ENVIROMENTAL MANAGEMENT ASSISTANCE (PTY) LTD

REPORT ON:

BCR MINERALS MINE RESIDUE GEOCHEMICAL CLASSIFICATION

Submitted to:

Environmental Management Assistance (Pty) Ltd

PO Box 386

Sundra

2200

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VILJOEN & ASSOCIATES

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PROJECT DETAILS

Project Type: Waste Classification

Waste Type: Mine Residue

Client: Environmental Management Assistance (Pty) Ltd

Location: Steelpoort, Limpopo

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DEFINITIONS

Aquifer

Denotes a geologic formation, or group of formations, of water-bearing permeable rock or sediment layers from which water can be usefully extracted.

Aquifer vulnerability

The tendency or likelihood for contaminants to reach a specified position in the groundwater system after introduction at some location above the uppermost aquifer. Sedimentary rocks composed of or derived from sand or sand-like particles.

Fracture

Part of the void space of a porous-medium domain that has a special spatial configuration: one of its dimensions - the aperture – is much smaller than the other two spatial dimensions. Fractures provide pathways for fluid and transport through otherwise impermeable or semi-pervious formations.

GLB+ Landfill site

A landfill referred to as a GLB+ is a large general waste site, requiring leachate management, which accepts only general waste. GLB+ sites usually have a positive water balance.

GLB- Landfill site

A landfill referred to as a GLB- is a relatively large general waste site, not requiring leachate management, and accepts only general waste. GLB- sites have a negative water balance.

Leachable Concentration (LC)

The leachable concentration of a particular element or chemical substance in a waste, expressed as mg/l.

Leachable Concentration Threshold (LCT)

The leachable concentration threshold limit for particular elements and chemical substances in a waste, expressed as mg/l.

Total Concentration (TC)

The total concentration of a particular element or chemical substance in a waste, expressed as mg/kg.

Total Concentration Threshold (TCT)

The total concentration threshold limit for particular elements or chemical substances in a waste, expressed as mg/kg.

Hazardous Waste

Hazardous Waste is waste that has the potential, even in low concentrations, to have a significant adverse effect on public health and the environment because of its inherent toxicological, chemical and physical characteristics. Hazardous Waste requires stringent control and management, to prevent harm or damage and hence liabilities. It may only be disposed of on a Hazardous Waste landfill (see Section 3, Minimum Requirements for Waste Disposal by Landfill). Hazardous Waste may only be disposed of at a landfill designed specifically for the disposal of Hazardous Waste and legally authorised by the Competent Authority, in terms of the Environmental Conservation Act. Landfills that can accept Hazardous Waste are classified as H:H landfills and H:h landfills.

H:H Landfill

H:H landfills can accept all wastes that are allowed to be landfilled.

H:h Landfill

H:h landfills are not as stringently designed, may only accept Hazard Rating 3 and 4 waste, and General Waste.

Hydraulic conductivity

Measure of the ease with which water will pass through the earth's material; defined as the rate of flow through a cross-section of one square metre under a unit hydraulic gradient at right angles to the direction of flow (m/d).

Hydraulic head

Hydraulic head is the height above a datum plane such as sea level of the column of water that can be supported by the hydraulic pressure at a given point in a groundwater system. Hydraulic heads provide an indication of the direction of groundwater flow and are used to determine hydraulic gradients.

Transmissivity

Transmissivity is the rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient. It is expressed as the product of the average hydraulic conductivity (K) and thickness (b) of the saturated portion of an aquifer (T = Kb).

Type 0 Waste

The disposal of Type 0 waste to landfill is not allowed. The waste must be treated and re assessed in terms of the Norms and Standards for Assessment of Waste for Landfill Disposal.

Type 1 Waste

Type 1 waste may only be disposed of at a Class A landfill designed in accordance with section 3(1) and (2) of these Norms and Standards, or, subject to section 3(4) of these Norms and Standards, may be disposed of at a landfill site designed in accordance with the requirements for a Hh / HH landfill as specified in the Minimum Requirements for Waste Disposal by Landfill (2nd Ed., Department of Water Affairs and Forestry, 1998).

Type 2 Waste

Type 2 waste may only be disposed of at a Class B landfill designed in accordance with section 3(1) and (2) of these Norms and Standards, or, subject to section 3(4) of these Norms and Standards, may be disposed of at a landfill site designed in accordance with the requirements for a GLB+ landfill as specified in the Minimum Requirements for Waste Disposal by Landfill (2nd Ed., DWAF, 1998).

Type 3 Waste

Type 3 waste may only be disposed of at a Class C landfill designed in accordance with section 3(1) and (2) of these Norms and Standards, or, subject to section 3(4) of these Norms and Standards, may be disposed of at a landfill site designed in accordance with the requirements for a GLB+ landfill as specified in the Minimum Requirements for Waste Disposal by Landfill (2nd Ed., DWAF, 1998).

Type 4 Waste

Type 4 waste may only be disposed of at a Class D landfill designed in accordance with section 3(1) and (2) of these Norms and Standards, or, subject to section 3(4) of these Norms and Standards, may be disposed of at a landfill site designed in accordance with the requirements for a GLB- landfill as specified in the Minimum Requirements for Waste Disposal by Landfill (2nd Ed., DWAF, 1998).

Water table

Or *phreatic surface* is the boundary between the unsaturated and saturated zone. It represents the upper surface of the groundwater body.

EXECUTIVE SUMMARY

During November 2015 *Environmental Management Assistance (Pty) Ltd* requested a proposal for a *Classification Of Waste Rock* deposits belonging to Bushveld Complex of BCR Chromium mine near Steelpoort.

A classification procedure was performed according to the National Environmental Management Act: Waste Act, 2008 (Act No.59 of 2008): National Norms and Standards for the Assessment of Waste for Land Disposal, as published in the Government Gazette No. 36784, dated August 2013.

The basis of the norms and standards is to define a pollution control barrier system for the waste to be disposed of. The approach was as follow:

- Identification of chemical substances present in the waste.

- Sampling and analyses to determine the total concentrations (TC) and leachable concentrations (LC) for the elements and chemical substances identified in the waste.

- The TC and LC limits of the chemical substances in the waste must be compared to the threshold limits for total concentration (TCT limits) and leachable concentrations (LCT limits) of the specific elements and chemical substances.

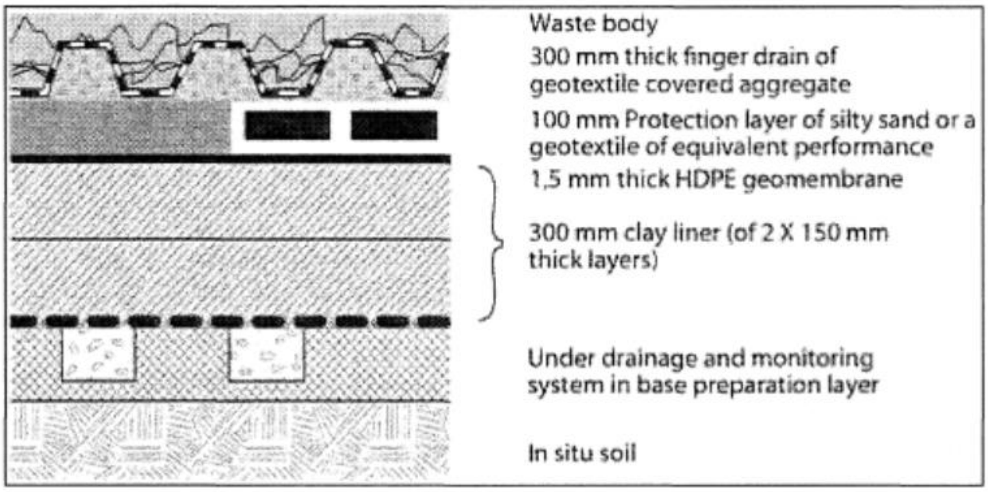
- Based on the TC and LC limits of the elements and chemical substances in the waste exceeding the corresponding TCT and LCT limits, respectively, the specific type of waste for disposal to land must be determined.

The residue deposits recorded alkaline pH and low to undetected levels of soluble (mobile) macro- and micro constituents. Given the nature and mineralogy of the Bushveld Complex, the total concentration analyses did reveal some micro constituents to be above detection levels whilst also exceeding TCT0 levels with regards to the Norms and Standards. Micro-elements that exceeded the TCT0 levels include cobalt, copper, manganese, nickel, vanadium and fluoride.

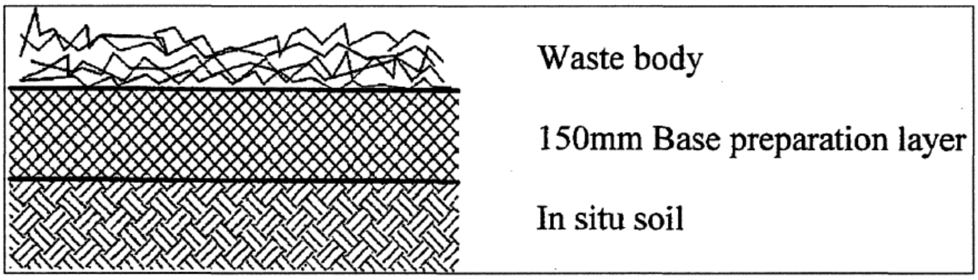
If the Norms and Standards methodology is strictly applied to the WRDs, it can neither be classed as Type 3 or a Type 4 waste material. According to the methodology, for a waste material to be classified as Type 4, the LC (leachable concentration) and the TC (total concentration) must be below the LCT0 and TCT0, while for a waste to be classified as Type 3, the LC and TC must be below the LCT1 and TCT1, respectively. However, the following is true for the waste rock:

(LC < LCT0 and TCT0 < TC < TCT1)

Strictly in terms of the National Norms and Standards for Disposal of Waste to Landfill (Government Notice R636), which is also applicable to MRSRDs, the containment barriers for the WRDs must comply with the minimum engineering design requirements of a Class C Landfill or Class D Landfill as shown below.



Class C Landfill engineering design.



Class D Landfill engineering design

The BCR WRDs recorded within LCT0 limits, and this together with the fact that the material is non-acid generating, the risk of poor quality leachate developing from the WRDs towards the receiving environment is perceived to be very low. A Class D Landfill Engineering Design is therefore proposed.

DECLARATION OF INDEPENDENCE

Chris J Viljoen, CEO Viljoen Associates, hereby declare:

- Viljoen Associates act as independent specialist in this investigation.
- The assessment is conducted in a scientific manner and findings will not be manipulated for a favourable outcome.
- Viljoen Associates have no financial, personal or any other interest in this application managed by Environmental Management Assistance (Pty) Ltd.
- All particulars furnished in this declaration are true and correct.

***M.Sc., Pr. Sci. Nat*.**

BCR MINERALS MINE RESIDUE GEOCHEMICAL CLASSIFICATION

1 TERMS OF REFERENCE

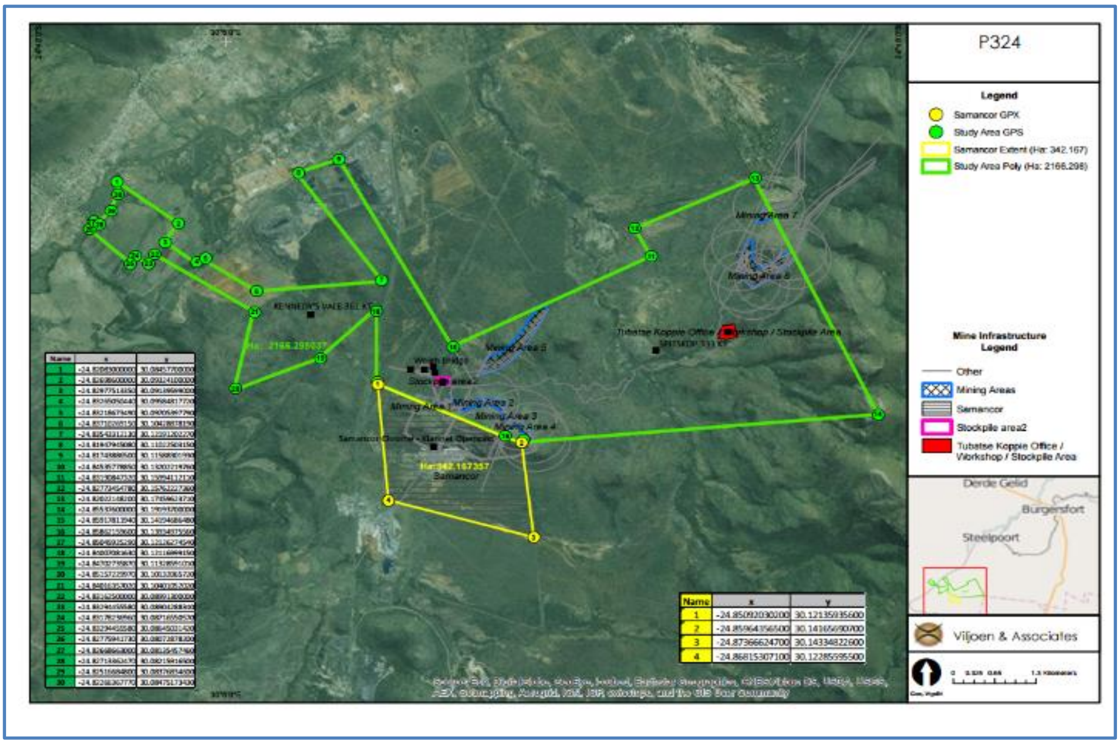


Figure 1. Area of investigation.

During November 2015 *Environmental Management Assistance (Pty) Ltd* requested a proposal for a *Classification Of Waste Rock* of BCR Chromium mine near Steelpoort.

The sampling area in *Mining Area 1* where prospecting bulk sampling has been conducted is approximately 18ha (**Figure 1**).

There is mainly one waste stream generated from blasting containing mainly anorthosite and pyroxenite, *i.e.* waste rock/overburden, which has no potential for acid mine drainage.

2 INVESTIGATION OBJECTIVE

Residue deposits have to be characterised to identify any potential risk to health or safety hazard and environmental impact that may be associated with the residue when stockpiled or deposited at the site on a prospecting, mining, exploration or production operation.

This objective was achieved through the following procedure:

- Classification of the waste according to GG 635 (NEMA).
- Risk assessment detailing the potential for groundwater and surface water related impacts.
- Proposal for a pollution control barrier system compliant with the commensurate norms and standards for disposal of waste to landfill.
- Chemical characterisation in terms of Regulations regarding the planning and management of residue stockpiles and residue deposits from a prospecting, mining, exploration or production operation (Government Gazette No. 39020, dated 24 July 2015; NEM:WA, 2008).

Samples were subjected to tests as stipulated in the GG 635 National Norms and Standards for the assessment of waste for landfill disposal (NEMA, Act 59 of 2008) and acid-base-accounting as proposed per Section 4(2)(b) (Government Gazette No. 39020, dated 24 July 2015) regarding the chemical characteristics of mine residue deposits.

Product ore stockpiles present on-site is exempted from waste classification as per the Norms and Standards as it is not regarded as a waste product. Nevertheless, an impact assessment should be conducted on any temporary residue deposit that may pose a potential hazard to the environment. A water leach procedure was conducted on the product stockpiles and the data was used for a risk assessment.

3 PROBLEM ANALYSES

3.1 Location And Topography

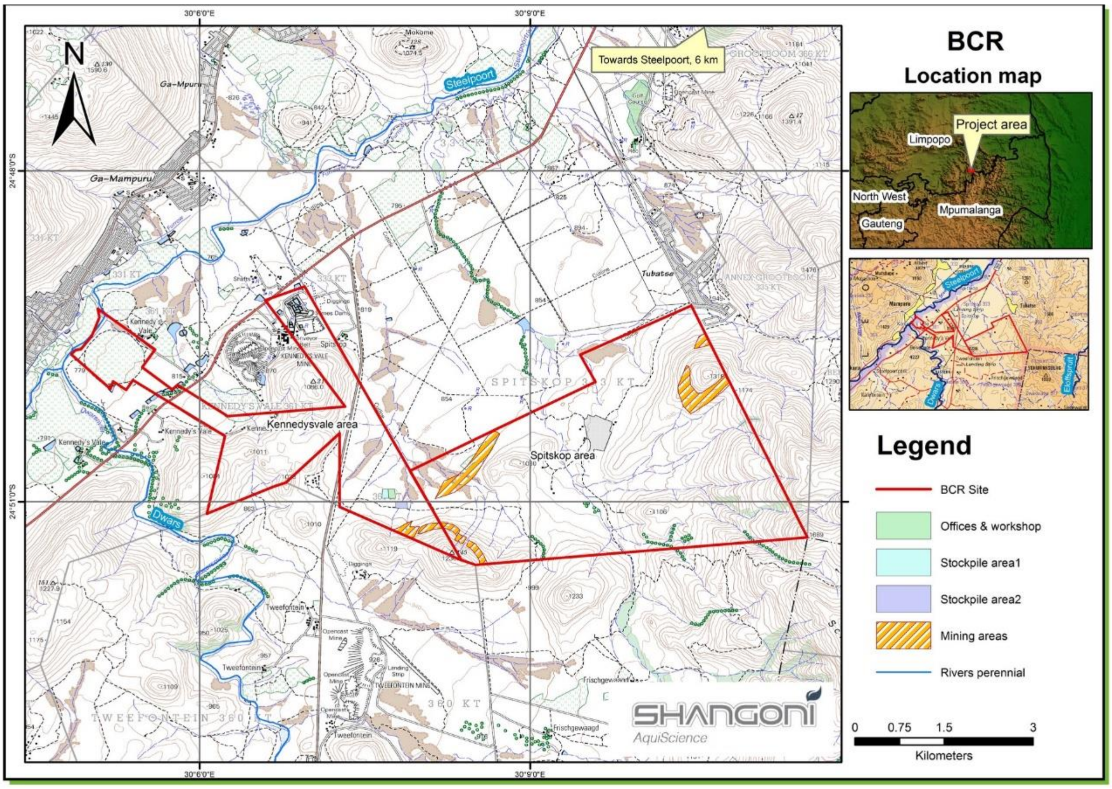


Figure 2. Location of BCR Minerals.

BCR Minerals is situated on portions 24, 25, 26 and 28 of the farm Spitskop 333 KT and portions 8 and 22 of the farm Kennedy's Vale 361 KT in the Sekhukhune District, north of Tweefontein Chrome Mine and south of Spitzkop Platinum Mine (**Figure 2**).

The BCR Minerals study area is located approximately 4 km south from the R555 and "Tweefontein" road intersection and approximately 17 km south west from Steelpoort. BCR Minerals lies on the north-western slopes of the foothills of the Schurinksberg and is situated in the primary catchment of the Olifants River.

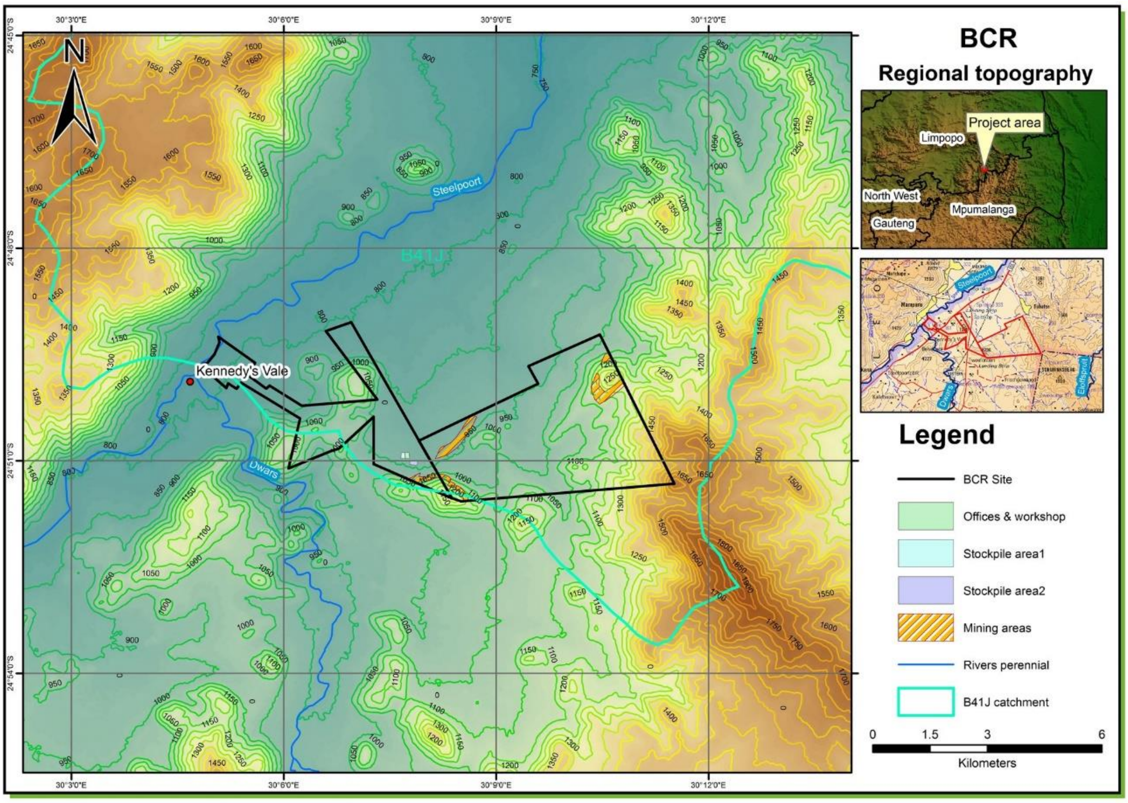


Figure 3. Regional Topography.

Locally, the site drains towards the Steelpoort River through various unnamed tributaries that originates in the surrounding mountains and hills.

The relief changes by more than 600 m from the Steelpoort River (~ 750 metre above mean sea level) to the eastern edge of the quaternary drainage (B41J) surface water divide (~ 1600 mamsl).

These elevated areas slope steeply down to the flatter areas where the mine infrastructure is located (**Figure 3**).

3.2 Regional Geology

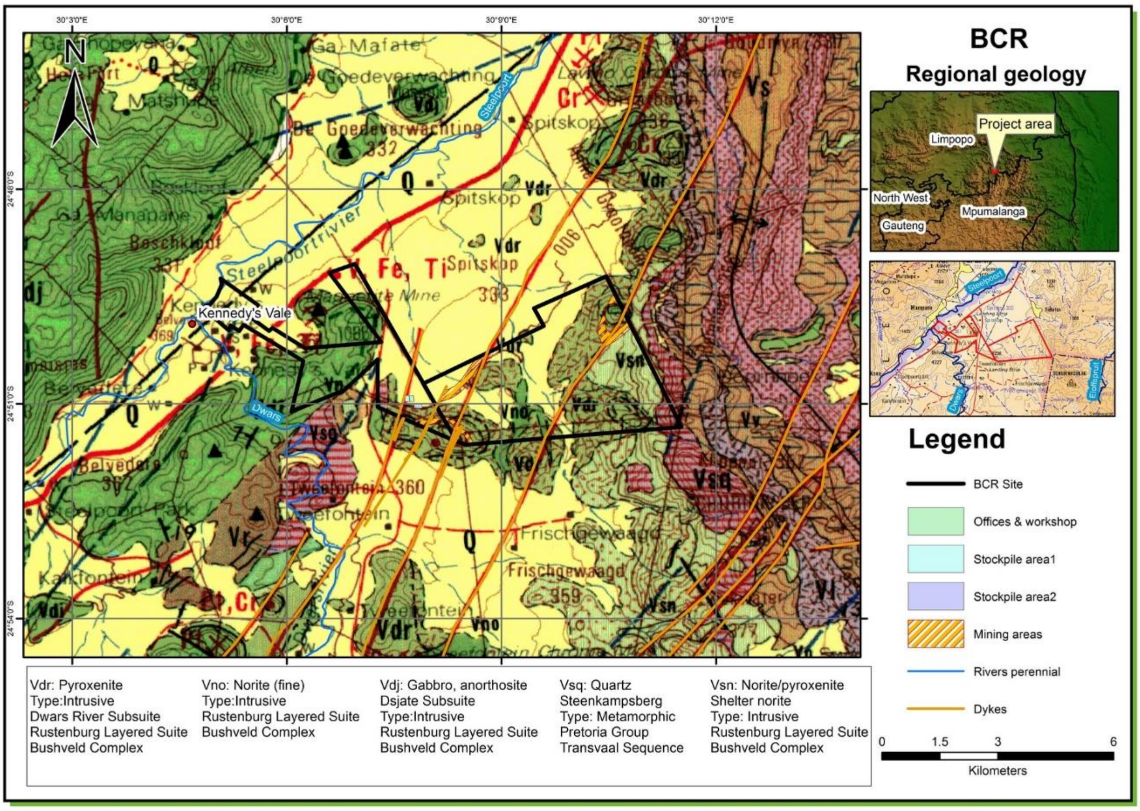


Figure 4. Regional Geology.

The BCR Minerals mining area is underlain by the Rustenburg Layer Suite / Dwars River rocks of the Archaean age Bushveld Igneous Complex.

The Bushveld Igneous Complex overlies the Transvaal Supergroup's Pretoria Group. Younger deposits (Q; quaternary sedimentary deposits) occur throughout the area (**Figure 4**).

The Bushveld Igneous Complex (BIC) formed as massive crustal emplacements of predominantly mafic intrusive and extrusive rocks, and comprises of suites of layered mafic complexes and sills that intruded the floor rocks of the Transvaal Supergroup.

The BIC is divided into the Rustenburg Layered Suite, Lebowa Granite Suite, Rashoop Granophyre Suite and Rooiberg Group. BCR Minerals is underlain by rocks of the Rustenburg Layered Suite (BIC), ranging from dunite, pyroxenite, norite, gabbro and anorthosite to magnetite and appatite rich diorite.

3.3 Regional Geohydrology

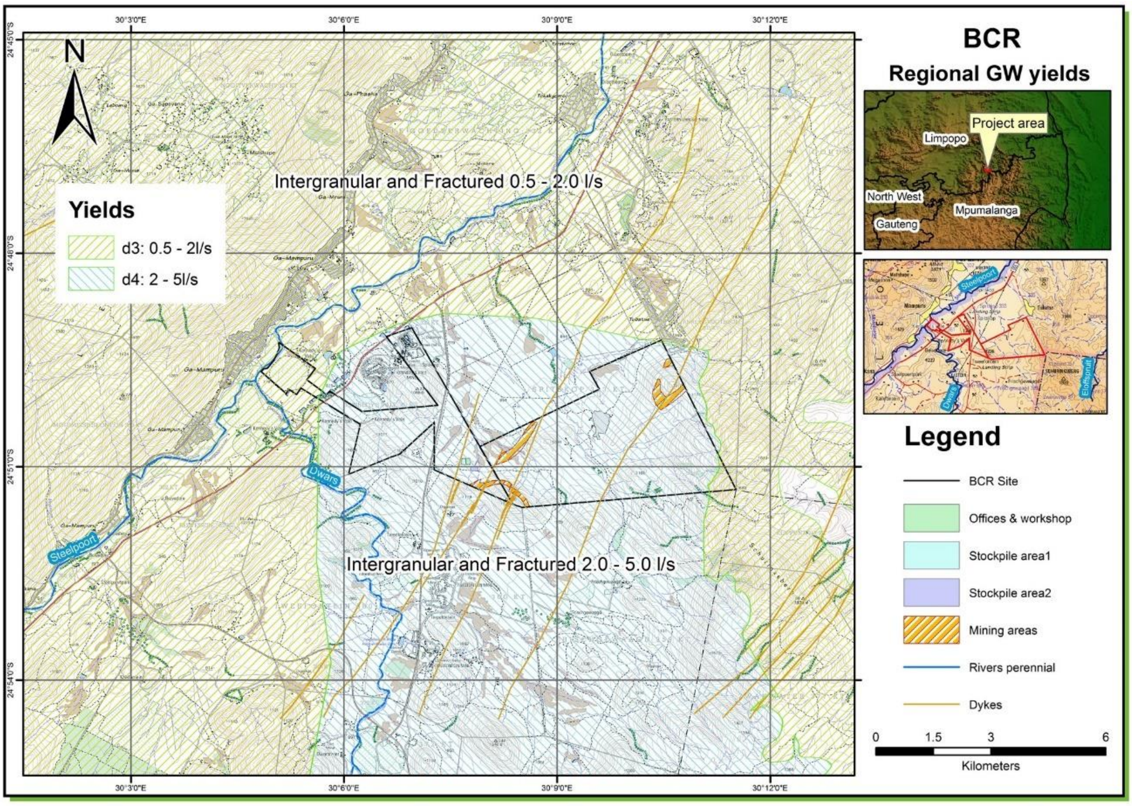


Figure 5. Regional Geohydrology.

The geology of the BCR Minerals study area is characterised by the mafic rocks (pyroxenite, norite and anorthosites) of the Rustenburg Layered Suite of the Bushveld Igneous Complex. The rocks are overlain by weathered material, hillwash and alluvial deposits. Accordingly, the following aquifer systems can be distinguished for the area of interest (Delta H, 2016):

- A shallow weathered aquifer.
- An alluvial aquifer system replacing or overlying the weathered aquifer in the vicinity of river courses.
- A deeper fractured aquifer system within the Bushveld Igneous Complex.

The Spitskop and Kennedy's Vale farms are intruded by several dolerite dykes, expected to be of several ages from the Waterberg and the Karoo Supergroup. These dykes are generally steeply dipping and have varying thickness but do not seem to exceed 20 metres in thickness. These dykes are suspected to form preferential flow pathways for the movement of groundwater and groundwater exploration should be targeting these linear features through geophysical surveys.

A review of the geohydrological investigation by Delta H (2016) revealed that magnetic and electro-magnetic geophysical surveys were conducted targeting these features. Seven proposed drill sites were recommended based on the geophysical results for future groundwater monitoring network and should be implemented.

The regional hydrogeology is characterized by an intergranular and fractured aquifer system. The fractured aquifer, attributed to the presence of the Rustenburg Layered Suite has a potential yield of 2 to 5 l/s.

A micro-fractured matrix in these aquifers provide the storage capacity with limited groundwater movements while secondary features such as fractures / faults and bedding planes enhance the groundwater flow. The intergranular aquifer is associated with the river alluvial and quaternary sand deposits.

Based on the aquifer classification map (Parsons and Conrad, 1998), the aquifer system underlying the BCR Minerals study area is regarded a “minor aquifer”. In this classification system, it is important to note that the concepts of Minor and Poor Aquifers are relative and that yield is not quantified.

Within any specific area, all classes of aquifers should therefore, in theory, be present. Therefore, based on the 1:500 000 hydrogeological map sheets (**Figure 5**), the BCR Minerals study area is located on an aquifer classed as a minor, intergranular and fractured aquifer system with potential groundwater yields up to 5 litres a second (*i.e.* a moderately yielding aquifer of acceptable quality water).

3.4 Hydrocensus

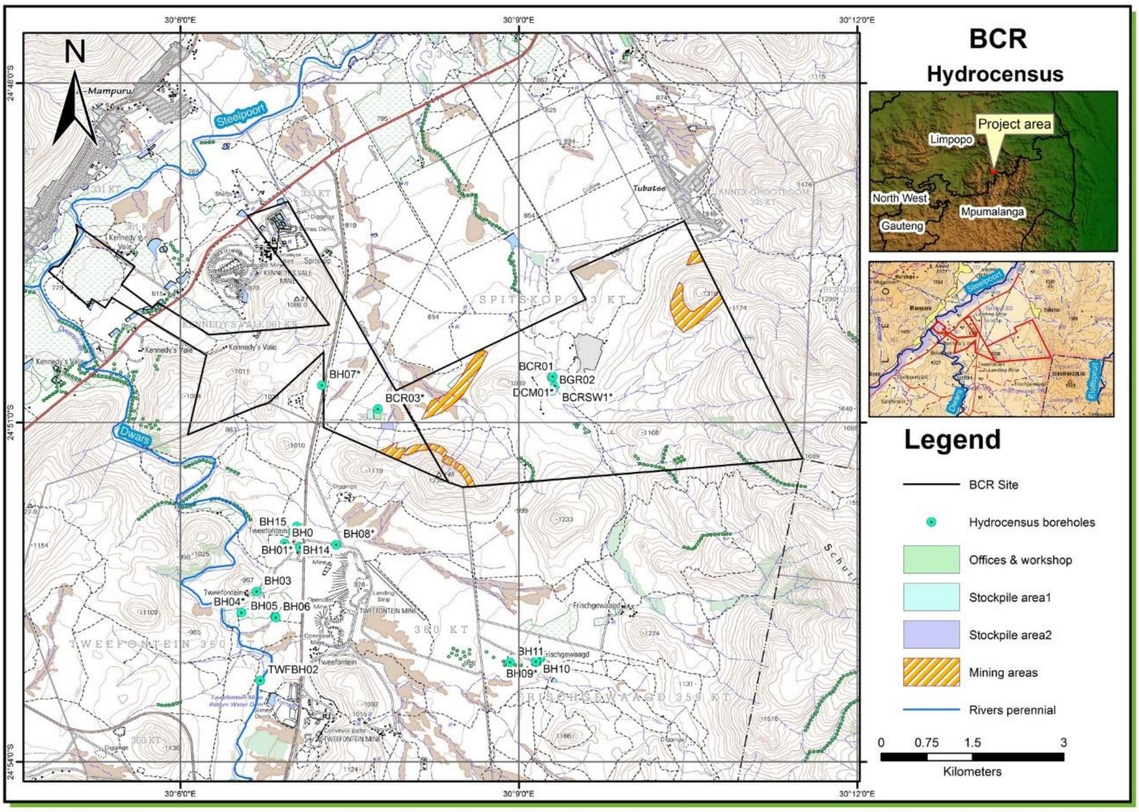


Figure 6. Hydrocensus Boreholes.

A (borehole) hydrocensus was initiated on the 19th of October 2015 (Delta H, 2016) to assess local groundwater levels and groundwater quality within the vicinity of the BCR Minerals study area.

A total of 21 boreholes were visited in the field while ten water samples, including one surface water sample at an unnamed tributary were taken.

The water samples were analysed for major and trace elements to provide an evaluation of the ambient groundwater quality that serves as a baseline for current and future groundwater developments.

A summary of the boreholes identified is summarised in **Table1** and shown spatially in **Figure 6**.

Groundwater levels range from 7 m to 33 m, with an average level of 23 mbgl.

TABLE 1: HYDROCENSUS INFORMATION (DELTA H, 2016)

Borehole ID	Coordinates (WGS84)		Elevation (mamsl)	Water level (mbgl)
BCR01	-24.8433	30.15489997	830	NAWL
BCR03*	-24.84799999	30.12919997	891	NAWL
BGR02	-24.84530001	30.15489997	843	NAWL
BH0	-24.86779997	30.1154	939	32.62
BH01*	-24.86840003	30.1177	924	NAWL
BH03	-24.87490003	30.1113	907	25.64
BH04*	-24.87799999	30.109	886	NAWL
BH05	-24.87859997	30.11399997	895	NAWL
BH06	-24.87869997	30.11409997	893	NAWL
BH07*	-24.84450004	30.12090004	890	26.4
BH08*	-24.86799996	30.12299996	932	NAWL
BH09*	-24.88459999	30.15320004	1021	NAWL
BH10	-24.88519996	30.15249998	1020	blocked
BH11	-24.88529996	30.14869996	1007	13.88
BH12*	-24.86630003	30.1177	930	20.57
BH13	-24.86529998	30.11720002	922	NAWL
BH14	-24.86650002	30.11700002	925	22.84
BH15	-24.86620003	30.11660004	925	24.08
DCM01*	-24.84320001	30.15499997	828	NAWL
TWFBH01*	-24.90320002	30.10759997	896	8.23
TWFBH02	-24.88800002	30.11179998	887	6.85

NAWL – No access to water level

The BCR Minerals study area users are supplied by both groundwater and a dedicated raw water pipeline for water use. Groundwater users range from small scale rural domestic use to larger scale domestic use at industrial and mine sites. A number of groundwater users were identified and are summarised below:

- All surveyed boreholes, except for BCR03, are located up gradient from the WRDs (refer to **Figure 7**).

- BCR Minerals use one borehole, BCR03, for domestic water supply. The borehole is located within the mine office area.

- A second borehole (BH COMSUPPLY01), located approximately 2.6 km east (up gradient) of the mine office, supplies a community and school towards the east. Two boreholes in close vicinity of borehole DCM01 are equipped but not functional. Borehole BCR01 is blocked and borehole BCR02 is equipped with a broken hand pump.

- Industrial Steel Park, located approximately 2.5 km southwest (up gradient) of BCR Minerals has two boreholes. One borehole, BH01 is currently equipped and in use, supplying the whole

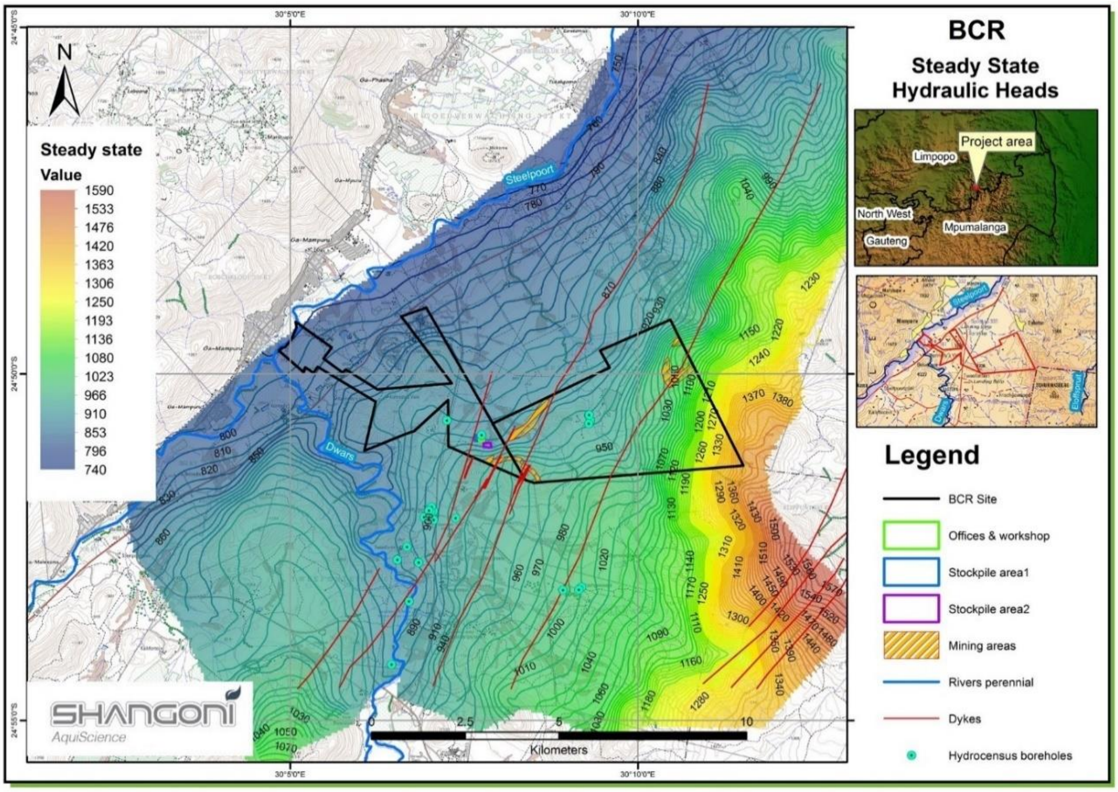


Figure 7. Steady state hydraulic heads, hydrocensus boreholes and direction of groundwater flow depicted by arrows (Delta-H, 2016).

3.5 Legal Framework

The following changes in terms of the National Environmental Management Waste Amendment Act ((NEMWAA (Act 26 of 2014)) have occurred that will be applicable to the BCR mine residue classification project:

- The exclusion of Mine Residue Stockpiles and Residue Deposits (MRSRD) has been removed from Section 4 of the NEM:WA and the definition of hazardous waste in Schedule 3 now specifically includes MRSRD's. This implies that all functional elements of waste management that are enforced in NEM:WA (waste generation, storage, transportation, recovery, recycling, reuse and ultimate disposal) become enforceable on MRSRD's. The regulations for the management, classification and assessment of waste as well as design of disposal facilities under NEM:WA will now also apply to MRSRDs.

- The inclusion of MRSRD's into the definition of waste also implies that the MRSRD are subject to the licensing requirements in terms of the NEM:WA.

This implies that prior to construction, expansion or decommissioning of any facility relating to MRSRD (e.g. tailings disposal facility, waste rock dump, recovery / reworking plant, etc.) or undertaking any other waste management activity listed in GN R.921, a waste management licence may need to be applied for (depending on whether the proposed activity / facility triggers the stipulated thresholds or not) supported by the relevant environmental impact assessment and public consultation process.

3.6 Methodology

3.6.1 Waste Material

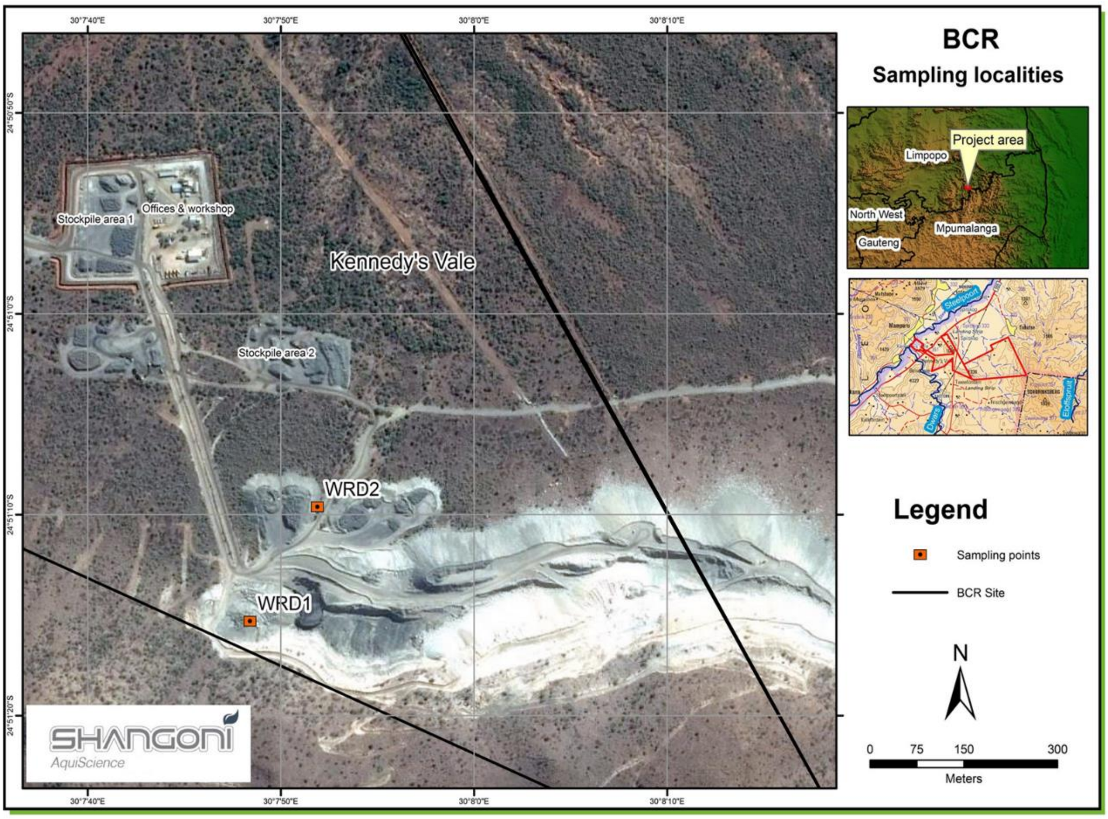


Figure 8. Sampling Localities.

A site visit was conducted during July 2016 by Viljoen Associates assisted by Shangoni and two samples (**Figure 8**) were taken from the main waste rock site. The samples were subjected to geochemical analyses which included acid-base-accounting and analyses for total and soluble inorganic constituents (as per Norms and Standards). Sample identification is as follows:

1. Waste rock 1,

2. Waste rock 2.

Saturated distilled water extracts results for the product ore stockpiles (‘stockpile areas’) was also conducted.

3.6.2 Acid Base Accounting

Acid-base Accounting (ABA) is a static test where the net potential of the rock in order to produce acidic drainage is determined. This test is an important first order assessment of the potential leachate that could be expected from the rock material. A description of the different ABA components is given below:

- AP (Acid Potential) is determined by multiplying the %S with a factor of 31.25. The unit of AP is kg $CaCO_3$/t rock and indicates the theoretical amount of calcite neutralized by the acid produced.

- The NP (Neutralization Potential) is determined by treating a sample with a known excess of standardized hydrochloric or sulphuric acid (the sample and acid are heated to insure reaction completion). The paste is then back-titrated with standardized sodium hydroxide in order to determine the amount of unconsumed acid. NP is also expressed as kg $CaCO_3$/t rock as to represent the amount of calcite theoretically available to neutralize the acidic drainage.

- NNP is determined by subtracting AP from NP.

In order for the material to be classified in terms of their ARD potential, the ABA results could be screened in terms of its NNP, %S and NP:AP ratio as follows:

- A rock with NNP < 0 kg $CaCO_3$/t will theoretically have a net potential for acidic drainage. A rock with NNP > 0 kg $CaCO_3$/t rock will have a net potential for the neutralization of acidic drainage. Because of the uncertainty related to the exposure of the carbonate minerals or the pyrite for reaction, the interpretation of whether a rock will actually be net acid generating or neutralizing is more complex.

- Research has shown that a range from -20 kg $CaCO_3$/t to 20 kg $CaCO_3$/t exists that is defined as a “grey” area in determining the net acid generation or neutralization potential of a rock. Material with a NNP above this range is classified as Rock Type IV - No Potential for Acid Generation, and material with a NNP below this range as Rock Type I - Likely Acid Generating.

- Further screening criteria could be used that attempts to classify the rock in terms of its net potential for acid production or neutralization. The screening methods presented in in **Table 2**, and as proposed by Price (1997), use the NP:AP ratio to classify the rock in terms of its potential for acid generation.

- Soregaroli and Lawrence (1998) further states that samples with less than 0.3% sulphide sulphur are regarded as having insufficient oxidisable sulphides to sustain long term acid generation. Material with a %S below 0.3% is therefore classified as Rock Type IV - No Potential for Acid Generation, and material with a %S of above 0.3%, as Rock Type I - Likely Acid Generating.

TABLE 2: SCREENING METHODS USING THE NP:AP RATIO (PRICE, 1997)

Potential for acid generation	NP:AP Screening Criteria	Comments
Rock Type I. Likely Acid Generating	<1:1	Likely AMD generating.
Rock Type II. Possibly Acid Generating	1:1 – 2:1	Possibly AMD generating if NP is insufficiently reactive or is depleted at a faster rate than sulphides.
Rock Type III. Low Potential for Acid Generation.	2:1 – 4:1	Not potentially AMD generating unless significant preferential exposure of sulphides along fracture planes, or extremely reactive sulphides in combination with insufficient reactive NP.
Rock Type IV. No potential for Acid Generation	>4:1	No further AMD testing required unless materials are to be used as a source of alkalinity.

3.6.3 Waste Classification

The National Environmental Management Act: Waste Act, 2008 (Act No.59 of 2008) governs the fate of waste generated in South Africa for disposal. The aim of this act is to:

- Regulate waste management in order to protect health and the environment by providing reasonable measures for the prevention of pollution and ecological degradation and for securing ecologically sustainable development.

- Provide for institutional arrangements and planning matters.

- Provide for national norms and standards for regulating the management of waste by all spheres of government.

- Provide for specific waste management measures.

- Provide for the licensing and control of waste management activities.

- Provide for the remediation of contaminated land.

- Provide for the national waste information system.

- Provide for compliance and enforcement.
- Provide for matters connected therewith.

New Requirements For Mine Dumps And Stock Piles

Until recently, mining waste was regulated under the Mineral and Petroleum Resources Development Act 28 of 2002 (MPRDA). With effect from 24 July 2015, the establishment and reclamation of mine dumps and stockpiles of similar waste from or incidental to a mining operation must comply with the new regulations regarding the planning and management of residue stockpiles and residue deposits from a prospecting, mining, exploration, or production operation (the Mining Residue Regulations) published under the National Environmental Management: Waste Act 59 of 2008 (NEM: WA). The Mining Residue Regulations supersede regulation 73 of the Mineral and Petroleum Resources Development Regulations (MPRD Regulations), which previously regulated mining waste. Most of the provisions in the Mining Residue Regulations echo those in regulation 73 of the MPRD Regulations, but there are some significant changes.

Waste Management Licenses

A waste management licence under NEM: WA is now required for the creation of a residue stockpile. Applicants for waste management licences must undertake an environmental impact assessment (EIA) process in accordance with the National Environmental Management Act 107 of 1998 (NEMA). Only a basic EIA assessment is required if the waste in question is generated from prospecting or activities requiring mining permits, but a full scoping and environmental assessment is required if the waste is generated by activities requiring a mining right, exploration right, or production right. This means that the mining industry will now have to pay for more detailed and stringent EIA processes involving considerably more public participation than was previously the case under the MPRDA.

Registered engineers must design stockpiles. Under the MPRD Regulations, stockpiles had to be designed by a ‘competent person’. The Mining Residue Regulations now require that this be done by a civil or mining engineer, registered under the Engineering Profession of South Africa Act 114 of 1990. Stockpiles must also comply with landfill requirements. Stockpiles must now comply with the National Norms and Standards for the Assessment of Waste for Landfill Disposal, 2013; and National Norms and Standards for Disposal of Waste to Landfill, 2013.

National Norms And Standards

On 23 August 2013, Waste Classification and Management Regulations were published under the National Environmental Management: Waste Act. Two sets of national Norms and Standards were published at the same time:

i) The National Norms and Standards for the Assessment of Waste for Landfill Disposal ("Assessment Norms and Standards").

ii) National Norms and Standards for Disposal of Waste to Landfill ("Disposal Norms and Standards").

The Regulations and Norms and Standards marked a significant shift in waste classification and associated management regime which came before it, under which wastes were classified and regulated with reference to the Minimum Requirements for Handling, Classification and Disposal of Hazardous Waste and for Waste Disposal by Landfill, published by the former Department of Water Affairs and Forestry (DWAF), currently known as the Department of Water and Sanitation (DWS).

The classification of MRSRDs in South Africa is also performed according to this new Standard for Assessment of Waste for Landfill Disposal (GNR 635) as published in the Government Gazette, No. 36784 dated 23 August 2013.

Approach

- To assess waste for the purpose of disposal to landfill, the following is required:
  - Identification of chemical substances present in the waste.
  - Sampling and analyses to determine the total concentrations (TC) and leachable concentrations (LC) for the elements and chemical substances identified in the waste.
- Within three (3) years of the date of commencement of the regulations, all analyses of the TC and LC of elements and chemical substances in waste must be conducted by laboratories accredited by the South African National Accreditation System (SANAS) to conduct the particular techniques and analysis methods required.
- The TC and LC limits of the chemical substances in the waste must be compared to the threshold limits (Table 3) for total concentration (TCT limits) and leachable concentrations (LCT limits) of the specific elements and chemical substances.
- Based on exceedance of the TC and LC limits of the elements and chemical substances in the waste, the specific type of waste for disposal to landfill is determined.

The samples were analysed by UIS Analytical, a SANAS accredited laboratory situated in Pretoria. Analyses and interpretation were based upon the parameters and thresholds as supplied in **Table 3**, as stipulated in Standard for Assessment of Waste for Landfill Disposal (GNR 635).

The parameters and thresholds for total and leachable constituents are shown in Table 3.

TABLE 3: PARAMETERS INCLUDED FOR TOTAL CONCENTRATION (TC) ANALYSES AND TOTAL CONCENTRATION THRESHOLDS (TCT) AS PER THE STANDARD FOR ASSESSMENT OF WASTE FOR LANDFILL DISPOSAL (GNR 635)

Elements & Chemical Substances in Waste	TCT0 (mg/kg)	TCT1 (mg/kg)	TCT2 (mg/kg)	LCT0 (mg/l)	LCT1 (mg/l)	LCT2 (mg/l)	LCT3 (mg/l)
Metal Ions							
Arsenic (As)	5.8	500	2000	0.01	0.5	1	4
Boron (B)	150	15 000	60 000	0.5	25	50	200
Barium (Ba)	62.5	6 250	25 000	0.7	35	70	280
Cadmium (Cd)	7.5	260	1040	0.003	0.15	0.3	1.2
Cobalt (Co)	50	5000	20 000	0.5	25	50	200
Total chromium (Cr_{total})	46 000	800 000	N/A	0.1	5	10	40
Hexavalent chromium (Cr^{6+})	6.5	500	2000	0.05	2.5	5	20
Copper (Cu)	16	19 500	78 000	2.0	100	200	800
Mercury (Hg)	0.93	160	640	0.006	0.3	0.6	2.4
Manganese (Mn)	1000	25 000	100 000	0.5	25	50	200
Molybdenum (Mo)	40	1000	4000	0.07	3.5	7	28
Nickel (Ni)	91	10 600	42 400	0.07	3.5	7	28
Lead (Pb)	20	1900	7600	0.01	0.5	1	4
Antimony (Sb)	10	75	300	0.02	1.0	2	8
Selenium (Se)	10	50	200	0.01	0.5	1	4
Vanadium (V)	150	2680	10 720	0.2	10	20	80
Zinc (Zn)	240	160 000	640 000	5.0	250	500	2000
Inorganic anions							
TDS				1000	12 500	25 000	100 000
Chloride (Cl)				300	15 000	30 000	120 000
Sulphate (SO_4)				250	12 500	25 000	100 000
Nitrate as nitrogen (NO_3-N)				11	550	1100	4400
Fluoride (F)	100	10 000	40 000	1.5	75	150	600
Total Cyanide (CN^-_{total})	14	10 500	42 000	0.07	3.5	7	28

Notes on total concentration thresholds

- TCT1 limits, where appropriate, is derived from the land remediation values for commercial/industrial land determined by the Department of Environmental Affairs' "Framework for the Management of Contaminated Land", March 2010. The TCT2 limits were derived by multiplying TCT1 by a factor of 4, as used by the Environmental Protection Agency, Australian State of Victoria.

- If South African limits for TCT1 were unavailable, in general, the limits published by the Environmental Protection Agency, Australian State of Victoria were used.

- Some TC limits were adjusted because of various attenuation factors observed in landfills.

- Where available, the TCT0 limits were obtained from SA Soil Screening Values that are protective of water resources. If not available, the State of Victoria value for fill material (EPA Victoria, Classification of Wastes) was selected. If limits were not available in these references, a conservative value was obtained by dividing the TCT1 value by 100.

Notes on leachable concentration thresholds

- LCT1 limits have, where possible, been derived from the lowest value of the standard for human health effects listed for drinking water (LCTO) in South Africa (DWAF, SANS) by multiplying with a Dilution Attenuation Factor (DAF) of 50 as proposed by the Australian State of Victoria, "Industrial Waste Resource Guidelines: Solid Industrial Waste Hazard Categorization and Management", June 2009 (www.epa.vic.gov.aus). If no standard was available in South Africa then the limits given by the WHO or other appropriate drinking water standard, such as those published in the California Regulations was used.

- LCT2 limits were derived by multiplying the LCT1 value with a factor of 2, and the LCT3 limits derived by multiplying the LCT2 value with a factor of 4. The factors applied represents a conservative assessment of the decrease in risk achieved by the increase in environmental protection provided by more comprehensive liner designs in higher classes of landfill and landfill operating requirements.

3.7 Determining Of Waste Types For Landfill Purposes

3.7.1 Waste Classification

(1) The specific type of waste for disposal to landfill must be determined by comparing the TC and LC of the elements and chemical substances in the waste with the TCT and LCT limits specified in Section 6 of the Norms and Standards.

(2) Based on the assessment of the particular waste destined for disposal to landfill, the type of waste is determined as follows:

(a) Wastes with any element or chemical substance concentration above the LCT3 or TCT2 limits (LC > LCT3 or TC > TCT2) are Type 0 Wastes;

(b) Wastes with any element or chemical substance concentration above the LCT2 but below or equal to the LCT3 limits, or above the TCT1 but below or equal to the TCT2 limits (LCT2 < LC ≤ LCT3 or TCT1 < TC ≤ TCT2), are Type 1 Wastes;

(c) Wastes with any element or chemical substance concentration above the LCT1 but below or equal to the LCT2 limits and all concentrations below or equal to the TCT1 limits (LCT1 < LC ≤ LCT2 and TC ≤ TCT1) are Type 2 Wastes;

(d) Wastes with any element or chemical substance concentration above the LCT0 but below or equal to the LCT1 limits and all TC concentrations below or equal to the TCT1 limits (LCT0 < LC ≤ LCT1 and TC ≤ TCT1) are Type 3 Wastes; or

(e) Wastes with all element and chemical substance concentration levels for metal ions and inorganic anions below or equal to the LCT0 and TCT0 limits (LC ≤ LCT0 and TC ≤ TCT0), and with all chemical substance concentration levels also below the following total concentration limits for organics and pesticides, are Type 4 Wastes.

Chemical Substances in Waste	**Total Concentration (mg/kg)**
Organics	
TOC	30 000 (=3%)
BTEX	6
PCBs	1
Mineral Oil (C10 to C40)	500
Pesticides	
Aldrin + Dieldrin	0.05
DDT + DDD + DDE	0.05
2,4-D	0.05
Chlordane	0.05
Heptachlor	0.05

(3) If a particular chemical substance in a waste is not listed with corresponding LCT and TCT limits in section 6 of these Norms and Standards, and the waste has been classified as hazardous in terms of regulation 4(2) of the Regulations based on the health or environmental hazard characteristics of the particular element or chemical substance, the following applies:

- the waste is considered to be Type 1 Waste; and
- the Department must be informed in writing in 30 days of the particular element or chemical substance not listed in section 6 of these Norms and Standards.

(4) Notwithstanding section 7(2) of these Norms and Standards, if the TC of an element or chemical substance is above the TCT2 limit, and the concentration cannot be reduced to below the TCT2 limit, but the LC for the particular element or chemical substance is below the LCT3 limit, the waste is considered to be Type 1 Waste.

(5) Wastes listed in item (2)(b) of Annexure 1 to the Regulations are considered to be Type 1 Waste, unless assessed and determined otherwise in terms of these Norms and Standards.

(6) Notwithstanding section 7(2) of these Norms and Standards, wastes with all element or chemical substance leachable concentration levels for metal ions and inorganic anions below or equal to the LCT0 limits are considered to be Type 3 waste, irrespective of the total concentration of elements or chemical substances in the waste, provided that-

(a) all chemical substance concentration levels are below the following total concentration limits for organics and pesticides:

Chemical Substances in Waste	**Total Concentration (mg/kg)**
Organics	
TOC	30 000 (=3%)
BTEX	6
PCBs	1
Mineral Oil (C10 to C40)	500
Pesticides	
Aldrin + Dieldrin	0.05
DDT + DDD + DDE	0.05
2,4-D	0.05
Chlordane	0.05
Heptachlor	0.05

3.8 Aquifer Vulnerability

The DRASTIC model (Aller *et. al*., 1987) concept developed for the USA is well suited for producing a groundwater vulnerability evaluation for South African aquifers. DRASTIC evaluates the intrinsic vulnerability (IV) of groundwater by considering factors including Depth to water table, natural Recharge rates, Aquifer media, Soil media, Topographic aspect, Impact of vadose zone media and hydraulic Conductivity. Different ratings are assigned to each factor and then summed together with respective constant weights to obtain a numerical value to be used as the vulnerability index for an area:

DRASTIC Index (IV) = DrDw + RrRw+ ArAw + SrSw + TrTw + IrIw + CrCw

Where D, R, A, S, T, I, and C are the parameters, r is the rating value, and w the constant weight assigned to each parameter (Lynch *et al*, 1994).

The scores associated with the vulnerability of South African aquifers are shown in **Table 4**.

TABLE 4: SOUTH AFRICAN NATIONAL GROUNDWATER VULNERABILITY INDEX TO POLLUTION (LYNCH ET AL, 1994)

Score	Vulnerability
50-87	Least susceptible
87 - 109	Moderate susceptible
109 - 183	Most susceptible

The concept of DRASTIC is based on:

- A contaminant is introduced at the surface of the earth.
- A contaminant is flushed into the groundwater by precipitation.
- A contaminant has the mobility of water.
- The area evaluated is 0.4 km^2 or larger.

3.9 Environmental Impact Assessment

A concluding risk assessment rating was established by incorporating the available data and geohydrological information into a source-pathway-receptor-consequence risk model using a standard template. The significance or quantification of the risk process follows the established impact/risk assessment facets:

Probability = Likelihood of an impact occurring	Magnitude = Duration + Extent + Environment/3

The weight assigned to the various parameters for positive and negative impacts is presented in **Table 5**. The significance or severity of the impact is then determined and categorised into one of four categories, listed in **Table 6** and described in **Table 7**.

TABLE 5: IMPACT RATING

Rating	Probability	Duration	Extent	Consequence
1	Rare	Temporary	Effect limited to the site. (meters)	Limited damage to minimal area of low significance.
2	Unlikely	Short term	Effect limited to the activity and its immediate surroundings. (tens of meters)	Minor effects on biological or physical environment.
3	Possible	Medium term	Impacts on extended area beyond site boundary (hundreds of meters)	Moderate, short-term effects but not affecting ecosystem functioning. Rehabilitation requires intervention of external specialists.
4	Likely	Long term	Impact on local scale / adjacent sites (km's)	Serious medium term environmental effects.
5	Almost certain	Permanent	Extends widely (nationally or globally)	Very serious, long-term environmental impairment of ecosystem function that may take several years to rehabilitate

TABLE 6: SEVERITY OF THE IMPACT

Environmental Impact Rating					
Probability	Magnitude				
	1 Minor	2 Low	3 Medium	4 High	5 Major
5 Almost Certain	Medium (11)	High (16)	High (20)	Very High (23)	Very High (25)
4 Likely	Low (7)	Medium (12)	High (17)	Very High (21)	Very High (24)
3 Possible	Low (4)	Medium (8)	High (13)	High (18)	Very High (22)
2 Unlikely	Low (2)	Low (5)	Medium (9)	High (14)	High (19)
1 Rare	Low (1)	Low (3)	Low (6)	Medium (10)	High (15)

TABLE 7: DESCRIPTION OF THE IMPACT OR SEVERITY RATING

Score	Description	Rating
1 - 7	An acceptable impact for which mitigation is desirable but not essential. The impact by itself is insufficient even in combination with other low impacts to prevent the development being approved. These impacts will result in either positive or negative short term effects on the social and/or natural environment.	Low / Negligible
8 - 12	An important impact which requires mitigation. The impact is insufficiently itself to prevent the implementation of the project but which in conjunction with other impacts may prevent its implementation. These impacts will usually result in either a positive or negative medium to long term effect on the social and/or natural environment.	Medium / Minor
13 - 18	A serious impact, if not mitigated, may prevent the implementation of the project (if it is a negative impact). These impacts would be considered by society as constituting a major and usually long-term change to the (natural and/or social) environment and result in severe	High / Moderate

	effects or beneficial effects.	
19 - 25	A serious impact, which if negative, may be sufficient by itself to prevent implementation of the project. The impact may result in permanent change. Very often these impacts are immitigable and usually result in very severe effects or very beneficial effects.	High / Major

3.10 Results

3.10.1 Acid Base Accounting (ABA)

The ABA results are summarised in **Table 8**.

TABLE 8: ACID BASE ACCOUNTING RESULTS

Acid – Base Accounting Modified Sobek (EPA-600)	**Sample Identification**	
	WRD1	**WRD2**
Sample Number	**470275**	**470276**
Paste pH	9.20	7.14
Total Sulphur (%) (LECO)	<0.03	<0.03
Acid Potential (AP) (kg/t)	0.09	0.09
Neutralization Potential (NP)	32.5	26.5
Nett Neutralization Potential (NNP)	32.4	26.4
Neutralising Potential Ratio (NPR) (NP : AP)	346.8	282.1
Rock Type	**IV**	**IV**
Comments	**No acid generation potential**	

The following observations is made from the ABA results:

- The total S% (determined in a LECO furnace) was used to determine the Acid Potential (AP) of the rock. This is an overestimation as it assumes that all the sulphur in the tailings will be acid-producing.

- No sulphides were detected in the any of the samples and therefore the acid potential calculated is low to zero. Generally, sulphide minerals are rarely present in the Bushveld Complex rocks.

- The neutralisation potential of the waste rock is very high (26.4 – 32.5 kg/t $CaCO_3$) which indicates that the rock has high potential to neutralise acid.

- The NP:AP indicates the potential for the rock to generate acid drainage, whereas the %S indicates whether this drainage will be over the long term. From the results it is evident that no net acidification is predicted for the material due to the absence of sulphide minerals and the high neutralising potential of the rocks.

- The waste rock at BCR classifies as having no potential to generate acid-mine drainage with potentially no/low salt load that will emanate from the residue material. Refer to Section 6.2.2 for more detail on potential of substandard quality leachate to develop from the dumps.

3.10.2 Waste Classification Results

Total and leachable concentrations were evaluated according to their respective concentration thresholds as per the National Norms and Standards for the Assessment of Waste for Landfill Disposal (National Environmental Management: Waste Act, 2008 (Act No. 59 of 2008)). The results are displayed and discussed in the following sections. Exceedance of a respective threshold is shown by a specific colour shading as indicated below:

Shading	Interpretation
	≥ TCT0 or LCT0 ≤ TCT1 or LCT1
	≥ TCT1 or LCT1 ≤ TCT2 or LCT2
	≥ TCT2 or LCT2 < LCT3
	≥ LCT3

<u>Total Concentrations</u>

The total inorganic concentrations for the waste rock material at BCR are shown in **Table 9**. Laboratory certificates of analyses can be viewed in Appendix A.

Concerning the total inorganic constituents, cobalt (Co), manganese (Mn), nickel (Ni), vanadium (V) and fluoride (F) recorded above the TCT0 limits for both samples while copper (Cu) in WRD1 exceed the TCT0 limits. This is not unexpected as the Bushveld Complex is known for platinum group metals (PGMs), with associated Cu, Ni and Co mineralization, Cr and V bearing ore formations including fluorspar (CaF_2).

All other inorganic constituents recorded well within TCT0 limits. All constituents remain well within TCT1 limits.

TABLE 9: TOTAL CONCENTRATION RESULTS EVALUATED ACCORDING TO THE TOTAL CONCENTRATION THRESHOLD (TCT) LIMITS

Constituents	WRD1	WRD2	TCT0 mg/kg	TCT1 mg/kg
	mg/kg	mg/kg	mg/kg	mg/kg
As, Arsenic (mg/k	1.011	0.839	5.8	500
B, Boron	0.461	3.749	150	15 000
Ba, Barium	29.8	58.0	62.5	6 250
Cd, Cadmium	0.049	0.029	7.5	260
Co, Cobalt	65.9	60.4	50	5 000
Cr_{Total}, Chromium Total	4243	18947	46 000	800 000
Cu, Copper	31.7	8.73	16	19 500
Hg, Mercury	0.0166	0.0071	0.93	160
Mn, Manganese	1426	1054	1000	25 000
Mo, Molybdenum	4.80	5.41	40	1 000
Ni, Nickel	429	376	91	10 600
Pb, Lead	1.55	0.99	20	1 900
Sb, Antimony	0.339	0.572	10	75
Se, Selenium	0.107	0.002	10	50
V, Vanadium	154	256	150	2 680
Zn, Zinc	81.5	130	240	160 000
Cr(VI), Chromium (VI) Total [s]	<5	<5	6.5	500
Total Fluoride [s] mg/kg	139	134	100	10 000
Total Cyanide as CN mg/kg	<0.1	<0.1	14	10 500
Total Sulphur (%)	<0.003	<0.003	-	-
Sulphide Sulphur (%)	<0.01	<0.01	-	-
Sulphate Sulphur (%)	<0.01	<0.01	-	-

**Aqua Regia microwave digestion*

* Trace elements in ore/soil by ICP-MS, Fluoride in soil/ore by selective electrode, Cyanide in soil/ore by spectrophotometer, Sulphur speciation

<u>Leachable Concentrations</u>

The leachable (reagent water method) concentrations for the waste are shown in **Table 10** and in Appendix A.

All inorganic constituents recorded below detection limits and also within the LCT0 limits, suggesting low mobility of the elements of concern as identified in the total concentration data. All trace elements (metals) recorded within low to undetected levels. A low total dissolved solids concentration of 34 and 44 mg/l was recorded for the waste rock deposits with sulphate (SO_4) and chloride (Cl) recording in the very low to undetected levels. This together with the risk of acid generating potential being zero, the risk of toxic leachate development from the WRDs is therefore perceived to be low to very low.

TABLE 2: LEACHABLE CONCENTRATION RESULTS EVALUATED ACCORDING TO THE LEACHABLE CONCENTRATION THRESHOLD (LCT) LIMITS

Constituents	Unit	WRD1	WRD2	LCT0
pH	-	9.43	9.52	-
As, Arsenic	mg/l	0.001	<0.001	0.01
B, Boron	mg/l	0.240	0.229	0.5
Ba, Barium	mg/l	0.224	0.241	0.7
Cd, Cadmium	mg/l	<0.0001	0.0001	0.003
Co, Cobalt	mg/l	0.003	0.002	0.5
CrTotal, Chromium Total	mg/l	0.068	0.177	0.1
Cr(VI), Chromium (VI)	mg/l	<0.05	<0.05	0.05
Cu, Copper	mg/l	0.007	0.007	2.0
Hg, Mercury	mg/l	0.0021	0.0012	0.006
Mn, Manganese	mg/l	0.045	0.029	0.5
Mo, Molybdenum	mg/l	<0.001	<0.001	0.07
Ni, Nickel	mg/l	0.005	0.017	0.07
Pb, Lead	mg/l	<0.001	0.001	0.01
Sb, Antimony	mg/l	0.001	0.001	0.02
Se, Selenium	mg/l	0.004	0.002	0.01
V, Vanadium	mg/l	0.004	0.004	0.2
Zn, Zinc	mg/l	0.005	0.041	5
Total Dissolved Solids	mg/l	34	44	1000
Chloride as Cl	mg/l	<0.25	<0.25	300
Sulphate as SO_4	mg/l	8.44	6.26	250
Nitrate as N	mg/l	<0.3	<0.3	11
Fluoride as F	mg/l	0.26	<0.1	1.5
Total Cyanide as CN	mg/l	<0.01	<0.01	0.07

Reagent used: *distilled water*

Ratio *1:20*

3.10.3 Product Stockpile

As previously mentioned, product stockpiles (and topsoil stockpiles) are not deemed as waste material and is exempt from waste classification regulations. However, it could trigger a water use license in terms of the National Water Act (‘g’ activity) for which an impact assessment is required. A leach procedure was performed on the product stockpiles. The results are tabulated in Table 11. The data shows that all micro-elements recorded within low to undetected levels and the potential for poor quality leachate development given the low/no risk of acid generation is therefore perceived to be low.

TABLE 11: LEACHATE RESULTS FOR PRODUCT ORE STOCKPILES

Element	Sample number	
	052	056
	Results (mg/kg)	
Li	0.001	0.001
Be	0.000	0.000
B	0.024	0.031
Ti	0.013	0.008
V	0.002	0.002
Cr	0.001	0.001
Mn	0.013	0.007
Co	0.000	0.000
Ni	0.029	0.064
Cu	0.010	0.006
Zn	0.909	0.866
As	0.001	0.001
Br	0.825	1.549
Se	0.003	0.005
Rb	0.005	0.009
Sr	0.022	0.042
Mo	0.001	0.001
Cd	0.000	0.001
Sn	0.001	0.000
Sb	0.000	0.000
Te	0.000	0.000
I	0.023	0.023
Cs	0.000	0.000
Ba	0.007	0.013
La	0.000	0.000
W	0.001	0.001
Pt	0.000	0.000
Hg	0.001	0.001
Tl	0.000	0.000
Pb	0.311	0.714
Bi	0.000	0.000
U	0.000	0.000

3.10.4 Waste Acceptance Criteria

The Disposal Norms and Standards specify various classes of landfill sites and the types of waste that may be disposed of into the various classes of landfill sites including the requirements for such disposal. Currently this criterion also refers to MRSRDs. They also impose waste disposal restrictions, including prohibitions and restrictions on the disposal of waste to landfill with reference to particular compliance timeframes. Waste types and respective landfill requirements are shown in **Table 12**.

TABLE 12: WASTE TYPE AND LANDFILL DISPOSAL REQUIREMENTS

Waste Type	Landfill Disposal Requirement
Type 0 Waste	The disposal of Type 0 waste to landfill is not allowed. The waste must be treated and re-assessed in terms of the Norms and Standards for Assessment of Waste for Landfill Disposal.
Type 1 Waste	Type 1 waste may only be disposed of at a Class A landfill designed in accordance with section 3(1) and (2) of these Norms and Standards, or, subject to section 3(4) of these Norms and Standards, may be disposed of at a landfill site designed in accordance with the requirements for a ***H:h / H:H*** **landfill** as specified in the Minimum Requirements for Waste Disposal by Landfill (2nd Ed., Department of Water Affairs and Forestry, 1998).
Type 2 Waste	Type 2 waste may only be disposed of at a Class B landfill designed in accordance with section 3(1) and (2) of these Norms and Standards, or, subject to section 3(4) of these Norms and Standards, may be disposed of at a landfill site designed in accordance with the requirements for a GLB+ landfill as specified in the Minimum Requirements for Waste Disposal by Landfill (2nd Ed., DWAF, 1998).
Type 3 Waste	Type 3 waste may only be disposed of at a Class C landfill designed in accordance with section 3(1) and (2) of these Norms and Standards, or, subject to section 3(4) of these Norms and Standards, may be disposed of at a landfill site designed in accordance with the requirements for a GLB+ landfill as specified in the Minimum Requirements for Waste Disposal by Landfill (2nd Ed., DWAF, 1998).
Type 4 Waste	Type 4 waste may only be disposed of at a Class D landfill designed in accordance with section 3(1) and (2) of these Norms and Standards, or, subject to section 3(4) of these Norms and Standards, may be disposed of at a landfill site designed in accordance with the requirements for a GLB- landfill as specified in the Minimum Requirements for Waste Disposal by Landfill (2nd Ed., DWAF, 1998).

3.10.5 Waste Classification Of Residue Deposits

If the Norms and Standards methodology is strictly applied to the WRDs, it can neither be classed as Type 3 nor a Type 4 waste material. According to the methodology for a waste material to be classified as Type 4, the LC (leachable concentration) and the TC (total concentration) must be below the LCT0 and TCT0, while for a waste to be classified as Type 3, the LC and TC must be below the LCT1 and TCT1, respectively.

> “(d) Wastes with any element or chemical substance concentration above the LCT0 but below or equal to the LCT1 limits and all TC concentrations below or equal to the TCT1 limits (LCT0 < LC ≤ LCT1 and TC ≤ TCT1) are Type 3 Wastes.
>
> (e) Wastes with all element and chemical substance concentration levels for metal ions and inorganic anions below or equal to the LCT0 and TCT0 limits (LC ≤ LCT0 and TC ≤ TCT0), and with all chemical substance concentration levels also below the following total concentration limits for organics and pesticides, are Type 4 Wastes.”

However, the following is true:

(LCT0 < LC ≤ and TC > TCT0)

3.10.6 Assessment Of Risk Towards The Receiving Environment

Four methodologies were used to assess the long-term potential risk that the WRDs may pose towards the receiving natural water environment.

These included:

- An aquifer vulnerability assessment using the DRASTIC model (refer to Section 5.5 for methodology).
- Assessing the acid generation potential of the waste deposits.
- Evaluation of the leachable results with relevant water quality guidelines as proposed by the DWS (DWAF, 1996; DWAF, 1998); iv) including a risk assessment using the source-pathway-receptor model for assessing potential risk.

3.10.7 Aquifer Vulnerability

Table 13 summarizes the rating and weighting values and the final score for the vulnerability of the aquifer in vicinity of the proposed study area. The final DRASTIC score of 96 indicates that the aquifer/s in the region has a medium susceptibility to pollution and a medium level of aquifer protection is therefore required.

TABLE 13: DRASTIC VULNERABILITY SCORES

Factor	Range/Type	Weight	Rating	Total
D	5 - 30 m	5	5	25
R	10 - 50 mm	4	6	24
A	Fractured and weathered	3	3	9
S	Sandy-clay loam	2	4	8
T	0-2%	1	10	10
I	Bushveld	5	4	20
C	-	3	-	-
DRASTIC SCORE = 96				

In order to achieve the Groundwater Quality Management Index, a points scoring system as presented in **Table 14** to **Table 16** was used.

TABLE 14: RATINGS FOR THE AQUIFER SYSTEM MANAGEMENT AND SECOND VARIABLE CLASSIFICATIONS

Aquifer System Management Classification		
Class	**Points**	**Study Area**
Sole Source Aquifer System	6	
Major Aquifer System	4	
Minor Aquifer System	2	2
Non-Aquifer System	0	
Special Aquifer System	0-6	
Second Variable Classification (weathered/fractured)		
High	3	
Medium	2	
Low	1	1

TABLE 15: RATINGS FOR THE GROUNDWATER QUALITY MANAGEMENT (GQM) CLASSIFICATION SYSTEM

Aquifer System Management Classification		
Class	**Points**	**Study Area**
Sole Source Aquifer System	6	
Major Aquifer System	4	
Minor Aquifer System	2	2
Non-Aquifer System	0	
Special Aquifer System	0-6	
Aquifer Vulnerability Classification		
High	3	
Medium	2	2
Low	1	

The occurring aquifer(s), in terms of the above definitions, is classified as a minor aquifer system. The vulnerability, or the tendency or likelihood for contamination to reach a specified position in the groundwater system after introduction at some location above the uppermost aquifer is classified as medium. The level of groundwater protection based on the Groundwater Quality Management Classification:

GQM Index = Aquifer System Management x Aquifer Vulnerability

= 2 X 2 = 4

Table 16 tabulates the final GQM for the study area.

TABLE 16: GQM INDEX FOR THE STUDY AREA

GQM Index	Level of Protection	Study Area
<1	Limited	
1-3	Low level	
3-6	Medium level	4
6-10	High level	
>10	Strictly non-degradation	

The ratings for the Aquifer System Management Classification and Aquifer Vulnerability Classification yield a GQM index of 4 for the study area, indicating that medium level groundwater protection may be required to adhere to DWS's water quality objectives.

Reasonable and sound groundwater protection measures are required to ensure that no cumulative pollution affects the aquifer, even in the long term. In terms of DWA's overarching water quality management objectives which is:

- Protection of human health.
- Protection of the environment, the significance of this aquifer classification is that if any potential risk exist, measures must be triggered to limit the risk to the environment, in this case being the protection of the primary and secondary underlying aquifers.

3.10.8 Water Quality Guidelines

The leachable results were evaluated according to relevant Target Water Quality Guideline Ranges (TWQGR) as proposed by the DWS (DWAF, 1996). These guidelines include Domestic, Livestock Watering and Irrigation TWQGR.

The results and guidelines are presented in **Table 17**.

The only constituents that exceed the TWQGR are pH, which recorded an alkaline pH of 9.43 and 9.52. According to the DWS, the only effect this may have on domestic users are aesthetic concerns, whereas with regards to irrigation may be the unavailability of macro- and micronutrients. However, ambient pH levels of groundwater are ideal ranging between 7.6 and 8.3 (Delta H, 2016) and the contribution of seepage from the WRDs (if any) should have an insignificant effect on ambient pH levels. The alkaline pH levels should rather be considered as a positive.

TABLE 17: LEACHATE RESULTS EVALUATED ACCORDING TO RELEVANT DWS TARGET WATER QUALITY GUIDELINE RANGES (DWAF, 1996)

Constituents	Unit	WRD1	WRD2	Relevant TWQGR (DWS)		
				Domestic	Livestock Watering	Irrigation
pH	-	9.43	9.52	6 - 9	NA	6.5 - 8.4
As, Arsenic	mg/l	0.001	<0.001	0 - 0.01	0 - 1	0 - 0.1
B, Boron	mg/l	0.240	0.229	NA	0 - 5	0 - 0.5
Ba, Barium	mg/l	0.224	0.241	NA	NA	NA
Cd, Cadmium	mg/l	<0.0001	0.0001	0 – 0.005	0 – 0.01	0 – 0.01
Co, Cobalt	mg/l	0.003	0.002	NA	0 - 1	0 – 0.05
CrTotal, Chromium Total	mg/l	0.068	0.177	NA	NA	NA
Cr(VI), Chromium (VI)	mg/l	<0.05	<0.05	0 – 0.05	0 - 1	0- 0.1
Cu, Copper	mg/l	0.007	0.007	0 - 1	0 – 0.5	0 – 0.2
Hg, Mercury	mg/l	0.0021	0.0012	0 – 0.001	0 – 0.001	NA
Mn, Manganese	mg/l	0.045	0.029	0 – 0.05	0 - 10	0 – 0.02
Mo, Molybdenum	mg/l	<0.001	<0.001	NA	0 – 0.01	0 – 0.01
Ni, Nickel	mg/l	0.005	0.017	NA	0 - 1	0 – 0.2
Pb, Lead	mg/l	<0.001	0.001	0 – 0.01	0 – 0.1	0 – 0.2
Sb, Antimony	mg/l	0.001	0.001	NA	NA	NA
Se, Selenium	mg/l	0.004	0.002	0 – 0.02	0 - 50	0 – 0.3

Constituents	Unit	WRD1	WRD2	Relevant TWQGR (DWS)		
				Domestic	Livestock Watering	Irrigation
V, Vanadium	mg/l	0.004	0.004	0 – 0.1	0 - 1	0 – 0.1
Zn, Zinc	mg/l	0.005	0.041	0 - 3	0 - 20	0 - 1
Total Dissolved Solids	mg/l	34	44	0 - 450	0 - 1000	NA
Chloride as Cl	mg/l	<0.25	<0.25	0 - 100	0 - 1500	0 - 100
Sulphate as SO_4	mg/l	8.44	6.26	0 - 200	0 - 1000	NA
Nitrate as N	mg/l	<0.3	<0.3	0 - 6	0 - 22	0 – 0.5
Fluoride as F	mg/l	0.26	<0.1	0 - 1	0 - 2	0 - 2
Total Cyanide as CN	mg/l	<0.01	<0.01	NA	NA	NA

NA – Not available

3.10.9 Acid Generating Potential

As discussed previously, the BCR WRDs do not contain any sulphidic material to generate acid (refer to Section 6.1 and **Table 8**) and contains very high neutralization potential with a consequent significant Net Neutralization Potential. The acidification potential, even in the long-term, is therefore considered to be very low to zero.

3.10.10 Source-Pathway-Receptor-Consequence Model And Risk Rating

To understand the linkage between hazard and risk it is useful to consider the commonly adopted Source-Pathway-Receptor-Consequence model (**Figure 9**).

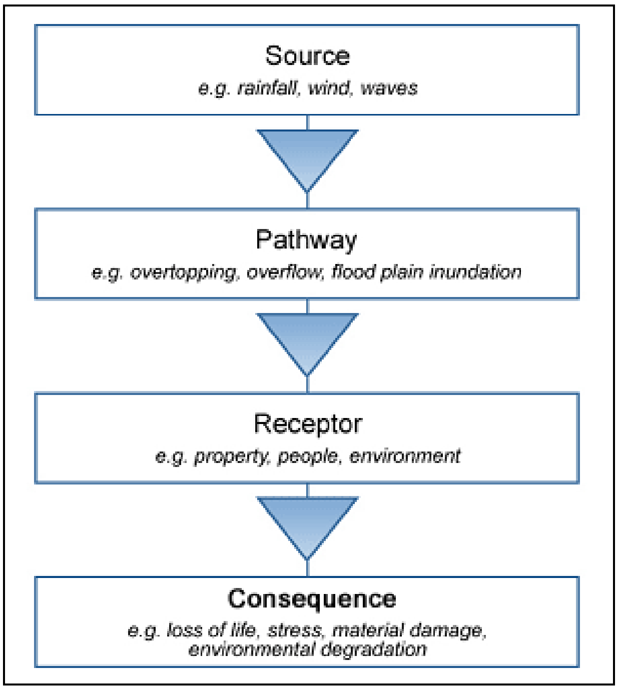


Figure 9: Source – Pathway – Receptor-Consequence Conceptual model.

This is, essentially, a simple conceptual model for representing systems and processes that lead to a particular consequence. For a risk to arise there must be hazard that consists of a 'source' or initiator event (*i.e.* point pollution source, high rainfall); a 'receptor' (*e.g.* flood plain properties, ground- or surface water, or any water user); and a pathway between the source and the receptor (i.e. groundwater, stormwater, base flow, flood routes including defences, overland flow or landslide).

A hazard does not automatically lead to a harmful outcome, but identification of a hazard does mean that there is a possibility of harm occurring, with the actual harm depending upon the exposure to the hazard and the characteristics of the receptor.

The final risk rating for the WRDs and product stockpiles on-site at RCB is summarised in **Table 18**.

TABLE 18: WATER POLLUTION RISK RATING

Parameter	Description	Rating
Probability	Unlikely • Salinity impacts are insignificant and the only impact may arise from metal leachate. However, the material is non-acid generating and therefore unlikely-rare.	1
Duration	Long term • In the unlikely probability that poor quality leachate may occur, the duration is considered long-term – especially for groundwater.	4
Extent	Largely unknown given the absence of boreholes and aquifer parameters downgradient from the sources. The aquifers in the bushveld complex is generally not known for good aquifers and rate of plume migration may be slow and retarded. However, if preferential flow pathways exist (especially in vicinity of the dyke/s) impacts could extend hundreds of meters.	3
Consequence	Given the absence of significant end-users (domestic, livestock, irrigation, aquatic users), limited harm to an area of low significance is foreseen.	1
Significance	**Low**	**6**

3.10.11 Standard Containment Barrier Design

Strictly in terms of the National Norms and Standards for Disposal of Waste to Landfill (Government Notice R636), which is also applicable to MRSRDs, containment barriers must comply with the minimum engineering design requirements of a Class C Landfill OR Class D Landfill as shown in **Figure 10** and **11**, respectively (Scholtz, 2016).

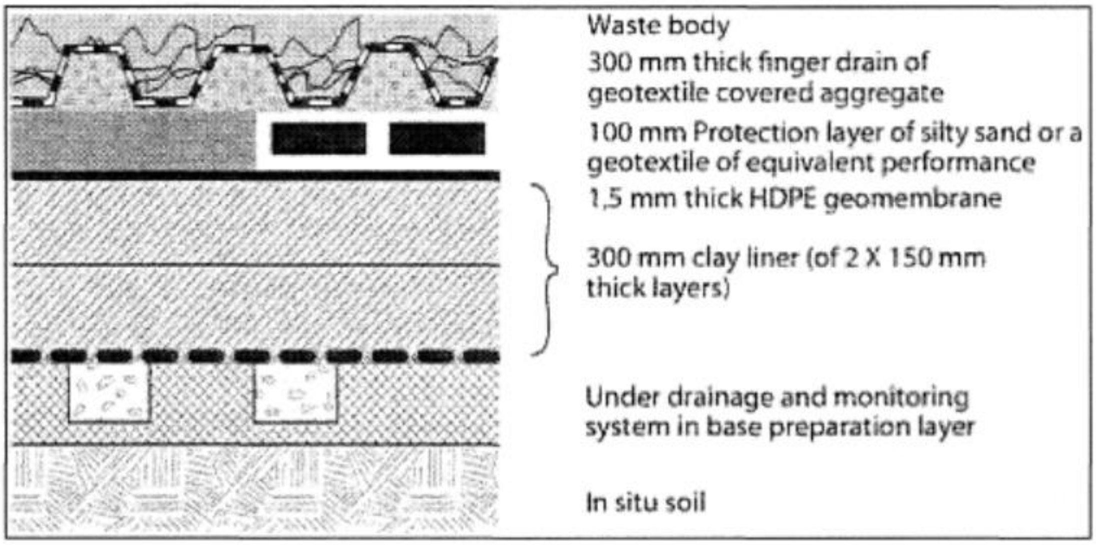


Figure 10. Class C Landfill Engineering Design.

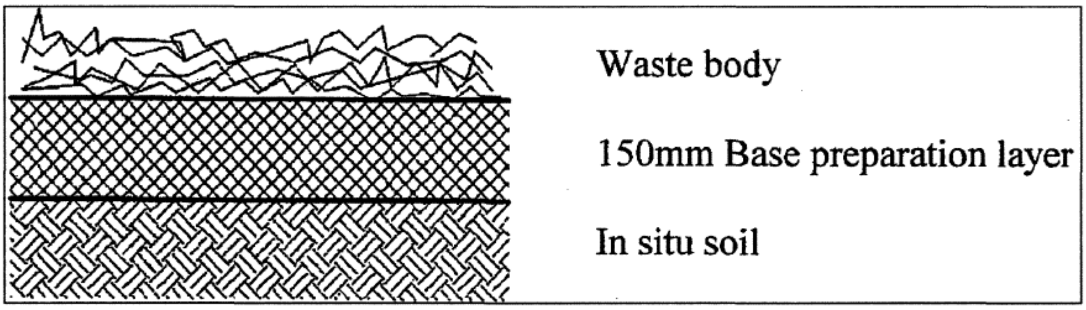


Figure 11. Class D Landfill Engineering Design.

The BCR WRDs recorded within LCT0 limits, and this together with the fact that the material is non-acid generating, the risk of poor quality leachate developing from the WRDs towards the receiving environment is perceived to be very low. A Class D Landfill Engineering Design is therefore proposed

4 REFERENCES

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This investigation was done on available information and subsequent interpretation of data to reveal the properties on site with the techniques described.

M.Sc., Pr.Sci.Nat., SACNSP: 400131/96,

Professional Indemnity Insurance: CFP Brokers Hollard Insurance: SPL/SLFG/000007248

APPENDIX A

ANALYTICAL REPORT: Acid / Base Accounting (ABA)

To:	Shangoni AquiScience	Date of Request: 25.05.2016	UIS Analytical Services
Attention:	Ockie Scholtz		Analytical Chemistry
Project ID:			Laboratories 4, 6
Site Location:			
Order No:			Fax: (012) 665 4294

92 53 16
UIS
analytical services

Certificate of analysis: 14706

Note: No unauthorised copies may be made of this report.

Lims ID	Sample ID	Paste pH	Total Sulphur	Acid Potential (AP)	Neutralization Potential (NP)	Nett Neutralization Potential (NNP)	Neutralising Potential Ratio (NPR) (NP : AP)
			%	kg CaCO3/t	kg CaCO3/t	kg CaCO3/t	AP:NP
470275	WRD/1/30/06/16	9.20	<0.03	0.09	32.5	32.4	346.8
470276	WRD/2/30/06/16	7.14	<0.03	0.09	26.5	26.4	282.1
470276QC	Duplicate	7.14	<0.03	0.09	26.4	26.3	281.2

		Chemical elements:	ABA
		Instrument:	Methohm Titrino, LECO CS 230
		Method	EPA 600 Modified Sobek
Date:	14/06/2016	Date:	14/06/2016
Analysed by:	V. van Wyk	Authorised :	JJ Oberholzer

Page 1 of 1

ANALYTICAL REPORT: Major Oxides & Total Trace elements

No unauthorised copies may be made of this report.

To:	Shangoni AquiScience
Attention:	Ockie Scholtz
Project ID:	
Site Location:	
Order No:	

Date of Request : 05.07.2016

UIS Analytical Services
Analytical Chemistry
Laboratories 4, 6
Tel: (012) 665 4291
Fax: (012) 665 4294

analytical services

Certificate of analysis: 14706

Note: all results in percentage (%) unless specified otherwise

Lims ID	Sample ID	As	B	Ba	Cd	Co	Cr	Cu	Hg	Mn	Mo	Ni	Pb	Sb	Se	V	Zn
	Total trace elements	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
470275	WRD/1/30/06/16	1.011	0.461	29.8	0.049	65.9	4243	31.7	0.0166	1426	4.80	429	1.55	0.339	0.107	154	81.5
470276	WRD/2/30/06/16	0.839	3.749	58.0	0.029	60.4	18947	8.73	0.0071	1064	5.41	376	0.99	0.572	0.002	256	130
470276 QC	Duplicate	0.827	3.715	58.4	0.025	61.0	18414	8.26	0.0061	1063	5.49	378	1.01	0.565	0.002	251	129

Lims ID	Sample ID	Total Sulphur	Sulphide Sulphur	Sulphate Sulphur
		%	%	%
470275	WRD/1/30/06/16	<0.003	<0.01	<0.01
470276	WRD/2/30/06/16	<0.003	<0.01	<0.01
470276 QC	Duplicate	<0.003	<0.01	<0.01

Lims ID	Sample ID	Cr6+	F	CN
		mg/kg	mg/kg	mg/kg
470275	WRD/1/30/06/16	<5	139	<0.1
470276	WRD/2/30/06/16	<5	134	<0.1
470276 QC	Duplicate	<5	132	<0.1

Chemical elements:	As,B,Ba,Cd,Co,Cr,Cu,Hg,Mn,Mo,Ni,Pb,Sb,Se,V,Zn
Instrument:	ICP-OES, ICP-MS, LECO CS 230 Spectrophotometer Ion selective electrode
Method	Trace elements in ore/soil by ICP-MS, Fluoride in soil/ore by selective electrode, Cyanide in soil/ore by spectrophotometer, Sulphur speciation

Date:	14.07.2016	Date:	14.07.2016
Analysed by:	A Motsepe	Authorised :	JJ Oberholzer

Page 1 of 1

ANALYTICAL REPORT: Water Leach

No unauthorised copies may be made of this report.

To: Shangoni AquiScience
Attention: Ockie Scholtz
Project ID:
Site Location:
Order No:

Date of Request : 05.07.2016

UIS Analytical Services
Analytical Chemistry
Laboratories 4, 6

Fax: (012) 665 4294

UIS analytical services

Certificate of analysis: 14706

Note: all results in parts per million (ppm) unless specified otherwise

Lims ID	Sample ID	As	B	Ba	Cd	Co	Cr	Cu	Hg	Mn	Mo	Ni	Pb	Sb	Se	V	Zn
	WATER LEACH 1:20	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
471679	WRD/1/30/06/16/Water/leach	0.001	0.240	0.224	<0.0001	0.003	0.068	0.007	0.0021	0.045	<0.001	0.005	<0.001	0.001	0.004	0.004	0.005
471680	WRD/2/30/06/16/Water/leach	<0.001	0.229	0.241	0.0001	0.002	0.177	0.007	0.0012	0.029	<0.001	0.017	0.001	0.001	0.002	0.004	0.041
471680 QC	Duplicate	<0.001	0.215	0.236	<0.0001	0.002	0.175	0.007	0.0013	0.030	<0.001	0.016	0.001	0.001	0.003	0.004	0.040

Lims ID	Sample ID	pH	pH Temp	TDS	EC	TDS by EC	P Alk.	M Alk.	F	Cl	NO2	NO3	NO3 as N	PO4	SO4	NH4	NH3	Acidity to pH8.3	CN (Total)	Cr 6+	TSS
	WATER LEACH 1:20		Deg C	mg/l	mS/m	mg/l	mg/l CaCO3	mg/l CaCO3	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l CaCO3	mg/l	mg/l	mg/l
471679	WRD/1/30/06/16/Water/leach	9.43	20.5	34	4.77	33	7.00	29.8	0.26	<0.25	<0.2	<0.3	<0.3	<0.8	8.44	nr	nr	nr	<0.01	<0.05	nr
471680	WRD/2/30/06/16/Water/leach	9.52	20.7	44	5.21	36	8.20	34.6	<0.1	0.356	<0.2	<0.3	<0.3	<0.8	6.26	nr	nr	nr	<0.01	<0.05	nr
471680 QC	Duplicate	9.54	20.9	47	5.21	36	8.50	36.2	<0.1	0.366	<0.2	<0.3	<0.3	<0.8	6.20	nr	nr	nr	<0.01	<0.05	nr

Chemical elements: As, B, Ba, Cd, Co, Cr, Cr6+, Cu, Hg, Mn, Mo, Ni, Pb, Sb, Se, V, Zn, Anions, pH, NH4, Alkalinity, CN, Cr6+
Instrument: ICP-MS Perkin Elmer NexION 300D IC Spectrophotometer

Date: 14.07.2016
Analysed by: UIS Waterlab

Date: 14.07.2016
Authorised : JJ Oberholzer

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