	<0.025
Mo, Molybdenum	<0.025	<0.025	<0.025	<0.025	<0.025
Ni, Nickel	<0.025	<0.025	<0.025	<0.025	<0.025
Pb, Lead	<0.010	<0.010	<0.010	<0.010	<0.010
Sb, Antimony	<0.010	<0.010	<0.010	<0.010	<0.010
Se, Selenium	<0.010	<0.010	<0.010	<0.010	<0.010
V, Vanadium	<0.025	<0.025	<0.025	<0.025	<0.025
Zn, Zinc	<0.025	<0.025	<0.025	<0.025	<0.025
Inorganic Anions	**mg/ℓ**	**mg/ℓ**	**mg/ℓ**	**mg/ℓ**	**mg/ℓ**
Total Dissolved Solids at 180ºC	52	38	38	76	60
Total Alkalinity as CaCO3	24	20	24	28	28
Chloride as Cl	<5	<5	<5	<5	<5
Sulphate as SO4	<5	<5	<5	18	18
Nitrate as N	<0.2	<0.2	<0.2	<0.2	<0.2
Fluoride as F	<0.2	<0.2	<0.2	<0.2	<0.2
Total Cyanide as CN	<0.01	<0.01	<0.01	<0.01	<0.01
pH Value at 25˚C	7.8	7.7	7.7	7.3	7.4
Electrical Conductivity in mS/m at 25˚C	5.4	4.4	5.1	10.2	10.2

Acid Base Accounting	See attached report 51396 ABA
Nett Acid Generation	See attached report 51396 NAG
X-ray Diffraction [s]	See attached report 51396 XRD
X-ray Fluoresence [s]	See attached report 51396 XRF

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Date completed:	**2015/05/11**
Order number:	**VMC3049**
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LCT0 mg/l
0.01
0.5
0.7
0.003
0.5
0.1
0.05
2.0
0.006
0.5
0.07
0.07
0.01
0.02
0.01
0.2
5
1000
300
250
11
1.5
0.07