THABAZIMBI IRON ORE MINE (PTY) LTD: A SUBSIDIARY OF ARCELORMITTAL SOUTH AFRICA LIMITED – THABAZIMBI IRON ORE MINE

Desktop Geohydrological Report for a Waste Management Licence Application

Final Report

Report date: August 2020

SHANGONI AquiScience

A division of Shangoni Management Services Pty Ltd

www.shangoni.co.za

Project:	Desktop Geohydrological Report
Client:	Thabazimbi Iron Ore Mine (Pty) Ltd: A Subsidiary of ArcelorMittal South Africa Limited
Site:	Thabazimbi Iron Ore Mine
Location:	Thabazimbi, Limpopo Province
Project Number:	ARC-THA-19-09-10
Report Number:	AS-ARC-THA-19-09-10
Report type:	FINAL
Version:	I
Compiled by:	Ockie Scholtz, *Pr.Sci.Nat*. (*M.Sc Geohydrology*)
Report date:	05 August 2020

Ockie Scholtz (*Pr.Sci.Nat 400220/09)*

Senior Geohydrologist

Shangoni Management Services

DECLARATION OF INDEPENDANCE

I, Ockert F. Scholtz declare that

General declaration:

- I act as the independent specialist in this application.
- I will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant.
- I declare that there are no circumstances that may compromise my objectivity in performing such work.
- I have expertise in conducting the specialist report relevant to this application.
- I have no, and will not engage in, conflicting interests in the undertaking of the activity.
- I undertake to disclose to the applicant and the competent authority all material information in my possession that reasonably has or may have the potential of influencing - any decision to be taken with respect to the application by the competent authority; and - the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority.

Signature of the specialist: Ockert F. Scholtz, *Pr.Sci.Nat*

Shangoni AquiScience, a division of Shangoni Management Services (Pty) Ltd

Name of company:

05 August 2020

Date:

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION AND BACKGROUND

Thabazimbi Iron Ore Mine (Pty) Ltd., a subsidiary of ArcelorMittal South Africa Limited: Thabazimbi Iron Ore Mine ("TIOM") requested Shangoni Management Services (Pty) Ltd to apply for a waste management licence ("WML") and Environmental Authorisation ("EA"). The WML and EA are in reference to the reworking/reclamation of the existing D1-Old Plant Discard Dump, D2- Old Plant Discard Dump, D3 – Supply Chain Discard Dump and the existing Slimes Dams. The aim of the reworking activities is to supply high quality iron ore to the AMSA Vanderbijlpark Steel Works, aggregate to the construction market and low Fe ore to the cement factories.

As part of the proposed reworking activities, a stand-alone plant with associated infrastructure to process low grade iron ore will be established next to the D2 – Old Plant Discard Dump.

In 2015, Kumba Iron Ore, a business unit of the Anglo-American group, commenced closure proceedings of the Thabazimbi Mine. Kumba's decision to close the operation followed an extensive review of the mine and was in response to a combination of factors that have affected the mine's economic viability.

Mining operations at Thabazimbi ceased on 1 September 2016. In 2018 the mine was transferred from Anglo American Kumba Iron Ore to ArcelorMittal SA ("AMSA"). The mine exclusively supplied AMSA and was funded by the South African steelmaker. The transfer agreement sees AMSA becoming solely responsible for Thabazimbi's closure and rehabilitation.

The main objectives of this report were to provide relevant background and baseline information with reference to the geohydrology of the project area and to rate the anticipated reclamation impacts at TIOM in an impact assessment.

2. GEOGRAPHICAL SETTING

2.1 Location

TIOM is situated in the Thabazimbi Local Municipality, near the town of Thabazimbi, which falls within the Waterberg District Municipality of the Limpopo Province (Figure 1). The mining area falls within the Crocodile West Marico Water Management Area and quaternary drainage regions A24J, A24F and A24H (Figure 2).

THABAZIMBI IRON ORE MINE LOCALITY AND LAYOUT

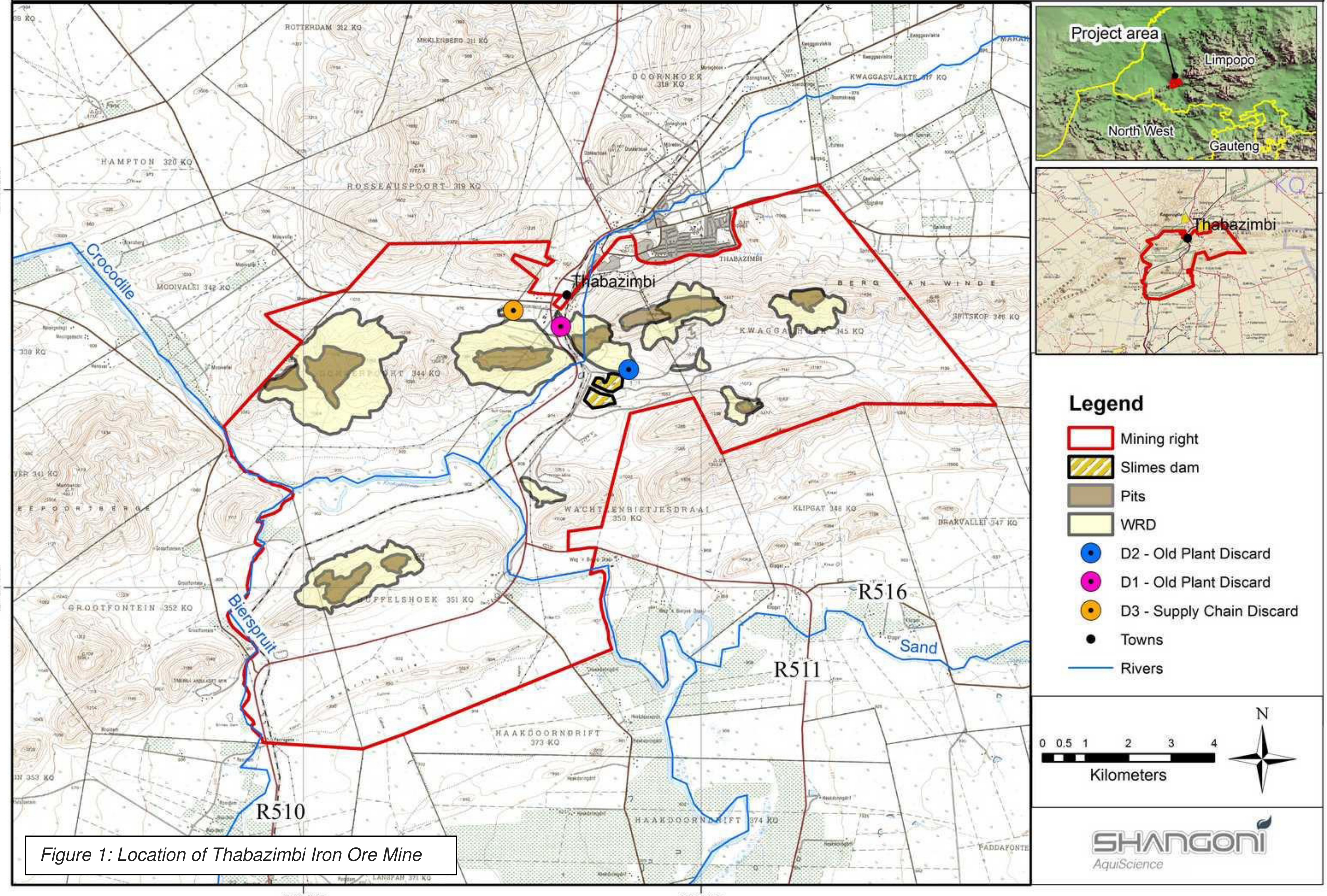


Figure 1: Location of Thabazimbi Iron Ore Mine

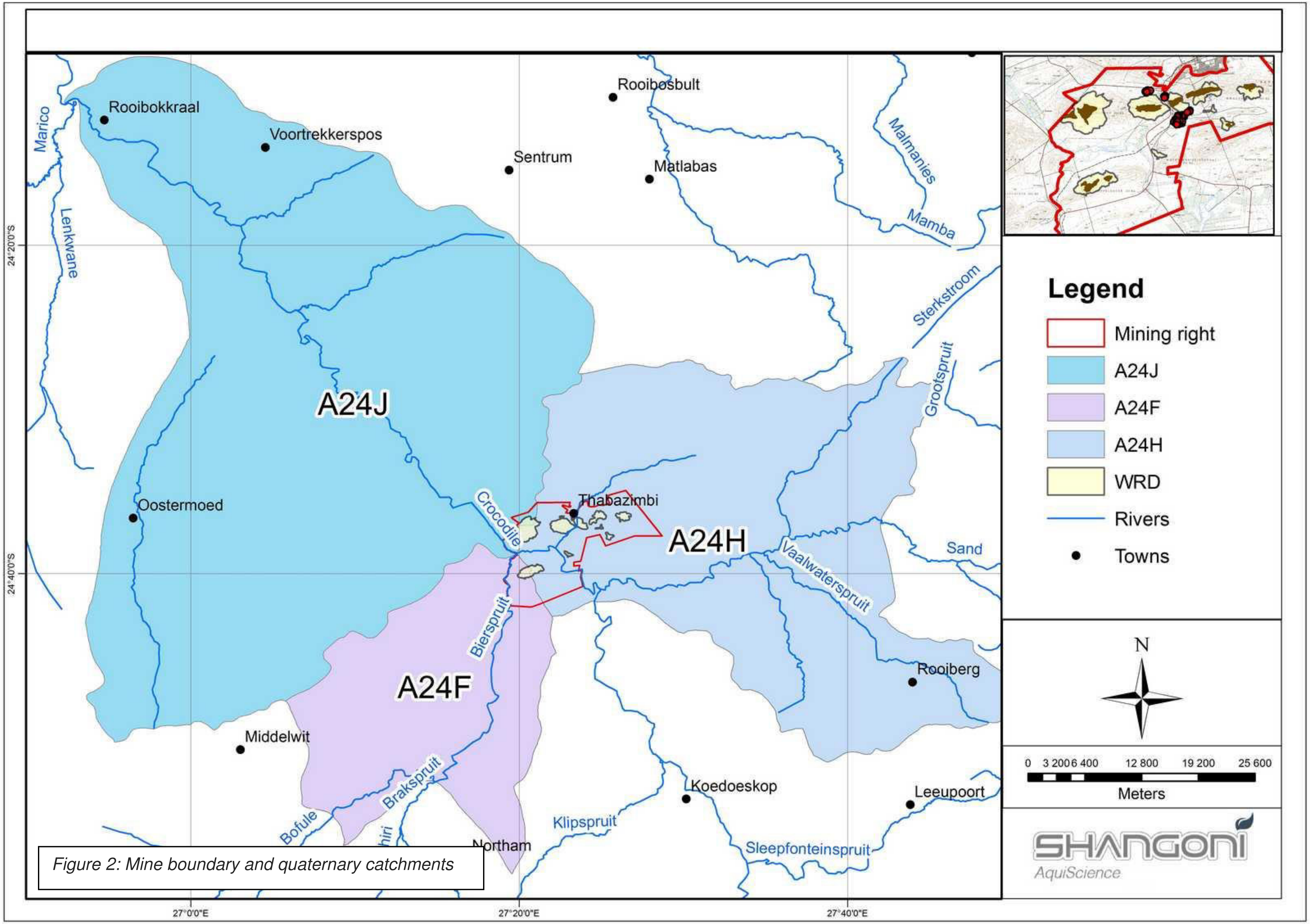


Figure 2: Mine boundary and quaternary catchments

2.2 Topography and drainage

The topography is characterised by contrasting mountain landscapes, hills and valleys. The catchment can be highly modified in terms of topography as it is characterised by mine residue deposits, stockpiles, excavations and open pits. Topographical highs are approximately 1300 to 1500 meters above sea level ("mamsl") at the mountain ranges and lows on the valley floor approximately 900 to 1000 mamsl. A topography map of TIOM can be viewed in Figure 3.

Several river systems drain the project area, the most prominent being the perennial Crocodile River and ephemeral and highly modified Bierspruit. The regional drainage features include the Rooikuilspruit, Sand River, Sterkspruit, Vaalwaterspruit and Klipspruit. Most of these systems are ephemeral. Several other small streams, tributaries and storm water canals further characterises of the landscape.

The ecosystem function/categories are classified as either B or C, which is an indication of the largely unimpacted status of the natural environment. The categories are defined as:

B *Largely natural with few modifications. A small change in natural habitats and biota may have taken place but the ecosystem functions are essentially unchanged.*

C *Moderately modified. Loss and change of natural habitat and biota have occurred, but the basic ecosystem functions are still predominantly unchanged.*

Table 1 provides a summary of the key water resources information. The study area is in the Crocodile West and Marico Water Management Area.

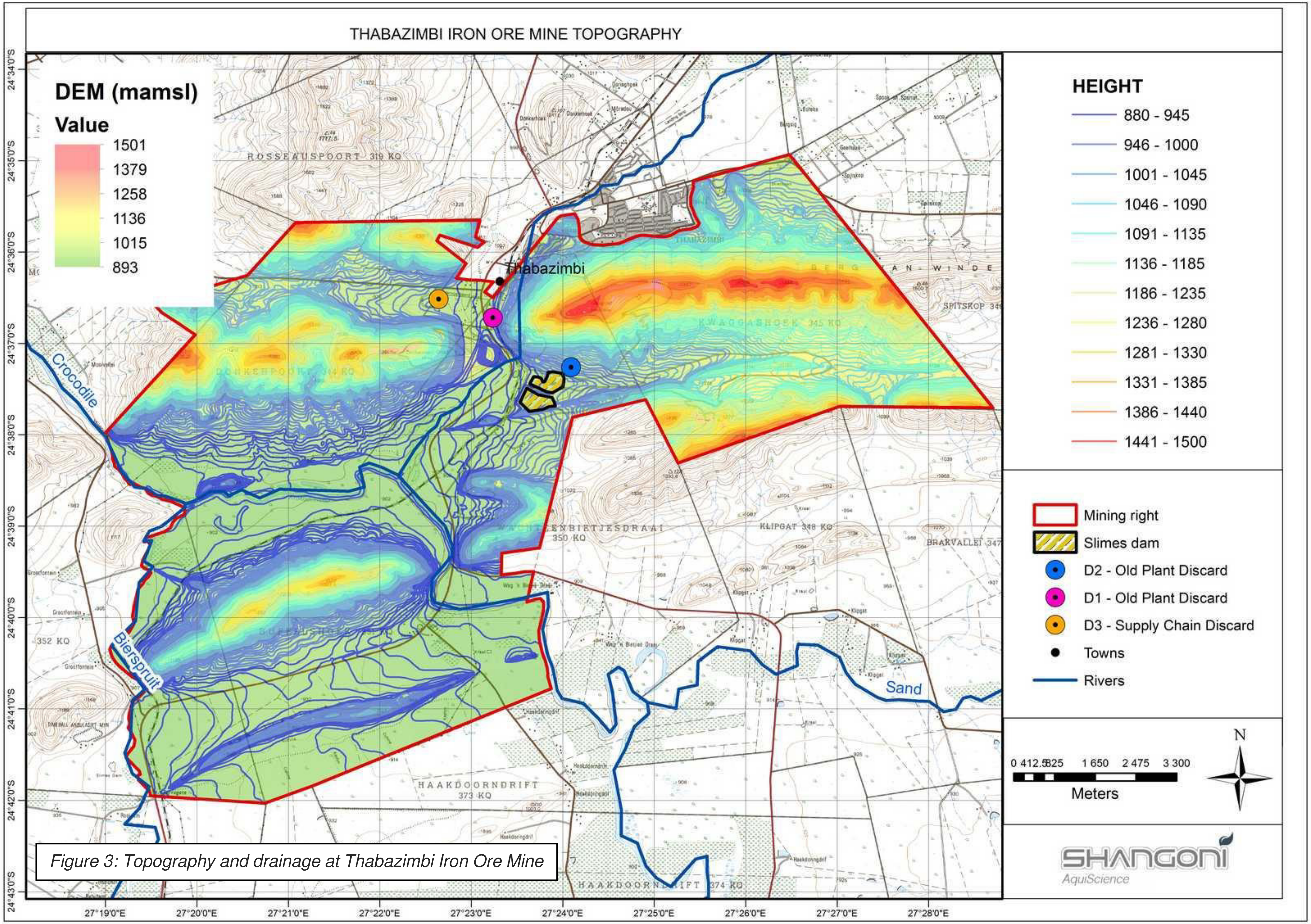
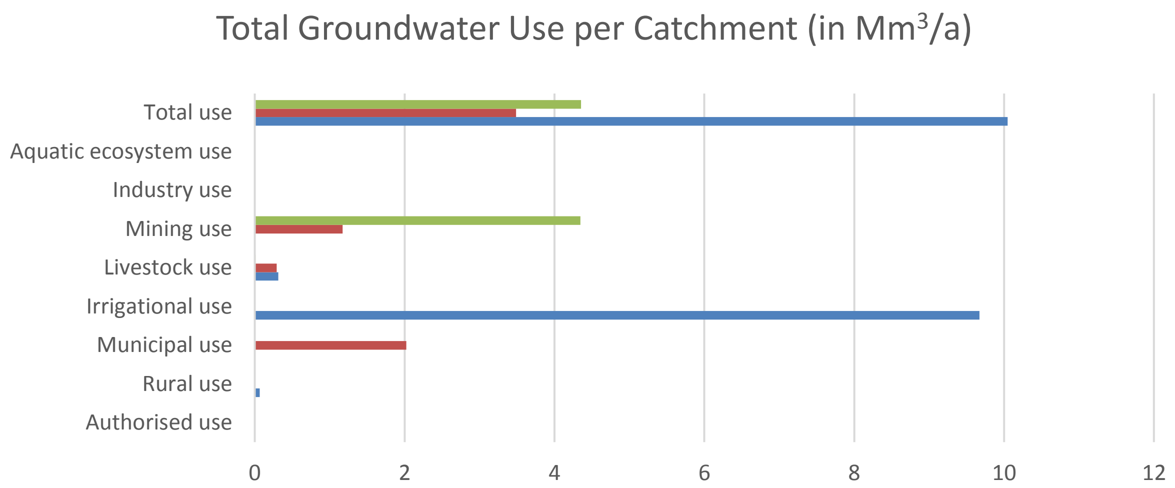


Figure 3: Topography and drainage at Thabazimbi Iron Ore Mine

Table 1: Key water resources information

Attribute/Catchment	A24J	A24H	A24F
Quaternary catchment area (km^2)	2515.9	1338.2	590.7
Mean annual rainfall (mm/a)	538	639	602
Mean annual runoff (mm/a)	6	34	13
Baseflow (mm/a)	0	4	0
Mean annual evaporation (mm/a)	1800 – 2000	1700 - 1800	1700 – 2000
Total groundwater use (Mm^3/a)	10.0475	3.4878	4.3545
Ecoregion	Limpopo Plain & Western Bankenveld	Western Bankenveld, Limpopo Plain, & Bushveld Basin	Western Bankenveld & Bushveld Basin
Present Eco Status Category	B	C	B
Recharge (mm/a)	13.8	27.88	17.77
Exploitation potential (Mm^3/a)	1.3	12	5
Vegetation type	Clay Thorn Bushveld, Savanna Bushveld & Sweet Bushveld	Mixed Bushveld & Waterberg Moist Mountain Bushveld	Mixed Bushveld & Clay Thorn Bushveld
Groundwater Region	Makoppa Dome, & Western Bankenveld and Bushveld	Waterberg Plateau, Western Bankenveld and Bushveld, & Western Bushveld Complex	Western Bushveld Complex & Western Bankenveld and Bushveld
Groundwater General Authorization m^3/ha/a	75	75	75

Irrigation is by far the greatest groundwater user in the region. This is followed by mining, municipal and livestock watering uses (Figure 4).



	Authorised use	Rural use	Municipal use	Irrigational use	Livestock use	Mining use	Industry use	Aquatic ecosystem use	Total use
A24F	0	0	0	0	0.0091	4.3454	0	0	4.3545
A24H	0	0	2.0236	0	0.292	1.1722	0	0	3.4878
A24J	0	0.065	0	9.6708	0.3117	0	0	0	10.0475

Figure 4: Total groundwater use in the relevant quaternary catchments

2.3 Climate

The site is located within a summer rainfall climatic region. The winters are typically cold but receive very little precipitation, whilst summers are hot and have high precipitation. The Mean Annual Precipitation ("MAP") ranges between 540 and 640 mm. Of the total MAP, approximately 90% falls between October and April. The winter months have a median rainfall of 0 mm but experience average minimum temperatures as low as of 2.8°C in June. The run-off, level of inundation and flow will all be higher in the summer months.

The area is known for its relatively high temperatures, with day temperatures that may rise above 40°C in summer. The mean maximum summer temperature is about 30°C.

3. SCOPE OF WORK

The aims of the project were to i) determine baseline geohydrological conditions; ii) assess probable water related impacts; and iii) to propose management plans and monitoring protocols to pro-actively manage all future potential water related impacts related to reworking/reclamation of the discard and slimes facilities at Thabazimbi Iron Ore Mine.

4. METHODOLOGY

The focus areas required to assess the geohydrological conditions were:

- Description of baseline environmental conditions.
- Determination of baseline (*status quo*) geohydrology of the area, which included a desktop study of the groundwater conditions and relevant environmental factors.
- Geochemical assessment of the facilities, which included whole rock analyses and leach assays.
- Development of a conceptual model based on current geohydrological conditions.
- Risk assessment of the geohydrological impact resulting from the activities. This included a description of anticipated groundwater related impacts during reworking/reclamation.
- Recommendations on a groundwater management framework and monitoring programme which will assist in the development of rehabilitation measures based on physical, hydraulic and hydro-geochemical information as gathered and predicted in the preceding phases.

A desk study was conducted to gather all relevant environmental information, including topographical, hydrological and geohydrological data. The investigation relied on information gathered from previous relevant studies conducted for the area as well as the results from the geochemical assessment.

4.1 Aquifer classification

The aquifer classification system used to classify South African aquifers is the National Aquifer Classification System developed by Parsons (1995). This system has a certain amount of flexibility and can be linked to second classifications such as a vulnerability or usage classification. Parsons suggested that aquifer classification forms a very useful planning tool that can be used to guide the management of groundwater issues.

The South African Aquifer System Management Classification is presented by five major classes listed below and defined in Table 2:

- Sole Source Aquifer System
- Major Aquifer System
- Minor Aquifer System
- Non-Aquifer System
- Special Aquifer System

Table 2: Aquifer classification scheme (Parsons, 1995)

Aquifer system	Defined by Parsons (1995)	Defined by DWA minimum requirements (DWAF, 1998)
Sole source aquifer	An aquifer that is used to supply 50% or more of domestic water for a given area, and for which there are no reasonable alternative sources should the aquifer become depleted or impacted upon. Aquifer yields and natural water quality are immaterial.	An aquifer, which is used to supply 50% or more of urban domestic water for a given area for which there are no reasonably available alternative sources should this aquifer be impacted upon or depleted.
Major aquifer	Highly permeable formations, usually with a known or probable presence of significant fracturing. They may be highly productive and able to support large abstractions for public supply and other purposes. Water quality is generally very good.	High yielding aquifer (5-20 l/s) of acceptable water quality.
Minor aquifer	These can be fractured or potentially fractured rocks that do not have a high primary hydraulic conductivity, or other formations of variable hydraulic conductivity. Aquifer extent may be limited and water quality variable. Although these aquifers seldom produce large quantities of water, they are both important for local supplies and in supplying base flow for rivers.	Moderately yielding aquifer (1-5 l/s) of acceptable quality or high yielding aquifer (5-20 l/s) of poor-quality water.
Non-aquifer	These are formations with negligible hydraulic conductivity that are generally regarded as not containing groundwater in exploitable quantities. Water quality may also be such that it renders the aquifer unusable. However, groundwater flow through such rocks does occur, although imperceptible, and needs to be considered when assessing risk associated with persistent pollutants.	Insignificantly yielding aquifer (< 1 l/s) of good quality water or moderately yielding aquifer (1-5 l/s) of poor quality or aquifer which will never be utilised for water supply and which will not contaminate other aquifers.
Special aquifer	An aquifer designated as such by the Minister of Water Affairs, after due process.	

4.2 Aquifer vulnerability

Groundwater plays an important role in supplying water to many regions of Southern Africa due to its low annual average precipitation of 460 mm, which is well below the world average of 860 mm. The quality of groundwater resources in South Africa has therefore received considerable focus and attention on the need for a proactive approach to protect these sources from contamination (Lynch *et. al.*, 1994). Groundwater protection needs to be prioritised based upon the susceptibility of an aquifer towards pollution. This can be done in two ways, namely i) pollution risk assessments and ii) aquifer vulnerability. Pollution risk assessments consider the characteristics of a specific pollutant, including source and loading while aquifer vulnerability considers the characteristics of the aquifer itself or parts of the aquifer in terms of its sensitivity to being adversely affected by a contaminant should it be released.

The DRASTIC model concept developed for the USA (Aller *et. al.*, 1987) is well suited for producing a groundwater vulnerability evaluation for South African aquifers. The DRASTIC evaluates the intrinsic vulnerability (*IV*) of an aquifer by considering factors including **D**epth to water table, natural **R**echarge rates, **A**quifer media, **S**oil media, **T**opographic aspect, **I**mpact of vadose zone media, and hydraulic **C**onductivity. Different ratings are assigned to each factor and then summed together with respective constant weights to obtain a numerical value to quantify the vulnerability:

$$\text{DRASTIC Index } (IV) = DrDw + RrRw + ArAw + SrSw + TrTw + IrIw + CrCw$$

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 3.

Table 3: South African National Groundwater Vulnerability Index to Pollution (Lynch et al, 1994)

Score	Vulnerability
50-87	Least susceptible
87 - 109	Moderate susceptible
109 - 226	Most susceptible

The concept of DRASTIC in vulnerability assessments is based on:

- A contaminant is introduced at the surface of the earth or just below it.
- 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.

The weighting for each parameter is constant. The minimum value for the DRASTIC index that one can calculate (assuming all seven factors were used in the calculation) is therefore 24 with the maximum value being 226. The higher the DRASTIC index the greater the vulnerability and possibility of the aquifer to become polluted if a pollutant is introduced at the surface or just below it.

4.3 Darcy Velocity

An important aspect in mass transport modelling to quantify is velocity as it is an indication of the rate at which groundwater and groundwater contamination would be or are moving. Two types of groundwater velocities are of interest to geohydrologists:

- The Darcy flux (or velocity) is the hydraulic conductivity (K) times the gradient of the water/piezometric level (i.e. q=Ki).
- Seepage velocity: The seepage velocity is defined as the Darcy flux divided by the effective porosity. This is also referred to as the average linear velocity.

Conservative saturated zone K values were used to *simulate worse case scenarios* with regards to contaminant transport. The average groundwater flow velocities, more accurately termed the Darcy velocity or seepage velocity (see above) are calculated using the equation:

$$v = \frac{Ki}{\emptyset}$$

where: v = seepage velocity (m/day)

K = hydraulic conductivity (m/day)

I = average hydraulic gradient

ϕ = probable average porosity

4.4 Groundwater quality

Relevant groundwater quality data was obtained from the 2018 *Annual Water Monitoring Report* as compiled by GCS (2018). The data and a discussion thereof are presented in Section 5.6.

4.5 Groundwater recharge

Recharge is defined as the addition of water to the saturated zone, either by the downward percolation of precipitation or surface water and/ or the lateral migration of groundwater from adjacent aquifers. The main source of recharge into the shallow primary aquifers is direct rainfall recharge that infiltrates the aquifer through the overlying unsaturated zone. Recharge to the deep aquifer/s is/are limited to vertical seepage from the shallow aquifer through permeable fracture systems that link the two aquifers hydraulically. Due to the heterogeneous nature of such fracture systems, it is assumed to be highly variable and some aquifers may be connected while others may be not.

5. PREVAILING GROUNDWATER CONDITIONS

A variety of anthropogenic activities affect groundwater flow and chemistry, the extent of which can only be quantified if the pre-mining situation was known. The purpose of this section is, therefore, to describe the pre-project environment to such an extent to quantify or qualify an impact should it be necessary. The area under investigation is not unaffected as Thabazimbi Iron Ore Mine is an already existing mine.

The status quo physical, hydrochemical and geochemical properties of the geohydrological regime are discussed in the following sections.

5.1 Geology

5.1.1 Regional geology

The geology of the Thabazimbi area consists of rocks of the late Archean to early Proterozoic Transvaal Supergroup. The Transvaal Supergroup in the Thabazimbi area mainly consists of the Chuniespoort and Pretoria Groups. Iron ore deposits are hosted by the Penge Formation of the Chuniespoort Group, which is usually in conformable contact with the underlying Malmani Subgroup.

The Malmani Subgroup of the Chuniespoort Group is up to 2000 m thick and is subdivided into five formations based on chert content, stromatolite morphology, intercalated shales and erosion surfaces. The stratigraphic succession of the Malmani Subgroup consists from oldest to youngest of the Oaktree Formation, successively overlain by the Monte Christo, Lyttelton, Eccles and Frisco Formations (Eriksson et al, 2006). The stratigraphy of the Thabazimbi area is summarised in Table 4.

Table 4: Stratigraphy of the Thabazimbi Iron Ore Mine area

	Group	Formation	Lithology
Transvaal Supergroup			Diabase Intrusions
	Pretoria	Magaliesberg Quartzite	Quartzite
		Silverton Shale	Shale
		Daspoort Quartzite	Quartzite
		Strubenkop Shale	Shale, quartzite and conglomerate
		Hekpoort Andesite	Andesite
		Timeball Hill	Shale, quartzite
		Rooihoogte	Quartzite, diamictite and conglomerate

	Unconformity			
	Chuniespoort	Penge		Banded Iron Formation
		Malmani Subgroup	Frisco	Stromatolitic dolomite and shale
			Eccles	Chert-rich dolomite and shale
			Lyttleton	Shales, quartzites and stromatolitic dolomites
			Monte Christo	Erosive breccia and stromatolitic and oolitic platformal dolomites
			Oaktree	Carbonaceous shales, stromatolitic dolomites and locally developed quartzires

5.1.2 Local geology

The iron ore at the Thabazimbi Mine consists of high-grade haematite (Fe_2O_3) which occurs in the basal parts of the Penge Formation and is underlain by the chert-poor dolomite of the Frisco Formation (Malmani Subgroup) as presented in Figure 5.

The Penge formation is usually in conformable contact with the underlying Malmani Subgroup and is composed mainly of gruneritic-banded chert with interbedded carbonaceous shale. However, at the Thabazimbi Mine the chert-rich basal part of the Penge Formation is missing. The basal unit of the Penge Formation therefore unconformably overlies the Malmani Subgroup and is most likely due to normal faulting in the Thabazimbi area (Netshiozwi, 2002).

The Penge formation is furthermore unconformably overlain by the clastic sediments and volcanic rocks of the Pretoria Group. The intrusion of the Bushveld Complex tilted the lithology approximately 60^{o} to the south. Waterberg-age tectonism duplicated the ore zone due to faulting, while subsequent differential weathering formed two prominent mountain ranges, the Northern and Southern Ranges, with a smaller Middle Range in between. Post-Karoo normal faulting and the intrusion of dolerite dykes have further disrupted the ore zone.

5.1.3 Structural geology

The Thabazimbi area has a complex structural setting and tectonic history. The iron ore deposits are situated along the east-west trending Mohlapitsi fold belt, which were influenced by generations of fault movements. The Penge Formation is intensely folded and faulted along the Mohlapitsi fold belt and axial planes of the folds are near-vertical or tend to dip steeply towards the south-east.

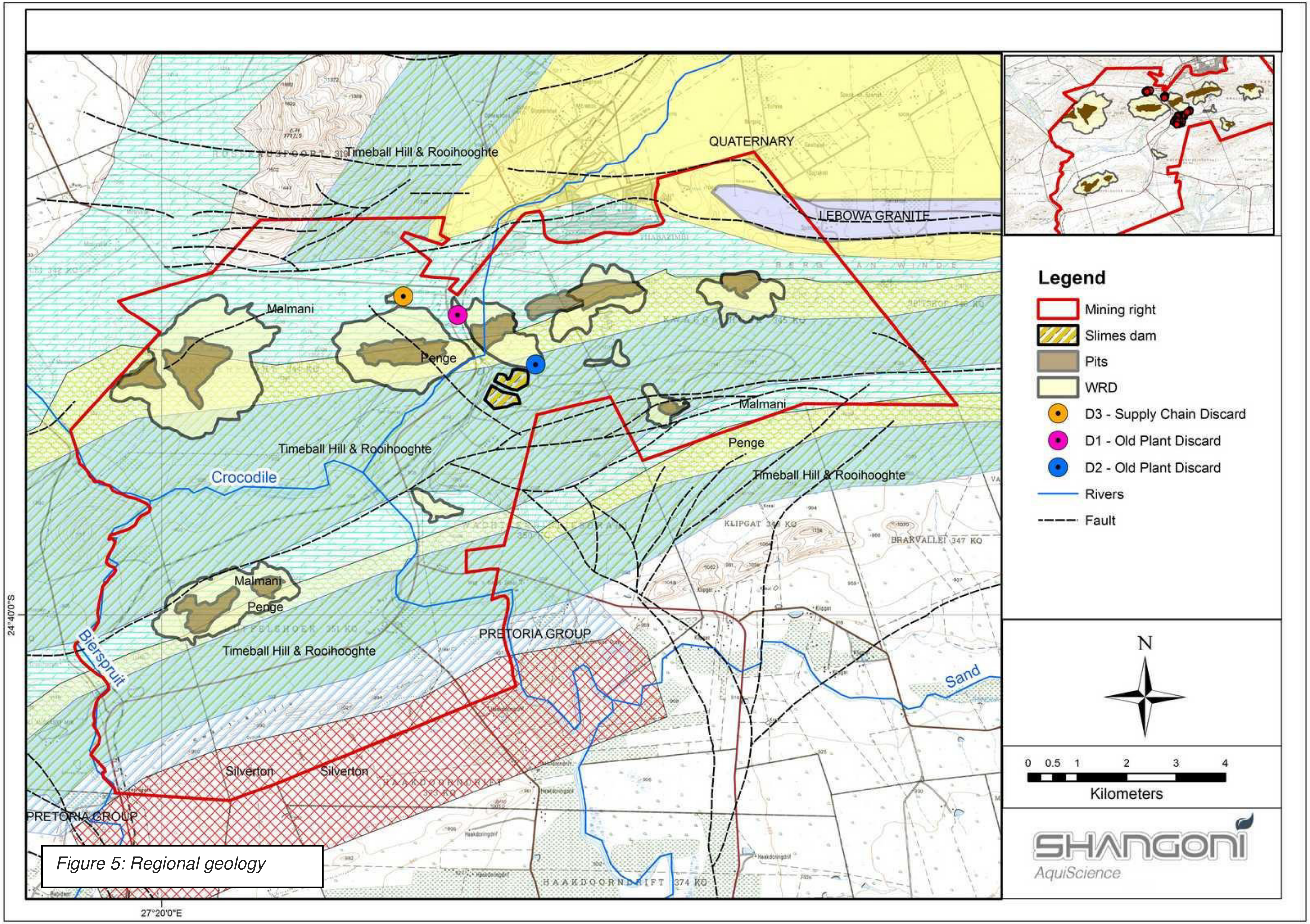


Figure 5: Regional geology

Initial deformation along the Mohlapitsi fold zone started before the intrusion of the Bushveld Igneous Complex. The intrusion of the Bushveld Complex resulted in the southward dipping of the Transvaal Supergroup lithology in the Thabazimbi area. The southward dipping of the Transvaal Supergroup was followed by a period of denudation and erosion, which eroded large parts of the Transvaal Supergroup lithology. The Waterberg Group red-beds was deposited on the erosional surface. A deformed unconformity between the Bushveld Complex and Waterberg Group strata indicates further Post-Waterberg aged deformation.

The Thabazimbi area has undergone intense low-angle thrusting from the south and contains several east-west striking thrust faults, especially between the Northern and Southern Ranges. Along the thrust faults, dolomites are strongly folded and faulted. At the Donkerpoort-West pit, the Penge Formation shows intense fold structures which are cut by younger faults (Netshiozwi, 2002). Post-Karoo tensional deformation resulted in the development of several east-west and north-south striking faults (Steenekamp and Fourie, 1998).

Potential preferential pathways created by dykes and faults intersect several of the pits, especially at Donkerpoort West/Kumba, Buffelshoek and Kwaggashoek.

5.3 Hydrogeology

5.3.1 Unsaturated zone (vadose zone)

The characteristics of vadose zone vulnerability dominating factors are closely related to the migration and transformation mechanisms of contaminants in the vadose zone, which directly affect the state of the contaminants percolating to the groundwater. The permeability and thickness of the unsaturated zone are some of the main factors determining the infiltration rate, the amount of runoff and consequently the effective recharge percentage of rainfall to the aquifer. The type of material forming the unsaturated zone as well as the permeability and texture will significantly influence the mass transport of surface contamination to the underlying aquifer(s). Factors like ion exchange, retardation, biodegradation and dispersion all play a role in the unsaturated zone.

The thickness of the unsaturated zone was determined by subtracting the undisturbed static water levels in the study area from the topography. Water level measurements showed that the depth to water level, and thus the unsaturated zone, generally varies between 2 and 80 mbs.

5.3.2 Saturated zone

On a regional scale, six (6) different aquifer regions are distinguished in the Thabazimbi area and can be grouped as:

- Crocodile River primary aquifer;

- Quartzite, shale and andesite aquifer;
- Penge banded iron formation aquifer;
- Malmani Subgroup dolomite aquifer;
- Breccia Basin aquifer; and
- Bushveld Igneous Complex aquifer.

The weathered aquifer can be described as an intergranular water table aquifer that may be laterally connected to alluvial aquifers associated with river systems. The average depth of weathering is between 20 and 30 mbs while average water levels are between 20 and 40 mbs (GCS, 2018; 2019).

The water table is a subdued reflection of the topography, and groundwater flow is from areas of higher lying ground to the north east and south west towards the Crocodile River, Sand River, and Rooikuilspruit. The flow gradient in the high-lying area is steep, around 1:20 and flattens out into the valleys and in the vicinity of the Crocodile River, where the gradient averages 1:300. The regional drainage features include the perennial Crocodile River, Rooikuilspruit, and Sand River, as well as the ephemeral Sterkspruit, Vaalwaterspruit, Bierspruit, and Klipspruit.

5.3.3 Hydraulic conductivity

Groundwater Consulting Services ("GCS") developed a numerical groundwater model for Thabazimbi to simulate closure and rehabilitation scenarios and aquifer responses to rehabilitation. Table 5 presents the range of hydraulic properties for the different hydrogeological formations represented by the model developed and calibrated by GCS. The model was assigned recharge and effective porosity zones similar to the assigned hydraulic conductivity zones (GCS, 2019).

Table 5: Hydraulic parameters for the Thabazimbi Mine aquifers (GCS, 2019)

Hydrostratigraphic unit	Hydraulic conductivity (m/d)		Transmissivity (m^2/d)	Effective porosity
	Horizontal	vertical		
Alluvium / Quaternary sedimentary cover and weathered aquifer	$8.2x10^{+0}$ – $1.0x10^{+2}$	$8.2x10^{-1}$ – $1.0x10^{+3}$	$4.1x10^{+2}$ – $5x10^{+3}$	$3.0x10^{-1}$
Fractured aquifer	$9.8x10^{+3}$ – $1.7x10^{-1}$	$9.8x10^{+2}$ – $1.7x10^{-2}$	$1.5x10^{+0}$ – $2.6x10^{+1}$	$1.0x10^{-3}$ – $5.0x10^{-2}$
Lineament structures – faults	$1.5x10^{+0}$	$1.5x10^{+0}$	$3.0x10^{+2}$	$5.0x10^{-2}$
Diabase	$5.0x10^{-3}$	$5.0x10^{-4}$	$1.1x10^{+0}$	$6.0x10^{-3}$
Breccia Basin	$2.8 x 10^{+1}$	$2.8 x 10^{+2}$	$1.4x10^{+3}$	$3x10^{-1}$

5.4 Groundwater levels

Thabazimbi Iron Ore Mine maintains an effective surface and groundwater monitoring programme. The objective of the monitoring programme is to detect any changes in the water levels and water quality at cessation of mine production compared to the available mine and natural baseline environments. The monitoring network consists of regional boreholes to obtain background data away from the mine and local monitoring boreholes within the mining site. Water quality as well as water levels are monitored to determine the hydraulic heads as well as the contaminant risk to the natural environment and to surrounding users.

Monitoring of water levels were conducted at 58 boreholes during the 2018 annual water monitoring period by GCS. The monitoring was conducted on a quarterly basis for the first year, thereafter bi-annually. The current distribution of the groundwater water monitoring points is shown in Figure 6.

The groundwater levels obtained during the August 2019 monitoring event ranged between 5.75 and 73.36 mbs. Generally, groundwater levels have increased post closure and stabilised since 2017 (GCS, 2019).

Seventeen boreholes, which are in vicinity of the 2 discard dumps and 4 slimes compartments, are applicable to this project. These boreholes are listed in Table 6 and their locations relative to the facilities are shown in Figure 7. These boreholes mostly function as source monitoring boreholes to identify seepage from the facilities into the groundwater while others are background boreholes located upgradient from the facilities.

Table 6: Groundwater monitoring localities relevant to the project

Facility	Boreholes
Slimes compartments	NBH2, BA06 BH1314, BA6 Slikdam-16
D1 -old plant discard	BH013330, SM1, BTD1, BHO1330, Boorgat16a-35, BHO1323
D3 -Supply chain discard	BH01332, BH01328, Borehole 9-24, BH1327, BH01325,

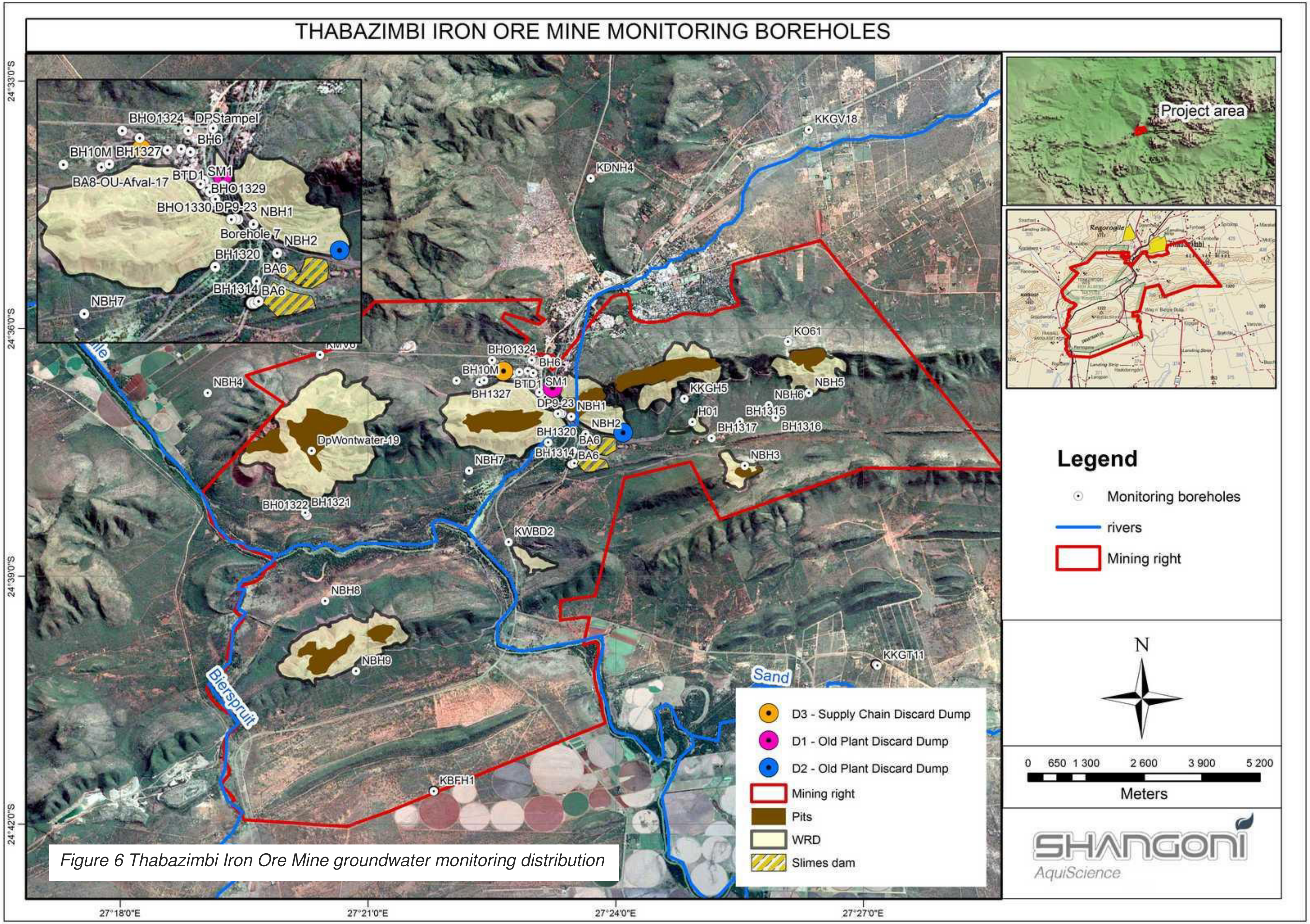


Figure 6 Thabazimbi Iron Ore Mine groundwater monitoring distribution

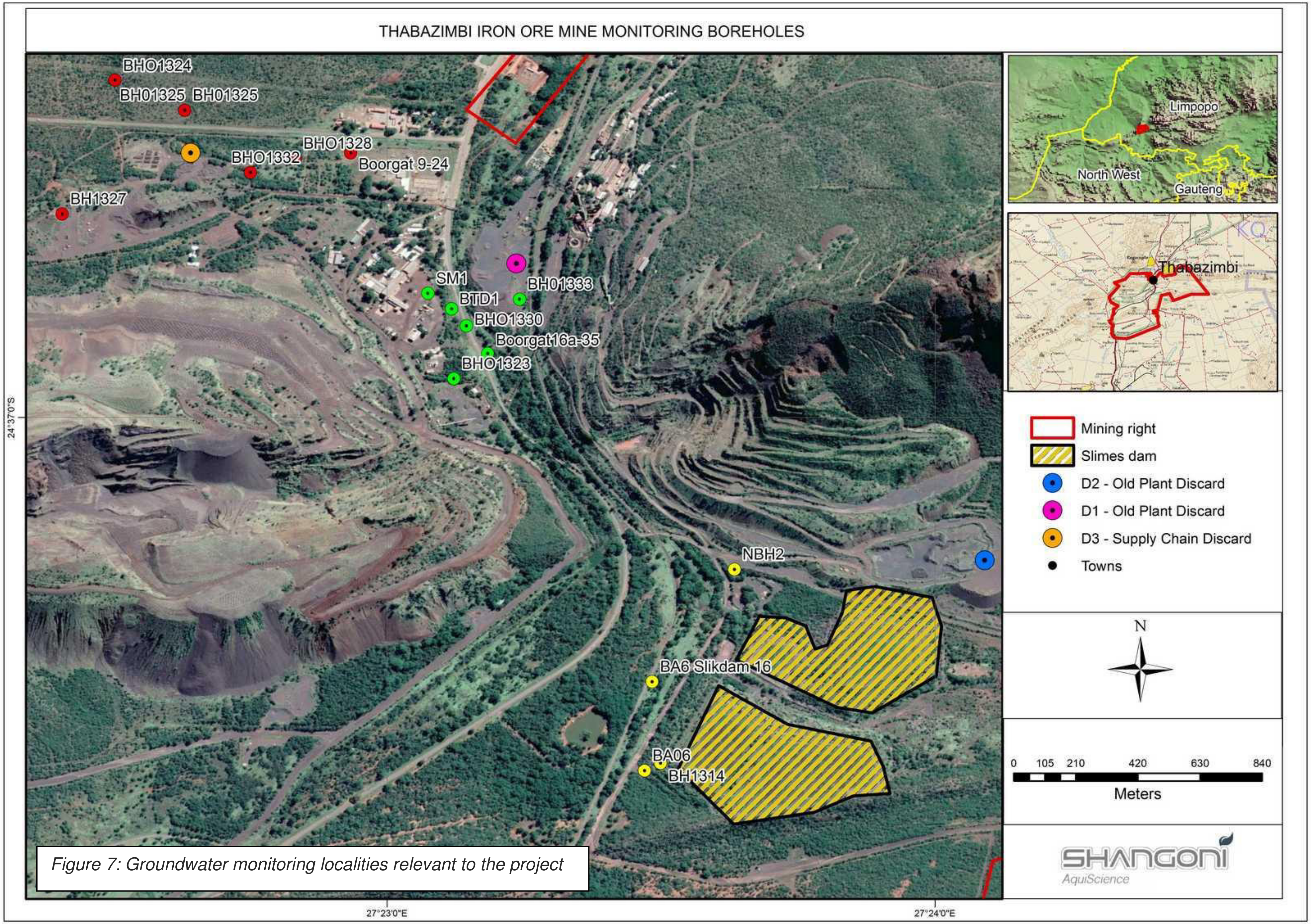


Figure 7: Groundwater monitoring localities relevant to the project

Figure 8 shows the available groundwater levels for the boreholes relevant to the present project. Rebounding water levels are evident between December 2016 to April 2017 during post closure where after a seasonal effect is noted.

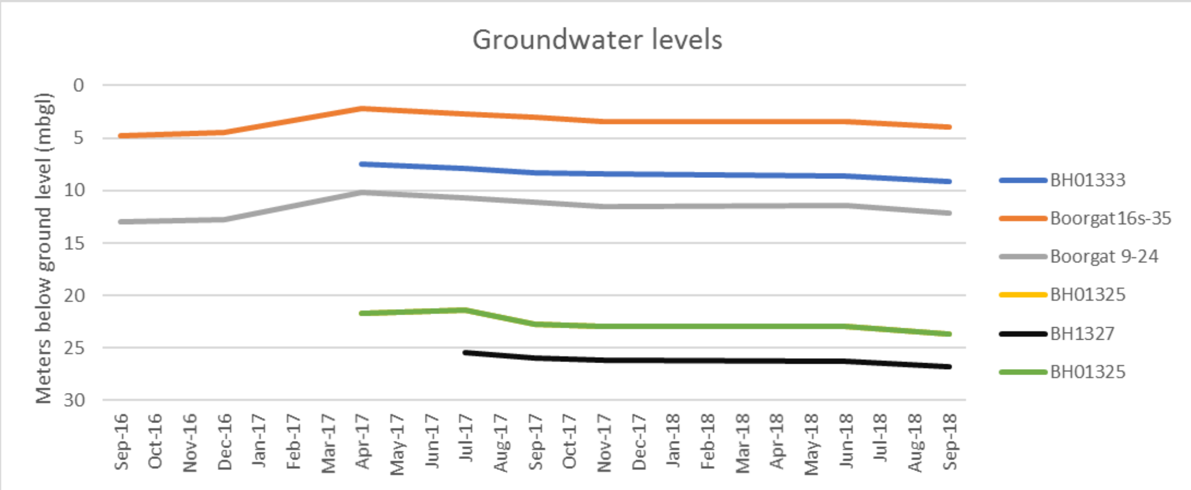


Figure 8: Groundwater levels recorded within boreholes relevant to the project

5.5 Groundwater potential contaminants

As part of this study, a geochemical investigation was performed to identify contaminants of concern ("CoC") and specific elements that will pose an environmental and leachate risk. Whole rock elemental analyses (aqua regia) including a leachate assessment (1:20 solid:distilled water) were performed. Where relevant, the results were evaluated according to the National Norms and Standards for the Assessment of Waste for Landfill Disposal (GNR635).

A total of 35 samples were taken on 10 December 2019 from the 4 slimes compartments and 2 discard dumps. These were subsequently composited into 6 samples representing the various facilities. The sampling localities can be viewed in Figure 9.

The results for the major elements as recorded in the whole rock analyses are displayed in figure 10. Some differences exist between the slimes and the discard facilities but only with regards to contents of silica oxide (SIO_2), iron oxide/hematite (Fe_2O_3), total iron, calcium oxide (CaO) and magnesium oxide (MgO). The iron content is substantially greater in the slimes compared to the discard samples with Fe_2O_3 ranging between 68% and 76% and 40% to 44%, respectively. MnO and Al_2O_3 are also slightly more raised in the slimes samples. The discard samples are dominated by SiO (40 – 44%), followed by Fe_2O_3 (~47%), CaO and MgO (1% – 2%).

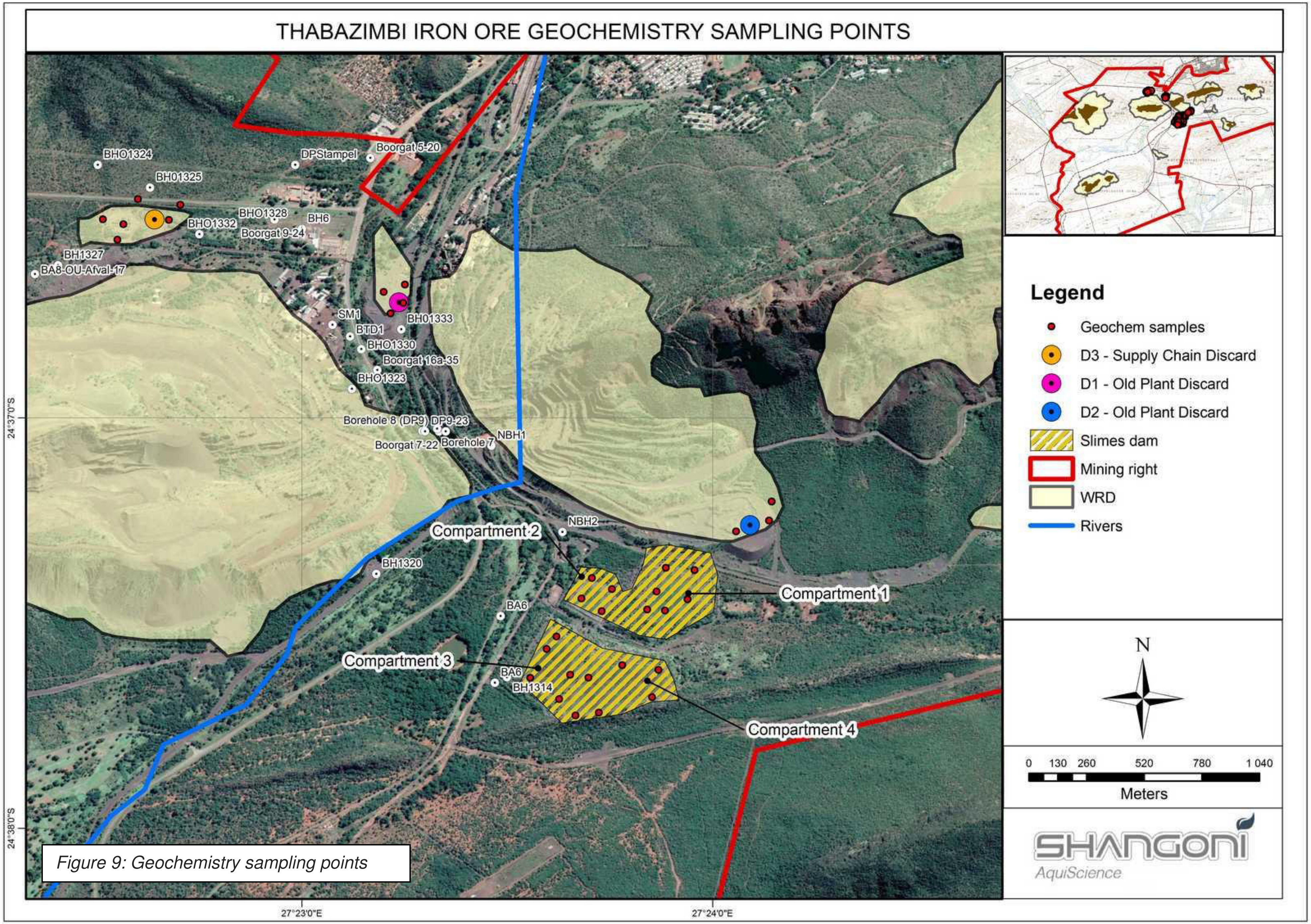
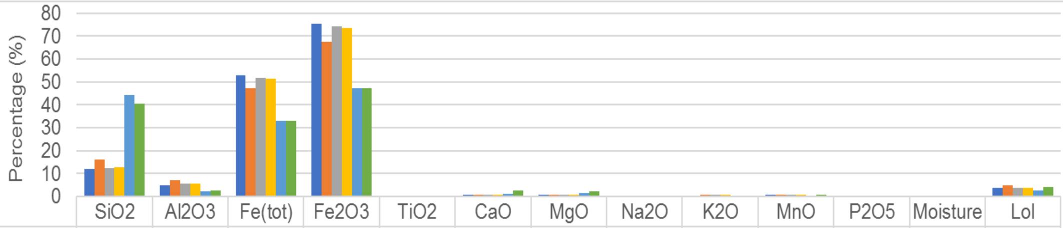


Figure 9: Geochemistry sampling points



	SiO2	Al2O3	Fe(tot)	Fe2O3	TiO2	CaO	MgO	Na2O	K2O	MnO	P2O5	Moisture	LoI
Slimes 1	11.8	4.76	52.8	75.5	0.261	0.68	0.87	0.028	0.463	0.816	0.081	0.04	3.7
Slimes 2	16.2	7.15	47.3	67.6	0.321	0.6	0.85	0.033	0.699	0.893	0.08	-0.06	4.89
Slimes 3	12.5	5.55	51.8	74.1	0.29	0.8	0.92	0.036	0.59	0.805	0.096	-0.02	3.83
Slimes 4	12.9	5.75	51.4	73.4	0.28	0.64	0.75	0.031	0.608	0.861	0.082	0.02	3.81
Old Plant Discard	44.2	2.19	33.1	47.3	0.125	1.17	1.3	0.02	0.423	0.413	0.033	0.08	2.64
Supply Chain Discard	40.4	2.51	32.9	47.1	0.42	2.46	2.33	0.047	0.346	0.66	0.023	0	4

Figure 10: Whole rock analyses of major oxides, loss on material on ignition (LoI) and moisture content

The National Norms and Standards for the Assessment of Waste for Landfill Disposal (GNR635) under section 7(1)(c) of the National Environmental Management: Waste Act, 2008 (Act No. 59 of 2008) were promulgated on 23 August 2013. According to these Norms and Standards, waste is classified as a certain "Type" based on its risk profile, ranging from *Type 0* (extremely hazardous) to *Type 4* (inert insignificant risk).

The criteria below are used to determine the risk for contaminant release (Table 7).

Table 7: Description of risk associated with disposal to land

Criteria	Waste Disposal Risk Rating	Description of Risk associated with disposal to land
LC > LCT3, or TC > TCT2	Type 0: Very High Risk	Considered very high-risk waste with a very high potential for contaminant release. Requires very high level of control and ongoing management to protect health and environment.
LCT2 < LC ≤ LCT3, or TCT1 < TC ≥ TCT2	Type 1: High Risk	Considered high risk waste with a very high potential for contaminant release. Requires very high level of control and ongoing management to protect health and environment.
LCT1 < LC ≤ LCT2 and TC ≤ TCT1	Type 2: Moderate Risk	Considered moderate risk waste with some potential for contaminant release. Requires proper control and ongoing management to protect health and the environment.
LCT0 < LC ≤ LCT1 and TC ≤ TCT1	Type 3: Low Risk	Low risk waste with low potential for contaminant release. Requires some level of control and ongoing management to protect health and the environment.
TC < 20 x LCT1, or LC ≤ LCT1 and TC ≤ TCT1	Type 4: Inert Waste	Very low risk waste that- (a) Does not undergo any significant physical, chemical or biological transformation; (b) does not burn, react physically or chemically or otherwise affect any matter with which it may come into contact; and (c) does not impact negatively on the environment because of its very low pollutant content and because the toxicity of its leachate is insignificant. Only basis control and management required.

The whole rock elemental analysis revealed certain elements to be present in the parts per billion (ppb) and parts per million (ppm) ranges (Table 8). The significance of these concentrations is directly related to the degree of toxicity that may result after exposure long- or short term. Therefore, threshold limits were established to "classify" waste materials (including mining related stockpiles or residue dumps) with reference to their potential environmental risk.

Table 8: Total trace element concentration results evaluated according to the Total Concentration Threshold (TCT) Limits

Elements & Chemical Substances	Slimes 1	Slimes 2	Slimes 3	Slimes 4	Old Plant Discard	Supply Chain Discard	*TCT0*	*TCT1*
Ag, silver (mg/kg)	0.07	0.08	0.07	0.08	0.04	0.05	n/a	n/a
As, arsenic (mg/kg)	16.2	16.2	15.9	14.2	9.58	11.4	5.8	500
B, boron (mg/kg)	21.0	31.0	31.7	33.9	19.2	20.7	150	15000
Ba, barium (mg/kg)	154	209	181	180	86	129	62.5	6250
Be, beryllium (mg/kg)	2.96	3.31	3.22	3.12	1.75	1.85	n/a	n/a
Bi, bismuth (mg/kg)	0.28	0.31	0.26	0.28	0.16	0.28	n/a	n/a
Cd, cadmium (mg/kg)	0.15	0.17	0.15	0.14	0.07	0.11	7.5	260
Ce, cerium (mg/kg)	50.6	23.5	36.8	28.2	37.4	49.4	n/a	n/a
Co, cobalt (mg/kg)	18.5	23.7	20.3	21.3	11.7	14.9	50	5000
Cr, chromium (mg/kg)	96.9	105.4	97.6	93.2	46.3	87.5	46000	800000
Cs, caesium (mg/kg)	1.23	1.17	1.38	1.09	1.70	1.43	n/a	n/a
Cu, copper (mg/kg)	68.7	111	63.9	63.0	18.8	39.5	16	19500
Ga, gallium (mg/kg)	4.70	7.20	5.47	6.19	3.26	4.47	n/a	n/a
Ge, germanium (mg/kg)	2.30	1.89	2.44	1.88	2.66	2.56	n/a	n/a
Hf, Hafnium (mg/kg)	2.29	3.08	2.29	2.46	1.19	1.62	n/a	n/a
Hg, mercury (mg/kg)	0.05	0.04	0.06	0.05	0.01	0.03	0.93	160
Ho, holmium (mg/kg)	0.58	0.52	0.55	0.54	0.45	0.50	n/a	n/a
La, lanthanum (mg/kg)	36.0	12.3	22.5	17.2	29.1	33.6	n/a	n/a
Li, lithium (mg/kg)	16.7	16.9	18.0	15.6	14.0	19.9	n/a	n/a
Mn, manganese (mg/kg)	6731	7334	6655	7079	3385	5468	1000	25000
Mo, molybdenum (mg/kg)	1.13	1.04	0.98	0.92	0.63	0.69	40	1000
Nb, niobium (mg/kg)	3.47	3.07	3.69	2.86	2.07	3.06	n/a	n/a

Elements & Chemical Substances	Slimes 1	Slimes 2	Slimes 3	Slimes 4	Old Plant Discard	Supply Chain Discard	*TCT0*	*TCT1*
Nd, neodymium (mg/kg)	20.4	11.4	16.1	14.3	16.6	19.2	n/a	n/a
Ni, nickel (mg/kg)	82.7	100	86.6	84.5	46.1	64.4	91	10600
Pb, lead (mg/kg)	6.97	8.21	8.36	8.65	4.85	5.59	20	1900
Rb, rubidium (mg/kg)	12.2	3.28	7.61	4.02	12.3	10.2	n/a	n/a
Sb, antimony (mg/kg)	1.69	1.55	1.76	1.56	1.09	1.25	10	75
Sc, scandium (mg/kg)	3.85	6.30	5.36	5.43	4.58	4.29	n/a	n/a
Se, selenium (mg/kg)	0.08	0.13	0.02	0.12	0.02	0.09	10	50
Sn, tin (mg/kg)	1.05	1.20	1.08	1.03	0.86	1.27	n/a	n/a
Sr, strontium (mg/kg)	30.8	31.2	32.1	34.5	12.5	17.8	n/a	n/a
Ta, tantalum (mg/kg)	0.34	0.35	0.35	0.31	0.26	0.47	n/a	n/a
Te, tellurium (mg/kg)	0.05	0.06	0.06	0.05	0.04	0.08	n/a	n/a
Th, thorium (mg/kg)	14.3	9.34	9.74	9.49	12.6	11.3	n/a	n/a
Tl, thallium (mg/kg)	0.22	0.25	0.21	0.21	0.21	0.16	n/a	n/a
U, uranium (mg/kg)	3.70	4.09	3.90	3.81	2.23	2.13	n/a	n/a
V, vanadium (mg/kg)	29.4	28.1	31.4	26.9	19.5	24.5	150	2680
W, tungsten (mg/kg)	3.17	1.78	2.69	1.92	2.73	3.09	n/a	n/a
Y, yttrium (mg/kg)	22.4	16.6	19.2	19.0	16.3	19.5	n/a	n/a
Zn, zinc (mg/kg)	57.4	69.1	63.5	57.1	33.1	50.2	240	160000
Zr, zirconium (mg/kg)	117	153	103	130	59.0	73.0	n/a	n/a
F^-, fluoride (mg/kg)	184	255	240	186	133	209	100	10000
Cr^{6+}, hexavalent chromium (mg/kg)	<5	<5	<5	<5	<5	<5	6.5	500

Certain elements recorded concentrations that exceed the TCT0 thresholds, but none were recorded to exceed the TCT1 threshold limits. The following elements exceed the TCT0 limits:

- Arsenic (As), barium (Ba), copper (Cu), manganese (Mn), nickel (Ni) and fluoride (F).

It must be stressed that the exceedances of these elements only imply potential risks since only the bioavailable fractions are potentially hazardous to the environment.

The results of the leachate assessments are shown in Table 9. The results, evaluated according to the GNR635 LCT limits, show low mobility of trace elements, most being in undetected ranges while major elements such as calcium (Ca), potassium (K), sodium (Na), magnesium (Mg), chloride (Cl) and silicon (Si) recorded in ppm ranges. The pH levels are circum-neutral to slightly alkaline and TDS levels are relatively low. Traces of nitrate (NO_3) were recorded for most samples, while F leached in ppm ranges for the 4 slimes compartments but was undetected in the discard samples. Sulphate (SO_4) was undetected in all samples. None of the elements that exceeded the TCT0 limits were detected in substantial amounts in the leachate assessment and these, including the remaining potentially hazardous elements, recorded well below the LCT0 limits and can be regarded as non-mobile.

Table 9: Leachable inorganic concentration results evaluated according to the Leachable Concentration Threshold (LCT) Limits

Elements & Chemical Substances	Slimes 1	Slimes 2	Slimes 3	Slimes 4	Old Plant Discard	Supply Chain Discard	LCT0	LCT1
Inorganics and anions								
pH	7.84	7.70	7.91	7.80	7.91	8.66	n/a	n/a
TDS (mg/l)	62.0	122	46.0	76.0	40.0	46.0	1000	12500
EC (mS/m)	7.27	14.9	7.29	8.11	4.68	6.60	n/a	n/a
P Alk, carbonate alkalinity (mg/l $CaCO_3$)	<0.6	<0.6	<0.6	<0.6	<0.6	2.40	n/a	n/a
M Alk, total alkalinity (mg/l $CaCO_3$)	33.2	32.4	29.3	29.1	22.2	30.5	n/a	n/a
F, fluoride (mg/l)	0.30	0.32	0.30	0.31	<0.1	<0.1	100	10000
Cl, chloride (mg/l)	1.42	8.69	3.24	5.76	<0.25	<0.25	300	15000
NO_3, nitrate (mg/l)	<0.1	0.72	0.40	0.10	0.38	<0.1	11	550
SO_4, sulphate (mg/l)	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8	250	12500
Chemical elements								
Ag, silver (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	n/a	n/a
Al, aluminium (mg/l)	0.299	0.014	0.180	0.035	0.090	0.048	n/a	n/a
As, arsenic (mg/l)	0.001	0.001	0.001	<0.001	<0.001	<0.001	0.01	0.5
Au, gold (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	n/a	n/a
B, boron (mg/l)	0.079	0.030	0.027	0.027	0.045	0.042	0.5	25
Ba, barium (mg/l)	0.188	0.075	0.074	0.079	0.127	0.120	0.7	35
Be, beryllium (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	n/a	n/a
Bi, bismuth (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	n/a	n/a
Ca, calcium (mg/l)	10.3	16.7	9.88	11.2	7.00	8.27	n/a	n/a
Cd, cadmium (mg/l)	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.003	0.15
Ce, cerium (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	n/a	n/a
Co, cobalt (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.5	25

Elements & Chemical Substances	Slimes 1	Slimes 2	Slimes 3	Slimes 4	Old Plant Discard	Supply Chain Discard	LCT0	LCT1
Cr, chromium (mg/l)	0.009	0.011	0.009	0.008	<0.001	0.001	0.1	5
Cs, caesium (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	n/a	n/a
Cu, copper (mg/l)	0.002	0.005	<0.001	<0.001	<0.001	<0.001	2.0	100
Fe, iron (mg/l)	0.24	0.01	0.09	0.01	0.04	0.02	n/a	n/a
Ga, gallium (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	n/a	n/a
Ge, germanium (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	n/a	n/a
Hf, hafnium (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	n/a	n/a
Hg, mercury (mg/l)	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.006	0.3
Ho, holmium (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	n/a	n/a
Ir, iridium (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	n/a	n/a
K, potassium (mg/l)	2.21	3.99	1.99	1.79	0.48	0.55	n/a	n/a
La, lanthanum (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	n/a	n/a
Li, lithium (mg/l)	0.001	0.001	0.001	0.001	0.001	0.002	n/a	n/a
Mg, magnesium (mg/l)	2.17	4.0	2.14	2.44	1.32	1.47	n/a	n/a
Mn, manganese (mg/l)	0.008	0.005	0.002	<0.001	<0.001	<0.001	0.5	25
Mo, molybdenum (mg/l)	0.003	0.004	0.003	0.003	<0.001	<0.001	0.07	3.5
Na, sodium (mg/l)	5.89	6.17	2.95	4.40	2.58	2.61	n/a	n/a
Nb, niobium (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	n/a	n/a
Nd, neodymium (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	n/a	n/a
Ni, nickel (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.07	3.5
Pb, lead (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.01	0.5
Pt, platinum (mg/l)	<0.001	<0.001	<0.001	<0.001	0.001	0.001	n/a	n/a
Rb, rubidium (mg/l)	0.001	0.001	<0.001	<0.001	<0.001	<0.001	n/a	n/a
Sb, antimony (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.02	1
Sc, scandium (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	n/a	n/a
Se, selenium (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.01	0.5
Si, silicon (mg/l)	3.54	2.98	2.45	2.21	2.01	2.33	n/a	n/a
Sn, tin (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	n/a	n/a
Sr, strontium (mg/l)	0.010	0.014	0.007	0.008	0.006	0.005	n/a	n/a

Elements & Chemical Substances	Slimes 1	Slimes 2	Slimes 3	Slimes 4	Old Plant Discard	Supply Chain Discard	LCT0	LCT1
Ta, tantalum (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	n/a	n/a
Te, tellurium (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	n/a	n/a
Th, thorium (mg/l)	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	n/a	n/a
Ti, titanium (mg/l)	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	n/a	n/a
Tl, thallium (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	n/a	n/a
U, uranium (mg/l)	0.0002	0.0002	0.0002	0.0002	<0.0001	<0.0001	n/a	n/a
V, vanadium (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.2	10
W, tungsten (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	n/a	n/a
Y, yttrium (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	n/a	n/a
Zn, zinc (mg/l)	0.002	0.014	0.001	0.002	0.002	0.005	5	250
Zr, zirconium (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	n/a	n/a
Cr^{6+}, hexavalent chromium (mg/l)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	6.5	500

5.6 Water quality

As mentioned previously, 17 boreholes are applicable to this project (refer to Table 6 and Figure 7). These boreholes function either as source monitoring or background boreholes located up- or downgradient relative the slime compartments or discard dumps. Bi-annual groundwater monitoring is performed by GCS and the 2018 annual monitoring report (GCS, 2018) was made available for sourcing of data.

5.6.1 Groundwater monitoring at the slimes dam compartments

Four (4) boreholes monitor the groundwater quality downgradient from the 4 slimes compartments at TIOM. Data for the 2 bi-annual monitoring periods in 2018 are displayed in Table 10 and Stiff diagrams and an Expanded Durov diagram in figures 11 and 12. Note that no data is available for *BA6* or *BA6 Slikdam-16*. According to GCS (2018) these boreholes are most probably destroyed.

Table 10: Groundwater quality sampled from groundwater downgradient from the slimes compartments (GCS, 2018)

Parameters	SANS 214: 2015	NBH2		BH1314	
		Jun-18	Nov'18	Jun-18	Nov-18
pH	5.0-9.7	7.4	7.65	7.66	7.86
EC (mS/m)	170	42.3	45.4	19.4	25.9
TDS (mg/l)	1200	314	298	132	130

Total alkalinity (mg $CaCO_3$/l)	na	222	203	34.9	25.9
Total hardness (mg $CaCO_3$/l)	na	249	215	89	86
Ca (mg/l)	na	29.8	27.4	14.3	14.8
Mg (mg/l)	na	42.3	35.7	13	12
Na (mg/l)	200	23.2	19.8	18.2	17.2
K (mg/l)	na	0.806	0.785	0.825	0.665
Cl (mg/l)	300	37	33.5	58.7	65
SO_4 (mg/l)	250, 500	7.05	6.38	<0.141	<0.141
NO_3-N (mg/l)	11	2.49	4.28	0.201	0.262
NH_4-N (mg/l)	1.5	0.04	0.058	0.223	0.272
PO_4-P (mg/l)	na	<0.005	<0.005	<0.005	<0.005
F (mg/l)	1.5	<0.263	<0.263	<0.263	<0.263
Al (mg/l)	0.3	<0.002	<0.002	<0.002	<0.002
As (mg/l)	0.007	<0.006	<0.006	<0.006	<0.006
Ba (mg/l)	0.7	0.022	0.019	0.005	0.009
Be (mg/l)	na	<0.005	<0.005	<0.005	<0.005
Bi (mg/l)	na	<0.004	<0.004	<0.004	<0.004
B (mg/l)	2.4	<0.013	<0.013	<0.013	<0.013
Cd (mg/l)	0.003	<0.002	<0.002	<0.002	<0.002
Co (mg/l)	na	<0.03	<0.003	<0.003	<0.003
Cu (mg/l)	2	0.005	<0.002	<0.002	<0.002
Cr (mg/l)	0.05	<0.003	<0.003	<0.003	<0.003
Ga (mg/l)	na	0.006	<0.001	0.003	<0.001
Fe (mg/l)	0.3, 2	<0.004	<0.004	<0.004	<0.004
Pb (mg/l)	0.01	<0.004	<0.004	<0.004	<0.004
Li (mg/l)	na	0.014	0.013	0.015	0.013
Mn (mg/l)	0.4; 0.1	**0.11**	0.036	<0.001	<0.001
Mo (mg/l)	na	<0.004	<0.004	<0.004	<0.004
Ni (mg/l)	0.07	<0.002	<0.002	<0.002	<0.002
Rb (mg/l)		<0.002	<0.002	<0.002	<0.002
Se (mg/l)	0.04	<0.002	<0.002	<0.002	<0.002
Ag (mg/l)	na	<0.001	<0.001	<0.001	<0.001
Sr (mg/l)	na	<0.002	0.054	<0.002	<0.002
Zn (mg/l)	5	<0.002	<0.002	<0.002	<0.002

na not applicable

* Highlighted field indicate exceedances of target values

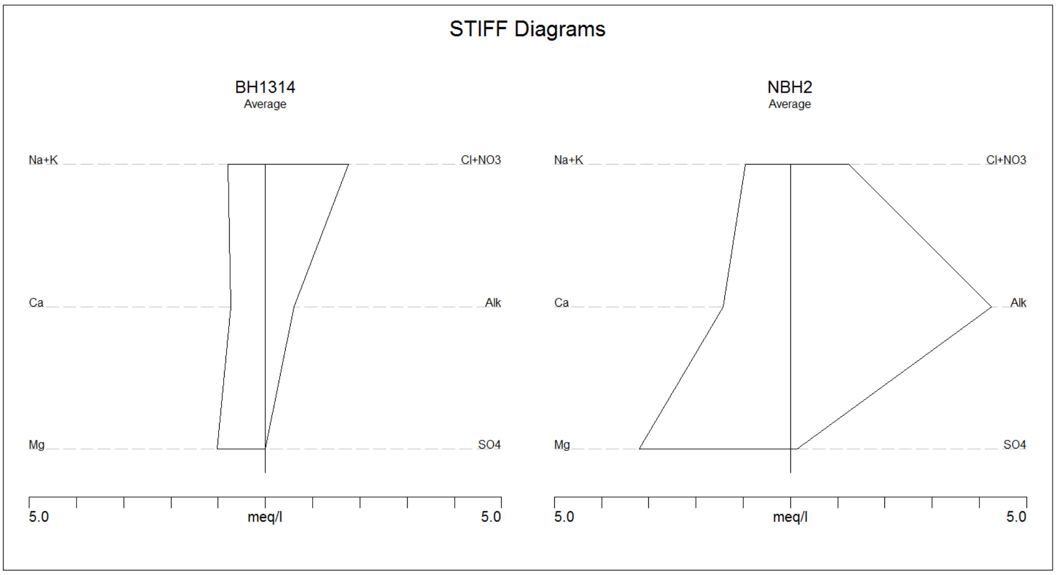


Figure 11: Stiff diagrams based on average meq/l for the June and November 2018 bi-annual periods for boreholes at the slimes compartments

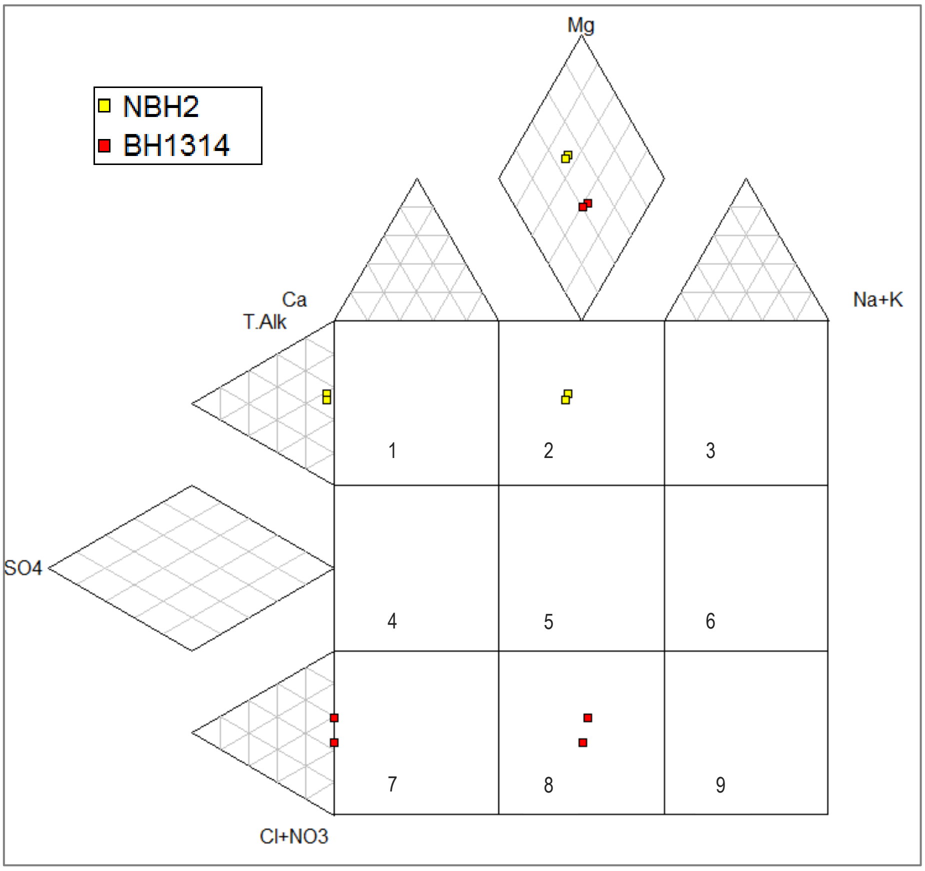


Figure 12: Expanded Durov diagram for the June and November 2018 bi-annual periods for boreholes at the slimes compartments

Two different chemical profiles exist for the *NBH2* and BH1314. *NBH2* is a Mg-CO_3 type water and plot in Field 2 of the Expanded Durov diagram. These types of groundwaters are typical of fresh, clean, relatively young groundwater that has started to undergo Mg ion exchange, often found in- dolomitic terrain. The pH of *NBH2* is circum-neutral (7.4-7.65), non-saline and hard. Nitrate (NO_3) is slightly raised (2.4 - 4.28 mg N/l) but still in the low ranges and well within SANS 241: 2015 drinking water quality guidelines. Except for manganese (Mn), all trace metals recorded well within drinking water guidelines, most being undetected. Manganese recorded a concentration of 0.11 mg/l during June 2018, marginally exceeding the SANS standards of 0.1 mg/l.

In contrast, *BH1314* displays a Mg-Cl type water and plot in Field 8 of the Expanded Durov diagram. These water types are typically a mix of different types – either clean water from fields 1 and 2 that has undergone Cl mixing/contamination or old stagnant NaCl dominated water that has mixed with water richer in Mg. The pH of *BH1314* is circum-neutral with non-saline and moderately soft water. All trace metals recorded in the ppb or undetected ranges while NO_3 and NH_4 concentrations recorded in the low ranges. All parameters as analyses are well within the SANS 241: 2015 Drinking Water Guidelines.

5.6.2 Groundwater monitoring at D1 – Old Plant Discard Dump

Six (6) boreholes monitor the groundwater quality downgradient from the Old Plant Discard at TIOM. Data for the 2 bi-annual monitoring periods in 2018 (GCS, 2018) are displayed in Table 11, while Stiffs and an Expanded Durov diagram are displayed in figures 13 and 14. Note that no data is available for boreholes *BH01330* and *BH01323* as these are monitored for water level and biomonitoring only.

Table 11: Groundwater quality sampled from boreholes downgradient from the Old Plant Discard

Parameters	SANS 214: 2015	BH01333		SM1		BTD1		Boorgat16a-35	
		Jun-18	Nov'18	Jun-18	Nov-18	Jun-18	Nov-18	Jun-18	Nov-18
pH	5.0-9.7	7.02	7.67	7.95	8.14	8.43	8.54	7.39	8.02
EC (mS/m)	170	69.1	90.5	33.3	43.3	105	143	72	95.8
TDS (mg/l)	1200	502	543	251	266	869	921	563	685
Total alkalinity (mg $CaCO_3$/l)	na	269	213	234	251	803	856	351	436
Total hardness (mg $CaCO_3$/l)	na	408	339	215	213	634	636	464	565
Ca (mg/l)	na	86	78.5	38.6	37.1	19.6	20	86.2	121
Mg (mg/l)	na	46.9	34.9	28.9	29.2	142	142	60.4	63.8
Na (mg/l)	200	36.3	55.7	14.4	13.6	119	123	33.8	35.3
K (mg/l)	na	3.83	13.8	2.71	1.62	1.48	0.74	1.71	1.83
Cl (mg/l)	300	77.9	114	7.76	10.1	73.3	77.5	67	74.8
SO_4 (mg/l)	250, 500	73.8	101	<0.141	<0.141	1.12	8.71	41.1	49.6

NO_3-N (mg/l)	11	0.27	0.982	<0.194	0.448	<0.194	0.296	5.92	8.75
NH_4-N (mg/l)	1.5	0.026	0.054	0.134	0.161	0.4	0.417	0.021	0.047
PO_4-P (mg/l)	na	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
F (mg/l)	1.5	0.286	0.301	<0.263	0.274	0.431	0.493	<0.263	0.265
Al (mg/l)	0.3	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
As (mg/l)	0.007	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
Ba (mg/l)	0.7	0.031	0.02	0.03	0.043	0.317	0.334	<0.002	0.002
Be (mg/l)	na	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Bi (mg/l)	na	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
B (mg/l)	2.4	0.021	0.023	0.141	0.124	0.117	0.116	0.023	<0.013
Cd (mg/l)	0.003	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Co (mg/l)	na	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Cu (mg/l)	2	0.005	<0.002	<0.002	<0.002	0.014	0.004	0.007	<0.002
Cr (mg/l)	0.05	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Ga (mg/l)	na	0.01	<0.001	0.003	<0.001	0.003	<0.001	0.001	<0.001
Fe (mg/l)	0.3, 2	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Pb (mg/l)	0.01	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Li (mg/l)	na	0.003	0.002	0.015	0.001	0.006	0.006	0.004	0.004
Mn (mg/l)	0.4; 0.1	**0.839**	0.049	**0.652**	**0.788**	0.086	0.042	<0.001	<0.001
Mo (mg/l)	na	<0.004	<0.004	0.01	0.005	0.009	0.008	<0.004	<0.004
Ni (mg/l)	0.07	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Rb (mg/l)		0.004	<0.002	0.003	<0.002	0.003	<0.002	0.005	<0.002
Se (mg/l)	0.04	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Ag (mg/l)	na	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Sr (mg/l)	na	0.004	0.102	0.003	0.059	0.003	0.163	0.005	0.085
Zn (mg/l)	5	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002

Fairly similar water quality profiles are evident for the boreholes at the Old Plant Discard. Boreholes *BH01333*, *Boorgat16a-35* and *SM1* display Mg(Ca)-HCO_3^- while *BTD1* has a Mg(Na)-HCO_3^- type character. Groundwater from these boreholes all plot in Field 2 of the Expanded Durov Diagram, which is typical of fresh, clean, relatively young groundwater that has started to undergo Mg ion exchange, often found in dolomitic terrain. Although the chemical profiles and ratios between elements are relatively similar, substantial differences in their macro-elemental concentrations are evident, especially with reference to Ca, Mg, Na, Cl, HCO_3 and SO_4. Manganese (Mn) is the only element with substantial variances, which is slightly raised in boreholes *BH01333* and *SM1*. Some of these variances can be attributed to redox while others could be geology related or related to seepages. Relatively raised NO_3 is present in borehole *Boorgat16a-35* but is absent from the remaining boreholes.

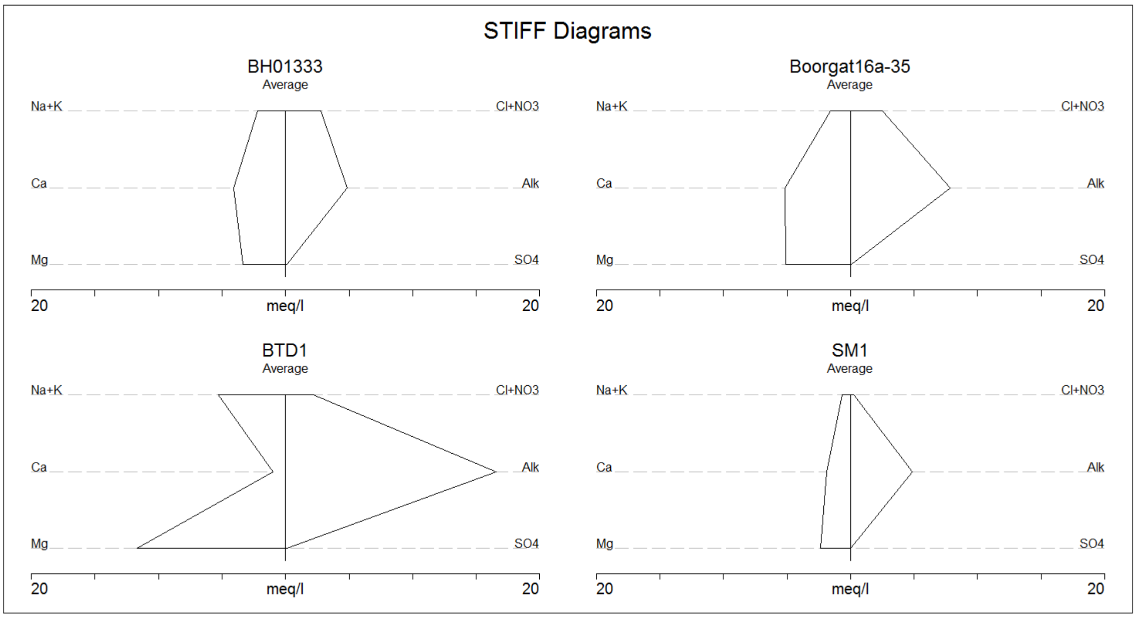


Figure 13: Stiff diagrams based on average meq/l for the June and November 2018 bi-annual periods for boreholes at the Old Plant Discard Dump

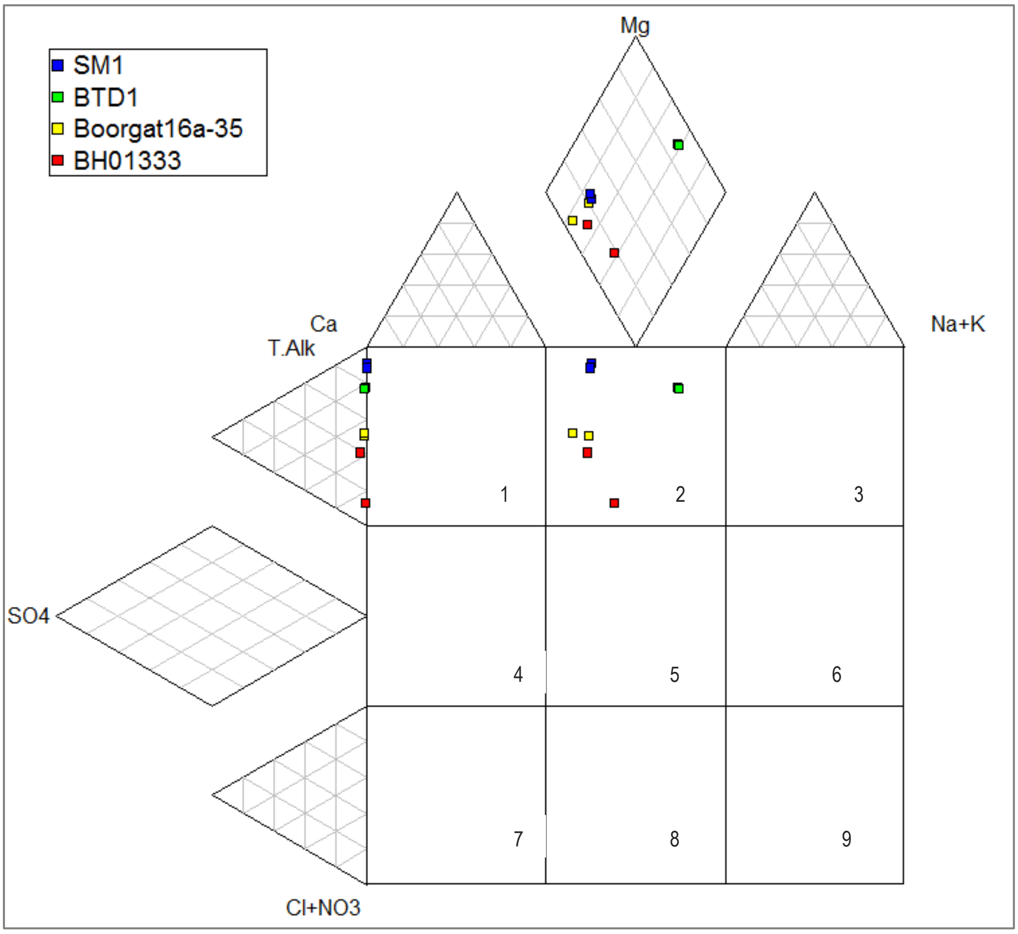


Figure 14: Expanded Durov diagram for the June and November 2018 bi-annual periods for boreholes at the Old Plant Discard Dump

5.6.3 Groundwater monitoring at D3 – Supply Chain Discard Dump

Five (5) boreholes are included in the routine groundwater monitoring programme in vicinity of the Supply Chain Discard Dump at Thabazimbi Iron Ore Mine. Data for the 2 bi-annual monitoring periods in 2018 (GCS, 2018) are displayed in Table 12. Note that only one (1) dataset is available (November 2018) for *BH01332* and *BH01328*. Stiffs and an Expanded Durov Diagram can be viewed in figures 15 and 16, respectively.

Except for one (1) dataset, all samples plot in Field 2 of the Expanded Durov diagram and as mentioned previously these groundwater types are typical of fresh, clean recently recharged groundwater that has started to undergo Mg ion exchange, mostly within dolomitic aquifers. The Stiff diagrams indicate Mg(Ca)-HCO_3^- type groundwaters typical for dolomitic geological subsurface.

The pH levels recorded in circum-neutral ranges. Compared to the other boreholes relevant to this study, the groundwater in vicinity of the Supply Chain Discard Dump are relatively more saline with TDS ranging between 138 and 1193 mg/l. The EC recorded for *B01327* in November 2018 (181 mS/m) exceed the permissible SANS 241 guidelines for EC set at <170 mS/m.

The arsenic (As) concentrations in borehole *B01325* are relatively high with 0.02 and 0.024 mg/l recorded in June and November 2018, respectively. Both these As levels exceed the permissible SANS guidelines. Similarly, Mn concentrations recorded in high to elevated concentrations in *BH01328*, *B01325* and *B01327* ranging between 0.28 and 5.7 mg/l. the former recorded for *B01327* in June 2018 and the latter in *B01325* also in June 2018. Nitrate (NO_3) was recorded to be slightly raised in boreholes *Borehole 9-24* and *B01327*, ranging between 3.62 and 8.75 mg N/l but remain within SANS drinking water guidelines of <11 mg N/l.

Table 12: Groundwater quality sampled from boreholes in vicinity of the Supply Chain Discard

Parameters	SANS 214: 2015	BH01332		BH01328		Borehole 9-24		B01325		B01327	
		Jun-18	Nov'18	Jun-18	Nov-18	Jun-18	Nov-18	Jun-18	Nov-18	Jun-18	Nov-18
pH	5.0-9.7	-	8.09	-	8.06	6.99	7.77	6.93	7.49	7.06	7.56
EC (mS/m)	170	-	77.6	-	66.9	58.3	72.2	22.7	22.4	140	**181**
TDS (mg/l)	1200	-	566	-	441	418	465	138	147	1077	1193
Total alkalinity (mg $CaCO_3$/l)	na	-	429	-	294	237	262	111	126	579	657
T hardness (mg $CaCO_3$/l)	na	-	442	-	302	-	336	-	89	-	804
Ca (mg/l)	na	-	70.6	-	46.2	56.4	58.1	10.8	11.9	134	146
Mg (mg/l)	na	-	64.5	-	45.4	44.7	46.5	12.8	14.3	108	107
Na (mg/l)	200	-	40.2	-	50.3	28.3	29.5	10.5	11.3	129	128
K (mg/l)	na	-	1.58	-	0.834	1.57	2.44	2.45	2.54	1.92	1.87
Cl (mg/l)	300	-	84.1	-	89.9	64.9	72.7	4.71	5.09	184	230
SO_4 (mg/l)	250, 500	-	23.1	-	<0.141	29.7	37.7	3.15	<0.141	106	112
NO_3-N (mg/l)	11	-	0.512	-	0.966	3.62	5.14	<0.194	0.369	7.38	8.75
NH_4-N (mg/l)	1.5	-	0.04	-	0.054	0.03	0.067	0.061	0.03	0.068	0.019
PO_4-P (mg/l)	na	-	<0.005	-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
F (mg/l)	1.5	-	<0.263	-	0.277	<0.263	<0.263	<0.263	<0.263	<0.263	0.275
Al (mg/l)	0.3	-	<0.002	-	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
As (mg/l)	0.007	-	<0.006	-	<0.006	<0.006	<0.006	**0.02**	**0.024**	<0.006	<0.006
Ba (mg/l)	0.7	-	0.024	-	0.416	0.021	0.023	2.24	3.26	<0.002	<0.002
Be (mg/l)	na	-	<0.005	-	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Bi (mg/l)	na	-	<0.004	-	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
B (mg/l)	2.4	-	<0.013	-	<0.013	0.013	<0.013	<0.013	<0.013	<0.013	<0.013

Cd (mg/l)	0.003	-	<0.002	-	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Co (mg/l)	na	-	<0.003	-	<0.003	<0.003	<0.003	<0.003	<0.003	0.008	<0.003
Cu (mg/l)	2	-	0.003	-	<0.002	0.006	<0.002	<0.002	<0.002	0.021	<0.002
Cr (mg/l)	0.05	-	<0.003	-	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Ga (mg/l)	na	-	<0.001	-	<0.001	0.005	<0.001	<0.001	<0.001	0.033	<0.001
Fe (mg/l)	0.3, 2	-	<0.004	-	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Pb (mg/l)	0.01	-	<0.004	-	2.44	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Li (mg/l)	na	-	0.004	-	0.005	0.004	0.005	<0.001	0.002	<0.001	<0.001
Mn (mg/l)	0.4; 0.1	**-**	<0.001	**-**	**2.44**	<0.001	<0.001	**5.7**	**5.1**	**0.277**	0.013
Mo (mg/l)	na	-	<0.004	-	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	0.005
Ni (mg/l)	0.07	-	<0.002	-	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Rb (mg/l)		-	<0.002	-	<0.002	0.004	<0.002	0.006	<0.002	0.029	<0.002
Se (mg/l)	0.04	-	<0.002	-	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Ag (mg/l)	na	-	<0.001	-	<0.001	<0.001	<0.001	<0.001	<0.001	0.012	<0.001
Sr (mg/l)	na	-	0.063	-	0.077	0.004	0.072	0.006	0.055	0.029	0.05
Zn (mg/l)	5	-	<0.002	-	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002

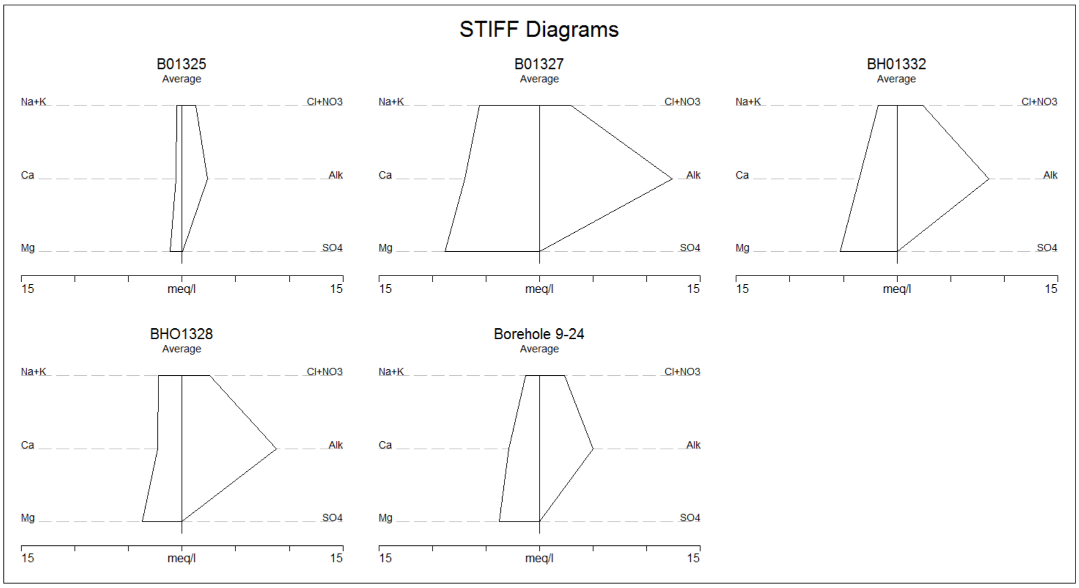


Figure 15: Stiff diagrams based on average meq/l for the June and November 2018 bi-annual monitoring periods for boreholes at the Supply Chain Discard Dump

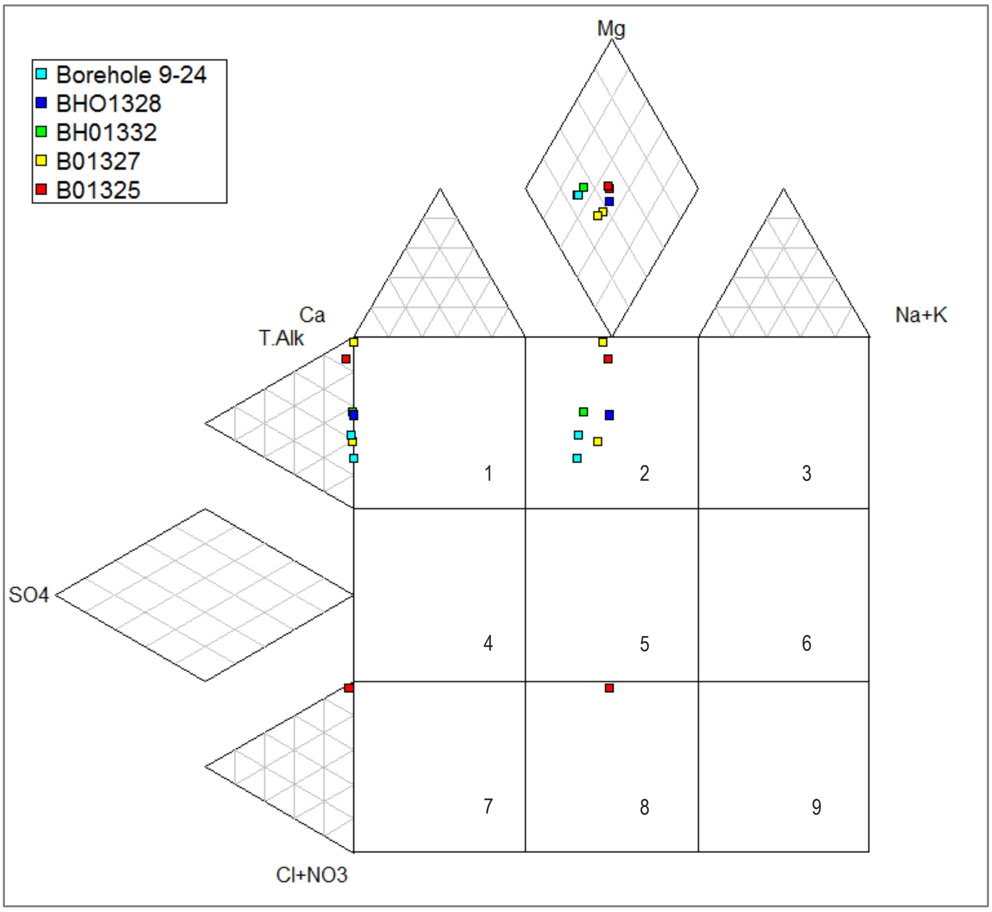


Figure 16 Expanded Durov diagram for the June and November 2018 bi-annual monitoring periods for boreholes at the Supply Chain Discard Dump

6. AQUIFER CHARACTERISATION

6.1 Aquifer vulnerability

Groundwater plays an important role in supplying water to many regions of Southern Africa due to its low annual average precipitation of 460 mm, which is well below the world average of 860 mm. The quality of groundwater resources in South Africa has therefore received considerable focus and attention on the need for a proactive approach to protect these sources from contamination (Lynch *et. al.*, 1994). Groundwater protection needs to be prioritised based upon the susceptibility of an aquifer towards pollution. This can be done in two ways, namely i) pollution risk assessments and ii) aquifer vulnerability. Pollution risk assessments consider the characteristics of a specific pollutant, including source and loading while aquifer vulnerability considers the characteristics of the aquifer itself or parts of the aquifer in terms of its sensitivity to being adversely affected by a contaminant should it be released.

The DRASTIC model concept developed for the USA (Aller *et. al.*, 1987) is well suited for producing a groundwater vulnerability evaluation for South African aquifers. The DRASTIC evaluates the intrinsic vulnerability (*IV*) of an aquifer by considering factors including **D**epth to water table, natural **R**echarge rates, **A**quifer media, **S**oil media, **T**opographic aspect, **I**mpact of vadose zone media, and hydraulic **C**onductivity. Different ratings are assigned to each factor and then summed together with respective constant weights to obtain a numerical value to quantify the vulnerability:

$$\text{DRASTIC Index } (IV) = DrDw + RrRw + ArAw + SrSw + TrTw + IrIw + CrCw$$

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 13.

Table 13: South African National Groundwater Vulnerability Index to Pollution (Lynch et al, 1994)

Score	Vulnerability
50-87	Least susceptible
87 - 109	Moderate susceptible
109 - 226	Most susceptible

The concept of DRASTIC in vulnerability assessments 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

The weighting for each parameter is constant. The minimum value for the DRASTIC index that one can calculate (assuming all seven factors were used in the calculation) is therefore 24 with the maximum value being 226. The higher the DRASTIC index the greater the vulnerability and possibility of the aquifer to become polluted if a pollutant is introduced at the surface or just below it. Note that conductivity values for fractured rock aquifers are difficult to estimate and sufficient information on hydraulic conductivity values for Southern Africa is not available at present. In addition, due to the considerable variation over short distances in hard rock aquifers, the use of this parameter was in doubt.

Because of the highly heterogenic nature of the aquifers and aquifer properties at TIOM it is not possible to characterise aquifer vulnerability on a micro-scale. Aquifer parameters will vary significantly over short distances. It is therefore clear that on a very small scale (microscopic scale or pore scale) a porous (homogenous) media approach would lead to an inadequate description with resulting inaccuracies. The realistic alternative, therefore, is to move to a coarser scale of aquifer description by introducing measurable phenomenological coefficients such as hydraulic gradients. In the continuum approach, the concept of the representative elementary volume (REV) is evoked. The REV is a theoretical approach in which representative values for flow (and transport) parameters are averaged over an appropriate volume. On a larger scale (macroscopic scale) parameters are averaged, and for a sufficiently large modelling cell size a porous media approach can be adopted by specifying regional representative aquifer parameters.

Table 14 summarizes the aquifer classification vulnerability scores for the aquifer/s in vicinity (based on the REV approach) of the project area. The final DRASTIC score of 101 indicates that the fractured aquifer in the region has a moderate susceptibility to pollution and a medium level of aquifer protection is, therefore, required.

Table 14: DRASTIC vulnerability scores (fractured aquifer)

Factor	Range/Type	Weight	Rating	Total
D	15 - 30 m	5	3	15
R	10 - 50 mm	4	6	24
A	Fractured	3	6	18
S	clay loam/silty loam	2	2	4
T	0-2%	1	10	10
I	Pretoria Group, dolomite	5	6	30
C	-	3	-	-
DRASTIC SCORE = 101				

6.2 Aquifer classification

The then Department of Water and Sanitation ("DWS"), currently the Department of Human Settlements, Water and Sanitation ("DHSWS"), has characterised South African aquifers based on the rock formations in which they occur together with its capacity to transmit water to boreholes drilled into specific formations. The water bearing properties of rock formations in South Africa can be classified into four classes defined as:

1. **Class a - Intergranular**
   - Aquifers associated either with loose and unconsolidated formations such as sands and gravels or with rock that has weathered to only partially consolidated material.
2. **Class b - Fractured**
   - Aquifers associated with hard and compact rock formations in which fractures, fissures and/or joints occur that are capable of both storing and transmitting water in useful quantities.
3. **Class c - Karst**
   - Aquifers associated with carbonate rocks such as limestone and dolomite in which groundwater is predominantly stored in and transmitted through cavities that can develop in these rocks.
4. **Class d - Intergranular and fractured**
   - Aquifers that represent a combination of Class A and B aquifer types. This is a common characteristic of South African aquifers. Substantial quantities of water are stored in the intergranular voids of weathered rock but can only be tapped via fractures penetrated by boreholes drilled into the fractured aquifer.

Each of these classes is further subdivided into groups relating to the capacity of an aquifer to transmit water to boreholes, typically measured in l/s. The groups therefore represent various ranges of borehole yields.

According to the regional geohydrological map as shown in Figure 17, the study areas are predominantly located in a c3 and d4 aquifer class regions. The groundwater yield potential is classed as fair to good on the basis that most of the boreholes on record in vicinity of the study areas produce between 0.5 and 5 l/s. These good aquifer regions are primarily associated with the east-west striking thrust faults at the mine. The vast majority of the Thabazimbi municipal groundwater is abstracted from the alluvial aquifer along the Crocodile River.

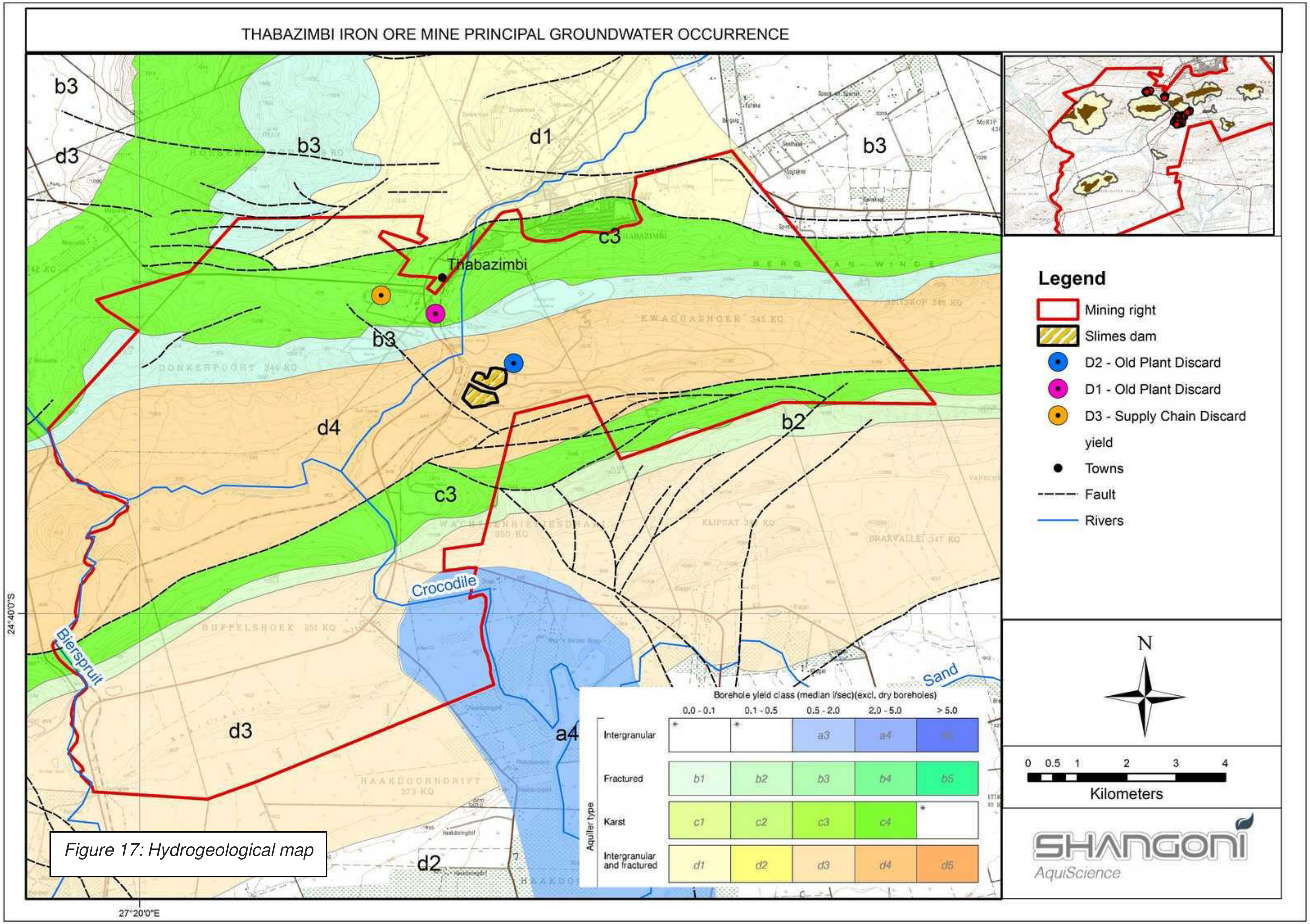


Figure 17: Hydrogeological map

According to the regional aquifer classification map of South Africa, the regional aquifer has been identified as a minor aquifer with good to fair groundwater quality, with EC ranging between 70 and 300 mS/m and sporadic NO_3 and F of >10 mg/l and F >1.55 mg/l, respectively. The aquifer/s has/have a medium vulnerability and a medium susceptibility towards contamination. Based on the 'undisturbed' underlying hydrogeology of the project area the aquifers are classified, according to Parsons (1995), as a minor aquifer. A 'special' and primary intergranular aquifer region is identified more towards the south of Thabazimbi and the mining area.

The principle groundwater occurrences and yields expected are summarised in Table 15.

Table 15: Principle groundwater occurrences and classification according to the Parsons (Parsons, 1995) classification system for undisturbed aquifers

Aquifer	Type	Lithology	Groundwater occurrence	Probable yield (l/s)	Classification
Pretoria Group	Confined to semi-confined	Shale, quartzite, andesite, diabase, conglomerate	Contacts between different rock lithologies and bedding planes within sedimentary rock	2 – 5	**Minor aquifer**
Chuniespoort (Malmani Subgroup & Penge Formation)	Confined to semi-confined	Dolomite, shale, erosive breccia	a) Well developed joints and fractures occur in the competent (banded iron) are favourable for high yielding aquifers b) Carbonate rocks of the Malmani Subgroup have moderate to high yields. Groundwater occurs in fractures, joints, solution cavities and diabase intrusive contact zones.	0.5 – 2.0	**Minor aquifer**

6.3 Aquifer protection classification

In order to achieve the Groundwater Quality Management Index a point scoring system as presented in tables 16 and 17 was used for the naturally occurring undisturbed aquifers in the wider study area.

The occurring aquifer, 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 is shown in Table 18.

Table 16: 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 (fractured)		
High	3	
Medium	2	2
Low	1	

Table 17: 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	

GQM Index = Aquifer System Management x Aquifer Vulnerability:

2 X 2 = 4

Table 18: 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 a **medium level of groundwater protection** is required to adhere to DHSWS's water quality objectives. Reasonable and sound groundwater protection measures are recommended to ensure that no cumulative pollution affects the aquifer, during short- and long-term. DHSWS's water quality management objectives are to protect human health and the environment. Therefore, the significance of this aquifer classification is that if any potential risk exists, measures must be taken to limit the risk to the environment, which in this case is the protection of the underlying sedimentary and dolomitic aquifers, the primary aquifer associated with the Crocodile River and aquatic ecosystem of the Crocodile River and its tributaries.

7. CONCEPTUAL MODEL

The conceptual geohydrological model is an idealisation of the real world that summarises the current understanding of site conditions and how the groundwater flow system works. It includes all the important features of the flow system, while incorporating simplifying assumptions. The conceptual model relies heavily on the information gathered during field investigation phases.

The geology in any geohydrological setting forms the basis for groundwater flow and aquifer development. The geohydrology in the study area is no exception and will conform thereto.

A conceptual model was developed based on the review of available data and the information gathered. The model is a simplified representation of the geohydrological conditions and processes taking place in the study area and forms the cornerstone for understanding and describing the geohydrological environment and its behaviour. It describes the simplifying assumptions necessary to represent the real-world system.

7.1 General aquifer system

The regional aquifer types in the Thabazimbi area can be grouped into the following aquifer units:

- Crocodile River primary aquifer;
- Quartzite, shale and andesite aquifer;
- Penge banded iron formation aquifer;
- Malmani Subgroup dolomite aquifer;
- Breccia Basin aquifer;
- Bushveld Igneous Complex aquifer; and
- Diabase intrusions.

The average depth of weathering was determined from previous fieldwork programmes (GCS, 2015) to occur between 20-30 mbs. Average water levels of the monitoring boreholes from the 2018 annual period were measured to be between 3-80 mbs (GCS, 2018).

Generally, the water table is a subdued reflection of the topography, and groundwater flow is from areas of higher lying ground to the north east and south west towards the Crocodile River, Sand River and Rooikuilspruit. The flow gradient in the high-lying area is steep, around 1:20 and flattens out into the valleys and in the vicinity of the Crocodile River, where the gradient averages 1:300. The regional drainage features include the perennial Crocodile River, Rooikuilspruit and Sand River, as well as the ephemeral Sterkspruit, Vaalwaterspruit, Bierspruit, and Klipspruit.

The discontinuous contact between the Penge Formation and Malmani Subgroup represents an unconformity and possess relatively high permeability values (WSM Leshika, 2007). The high permeability may have resulted in the formation of higher secondary porosity and weathering on the contact, resulting in higher transmissivity and storage.

The following two-layer aquifer model is proposed to conceptualise the Thabazimbi aquifers at a regional scale:

- A shallow weathered aquifer system (i.e. intergranular water table aquifer) that may be laterally connected to alluvial aquifers associated with river systems with a thickness of approximately 25 – 50 m; and
- A deeper, fractured bedrock aquifer system underlying the shallow weathered aquifer with a thickness of approximately 150 m.

7.2 Recharge

The infiltration of water from the shallow weathered aquifer system to the deeper fractured bedrock aquifer system is heterogeneous and requires permeable soils, or permeable horizons (i.e. 'infiltration routes'), and 'open' and interconnected fracture systems in the bedrock. Hydraulic continuity must exist between groundwater reservoir(s) in the overlying horizons (or weathered overburden) and the underlying bedrock. The fracture zones act as conduits for deeper flow from groundwater reservoirs located in upper permeable soils or the weathered overburden. Groundwater flows through interconnected fracture systems with the potential of rapid vertical groundwater flow from the weathered overburden (and surface water bodies) to greater depths along interconnected conductive zones.

High transmissivity aquifer units, such as the upper Breccia Basin and the Crocodile River alluvial aquifer units, may enhance both lateral flow in the shallow weathered aquifer and vertical flow between the shallow and deeper aquifer systems. Lateral groundwater flow in the shallow aquifer is predominantly driven by topographic gradients and/or localised recharge mounds due to e.g. irrigation and seepage from the tailings storage facility (TSF), etc.

There are several processes occurring at surface that contribute to the amount of recharge to groundwater from rainfall. Figure 18 presents a simplified water balance for illustrative purposes. Precipitation (P) that falls on the land surface enters various pathways of the hydrologic cycle. Some water can be temporarily stored on the land surface in wetlands, perched aquifers and water puddles (∆SW), some will be evaporated directly from surface (ET) or from wetlands, perched aquifers and puddles (ETW). Some water will drain across the land surface to stream channels (run-off, RO) and some water will infiltrate through porous surface soil and seep into the ground. Water is stored in the vadose (unsaturated) zone from where it can be accessed by vegetation via the roots and used by the plants (transpired). Water infiltrating the soil/rock matrix reaching the water table is called groundwater recharge (RCH) and contributes to groundwater storage (∆SGW).

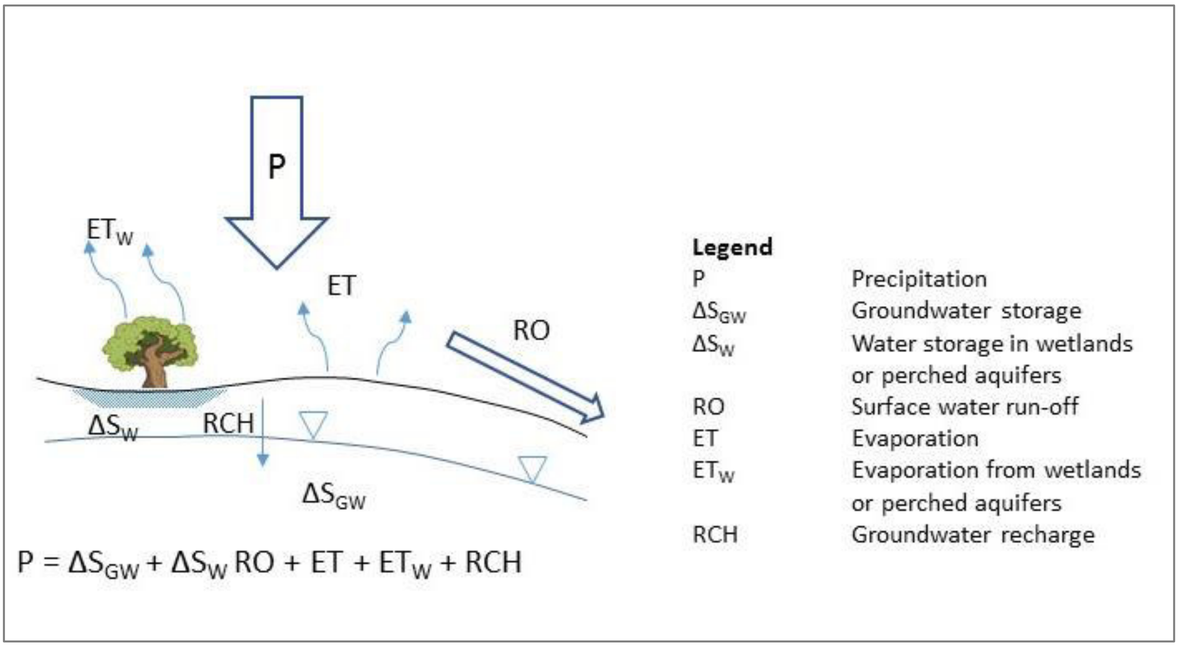


Figure 18: Surface processes related to precipitation and groundwater recharge

The collection of direct field measurements for groundwater recharge is difficult and was not included in the field investigation.

Water enters the aquifer systems predominantly as recharge from precipitation deeper flow from interconnected higher lying areas. The deeper, regional groundwater flow is not discussed in this report. The effective groundwater recharge is estimated to be between ~ 0.3 and ~ 25 % of MAP.

The following mechanisms are expected to contribute to groundwater recharge in the study area:

- Direct infiltration of rainfall through the overlying unconsolidated material and the weathered matrix; and
- Significantly higher recharge compared to ambient is expected within disturbed sediments and from mine residue deposits while lesser recharge is expected from built-up or concreted/tarred surfaces.

GCS developed a groundwater model (GCS, 2019) and the recharge values calibrated are shown in Table 19.

Table 19: Recharge rates expected to occur into the geological formations

Hydrostratigraphic unit	Recharge	
	% (MAP)	mm/a
Bushveld Igneous Complex (BIC)	0.3	1.61
Banded Iron Formation (BIF)	5	32.25
Diabase	1	6.45
Dolomite	3	19.35
Granites, Quartzite and Shale	0.5	3.23
Quaternary surface deposit	1.5	9.68
Waterberg Sedimentary	1	6.45
Breccia Basin	10	64.50
Mine faults	4	25.8
Alluvial deposits – Crocodile River	4	25.8
Mine residue deposits/stockpiles	25	161.25

7.3 Potential contaminants of concern

The whole rock analyses revealed certain elements to be enriched within the discard and slimes material with reference to the GNR635 National Norms and Standards. These include Al, As, Cu, Ba Fe, Mn, F and Si of which only Mn, Si and F leached in noteworthy concentrations. Macro-elements including Ca, Mg, Na, Cl, K, F and NO_3 also leached in noteworthy concentrations, of which Ca, Mg and K do not pose any risks. Although As did not leach in any substantial concentrations, concentrations of this metalloid were recorded to be high in one borehole (*B01325*) downgradient from the Supply Chain Discard. Based on these tests the following potential contaminants of concern were identified:

- As, Mn, F, N (as NO_3 and NH_4), Na, Cl

8. GEOHYDROLOGICAL IMPACTS

The groundwater impact assessment focussed on the identification of the major groundwater related impacts that the activities, processes and actions may have on the receiving groundwater environment. The assessment as contained within this report aimed to achieve the following:

- To provide a detailed assessment of the potentially affected groundwater environment.
- To assess impacts on the study area in terms of groundwater criteria.
- To identify and recommend appropriate mitigation measures for potentially significant groundwater related impacts.

The environmental risk of any aspect is determined by a combination of parameters associated with the impact. Each parameter connects the physical characteristics of an impact to a quantifiable value to rate the environmental risk.

The methodology that was employed during the impact assessment follows international best practice. The impact assessment considered the potential impacts of the proposed project activities on groundwater resources, specifically groundwater quality and quantity impacts that could be expected from the activities. It is based on defining and understanding the three basic components of the risk, i.e. the source of the risk, the pathway and the target that experiences the risk (receptor).

After identification of the impacts, the nature and scale of each impact is predicted. The impact prediction provides a basis from which the significance of each impact is determined. Appropriate mitigation measures are subsequently developed with the impact and scale of impact as reference.

Table 20 and Table 21 indicate the methodology to be used to assess the Probability and Magnitude of the impact, respectively, while Table 22 provides the Risk Matrix that will be used to plot the Probability against the Magnitude to determine the Severity of the impact.

The discussion of each impact begins with the background, i.e. a description of the baseline conditions, the proposed project activities, which will cause an impact as well as the sensitive receptors. This is followed by an assessment of the significance of the impacts pre-mitigation, the presentation of recommended mitigation measures, and an assessment of the residual impact that would remain after the implementation of the mitigation measures. Because the mine will not be constructing any additional infrastructure for the mining activities, a construction phase was not included in the risk assessment.

The impact assessment is discussed for each of the following phases:

- Operational Phase
- Decommissioning
- Closure Phase

Table 20: Determining the Probability of impact

FREQUENCY OF ASPECT / UNWANTED EVENT	SCORE	AVAILABILITY OF PATHWAY FROM THE SOURCE TO THE RECEPTOR	SCORE	AVAILABILITY OF RECEPTOR	SCORE
Rare/Never known to have happened, but may happen	1	A pathway to allow for the impact to occur is never available	1	The receptor is never available	1
Unlikely/Known to happen in industry	2	A pathway to allow for the impact to occur is almost never available	2	The receptor is almost never available	2
Possible/< once a year	3	A pathway to allow for the impact to occur is sometimes available	3	The receptor is sometimes available	3
Likely/Once per year to up to once per month	4	A pathway to allow for the impact to occur is almost always available	4	The receptor is almost always available	4
Almost certain/Once a month - Continuous	5	A pathway to allow for the impact to occur is always available	5	The receptor is always available	5

Table 21: Determining the Magnitude of impact

SOURCE								RECEPTOR			
Duration of impact	Score	Extent	Score	Volume / Quantity / Intensity	Score	Toxicity / Destruction Effect	Score	Reversibility	Score	Sensitivity of environmental component	Score
Lasting days to a month	1	Effect limited to the site. (metres);	1	Very small quantities / volumes / intensity (e.g. < 50L or < 1Ha)	1	Non-toxic (e.g. water) / Very low potential to create damage or destruction to the environment	1	Bio-physical and/or social functions and/or processes will remain unaltered.	1	Current environmental component(s) are largely disturbed from the natural state. Receptor of low significance / sensitivity	1
Lasting 1 month to 1 year	2	Effect limited to the activity and its immediate	2	Small quantities / volumes / intensity (e.g.	2	Slightly toxic / Harmful (e.g. diluted brine) / Low potential to create	2	Bio-physical and/or social functions and/or processes might be negligibly altered or enhanced / Still reversible	2	Current environmental component(s) are moderately disturbed from the natural state.	2

SOURCE								**RECEPTOR**			
Duration of impact	Score	Extent	Score	Volume / Quantity / Intensity	Score	Toxicity / Destruction Effect	Score	Reversibility	Score	Sensitivity of environmental component	Score
		surroundings. (tens of metres)		50L to 210L or 1Ha to 5Ha)		damage or destruction to the environment				No environmentally sensitive components.	
Lasting 1 – 5 years	3	Impacts on extended area beyond site boundary (hundreds of metres)	3	Moderate quantities / volumes / intensity (e.g. > 210 L < 5000L or 5 – 8Ha)	3	Moderately toxic (e.g. slimes) Potential to create damage or destruction to the environment	3	Bio-physical and/or social functions and/or processes might be notably altered or enhanced / Partially reversible	3	Current environmental component(s) are a mix of disturbed and undisturbed areas. Area with some environmental sensitivity (scarce / valuable environment etc.).	3
Lasting 5 years to Life of Organisation	4	Impact on local scale / adjacent sites (km's)	4	Very large quantities / volumes / intensity (e.g. 5000 L – 10 000L or 8Ha–12Ha)	4	Toxic (e.g. diesel & Sodium Hydroxide)	4	Bio-physical and/or social functions and/or processes might be considerably altered or enhanced / potentially irreversible	4	Current environmental component(s) are in a natural state. Environmentally sensitive environment / receptor (endangered species / habitats etc.).	4
Beyond life of Organisation / Permanent impacts	5	Extends widely (nationally or globally)	5	Very large quantities / volumes / intensity (e.g. >	5	Highly toxic (e.g. arsenic or TCE)	5	Bio-physical and/or social functions and/or processes might be severely/substantially	5	Current environmental component(s) are in a pristine natural state.	5

SOURCE								RECEPTOR			
Duration of impact	Score	Extent	Score	Volume / Quantity / Intensity	Score	Toxicity / Destruction Effect	Score	Reversibility	Score	Sensitivity of environmental component	Score
				10 000 L or > 12Ha)				altered or enhanced / Irreversible		Highly Sensitive area (endangered species, protected habitats etc.)	

Table 22: Determining the severity of impact

ENVIRONMENTAL IMPACT RATING / PRIORITY					
PROBABILITY	**MAGNITUDE**				
	1 Minor	**2 Low**	**3 Medium**	**4 High**	**5 Major**
5 Almost Certain	Low	Medium	High	High	High
4 Likely	Low	Medium	High	High	High
3 Possible	Low	Medium	Medium	High	High
2 Unlikely	Low	Low	Medium	Medium	High
1 Rare	Low	Low	Low	Medium	Medium

8.1 Project description

The project involves the reclamation of the D1-Old Plant Discard Dump, D2- Old Plant Discard Dump, D3 – Supply Chain Discard Dump and existing slimes dam compartments. Existing infrastructure will be utilised during the reclamation process and the footprint of the mine will not be increased. An existing approved mobile crushing and screening plant will be utilised to screen and crush the materials. All the stockpiles will be beneficiated using dense medium separation where required. The product and waste (aggregate) will be stockpiled prior to being moved to the loadout and discard conveyor. The product will supply the AMSA Vanderbijlpark Steel Works and aggregate is envisioned to be sold to the construction market and low Fe ore to the cement factories following further studies.

8.2 Project duration

Processing of the existing D1-Old Plant Discard Dump, D2- Old Plant Discard Dump is planned to be completed over a 4-year period (2021 – 2025) and feeds into an existing project that is currently being undertaken to rework existing dumps located throughout the site, D3 – Supply Chain Discard Dump with the discard from the D1-Old Plant discard Dump, D2-Old Plant Discard Dump will be handled as low Product and aggregate throughout and Existing Slimes Dams should start up in 2024.

8.3 Potential geohydrological impacts during the construction phase

As mentioned previously, existing infrastructure will be utilised during the reclamation process and the footprint of the mine will not increase. An existing approved mobile crushing and screening plant will be utilised to screen and crush the materials where required. Other associated support infrastructure is limited to the following:

- Offices;
- Change house;
- Workshop facilities;
- Storage facilities;
- Analytical facilities;
- Tea room / canteen facilities;
- On-site toilets (Portable toilets); and
- Support contractor parking and office space.

Establishment will also be conducted in a relatively short period compared to the operational and post-closure phases. Therefore, any groundwater related impact occurring during this stage is anticipated to be minor and insignificant.

8.4 Potential geohydrological impacts during the operational phase

8.4.1 Impacts on groundwater quantity

It is assumed that that the reclamation projects are to be executed in layers from the top and the consequent flattened topography during reclamation will enhance rainwater ingress and thereby also seepage generation. Impacts on groundwater quantity during the operational or reclamation phase of the project are, therefore, associated with an increase in seepage rates from the facilities, which would have otherwise been rehabilitated with a lower seepage rate. However, since active deposition of slimes will cede, less process water will be disposed onto the facility and the seepage rate will therefore reduce over time to rainwater ingress rates. The likely net impact on the groundwater quantity during the operational reclamation phases of the facilities are, therefore, a decrease from the active deposition seepage rate, but an increase in seepage in comparison to a closed and rehabilitated facility.

Great uncertainty exists with regards to the seepage rates during the operational phases of reclamation. It is, however assumed that the seepage rate from the facilities will effectively reduce by 40% from the active disposal seepage rate of 25%mm/a to a seepage rate equal to un-rehabilitated spoils, estimated at 15% of MAP. Since the reclamation project postpones the final closure and rehabilitation of the facilities, so will be the gradual decline of the seepage rate to an estimated post closure seepage rate of 8% of MAP. In other words, while the seepage rate during the reclamation project will be approximately half the assumed seepage rate of active disposal facilities, it is estimated to be double the seepage rate of rehabilitated dumps.

The increase in the seepage rate over the reclaimed parts of the facilities are therefore likely to enhance the rebound of the water table locally, but unlikely to change the regional flow directions. No differentiable or measurable impacts on the rebounding regional groundwater flow regime are therefore foreseen during the operational phase (Table 23).

Table 23: Impact assessment on groundwater resource quantity during the operational phases

Environmental impact, extent, duration, significance and degree to which impact will cause irreplaceable loss	Risk rating (before mitigation) Probability	Magnitude	Severity	Environmental objective	Degree to which impact can be reversed and the supporting mitigatory action plan	Timeframe	Responsibility	Risk rating (after mitigation) Probability	Magnitude	Severity
ENVIRONMENTAL COMPONENT: Geohydrology										
ACTIVITY: Reclamation of discard and slimes										
PROJECT PHASE APPLICABILITY: Planning and Construction										
PROJECT PHASE APPLICABILITY: Operation – X										
PROJECT PHASE APPLICABILITY: Decommissioning, Closure and Post-Closure – X										
Impact description: Increased recharge with localised mounding of GW table. Duration of impact: Operational phase extending to post closure phase. Degree to which impact may cause irreplaceable loss: None	2	1	L	To minimise the extent of disturbance of the aquifer. To limit degeneration of groundwater quantity.	Management measures • No specific management measures are proposed other than to continue with water level and quality monitoring and effective clean and affected water separation. Action plans • No specific action plans or mitigation measures are proposed. • Continue with groundwater monitoring and separate clean and affected water.	Operational.	Environmental Manger	2	1	L

8.4.2 Impacts on groundwater quality

The two most common processes by which groundwater are contaminated include interstitial release and ion exchange release. Contaminants of concern identified during the geochemical assessment include As, Mn, F, N (as NO_3 and NH_4), Na and Cl. Status quo groundwater conditions at TIOM indicate relatively unimpacted water quality, with some exceptions, but during reclamation the enhanced seepage rate and oxidation reactions could result in substandard leachate generation and seepage towards the groundwater table.

The seepage quality from the facilities is likely to be circum-neutral to alkaline as no potential for acid formation exist but could contain traces of macro- and trace elements as listed above. Status quo groundwater monitoring results suggest that seepage loads from the facilities does not reach the groundwater table in excessive amounts. The loads emanating from the facilities may be diverted through several processes:

- Lateral movement of the seepage within the tailings, evaporation on the walls of the facilities and deposition of the load on the outer surface of the tailings.
- Lateral movement of the seepage above low permeability horizons in the soil zone (perched aquifers).
- Retention of salts within the unsaturated zone between the base of the tailings and the groundwater body.

Based on a worst-case scenario, the probability of groundwater pollution occurring during the operational phase of reclamation is likely, but the magnitude is expected to be low due to the expected alkaline nature of the seepage and localised nature thereof. Further to this, no receptor boreholes will be impacted on.

The impact assessment and final risk rating for impacts on groundwater quality during the operational phase can be viewed in Table 24.

8.4.3 Impacts on surface water

No direct impacts are expected on surface water resources during the operational phases of reclamation. Indirect impacts could occur as a result of discharge of substandard water that does not comply to release standards or from poor housekeeping. Effective stormwater management, especially clean and dirty water separation, is imperative to reduce the risk of affected water flowing into the receiving surface water environment.

The probability of impacts on surface water during the operational phase is unlikely but the magnitude is medium. Effective management and mitigation measures can reduce the risk to low (Table 25).

Table 24: Impact assessment on groundwater quality during the operational phase

Environmental impact, extent, duration, significance and degree to which impact will cause irreplaceable loss	Risk rating (before mitigation)			Environmental objective	Degree to which impact can be reversed and the supporting mitigatory action plan	Timeframe	Responsibility	Risk rating (after mitigation)		
	Probability	Magnitude	Severity					Probability	Magnitude	Severity
ENVIRONMENTAL COMPONENT: Geohydrology										
ACTIVITY: Reclamation of discard and slimes										
PROJECT PHASE APPLICABILITY: Planning and Construction										
PROJECT PHASE APPLICABILITY: Operation – X										
PROJECT PHASE APPLICABILITY: Decommissioning, Closure and Post-Closure – X										
Impact description: Contaminants of concern identified during the geochemical and geohydrological assessment include As, Mn, F, N (as NO_3 and NH_4), Na and Cl. Status quo groundwater conditions at TIOM indicate relatively unimpacted water quality, with some exceptions, but during reclamation a potential exist for an enhanced seepage rate, and oxidation reactions could result in substandard leachate generation and seepage towards the groundwater table. The seepage quality from the facilities is likely to be circum-neutral to alkaline as no potential for acid formation exist but could be rich in macro-elements, NO_3 and potentially As. The probability of groundwater pollution occurring during the operational phase of reclamation is likely, but the magnitude is expected to be low due to the localised nature. Further to this, no receptor boreholes will be impacted on.	3	3	M	To minimise the extent of disturbance of the aquifer. To limit degeneration of groundwater quality.	Management measures: • Minimize seepage, prevent contact between clean and dirty areas, and to recycle contaminated water. • Contain all affected water within the affected water circuit. • Minimise plume migration where relevant. • Minimise ponding of water within the reclamation area. Action plans: • All contaminated/affected water from the area to be directed to lined pollution control dams (PCDs). • PCDs to comply with GN704. • PCDs to be designed so that no polluted water system at the mine is likely to spill into any clean water system more than once in 50	Operational.	Environmental Manger	2	2	L

Environmental impact, extent, duration, significance and degree to which impact will cause irreplaceable loss	Risk rating (before mitigation)			Environmental objective	Degree to which impact can be reversed and the supporting mitigatory action plan	Timeframe	Responsibility	Risk rating (after mitigation)		
	Probability	Magnitude	Severity					Probability	Magnitude	Severity
Duration of impact: Operational phase extending to post closure phases. Degree to which impact may cause irreplaceable loss: None					years and will have a minimum of 800 mm freeboard above spillway level. • Should environmentally unacceptable concentrations of constituents of concern be identified during monitoring of the seepage plume, hydraulic plume containment should be initiated. • Routinely update water balance and do not allow surplus water to be released. • Relevant areas should be free-draining, and ponding of water should be minimised as far as practical or relevant.					

Table 25: Impact assessment on surface water during the operational phase

<table>
<tr><th rowspan="2">Environmental impact, extent, duration, significance and degree to which impact will cause irreplaceable loss</th><th colspan="3">Risk rating (before mitigation)</th><th rowspan="2">Environmental objective</th><th rowspan="2">Degree to which impact can be reversed and the supporting mitigatory action plan</th><th rowspan="2">Timeframe</th><th rowspan="2">Responsibility</th><th colspan="3">Risk rating (after mitigation)</th></tr>
<tr><th>Probability</th><th>Magnitude</th><th>Severity</th><th>Probability</th><th>Magnitude</th><th>Severity</th></tr>
<tr><td colspan="11">ENVIRONMENTAL COMPONENT: Surface water</td></tr>
<tr><td colspan="11">ACTIVITY: Reclamation of discard and slimes</td></tr>
<tr><td colspan="11"><table><tr><td rowspan="3">PROJECT PHASE APPLICABILITY</td><td>Planning and Construction</td><td></td></tr><tr><td>Operation</td><td>X</td></tr><tr><td>Decommissioning, Closure and Post-Closure</td><td></td></tr></table></td></tr>
<tr><td><u>Impact description:</u>
No direct impacts are expected on surface water resources during the operational phases of reclamation. Indirect impacts could occur as a result of discharge of substandard water that does not comply to release standards.

<u>Degree to which impact may cause irreplaceable loss:</u> None</td><td>2</td><td>3</td><td>M</td><td>To minimise the extent of disturbance of the natural surface water environment.
To limit degeneration of surface water quality.</td><td>Management measures:
Minimize seepage, prevent contact between clean and dirty areas, and to recycle contaminated water.
Contain all affected water within the affected water circuit.
Action plans:
All contaminated/affected water from the area to be directed to lined pollution control dams (PCDs).
PCDs to comply with GN704.
Intercept seepage.
PCDs to be designed so that no polluted water system at the mine is likely to spill into any clean water system more than once in 50</td><td>Operational.</td><td>Environmental Manger</td><td>1</td><td>2</td><td>L</td></tr>
</table>

Environmental impact, extent, duration, significance and degree to which impact will cause irreplaceable loss	Risk rating (before mitigation)			Environmental objective	Degree to which impact can be reversed and the supporting mitigatory action plan	Timeframe	Responsibility	Risk rating (after mitigation)		
	Probability	Magnitude	Severity					Probability	Magnitude	Severity
					years and will have a minimum of 800 mm freeboard above spillway level. • A monitoring programme should be incorporated and be updated and assessed by a professional geohydrologist on a yearly basis. • Do not discharge contaminated water into the receiving environment that does not comply to relevant release limits.					

8.4.4 Groundwater management

Groundwater management should be dealt with from a risk-based approach and be focussed on the source-pathway-receptor model. Refer to the Conceptual Site Model in Section 7 for a more detailed discussion on risk-based approach that should be followed.

Monitoring is crucial to verify whether the activities will impact on the local receiving surface and groundwater regime. Important management measures could include:

- Status quo monitoring to be continued with respect to the main pollution sources.
- Monitor groundwater in source and receptor boreholes and receiving surface water environment up- and downstream relative to the mine and/ or from pollution sources.
- Separation of clean and affected water through diversion canals and an affected water management system that collects affected runoff water from dirty management areas.
- Handle and store hazardous material according to manufacturing requirements.
- Train staff and implement correct procedures for the handling of hazardous substances.
- Only qualified staff should handle hazardous materials.
- Contain and clean spillages of hazardous material.
- If environmentally unacceptable concentrations of constituents of concern are identified during monitoring, hydraulic plume containment should be initiated.
- Should it be indicated through monitoring and investigation that groundwater users are impacted upon in terms of groundwater quality or quantity, alternative water sources must be made available to such users.

8.5 Decommissioning phase

The decommissioning phase will commence when the reclamation activities have reached their life cycles. This phase will continue until closure is obtained, at which point in time the Post-Closure Phase will commence. The following activities, which are expected to impact on the surrounding environmental aspect, are anticipated to take place during the decommissioning phase of mining.

- Removal of other redundant surface infrastructure (depending on the agreed end land use), and rehabilitation of the remaining footprint areas.
- Monitoring and maintenance of rehabilitated surface land use areas, as well as surface water and groundwater.
- Utilisation and management of the water balance to reflect the actual situation during the Decommissioning Phase.

In view of the expected short timeframe for the decommissioning phase, no measurable impacts on the groundwater quality, quantity or flow regime are foreseen. The reworking falls within the larger TIOM mining area and closure of these facilities is part of this existing plan. The objective in the existing closure plan is to evaluate the feasibility for reworking these waste materials economically and finally rehabilitate as part of the bigger mining area. A zero-effluent operating principle should be committed to whereby contaminated water will be prevented from entering the receiving environment through actions like recycling, containment and reuse and/or treatment.

8.6 Closure phase

8.6.1 Groundwater quantity

The impact as a result of the reclamation is anticipated to be positive after closure. This is due to the removal of the facilities, which are sources of increased recharge (and seepage) into the aquifer/s. It is assumed that rehabilitation of the footprints will be conducted to allow land-use similar to current land-use in the study area. Therefore, infiltration during post-closure will be similar to the regional average and no post closure impacts on groundwater levels are expected. Raised groundwater levels, if any, are expected to decline to background levels resulting in a low significance impact.

The impact assessment and final risk rating for impacts on groundwater quantity during the post-closure phase can be viewed in Table 26.

8.6.2 Groundwater quality

The reclamation footprints will be rehabilitated to a land-use similar to that prevalent in the study area. Total reclamation of the facilities (100% reduction in height) will obviously result in long term reduction of the potential pollution source strengths as potentially pollution material is removed. No significant leaching of contaminants is expected during the post-closure phase and a net positive impact of the total removal of the potential pollution source is recognised. Groundwater quality beneath the reclaimed footprints is expected to return to a quality similar to the background quality resulting in a low/insignificant impact.

The impact assessment and final risk rating for impacts on groundwater quality during the post-closure phase can be viewed in Table 27.

Table 26: Impact assessment on groundwater quantity during the closure phase

Environmental impact, extent, duration, significance and degree to which impact will cause irreplaceable loss			Risk rating (before mitigation)			Environmental objective	Degree to which impact can be reversed and the supporting mitigatory action plan	Timeframe	Responsibility	Risk rating (after mitigation)		
			Probability	Magnitude	Severity					Probability	Magnitude	Severity
ENVIRONMENTAL COMPONENT: Geohydrology												
ACTIVITY: Reclamation of discard and slimes												
PROJECT PHASE APPLICABILITY	Planning and Construction											
	Operation											
	Decommissioning, Closure and Post-Closure	X										
<u>Impact description:</u> Current groundwater mounding will decline. Complete removal of the tailings and rehabilitation of the footprint will result in a seepage flux comparable with background groundwater recharge rates. Any residual groundwater mounding, if any, is likely to be limited to the footprints. Provided all material is removed, the significance of impacts on groundwater quantity is low to insignificant. <u>Duration of impact:</u> Closure phase <u>Degree to which impact may cause irreplaceable loss:</u> None			2	2	L	To minimise the extent of disturbance of the aquifer. To reduce recharge to mine voids.	Management measures • No specific management measures are proposed other than to continue with water level and quality monitoring and effective clean and affected water separation. Action plans • No specific action plans or mitigation measures are proposed. • Continue with groundwater monitoring and separate clean and affected water.	Operational.	Environmental Manger	2	2	L

Table 27: Impact assessment on groundwater quality during the closure phase

Environmental impact, extent, duration, significance and degree to which impact will cause irreplaceable loss			Risk rating (before mitigation)			Environmental objective	Degree to which impact can be reversed and the supporting mitigatory action plan	Timeframe	Responsibility	Risk rating (after mitigation)		
			Probability	Magnitude	Severity					Probability	Magnitude	Severity
ENVIRONMENTAL COMPONENT: Geohydrology												
ACTIVITY: Reclamation of discard and slimes												
PROJECT PHASE APPLICABILITY	Planning and Construction											
	Operation											
	Decommissioning, Closure and Post-Closure	X										
<u>Impact description:</u> The reclamation footprints will be rehabilitated to a land-use similar to that prevalent in the study area. Total reclamation of the facilities (100% reduction in height) will obviously result in long term reduction of the pollution source strengths as potentially pollution material is removed. Some residual soil contamination may remain within the footprints but if this is rehabilitated to acceptable and National standards, no significant leaching of contaminants is expected during the post-closure phase and a net positive impact of the total removal of the pollution source is recognised. Groundwater quality beneath the reclaimed footprints is expected to return to a quality similar to the background quality resulting in a low/insignificant impact. <u>Duration of impact:</u> Closure phase <u>Degree to which impact may cause irreplaceable loss:</u> None			2	2	L	To minimise the extent of disturbance of the aquifer. To limit degeneration of groundwater quality.	Management measures • No specific management measures are proposed other than to continue with water level and quality monitoring and effective clean and affected water separation. Action plans • No specific action plans or mitigation measures are proposed. • Continue with groundwater monitoring and separate clean and affected water.	Operational.	Environmental Manger	2	2	L

8.6.3 Cumulative impacts

Cumulative impacts of current and potential neighbouring and future mining activities and other industries within the area were neglected due to data limitations. However, given the nature of the project activities and geological and geohydrological context, no cumulative impacts are anticipated if rehabilitation is conducted according to National and industry acceptable standards.

8.6.4 Ground- and surface water management

The reclamation activities falls within the larger TIOM mining area and that the closure of these facilities is part of this existing plan. The objective in the existing closure plan is to see if these waste materials cannot be utilised economical and them rehabilitated as part of the bigger mining area.

The main groundwater management objectives and principles that should be maintained during closure and reclamation of these facilities are to prevent, minimise or contain contamination of groundwater and natural surface water resources. Management activities or mitigation measures to include the following:

- Pond formation should be prevented on surface by creating a free-draining surface through landscaping along slopes and filling of holes/fractures/cracks in flat-lying areas.
- A rehabilitation plan must be implemented, and the plan should be done in the line with the contents of National Water Act (Act No 36 of 1998) and National Environmental Management Act (Act No 107 of 1998) to avoid subsequent negative environmental impacts that may occur.
- Commit to a zero-effluent operating principle whereby contaminated water will be prevented from entering the receiving surface water environment through actions like recycling, reuse or treatment during the short- and long-term.
- Re-establish surface drainage to the pre-mining conditions as far as practical.
- Continuation of the monitoring programme to establish post closure trends.
- Groundwater qualities near the project activities should be monitored on a regular basis throughout and post closure phases.
- Routinely refine, update and validate the conceptual and numerical models by incorporation of ongoing monitoring data.

9. GROUNDWATER MONITORING SYSTEM

The observation and recording of environmental data are costly; therefore, the philosophy and reasoning behind an environmental monitoring system should always be sound. The benefits of sound environmental monitoring are not only legal compliance, but also certain business benefits such as the improvement of operational efficiency, the improvement of risk management, the reduction of liabilities, the avoidance of adverse publicity and ultimately the improvement of business performance.

Current Environmental Legislation in South Africa requires mining and industry to comply with the philosophy of Integrated Environmental Management. The applicable legislation includes inter alia the Constitution, the National Environmental Management Act, the Environment Conservation Act, the Minerals and Petroleum Resources Development Act, and the National Water Act, to name but a few of the more prominent acts.

Environmental Management policies in South Africa advocate the Risk Based Approach, subject to the implementation of the Best Practical Environmental Option, using the management hierarchy of Source-Pathway-Receptor. The Source-Pathway-Receptor hierarchy requires an in-depth understanding of the origin of all pollutants, the pathway these pollutants could follow into the environment and the fate of these pollutants. The overarching Risk Profile relates to protection of Human Health and the Environment. The Best Practical Environmental Option is a minimum requirement in terms of South African Environmental Management Policy and forms the basis of all source control measures to be implemented.

9.1 Groundwater monitoring network

9.1.1 Source plume, impact and background monitoring

Prior to the design of any monitoring programme, the current understanding of the groundwater system must be understood in terms of i) flow dynamics and behaviour, ii) potential sources of groundwater and related surface water impacts; iii) receptors that may be affected by impacts to groundwater and surface water; and iv) the pathways that could potentially connect them. No risk exists if an impact source is not linked to a potential receptor.

A deterioration in groundwater quality is the most significant risk associated with the activities.

The source-pathway-receiver model provides a conceptual portrayal of the mode through which contaminants act and the potential harm they may inflict on a receiving water body and/or organism. The conceptual model is used to develop management action plans and reclamation alternatives that are directed towards mitigating potentially harmful effects caused by the contaminants of concern. Refer to the conceptual site model discussion under Section 7 for a more detailed discussion on interaction between potential sources of contamination and receptors that could be affected using the source – pathway – receptor methodology.

9.1.2 System response monitoring network

A Water Management Plan is required to ensure that the activities do not impact negatively on groundwater levels and water quality. It will also serve as early warning systems to implement mitigation measures at early stages to reduce cumulative impacts. To ensure that the groundwater environment is protected, monitoring of water quality and levels are required on an on-going basis.

Monitoring is required for the following purposes:

1. To detect the actual impact on groundwater quality timeously.
2. To assess whether the mitigation measures given in Section 8 are effective, supporting the update of mitigation measures where necessary.
3. Models can be updated and refined based on new information to support adaptive management measures. Model confidence levels can be increased, and groundwater impacts be predicted with more accuracy. With updated and high confidence predictions, the client can act in a pre-emptive manner, thus reducing risks, rather than acting retrospectively when monitoring data reveals a problem.
4. To interrogate unknowns identified in this report, in which various field investigations can be carried out to test and improve the conceptual hydrogeological understanding of the aquifer system.

As mentioned previously, monitoring in general should follow the risk-based approach to define or characterise the risks that the operations and associated infrastructure may pose on the receiving environment.

Risk assessments involve the understanding of the generation of a hazard, the probability that the hazard will occur, and the consequences should it occur, i.e. understanding the complete cause and effect cycle. The most basic risk assessment methodology is based on defining and understanding the three basic components of the risk, i.e. the source of the risk (source term), the pathway along which the risk propagates, and finally the target that experiences the risk (receptor). The risk assessment approach is aimed at describing and defining the relationship between cause and effect.

The main objective in positioning monitoring boreholes is to intercept groundwater i) upgradient from the source (background); ii) at the source; iii) moving away/downgradient from the source; and iv) interception at selected intervals towards a final receptor.

9.1.3 Monitoring frequency

The status quo monitoring, as per the *Annual Water Monitoring Report (GCS, 2018),* should continue at TIOM

9.2 Monitoring parameters

The status quo monitoring should continue, as per the *Annual Water Monitoring Report* (GCS, 2018).

9.3 Monitoring boreholes

It is recommended that the status quo surface and groundwater monitoring programme be continued. No new monitroring boreholes are recommended at this stage.

10. CONCLUSION AND RECOMMENDATIONS

Thabazimbi Iron Ore Mine (Pty) Ltd., a subsidiary of ArcelorMittal South Africa Limited: Thabazimbi Iron Ore Mine ("TIOM") requested Shangoni Management Services (Pty) Ltd to apply for a waste management licence ("WML") and Environmental Authorisation ("EA"). The WML and EA are for the reworking/reclamation of the existing D1-Old Plant Discard Dump, D2- Old Plant Discard Dump, D3 – Supply Chain Discard Dump and the existing Slimes Dams. The aim of the reworking activities is to supply high quality iron ore to the AMSA Vanderbijlpark Steel Works , aggregate to the construction market and low Fe ore to the cement factories.

The present/status quo groundwater conditions do not indicate substantial impacts on the geohydrological regime in vicinity of the slimes and discard facilities. However, contaminants of concern were identified and these, *inter alia*, should be closely monitored in the groundwater system. Impacts on the groundwater quantity during the operational or reclamation phase of the project are potentially an increase in seepage rates from the facilities, which would have otherwise remained rehabilitated with a lower seepage rate.

The seepage quality from the facilities is likely to be circum-neutral to alkaline as no potential for acid formation exist but it could contain traces of macro- and trace elements. Status quo groundwater monitoring results suggest that seepage loads from the facilities does not reach the groundwater table in substantial amounts, although an arsenic (As) concentration exceeding SANS drinking water standards, was recorded in groundwater in vicinity of the Supply Chain Discard Dump, while nitrate (NO_3) was also recorded in raised concentrations. It is, however, at this stage unknown if the As and NO_3 present is a natural phenomenon or mining related due to seepage from the dumps.

The reclamation footprints will be rehabilitated to a land-use similar to that prevalent in the study area. Total reclamation of the facilities (100% reduction in height) will obviously result in long term reduction of the potential pollution source strengths as potentially pollution material is removed. Some potential residual soil contamination may remain within the footprints but if this is rehabilitated to acceptable and National standards, no significant leaching of contaminants is expected during the post-closure phase and a net positive impact of the total removal of the potential pollution source is recognised. The groundwater quality directly beneath the reclaimed footprints is unknown but if raised compared to ambient, it is expected to return to a quality similar to the background quality resulting in a low/insignificant impact.

A Water Management Plan is required to ensure that the infrastructure do not impact negatively on water quality to unacceptable levels. It will also serve as early warning systems to implement mitigation measures at early stages to reduce cumulative impacts. To ensure that the natural receiving environment is protected, monitoring is required on an on-going basis even during the closure phases. Status quo monitoring is recommended to continue.

Based on the findings of the geohydrological assessment, no fatal flaws have been identified that may limit the reclamation activities. It is the opinion of the specialist that the proposed project may proceed on condition that all mitigation measures as outlined and discussed in this report be adhered to.

REFERENCES

Aller, L., Bennet, T., Lehr, J.H., Petty, R.J. and Hacket, G. 1987. DRASTIC: A standardized system for evaluating groundwater pollution using hydrological settings. Prepared by the National Water Well Association for the US EPA Office of Research and Development, Ada, USA.

Eriksson, P.G., Altermann, W., and Hartzer, F.J. 2006. The Transvaal Supergroup and its precursors, in Johnson, M.R., Anhaeusser, C.R., and Thomas, R.J., eds., The Geology of South Africa: Johannesburg, Geological Society of South Africa and Pretoria, Council for Geoscience p. 237-260.

GCS, 2018. Thabazimbi Mine – Surface and Groundwater Monitoring Report. GCS Project Number: 17-1014

GCS, 2019. Thabazimbi Mine – Task II: Closure Assessment Groundwater Model Update (in DRAFT format). GCS Project Number: 16-0659.

Lynch, S.D., Reynders, A.G. and Schulze, R.E., 1994: A DRASTIC approach to groundwater vulnerability mapping in South Africa. SA Jour. Sci., Vol. 93, pp 56 - 60.

Netshiozwi, S.T. 2002. Origin of high-grade hematite ores at Thabazimbi Mine, Limpopo Province, South Africa. MSc dissertation (unpubl.), Rand Afrikaans University, Johannesburg, 135pp

Parsons, R.P., 1995: A South African aquifer system management classification; WRC Report No. 77/95, Water Research Commission, Pretoria.

South African National Standards, 241: 2015 Drinking Water Standards.

Steenekamp, G and Fourie, I, 1998. The water supply potential of the Donkerpoort Basin for sustained groundwater yield and preliminary investigation of the pollution risks in the Donkerpoort Basin and other selected areas. Geohydrological Report prepared by Iscor Mining Consulting Services. Iscor.

WSM Leshika, 2007. Project Phoenix: Thabazimbi – Groundwater Model for the Dewatering of the Thabazimbi Mine Area – Final Report (Amended), April 2007.

Appendix A

Geochemical data

ANALYTICAL REPORT: Total Trace elements

No unauthorised copies may be made of this report.

To:	**Shongoni Management Services**	Date of Request : 17.12.2019	UIS Analytical Services
Attention:	**Ockie Scholtz**		Analytical Chemistry
Project ID:			Laboratories 4, 6
Site Location:			Tel: (012) 665 4291
Order No:			Fax: (012) 665 4294

Certificate of analysis: 30628

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

Lims ID	**Sample ID**	**Ag**	**As**	**B**	**Ba**	**Be**	**Bi**	**Cd**	**Ce**	**Co**	**Cr**	**Cs**	**Cu**	**Ga**	**Ge**	**Hf**	**Hg**	**Ho**	**La**	**Li**	**Mn**	**Mo**
	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**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**
689281	**Composite/01/Slimes/01**	0.07	16.2	21.0	154	2.96	0.28	0.15	50.6	18.5	96.9	1.23	68.7	4.70	2.30	2.29	0.05	0.58	36.0	16.7	6731	1.13
689282	**Composite/02/Slimes/02**	0.08	16.2	31.0	209	3.31	0.31	0.17	23.5	23.7	105.4	1.17	111	7.20	1.89	3.08	0.04	0.52	12.3	16.9	7334	1.04
689283	**Composite/03/Slimes/03**	0.07	15.9	31.7	181	3.22	0.26	0.15	36.8	20.3	97.6	1.38	63.9	5.47	2.44	2.29	0.06	0.55	22.5	18.0	6655	0.98
689284	**Composite/04/Slimes/04**	0.08	14.2	33.9	180	3.12	0.28	0.14	28.2	21.3	93.2	1.09	63.0	6.19	1.88	2.46	0.05	0.54	17.2	15.6	7079	0.92
689285	**Composite/05/Waste/Rock/01/01.2**	0.04	9.58	19.2	86	1.75	0.16	0.07	37.4	11.7	46.3	1.70	18.8	3.26	2.66	1.19	0.01	0.45	29.1	14.0	3385	0.63
689286	**Composite/06/Waste/Rock/02**	0.05	11.4	20.7	129	1.85	0.28	0.11	49.4	14.9	87.5	1.43	39.5	4.47	2.56	1.62	0.03	0.50	33.6	19.9	5468	0.69
689281 QC	**Duplicate**	0.07	16.2	21.8	152	2.71	0.28	0.15	50.5	18.7	95.8	1.34	67.7	4.71	2.27	2.28	0.05	0.57	35.6	17.0	6641	1.12

Lims ID	**Sample ID**	**Nb**	**Nd**	**Ni**	**Pb**	**Rb**	**Sb**	**Sc**	**Se**	**Sn**	**Sr**	**Ta**	**Te**	**Th**	**Tl**	**U**	**V**	**W**	**Y**	**Zn**	**Zr**	**F**	**Cr6+**
	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**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**
689281	**Composite/01/Slimes/01**	3.47	20.4	82.7	6.97	12.2	1.69	3.85	0.08	1.05	30.8	0.34	0.05	14.3	0.22	3.70	29.4	3.17	22.4	57.4	117	184	<5
689282	**Composite/02/Slimes/02**	3.07	11.4	100	8.21	3.28	1.55	6.30	0.13	1.20	31.2	0.35	0.06	9.34	0.25	4.09	28.1	1.78	16.6	69.1	153	255	<5
689283	**Composite/03/Slimes/03**	3.69	16.1	86.6	8.36	7.61	1.76	5.36	0.02	1.08	32.1	0.35	0.06	9.74	0.21	3.90	31.4	2.69	19.2	63.5	103	240	<5
689284	**Composite/04/Slimes/04**	2.86	14.3	84.5	8.65	4.02	1.56	5.43	0.12	1.03	34.5	0.31	0.05	9.49	0.21	3.81	26.9	1.92	19.0	57.1	130	186	<5
689285	**Composite/05/Waste/Rock/01/01.2**	2.07	16.6	46.1	4.85	12.3	1.09	4.58	0.02	0.86	12.5	0.26	0.04	12.6	0.21	2.23	19.5	2.73	16.3	33.1	59.0	133	<5
689286	**Composite/06/Waste/Rock/02**	3.06	19.2	64.4	5.59	10.2	1.25	4.29	0.09	1.27	17.8	0.47	0.08	11.3	0.16	2.13	24.5	3.09	19.5	50.2	73.0	209	<5
689281 QC	**Duplicate**	3.44	20.7	81.9	6.61	12.5	1.70	3.90	0.08	1.01	30.9	0.34	0.05	14.3	0.21	3.72	29.6	3.18	23.0	58.0	118	203	<5

Chemical elements:	Ag, , As, Au, B, Ba, Be, Bi, Cd, Ce, Co, Cr, Cs, Cu, Ga, Ge, Hf, Hg, Ho, Ir, La, Li, Mn, Mo, Nb, Nd, Ni, Pb, Pt, Rb, Sb, Sc, Se, Sn, Sr, Ta, Te, Th, Tl, U, V, W, Y, Zn, Zr,F,Cr6+
Instrument:	ICP-MS,Ion Selective Electrode,UV-Vis
Method	Trace Elements in soil/ore by ICP-MS

Date:	30.01.2020	Date:	05.02.2020
Analysed by:	MA Motsepe	Authorised :	JJ Oberholzer

ANALYTICAL REPORT: Water Leach

No unauthorised copies may be made of this report.

To:	**ShongoninManagement Services**	Date of Request :17.12.2019	UIS Analytical Services
Attention:	**Ockie Scholtz**		Analytical Chemistry
Project ID:			Laboratories 4, 6
Site Location:			
Order No:			Fax: (012) 665 4294

Certificate of analysis: 30628

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

Lims ID	Sample ID	Ag	Al	As	Au	B	Ba	Be	Bi	Ca	Cd	Ce	Co	Cr
	WATER LEACH 1:4	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
	Leach Blank	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	<0.001	<0.001	0.01	<0.0001	<0.001	<0.001	<0.001
689 287	**Composite/01/Slimes/01/Water/Leach**	<0.001	0.299	0.001	<0.001	0.079	0.188	<0.001	<0.001	10.3	<0.0001	<0.001	<0.001	0.009
689287 QC	**Duplicate**	<0.001	0.302	<0.001	<0.001	0.078	0.189	<0.001	<0.001	10.5	<0.0001	<0.001	<0.001	0.008
689 288	**Composite/02/Slimes/02/Water/Leach**	<0.001	0.014	0.001	<0.001	0.030	0.075	<0.001	<0.001	16.7	<0.0001	<0.001	<0.001	0.011
689 289	**Composite/03/Slimes/03/Water/Leach**	<0.001	0.180	0.001	<0.001	0.027	0.074	<0.001	<0.001	9.88	<0.0001	<0.001	<0.001	0.009
689 290	**Composite/04/Slimes/04/Water/Leach**	<0.001	0.035	<0.001	<0.001	0.027	0.079	<0.001	<0.001	11.2	<0.0001	<0.001	<0.001	0.008
689 291	**Composite/05/Waste/Rock/01/01.2/Water/Leach**	<0.001	0.090	<0.001	<0.001	0.045	0.127	<0.001	<0.001	7.00	<0.0001	<0.001	<0.001	<0.001
689 292	**Composite/06/Waste/Rock/02/Water/Leach**	<0.001	0.048	<0.001	<0.001	0.042	0.120	<0.001	<0.001	8.27	<0.0001	<0.001	<0.001	0.001

Lims ID	Sample ID	Cs	Cu	Fe	Ga	Ge	Hf	Hg	Ho	Ir	K	La	Li	Mg	Mn	Mo	Na	Nb
	WATER LEACH 1:4	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
	Leach Blank	<0.001	<0.001	0.00	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.001	0.04	<0.001	<0.001	0.002	<0.001	<0.001	0.05	<0.001
689 287	**Composite/01/Slimes/01/Water/Leach**	<0.001	0.002	0.24	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.001	2.21	<0.001	0.001	2.17	0.008	0.003	5.89	<0.001
689287 QC	**Duplicate**	<0.001	0.002	0.24	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.001	2.27	<0.001	0.002	2.19	0.008	0.004	5.93	<0.001
689 288	**Composite/02/Slimes/02/Water/Leach**	<0.001	0.005	0.01	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.001	3.99	<0.001	0.001	4.0	0.005	0.004	6.17	<0.001
689 289	**Composite/03/Slimes/03/Water/Leach**	<0.001	<0.001	0.09	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.001	1.99	<0.001	0.001	2.14	0.002	0.003	2.95	<0.001
689 290	**Composite/04/Slimes/04/Water/Leach**	<0.001	<0.001	0.01	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.001	1.79	<0.001	0.001	2.44	<0.001	0.003	4.40	<0.001
689 291	**Composite/05/Waste/Rock/01/01.2/Water/Leach**	<0.001	<0.001	0.04	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.001	0.48	<0.001	0.001	1.32	<0.001	<0.001	2.58	<0.001
689 292	**Composite/06/Waste/Rock/02/Water/Leach**	<0.001	<0.001	0.02	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.001	0.55	<0.001	0.002	1.47	<0.001	<0.001	2.61	<0.001

Lims ID	Sample ID	pH	pH Temp	TDS	EC	TDS by Sum	TDS by EC	P Alk.	M Alk.	F	Cl	NO2	NO3	NO3 as N
	WATER LEACH 1:4		Deg C	mg/l	mS/m	mg/l	mg/l	mg/l CaCO3	mg/l CaCO3	mg/l	mg/l	mg/l	mg/l	mg/l
	Leach Blank	5.76	25.5	<30	1.15	n/a	8.05	<0.6	<3.5	<0.1	<0.25	<0.2	<0.3	<0.1
689287	**Composite/01/Slimes/01/Water/Leach**	7.84	22.2	62.0	7.27	65.1	50.9	<0.6	33.2	0.30	1.42	<0.2	<0.3	<0.1
689287 QC	**Duplicate**	7.87	22.2	64.0	7.05	64.1	49.4	<0.6	31.4	0.30	1.28	<0.2	<0.3	<0.1
689288	**Composite/02/Slimes/02/Water/Leach**	7.70	22.0	122	14.9	92.0	104	<0.6	32.4	0.32	8.69	<0.2	3.19	0.72
689289	**Composite/03/Slimes/03/Water/Leach**	7.91	21.9	46.0	7.29	53.5	51.0	<0.6	29.3	0.30	3.24	<0.2	1.75	0.40
689290	**Composite/04/Slimes/04/Water/Leach**	7.80	22.0	76.0	8.11	61.2	56.8	<0.6	29.1	0.31	5.76	<0.2	0.45	0.10
689291	**Composite/05/Waste/Rock/01/01.2/Water/Leach**	7.91	22.1	40.0	4.68	37.7	32.8	<0.6	22.2	<0.1	<0.25	<0.2	1.67	0.38
689292	**Composite/06/Waste/Rock/02/Water/Leach**	8.66	24.5	46.0	6.60	44.0	46.2	2.40	30.5	<0.1	<0.25	<0.2	<0.3	<0.1

Lims ID	Sample ID	PO4	SO4	Sum of Cations	Sum of Anions	Ion Balance	NH4	NH3	Acidity to pH8.3	CN (free)	CN (Total)	Cr 6+	TSS	TOC
	WATER LEACH 1:4	mg/l	mg/l	me/l	me/l	%	mg/l	mg/l	mg/l CaCO3	mg/l	mg/l	mg/l	mg/l	mg/l
	Leach Blank	<0.8	0.56	n/a	n/a	n/a						<0.05		
689287	**Composite/01/Slimes/01/Water/Leach**	<0.8	12.3	1.06	1.12	-2.79						<0.05		
689287 QC	**Duplicate**	<0.8	12.2	1.07	1.09	-0.63						<0.05		
689288	**Composite/02/Slimes/02/Water/Leach**	<0.8	21.1	1.54	1.51	1.11						<0.05		
689289	**Composite/03/Slimes/03/Water/Leach**	<0.8	6.50	0.88	0.94	-3.32						<0.05		
689290	**Composite/04/Slimes/04/Water/Leach**	<0.8	11.1	1.01	1.06	-2.68						<0.05		
689291	**Composite/05/Waste/Rock/01/01.2/Water/Leach**	<0.8	5.36	0.60	0.66	-4.88						<0.05		
689292	**Composite/06/Waste/Rock/02/Water/Leach**	<0.8	5.94	0.67	0.81	-9.21						<0.05		

Chemical elements:	Ag, Al, As, Au, B, Ba, Be, Bi, Ca, Cd, Ce, Co, Cr, Cs, Cu, Fe, Ga, Ge, Hf, Hg, Ho, Ir, K, La, Li, Mg, Mn, Mo, Na, Nb, Nd, Ni, Pb, Pt, Rb, Sb, Sc, Se, Si, Sn, Sr, Ta, Te, Th, Ti, Tl, U, V, W, Y, Zn, Zr	Anions, pH, NH4, Alkalinity, CN, Cr6+	
Instrument:	ICP-MS Perkin Elmer NexION 300D	Ion Chromatography	Spectrophotometer; Ion Selective Probe

Date:	09.01.2020	Date:	31.01.2020
Analysed by:	UIS Waterlab/MA Motsepe	Authorised :	JJ Oberholzer

To:	ShongoninManagement Services
Attention:	Ockie Scholtz
Project ID:	
Site Location:	
Order No:	

Lims ID	Sample ID	Nd	Ni	Pb	Pt	Rb	Sb	Sc	Se	Si	Sn	Sr	Ta	Te	Th	Ti	Tl	U	V	W	Y	Zn	Zr
	WATER LEACH 1:4	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
	Leach Blank	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.07	<0.001	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001
689 287	Composite/01/Slimes/01/Water/Leach	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	3.54	<0.001	0.010	<0.001	<0.001	<0.0001	0.002	<0.001	0.0002	<0.001	<0.001	<0.001	0.002	<0.001
689287 QC	Duplicate	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	0.001	3.57	<0.001	0.010	<0.001	<0.001	<0.0001	0.002	<0.001	0.0002	<0.001	<0.001	<0.001	0.002	<0.001
689 288	Composite/02/Slimes/02/Water/Leach	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	2.98	<0.001	0.014	<0.001	<0.001	<0.0001	<0.001	<0.001	0.0002	<0.001	<0.001	<0.001	0.014	<0.001
689 289	Composite/03/Slimes/03/Water/Leach	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	2.45	<0.001	0.007	<0.001	<0.001	<0.0001	<0.001	<0.001	0.0002	<0.001	<0.001	<0.001	0.001	<0.001
689 290	Composite/04/Slimes/04/Water/Leach	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	2.21	<0.001	0.008	<0.001	<0.001	<0.0001	<0.001	<0.001	0.0002	<0.001	<0.001	<0.001	0.002	<0.001
689 291	Composite/05/Waste/Rock/01/01.2/Water/Leach	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	2.01	<0.001	0.006	<0.001	<0.001	<0.0001	<0.001	<0.001	<0.0001	<0.001	<0.001	<0.001	0.002	<0.001
689 292	Composite/06/Waste/Rock/02/Water/Leach	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	2.33	<0.001	0.005	<0.001	<0.001	<0.0001	<0.001	<0.001	<0.0001	<0.001	<0.001	<0.001	0.005	<0.001

	WATER LEACH 1:4
	Leach Blank
689287	Composite/01/Slimes/01/Water/Leach
689287 QC	Duplicate
689288	Composite/02/Slimes/02/Water/Leach
689289	Composite/03/Slimes/03/Water/Leach
689290	Composite/04/Slimes/04/Water/Leach
689291	Composite/05/Waste/Rock/01/01.2/Water/Leach
689292	Composite/06/Waste/Rock/02/Water/Leach

Date:	09.01.2020
Analysed by:	UIS Waterlab/MA Motsepe

ANALYTICAL REPORT: Major & Minor Elements

To: **Shongoni Management Services**
Attention: **Ockie Scholtz**

Tel:
E-mail:

Date of Request: 17.12.2019

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

Certificate of analysis: 30628

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

Lims ID	Sample ID	SiO2	Al2O3	Fe(tot)	Fe2O3	TiO2	CaO	MgO	Na2O	K2O	MnO	P	Ba	Cr	Cu	Ni	Sr	V	Zn	Moisture	LOI
		%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
689281	**Composite/01/Slimes/01**	11.8	4.76	52.8	75.5	0.261	0.68	0.87	0.028	0.463	0.816	0.081	0.014	0.011	0.007	0.008	0.005	0.001	0.005	0.040	3.70
689282	**Composite/02/Slimes/02**	16.2	7.15	47.3	67.6	0.321	0.60	0.85	0.033	0.699	0.893	0.080	0.020	0.011	0.011	0.010	0.004	0.001	0.007	-0.060	4.89
689283	**Composite/03/Slimes/03**	12.5	5.55	51.8	74.1	0.290	0.80	0.92	0.036	0.590	0.805	0.096	0.017	0.011	0.006	0.008	0.004	0.001	0.006	-0.020	3.83
689284	**Composite/04/Slimes/04**	12.9	5.75	51.4	73.4	0.280	0.64	0.75	0.031	0.608	0.861	0.082	0.017	0.010	0.007	0.008	0.004	0.001	0.005	0.020	3.81
689285	**Composite/05/Waste/Rock/01/01.2**	44.2	2.19	33.1	47.3	0.125	1.17	1.30	0.020	0.423	0.413	0.033	0.008	0.003	0.002	0.004	0.003	<0.001	0.002	0.080	2.64
689286	**Composite/06/Waste/Rock/02**	40.4	2.51	32.9	47.1	0.420	2.46	2.33	0.047	0.346	0.660	0.023	0.012	0.009	0.004	0.006	0.001	0.005	0.005	0.000	4.00
689281 QC	**Duplicate**	11.9	4.85	52.8	75.4	0.255	0.67	0.89	0.029	0.467	0.805	0.081	0.014	0.011	0.007	0.008	0.003	0.001	0.006	-0.020	3.71

Note: Analysis done on sample as received before drying

Note: LOI does not include moisture

Chemical elements: Si, Al, Fe, Ti, Ca, Mg, Na, K, Mn, P, Ba< Sr, Cr, Cu, V, Ni, Zn, Zr
Instrument: ICP-OES,
Method: Major & Minor elements in Ore/Soil by ICP-OES

Date: 04.02.20020
Analysed by: MA Motsepe

Date: 05.02.20020
Authorised : JJ Oberholzer