DWARSRIVIER

DWARSRIVIER

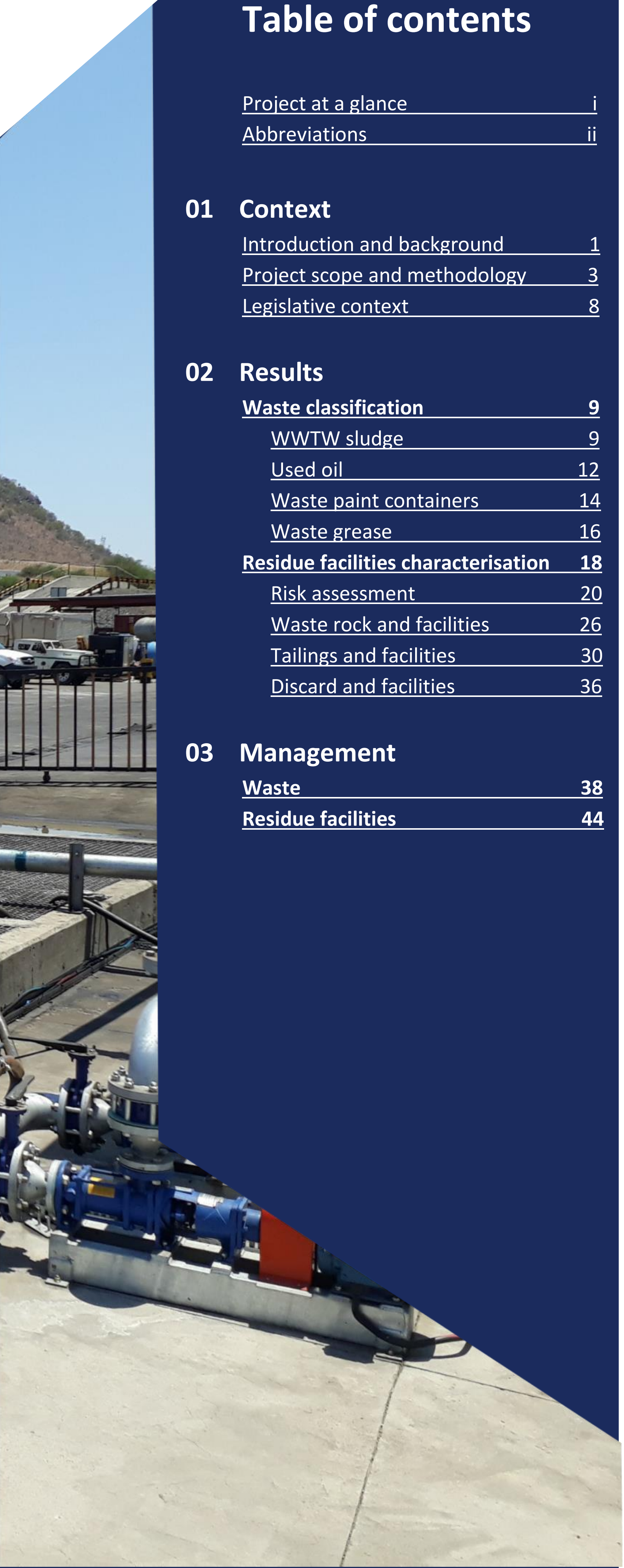
Project: DWR/18/01
Report: DWR/18/01/01
Client: Dwarsrivier Chrome Mine (Pty) Ltd

nettZero

Waste classification and characterisation Phase 4 report

Draft

December 2018



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Figures ( ) and maps ( )

Appendices

Dwarsrivier Chrome Mine: Waste classification and characterisation phase 4

Dwarsrivier Chrome Mine (Pty) ltd

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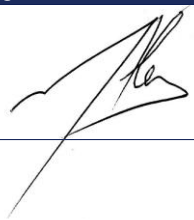
Author	Marius Alers		4 December 2018

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Pieter Schoeman	Submission of final report		
Thandiwe Buthelezi	Submission of final report		

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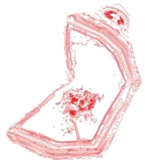
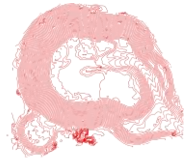
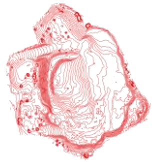
Project at a glance

Residue characterization

		New TSF	Old TSF	North WRD	Discard dump	South WRD	TSF fill pit (North)	TSF fill pit (South)
								
Material stored:		Tailings	Tailings	Waste rock	Discard	Waste rock	Tailings	Tailings
Waste class. (iLEH classification):		Type 3	Type 3	Type 3	Type 3	Type 3	Type 3	Type 3
Liner type (required i.t.o. GN 636):		Class C	Class C	Class C	Class C	Class C	Class C	Class C
Liner type (Actual installed):		Class C	≈ Class D	None	None	None	None	None
Potential risk:	to aquatic env.	Low	Mod	Mod	Mod	Mod	Mod	Mod
	to terrestrial env.	Mod	Mod	Mod	Mod	Mod	Mod	Mod
	to human health	Low	Low	Low	Low	Low	Low	Low
Material characteristics:	Friction angle (Φ')	32.6°	33°	33.5°	≈ 34° - 37°	33.5°	32.6°	32.6°
	Cohesion (c')	8 kPa	7.2 kPa	12.9 kPa	≈ < 5 kPa	12.9 kPa	8 kPa	8 kPa
	Permeability (cm/s)	3.15×10^{-4}	2.35×10^{-4}	2.66×10^{-5}	$\approx 1 \times 10^{-3} - 1 \times 10^{-4}$	2.66 x 10-5	3.15×10^{-4}	3.15×10^{-4}
	Void ratio's	0.71	0.731	0.312	≈ 0.45 – 0.55	0.312	0.71	0.71
	Density (g/cm³)	2.269	2.27	2.344	-	2.344	2.269	2.269

Waste classification

		Used Oil	WWTW sludge	Waste grease	Paint containers	Waste rock	Tailings	Discard
								
DWAF guideline class.:		-	A1c	-	-	-	-	-
Waste class. type:		Type 1	Type 3	Type 1	Type 4 (Dry, <3% wt.) Type 1 (Wet, >3% wt.)	Type 3	Type 3	Type 3
GHS class.:	Physical hazards	-	-	-	-	-	-	-
	Health hazards	Cat. 5	-	-	-	-	-	-
	Aquatic hazards	Cat. 4	Cat. 4	Cat. 3	-	-	-	-
Waste type:		Hazardous	Hazardous	Hazardous	Non-haz. (dry,<3% wt.); Haz. (wet,>3% wt.)	Non-hazardous	Non-hazardous	Non-hazardous
Disposal requirement:		Not allowed ito GN 636, s5 (1j)	> Class C (≈ GLB+)	Class A (≈ Hh/HH)	Class D (dry,<3% wt.); Class A (wet,>3% wt.)	> Class C (≈ GLB+)	> Class C (≈ GLB+)	> Class C (≈ GLB+)

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Abbreviations and definitions

ABA – Acid Based Accounting
ASTM – American Society for Testing and Materials
DCM – Dwarsrivier Chrome Mine
DWAF – Department Water Affairs and Forestry (before 2008)
DWS – Department Water and Sanitation
EPA – Environmental Protection Agency
ERM – Environmental Resource Management (Pty) Ltd
GCS – GCS (Pty) Ltd
GHS – Global Harmonizing System
GN – Government Notice
GNR – Government Notice Regulation
iLEH – Irene Lea Environmental and Hydrology cc
LC_{50} and EC_{50} – Half Lethal concentration (LC_{50}) and Half Effective concentration (EC_{50})
LCT – Leachable Concentration Thresholds
NEMA – National Environmental Management Act (Act 107 of 1998)
NEM:WA – National Environmental Management Waste Act (Act 59 of 2008)
NWA – National Water Act
OEM – Original equipment manufacturer
PSD – Particle Size Distribution
SANS – South African National Standard
TCLP – Toxicity Characteristic Leaching Procedure
TCT – Total Concentration Thresholds
TS – Total Solids
TSF – Tailings Storage Facility
VFA – Volatile Fatty Acids
VS – Volatile Solids
WRC – Water Research Commission
WRD – Waste Rock Dump
WWTW – Waste Water Treatment Works

Icons, buttons and directions

A. - Abbreviations icon. Link to abbreviations

- Button back to table of contents

- This indicates chapter 1. These are on the right side of each page

01 Context

1. Introduction

Dwarsrivier Chrome Mine (Pty) Ltd (Dwarsrivier) is situated approximately 25km southwest of Steelpoort on the border between Limpopo and Mpumalanga. It holds the surface and mining rights for Portion 1 (Remaining Extent) and Portion O (Remaining Extent) of the farm Dwarsrivier 372 KT. Dwarsrivier ended open pit operations in 2006 and is currently producing chromite ore from underground via two decline shafts, with a dense medium separation and spiral beneficiation plant to concentrate the ore to client specifications. The underground mine is a trackless, board and pillar operation with a production rate of approximately 120,000t of chromite ore per month. Dwarsrivier is both ISO 14001 and OHSAS 18001 certified for the whole operation, and ISO 9001 certified for the beneficiation plant. A total of 1709 employees are on site, of which approximately 1 133 are permanent employees and the bulk contractors. Dwarsrivier has various environmental authorizations, water use licences, general authorizations, and permits to conduct its activities.

Dwarsrivier undertook waste classification during 2017 and 2018 in a phased approach. It has classified the bulk of its waste streams via classification phases 1, 2 and 3, and has appointed Nettzero (Pty) Ltd (Nettzero) to complete the classification of the remaining waste streams, to conduct characterisation of its residue stockpiles as per the residue stockpile regulations (GN 632, gg 39020) and to classify its sewage sludge according to the Guidelines for the utilisation and disposal of wastewater sludge (DWAF, TT 261/06).

2. Project background

DCM initiated a project to update the mines waste classifications for all their waste streams in 2017. The first phase of the project included the following tasks:

- The compilation of a comprehensive waste register for the operation, detailing each waste stream, its waste classification and other waste management related information (e.g. source, storage location, volumes, transporter, recycling/disposal facility).
- An independent comprehensive study for the waste characterisation and classification of mining waste material including residue stockpiles and residue deposits to meet the requirements detailed in Waste Classification Regulations (National Environmental Management Waste Act, Act 59 of 2008: Waste Classification and Management Regulations 2013 (GN R634 of 23 August 2013).
- The classification of all other waste streams generated by the Dwarsrivier Chrome Mine operation;
- Specifically, the following activities are required in terms of these regulations:

ERM was appointed by the mine in 2017 to conduct this work. ERM recommended a three phased approach:

1. **Phase 1:** Identify waste streams and which streams require analysis;
2. **Phase 2:** Assess waste to determine the waste types in terms of the National Norms and Standards for the Assessment of Waste for Landfill Disposal, GNR 635 of 23 August 2013 and need for classification according to SANS 10234; and
3. **Phase 3:** Classification of identified hazardous wastes according to SANS10234

…project background

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A.

Context

ERM proceeded to compile Phase 1 of the project.

The mine appointed GCS (Pty) Ltd (GCS) and Irene Leah Environmental and Hydrology cc (iLEH) in 2018 to proceed with Phase 2 and Phase 3 of the project. Phase 2 and Phase 3 of the project included the following activities:

Phase 2: Waste Assessment

The waste assessments included the following waste streams:

GCS

- Process and Office Wastes
- Used oil;
- Degreaser or solvents;
- Unused chemicals/ redundant chemicals;
- Paint;
- Cleaning liquids;
- Flocculants;
- Pre-mix ready concrete waste packaging;
- Clarifier sludge.
- Contaminated soil;
- Sludge from diesel tank containment;
- Oil contaminated wastes (e.g. oily rags, oily filters);
- Chemical spills; and
- Silt (from silt traps and storm water system).

iLEH

- Waste rock
- Discard rock
- Tailings material

Phase 3: Waste Classification

The scope of work for the waste classification in terms of SANS 10234 included the following waste streams:

GCS

- Used Oil;
- Degreaser or solvents;
- Unused chemicals/ redundant chemicals;
- Packaging from hazardous products;
- Paint;
- Cleaning liquids;
- Flocculent containers;
- Pre-mix ready concrete waste packaging;
- Clarifier sludge;
- Fluorescent tubes; and
- Oily rags.

iLEH

- Waste rock
- Discard rock
- Tailings material

The above waste classification studies of iLEH, in addition to the waste classification, has also assessed toxicity of the leachates in terms of its LC50 or EC50 using a 72-hour green algae, 24 – 48 hour water flea, and a 96 hour guppy exposure using a 100% leachate.

The waste classifications provide valuable leachate and risk information which will be incorporated into the characterisation of these waste stream's storage facilities (see project for detail).

1. Project scope and methodology

The scope of work for this project includes the following 3 main areas:

1. Characterisation of:
   a) the north shaft waste rock dump (WRD),
   b) new tailings storage facility (TSF),
   c) old tailings storage facility (TSF),
   d) north pit tails backfill area,
   e) discard dump,
   f) south shaft waste rock dump (WRD),
   g) the south pit backfill area.

2. Waste classification of the sewage sludge and classification in terms of the DWS guideline on WWTW.

3. Assessment of used oil, paint containers and waste grease in terms of the Global Harmonizing System (GHS)

**For detail of the legislation and standards used in the above assessments, classifications and characterisations, see legislative context (page 8).*

1.1. Characterisation

1.1.1. Overview of process

The characterisation for the above facilities (bullet points 1, facilities a – g) included sampling and test work, analysis and risk determination, all of which provided the information to conclude on the characterisation of the facility. The objective of the characterisation of these facilities is, simply put, to determine its behaviour and resultant risks and hazards, both from an environmental and health perspective. This is done by understanding the material, its properties (chemical and physical) and how these, considering the dimensions and location of the facilities, will behave under certain storage conditions to ultimately affect potential receptors. Understanding the materials and its properties will tell us what these materials are made of (chemically and mineralogically), their structure (particle size distribution), and its behaviour (consolidation, shearing, permeability) under certain conditions. This provides us with the information to estimate the potential risks these materials might pose under predicted storage conditions (how it will fail (shear), how it will consolidate, etc.) and what its composition and toxicity is.

The main risks (which can form hazards) from these facilities are particulate matter formation (PM), seepage and resultant leachate formation, and failure of the facilities. These risks can cause hazards through inhalation of the PM, contamination and resultant pollution of natural resources through the interaction with the leachates, and biological (human and natural) loss through failure of facilities.

Each of these hazards will be evaluated and scored, where possible, to indicate its hazard level. Scoring will be done as per the risk assessment criteria (see figure 10 page 19).

1.1.2. Sampling and test work

1.1.2.1. Sample collection and preparation

Material were collected from the 5 facilities a, b, c, e, and f, mentioned above under bullet point one (and as is indicated on the DCM layout map facilities 1, 2, 4, 5, and 7 on page 7). Roughly ≈90kg of sample were collected at each of the 5 facilities, thus collectively amounting to about ≈450kg of sample. The six waste rock samples from facilities a and f were then repeatedly quartered and made into one composite sample of ≈90kg. Similarly, the six tailings samples from facilities b and c were also repeatedly quartered and made into one composite sample of ≈90kg. The discard sampling was only done at the one facility and the three samples were also quartered and made into one composite sample of ≈90kg. The ≈90kg composite waste rock sample, the ≈90kg composite tailings sample, and the ≈90kg discard sample were then delivered to the M & L laboratory in Johannesburg and the Geolab laboratory in Pretoria, both on the 20th September 2018.

1.1.2.2. Sampling locations

Sample locations are indicated on the detailed facility maps on the following pages:

- New TSF on page 32
- North shaft waste rock dump on page 29
- Discard dump on page 37
- Old TSF on page 33
- South shaft waste rock dump on page 28

1.1.2.3. Laboratory analysis

1.1.2.3.1. Geotechnical analysis

The geotechnical analysis focused on the physical properties of the waste rock and tailings material and included the following tests and preparations:

- Proctor to 95% (preparations),
- shear box test,
- constant head permeability test,
- PSD analysis (sieve analysis)

The above test work was undertaken to achieve the following test results:

- Particle size analysis with grading modulus,
- Shear strength,
- Void ratio's,
- Densities (dry and wet),
- Specific gravities,
- Moisture contents

1.1.2.3.2. Geochemical and mineral analysis

The geochemical and mineral analysis focused on the chemical and mineral characteristics of the material. The chemical characteristics included, not only, its chemical composition, but also its leaching behaviour. **Total concentrations** were tested by digesting the sample in acid and then doing a multi-element trace analysis by Inductively Coupled Plasma Mass Spectrometry (ICP-MS). This method is commonly referred to as the aqua regia digestion method.

The **leaching** behaviour was tested under three leaching conditions, which entailed digesting the sample using the following solutions:

- a 5% de-ionised water solution,
- a 5% acetic acid solution, and
- a 5% $Na_2B_4O_7$ solution.

The 5% de-ionised water test is commonly used in waste classification when testing inorganic waste types. This testing type was done on both the previous residue related waste classifications in 2009 and 2018, which was done by EScience and iLEH, respectively. The 5% acetic acid solution is more commonly called the TCLP test and represents a relatively more "aggressive" leaching scenario. The 5% $Na_2B_4O_7$ solution on the other hand represents a less "aggressive" leaching scenario. The testing standards for the above leaching tests are:

- EPA 1311 and ASTM Method D-4874 (TCLP test)
- ASTM D3987 (5% de-ionised water)
- Method W044-28-O (5 % $Na_2B_4O_7$ solution)

1.2. Waste classification (Sewage sludge)

The Waste Water Treatment Works (WWTW) sludge was tested and analysed according to the *DWAF guideline on the utilisation and disposal of* *wastewater sludge vol 1 – 5, 2006 (WRC Report No. TT 261/06)(Will be referred to in this report going forward as the DWAF guidelines).*

1.2.1. Sampling

Samples were collected at the waste water treatment works, which is located near the main offices. A total of ≈3kg (3 x 1kg samples) of material were collected on the 19th September 2018 and placed in three sealable Ziploc bags. The samples were then placed in a container at room temperature and delivered to the M & L laboratory the following day.

1.2.2. Laboratory analysis

The WWTW sludge suite of analysis conducted can be subdivided into 5 areas, nl.:

1. Physical characteristics
2. Nutrients
3. Metals and micro-elements
4. Organic pollutants
5. Microbiological quality

The physical characteristics analysed includes pH, Total Solids (TS), Volatile Solids (VS), and Volatile Fatty Acids (VFA).

The nutrients analysed includes Total Kjeldahl Nitrogen, Phosphorus, and Potassium.

The Metals and micro-elements analysed includes Arsenic (As), Boron (B), Barium (Ba), Cadmium (Cd), Cobalt (Co), Chromium (Cr), Copper (Cu), Phosphorus (P), Mercury (Hg), Manganese (Mn), Molybdenum (Mo), Sodium (Na), Nickel (Ni), Lead (Pb), Antimony (Sb), Selenium (Se), Vanadium (V), and Zinc (Zn).

The organic pollutants analysed included the Poly Aromatic Hydrocarbons (PAH's) Naphthalene, Acenaphthylene, Acenaphthene, Fluorene, Phenanthrene, Anthracene, Fluoranthene, Pyrene, Benzo(a)anthracene, Chrysene, Benzo(b+k)fluoranthene, and Benzo(a)pyrene.

The microbiological quality analysed includes faecal coliform and total helminth ova.

1.3. Waste classification in terms of SANS 10234 (GHS)(Used oil, Waste paint containers, and Waste grease)

The used oil, waste paint containers and waste grease all fall under the definition of 'expired, spoilt or unusable hazardous products' and therefore do not require classification in terms of regulation 4(1), nor assessment in terms of Regulation 8(1)(a) of the waste classification and management regulations (GN 634 of 2013).

This means the waste types above need not be classified according to the regulations but still be classified according to the GHS as standardized in SANS 10234. The waste paint containers and the waste grease are expected to undergo negligible chemical or physical alteration from product (as received from OEM) to waste and the OEM MSDS will provide enough information to do a GHS classification. Hence, no analysis was done on these two waste types.

The used oil is expected to undergo some chemical and physical change throughout its usage, handling and storage lifecycle, seen that the used oil is expected to encounter other hydrocarbons, degreasers, water and other chemicals such as antifreezes. This might cause a change from its original OEM composition and thus possible changes to the GHS classification. Hence, the used oil has been subjected to a full total concentration lab test to analyse the chemical composition.

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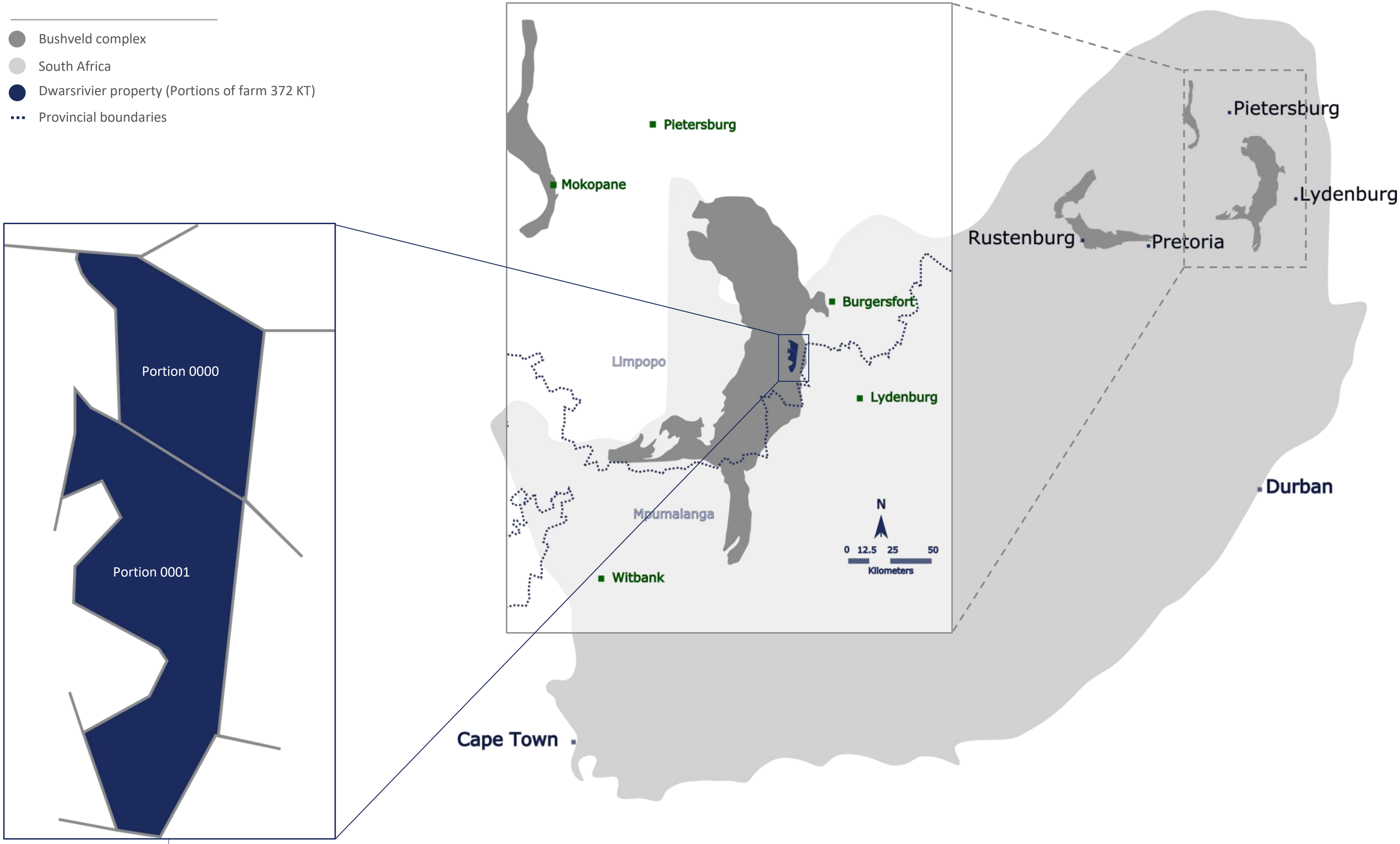
Project location

- Bushveld complex
- South Africa
- Dwarsrivier property (Portions of farm 372 KT)
- Provincial boundaries



To detailed map on next page

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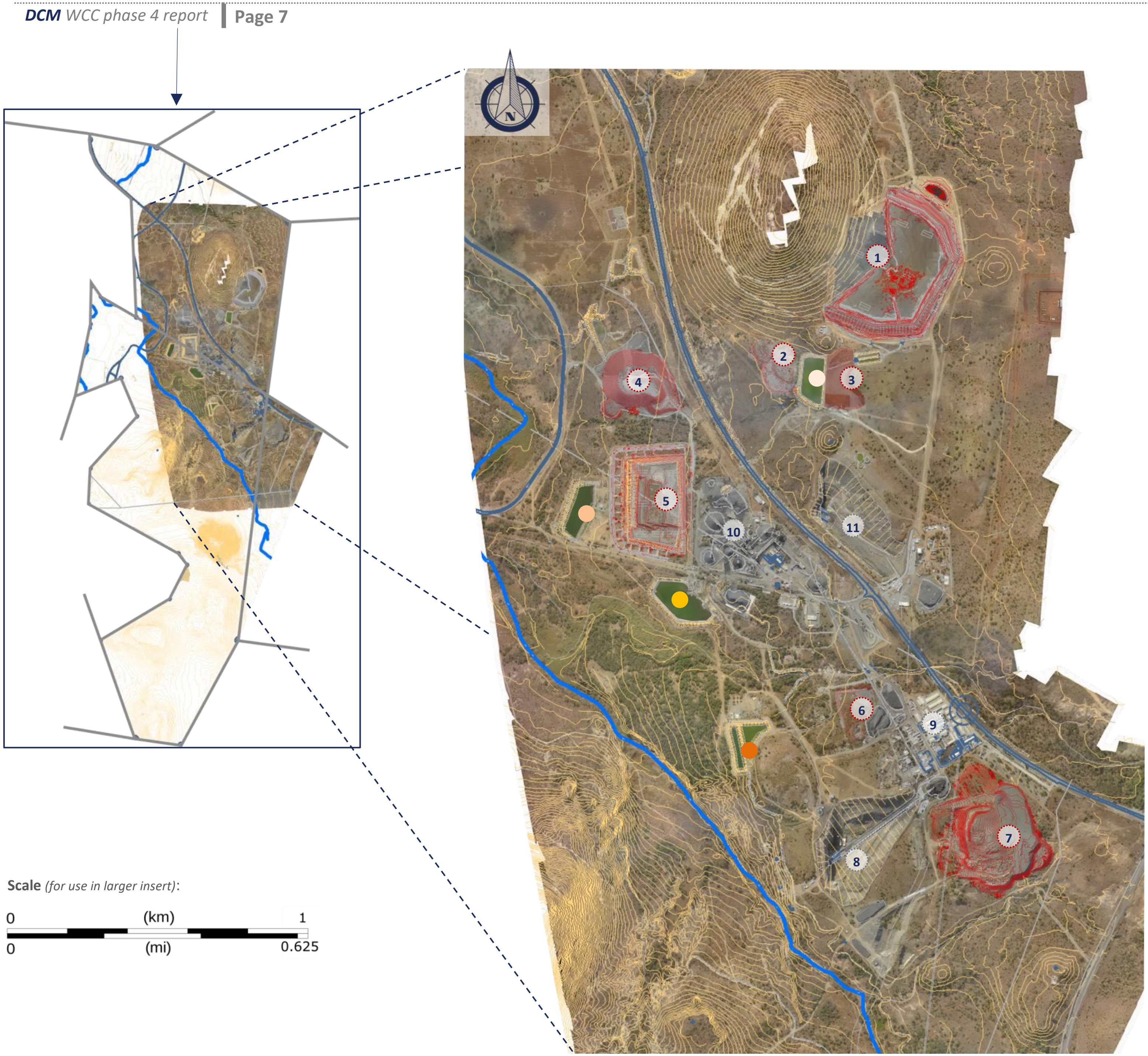
A.

DCM operational layout



Legend:

- Groot Dwarsrivier
- Topographical contours
- Public roads
- DCM infrastructure
- Residue facilities studied

Residue facilities of study *Link to map.*

1. New TSF
2. North Waste Rock Dump
3. North Pit Tailings backfill area
4. Discard dump
5. Old TSF
6. South Pit Tailings backfill area
7. South Waste Rock Dump

Main DCM infrastructure

8. South shaft (decline)
9. Main offices
10. Processing plant
11. North shaft (decline)

Main dirty water facilities

- DAM 26 (Near south shaft (No. 8))
- URWD (Near old TSF (No. 5))
- LRWD (Near old TSF (No. 5))
- New RWD (Near new TSF (No. 1))

Legislative context

1. Residue characterisation

The residue characterisation process is regulated under the '*regulations regarding the planning and management of residue stockpiles and residue deposits from a prospecting, mining, exploration or production operation'* published in government notice regulation no. 632 on 24 July 2015.

This regulation is published under NEM:WA and forms part of the department environmental affairs' waste division.

2. Waste classification

The waste classification suite of regulation and norms and standards has first been published in government gazette no. 36 784 in August 2013, under government notices 634 – 636.

This regulations are also published under NEM:WA and forms part of the department environmental affairs' waste division.

The GNR 634 regulation (4) refers to SANS 10234 as standardisation for the GHS classification process. The version used in this study is the latest version published by SANS, which is the 2008 version, SANS 10234: 2008.

3. WWTW sludge DWAF classification

The classification of the WWTW sludge is done in terms of the waste regulations mentioned above as well as the *DWAF guideline on the utilisation and disposal of wastewater sludge vol 1 – 5, 2006 (WRC Report No. TT 261/06)*.

The DWAF guideline is, as per the namesake, a guideline on how to use and dispose of the waste water sludge. It has been completed in 2006 by the water research commission for the then department of water affairs and forestry.

The WWTW sludge sampled at the DCM sewage plant has been classified according to the DWAF guideline.

02 Results

Waste classification (WWTW DWAF)

1. WWTW sludge

1.1. WWTW sludge DWAF guidelines classification results

The WWTW sludge has been sampled and analysed as per the DWAF guidelines (see legislative context). The guidelines use the sample results to classify the sludge into a **pollution class**, a **stability class** and a **microbiological class** (See figure 1 below)**.** The pollution class is divided into class a, class b, and class c, the stability class into class 1, class 2 and class 3, and the microbiological class into class A, class B and class C.

In figure 1 below we used the laboratory results in the test results columns to classify each sample using the thresholds in the classes columns.

Figure 1: WWTW DWAF classification table

Elements & Chemical substances in Waste	DWAF classes			Test results			DWAF classification		
	1/A/a	2/B/b	3/C/c	Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3
Physical characteristics									
pH	*Use vector classification system. See DWAF guidelines Table 4, page 24.*			9	9,4	9,3	TS used for vector classification		
Total Solids (TS)				98,75%	98,74%	98,59%	Class 1	Class 1	Class 1
Volatile solids (VS)				10,42%	11,20%	12,75%	TS used for vector classification		
Volatile Fatty Acids (VFA)				2836%	2984%	2985%			
Metals and micro-elements									
Ag, Silver (mg/kg)									
As, Arsenic (mg/kg)	< 40	40 - 75	> 75	< 2	< 2	< 2	Class a	Class a	Class a
B, Boron (mg/kg)	< 23	23 - 72	> 72	44	46	42	Class b	Class b	Class b
Ba, Barium (mg/kg)	< 108	108 - 250	> 250	29	32	34	Class a	Class a	Class a
Cd, Cadmium (mg/kg)	< 40	40 - 85	> 85	< 0,05	< 0,05	< 0,05	Class a	Class a	Class a
Co, Cobalt (mg/kg)	< 5	5 - 38	> 38	18,90	19,41	16	Class b	Class b	Class b
Cr, Chromium Total (mg/kg)	< 1 200	1 200 - 3 000	> 3 000	157	178	173	Class a	Class a	Class a
Cu, Copper (mg/kg)	< 1 500	1 500 - 4 300	> 4 300	43	46	49	Class a	Class a	Class a
P, Phosphorus (mg/kg)	*No thresholds*			*2 022*	*2 208*	*2 468*	*No classification*		
Hg, Mercury (mg/kg)	< 15	15 - 55	> 55	< 0,1	< 0,2	< 0,3	Class a	Class a	Class a
Mn, Manganese (mg/kg)	< 260	260 - 1 225	> 1 225	226	234	201	Class a	Class a	Class a
Mo, Molybdenum (mg/kg)	< 4	4 - 12	> 12	1,11	0,96	0,96	Class a	Class a	Class a
K, Potassium (mg/kg)	*No thresholds*			*3 781*	*4 003*	*4 306*	*No classification*		
Ni, Nickel (mg/kg)	< 420	420	> 420	191	197	168	Class a	Class a	Class a
Pb, Lead (mg/kg)	< 300	300 - 840	> 840	< 0,05	< 0,05	< 0,05	Class a	Class a	Class a
Sb, Antimony (mg/kg)	< 1,1	1,1 - 7	> 7	< 1	< 1	< 1	Class a	Class a	Class a
Se, Selenium (mg/kg)	< 5	5 - 15	> 15	43	45	35	Class c	Class c	Class c
V, Vanadium (mg/kg)	< 85	85 - 430	> 430	30	33	32	Class a	Class a	Class a
Zn, Zinc (mg/kg)	< 2 800	2 800 - 7 500	> 7 500	153	174	169	Class a	Class a	Class a
Nutrients									
Cl, Chlorite (mg/kg)	No macro element thresholds			7 304	7 527	6 729	No classification required		
SO4, Sulphate (mg/kg)				0,49	0,54	6,4			
NO3, Nitrate (mg/kg)				0	0	11,8			
N, Nitrogen (mg/kg)				0	0	2,67			
F, Fluoride (mg/kg)				1	1	1			
NH4, Ammonia as N (mg/kg)				995					
Organic pollutants									
Naphthalene (µg/kg)	Sum to be below 6mg/kg			BDL	BDL	BDL	No PAH's detected, no action required		
Acenaphthylene (µg/kg)				BDL	BDL	BDL			

…waste classification (WWTW DWAF)

Elements & Chemical substances in Waste	DWAF classes			Test results			DWAF classification		
	1/A/a	2/B/b	3/C/c	Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3
Acenaphthene (µg/kg)				BDL	BDL	BDL			
Fluorene (µg/kg)				BDL	BDL	BDL			
Phenanthrene (µg/kg)				BDL	BDL	BDL			
Anthracene (µg/kg)				BDL	BDL	BDL			
Fluoranthene (µg/kg)				BDL	BDL	BDL			
Pyrene (µg/kg)				BDL	BDL	BDL			
Benzo(a)anthracene (µg/kg)				BDL	BDL	BDL			
Chrysene (µg/kg)				BDL	BDL	BDL			
Benzo (b+k) fluoranthene (µg/kg)				BDL	BDL	BDL			
Benzo(a)pyrene (µg/kg)				BDL	BDL	BDL			
Microbiological quality									
Faecal coliforms	< 1 000	At least x2 < 1 x 10^5 and 1 sample allowed > 1 x 10^5 but < 1 x 10^7	> 1 x 10^7	< 10	< 10	< 10	Class A	Class A	Class A
Helminth Ova	< 0,25	< 1	> 4	Awaiting results					

The lowest rating achieved per classification group (Microbiological, Stability, and Pollution) was used to set a class for each group. The pollution class from figure 1 above were all class a, except for Selenium, Boron, and Cobalt, which fell in classes c, b and b, respectively. The lowest of these are class c, and hence the pollution class is rated as c. Similarly, all microbial results fell in class A and hence the microbial class is A. The stability class uses vector options to delineate the stability type and is detailed in the DWAF guidelines volume 1, Table 4, page 24, which in figure 1 classified as a stability class 1.

Figure 2: DCM sludge classification

Microbiological class	A	B	C
Stability class	1	2	3
Pollution class	a	b	c

A1c

Results discussion

The total solids were above 90 % and placed the sludge in a stability class 1, due to the compliance to vector reduction option 8. The selenium concentrations placed the sludge into a class c pollution class. No faecal coliform where observed in the laboratory tests, placing the microbiological class into a class A. This results in a sludge DWAF classification of **A1c**. The samples tested low for nitrate and nitrogen but high for ammonia and phosphorus. No poly aromatic hydrocarbons were detected.

The class c pollution classification restricts management options but can potentially be cleared for use as fertilizer during rehabilitation if used at low application rates. The management options are discussed in detail in section 3.

1.2. WWTW sludge waste classification results

The total concentrations of the WWTW sludge is provided in figure 3 below. All metal concentrations and inorganic ion concentrations were below the zero total concentration thresholds (TCT), except for copper (Cu), nickel (Ni) and selenium (Se). These three elements were above the TCT 0 values but below the TCT 1 values, qualifying the entire waste sample as type 3. The selenium was a common element of

…waste classification (WWTW Waste class.)

concern in both the waste classification and the DWAF classification of the WWTW sludge analysed in figure 1 above and figure 3 below.

Figure 3: WWTW sludge waste classification table (all in mg/kg)

	Thresholds			Results			Classification		
Elements tested	TCT 0	TCT 1	TCT 2	Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3
Metal ions									
As, Arsenic (mg/kg)	5,8	500	2 000	< 2	< 2	< 2	Type 4	Type 4	Type 4
B, Boron (mg/kg)	150	15 000	60 000	44	46	42	Type 4	Type 4	Type 4
Ba, Barium (mg/kg)	62,5	6 250	25 000	29	32	34	Type 4	Type 4	Type 4
Cd, Cadmium (mg/kg)	7,5	260	1 040	< 0,05	< 0,05	< 0,05	Type 4	Type 4	Type 4
Co, Cobalt (mg/kg)	50	5 000	20 000	18,9	19,41	16	Type 4	Type 4	Type 4
Cr, Chromium Total (mg/kg)	46 000	800 000	N / A	157	178	173	Type 4	Type 4	Type 4
Cu, Copper (mg/kg)	16	19 500	78 000	43	46	49	Type 3	Type 3	Type 3
Hg, Mercury (mg/kg)	0,93	160	640	< 0,1	< 0,2	< 0,3	Type 4	Type 4	Type 4
Mn, Manganese (mg/kg)	1 000	25 000	100 000	226	234	201	Type 4	Type 4	Type 4
Mo, Molybdenum (mg/kg)	40	1 000	4 000	1,11	0,96	0,96	Type 4	Type 4	Type 4
Ni, Nickel (mg/kg)	91	10 600	42 400	191	197	168	Type 3	Type 3	Type 3
Pb, Lead (mg/kg)	20	1 900	7 600	< 0,05	< 0,05	< 0,05	Type 4	Type 4	Type 4
Sb, Antimony (mg/kg)	10	75	300	< 1	< 1	< 1	Type 4	Type 4	Type 4
Se, Selenium (mg/kg)	10	50	200	43	45	35	Type 3	Type 3	Type 3
V, Vanadium (mg/kg)	150	2 680	10 720	30	33	32	Type 4	Type 4	Type 4
Zn, Zinc (mg/kg)	240	160 000	640 000	153	174	169	Type 4	Type 4	Type 4
Inorganic anions									
Cl, Chlorite (mg/kg)	-	-	-	7304	7527	6729	Type 4	Type 4	Type 4
SO4, Sulphate (mg/kg)	-	-	-	0,49	0,54	6,4	Type 4	Type 4	Type 4
NO3, Nitrate (mg/kg)	-	-	-	0	0	11,8	Type 4	Type 4	Type 4
N, Nitrogen (mg/kg)	-	-	-	0	0	2,67	Type 4	Type 4	Type 4
F, Fluoride (mg/kg)	100	10 000	40 000	1	1	1	Type 4	Type 4	Type 4
CN, Cyanide Total (mg/kg)	14	10 500	42 000	-	-	-	Type 4	Type 4	Type 4

1.3. WWTW sludge GHS classification

Physical hazard

The WWTW sludge has no physical hazards. The pH is high and thus more basic but has no physical hazard effect.

Health hazards

This waste stream contains trace amounts of metals and micro-elements (see figure 3 above), of which only selenium, cobalt and boron exceed the waste classification zero total concentration thresholds. These thresholds however are disposal related with a strong emphasis on leachate, while the GHS focuses strongly on acute and chronic hazards largely from an exposure points of view. Thus, from a GHS perspective these trace elements do not even make up one tenth of a percentage of the total concentration on a weight basis, varying between 0.0035 % (35 mg/kg) to a high of 0.0197 % (197 mg/kg). The macro-elements phosphorus, potassium, and chlorite constitute higher weight concentrations at 0.25 %, 0.43 % and 0.75 %, respectively, but are still below 1 %. The bulk of the sludge material (98 % - 99%) consists of organic matter in the form of fats, fatty acids, and other organic matter. Negligible acute hazards are expected from inhalation as no airborne pathogens or volatile gases have been observed in the lab analysis. Hazards might be expected on contact with skin when there is open lacerations or other injuries and the sludge contains pathogens. This causes a potential H313 hazard as it '***may be*** *harmful in contact with skin*'. Oral exposure to the material might have an acute toxicity, albeit low, as it may be harmful if swallowed (hazard H303). This is a precautionary approach as the faecal coliforms tested were below detection limits and thus safe, but breakthroughs might happen from time to time. The H303 emphasis in this case is thus on '***may be***…'. The toxicity is also expected to only be at larger quantities and thus falls in category 5.

Hazards to aquatic environment

The WWTW sludge's high phosphorus, nutrient and organic load can be hazardous to the aquatic environment, but only at larger quantities and on a chronic level. Short term acute exposure is expected to have negligible effect on the aquatic systems, while a long-term chronic exposure might cause aquatic system toxicity due to the nutrient and organic loads and its direct and indirect effects, such as dissolved oxygen decreases. This however does not fall in SANS 10234's 1st, 2nd, or 3rd hazard categories but the 4th category. This hazard category has been introduced in the classification system as a "safety net" when the available data do not allow for classification under the formal criteria but there are nevertheless some grounds for concern. The hazards are in line with H402: Harmful to aquatic life.

Figure 4: WWTW sludge GHS classification table

Hazard class	Hazard category	Hazard statement
Physical hazard		
Explosives	None	None
Flammable gasses	None	None
Flammable aerosols	None	None
Oxidising gasses	None	None
Gasses under pressure	None	None
Flammable liquids (<93 °)	None	None
Flammable solids	None	None
Self-reactive substances and mixtures	None	None
Pyrophoric substances	None	None
Self-heating substances and mixtures	None	None
Substances and mixture that on contact with water emits flammable gasses	None	None
Oxidising substances and mixtures	None	None
Organic peroxides	None	None
Corrosive to metals	None	None
Health hazards		
Acute Toxicity: Oral	Category 5	H303: May be harmful if swallowed
Acute toxicity: Dermal	Category 5	H313: May be harmful in contact with skin
Acute toxicity: Inhalation	None	None
Skin corrosion and irritation	None	None
Serious eye damage and irritation	None	None
Respiratory sensitization and skin sensitization	None	None
Germ cell mutagenicity	None	None
Carcinogenicity	None	None
Reproductive toxicity	None	None
STOT-SE	None	None
STOT-RE	None	None
Aspiration hazard	None	None
Aquatic hazards		
Acute aquatic toxicity	None	None
Chronic aquatic toxicity	Category 4	H402: Harmful to aquatic life

2. Used oil (GHS classification)

The used oil has been sampled and analysed for total concentration of elements (metals and micro elements, selected macro elements). This result, together with the MSDS of the product, has been used to complete the below GHS classification.

Physical hazards

…waste classification (Used oil GHS)

Used oil has almost identical properties as its original product (as from the OEM). With >80 % weight rated long chain carbon composition, the flashpoint is significantly above 93°C. Most used oil and original manufactured hydraulic oil have flashpoints above 200°C. Used oil is also relatively stable.

Figure 5: Used oil total concentrations

Elements & Chemical substances in Waste	Sample results
Metal ions	
As, Arsenic (mg/kg)	< 2
B, Boron (mg/kg)	< 0,6
Ba, Barium (mg/kg)	1,2
Cd, Cadmium (mg/kg)	< 0,05
Co, Cobalt (mg/kg)	< 0,1
Cr, Chromium Total (mg/kg)	< 0,3
K, Potassium (mg/kg)	160
Cu, Copper (mg/kg)	< 0,2
Hg, Mercury (mg/kg)	< 0,1
Mn, Manganese (mg/kg)	2,15
Mo, Molybdenum (mg/kg)	< 0,1
Ni, Nickel (mg/kg)	< 0,3
Pb, Lead (mg/kg)	< 0,05
Sb, Antimony (mg/kg)	< 1
Se, Selenium (mg/kg)	< 3
V, Vanadium (mg/kg)	1,6
Zn, Zinc (mg/kg)	191
Inorganic anions	
Cl, Chlorite (mg/kg)	< 1
SO4, Sulphate (mg/kg)	0,02
Cr (VI), Chromium 6+ (mg/kg)	< 0,1
P, Phosphorus (mg/kg)	209

Only trace quantities of carbon-based gases are produced above the oil's liquid film and used oil therefore has high autoignition (>300°C) and flashpoint (>200°C) temperatures. This makes it a low explosive and flammable hazard. It is nonetheless combustible and burns well in the presence of oxygen, forming dangerous carbon-based gases such as carbon monoxide. Burning is however not sustained and, together with high flashpoints (>35°C), the material is thus considered a non-flammable chemical according to SANS 10234 as per section 9.6.1.3.

Health hazards

All micro and macro elements measured and studied presents no acute health hazard as they were all below detection limits, with only potassium, barium, manganese, vanadium, and zinc measuring trace concentrations. All, except zinc, were below 0.0002 % on a weight basis. Zinc has low to negligible health hazards at such low concentrations (< 0.02 %).

Aquatic environment hazards

Used oil has a negligible acute toxicity to aquatic environments, with general acute toxicity estimates (based on ingredients) > 100 mg/l. It however might have direct and indirect chronic effects at higher volumes and concentrations, but are generally considered non-hazardous at lower concentrations, with average bioconcentration factors (BCF) < 500 and Log K_{ow} < 4. Our assessment places used oil into a Category 4 chronic hazard, which has been introduced in the classification system as a "safety net" when the available data do not allow for classification under the formal criteria but there are nevertheless some grounds for concern. Used oil according to the formal classification criteria are non-hazardous whereas we consider there to be some cause for concern at higher volumes when spilled or released, thus category 4.

Figure 6: Used oil GHS classification

Hazard class	Hazard category	Hazard statement
Physical hazard		
Explosives	None	None
Flammable gasses	None	None
Flammable aerosols	None	None
Oxidising gasses	None	None
Gasses under pressure	None	None
Flammable liquids (<93 °)	None	None.
Flammable solids	None	None
Self-reactive substances and mixtures	None	None
Pyrophoric substances	None	None
Self-heating substances and mixtures	None	None

…waste classification (Used oil GHS)

Hazard class	Hazard category	Hazard statement
Substances and mixture that on contact with water emits flammable gasses	None	None
Oxidising substances and mixtures	None	None
Organic peroxides	None	None
Corrosive to metals	None	None
Health hazards		
Acute Toxicity: Oral	None	None
Acute toxicity: Dermal	None	None
Acute toxicity: Inhalation	None	None
Skin corrosion and irritation	None	None
Serious eye damage and irritation	None	None
Respiratory sensitization and skin sensitization	None	None
Germ cell mutagenicity	None	None
Carcinogenicity	None	None
Reproductive toxicity	None	None
STOT-SE	None	None
STOT-RE	None	None
Aspiration hazard	None	None
Aquatic hazards		
Acute aquatic toxicity	None	None
Chronic aquatic toxicity	Category 4	H402: Harmful to aquatic life

3. Waste paint containers

The waste paint containers have not been sampled and analysed for total concentrations or leachable concentrations due to the high variety of paints and varying disposal conditions. Varying disposal conditions mean some generators on site might have 15 % paint by weight left in the container during disposal while another generator might have used it effectively and disposed it with less than 3 % by weight left in the container. The best representative testing would be to test it at what the standard would be (eg. < 3 %) or collect several containers and take a representative sample.

Waste paint containers in developed countries, such as the USA, Europe, and Australia, are generally not considered to be hazardous if it contains less than 3 %, by weight of its original content. In these countries waste paint containers with paint contents above the generally accepted 3 % by weight however are considered hazardous due to its ignitability, toxicity, and/or due to its specific listings.

In general, as a precautionary approach, most large corporations classify empty paint containers as hazardous due to the difficulty in regulating / controlling the 3 %, or similar, restrictions. The MSDS's provided for the paints used on site indicate that all paints are hazardous in terms of the GHS.

3.1. Waste and GHS classification

The MSDS of the QD gloss enamel paint of Excelsior paints provided by the mine indicate a toluene and xylene total concentration of > 12.5 % and > 20 %, respectively. This translates to a toluene and xylene concentration of > 125 000 mg/kg and > 200 000 mg/kg, respectively. The toluene TCT 1 threshold is 1 150 mg/kg and the xylene TCT 1 threshold 890 mg/kg. Theoretically, to achieve a < TCT 1 concentration for this paint, on a weight basis, it must be reduced to at least < 1 %. Most other QD enamels, however, have a 20 – 30 % hydrocarbon blend varying between aliphatic hydrocarbons and other C9 – C11 carbon chains. Plascon paints reports a 20 % - 30 % aliphatic hydrocarbon solvent range and a 5% - 15% hydrocarbon blend (C9 – C11). The TCT 1 for C6 – C9 is 650 mg/kg and 10 000 mg/kg for C10 – C36. A 10 % weight volume typically amounts to a concentration of 100 000 mg/kg and the hydrocarbon content in typical enamel paints vary between 200 000 mg/kg to 300 000 mg/kg. All these concentrations are when wet. When the paint dries out, the solvents evaporate, and the TC are expected to fall to within the TCT 0 ranges. Therefore, various countries consider a < 3 % by weight paint container that is dried out as non-hazardous and safe for disposal at non-hazardous waste facilities.

The trace metal elements such as titanium (Ti), Chromite (Ch), Iron (Fe) and others are predominantly pigment related. Titanium oxide mostly replaced lead in almost all the old lead-based paints. As a micro-element and metal, it is not listed in either the TCT or LCT tables of the norms and standards, meaning there is no landfilling related thresholds. Certain impurities are expected but are expected to be below the TCT 1 values. After drying, none of these are expected to leach out in concentrations above the LCT 0 values.

The classifications will be done assuming the containers have a ≈ < 3 % by weight paint residue and the paint is dry (the < 3 % wt. requirement is a suggested standard. This can be amended as the mine sees fit). Where the waste has above ≈ 3 % wt. residue and is still wet, it must be considered a hazardous waste and revert to a normal OEM MSDS and classification.

The waste paint containers are not expected to fall within the GHS's physical, health, or aquatic hazard categories and classifies as non-hazardous when dry and at less than < 3 % - 4 % of original weight.

Figure 7: Waste paint containers (< 3 % wt.) GHS classification

Hazard class	Hazard category	Hazard statement
Physical hazard		
Explosives	None	None
Flammable gasses	None	None
Flammable aerosols	None	None
Oxidising gasses	None	None
Gasses under pressure	None	None
Flammable liquids (<93 °)	None	None.
Flammable solids	None	None
Self-reactive substances and mixtures	None	None
Pyrophoric substances	None	None
Self-heating substances and mixtures	None	None
Substances and mixture that on contact with water emits flammable gasses	None	None
Oxidising substances and mixtures	None	None
Organic peroxides	None	None
Corrosive to metals	None	None
Health hazards		
Acute Toxicity: Oral	None	None
Acute toxicity: Dermal	None	None
Acute toxicity: Inhalation	None	None
Skin corrosion and irritation	None	None
Serious eye damage and irritation	None	None
Respiratory sensitization and skin sensitization	None	None
Germ cell mutagenicity	None	None
Carcinogenicity	None	None
Reproductive toxicity	None	None
STOT-SE	None	None
STOT-RE	None	None
Aspiration hazard	None	None
Aquatic hazards		
Acute aquatic toxicity	None	None
Chronic aquatic toxicity	None	None

Figure 8: Waste paint containers waste classification table (all in mg/kg)

…waste classification (Waste paint)

Elements considered	TCT 0	TCT 1	TCT 2	Calculated / Estimated	Calculated class
Metal ions					-
As, Arsenic	5,8	500	2 000	< 5,8	Type 4
B, Boron	150	15 000	60 000	< 150	Type 4
Ba, Barium	62,5	6 250	25 000	< 62,5	Type 4
Cd, Cadmium	7,5	260	1 040	< 7,5	Type 4
Co, Cobalt	50	5 000	20 000	< 50	Type 4
Cr, Chromium Total	46 000	800 000	N / A	< 46 000	Type 4
Cr (VI), Chromium (VI)	6,5	500	2 000	< 6,5	Type 4
Cu, Copper	16	19 500	78 000	< 16	Type 4
Hg, Mercury	0,93	160	640	< 0,93	Type 4
Mn, Manganese	1 000	25 000	100 000	< 1 000	Type 4
Mo, Molybdenum	40	1 000	4 000	< 40	Type 4
Ni, Nickel	91	10 600	42 400	< 91	Type 4
Pb, Lead	20	1 900	7 600	< 20	Type 4
Sb, Antimony	10	75	300	< 10	Type 4
Se, Selenium	10	50	200	< 10	Type 4
V, Vanadium	150	2 680	10 720	< 150	Type 4
Zn, Zinc	240	160 000	640 000	< 240	Type 4
Inorganic anions					-
Cl, Chlorite	-	-	-	-	-
SO4, Sulphate	-	-	-	-	-
NO3, Nitrate	-	-	-	-	-
N, Nitrogen	-	-	-	-	-
F, Flouride	100	10 000	40 000	< 100	Type 4
CN, Cyanide Total	14	10 500	42 000	< 14	Type 4

4. Waste grease (GHS classification)

Waste grease falls under annexure 1 of the waste classifications and management regulations and do not require classification. It is a type 1 waste by default and required to be disposed at a class A landfill.

Waste grease are expected to have an 80 – 99 % similarity to its original compositions. Some impurities will likely develop during usage and handling. The original compositions from the OEM's vary but generally consist of 80% - 99% petroleum distillates and < 5 % additives. The additives are usually considerably more hazardous and consists of compounds such as Zinc dialkyldithiophosphate (CAS 68649-42-3), alkylated diphenyl amines (CAS 68411-46-1), hydroxyalkaryl long-chain akyl ester (CAS 2082-79-3), and pentaerythritol (CAS 115-77-5). Other compounds are also present but in trace quantities, below 1 %.

Physical hazard

Waste grease has no physical hazards as it has high flashpoints (>230 °C), high viscosity (≈ > 28mm^2/s @ 40°C), and very low vapor pressure (< 0.013 kPa @ 20°C estimated).

Health hazards

The petroleum distillates do not have health hazards at the quantities that is expected during accidental ingestion or inhalation. The additives also do not have health hazards at the expected concentrations.

Aquatic hazards

The additives, although constituting < 5 % of composition, do have H402, H412 and H413 hazards, which are harmful to aquatic life (H402), harmful to aquatic life with long-lasting effects (H412), and may cause long-lasting harmful effects to aquatic life (H413), respectively.

Toxicity

Expected to be harmful to aquatic organisms. May cause long-term adverse effects in the aquatic environment (H402, H412, and H413).

Bioaccumulation

Base oil component – Has the potential to bioaccumulate, however metabolism or physical properties may reduce the bioconcentration or limit bioavailability.

Biodegradation

Base oil component – Expected to be inherently biodegradable

Mobility

Base oil component – Low solubility, floats and is expected to migrate from water to the land. Expected to partition to sediment and wastewater solids.

Figure 9: Waste grease GHS classification

Hazard class	Hazard category	Hazard statement
Physical hazard		
Explosives	None	None
Flammable gasses	None	None
Flammable aerosols	None	None
Oxidising gasses	None	None
Gasses under pressure	None	None
Flammable liquids (<93 °)	None	None.
Flammable solids	None	None
Self-reactive substances and mixtures	None	None
Pyrophoric substances	None	None
Self-heating substances and mixtures	None	None
Substances and mixture that on contact with water emits flammable gasses	None	None
Oxidising substances and mixtures	None	None
Organic peroxides	None	None
Corrosive to metals	None	None
Health hazards		
Acute Toxicity: Oral	None	None
Acute toxicity: Dermal	None	None
Acute toxicity: Inhalation	None	None
Skin corrosion and irritation	None	None
Serious eye damage and irritation	None	None
Respiratory sensitization and skin sensitization	None	None
Germ cell mutagenicity	None	None
Carcinogenicity	None	None
Reproductive toxicity	None	None
STOT-SE	None	None
STOT-RE	None	None
Aspiration hazard	None	None
Aquatic hazards		
Acute aquatic toxicity	Category 3	H402: Harmful to aquatic life
Chronic aquatic toxicity	Category 3	H412: Harmful to aquatic life with long-lasting effects

One of the main purposes of the characterisation of residue stockpiles are to gain a better understanding of the materials that these residue stockpiles are composed of, their physical and chemical properties, and their behaviours under certain conditions. This understanding is necessary to determine the risks that these facilities pose and to provide the information that will guide mitigation measures or, in the case of project development, design measures. The residue stockpile regulations, published in GNR 632, GG 39020 on July 2015, provides legislative guidance on what to include in such characterisations and how to go about characterising such facilities.

This chapter will first give an overview of the risks identified with each of these facilities and then discuss the characterisation of each residue facility separately.

For this study's characterisation, we will focus largely on each facility's:

- **ability to permeate fluids,** measured using its void ratio and permeability characteristics,
- **stability / likelihood of failure**, estimated using the shear strength, facility dimensions and other strain values,
- **leachate and toxicity** that forms from leaching, determined using the material's mineralogy, chemical composition (total concentrations), and leachable concentrations (tested using de-ionised water, acetic acid (TCLP test), and $Na_2B_4O_7$ solutions)
- **sensitive receptors** surrounding the facilities that might be influenced by the facility

These four characteristics above will provide an overview of each facility's character which in return have been used to determine the hazards and their potential risk to ultimately cause harm. The following five main **hazards** have been identified that might cause harm, both from a health and environmental perspective:

1. Leachate (material, excl. supernatant compounds)
2. Leachate (incl. supernatant compounds)
3. Stability
4. Particulate matter emission
5. Land occupation (footprint)

The leachate has been divided into leachate that exclude supernatant compounds and leachate that includes supernatant compounds. This has been done to clearly distinguish between the source pathways and assess them separately. The main **receptors** of the above hazards have been grouped into the following three categories:

- The aquatic environment
- The biological environment (All biota except from the aquatic environment)
- Human health

The three receptor categories above cover all sensitive receptors of the study. Since our approach to risk is largely end receptor focused, some environmental units that are generally considered receptors we considered midpoint receptors, meaning they function largely as carriers and not receptors themselves. We still call them midpoint receptors. As an example, we consider groundwater as a midpoint receptor functioning as carrier that moves potential contaminants to the actual receptors. As remiss as this might sound, no risk is omitted, seen that, in our view, groundwater contamination only causes harm as soon as a human uses the water, when their health or wellbeing are directly or indirectly affected by it, or when it harms biota or the ecosystem. These main aquatic, biological and human receptors we consider the endpoint receptors, as they are the biota that makes up life itself and who will ultimately be affected. Thus, as example, we assessed the leachates' ability to harm the aquatic environment, which by default takes into account the leachate properties itself, how the leachate leaves the facility, enters the midpoint receptor and is transported in it (using the numerical model), and, if released to endpoint receptors (in this case at the Groot and Klein Dwarsrivier head boundaries), how it will affect aquatic life. If the leachate risk to harm aquatic life is high, it would mean that the leachate is expected to leach into the groundwater, move according to the transport model (numerical model) to the surface water boundary, release into the surface water stream (such as via seepage) and harm the aquatic life. This flow is called the cause to effect pathway.

Each of the 5 hazards above have been assessed in their ability (risk) to harm each of the 3 receptors listed above.

Risk ratings have then been assigned using the following matrix:

Figure 10: Risk matrix

Duration (Du)		Value
Temporary	*A period of less than 1 year*	1
Short term	*A period of less than 5 years*	2
Medium term	*A period of less than 15 years*	3
Long term	*A period of less than 20 years*	4
Permanent	*Irreversible*	5

Extent (Ex)		Value
On site	*A period of less than 1 year*	1
Local	*A period of less than 5 years*	2
Regional	*A period of less than 15 years*	3
National	*Within country boundaries*	4
International	*Outside country boundaries*	5

Probability (Pr)		Value
Unlikely	*Probably will not happen*	1
Improbable	*Some possibility, low likelihood*	2
Probable	*Distinct possibility*	3
Highly probable	*Most likely*	4
Definite	*Occur irrespective of intervention*	5

Severity (Se)		Value
No effect	*No effect on receptor*	0
Minor	*No impact on processes*	2
Low	*Slight impact on processes*	4
Moderate	*Processes modified but continuing*	6
High	*Processes altered, temporary cease*	8
Very high	*Cessation of processes*	10

Risk significance	
Low	*< 30*
Moderate	*30 - 59*
High	*≥ 60*

The risk ratings were then used to calculate the overall risk significance and rate it according to the risk significance table above. The significance was calculated as follows:

Significance = (Duration (Du) + Extent (Ex) + Severity (Se)) x Probability

Risk assessment overview

The detailed risk assessment for each residue facility has been tabled in figure 16 below. Each receptor category will be discussed in more detail below.

A. Harm to the aquatic environment

All facilities have been assessed to have a moderate risk of harm to the aquatic environment, except the new TSF, which has a low risk. Although there isn't currently a known pathway from the groundwater to the aquatic environment, the groundwater contamination and resultant plume has a high probability of creating a pathway in future when water levels around the shafts and dewatering levels restore. The risk is related to the leachate which includes the supernatant compounds, pointing to the almost exclusive impact of the nitrate (NO3) and nitrogen related compounds that possibly 'clings' to the solid material after, what is currently assumed, the blasting and material handling. The leachate tests have proven that the nitrogen (mostly in the form of nitrate) does not form part of the mineralogy or minerals internal structures, and where so, in largely trace amounts. The elements that were tested within the residue materials were mostly trace. All leachable concentrations (LC) (see figure 14 and 15 below) for all residue material, tested during this study, were within type 4 limits as per the waste regulations and classifies as an inert waste. The total concentration (TC) elements tested for waste rock and discard rock showed a type 4 classification while the TSF sample classified as a type 3 waste due to an exceedance of the TCT0 thresholds for copper and selenium. The TC for NO_3^- in waste rock were 16,3 mg/kg, equivalent to 0.00163 % (weight basis). Nitrate will be discussed in more detail below.

Nitrogen related contamination is not a new issue and is well known and studied around the world. Tests was done in Finland on the leaching of nitrogen from waste rock samples by isolating the waste rock samples that were freshly collected from a mining area and exposing them to natural rain water drainage (Karlsson. T & Kauppila.T). The resultant leached water was regularly sampled over a year and the trends analysed. It typically showed a major peak in nitrogen leaching during the first few rain events after the material was exposed, which they called the 'first flush'. They also found that after a year, roughly half of the total nitrogen that originated from explosives leached out. This study was presented at the 10th ICARD IMWA conference in Santiago, Chile, in 2015, and is just one of the many studies that is available on explosives related nitrogen leaching from residue facilities.

Figure 11: Total concentrations for tailings (all in mg/kg)

Elements tested	iLEH (2017)	Nettzero	iLEH	Nettzero
Metal ions				
As, Arsenic	44,4	<2	Type 3	Type 4
B, Boron	<10	10	Type 4	Type 4
Ba, Barium	39,2	24	Type 4	Type 4
Cd, Cadmium	2,4	<0,05	Type 4	Type 4
Co, Cobalt	39,2	5,17	Type 4	Type 4
Cr, Chromium Total	26800	206	Type 4	Type 4
Cr (VI), Chromium (VI)		<0,1	Type 4	Type 4
Cu, Copper	14,8	28	Type 4	Type 3
Hg, Mercury		<0,1	Type 4	Type 4
Mn, Manganese	880	97	Type 4	Type 4
Mo, Molybdenum	<10	<0,1	Type 4	Type 4
Ni, Nickel	416	68	Type 3	Type 4
Pb, Lead	11,6	<0,05	Type 4	Type 4

The explosives related nitrogen is expected to 'cling' to the residue material as supernatant making it more readily available for dissolution with rain and pore water, as all the other intrinsic elements are bound in mineral structures (mainly covalent) and more difficult to enter into solution. The high NO_3^- dissolution could also have indirect effects on other cation related dissolutions, as the high nitrate dissolution causes a cation-anion imbalance which might bring more cations into solution,

Elements tested	iLEH (2017)	Nettzero	iLEH	Nettzero
Sb, Antimony	<8	<1	Type 4	Type 4
Se, Selenium	6,4	10,63	Type 4	Type 3
V, Vanadium	144,4	12,02	Type 4	Type 4
Zn, Zinc	78,4	208	Type 4	Type 4
Inorganic anions				
Cl, Chlorite	-	33	-	-
SO4, Sulphate	-	0,09	-	-
NO3, Nitrate	-	6,2	-	-
N, Nitrogen	-	1,4	-	-
F, Flouride	-	<0,1	-	Type 4
CN, Cyanide Total	-	<0,1	-	Type 4

thus exacerbating leaching of elements that might otherwise not be such a significant leaching risk (such as Mg and Ca). It might be vice-versa as well, or a negative feedback loop, where dissolution of cations such as Mg and Ca (which is common in these mafic rocks) causes a higher dissolution of the NO_3^- anion.

There were 3 waste rock related samples taken in 2017 as part of the iLEH waste classification. These results are also added to figures 11 – 14 above and below. There seems to be a few significant differences between the results of the iLEH samples taken in 2017 and the results of the sampling that formed part of this report. The reasons might be related to sample locations. The analysis of the samples that formed part of this study included NO_3^- and N, which measured 16.35 mg/kg. This might sound small on a percentage basis (0.00164 %), but putting it into perspective in terms of the larger volumes, which are in the millions of tons (total waste rock storage, both in rehab pits and in dumps), can be considerably more significant and one of the most plausible explanations for the nitrate contamination in the groundwater. As an example, if we isolate a one square meter by twenty meter high column of waste rock (on one of the dumps), this column of material will have a 20 m^3 volume. At the measured densities (see the WRD south characterisation sheets) of 2.344 t/m^3 the total weight will be 46.8 tons, or 46 800 kg. With a total NO_3^- concentration of 16.4 mg/kg (see the nettzero column in figure 9 below), the total weight of NO_3^- in this one square meter by twenty meter column of waste rock will be 765 180 mg, or ≈ 765 g of NO_3^- (46 800 kg x 6.2 g/kg). This 765 g of nitrate for every 46.8 tons of waste rock is not necessarily all available for leaching and the availability is difficult to ascertain. It might not be available, which means it will remain as supernantant for the foreseable future, or it might be readily available and gradually leach out over the remaining lifetime of the facility.

Figure 12: Total concentrations for waste rock (all in mg/kg)

	iLEH results				iLEH classification			
Elements tested	WRD N	WRD S	WRD reh	Nettzero	WRD N	WRD S	WRD reh	Nettzero
Metal ions								
As, Arsenic	30	<4	30	<0,02	Type 3	Type 4	Type 3	Type 4
B, Boron	<10	<10	<10	5,42	Type 4	Type 4	Type 4	Type 4
Ba, Barium	48	44,4	73,6	26	Type 4	Type 4	Type 4	Type 4
Cd, Cadmium	2,4	6	3,6	<0,05	Type 4	Type 4	Type 4	Type 4
Co, Cobalt	39,6	45,6	49,2	4,1	Type 4	Type 4	Type 4	Type 4
Cr, Chromium Total	4400	4400	6800	105	Type 4	Type 4	Type 4	Type 4
Cr (VI), Chromium (VI)				<0,1	Type 4	Type 4	Type 4	Type 4
Cu, Copper	<4	9,2	<4	11,5	Type 4	Type 4	Type 4	Type 4
Hg, Mercury				<0,1	Type 4	Type 4	Type 4	Type 4
Mn, Manganese	844	1084	1124	70	Type 4	Type 3	Type 3	Type 4
Mo, Molybdenum	<10	<10	<10	<0,1	Type 4	Type 4	Type 4	Type 4
Ni, Nickel	338	388,4	388	27	Type 3	Type 3	Type 3	Type 4
Pb, Lead	12,4	6	12,8	<0,05	Type 4	Type 4	Type 4	Type 4
Sb, Antimony	<8	<8	<8	<1	Type 4	Type 4	Type 4	Type 4
Se, Selenium	<4	<4	<4	4,52	Type 4	Type 4	Type 4	Type 4
V, Vanadium	<10	<10	28,8	7,62	Type 4	Type 4	Type 4	Type 4
Zn, Zinc	46,4	49,2	56	109	Type 4	Type 4	Type 4	Type 4
Inorganic anions								
Cl, Chlorite	-	-	-	6	-	Type 4	Type 4	Type 4

Elements tested	iLEH results WRD N	iLEH results WRD S	iLEH results WRD reh	Nettzero	iLEH classification WRD N	iLEH classification WRD S	iLEH classification WRD reh	Nettzero
SO4, Sulphate	-	-	-	0,02	-	Type 4	Type 4	Type 4
NO3, Nitrate	-	-	-	16,35	-	Type 4	Type 4	Type 4
N, Nitrogen	-	-	-	3,69	-	Type 4	Type 4	Type 4
F, Flouride	-	-	-	<0,1	-	Type 4	Type 4	Type 4
CN, Cyanide Total	-	-	-	<0	-	Type 4	Type 4	Type 4

Figure 13: Total concentrations for discard rock (all in mg/kg)

Elements tested	iLEH DSC_A	iLEH DSC S_A	Nettzero	iLEH DSC_A	iLEH DSC S_A	Nettzero
Metal ions						
As, Arsenic	13,6	20,8	<2	Type 3	Type 3	Type 4
B, Boron	<10	<10	26	Type 4	Type 4	Type 4
Ba, Barium	31,6	29,2	33	Type 4	Type 4	Type 4
Cd, Cadmium	3,2	2,4	<0,05	Type 4	Type 4	Type 4
Co, Cobalt	51,2	42,8	9,07	Type 3	Type 4	Type 4
Cr, Chromium Total	8000	8000	187	Type 4	Type 4	Type 4
Cr (VI), Chromium (VI)	<5	<5	<5	Type 4	Type 4	Type 4
Cu, Copper	<4	<4	51	Type 4	Type 4	Type 3
Hg, Mercury	-	-	<0,1	Type 4	Type 4	Type 4
Mn, Manganese	1152	1092	110	Type 3	Type 3	Type 4
Mo, Molybdenum	<10	<10	<0,1	Type 4	Type 4	Type 4
Ni, Nickel	452	428	63	Type 3	Type 3	Type 4
Pb, Lead	8	10	1,55	Type 4	Type 4	Type 4
Sb, Antimony	<8	<8	<1	Type 4	Type 4	Type 4
Se, Selenium	<4	<4	33	Type 4	Type 4	Type 3
V, Vanadium	11,6	<10	38	Type 4	Type 4	Type 4
Zn, Zinc	47,2	36,8	187	Type 4	Type 4	Type 4
Inorganic anions						
Cl, Chlorite	-	-	69	-	-	-
SO4, Sulphate	-	-	<0,01	-	-	-
NO3, Nitrate	-	-	6,9	-	-	-
N, Nitrogen			1,56	-	-	-
F, Flouride	101	101	<0,1	Type 3	Type 3	Type 4
CN, Cyanide Total	-	-	0,4	-	-	Type 4

From the risk assessment perspective, we focused on the receptors, which has been identified as human health, the aquatic environment, and the biological / terrestrial environment. We thus assessed the risk of these hazards (mainly came down to nitrate) in their ability to cause harm to the aquatic environment. The total concentrations discussed above is what might be present but doesn't necessarily mean it is available to leach. To understand the risk to aquatic life, we need to understand what will leach, what is leaching, and how it will move from the source of leaching to the receptor (the pathway). As we have discussed above, nitrate is present in the material in potential higher than normal concentrations (0.00164 % by weight). How much of this total concentration leach might be derived from the historical groundwater quality results, which seems to also single out nitrate as the biggest element of concern, followed by Ca, Mg and occasionally Cl and F. The leachable concentrations obtained from the de-ionised leach tests did not highlight any micro element or anion concerns. Based on the leachable concentrations, a plume seems rather strange. The large deviation between NO_3^- concentration from total concentration tests and NO_3^- concentration from leachable concentration tests might indicate that the leachable tests are not well representative of actual residue facility leaching conditions, or, alternatively, the nitrate within the groundwater might have another source. We see the most plausible source as explosives, seen that the NO_3^- does not really form part of the mineral structures of the minerals found in the XRD tests and the NO_3^- concentrations in the total concentration tests can thus only be supernatant in nature. Being supernatant means NO3- within the residue material can only be derived through contact with it, such as from its handling. Narrowing down nitrate related chemicals used in the process, coupled with the volumes required to cause such a large-scale contamination and, in such quantities, explosives are increasing more conceivable as a source. Processing plant chemicals were also suggested as another potential source of nitrate, but we find it unlikely that the waste rock would be contaminated due to the processing plant chemicals seen that the waste rock did not go through the processing plant. The reason for the nearly negligible nitrate concentration in the leach tests is not known but it might be that the leach conditions on site differs from that simulated in the leach tests. Alternatively, it might also be that the nitrate observed in the total concentrations is not available for leaching and will remain locked up as a supernatant compound. If so, then the nitrate concentrations in the groundwater were derived largely from the initial leaching of the nitrate, while what was observed now is then largely stationary.

Considering all the above, the potential receptors, and the simulated pathway (using the numerical model), our assessment of the leachate risk to the aquatic environment is a moderate significance due to:

- moderate severity, as we expect processes to continue within the aquatic environment but in a modified way,
- regional extent, as we expect it to influence the downstream as well (but will likely assimilate within a few kilometres downstream),
- long term duration, and
- high probability of occurring.

Figure 14: Leachable concentrations for waste rock samples tested using a 5 % de-ionised water solution (all as mg/l)

	iLEH (2017)					iLEH (2017)				
Elements tested	**WRD N**	**WRD S**	**WRD R**	**Nettzero**	**EScience**	**WRD N**	**WRD S**	**WRD R**	**Nettzero**	**EScience**
Metal Ions										
As, Arsenic	<0,01	<0,01	<0,01	<0,02	0,002	Type 4	Type 4	Type 4	Type 4	Type 4
B, Boron	<0,025	<0,025	<0,025	<0,006	0,03	Type 4	Type 4	Type 4	Type 4	Type 4
Ba, Barium	<0,025	<0,025	<0,025	0,036	0,5	Type 4	Type 4	Type 4	Type 4	Type 4
Cd, Cadmium	<0,003	<0,003	<0,003	<0,001	<0,001	Type 4	Type 4	Type 4	Type 4	Type 4
Co, Cobalt	<0,025	<0,025	<0,025	0,001	<0,001	Type 4	Type 4	Type 4	Type 4	Type 4
Cr, Chromium Total	0,032	0,082	0,025	0,025	<0,003	Type 4	Type 4	Type 4	Type 4	Type 4
Cr (VI), Chromium (VI)	<0,01	<0,01	<0,01	<0,01		Type 4	Type 4	Type 4	Type 4	Type 4
Cu, Copper	<0,01	<0,01	<0,01	0,003	<0,002	Type 4	Type 4	Type 4	Type 4	Type 4
Hg, Mercury	<0,001	<0,001	<0,001	<0,001	<0,001	Type 4	Type 4	Type 4	Type 4	Type 4
Mn, Manganese	0,063	0,053	0,055	0,019	<0,001	Type 4	Type 4	Type 4	Type 4	Type 4
Mo, Molybdenum	<0,025	<0,025	<0,025	<0,001	0,001	Type 4	Type 4	Type 4	Type 4	Type 4
Ni, Nickel	<0,025	<0,025	<0,025	0,009	<0,003	Type 4	Type 4	Type 4	Type 4	Type 4
Pb, Lead	<0,01	<0,01	<0,01	<0,01	<0,001	Type 4	Type 4	Type 4	Type 4	Type 4
Sb, Antimony	<0,02	<0,02	<0,02	<0,01	<0,01	Type 4	Type 4	Type 4	Type 4	Type 4
Se, Selenium	<0,01	<0,01	<0,01	<0,03	0,003	Type 4	Type 4	Type 4	Type 4	Type 4
V, Vanadium	<0,025	<0,025	<0,025	0,002	0,01	Type 4	Type 4	Type 4	Type 4	Type 4
Zn, Zink	<0,025	<0,025	<0,025	<0,005	<0,005	Type 4	Type 4	Type 4	Type 4	Type 4
Inorganic anions										
Cl, Chlorite	<2	2	<2	1,5	2,1	Type 4	Type 4	Type 4	Type 4	Type 4
SO4, Sulphate	2	<2	<2	1	3,5	Type 4	Type 4	Type 4	Type 4	Type 4
NO3, Nitrate	<0,1	<0,1	<0,1	0,2	1,1	Type 4	Type 4	Type 4	Type 4	Type 4
N, Nitrogen	-	-	-	<0,1	0,2	-	-	-	Type 4	-
F, Flouride	0,2	0,2	<0,2	0,1	-	Type 4	Type 4	Type 4	Type 4	-

…residue characterisation (Waste rock and facilities)

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Elements tested	iLEH (2017)					iLEH (2017)				
	WRD N	WRD S	WRD R	Nettzero	EScience	WRD N	WRD S	WRD R	Nettzero	EScience
CN, Cyanide Total	-	-	-	<0,01	-	-	-	-	Type 4	-

Figure 15: Leachable concentrations for tailings samples tested using a 5 % de-ionised water solution (all as mg/l)

Elements	iLEH (2017)	Nettzero	EScience	iLEH (2017)	Nettzero	EScience
Metal Ions						
As, Arsenic	<0,01	<0,02	0,002	Type 4	Type 4	Type 4
B, Boron	<0,025	<0,006	0,02	Type 4	Type 4	Type 4
Ba, Barium	0,04	0,034	0,4	Type 4	Type 4	Type 4
Cd, Cadmium	<0,003	<0,001	<0,001	Type 4	Type 4	Type 4
Co, Cobalt	<0,025	<0,001	<0,001	Type 4	Type 4	Type 4
Cr, Chromium Total	0,39	0,062	0,01	Type 3	Type 4	Type 4
Cr (VI), Chromium (VI)	<0,01	<0,01	-	Type 4	Type 4	Type 4
Cu, Copper	0,047	0,004	<0,002	Type 4	Type 4	Type 4
Hg, Mercury	<0,001	<0,001	<0,001	Type 4	Type 4	Type 4
Mn, Manganese	0,235	0,006	<0,001	Type 4	Type 4	Type 4
Mo, Molybdenum	<0,025	<0,001	<0,001	Type 4	Type 4	Type 4
Ni, Nickel	0,114	0,006	<0,003	Type 3	Type 4	Type 4
Pb, Lead	0,012	<0,01	<0,001	Type 3	Type 4	Type 4
Sb, Antimony	<0,02	<0,01	<0,01	Type 4	Type 4	Type 4
Se, Selenium	<0,01	<0,03	0,004	Type 4	Type 4	Type 4
V, Vanadium	<0,025	<0,002	0,02	Type 4	Type 4	Type 4
Zn, Zink	<0,025	<0,005	<0,005	Type 4	Type 4	Type 4
Inorganic anions						
Cl, Chlorite	4	1,7	2,1	Type 4	Type 4	Type 4
SO4, Sulphate	6	1,2	2,9	Type 4	Type 4	Type 4
NO3, Nitrate	1	0,6	0,2	Type 4	Type 4	Type 4
N, Nitrogen	-	0,1	-	-	Type 4	-
F, Flouride	0,3	0,01	-	Type 4	Type 4	-
CN, Cyanide Total	-	-	-	-	-	-

Harm to the biological environment

The risk to the biological environment has been assessed as moderate mainly due to the residue facilities' location within an area of high endemism. Total footprints of the facilities combined amounts to roughly ≈ 373 379 m^2, or ≈ 37.34 ha. These footprints are between moderately to significantly altered. Rehabilitation and restoration are ongoing. The leachate, dam failure, and particulate matter emissions are expected to have negligible effects on the biological environment.

Harm to human health

All the residue facilities are expected to have a low risk significance to harm human health. Some particulate matter emissions are expected and observed in the form of dust, but the $PM_{2.5}$ and PM_{10} fractions are small (PSD analysis pointed to a < 75 micron fraction of ≈ 3.7 % for waste rock and ≈ 14 – 25 % for tailings) and the total particulate matter emissions from these facilities are also small, which, together with total emissions and < 75 micron fraction, results in a low dust related health risk. Dam failure risks have been assessed also as low. The new TSF have a factor of safety of 1.537 at final design, while the other facilities have estimated factors of safety > 1.5. Additionally, the waste rock material tested have moderate shear strengths and are situated on low – medium sloping basins with high bearing capacities (in excess of 300 kPa). The apparent cohesion (c') of the waste rock was 12.9 kPa with a friction angle (Φ') of 33.5°, translating to a moderate shear strength.

Figure 16: Residue facilities risk assessment

…residue characterisation (risk assessment)

Hazard	**Harm to aquatic env.**					**Harm to biological env.**					**Harm to human health**				
	Se	*Ex*	*Du*	*Pr*	**Risk**	*Se*	*Ex*	*Du*	*Pr*	**Risk**	*Se*	*Ex*	*Du*	*Pr*	**Risk**
TSF new															
Leachate (excl. supernatant)	2	2	4	3	24	0	2	3	1	5	2	1	2	1	5
Leachate (incl. supernatant)	6	2	4	1	12	2	1	2	1	5	6	2	1	1	9
Dam failure (stability)	8	3	3	1	14	6	3	2	1	11	8	2	1	1	11
Particulate matter emission	2	1	2	1	5	4	1	2	2	14	4	1	4	2	18
Land occupation (footprint)	2	1	4	2	14	4	1	4	3	27	0	1	1	1	2
TSF old															
Leachate (excl. supernatant)	2	2	4	3	24	0	2	3	1	5	2	1	2	1	5
Leachate (incl. supernatant)	6	3	4	4	39	2	1	2	1	5	6	2	1	3	27
Dam failure (stability)	8	3	3	1	14	6	3	2	1	11	8	2	1	1	11
Particulate matter emission	2	1	2	1	5	4	1	2	2	14	4	1	4	2	18
Land occupation (footprint)	2	1	4	2	14	6	1	3	3	30	0	1	1	1	2
Backfill north															
Leachate (excl. supernatant)	2	2	4	3	24	0	2	3	1	5	2	1	2	1	5
Leachate (incl. supernatant)	6	3	4	3	39	2	1	2	1	5	6	2	1	3	27
Dam failure (stability)	8	3	3	1	14	6	3	2	1	11	8	2	1	1	11
Particulate matter emission	2	1	2	1	5	4	1	2	2	14	4	1	4	2	18
Land occupation (footprint)	2	1	4	2	14	6	1	3	3	30	0	1	1	1	2
Backfill south															
Leachate (excl. supernatant)	2	2	4	3	24	0	2	3	1	5	2	1	2	1	5
Leachate (incl. supernatant)	6	3	4	3	39	2	1	2	1	5	6	2	1	3	27
Dam failure (stability)	8	3	3	1	14	6	3	2	1	11	8	2	1	1	11
Particulate matter emission	2	1	2	1	5	4	1	2	2	14	4	1	4	2	18
Land occupation (footprint)	2	1	4	2	14	6	1	3	3	30	0	1	1	1	2
WRD south															
Leachate (excl. supernatant)	2	2	4	3	24	0	2	3	1	5	2	1	2	1	5
Leachate (incl. supernatant)	6	3	4	3	39	2	1	2	1	5	6	2	1	3	27
Dam failure (stability)	8	3	3	1	14	6	3	2	1	11	8	2	1	1	11
Particulate matter emission	2	1	2	1	5	4	1	2	2	14	4	1	4	2	18
Land occupation (footprint)	2	1	4	2	14	6	1	3	3	30	0	1	1	1	2
WRD north															
Leachate (excl. supernatant)	2	2	4	3	24	0	2	3	1	5	2	1	2	1	5
Leachate (incl. supernatant)	6	3	4	3	39	2	1	2	1	5	6	2	1	3	27
Dam failure (stability)	8	3	3	1	14	6	3	2	1	11	8	2	1	1	11
Particulate matter emission	2	1	2	1	5	4	1	2	2	14	4	1	4	2	18
Land occupation (footprint)	2	1	4	2	14	6	1	3	3	30	0	1	1	1	2
Discard dump															
Leachate (excl. supernatant)	2	2	4	3	24	0	2	3	1	5	2	1	2	1	5
Leachate (incl. supernatant)	6	3	4	3	39	2	1	2	1	5	6	2	1	3	27
Dam failure (stability)	8	3	3	1	14	6	3	2	1	11	8	2	1	1	11
Particulate matter emission	2	1	2	1	5	4	1	2	2	14	4	1	4	2	18
Land occupation (footprint)	2	1	4	2	14	6	1	3	3	30	0	1	1	1	2

1. Waste rock and waste rock facilities

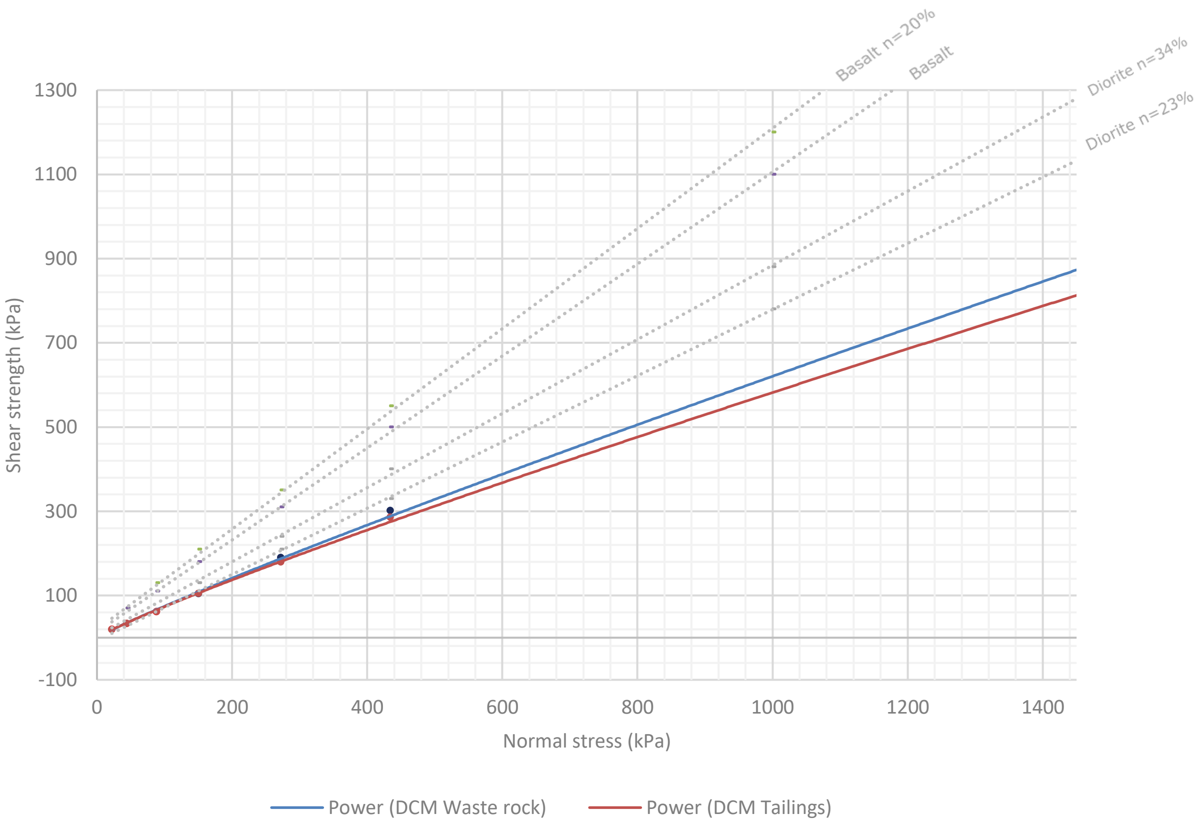
The waste rock facilities consist of south and north waste rock dumps. South WRD is the second largest residue facility studied, after the new TSF, with a footprint area measured as roughly 8.7 ha and a max height of 31 m (measured at location *24°56'17.35"* **S**, 30° 7'30.42" **E**). The total waste rock volume of the two facilities has been estimated at 870 502 m^3.

Strength and stress

The max shear strengths were tested at higher than average normal stresses of 150 kPa, 274 kPa, and 435 kPa and the results were 113.9 kPa, 191 kPa, and 435 kPa, respectively. The friction angle (Φ') measured 33.5° and closely matched the angle of repose of the waste rock materials at the face of the dump (measured at 33° - 34°). The samples exhibited a moderate amount of cohesion (c' – 12.9 kPa) likely due to the presence of ≈ 4 % clay content, including clay minerals and precipitation of secondary minerals causing possible grain-to-grain cementation. The clay content positively affected the shear strength compared to the tailing material, as the cohesion difference between the two materials is rough 5 kPa. The tailing is sandier while the waste rock is more clayey.

Comparative waste rock shear strengths were obtained from the report *Waste rock management and stability evaluation* (D. Olivier) and presented in figure 14 below. The DCM waste rock samples tested lower than the diorite and basalt based waste rock material when compared to profiles obtained from the D. Olivier report.

Figure 17: Linear failure envelope for the waste rock



Material characteristics

The waste rock sampled has a dry and wet density of 2.218 g/cm^3 and 2.344 g/cm^3, respectively, and a high specific gravity of 2.911 g/cm^3. Optimum dry density was achieved at a 5.4 % moisture content. The void ratios are 0.312, which converts to a porosity of 23.78 %. This falls within the lower end of the average gravel / sandy gravel material types. The permeability is also comparatively low and falls within the lower end of the semi-pervious permeability range (highlighted in blue below).

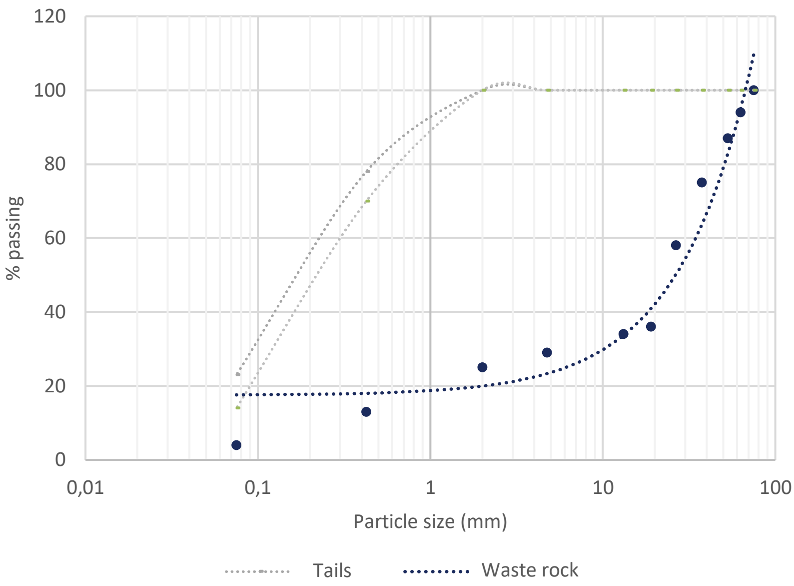
K (cm/s)	10^2	10^1	10	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}	10^{-8}	10^{-9}	10^{-10}
Relative permeability	Pervious				Semi-pervious				Impervious				

A lower permeability might be better in terms of leachate reduction and the waste rock facilities will have lower seepage rates than the more pervious tailings facilities, including, and perhaps especially, the two pits backfilled with tailings. The co-disposed discard material to the east of the facility will increase localised permeability, seen that the discard material has a higher porosity and permeability.

Particle size distribution

The waste rock samples were found to be well-graded containing variable quantities of the following grain sizes: fine gravel (19 mm – 4.75 mm); coarse sand (4.75 mm – 2.0 mm); medium sand (2.0 mm – 0.425 mm); fine sand (0.425 mm – 0.075 mm); and silt (<0.075 mm). The silt fraction is expected to be largely clay and represent 3.6 % of the PSD. Peak distributions were also observed in the 19 mm – 37.5 mm fractions

Figure 18: Particle size distribution graph



…residue characterisation (WRD South)

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Figure 19: WRD south characteristics

Dimensional parameters (current)	
Max height (m)	31
Footprint (Bottom) (m^2)	≈ 87 261
Footprint (Top) (m^2)	≈ 47 068
Total surface area (Top + sides) (m^2)	≈ 116 557
Est. volumes (m^3)	≈ 763 047

Material characteristics	
Dry density (g/cm^3)	2,218
Density (g/cm^3)	2,344
Specific gravity (g/cm^3)	2,911
Moisture (sampled) (%)	5,7
Moisture (prepared) (%)	14,5
Void ratio	0,312
Permeability (cm/s)	$2,66 \times 10^{-5}$

Material strength and stress			
Rate of shear (mm/min)	0,004	0,004	0,004
Normal stress at failure (kPa)	150	274	435
Max shear stress (kPa)	113,9	191	302
Strain at failure (%)	5,4	8,3	9,3
Φ' - Angle of internal friction (°)	33,5		
c' - Apparent cohesion of soil (kPa)	12,9		

● Sample locations

Mineralogy and particulates

Particle size (mm)	75	63	53	37,50	26,50	19	13,2	4,75	2	0,425	0,25	0,15	0,075	<0,075
Particle Size Distribution (PSD) (%)	-	6	7	12	17	22	2	5	4	12	3,3	3,1	3	3,6

Minerals	Actinolite	Biotite	Chromite	Diopside	Enstatite	Kaolinite	Plagioclase	Pyrophyllite	Smectite	Quartz
Mineralogy (% by weight)	0,88	-	1,75	1,45	21,87	0,34	69,77	0,06	2,87	1,02

…residue characterisation (WRD North)

Figure 20: WRD north characteristics

Dimensional parameters (current)	
Max height (m)	≈ 6 - 7
Footprint (Bottom) (m^2)	≈ 17 738
Footprint (Top) (m^2)	≈ 13 082
Total surface area (Top + sides) (m^2)	≈ 19 795
Est. volumes (m^3)	≈ 107 455

Material characteristics	
Dry density (g/cm^3)	2,218
Density (g/cm^3)	2,344
Specific gravity (g/cm^3)	2,911
Moisture (sampled) (%)	5,7
Moisture (prepared) (%)	14,5
Void ratio	0,312
Permeability (cm/s)	$2,66 \times 10^{-5}$

Material strength and stress			
Rate of shear (mm/min)	0,004	0,004	0,004
Normal stress at failure (kPa)	150	274	435
Max shear stress (kPa)	113,9	191	302
Strain at failure (%)	5,4	8,3	9,3
Φ' - Angle of internal friction (°)	33,5		
c' - Apparent cohesion of soil (kPa)	12,9		

Sample locations

Mineralogy and particulates

Particle size (mm)	75	63	53	37,50	26,50	19	13,2	4,75	2	0,425	0,25	0,15	0,075	<0,075
Particle Size Distribution (PSD) (%)	-	6	7	12	17	22	2	5	4	12	3,3	3,1	3	3,6

Minerals	Actinolite	Biotite	Chromite	Diopside	Enstatite	Kaolinite	Plagioclase	Pyrophyllite	Smectite	Quartz
Mineralogy (% by weight)	0,88	-	1,75	1,45	21,87	0,34	69,77	0,06	2,87	1,02

2. Tailings and tailings facilities

The tailings facilities consist of two mining pits filled with tailings at south and north shafts and an old and new TSF. The new TSF is the largest residue facility studied and has a designed lifetime of 23 years. Current footprint area was measured as roughly 12.5 ha and a max height of 10 m (measured at location *24°55'22.04"***S**, 30° 7'16.59" **E**). The tailings filled pits has a depth range of between 40 – 50 m (from figures 22 & 23 of the 2016 numerical model) with footprints of 12 233 m2 and 27 988 m2 for north and south pits, respectively. The old tailings dam has a max height of 13 m (measured at location 24°55'44.01"**S**, 30° 6'53.20"**E**) and footprint area of 5.6 ha. Total tailings volumes stored on site are estimated to be between ≈ 2.4 million and 3 million m^3 (≈ 5 – 6 million tons). Only the new TSF is still an operational facility where deposition is active. All other facilities have been partly rehabilitated and restoration is still in progress.

Material characteristics

The tailings material sampled has a dry and wet density of between 2.1 g/cm^3 and 2.27 g/cm^3, respectively, and a high specific gravity of 3.6 g/cm^3, which is mainly due to the high chromite and enstatite mineralogy. Optimum dry density was achieved at a ≈ 7 % moisture content. The void ratios are comparatively higher than the waste rock at between 0.71 and 0.73, which converts to a high porosity of 41 % - 42 %. This is typical of the finer sandy material types, as the particle size distribution also points to a denser fine-sand type material. The permeability is also comparatively higher and falls within the mid semi-pervious permeability range (highlighted in blue below). This permeability is also typical of an unconsolidated fine sand soil type.

K (cm/s)	10^2	10^1	10	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}	10^{-8}	10^{-9}	10^{-10}
Relative permeability	Pervious				Semi-pervious				Impervious				

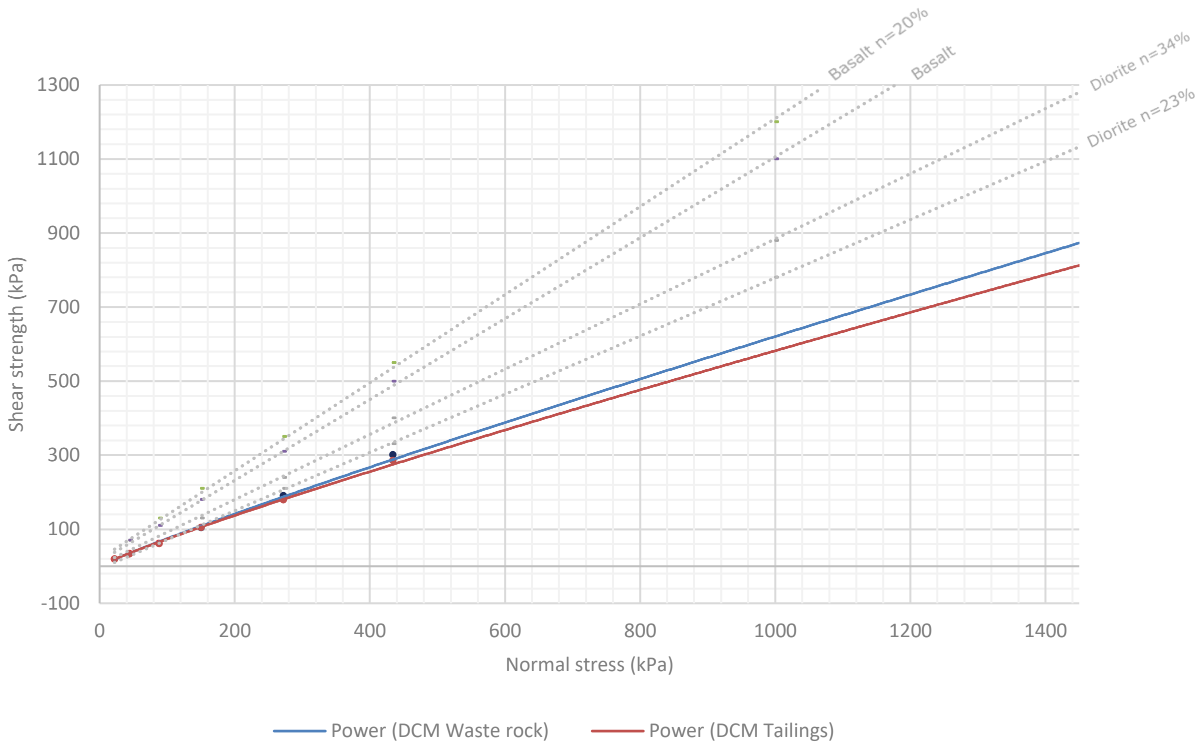
The higher permeability might be better in terms of stability as it plays a role in water drainage and management of phreatic surfaces. However, in terms of leachate, it will likely lead to higher seepage rates, depending on the permeability of the base soils or material layer. Where these materials have been deposited in the old pits, the higher permeability has, and will continue to, likely exacerbate the contamination issues.

Strength and stress

The max shear strengths were tested at higher than average normal stresses of 150 kPa, 274 kPa, and 434 kPa and the results were 105 kPa, 179.8 kPa, and 286.1 kPa, respectively. All the samples were found to behave like loose materials, that is, the principal stress difference gradually increased to a maximum. The friction angle (Φ') measured 32.6° and were slightly below the angle of repose of the tailings material (at 35° in the new TSF design report, Fraser Alexander). The samples exhibited a rather low amount of cohesion (c' – 8 kPa) compared to the waste rock material and is largely due to the ‘sandy nature’ and low clay content of the material. Due to the lower than normal cohesion, the shear strength is more due to the friction angle than the cohesion. The friction angles measured almost similar for waste rock and tailings material, between 32° - 34°, while the cohesion is higher for the waste rock than the tailings (12.9 kPa compared to 8 kPa). The cohesion seems to be the main differentiator that causes the higher shear strength of the waste rock material.

The linear failure envelope of the waste rock and tailings material is shown in figure 18 below. Basalt and diorite waste rock shear strengths from other projects are also projected for comparison. This material has much higher shear strengths due to their higher friction angles (35°-40°) (larger particle sizes and 'rough' particle geometry) and cohesion values (15 – 25 kPa).

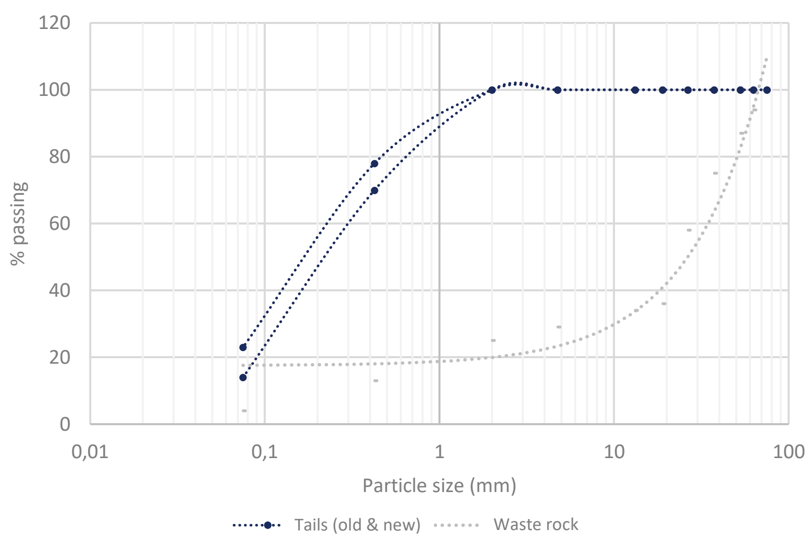
Figure 21: Linear failure envelope for the tailings



Particle size distribution

The particle size distribution is shown in figure 19 below. The distribution falls into a typical coarse to fine sand material type, with a low expected clay content. All samples had a 100 % passing rate up to 2 mm indicating that all size fractions were below 2 mm. The largest distribution range were between 0.425 mm - 2 mm and < 0.075 mm. The sandy particles consist of more than 50 % plagioclase, more than 22 % enstatite, and more than 13 % chromite, with smaller amounts of quartz, smectite, pyrophyllite, kaolinite, diopside, biotite, and actinolite.

Figure 22: Particle size distribution graph



...residue characterisation (TSF new)

Figure 23: TSF new characteristics

● Sample locations

Dimensional parameters (current)

Max height (m)	10
Footprint (Bottom) (m²)	≈ 125 387
Footprint (Top) (m²)	≈ 80 841
Total surface area (Top + sides) (m²)	≈ 129 390
Est. volumes (m³)	≈ 716 062

Material characteristics

Dry density (g/cm³)	2,119
Density (g/cm³)	2,269
Specific gravity (g/cm³)	3,623
Moisture (sampled) (%)	7,1
Moisture (prepared) (%)	13,8
Void ratio	0,71
Permeability (cm/s)	$3{,}15 \times 10^{-4}$

Material strength and stress

Rate of shear (mm/min)	0,004	0,004	0,004
Normal stress at failure (kPa)	150	272	434
Max shear stress (kPa)	105	179,7	286.1
Strain at failure (%)	5,6	5	8,1
Φ' - Angle of internal friction (°)	32,6		
c' - Apparent cohesion of soil (kPa)	8		

Mineralogy and particulates

Particle size (mm)	75	63	53	37,50	26,50	19	13,2	4,75	2	0,425	0,25	0,15	0,075	<0,075
Particle Size Distribution (PSD) (%)	-	-	-	-	-	-	-	-	-	22	21	16	16	25

Minerals	Actinolite	Biotite	Chromite	Diopside	Enstatite	Kaolinite	Plagioclase	Pyrophyllite	Smectite	Quartz
Mineralogy (% by weight)	1,52	1,62	13,64	5,08	22,6	0,75	51,13	0,82	2,15	0,69

…residue characterisation (TSF old)

Figure 24: TSF old characteristics

Dimensional parameters (current)	
Max height (m)	13
Footprint (Bottom) (m^2)	≈ 55 801
Footprint (Top) (m^2)	≈ 26 229
Total surface area (Top + sides) (m^2)	≈ 82 694
Est. volumes (m^3)	≈ 483 867

Material characteristics	
Dry density (g/cm^3)	2,1
Density (g/cm^3)	2,27
Specific gravity (g/cm^3)	3,637
Moisture (sampled) (%)	8,1
Moisture (prepared) (%)	16,5
Void ratio	0,731
Permeability (cm/s)	$2,35 \times 10^{-4}$

Material strength and stress			
Rate of shear (mm/min)	0,004	0,004	0,004
Normal stress at failure (kPa)	150	304	441
Max shear stress (kPa)	105,7	202,7	295
Strain at failure (%)	3,9	7,8	7,6
Φ' - Angle of internal friction (°)	33		
c' - Apparent cohesion of soil (kPa)	7,2		

● Sample locations

Mineralogy and particulates

Particle size (mm)	75	63	53	37,50	26,50	19	13,2	4,75	2	0,425	0,25	0,15	0,075	<0,075
Particle Size Distribution (PSD) (%)	-	-	-	-	-	-	-	-	-	30	24	18	14	14

Minerals	Actinolite	Biotite	Chromite	Diopside	Enstatite	Kaolinite	Plagioclase	Pyrophyllite	Smectite	Quartz
Mineralogy (% by weight)	1,55	1,12	10,66	4,64	27,28	1,07	48,35	0,89	3,49	0,95

…residue characterisation (South pit backfill)

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Figure 25: South pit backfill characteristics

Dimensional parameters (current)	
Max depth (m)	≈ 40 - 50
Footprint (Bottom) (m^2)	-
Footprint (Top) (m^2)	≈ 27 988
Total surface area (Top + sides) (m^2)	-
Est. volumes (m^3)	≈ 0.84 mil – 1.2 mil

Material characteristics	
Dry density (g/cm^3)	2,1
Density (g/cm^3)	2,27
Specific gravity (g/cm^3)	3,637
Moisture (sampled) (%)	8,1
Moisture (prepared) (%)	16,5
Void ratio	0,731
Permeability (cm/s)	$2,35 \times 10^{-4}$

Material strength and stress			
Rate of shear (mm/min)	0,004	0,004	0,004
Normal stress at failure (kPa)	150	304	441
Max shear stress (kPa)	105,7	202,7	295
Strain at failure (%)	3,9	7,8	7,6
Φ' - Angle of internal friction (°)	33		
c' - Apparent cohesion of soil (kPa)	7,2		

Mineralogy and particulates

Particle size (mm)	75	63	53	37,50	26,50	19	13,2	4,75	2	0,425	0,25	0,15	0,075	<0,075
Particle Size Distribution (PSD) (%)	-	-	-	-	-	-	-	-	-	30	24	18	14	14

Minerals	Actinolite	Biotite	Chromite	Diopside	Enstatite	Kaolinite	Plagioclase	Pyrophyllite	Smectite	Quartz
Mineralogy (% by weight)	1,55	1,12	10,66	4,64	27,28	1,07	48,35	0,89	3,49	0,95

…residue characterisation (North pit backfill)

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Figure 26: North pit backfill characteristics

Dimensional parameters (current)	
Max depth (m)	≈ 40 - 50
Footprint (Bottom) (m^2)	-
Footprint (Top) (m^2)	≈ 12 233
Total surface area (Top + sides) (m^2)	-
Est. volumes (m^3)	≈ 0.34 mil – 0.61 mil

Material characteristics	
Dry density (g/cm^3)	2,1
Density (g/cm^3)	2,27
Specific gravity (g/cm^3)	3,637
Moisture (sampled) (%)	8,1
Moisture (prepared) (%)	16,5
Void ratio	0,731
Permeability (cm/s)	$2,35 \times 10^{-4}$

Material strength and stress			
Rate of shear (mm/min)	0,004	0,004	0,004
Normal stress at failure (kPa)	150	304	441
Max shear stress (kPa)	105,7	202,7	295
Strain at failure (%)	3,9	7,8	7,6
Φ' - Angle of internal friction (°)	33		
c' - Apparent cohesion of soil (kPa)	7,2		

Mineralogy and particulates

Particle size (mm)	75	63	53	37,50	26,50	19	13,2	4,75	2	0,425	0,25	0,15	0,075	<0,075
Particle Size Distribution (PSD) (%)	-	-	-	-	-	-	-	-	-	30	24	18	14	14

Minerals	Actinolite	Biotite	Chromite	Diopside	Enstatite	Kaolinite	Plagioclase	Pyrophyllite	Smectite	Quartz
Mineralogy (% by weight)	1,55	1,12	10,66	4,64	27,28	1,07	48,35	0,89	3,49	0,95

3. Discard material

The discard material is deposited mainly at the discard dump, with limited co-disposal at the south waste rock dump between 2005 - 2012. The main active discard facility is thus the discard dump. The discard dump has a max height of roughly ≈ 42m and a footprint area of ≈ 4.7 ha. The total volumes have been estimated at 1,1 million m^3. The material consists of predominantly waste rock, but with a more than 60 % particle size distribution (PSD) > 53 mm. Where the waste rock material is more gravel type with an even PSD, the discard is predominantly large rocks. Due to the size of the material, no geotechnical assessments were done. However, geochemical assessments were done by crushing and milling the material before it was chemically digested. The material has a specific gravity of between 2.8 and 2.9 g/cm^3, like the waste rock material. The large PSD is likely to cause high porosity, void ratio and permeability, which is expected to range between 30 % - 35 %, 0.43 – 0.55, and > 1 x 10^{-3} cm/s, respectively. The discard material is also expected to have a very low cohesion in the < 4 kPa range but is expected to have a high friction angle (likely between 34° - 37°). As a result, the shear strength in the discard material is expected to be largely derived from its friction angle.

The angle of repose at the current discard dump has been measured 34°.

…residue characterisation (Discard dump)

Figure 27: Discard characteristics

Dimensional parameters (current)	
Max height (m)	42
Footprint (Bottom) (m^2)	≈ 46 971
Footprint (Top) (m^2)	≈ 9 685
Total surface area (Top + sides) (m^2)	≈ 64 563
Est. volumes (m^3)	≈ 1 106 286

Material characteristics	
Dry density (g/cm^3)	-
Density (g/cm^3)	-
Specific gravity (g/cm^3)	2,911
Moisture (sampled) (%)	-
Moisture (prepared) (%)	-
Void ratio	≈ 0,43 – 0.55
Permeability (cm/s)	≈ 1 x 10^{-3} - 1 x 10^{-4}

Material strength and stress			
Rate of shear (mm/min)	-	-	-
Normal stress at failure (kPa)	-	-	-
Max shear stress (kPa)	-	-	-
Strain at failure (%)	-	-	-
Φ' - Angle of internal friction (°)	≈ 34° - 37°		
c' - Apparent cohesion of soil (kPa)	≈ < 4		

● Sample locations

Mineralogy and particulates

Particle size (mm)	75	63	53	37,50	26,50	19	13,2	4,75	2	0,425	0,25	0,15	0,075	<0,075
Particle Size Distribution (PSD) (%)	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Minerals	Actinolite	Biotite	Chromite	Diopside	Enstatite	Kaolinite	Plagioclase	Pyrophyllite	Smectite	Quartz
Mineralogy (% by weight)	0,88	-	1,75	1,45	21,87	0,34	69,77	0,06	2,87	1,02

03 Management

The waste related management actions will be discussed for each waste type. Each waste type's actions will be discussed in terms of its handling and storage and its recycling, re-use, treatment or disposal.

1. WWTW Sludge

1.1. Handling and storage

Handling

As mentioned in the results chapter above, the sludge could occasionally have pathogen breakthroughs, although it is expected to be very seldom, if ever. However, as a preventative measure it is suggested to wear the appropriate safety gloves when handling the material, which should be non-penetrable, such as the latex type gloves.

- Wear appropriate PPE when handling the material

Storage

Due to the category 4 chronic aquatic hazard of the sludge it should be prevented from entering aquatic systems. Small amounts of sludge are however not expected to be hazardous, but continuous or high volume released to the aquatic systems can cause nutrient increases. It should preferably be contained or stored in such a way that it is prevented from entering the surface water systems. This can include storage in lidded containers, in bunded areas (such as the drying beds on site), and lined and roofed areas. See also the DWAF *Guidelines for the Utilisation and Disposal of Wastewater Sludge: Volume 2, part 5, page 16*.

- Effectively contain the material during storage to prevent it from entering surface water systems

1.2. Disposal, treatment or re-usage

Classifying as a **A1c** sludge type have some restrictions on management options due to the class c pollution type.

Overview

The DWAF guideline divides the management of sludge into the following five main management options:

1. Agricultural use at agronomical rates
2. On-site or off-site disposal
3. Beneficial use (other than agricultural use at agronomic rates)
4. Thermal treatment methods
5. Produce saleable products

The guidelines then proceed to evaluate the sludge type's (in this case A1c) appropriateness to each management option. The appropriateness is divided into five levels, nl. yes (level i), qualified yes (level ii), may be (level iii), qualified no (iv), and no (v). This is further illustrated in figure 28 below.

As each sludge type has its specific microbiological classification, stability classification, and pollution classification, these classifications determine the appropriateness opinion. As example, for a A1c sludge type, the pollution class is c, which means that for a pollution class c the management option appropriateness for the 'agricultural use at agronomical rates' management option is no (v), as per table 29. This means that agricultural use at agronomical rates is not an appropriate management option for a sludge type A1c, mainly due to the pollution class c classification. Thus, the appropriateness ratings in figure 28 below is used to rate the appropriateness of the five management options listed above. Table 29 provides the detailed rating for the DCM sludge type A1c.

Figure 28: Appropriateness evaluation definitions table (DWAF *Guidelines for the Utilisation and Disposal of Wastewater Sludge: Volume 1, Table 7, page 27*)

Appropriateness	Description
(i) Yes	Recognising that no management option can ever truly be applied without any restrictions, these options only have minor restrictions.
(ii) Qualified yes	The restrictions that apply do not have major implications and can be managed using good management practices.
(iii) May be	This can only be effectively applied under strict conditions and major management and cost implications could apply.
(iv) Qualified no	Only under unique conditions can this management option be applied for this class of sludge.
(v) No	This management option should not be considered for this class of sludge.

The DCM sludge type (A1c) management options, as per table 29 below, are in order of decreasing appropriateness:

1. Produce saleable products
2. On-site or off-site disposal
3. Beneficial use (other than agricultural use at agronomic rates)
4. Agricultural use at agronomical rates
5. Thermal treatment methods

The options above are the theoretical management options as per the DWAF guidelines. These are guidelines and therefore provides guidance, meaning some options might be appropriate in most cases, but might be more appropriate in other less common cases. As an example, a pollution class c causes a qualified no (iv) appropriateness option due to potential pollution but might be appropriate as management option at a facility with a proper liner system, such as at the new TSF. We will look at the practical management options and provide the risk-based assessment as to why.

Volume 4 of the guidelines discusses beneficial use at high loading rates. DCM indicated that they would like to use the sludge in rehabilitation. Usage in rehabilitation on mine tailings are usually considered once-off high rate sludge application (DWAF guidelines vol. 4, pg. 6) and is discussed in detail in part 4 of volume 4.

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Figure 29: Management options appropriateness evaluation table, per class.

Management option	Class	Appropriate option?	Major restrictions?	Class	Appropriate option?	Major restrictions?	Class	Appropriate option?	Major restrictions?
Agricultural use at agronomical rates	Microbiological class A	Yes (i)	None	Stability class 1	Yes (i)	None	Pollution class c	No (v)	The sludge metal content is too high for agricultural use. Source control should be implemented.
On-site or off-site disposal	Microbiological class A	May be (iii)	It is an inappropriate option for the disposal of a disinfected sludge. Disinfection tech. is costly and would be a waste of resources.	Stability class 1	Yes (i)	None. Note that vector attraction reduction options 9 and 10 do not apply.	Pollution class c	May be (iii)	Delisting according to the Minimum Requirements will be required.
Beneficial use (other than agricultural use at agronomic rates)	Microbiological class A	Yes (i)	None pertain to this microbiological class	Stability class 1	Qualified yes (ii)	Vector attraction reduction options 1 to 8 would be appropriate.	Pollution class c	Qualified no (iv)	High rate application of this sludge could cause long-term effects and source control should be implemented.
Thermal treatment methods	Microbiological class A	No (v)	It is not recommended to use thermal methods, such as incineration to manage a Microbiological class A sludge, as it was costly to achieve this classification in the first place.	Stability class 1	May be (iii)	Vector attraction reduction options 7 and 8 or an appropriate dewatering step should be applied as a pre-treatment step before thermal treatment.	Pollution class c	Qualified yes (ii)	Emissions of gaseous contaminants and the ash should be monitored and managed.
Produce saleable products	Microbiological class A	Yes (i)	Most saleable products will require disinfection process.	Stability class 1	Yes (i)	Long-term stability would be required for saleable products.	Pollution class c	May be (iii)	This depends on the product.

Preferred options: On-site or off-site disposal; Beneficial use (other than agricultural use at agronomic rates)

The most practical options for DCM in terms of management of the sludge is for on-site usage, both from an environmental and economical point of view. As discussed above, the usage during rehabilitation is considered mostly once off high rate application and is discussed in the guidelines in volume 4. There are some exceedances of the metal concentrations which places the sludge in a pollution class c. The soils to be rehabilitated will be considered industrial and the guidelines provides maximum permissible level (MPL) concentrations for some metals to ensure that the soil quality does not degrade to such an extent that remediation would be necessary. We will compare the total concentrations for the discard material, waste rock material and tailings material as the soil substrate against the MPL. We will then use this to determine appropriateness for use in rehabilitation and calculate the permissible application rate (PAR).

The discard, tailings, and waste rock are all above the MPL values for the iLEH test results but below MPL for the nettzero test results, taken during this study.

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Figure 30: Discard TC compared against MPL (all results in mg/kg)

Elements tested	MPL	Total concentrations tested			MPL status		
		iLEH DSC_A	iLEH DSC S_A	Nettzero	iLEH DSC_A	iLEH DSC S_A	Nettzero
As, Arsenic	20	13,6	20,8	<2	✓	✓	✓
Cd, Cadmium	5	3,2	2,4	<0,05	✓	✓	✓
Cr, Chromium	450	8000	8000	187	✗	✗	✓
Cu, Copper	375	<4	<4	51	✓	✓	✓
Hg, Mercury	9	-	-	<0,1	✓	✓	✓
Ni, Nickel	200	452	428	63	✗	✗	✓
Pb, Lead	150	8	10	1,55	✓	✓	✓
Zn, Zinc	700	47,2	36,8	187	✓	✓	✓

MPL - Maximum permissible level (DWAF guideline vol. 4, table 9, pg. 22)

Figure 31: Waste rock TC compared against MPL (all results in mg/kg)

Elements	MPL	Total concentrations tested				MPL status			
		WRD N	WRD S	WRD R	Nettzero	WRD N	WRD S	WRD R	Nettzero
As, Arsenic	20	30	<4	30	<0,02	✗	✓	✗	✓
Cd, Cadmium	5	2,4	6	3,6	<0,05	✓	✗	✓	✓
Cr, Chromium	450	4400	4400	6800	105	✗	✗	✗	✓
Cu, Copper	375	<4	9,2	<4	11,5	✓	✓	✓	✓
Hg, Mercury	9	-	-	-	<0,1	✓	✓	✓	✓
Ni, Nickel	200	338	388,4	388	27	✗	✗	✗	✓
Pb, Lead	150	12,4	6	12,8	<0,05	✓	✓	✓	✓
Zn, Zinc	700	46,4	49,2	56	109	✓	✓	✓	✓

MPL - Maximum permissible level (DWAF guideline vol. 4, table 9, pg. 22)

Figure 32: Tailings TC compared against MPL (all results in mg/kg)

Elements	MPL	Total concentrations tested		MPL status	
		iLEH	Nettzero	iLEH	Nettzero
As, Arsenic	20	44,4	<2	✗	✓
Cd, Cadmium	5	2,4	<0,05	✓	✓
Cr, Chromium	450	26800	206	✗	✓
Cu, Copper	375	14,8	28	✓	✓
Hg, Mercury	9	-	< 0,1	✓	✓
Ni, Nickel	200	416	68	✗	✓
Pb, Lead	150	11,6	<0,05	✓	✓
Zn, Zinc	700	78,4	208	✓	✓

MPL - Maximum permissible level (DWAF guideline vol. 4, table 9, pg. 22)

The discard, tailings, and waste rock are all below the MPL values for the test results taken during this study. Despite the exceedences, the sludge is expected to be beneficial in terms of material quality as it will aid in water retention, increase organic loading and various other advantages.

To Table of contents
A.

Part 4 of volume 4 further states that "*The metal content of the tailings or soil to be rehabilitated is likely to be higher than the MPL set for soils. Under normal conditions additional sludge application would not be allowed, especially if the sludge also contains elevated metal concentrations. However, sludge application can be beneficial in reducing the mobility of metals in the soil or tailings material, resulting in an increase in leachate quality. Once off sludge application to aid in revegetation of mine tailings can therefore be considered a viable option even when the metal content of the material exceed the MPL.*''

The beneficial usage as fertilizer in on-site rehabilitation are thus the preferred management option for the fertilizer.

Important management requirements in terms of usage in on site rehabilitation:

- Care should be taken to prevent release of the WWTW sludge to surface waters, or where prevention cannot be done, to control and contain runoff water contaminated with sludge.
- Additional test work might be necessary in future to gain a better average and overall understanding of metal concentrations, and the effect of the fertilizer on concentration movements.

Disposal to off-site landfills:

- Where not used in rehabilitation disposal should be to a Class C (GLB+) disposal facility

2. Used oil and waste grease

2.1. Handling and storage

Handling

Both waste streams should be handled as per their MSDS's. Both have no health hazards at accidental exposure concentrations, but appropriate care should be taken to prevent ingestions and eye contact.

Both pose hazards to the aquatic environment with oil a category 4 hazard and grease a category 3. Care should thus be taken to prevent spillages or release to the surface water or soil. When it happens, appropriate measures should be taken to contain and remediate or clean up the accidental spillage.

Storage

Both materials are considered hazardous and should be appropriately stored in contained areas where release to the environment is prevented and emergency spillages contained.

2.2. Disposal and re-cycling

Used oil has been prohibited from disposal ito. GN 636 section 5, paragraph 1 (j) and can be readily recycled.

It is not certain if and how well recycling of waste grease is functioning in South Africa. Where possible, preference should be given to recycling of waste grease. Where not possible, as a Type 1 pre-classified waste, disposal should be to a Class A facility (old Hh/HH facilities).

3. Used paint containers

3.1. Handling and storage

< 3 % wt. containers

Empty paint containers should be emptied with less than 3 % by weight of its original content. With < 3 % wt. content the containers can be placed in a general waste container. With little paint left and proper ventilation the containers should dry quickly, and the more hazardous solvents will evaporate.

> 3 % wt. containers

Containers with more than 3 % its original weight should be handled as a hazardous substance and stored on contained areas. Spillages should be cleaned up.

3.2. Disposal and recycling

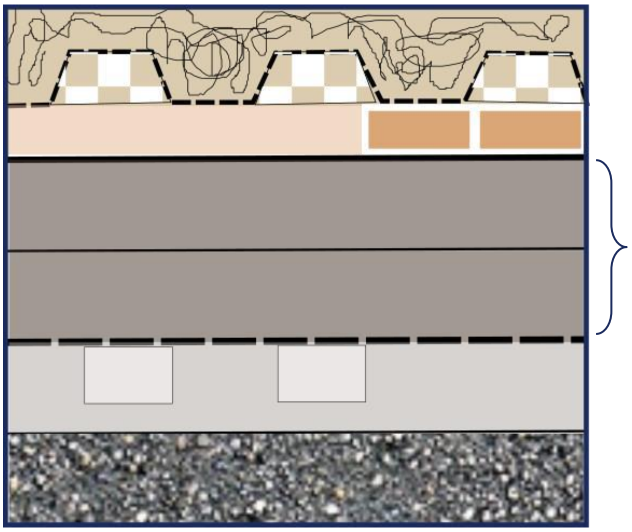
When dried out and < 3 % wt. the containers can be considered a general waste (Type 4). The paint containers can be recycled. Where not, it should be disposed at a Class D facility.

When wet and > 3 % wt., the containers are considered hazardous and falls into a pre-classified type 1 waste, which should be disposed at a Class A facility.

Management (Residue facilities)

According to the residue facilities' classification and according to the residue stockpile regulation's (GNR 632, GG 39 020, 2015) regulation 3, paragraph 4 (a)(b), all the waste facilities, characterised and classified during this study and previous studies in 2017 and 2018, should have a Class C barrier system (as per figure 33 below).

Figure 33: Class C liner as per GN 636, 2013



Of the 7 facilities studied, however only 1, the new TSF, is lined with a HDPE liner, while the old TSF is expected to have at least a Class D type clay compacted liner. All the other facilities have no pollution control barriers. To line these systems would be almost impossible currently. A few of the facilities are however expected to be re-located during closure to fill the portals and other voids. Whatever remains will be rehabilitated. This will allow DCM the opportunity to re-design the 'storage' of these material as it enters closure, which should include a detailed and in-depth contamination assessment on the residue material's nitrate concentration. This assessment should focus on simulation of long-term nitrate availability and release in order to ascertain how much nitrate really is still present on the material as supernatant, how much is available for leaching, what will the leaching risk be and then do a feasibility in terms of control barrier systems vs. just continuing with remediation. Remediation is inevitable and will likely start within the short term (1-3 years). If most of the leaching is during the 'first flush' then the long-term storage risk during closure might be low and the risk will largely remain with the legacy contamination that occurred during active deposition. The remediation should then address this. But, if the leaching risk is lower than during active deposition but still significant, then only focusing on remediation will be futile if the source is not controlled.

The closure and rehabilitation related groundwater management measures aren't clear from the closure and rehabilitation plans and this remains a big gap.

...residue management

Management summary

Our recommendation is to finalize the remediation strategy / approach, which should focus currently, as a matter of priority, just on protecting the potential sensitive receptors, which in this case is the surface water systems. No other known sensitive receptors exist on or near the property (such as groundwater users).

1. Remediation can be done through various plume interception options to either arrest the plume movement or remove the plume. The pumped water can be re-used in the system. But with a neutral and occasional positive water balance, pump and treat will likely be the option.

2. It is recommended to include a pertinent groundwater section into the closure and rehabilitation plan and integrate the concurrent remediation obligations into the annual rehabilitation plan.

References

Olivier, D. SRK, Waste rock dump management and stability evaluation

Karlsson, T., Kauppila, T. 2015. Release of explosives originated nitrogen from the waste rocks of a dimension stone quarry

Appendix 1

Lab results

Shearbox

Project:	Geochemical Assessment
Client:	NettZero
Geolab Job Nr:	G18-228
Test Method:	ASTM 3080-72

Sample Nr:	Tails New
Sample Depth:	-
Date:	2018-10-18

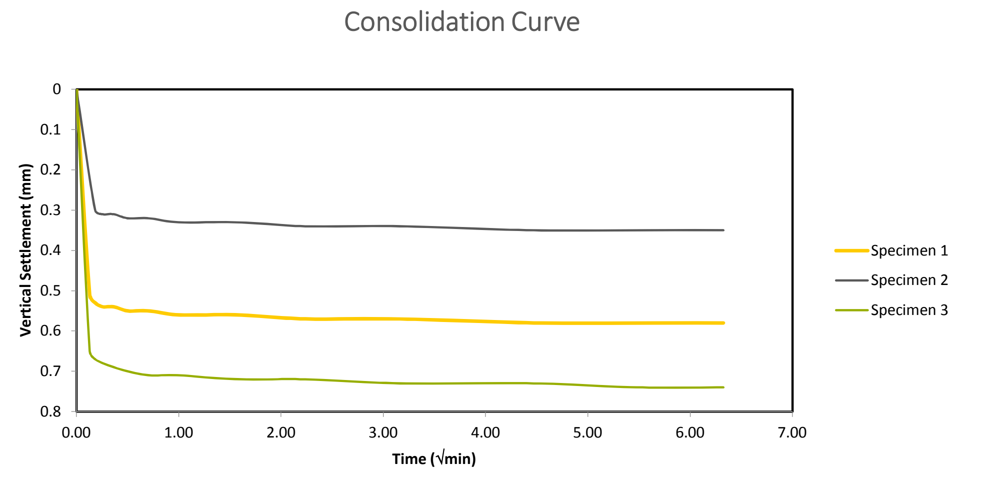
Results		
ϕ' =	**32.6**	**°**
c' =	**8.0**	**kPa**

Sampling Method:	Bag
Disturbed/Undist:	Disturbed
Remoulded To:	2118 kg/m³ Dry Density

Initial Sample Details	1	2	3	
Sample Height:	20	20	20	mm
Sample Diameter:	60	60	60	mm
Sample Mass	128.3	128.3	128.3	g
Dry Density:	2118.5	2118.5	2118.5	kg/m³
Density:	2268.8	2268.8	2268.8	kg/m³
Void Ratio:	0.710	0.710	0.710	
Moisture Content:	7.1	7.1	7.1	%
Specific Gravity		3.623		kg/m³

Shear Stage	1	2	3	
Rate of Shear:	0.004	0.004	0.004	mm/min
Normal Stress at Failure:	150.0	272.0	434.0	kPa
Max Shear Stress:	105.0	179.7	286.1	kPa
Strain at Failure:	5.6	5.0	8.1	%

Final Sample Details	1	2	3	
Moisture Content:	13.7	14.0	13.6	%



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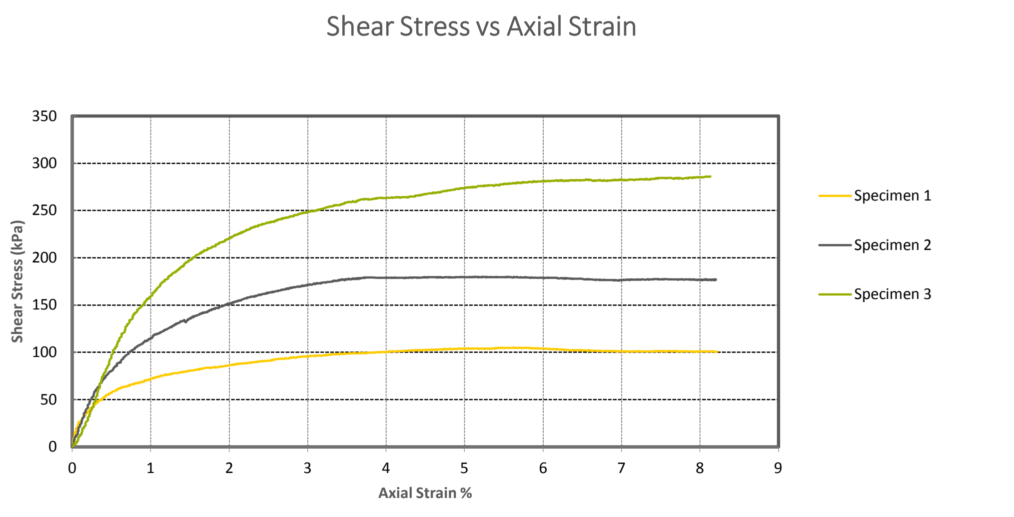
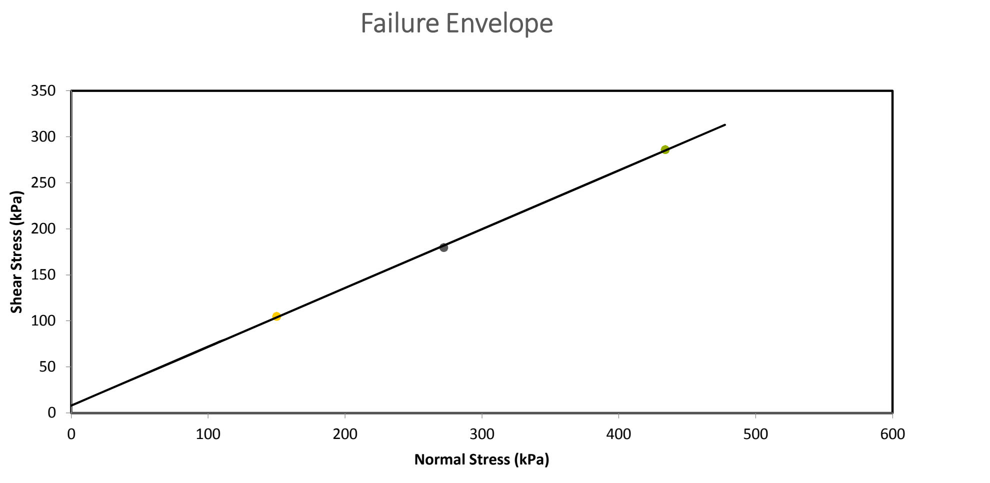
Shearbox

Project:	Geochemical Assessment
Client:	NettZero
Geolab Job Nr:	G18-228
Test Method:	ASTM 3080-72

Sample Nr:	Tails New
Sample Depth:	-
Date:	2018-10-18

Results		
φ' =	**32.6**	**°**
c' =	**8.0**	**kPa**





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Shearbox

Project:	Geochemical Assessment
Client:	NettZero
Geolab Job Nr:	G18-228
Test Method:	ASTM 3080-72

Sample Nr:	Tails Old
Sample Depth:	-
Date:	2018-10-18

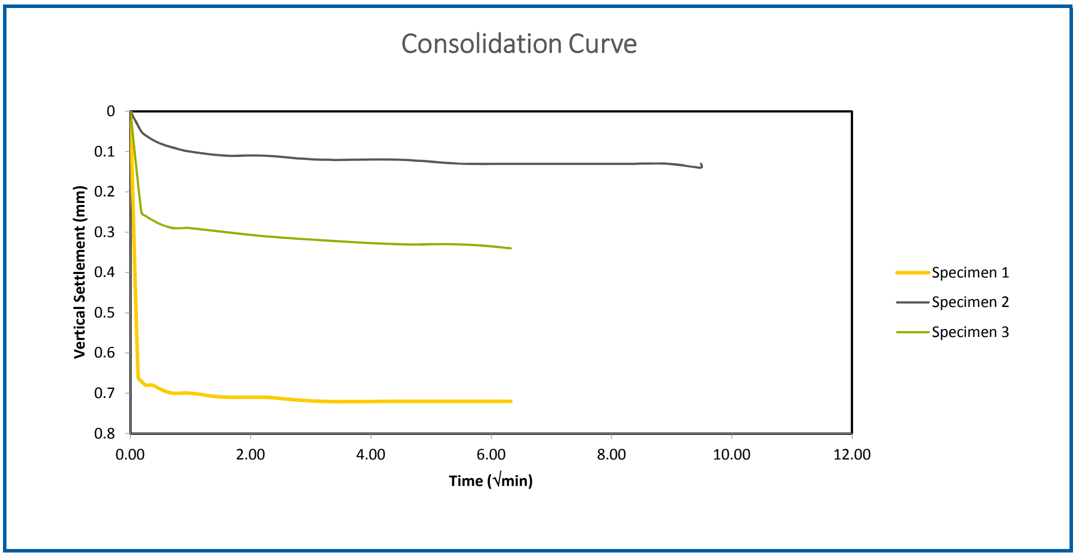
Results		
ϕ' =	**33.0**	**°**
c' =	**7.2**	**kPa**

Sampling Method:	Bag
Disturbed/Undist:	Disturbed
Remoulded To:	2100 kg/m³ Dry Density

Initial Sample Details	1	2	3	
Sample Height:	20	20	20	mm
Sample Diameter:	60	60	60	mm
Sample Mass	128.4	128.4	128.4	g
Dry Density:	2100.5	2100.5	2100.5	kg/m³
Density:	2270.6	2270.6	2270.6	kg/m³
Void Ratio:	0.731	0.731	0.731	
Moisture Content:	8.1	8.1	8.1	%
Specific Gravity		3.637		kg/m³

Shear Stage	1	2	3	
Rate of Shear:	0.004	0.004	0.004	mm/min
Normal Stress at Failure:	150.0	304.0	441.0	kPa
Max Shear Stress:	105.7	202.7	295.0	kPa
Strain at Failure:	3.9	7.8	7.6	%

Final Sample Details	1	2	3	
Moisture Content:	16.8	16.4	14.1	%



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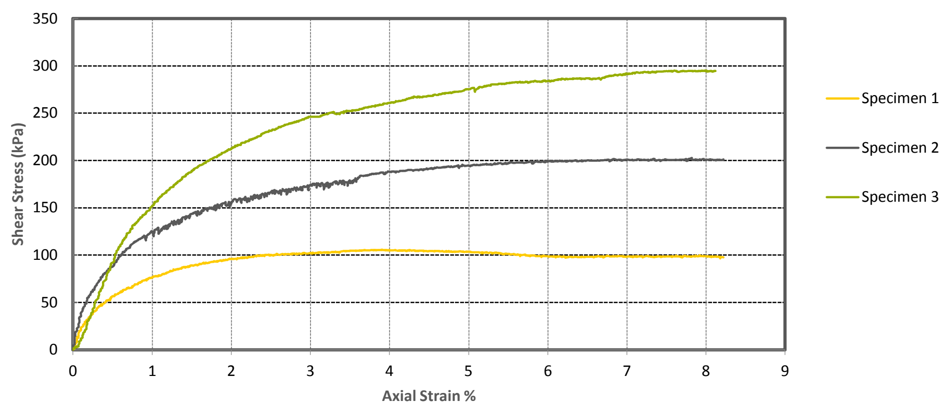
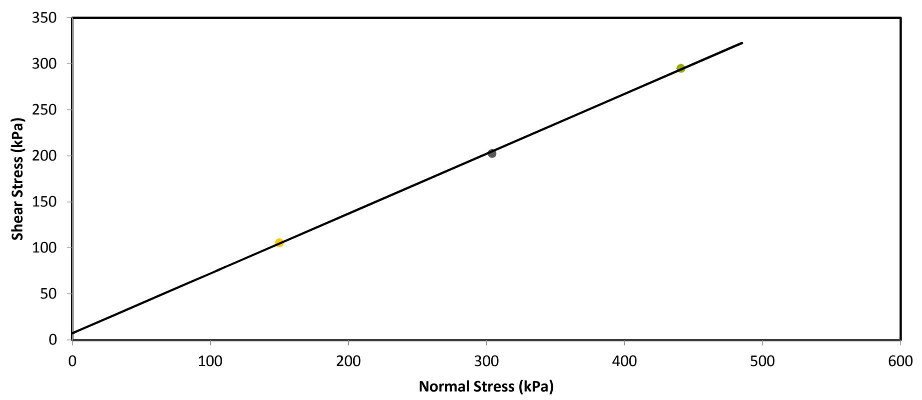
Shearbox

Project:	Geochemical Assessment
Client:	NettZero
Geolab Job Nr:	G18-228
Test Method:	ASTM 3080-72

Sample Nr:	Tails Old
Sample Depth:	-
Date:	2018-10-18

Results		
φ' =	33.0	°
c' =	7.2	kPa





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Shearbox

Project:	Geochemical Assessment
Client:	NettZero
Geolab Job Nr:	G18-228
Test Method:	ASTM 3080-72

Sample Nr:	Waste Rock
Sample Depth:	-
Date:	2018-10-23

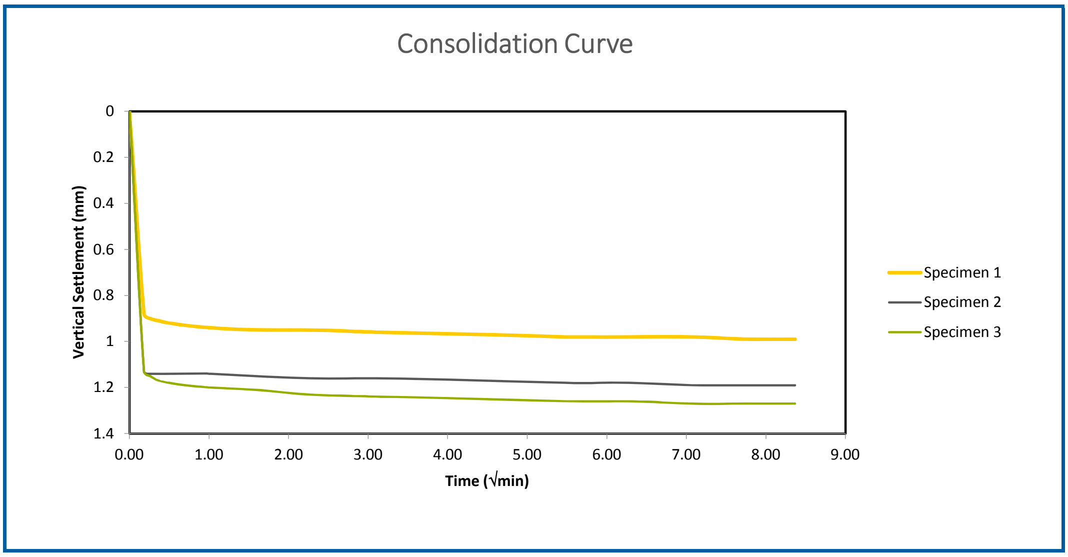
Results		
ϕ' =	33.5	°
c' =	12.9	kPa

Sampling Method:	Bag
Disturbed/Undist:	Disturbed
Remoulded To:	2219 kg/m³ Dry Density

Initial Sample Details	1	2	3	
Sample Height:	20	20	20	mm
Sample Diameter:	60	60	60	mm
Sample Mass	132.6	132.6	132.7	g
Dry Density:	2218.3	2218.3	2220.0	kg/m³
Density:	2344.9	2344.9	2346.7	kg/m³
Void Ratio:	0.312	0.312	0.311	
Moisture Content:	5.7	5.7	5.7	%
Specific Gravity		2.911		kg/m³

Shear Stage	1	2	3	
Rate of Shear:	0.004	0.004	0.004	mm/min
Normal Stress at Failure:	150.0	274.0	435.0	kPa
Max Shear Stress:	113.9	191.0	302.0	kPa
Strain at Failure:	5.4	8.3	9.3	%

Final Sample Details	1	2	3	
Moisture Content:	14.7	14.9	14.0	%



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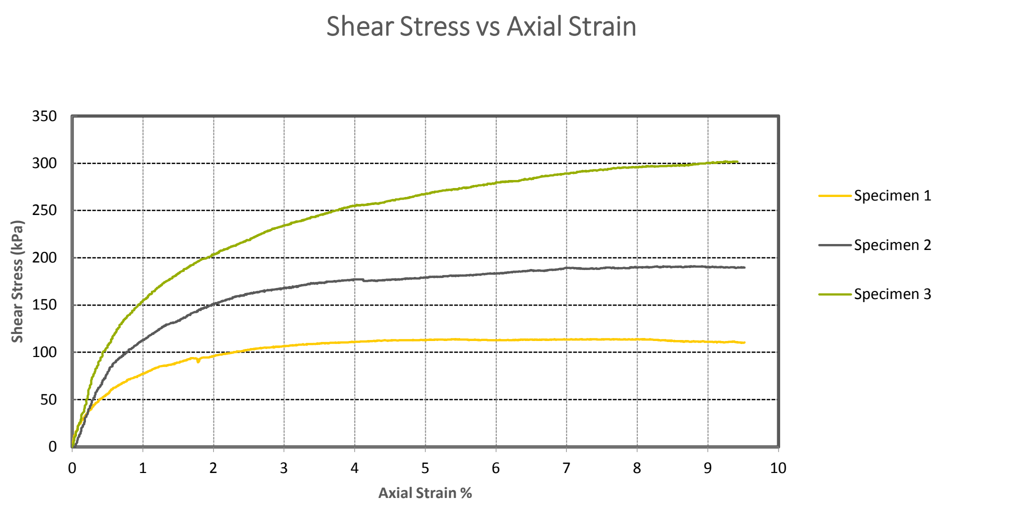
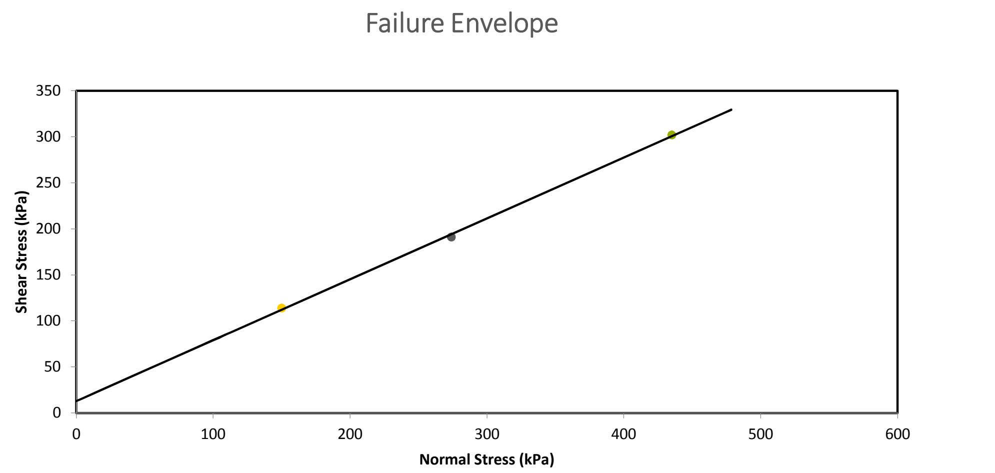
Shearbox

Project:	Geochemical Assessment
Client:	NettZero
Geolab Job Nr:	G18-228
Test Method:	ASTM 3080-72

Sample Nr:	Waste Rock
Sample Depth:	-
Date:	2018-10-23

Results		
φ' =	33.5	°
c' =	12.9	kPa





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SOIL ANALYSIS BY ...... : SOILLAB (Pty) Ltd
Lab reference No. .... : S18-1849

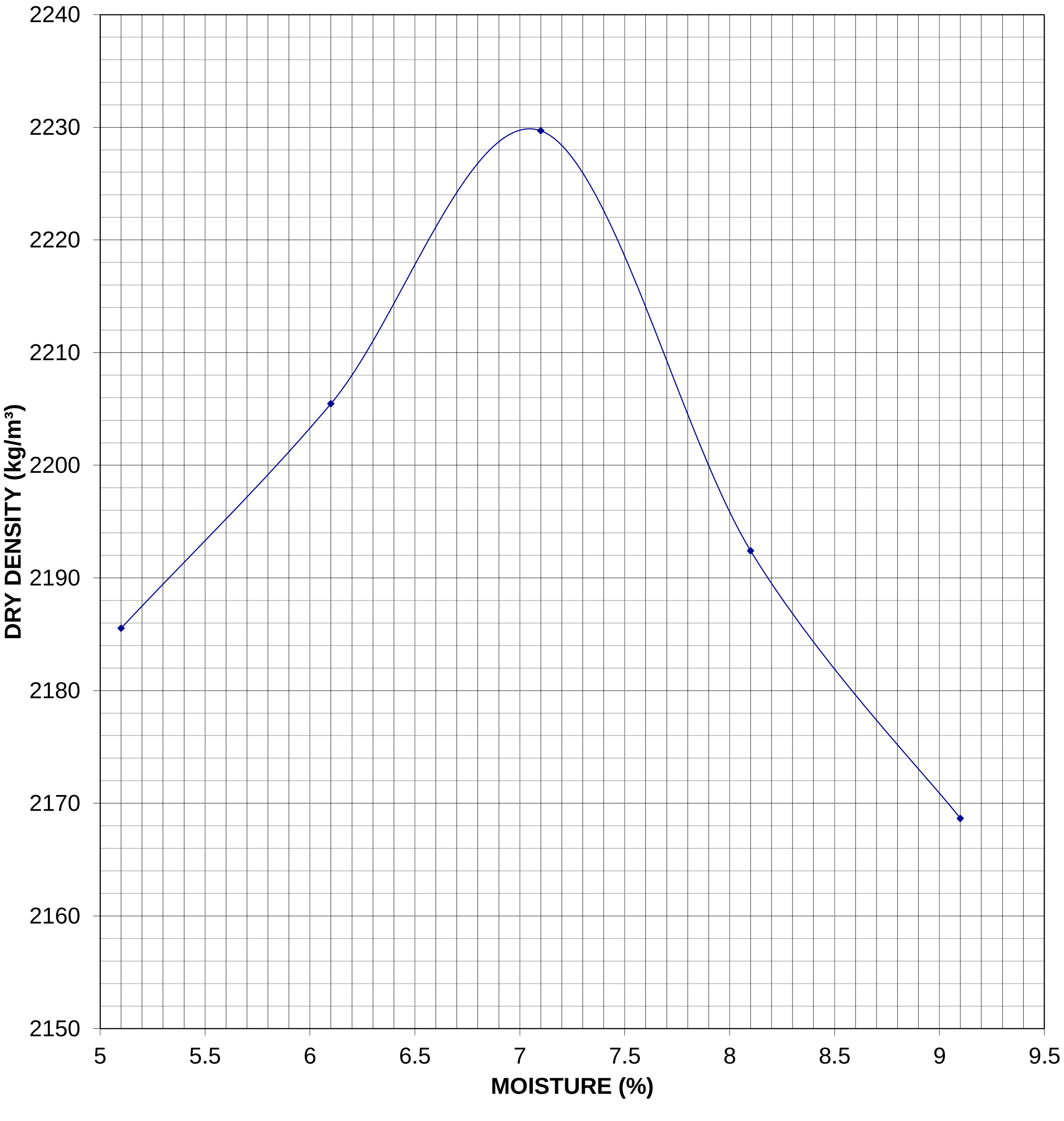
Page : 1
Date Printed : 2018-10-04

Customer .... : MARIUS ALERS				Job Number .... : S18-1849		
Job Description .... : DWARSRIVIER				Contract Number .... :		
Road Number .... :				Date .... : 2018-10-04		
SAMPLE DESCRIPTION						
Sample Number	55004	55005	55006			
Sample Position	TAILS NEW	WASTE ROCK	TAILS OLD			
Sample Depth (mm)						
Material Description	DARK GREY SAND	LIGHT GREY DOLERITE GRAVEL	DARK GREY SAND			
Max size of boulder (mm)	-	-	-			
SCREEN ANALYSIS (% PASS)						
75,00 mm	100	100	100			
63,00 mm	100	94	100			
53,00 mm	100	87	100			
37,50 mm	100	75	100			
26,50 mm	100	58	100			
19,00 mm	100	36	100			
13,20 mm	100	34	100			
4,750 mm	100	29	100			
2,000 mm	100	25	100			
0,425 mm	78	13	70			
0,075 mm	23	4	14			
SOIL MORTAR						
Coarse Sand 2,000-0,425	22	46	30			
Coarse Fine Sd 0,425-0,250	21	14	24			
Medium Fine Sd 0,250-0,150	16	13	18			
Fine Fine Sand 0,150-0,075	16	12	14			
Material <0,075	25	15	14			
CONSTANTS						
Grading Modulus	0.99	2.58	1.16			
Liquid Limit						
Plasticity Index	NP	NP	NP			
Linear Shrinkage (%)	0.0	0.0	0.0			
Sand Equivalent						
Classification - TRB	A-2-4 (0)	A-1-a (0)	A-2-4 (0)			
Classification - COLTO						
CBR / UCS VALUES						
MOD. AASHTO						
Max Dry Density (kg/m³)						
Optimum Moisture Cont (%) ...						
Moulding Moisture Cont (%) ...						
Dry Density (kg/m³)						
% of Max Dry Density						
100% Mod CBR/UCS						
% Swell						
NRB						
Dry Density (kg/m³)						
% of Max Dry Density						
100% NRB CBR/UCS.............						
% Swell						
PROCTOR						
Dry Density (kg/m³)						
% of Max Dry Density						
100% Proc CBR/UCS						
% Swell						
CBR / UCS VALUES						
100% Mod AASHTO						
98% Mod AASHTO						
97% Mod AASHTO						
95% Mod AASHTO						
93% Mod AASHTO						
90% Mod AASHTO						
Soillab No.:	S18-1849-01	S18-1849-02	S18-1849-03			

MOISTURE/DENSITY RELATIONSHIP @ STANDARD PROCTOR EFFORT

(TMH 1 A7)

PROJECT:	DWARSRIVER MINE
Soillab Job No.:	S18-1849-01
Description:	SAMPLE 1 - TAILS NEW
Maximum Dry Density (kg/m³):	2230
Optimum Moisture Content (%):	7.1



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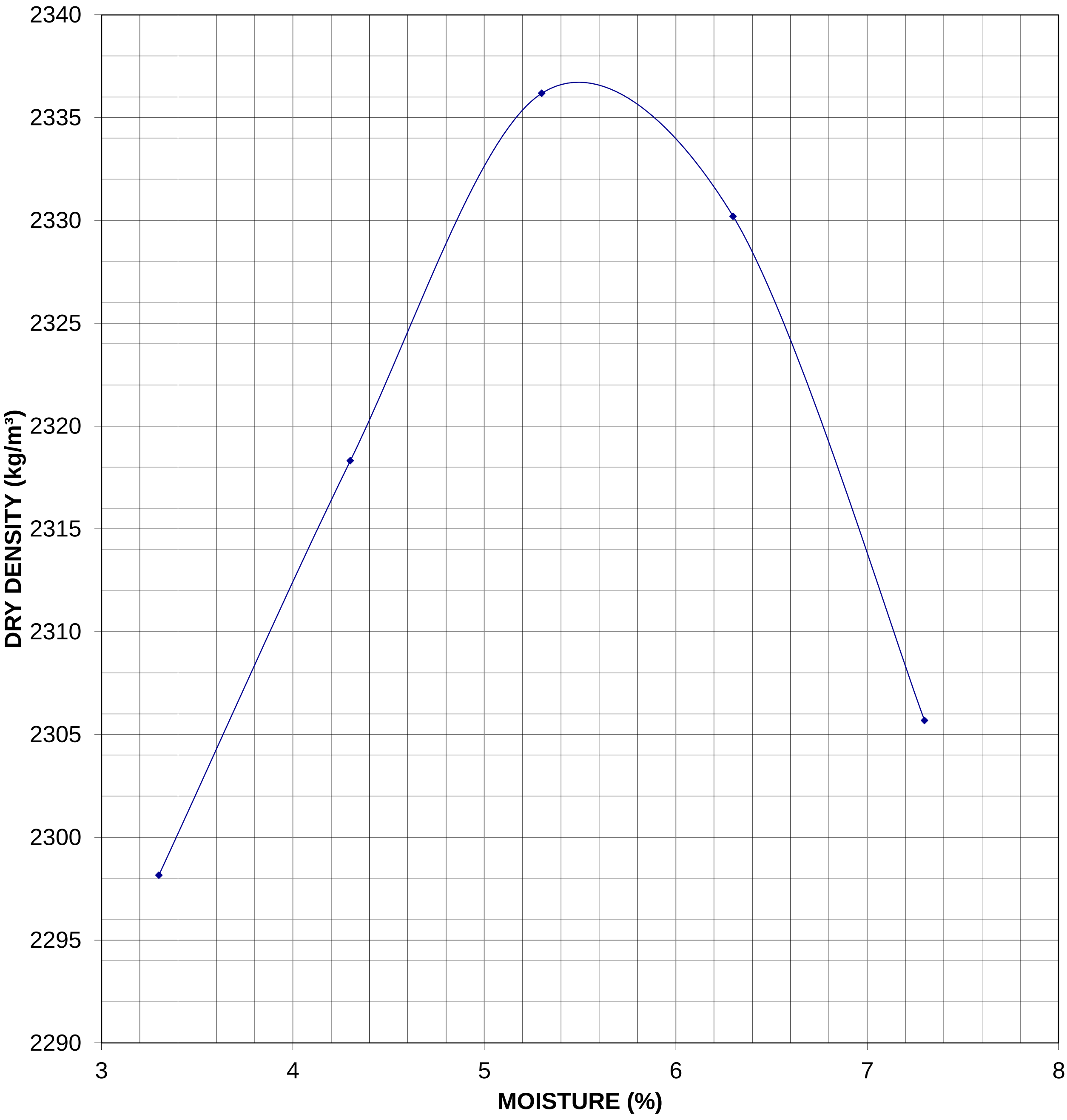
MOISTURE/DENSITY RELATIONSHIP @ STANDARD PROCTOR EFFORT

(TMH 1 A7)

PROJECT:	DWARSRIVER MINE
Soillab Job No.:	S18-1849-02
Description:	SAMPLE 2 - WASTE ROCK
Maximum Dry Density (kg/m³):	2336
Optimum Moisture Content (%):	5.7



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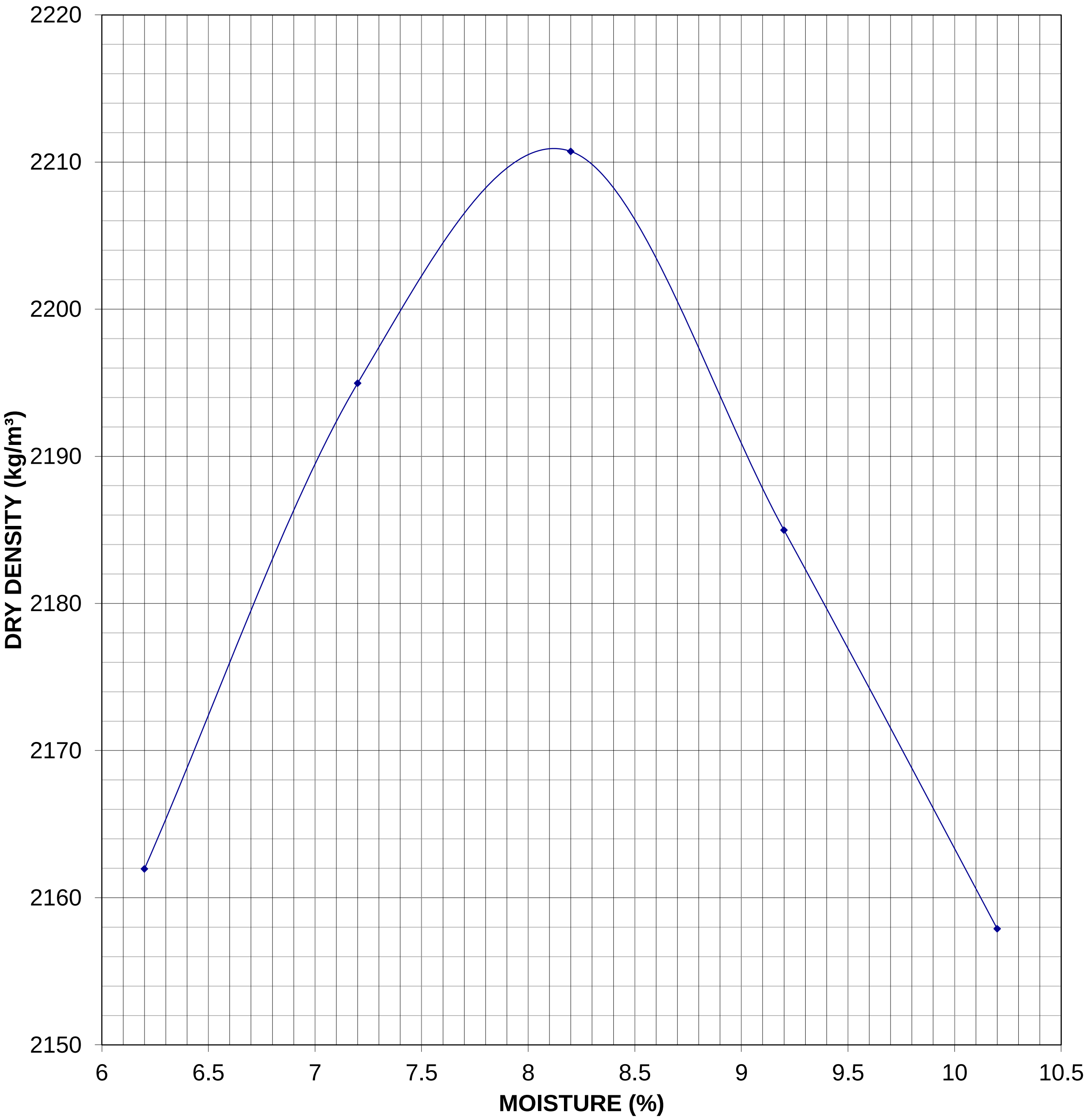
MOISTURE/DENSITY RELATIONSHIP @ STANDARD PROCTOR EFFORT

(TMH 1 A7)

PROJECT:	DWARSRIVER MINE
Soillab Job No.:	S18-1849-03
Description:	SAMPLE 3 - TAILS OLD
Maximum Dry Density (kg/m³):	2211
Optimum Moisture Content (%):	8.1



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Dr Sabine Verryn

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f: 086 565 7368
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XRD Analytical and Consulting cc
75 Kafue Street, Lynnwood Glen,
0081, South Africa

CLIENT: Soillab - Geolab

DATE: 10 November 2018

SAMPLES: 3 Samples – G18-228

ANALYSIS: Qualitative and quantitative XRD

After crushing, splitting and milling, the material was prepared for XRD analysis using a back loading preparation method.

They were analysed with a PANalytical AERIS diffractometer with PIXcel detector and fixed slits with Fe filtered Co-Kα radiation. The phases were identified using X'Pert Highscore plus software.

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

Comments:

- In case the results do not correspond to results of other analytical techniques, please let me know for further fine tuning of XRD results.
- Due to preferred orientation and crystallite size effects, results may not be as accurate as shown in the table.
- Mineral names may not reflect the actual compositions of minerals identified, but rather the mineral group.
- Traces of additional phases such as smectite and kaolinite may be present.
- Amorphous phases, if present, were not taken into account during quantification.

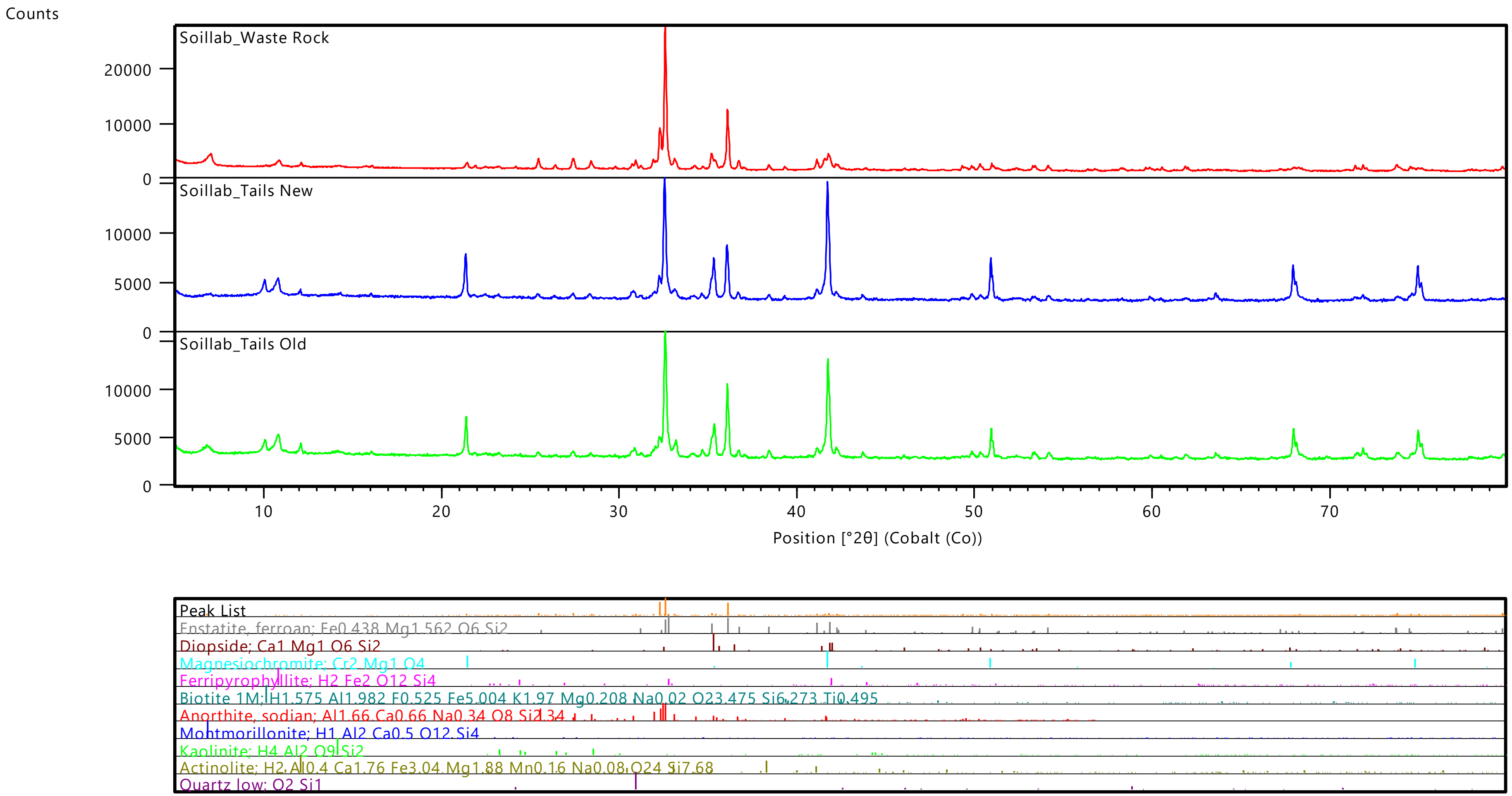
If you have any further queries, kindly contact me.

Dr. Sabine Verryn (Pr.Sci.Nat)

Samples will be stored for 3 months after which they will be discarded.

	Enstatite	Diopside	Chromite	Pyrophyllite	Biotite	Plagioclase	Smectite	Kaolinite	Actinolite	Quartz
Waste Rock	21.87	1.45	1.75	0.06	0	69.77	2.87	0.34	0.88	1.02
Tails New	22.6	5.08	13.64	0.82	1.62	51.13	2.15	0.75	1.52	0.69
Tails Old	27.28	4.64	10.66	0.89	1.12	48.35	3.49	1.07	1.55	0.95

0 = n.d. – not detected below the detection limit of 0.5-3 weight per cent


Counts
Soillab_Waste Rock
20000
10000
0
Soillab_Tails New
10000
5000
0
Soillab_Tails Old
10000
5000
0
10
20
30
40
50
60
70
Position [°2θ] (Cobalt (Co))
Peak List
Enstatite, ferroan; Fe0.438 Mg1.562 O6 Si2
Diopside; Ca1 Mg1 O6 Si2
Magnesiochromite; Cr2 Mg1 O4
Ferripyrophyllite; H2 Fe2 O12 Si4
Biotite 1M; H1.575 Al1.982 F0.525 Fe5.004 K1.97 Mg0.208 Na0.02 O23.475 Si6.273 Ti0.495
Anorthite, sodian; Al1.66 Ca0.66 Na0.34 O8 Si2.34
Montmorillonite; H1 Al2 Ca0.5 O12 Si4
Kaolinite; H4 Al2 O9 Si2
Actinolite; H2 Al0.4 Ca1.76 Fe3.04 Mg1.88 Mn0.16 Na0.08 O24 Si7.68
Quartz low; O2 Si1

Constant Head Permeability

Project:	Geochemical Assessment
Client:	NettZero
Geolab Job Nr:	G18-228
Date:	2018-10-22
Test Method:	ASTM D2434:1974

	Remoulded to:					
Sample Number:	**Density: kg/m³**	**w %**	**Water Head kPa**	**Flow (ΔV) ml**	**Time h:m:s**	**Permeability cm/s**
Tails New	2268	7.1	10.0	195.7	0:06:05	3.15E-04
Tails Old	2267	8.1	10.0	124.6	0:05:13	2.35E-04
Waste Rock	2320	5.7	10.0	206.7	1:16:25	2.66E-05

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M&L LABS

Certificate/Report

RESULTS REPORTED RELATED ONLY TO ITEMS TESTED

Ref No. :10654694
Issued at :Johannesburg
Date :26/10/2018

COMPANY NAME :NETTZERO (PTY) LTD
ADDRESS :4479 SERINGA STR LYDENBURG MPUMALANGA 1120
SUBJECT :ANALYSIS OF 3 SOLID SAMPLES
MARKED :AS BELOW
INSTRUCTED BY :MARIUS ALERS
ORDER NO. :
RECEIVED ON :21/09/2018
LAB NO(S) :E013241 - E013243
DATE ANALYSED :30/06/2017

The analysis was carried out on a 5% Aqueous Extracts of the crushed sample:

LAB NO.	E013241	E013242	E013243
SAMPLE MARKS	TSF 1	DSC 1	WRD 1
pH Value @ 25°C	7.8	7.8	7.8
Conductivity mS/m @ 25°C	5.09	5.25	5.34
Total Dissolved Solids	82	62	154
Calcium,Ca	3.4	3.0	4.5
Magnesium, Mg	1.4	1.3	1.8
Sodium,Na	4.2	4.8	3.9
Potassium,K	1.7	1.7	1.0
Chloride,Cl	1.7	2.0	1.5
Sulfate,SO4	1.2	0.5	1.0
Nitrate,NO3	0.6	0.5	0.2
Nitrate as N	0.1	0.1	<0.1
Fluoride,F	0.1	0.1	0.1
Hexavalent Chromium, Cr6+	<0.01	<0.01	<0.01
Cyanide,CN	0.01	<0.01	<0.01

The results are expressed in mg/l where applicable.

Note:The 1:20 Solid: Aqueous Extractions were carried out using deionised water.

2. The sample marked TSF 1 analysed on as received basis.

ALISON ACKERMAN
OPERATIONAL MANAGER

****

Authorised Signature (original blue ink)

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RESULTS REPORTED RELATED ONLY TO ITEMS TESTED

Ref No. :10654694
Issued at :Johannesburg
Date :26/10/2018

The analysis was carried out on a 5% Acetic Acid Extract of the crushed samples:

LAB NO.	E013241	E013242	E013243
SAMPLE MARKS	TSF 1	DSC 1	WRD 1
pH Value on a 10%extract@ 23°C	8.9	9.3	8.6
pH value @ 23°C(leach Solution)	4.9	4.80	4.80
Chloride,Cl	<0.1	<0.1	<0.1
Sulfate,SO4	<0.2	0.4	0.4
Nitrate,NO3	<0.1	<0.1	<0.1
Nitrate as N	<0.1	<0.1	<0.1
Fluoride,F	0.1	0.2	<0.1
Hexavalent Chromium, Cr6+	<0.01	<0.01	<0.01
Cyanide,CN	<0.01	0.01	0.01

The results are expressed in mg/l where applicable.

The 1:20 Solid: Acetic Extraction was carried out using Solution pH 5.0

2. The sample marked TSF 1 analysed on as received basis.

Note: The Formaldehyde results were supplied by a Sub Contracted Laboratory.

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RESULTS REPORTED RELATED ONLY TO ITEMS TESTED

Ref No. :10654694
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The analysis were carried out on a 5% $Na_2B_4O_7$ Extract of the crushed samples:

LAB NO.	E013241	E013242	E013243
SAMPLE MARKS	TSF 1	DSC 1	WRD 1
pH Value @ 25°C	9.5	9.5	9.5
Chloride,Cl	<0.1	<0.1	<0.1
Sulfate,SO4	<0.2	51	<0.2
Nitrate,NO3	0.2	0.6	<0.1
Nitrate as N	<0.1	0.1	<0.1
Fluoride,F	<0.1	<0.1	<0.1
Hexavalent Chromium, Cr6+	<0.01	<0.01	<0.01
Cyanide,CN	<0.01	<0.01	<0.01

The results are expressed in mg/l where applicable.
The 1:20 Solid: $Na_2B_4O_7$ Extraction were carried out using $Na_2B_4O_7$ Solution.

Method reference: A list Appended.

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RESULTS REPORTED RELATED ONLY TO ITEMS TESTED

Ref No. :10654694
Issued at :Johannesburg
Date :26/10/2018

COMPANY NAME :NETTZERO (PTY) LTD
ADDRESS :4479 SERINGA STR LYDENBURG MPUMALANGA 1120
SUBJECT :ANALYSIS OF 3 SOLID SAMPLES
MARKED :AS BELOW
INSTRUCTED BY :MARIUS ALERS
ORDER NO. :
RECEIVED ON :21/09/2018
LAB NO(S) :E013235(1) - E013235(3)
DATE ANALYSED :30/06/2017

The Analyses were carried out on milled sample.

LAB NO.	E01325(1)	E01325(2)	E01325(3)
SAMPLE MARKS	WTW1	WTW2	WTW3
Total Solids as TS (%)	98.75	98.74	98.59
Volatile Solids as VS (%)	10.42	11.2	12.75
Volatilte Fatty Acids as VFA(%)	2836	2984	2985

Note:1. The Total Solids & Volaltile Solids analysis were carried out using the EPA 1684 method.
2.The Volatile Fatty Acids analysis was carried out using the APHA 5560 C method.

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Ref. No. : ML-2018-06086_01
Issued at. : Johannesburg
Date : 29/10/2018
Contract No. : 10654694

Registration Number 1974/001476/07 VAT Number 4780103505
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Certificate/Report

COMPANY NAME	: NET ZERO
ADDRESS	: 4479 SERINGA STREET LYDENBURG 1120
SUBJECT	: ANALYSIS OF 5 SAMPLES
PROJECT REFERENCE	: ANALYSIS OF SOIL/OIL
INSTRUCTED BY	: Jolande Jonker
ORDER NUMBER	:
RECEIVED ON	: 21/09/2018
ANALYSIS COMPLETED	: 29/10/2018
DATE ANALYSED	: 21/9/2018 - 29/10/2018

BDL - Below Detection Limit

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Certificate/Report

Laboratory Number			E013235	E013235_02_1_1_1_1	E013235_03_1_1_1_1
Sampled Date					
Sample Marks			WTW1	WTW1	WTW1
Determinand	**Method References**	**Detection Limit**	**Result**	**Result**	**Result**
Free and Saline Ammonia as N(mg/kg)	WO44-09-G	0.10	995		
pH on Saturated paste			9.0	9.4	9.3

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Laboratory Number			E013241	E013242
Sampled Date				
Sample Marks			TSF1	DSC1
Determinand	**Method References**	**Detection Limit**	**Result**	**Result**
pH on Saturated paste			9.3	9.4

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Laboratory Number			E013243
Sampled Date			
Sample Marks			WRD1
Determinand	**Method References**	**Detection Limit**	**Result**
pH on Saturated paste			8.5

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Laboratory Number			E013241	E013242
Sampled Date				
Sample Marks			TSF1	DSC1
Determinand	**Method References**	**Detection Limit**	**Result**	**Result**
ANALYSIS WAS CARRIED OUT ON 5% AQUEOUS EXTRACTS OF A SAMPLE AS RECEIVED				
Arsenic as As(mg/l)	W044-28-O	0.02	<0.02	<0.02
Boron as B(mg/l)	W044-28-O	0.006	<0.006	<0.006
Barium as Ba(mg/l)	W044-28-O	0.001	0.034	0.035
Cadmium as Cd(mg/l)	W044-28-O	0.001	<0.001	<0.001
Cobalt as Co(mg/l)	W044-28-O	0.001	<0.001	<0.001
Chromium as Cr(mg/l)	W044-28-O	0.003	0.062	0.010
Copper as Cu(mg/l)	W044-28-O	0.002	0.004	0.003
Mercury as Hg(mg/l)	W044-30-C	0.001	<0.001	<0.001
Potassium as K(mg/l)	W044-28-O	0.005	1.72	1.66
Manganese as Mn(mg/l)	W044-28-O	0.001	0.006	0.007
Molybdenum as Mo(mg/l)	W044-28-O	0.001	<0.001	<0.001
Nickel as Ni(mg/l)	W044-28-O	0.003	0.006	<0.003
Lead as Pb(mg/l)	W044-28-O	0.01	<0.01	<0.01
Antimony as Sb(mg/l)	W044-28-O	0.01	<0.01	<0.01
Selenium as Se(mg/l)	W044-28-O	0.03	<0.03	<0.03
Vanadium as V(mg/l)	W044-28-O	0.002	<0.002	<0.002
Zinc as Zn(mg/l)	W044-28-O	0.005	<0.005	<0.005

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Laboratory Number			E013243
Sampled Date			
Sample Marks			WRD1
Determinand	**Method References**	**Detection Limit**	**Result**
ANALYSIS WAS CARRIED OUT ON 5% AQUEOUS EXTRACTS OF A SAMPLE AS RECEIVED			
Arsenic as As(mg/l)	W044-28-O	0.02	<0.02
Boron as B(mg/l)	W044-28-O	0.006	<0.006
Barium as Ba(mg/l)	W044-28-O	0.001	0.036
Cadmium as Cd(mg/l)	W044-28-O	0.001	<0.001
Cobalt as Co(mg/l)	W044-28-O	0.001	0.001
Chromium as Cr(mg/l)	W044-28-O	0.003	0.025
Copper as Cu(mg/l)	W044-28-O	0.002	0.003
Mercury as Hg(mg/l)	W044-30-C	0.001	<0.001
Potassium as K(mg/l)	W044-28-O	0.005	0.97
Manganese as Mn(mg/l)	W044-28-O	0.001	0.019
Molybdenum as Mo(mg/l)	W044-28-O	0.001	<0.001
Nickel as Ni(mg/l)	W044-28-O	0.003	0.009
Lead as Pb(mg/l)	W044-28-O	0.01	<0.01
Antimony as Sb(mg/l)	W044-28-O	0.01	<0.01
Selenium as Se(mg/l)	W044-28-O	0.03	<0.03
Vanadium as V(mg/l)	W044-28-O	0.002	0.002
Zinc as Zn(mg/l)	W044-28-O	0.005	<0.005

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Certificate/Report

Laboratory Number			E013241	E013242
Sampled Date				
Sample Marks			TSF1	DSC1
Determinand	**Method References**	**Detection Limit**	**Result**	**Result**
ANALYSIS WAS CARRIED OUT ON ACETIC ACID EXTRACTS OF A SAMPLE AS RECEIVED				
Arsenic as As(mg/l)	W044-28-O	0.02	<0.02	<0.02
Boron as B(mg/l)	W044-28-O	0.006	0.078	0.088
Barium as Ba(mg/l)	W044-28-O	0.001	0.24	0.21
Cadmium as Cd(mg/l)	W044-28-O	0.001	<0.001	<0.001
Cobalt as Co(mg/l)	W044-28-O	0.001	0.009	0.004
Chromium as Cr(mg/l)	W044-28-O	0.003	0.008	0.012
Copper as Cu(mg/l)	W044-28-O	0.002	0.034	0.019
Mercury as Hg(mg/l)	W044-30-C	0.001	<0.001	<0.001
Potassium as K(mg/l)	W044-28-O	0.005	5.47	5.27
Manganese as Mn(mg/l)	W044-28-O	0.001	0.78	1.23
Molybdenum as Mo(mg/l)	W044-28-O	0.001	<0.001	<0.001
Nickel as Ni(mg/l)	W044-28-O	0.003	0.14	0.030
Phosphorus as P(mg/l)		0.04	<0.04	<0.04
Lead as Pb(mg/l)	W044-28-O	0.01	<0.01	<0.01
Antimony as Sb(mg/l)	W044-28-O	0.01	<0.01	<0.01
Selenium as Se(mg/l)	W044-28-O	0.03	0.10	0.069
Vanadium as V(mg/l)	W044-28-O	0.002	0.002	<0.002
Zinc as Zn(mg/l)	W044-28-O	0.005	0.15	0.18

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Certificate/Report

Laboratory Number			E013243
Sampled Date			
Sample Marks			WRD1
Determinand	**Method References**	**Detection Limit**	**Result**
ANALYSIS WAS CARRIED OUT ON ACETIC ACID EXTRACTS OF A SAMPLE AS RECEIVED			
Arsenic as As(mg/l)	W044-28-O	0.02	<0.02
Boron as B(mg/l)	W044-28-O	0.006	2.19
Barium as Ba(mg/l)	W044-28-O	0.001	0.21
Cadmium as Cd(mg/l)	W044-28-O	0.001	<0.001
Cobalt as Co(mg/l)	W044-28-O	0.001	0.003
Chromium as Cr(mg/l)	W044-28-O	0.003	0.003
Copper as Cu(mg/l)	W044-28-O	0.002	0.022
Mercury as Hg(mg/l)	W044-30-C	0.001	<0.001
Potassium as K(mg/l)	W044-28-O	0.005	1.16
Manganese as Mn(mg/l)	W044-28-O	0.001	0.34
Molybdenum as Mo(mg/l)	W044-28-O	0.001	<0.001
Nickel as Ni(mg/l)	W044-28-O	0.003	0.016
Phosphorus as P(mg/l)		0.04	<0.04
Lead as Pb(mg/l)	W044-28-O	0.01	<0.01
Antimony as Sb(mg/l)	W044-28-O	0.01	<0.01
Selenium as Se(mg/l)	W044-28-O	0.03	0.037
Vanadium as V(mg/l)	W044-28-O	0.002	0.005
Zinc as Zn(mg/l)	W044-28-O	0.005	0.17

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Certificate/Report

Laboratory Number			E013241	E013242
Sampled Date				
Sample Marks			TSF1	DSC1
Determinand	**Method References**	**Detection Limit**	**Result**	**Result**
THE ANALYSIS WAS CARRIED OUT ON 5% NA2B4O7 EXTRACTION OF A SAMPLE				
Arsenic as As(mg/l)	W044-28-O	0.02	<0.02	<0.02
Barium as Ba(mg/l)	W044-28-O	0.001	0.18	0.19
Cadmium as Cd(mg/l)	W044-28-O	0.001	<0.001	<0.001
Cobalt as Co(mg/l)	W044-30-O	0.001	0.001	0.001
Chromium as Cr(mg/l)	W044-28-O	0.003	0.004	0.006
Copper as Cu(mg/l)	W044-28-O	0.002	0.002	0.002
Mercury as Hg(mg/l)	W044-30-C	0.001	<0.001	<0.001
Potassium as K(mg/l)	W044-28-O	0.005	7.09	8.50
Manganese as Mn(mg/l)	W044-28-O	0.001	0.003	0.007
Molybdenum as Mo(mg/l)	W044-28-O	0.001	<0.001	<0.001
Nickel as Ni(mg/l)	W044-28-O	0.003	0.003	0.005
Phosphorus as P(mg/l)	W044-28-O	0.04	<0.04	<0.04
Lead as Pb(mg/l)	W044-28-O	0.01	<0.01	<0.01
Antimony as Sb(mg/l)	W044-28-O	0.01	<0.01	0.021
Selenium as Se(mg/l)	W044-28-O	0.03	<0.03	<0.03
Vanadium as V(mg/l)	W044-28-O	0.002	<0.002	0.003
Zinc as Zn(mg/l)	W044-28-O	0.005	<0.005	0.005

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Date : 29/10/2018
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Laboratory Number			E013243
Sampled Date			
Sample Marks			WRD1
Determinand	**Method References**	**Detection Limit**	**Result**
THE ANALYSIS WAS CARRIED OUT ON 5% NA2B4O7 EXTRACTION OF A SAMPLE			
Arsenic as As(mg/l)	W044-28-O	0.02	<0.02
Barium as Ba(mg/l)	W044-28-O	0.001	0.19
Cadmium as Cd(mg/l)	W044-28-O	0.001	<0.001
Cobalt as Co(mg/l)	W044-30-O	0.001	0.001
Chromium as Cr(mg/l)	W044-28-O	0.003	0.003
Copper as Cu(mg/l)	W044-28-O	0.002	0.002
Mercury as Hg(mg/l)	W044-30-C	0.001	<0.001
Potassium as K(mg/l)	W044-28-O	0.005	1.24
Manganese as Mn(mg/l)	W044-28-O	0.001	<0.001
Molybdenum as Mo(mg/l)	W044-28-O	0.001	<0.001
Nickel as Ni(mg/l)	W044-28-O	0.003	0.003
Phosphorus as P(mg/l)	W044-28-O	0.04	<0.04
Lead as Pb(mg/l)	W044-28-O	0.01	<0.01
Antimony as Sb(mg/l)	W044-28-O	0.01	<0.01
Selenium as Se(mg/l)	W044-28-O	0.03	<0.03
Vanadium as V(mg/l)	W044-28-O	0.002	0.003
Zinc as Zn(mg/l)	W044-28-O	0.005	<0.005

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Certificate/Report

Laboratory Number			E013235	E013235_02_1_1_1_1	E013235_03_1_1_1_1
Sampled Date					
Sample Marks			WTW1	WTW1	WTW1
Determinand	Method References	Detection Limit	Result	Result	Result
THE ANALYSIS WAS CARRIED OUT ON ACID DISSOLUTION OF A SAMPLE AS RECEIVED					
Arsenic as As(mg/kg)	W044-28-O	2.0	<2.0	<2.0	<2.0
Boron as B(mg/kg)	W044-28-O	0.6	44	46	42
Barium as Ba(mg/kg)	W044-28-O	0.10	29	32	34
Cadmium as Cd(mg/kg)	W044-28-O	0.050	<0.050	<0.050	<0.050
Cobalt as Co(mg/kg)	W044-28-O	0.10	18.90	19.41	16.00
Chromium as Cr(mg/kg)	W044-28-O	0.30	157	178	173
Copper as Cu(mg/kg)	W044-28-O	0.20	43	46	49
Mercury as Hg(mg/kg)	W044-30-C	0.10	<0.10	<0.10	<0.10
Potassium as K(mg/kg)	W044-28-O	0.50	3781	4003	4306
Manganese as Mn(mg/kg)	W044-28-O	0.10	226	234	201
Molybdenum as Mo(mg/kg)	W044-28-O	0.10	1.11	0.96	0.96
Nickel as Ni(mg/kg)	W044-28-O	0.30	191	197	168
Phosphorus as P(mg/kg)	W044-28-O	4.0	2022	2208	2468
Lead as Pb(mg/kg)	W044-28-O	0.050	<0.050	<0.050	<0.050
Antimony as Sb(mg/kg)	W044-28-O	1.0	<1.0	<1.0	<1.0
Selenium as Se(mg/kg)	W044-28-O	3.0	43	45	35
Vanadium as V(mg/kg)	W044-28-O	0.20	30	33	32
Zinc as Zn(mg/kg)	W044-28-O	0.50	153	174	169

Ndileka Bangani

BDL - Below Detection Limit

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Date : 29/10/2018
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Certificate/Report

Laboratory Number			E013239	E013241	E013242
Sampled Date					
Sample Marks			OIL 1	TSF1	DSC1
Determinand	**Method References**	**Detection Limit**	**Result**	**Result**	**Result**
THE ANALYSIS WAS CARRIED OUT ON ACID DISSOLUTION OF A SAMPLE AS RECEIVED					
Arsenic as As(mg/kg)	W044-28-O	2.0	<2.0	<2.0	<2.0
Boron as B(mg/kg)	W044-28-O	0.6	<0.6	10.00	26
Barium as Ba(mg/kg)	W044-28-O	0.10	1.20	24	33
Cadmium as Cd(mg/kg)	W044-28-O	0.050	<0.050	<0.050	<0.050
Cobalt as Co(mg/kg)	W044-28-O	0.10	<0.10	5.17	9.07
Chromium as Cr(mg/kg)	W044-28-O	0.30	<0.30	206	187
Copper as Cu(mg/kg)	W044-28-O	0.20	<0.20	28	51
Mercury as Hg(mg/kg)	W044-30-C	0.10	<0.10	<0.10	<0.10
Potassium as K(mg/kg)	W044-28-O	0.50	160	679	1312
Manganese as Mn(mg/kg)	W044-28-O	0.10	2.15	97	110
Molybdenum as Mo(mg/kg)	W044-28-O	0.10	<0.10	<0.10	<0.10
Nickel as Ni(mg/kg)	W044-28-O	0.30	<0.30	68	63
Phosphorus as P(mg/kg)	W044-28-O	4.0	209	9.34	208
Lead as Pb(mg/kg)	W044-28-O	0.050	<0.050	<0.050	1.55
Antimony as Sb(mg/kg)	W044-28-O	1.0	<1.0	<1.0	<1.0
Selenium as Se(mg/kg)	W044-28-O	3.0	<3.0	10.63	33
Vanadium as V(mg/kg)	W044-28-O	0.20	1.60	12.02	38
Zinc as Zn(mg/kg)	W044-28-O	0.50	191	208	187

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Certificate/Report

Laboratory Number			E013243
Sampled Date			
Sample Marks			WRD1
Determinand	**Method References**	**Detection Limit**	**Result**
THE ANALYSIS WAS CARRIED OUT ON ACID DISSOLUTION OF A SAMPLE AS RECEIVED			
Arsenic as As(mg/kg)	W044-28-O	2.0	<2.0
Boron as B(mg/kg)	W044-28-O	0.6	5.42
Barium as Ba(mg/kg)	W044-28-O	0.10	26
Cadmium as Cd(mg/kg)	W044-28-O	0.050	<0.050
Cobalt as Co(mg/kg)	W044-28-O	0.10	4.10
Chromium as Cr(mg/kg)	W044-28-O	0.30	105
Copper as Cu(mg/kg)	W044-28-O	0.20	11.50
Mercury as Hg(mg/kg)	W044-30-C	0.10	<0.10
Potassium as K(mg/kg)	W044-28-O	0.50	384
Manganese as Mn(mg/kg)	W044-28-O	0.10	70
Molybdenum as Mo(mg/kg)	W044-28-O	0.10	<0.10
Nickel as Ni(mg/kg)	W044-28-O	0.30	27
Phosphorus as P(mg/kg)	W044-28-O	4.0	<4.0
Lead as Pb(mg/kg)	W044-28-O	0.050	<0.050
Antimony as Sb(mg/kg)	W044-28-O	1.0	<1.0
Selenium as Se(mg/kg)	W044-28-O	3.0	4.52
Vanadium as V(mg/kg)	W044-28-O	0.20	7.62
Zinc as Zn(mg/kg)	W044-28-O	0.50	109

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Certificate/Report

Laboratory Number			E013235	E013235_02_1_1_1_1	E013235_03_1_1_1_1
Sampled Date					
Sample Marks			WTW1	WTW1	WTW1
Determinand	**Method References**	**Detection Limit**	**Result**	**Result**	**Result**
THE ANALYSIS WERE CARRIED OUT ON A DRIED MILLED SAMPLE					
Total Nitrate as NO (mg/kg)			0.00	0.00	11.80
Total Nitrate as N(mg/kg)			0.00	0.00	2.67
Chloride, Cl(mg/kg)		1	7304	7527	6729
Fluoride, F(mg/kg)		0.10	1.00	1.00	1.00
Hexavalent chromium as Cr6+(mg/kg)	EPA 3060A	0.1	<0.1	<0.1	<0.1
Sulfate, SO4(%)		0.01	0.49	0.54	6.40
Total cyanide as CN(mg/kg)		0.1	0.38	0.63	0.36

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Edward Khumalo - TECHNICAL SIGN

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Certificate/Report

Laboratory Number			E013239	E013241	E013242
Sampled Date					
Sample Marks			OIL 1	TSF1	DSC1
Determinand	**Method References**	**Detection Limit**	**Result**	**Result**	**Result**
THE ANALYSIS WERE CARRIED OUT ON A DRIED MILLED SAMPLE					
Total Nitrate as NO (mg/kg)				6.20	6.90
Total Nitrate as N(mg/kg)				1.40	1.56
Chloride, Cl(mg/kg)		1	<1	33	69
Fluoride, F(mg/kg)		0.10		<0.10	<0.10
Hexavalent chromium as Cr6+(mg/kg)	EPA 3060A	0.1	<0.1	<0.1	<0.1
Sulfate, SO4(%)		0.01	0.02	0.09	<0.01
Total cyanide as CN(mg/kg)		0.1		<0.1	0.40

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Edward Khumalo - TECHNICAL SIGI

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Certificate/Report

Laboratory Number			E013243
Sampled Date			
Sample Marks			WRD1
Determinand	**Method References**	**Detection Limit**	**Result**
THE ANALYSIS WERE CARRIED OUT ON A DRIED MILLED SAMPLE			
Total Nitrate as NO (mg/kg)			16.35
Total Nitrate as N(mg/kg)			3.69
Chloride, Cl(mg/kg)		1	6
Fluoride, F(mg/kg)		0.10	<0.10
Hexavalent chromium as Cr6+(mg/kg)	EPA 3060A	0.1	<0.1
Sulfate, SO4(%)		0.01	0.02
Total cyanide as CN(mg/kg)		0.1	<0.1

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Comments:

*Note: 1.The total analysis on Samples marked DSC 1 and WRD 1where perfomed on crushed and milled samples.
2. Samples marked WTW and TSF 1 where perfomed on milled samples.

BDL - Below Detection Limit

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Certificate/Report

COMPANY NAME	: NET ZERO
ADDRESS	: 4479 SERINGA STREET LYDENBURG 1120
SUBJECT	: ANALYSIS OF 3 SLUDGE SAMPLES
PROJECT REFERENCE	: WTW1 SOIL 12/10/2018
INSTRUCTED BY	: MARIUS ALERS
ORDER NUMBER	:
RECEIVED ON	: 21/09/2018
ANALYSIS COMPLETED	: 24/10/2018
DATE ANALYSED	: 21/9/2018 - 21/09/2018

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 # Denotes test method is outsourced

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T0040

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Date : 29/10/2018
Contract No. : 10654694

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Certificate/Report

Laboratory Number	E013235_02_1_1_1_2	E013235_03_1_1_1_2	E013235_04_1_1_1_2
Sampled Date			
Sample Marks	WTW1	WTW2	WTW3
Determinand	**Result**	**Result**	**Result**
PAH (BASED ON EPA 8270)			
Naphthalene(µg/kg)	BDL	BDL	BDL
Acenaphthylene(µg/kg)	BDL	BDL	BDL
Acenaphthene(µg/kg)	BDL	BDL	BDL
Fluorene(µg/kg)	BDL	BDL	BDL
Phenanthrene(µg/kg)	BDL	BDL	BDL
Anthracene(µg/kg)	BDL	BDL	BDL
Fluoranthene(µg/kg)	BDL	BDL	BDL
Pyrene(µg/kg)	BDL	BDL	BDL
Benzo(a)anthracene(µg/kg)	BDL	BDL	BDL
Chrysene(µg/kg)	BDL	BDL	BDL
Benzo(b+k)fluoranthene(µg/kg)	BDL	BDL	BDL
Benzo(a)pyrene(µg/kg)	BDL	BDL	BDL

Gavin Linford

BDL - Below Detection Limit
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Comments:

Detection Limit:

PAH: 1000 µg/kg

BDL - Below Detection Limit
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Ref. No. : ML-2018-06086_02
Issued at. : Johannesburg
Date : 2018/10/29
Contract No. : 10654694

Certificate/Report

RESULTS REPORTED RELATED ONLY TO ITEMS TESTED

COMPANY NAME	: NET ZERO
ADDRESS	: 4479 SERINGA STREET LYDENBURG 1120 SOUTH AFRICA
SUBJECT	: ANALYSIS OF 3 SAMPLES
PROJECT REFERENCE	: WTW1 SOIL 12/10/2018
INSTRUCTED BY	: Jolande Jonker
ORDER NUMBER	:
RECEIVED ON	: 21-Sep-2018
ANALYSIS COMPLETED	: 22-Oct-2018
DATE ANALYSED	: 21/9/2018 - 21/9/2018

Printed Date: 2018/10/29

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RESULTS REPORTED RELATED ONLY TO ITEMS TESTED

Lab Number	E013235_02_1_1_1_1
Sample Name	WASTE SAMPLE
Sample Markings	WTW1
Sample Received As	PLASTIC BAG

Determinand	Method References	Specification	Result
Microbiology			
Faecal Coliform Bacteria (cfu/g)	SANS 5221		<10

Nomthandazo Nkomo

TECHNICAL SIGNATORY MICROBIOLOGY

Remarks: * This is not a SANAS accredited method and is not included in the SANAS Schedule of accreditation for this Laboratory

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These tests do not apply to any other samples of a similar nature.
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o <10 / <1= Not detected / less than the lower detection limit of the test method, for the specified sample type / volume of sample tested.

Printed Date: 2018/10/29

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RESULTS REPORTED RELATED ONLY TO ITEMS TESTED

Lab Number	E013235_03_1_1_1_1
Sample Name	WASTE SAMPLE
Sample Markings	WTW2
Sample Received As	PLASTIC BAG

Determinand	Method References	Specification	Result
Microbiology			
Faecal Coliform Bacteria (cfu/g)	SANS 5221		<10

Nomthandazo Nkomo

TECHNICAL SIGNATORY MICROBIOLOGY

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Printed Date: 2018/10/29

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RESULTS REPORTED RELATED ONLY TO ITEMS TESTED

Lab Number	E013235_04_1_1_1_1
Sample Name	WASTE SAMPLE
Sample Markings	WTW3
Sample Received As	PLASTIC BAG

Determinand	Method References	Specification	Result
Microbiology			
Faecal Coliform Bacteria (cfu/g)	SANS 5221		<10

Nomthandazo Nkomo

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