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**MODIKWA PLATINUM MINE GEOHYDROLOGICAL IMPACT  
ASSESSMENT: FOR THE PROPOSED SOUTH 3 OPENCAST  
PROJECT, AT FARM WINTERVELD 293 KT IN THE FETAKGOMO  
TUBATSE MUNICIPALITY, LIMPOPO PROVINCE, SOUTH  
AFRICA.**

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## Geohydrological Report


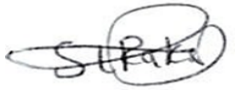

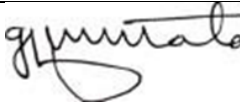


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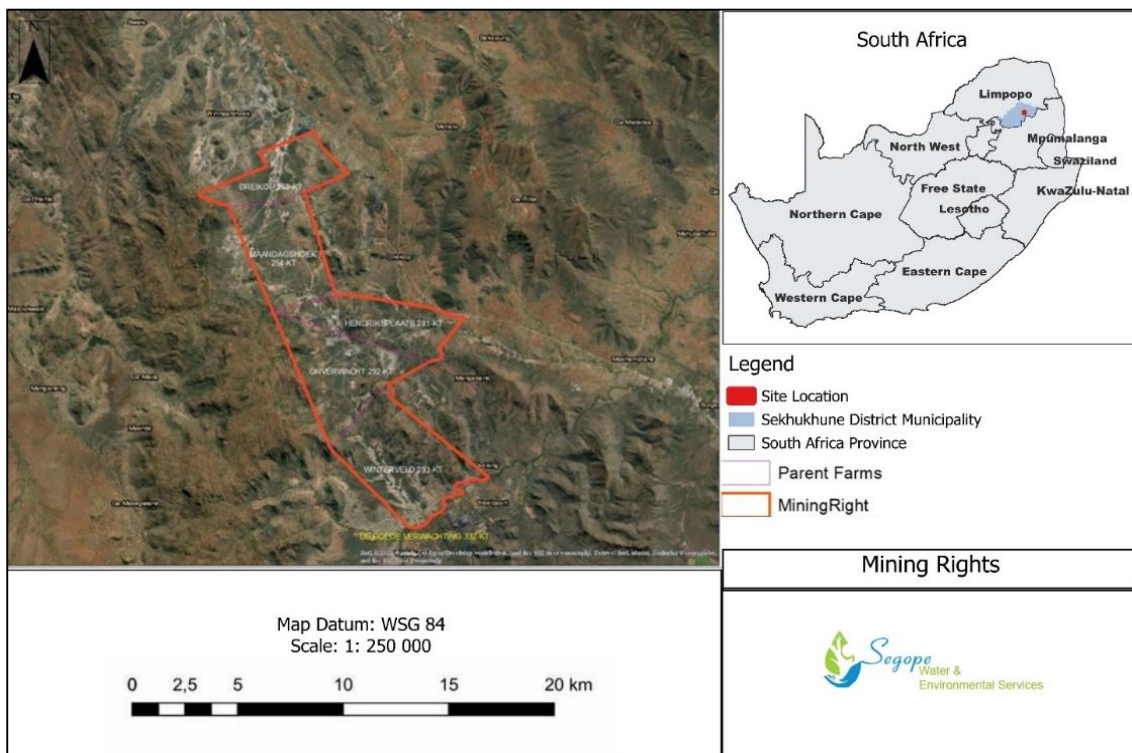
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## 1. INTRODUCTION

Segope Water and Environmental Services (Segope Consulting) has been appointed by Modikwa Platinum Mine (MPM) to undertake the geohydrological study in support of the proposed South 3 opencast mining project. The format and content of this report follows the listed items as stipulated for an Integrated Waste Water Management Plan (IWWMP) in the Regulations regarding the procedural requirements for Water Use License (WUL) applications and appeals, Government Notice (GN) R267, Government Gazette 40713 24 March 2017.

The MPM is situated in the Limpopo province within quaternary catchment B41J (Moopetsi and Tubatse River Catchments). The mine is located approximately 20 km west of Burgersfort and 18 km north of Steelpoort on the Eastern Limb of the Bushveld Complex. The mine currently has mining rights on Portions of farms Maandagshoek 254 KT, Driekop 253 KT, Hendriksplaats 281 KT, Overwatch 292 KT, Winterveld 293 KT and Doornbosch 294 KT ( **Figure 1.1**). The mine has both open pits and underground mining operations. The mine is proposing to develop an open pit mine and related infrastructures on farm Winterveld 293 KT. The mining method will follow the conventional opencast methods, which include the stripping at 40 to 60 thousand tonnes per month (ktpm) with concurrent backfill. The ore from the open pit will be extracted by a combination of excavation, crushing, washing and concentration and then be transported by truck to the primary crusher stockpile. Waste will be disposed to waste dumps on the surface. The methodology followed to conduct the Geohydrological study is detailed in **Section 3** of this report.



**Figure 1.1: Modikwa Platinum Mine mining right**

## 2. GEOGRAPHICAL SETTING

### 2.1 Site Description

The MPM is located within the Fetakgomo Tubatse Local Municipality (FTLM) in the Sekhukhune District Municipality of the Limpopo Province. The proposed South 3 opencast project is to be situated on farm Winterveld 293 KT, which is owned by the Samancor Chrome, and for which MPM has a lease agreement. The site locality and topography of an area is indicated in below. Access to South 3 Project area will be through a gravel road which joins a tarred road leading to R555 in Steelpoort town which then joins the regional road (R37) from Burgersfort.

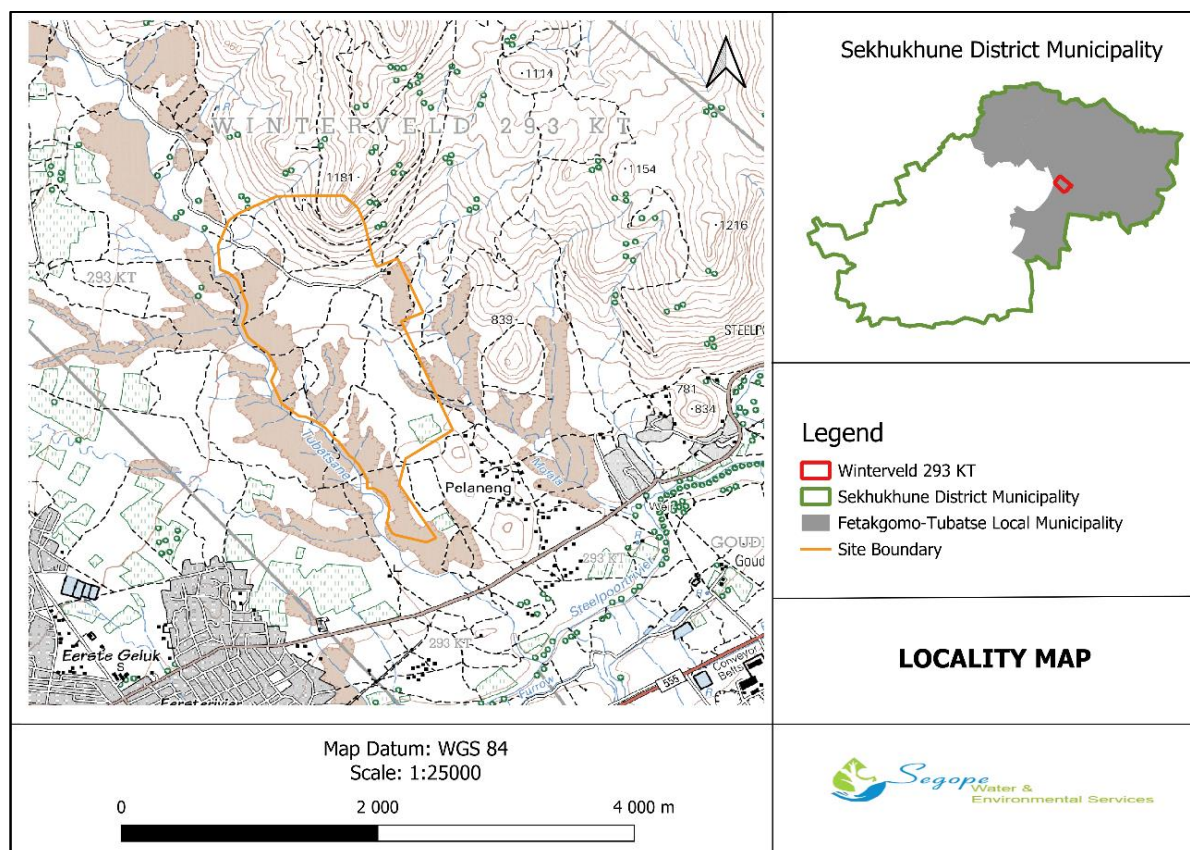


Figure 2.1: Site Locality and Topography

### 2.2 Topography and Drainage

The topography of the project area is extremely rugged, characterized by steep-sided hills and mountains in the north and north-eastern sides, with a broad relatively flat land towards the south and western parts. The lower lying valley areas between the steep-sided mountains are at an average height of 750 metres above mean sea level (mamsl). The highest ridges have elevations of approximately 1 300 mamsl at the north eastern side. The topography of the project



**Category A:** Unmodified natural

**Category B:** Largely natural

**Category C:** Moderately modified

**Category D:** Largely modified

Based on the site observations and the Provincial Water Resources Assessments for the National Water Balance of 1999, the sensitivity and present ecological status for the B41J quaternary catchment is **given as B** (Largely natural).

## 2.5 Climate

The MPM is situated in Limpopo province, which is a summer rainfall area, with a warm to hot climate and a relatively high humidity in summer. Average daily temperatures vary from 32°C in January to 24°C in July. The wind direction is mostly from the south-south east to north-north west. The Mean Annual Precipitation (MAP) for this area is approximately 705.85 mm, with the highest concentrations of rainfall between October and March (**Table 2.1**). The winter months contribute very little to the annual rainfall. **Figure 2.3** depicts the long-term annual average climatic conditions throughout the year.

**Table 2.1 : Temporal Distribution of Rainfall and Evapotranspiration in the Study Site**

Month	Mean Monthly Rainfall (mm)	Mean Monthly Evaporation(mm)
January	128.65	229.6
February	123.8	198.7
March	72.6	198.1
April	51.3	162.4
May	11.3	151.2
June	11.35	129.7
July	7.95	119.8
August	10.15	173.2
September	28.9	192.7
October	41.35	228.1
November	102.75	215
December	115.75	216.9
Annual	705.85	2201.5

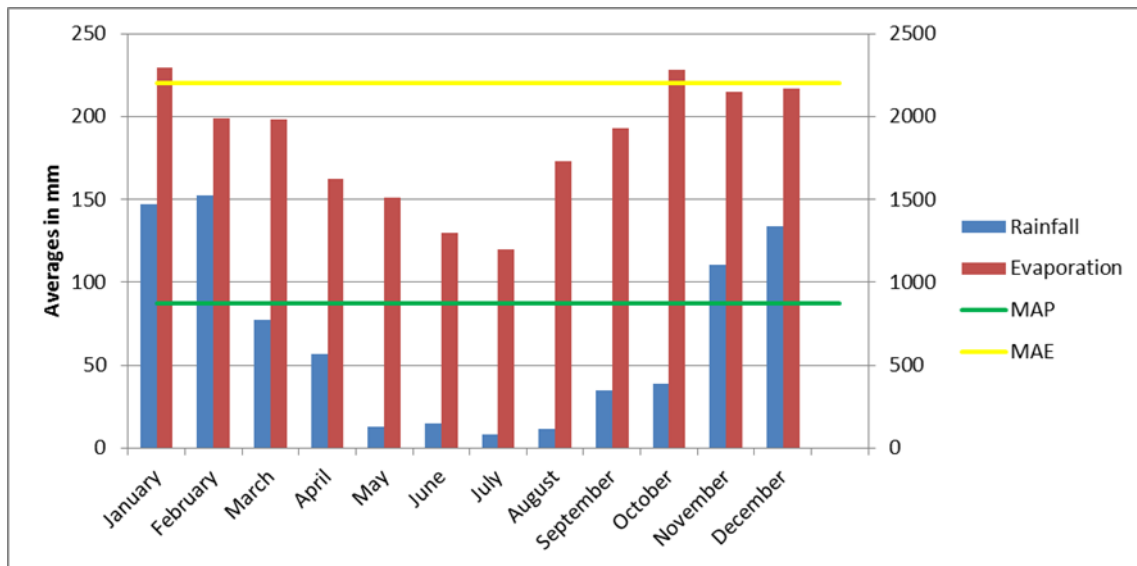


Figure 2.3: Summary of the Climatic Information for the Study Site

## 2.6 Geology

### 2.6.1 Regional Geology

Figure 2.4 below illustrates the regional geology of the study area. The study area falls within the Pilgrims Rest 1:250 000 geology series maps. The geology of the area consists mainly of the critical and main zones of the Rustenburg Layered Suite of the Bushveld Igneous Complex. The area encompasses intrusive igneous rocks, mainly norite and pyroxenite. Lithologies has mainly a south to south-eastern strike and dips at an angle of  $\pm 10-15^\circ$  in a westerly direction. Modikwa Platinum Mine is aiming to exploit ore reserves of the UG2 layer, hosted within these rocks.

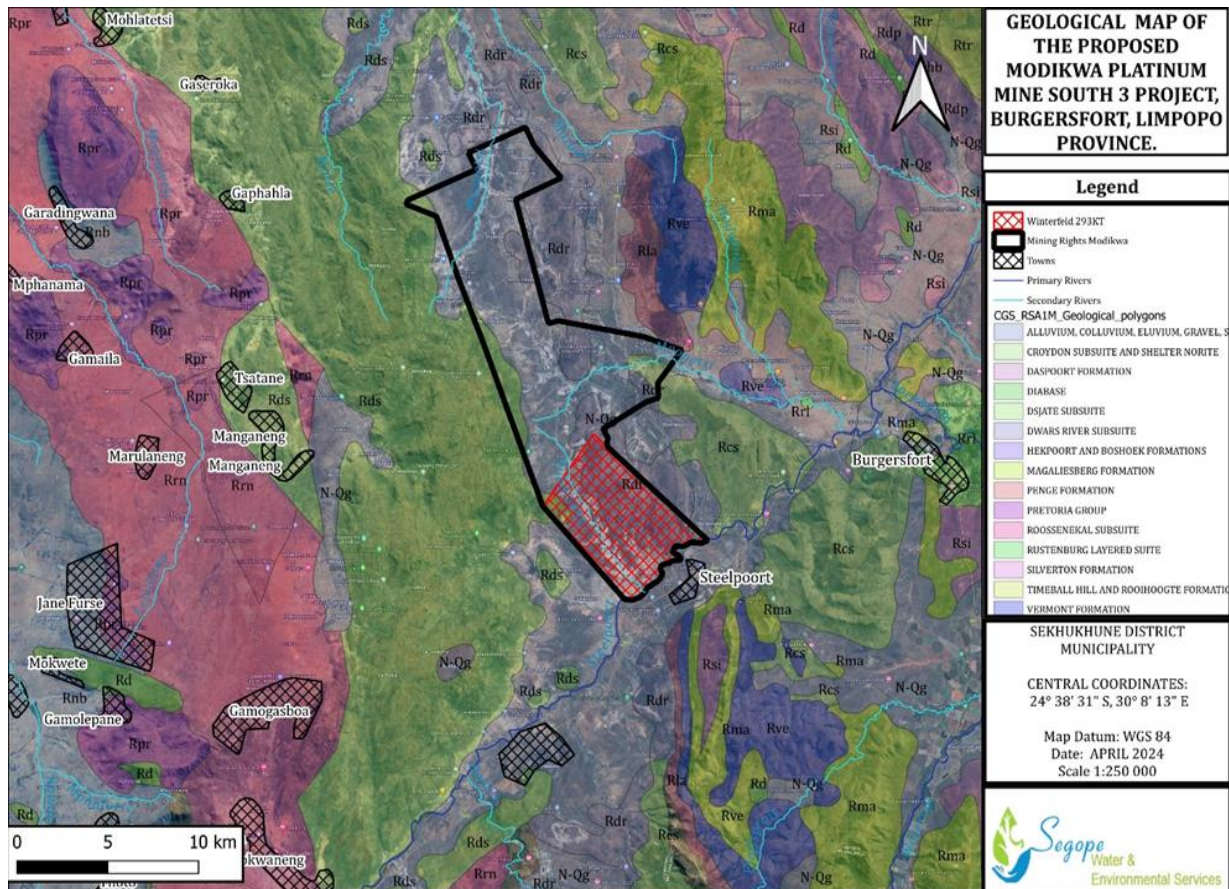


Figure 2.4 : Regional Geology Map (1:250 000 geology series)

## 2.7 Regional Hydrogeology

The Rustenburg Layered Suite rocks typically act as secondary aquifers (intergranular and fractured rock aquifers) (Haupt, 1995). However, the multi-layered weathering system present on these rocks could have up to two aquifer systems present in the form of a shallow, saprolitic aquifer with a weathered, intergranular soft rock base associated with the contact of fresh bedrock and the weathering zone, and a fractured bedrock aquifer. These aquifer systems are discussed below:

### 2.7.1 Shallow, saprolitic aquifer

The primary source of recharge into a shallow aquifer is rainfall that infiltrates the aquifer through the unsaturated (vadose) zone. In these systems, vertical movement of water is faster than lateral, as water moves predominantly under the influence of gravity. This aquifer may contain coarse, anorthositic sediment or turf clay sediment when underlain by Anorthosite or Gabbro-norite, respectively. The hydraulic conductivity of this aquifer ranges between  $10^{-8}$  and  $10^{-2}$  m/day, and porosity ranges between 0.4 and 0.7 for turf clay sediments. The hydraulic conductivity of the coarse, anorthositic sediment can reach up to 20 m/day with porosities ranging between values of 0.25 to 0.5.

### 2.7.2 Shallow weathered aquifer

This aquifer, which is recharged by rainfall, is often perched due to the impermeable clay horizons that might have developed underneath it. The recharge to this aquifer is estimated to be 3 - 5% of the annual rainfall. The well-developed clay layers in this aquifer restrict the downward filtration of recharged rainwater into the primary fractured aquifer. The most significant water accumulation is generally confined to the contact between the weathered and “fresh” bedrock. The borehole yields in this aquifer appear to be high due to the sandy/gritty nature of the weathered pyroxenite.

### 2.7.3 Fractured, bedrock aquifer

Groundwater movement is predominantly associated with secondary structures in this aquifer (fractures, faults, dykes, *etc.*). The average water level depth in the area ranges between 5 and 40 mbgl. Borehole yields in the Rustenburg Layered Suite fractured aquifers are generally low and can be expected to be between 0.1 and 2l/s, with regional flow resembling flow in the porous medium and obeying the Darcy’s law. These formations contain limited quantities of water resources due to the poor storage capacity of the igneous rock.

Groundwater quality in this area is also expected to be intermediate to poor, with EC values ranging from 4.4 to 120mS/m and possibly elevated Ca, Mg, Cl, and SO<sub>4</sub> and carbonate alkalinity concentrations according to Haupt (1995). Both the porosity and the hydraulic conductivity of the Rustenburg Layered Suite fractured aquifers are known to be low (Williams *et al.*, 2020). The commonly expected values of porosity and permeability for Igneous rock types, similar to those present in the Rustenburg Layered Suite, are 0.05 (porosity) and 10<sup>-5</sup> m.d<sup>-1</sup> (hydraulic conductivity), respectively (Kruse man & de Ridder, 1994). Groundwater movement in this aquifer will be preferential in secondary structures such as joints, faults, and fractures.

### 2.7.4 Deeper fractured aquifer

The presence of weathering and fracturing zones within the country rock controls groundwater occurrence. Groundwater is generally restricted to depths of 40– 70m below the surface, with most water strikes occurring in fracturing below the weathering. The most profound water strikes (70m) are associated with the contact zones of the main SW–SE trending dykes. Zones of high transmissivity are known to be associated with the dolerite dykes, and borehole yields varying from 2 to 20 l/s have been obtained in the general area. Aquifers are confined, anisotropic, and secondary with limited storage.

## 3. METHODOLOGY

The geohydrological report was constructed by first identifying what information is valuable or known as well as what gaps needs to be filled, and constructive recommendations were made. **Figure 3.1** below indicates the general site layout plan for the south 3 operations. The impact of the proposed mine was investigated through field investigations, data analyses, and the use of numerical models (flow and transport models). The following subsections will discuss the work completed to compile the groundwater report.

### 3.1 Desktop Study

This included gathering of information through the collation, scrutiny and evaluation of available and relevant meteorological, geographical, geological, hydrogeological and water quality data.

### 3.2 Hydrocensus

The Hydrocensus was done to be familiar with the site and to collect data from the study area and surrounding environments. It comprised a census of key boreholes, wells, springs and any other groundwater related information.

### 3.3 Sampling and Chemical Analyses

#### 3.3.1 Groundwater Sampling

Groundwater was sampled by bailing according to the Standard Operating Procedure for groundwater sampling. Seven boreholes were sampled for chemical analysis. The water quality sampling work was undertaken in accordance to the following guidelines:

- SABS ISO 5667-11: 2012 Guidance on sampling of groundwater
- SABS ISO 5667-2: 2012 Guidance on sampling techniques
- SABS ISO 5667-3: 2008 Guidance on the preservation and handling of samples

Samples were stored in a cool, dark container and submitted to a SANAS-accredited laboratory, Elements (Pty) Ltd, for analysis.

#### 3.3.2 Groundwater Analysis

The following groundwater parameters listed **Table 3.1** were analysed to understand the quality and Hydrochemical facies of the groundwater samples taken.

**Table 3.1 : Analyzed Groundwater Parameters**

Parameters	Parameters
Dissolved Aluminum	Fluoride
Dissolved Arsenic	Chloride
Dissolved Cadmium	Nitrite as NO <sub>2</sub>
Dissolved Calcium	Nitrate as NO <sub>3</sub>
Total Dissolved Chromium	Sulphate
Dissolved Cobalt	Ortho Phosphate as PO <sub>4</sub>
Dissolved Copper	Ammoniacal Nitrogen as NH <sub>4</sub>
Total Dissolved Iron	Hexavalent Chromium
Dissolved Lead	Total Alkalinity as CaCO <sub>3</sub>
Dissolved Magnesium	Carbonate Alkalinity as CaCO <sub>3</sub>
Dissolved Manganese	Bicarbonate Alkalinity as CaCO <sub>3</sub>
Dissolved Mercury	Electrical Conductivity @25°C
Dissolved Molybdenum	pH
Dissolved Nickel	Total Dissolved Solids

Dissolved Potassium	Total Suspended Solids
Dissolved Selenium	Dissolved Zinc
Dissolved Sodium	

### 3.4 Quality Assurance and Quality Controls (QA/QC)

The methodology followed for groundwater sampling is in accordance with the American Environmental Protection Agency (EPA). The SANAS-accredited Elements laboratory which is competent to carry out laboratory tasks in terms of the Accreditation for Conformity Assessment, Calibration and Good Laboratory Practice Act (Act 19 of 2006), was used for samples analysis. The SANAS's purpose is to instill confidence and peace of mind to companies and individuals through accreditation required for economic and social well-being for all.

### 3.5 Aquifer Classification

The aquifer(s) underlying the subject area were classified in accordance with "A South African Aquifer System Management Classification, December 1995". The main aquifers underlying the area were classified in accordance with the Aquifer System Management Classification document (DWAf and WRC, 1995). The aquifers were classified by using the following definitions:

- **Sole Aquifer System:** An aquifer which is used to supply 50% or more of domestic water for a given area, and for which there is no reasonably available alternative sources should the aquifer be impacted upon or depleted. Aquifer yields and natural water quality are immaterial.
- **Major Aquifer System:** 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 (Electrical Conductivity of less than 150 mS/m).
- **Minor Aquifer System:** These can be fractured or potentially fractured rocks which do not have a high primary permeability, or other formations of variable permeability. Aquifer extent may be limited and water quality variable. Although these aquifers seldom produce large quantities of water, they are important for local supplies and in supplying base flow for rivers.
- **Non-Aquifer System:** These are formations with negligible permeability that are 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, although imperceptible, does take place, and needs to be considered when assessing the risk associated with persistent pollutants.

### 3.6 Aquifer Vulnerability

Aquifer vulnerability is the intrinsic characteristics that determine the aquifer's sensitivity to the adverse effects resulting from the imposed pollutants (Rivera and Guerrero, 2008). It is

determined to indicate the tendency or likelihood for contamination to reach a specified position in the groundwater system after introduction of a contaminant at some location above the uppermost aquifer.

The following factors have an effect on groundwater vulnerability:

- **Depth to groundwater:** Indicates the distance and time required for pollutants to move through the unsaturated zone to the aquifer.
- **Recharge:** The primary source of groundwater is precipitation, which aids the movement of a pollutant to the aquifer.
- **Aquifer media:** The rock matrices and fractures which serve as water bearing units.
- **Soil media:** The soil media (consisting of the upper portion of the vadose zone) affects the rate at which the pollutants migrate to groundwater.
- **Topography:** Indicates whether pollutants will run off or remain on the surface allowing for infiltration to groundwater to occur.
- **Impact of the vadose zone:** The part of the geological profile beneath the earth's surface and above the first principal water-bearing aquifer. The vadose zone can retard the progress of the contaminants (DWAF, 2007).
- The Groundwater Decision Tool (GDT) was used to quantify the vulnerability of the aquifer underlying the site. Please note that vulnerability of groundwater is a relative, non-measurable and dimensionless property which is based on the concept that some areas are more vulnerable to groundwater contamination than others.

### 3.7 Groundwater Modelling

#### 3.7.1 Modelling Software

The groundwater model for the proposed South3 project site was constructed in Processing Modflow 8(Simcore Software), a pre- and post-processor for the finite difference MODFLOW flow model and MT3DMS transport model. PMWIN, originally developed by Chaing and Kinzelbach (1999), was used to create the model and to analyse and display the modelling results. PMWIN is an internationally accepted modelling package, which uses MODFLOW to calculate the solution of the groundwater flow equation using the finite difference approach. It simulates steady and non-steady flow in an irregularly shaped flow system in which aquifer layers can be confined, unconfined, or a combination of confined and unconfined. Flow from external stresses, such as flow to boreholes, aerial recharge, evapotranspiration, flow to drains, and flow through riverbeds, can be simulated. MT3D was used for contaminant transport simulations, taking advection and dispersion and sources/sinks into account.

The groundwater model was calibrated using observed groundwater data (water level and quality). Once calibrated, all future inflow rates and extent of contamination plumes were predicted for current and future scenarios.

The lateral extent of the model covering all proposed Surface infrastructures of the South3 project is shown in Figure below. The boundaries of the model were chosen based on surface water divides, which correlate to the groundwater flow patterns.

### 3.7.2 Conceptual Site Model

A Groundwater Conceptual Site Model was constructed and used as a descriptive representation of the groundwater system that incorporates an interpretation of the geological and hydrological conditions. The model was constructed based on the general hydrogeological conceptual model of two layers for this area. The first layer (30 to 40 m thick) represents the weathered and intergranular aquifer and the second layer representing the deeper fractured aquifers. The South 3 model is described on the sessions below. The main potential sources of contamination within the study area are the openpit ROM stockpile, Waste Rock Dump Latrines and Pollution control dams

### 3.7.3 The South 3 Opencast Model

Processing Modflow, a finite difference groundwater flow and contaminant transport modelling software package was used to construct the numerical groundwater flow model for the proposed South3 opencast area. The model was constructed to include all infrastructures of the South3 area.

#### a) Data Used

The construction, calibration and verification of the model was done using observed data. The model was first calibrated using steady state conditions in order to stimulate pre-mining water levels. Steady state modelling was followed by transient state calibration, using mainly monitored heads, sulphate, nitrate and TDS concentrations.

**Figure 6** illustrates the model construction and distribution of transmissivity values throughout the model area.

**Figure 3.1 :. Model construction and variation in colour represents the variation in T values.**

#### b) Recharge and Groundwater Level Response

The groundwater flow model considered the latest rainfall figures and it was assumed that the rainfall intensity impact uniformly on the groundwater recharge. The recharge package was updated to reflect the relative change in recharge rate based on measured rainfall data over time.

Groundwater flow simulations of the historical flows found that the first estimate of parameters is still valid and that a good fit was achieved for the period January 2012 –December 2018. Recharge was kept at an average of 4 % of annual rainfall (550 to 600mm).

### 3.7.4 Numerical modeling

Numerical groundwater modelling is considered to be the most reliable method of anticipating and quantifying the likely impacts on the groundwater regime. The finite difference numerical model was created using AquaVeo's Groundwater Modelling System (GMS10.0) as Graphical User Interface (GUI) for the well-established Modflow and MT3DMS numerical codes.

MODFLOW is a 3D, cell-centred, finite difference, saturated flow model developed by the United States Geological Survey. MODFLOW can perform both steady state and transient analyses and has a wide variety of boundary conditions and input options. It was developed by McDonald and Harbaugh of the US Geological Survey in 1984 and underwent eleven overall updates since. The latest update incorporates several improvements extending its capabilities considerably, the most important being the introduction of the new Newton formulation and solver, vastly improving the handling of dry cells which has proven to be problematic in the past.

### **3.7.5 Transport modelling**

Transport modelling was performed using MT3DMS. MT3DMS is a 3-D model for the simulation of advection, dispersion, and chemical reactions of dissolved constituents in groundwater systems. MT3DMS uses a modular structure similar to the structure utilized by MODFLOW, and is used in conjunction with MODFLOW in a two-step flow and transport simulation. Heads are computed by MODFLOW during the flow simulation and utilized by MT3DMS as the flow field for the transport portion of the simulation.

### **3.8 Risk Assessment**

The groundwater risk assessment was assessed by defining the three components, which are the source, the pathway and the receptor. The risk assessment approach is aimed at describing and defining the relationship between cause (source) through the groundwater pathway and the effect to the receptor. In the absence of any one of the three components, it is impossible to conclude that groundwater risk does/does not exist.

### **3.9 Mitigation and Management Measures**

The groundwater management measures were developed by taking in consideration the National Water Act, Act 36 of 1998 (NWA) and, to a lesser extent, the Mineral and Petroleum Resources Development Act, Act No. 28 of 2002 (MPRDA) and the National Environmental Management Act, Act 107 of 1998 (NEMA). The Chapter 4 of the NWA addresses uses of water.

The Department of Water and Sanitation (DWS), has recognized challenges facing both the water user and the authorities in managing groundwater in an integrated manner. This recognition has resulted in a number of guideline documents that provides the mining industry with an opportunity to marry together legislation and best practice into useable tools of implementation. The management measures discussed in this report was based on these Best Practice Guidelines (BPG) series (DWAF, 2008). The relevant guidelines for this report are listed below:

#### **Activity Series Guidelines**

- BPG A2. Water Management for Mine Residue Deposits
- BPG A4. Pollution Control Dams
- BPG A5. Water Management for Surface Mines

#### **Hierarchy Series Guidelines**

- H1. Pollution prevention
- H2. Minimization of impacts

### **General Series Guidelines**

- G3. Water monitoring systems
- G4. Impact prediction

## **4. DESKTOP STUDY**

A desktop study was done on all available information pertaining to groundwater situation at the proposed mine.

### **4.1 Information Reviewed**

The following information sources were reviewed:

- Geological Map (Scale 1:250 000) published by the Council for Geoscience.
- National Groundwater Database (NGDB) information managed by DWA (2005).
- The Letter by the Department of Minerals and Energy titled: Application for Integrated Environmental Authorisation in Terms of the National Environmental Management Act, 1998 (Act 107 Of 1998) As Amended (NEMA), And the Environmental Impact Assessment (EIA) Regulations, 2014 On the Farm Winterveld 293 Kt, Situated in The Fetakgomo Local Municipality Within Sekhukhune District Municipality of Limpopo Region.
- Modikwa Platinum Mine Integrated Water and Waste Management Plan, Portion o of the Farm Winterveld 293 KT, Segope Water and Environmental Services, June 2024.
- ENVIRONMENTAL IMPACT ASSESSMENT REPORT And ENVIRONMENTAL MANAGEMENT PROGRAMME REPORT FOR PUBLIC COMMENT,
- General Surface Layout plan and Drawings by the mine.

### **4.2 Activity Description**

The extent of the mining right at farm Winterveld 293 KT encloses an area of 293 hectares, and a mining right may not exceed a period of 30 years. South 3 Opencast Operation is an extension of the existing MPM operations. An application is being made to amend the current environmental authorisation to include proposed additional mining related infrastructure and activities associated with the Opencast. The key components of the proposed infrastructures associated with the proposed amendment includes:

- Opencast pit for extraction of the ore bearing materials,
- A waste rock dump for the storage of waste rock generated at the South 3 Opencast,
- Pollution Control Dams,
- Offices and associated infrastructure,
- Haul road connecting the existing South 2 Shaft with the South 3 Opencast,

- Septic Sewage System,
- Stormwater management infrastructure,
- Disturbances of the Tubatsane River during development of the haul road.

From the site visit that was conducted on the 14<sup>th</sup> of March 2024, it was noted that the area, where undisturbed is dominated by bushes and shrubs. Assuming that all phases of the project adhere to the mitigation and management commitments stipulated in this EIAr/EMPr, the EAP believes that significant impacts identified during the assessment can be mitigated and managed to reduce their level of significance and that impacts can be managed effectively by implementing the suggested mitigation strategies.

A description of the location and composition of the expected activities is listed in **Table 4.1** below.

**Table 4.1: South 3 Activity Summary**

Infrastructure	Location	Expected Hydrochemical/Geochemical Description
Pollution Control Dam	Winterveld 293 KT	Ca, Mg, Cl, SO <sub>4</sub> , HCO <sub>3</sub> , Elevated pH
Proposed Process Plant Area	Winterveld 293 KT	Ca, Mg, Cl, SO <sub>4</sub> , HCO <sub>3</sub> , Elevated pH
South Pit	Winterveld 293 KT	Ca, Mg, Cl, SO <sub>4</sub> , HCO <sub>3</sub> , Elevated pH
North Pit	Winterveld 293 KT	Ca, Mg, Cl, SO <sub>4</sub> , HCO <sub>3</sub> , Elevated pH
Main Pit	Winterveld 293 KT	Ca, Mg, Cl, SO <sub>4</sub> , HCO <sub>3</sub> , Elevated pH
RoM & Product Stockpile Area	Winterveld 293 KT	Ca, Mg, Cl, SO <sub>4</sub> , HCO <sub>3</sub> , Elevated pH
Settling Dam	Winterveld 293 KT	Ca, Mg, Cl, SO <sub>4</sub> , HCO <sub>3</sub> , Elevated pH
Sewerage Treatment Plant	Winterveld 293 KT	Coliform bacteria
Waste Rock Dump	Winterveld 293 KT	Ca, Mg, Cl, SO <sub>4</sub> , HCO <sub>3</sub> , Elevated pH

## 5. PREVAILING GROUNDWATER CONDITIONS

The critical aspect of any groundwater impact assessment or management system is the understanding of the hydrogeological setting and how the potential stresses will influence the natural groundwater conditions. The hydrogeological setting of the project site is described under the sessions below.

## 6. HYDROGEOLOGY

The prevailing hydrogeological conditions based on current information are discussed in the following subsections:

### 6.1 Hydrocensus

A Hydrocensus was conducted in June 2024 by Segope Water and Environmental Services (Segope Consulting). Hydrocensus was conducted to locate existing boreholes, springs and surface water resources. A Hydrocensus was done within 2 Km radius from the central point of the South 3 site.

#### 6.1.1 Boreholes

A total of 21 Boreholes were found within 2km radius from the site central point. This included monitoring boreholes, privately owned boreholes for domestic purposes as well as abandoned unused boreholes. A summary of the groundwater information gathered during the Hydrocensus and Hydrocensus points are detailed in **Table 6.1** and **Figure 6.1**, respectively.

No springs were identified within the 2 km radius. The use of groundwater in the community is predominately for domestic purposes. Although the aquifers are of limited extent with relatively low storage resulting in boreholes having relatively low sustainable yields, and therefore only moderate abstraction potential, groundwater is the sole source of water for most rural settlements around the proposed mining property.

**Table 6.1: Hydrocensus Information**

No.	ID	Latitude	Longitude	Elevation	Property	Casing Height	Static Water Level(mbgl)	Static water Level	Sampled(y/n)	Borehole use	Comment on Borehole condition
1	BHo1	24°43'22.07"S	30°10'2.33"E	790m	Winterveld 293 KT	0.3 m	23.15	22.85	Yes	Monitoring	Good condition to take depth and sample
2	BHo2	24°43'43.75"S	30°10'6.02"E	784 m	Winterveld 293 KT	0.36 m	14.60	14.24	Yes	Monitoring	Good condition to take depth and sample
3	BHo3	24°42'43.09"S	30°9'9.46"E	817m	Winterveld 293 KT	0.075 m	1.52	1.145	Yes	Monitoring	Good condition to take depth and sample
4	BHo4	24°43'22.88"S	30°10'11.82"E	777m	Winterveld 293 KT	0.1010 m	-	-	No	Monitoring	Borehole had Sewage
5	BHo5	24°42'50.09"S	30°10'9.56"E	794m	Winterveld 293 KT	1.005 m	-	-	No	Monitoring	Borehole Blocked
6	BHo6	24°43'28.08"S	30°10'11.86"E	782m	Winterveld 293 KT	0.21 m	15.91	15.71	Yes	Domestic	Good condition to take depth and sample
7	BHo7	24°42'57.64"S	30°10'10.94"E	800m	Winterveld 293 KT	1 m	-	-	No	Monitoring	Borehole blocked
8	BHo8	24°42'44.17"S	30°9'50.70"E	823m	Winterveld 293 KT	0.03m	-	-	No	Domestic	Borehole Blocked
9	BHo9	24°43'35.27"S	30°10'11.86"E	763m	Winterveld 293 KT	-	-	-	Yes	Domestic	Borehole equipped
10	BHo10	24°43'26.32"S	30°10'15.36"E	775m	Winterveld 293 KT	0 m	5.13	5.13	Yes	Not used	An open hole with no

											protection and unused
11	BH11	24°43'45.12"S	30°10'30.16"E	759m	Winterveld 293 KT	-	-	-	No	Domestic use	Borehole equipped
12	BH12	24°43'45.17"S	30°10'27.67"E	763m	Winterveld 293 KT	-	-	-	Yes	Domestic use	Borehole equipped
13	BH13	24°43'45.12"S	30°10'30.16"E	760m	Winterveld 293 KT	-	-	-	No	Domestic use	Borehole equipped
14	BH14	24°43'46.53"S	30°10'36.76"E	754m	Winterveld 293 KT	-	-	-	No	Domestic use	Borehole equipped
15	BH15	24°43'47.79"S	30°10'24.30"E	760m	Winterveld 293 KT	-	-	-	No	Domestic use	Borehole equipped
16	BH16	24°43'35.21"S	30°10'6.29"E	782m	Winterveld 293 KT	0.07m	-	-	No	Monitoring	Dry hole
17	BH17	24°43'40.71"S	30°10'31.88"E	757m	Winterveld 293 KT	-	-	-	No	Domestic use	Borehole equipped
18	BH18	24°43'43.93"S	30°10'27.30"E	762 m	Winterveld 293 KT	-	-	-	No	Domestic use	Domestic Use
19	BH19	24°43'50.00"S	30°10'17.56"E	772m	Winterveld 293 KT	-	-	-	No	Domestic use	Domestic Use
20	BH20	24°43'44.08"S	30°10'30.44"E	761m	Winterveld 293 KT	-	-	-	No	Domestic use	Domestic Use
21	BH21	24°43'36.78"S	30°10'22.81"E	766m	Winterveld 293 KT	-	-	-	No	Domestic use	Domestic Use

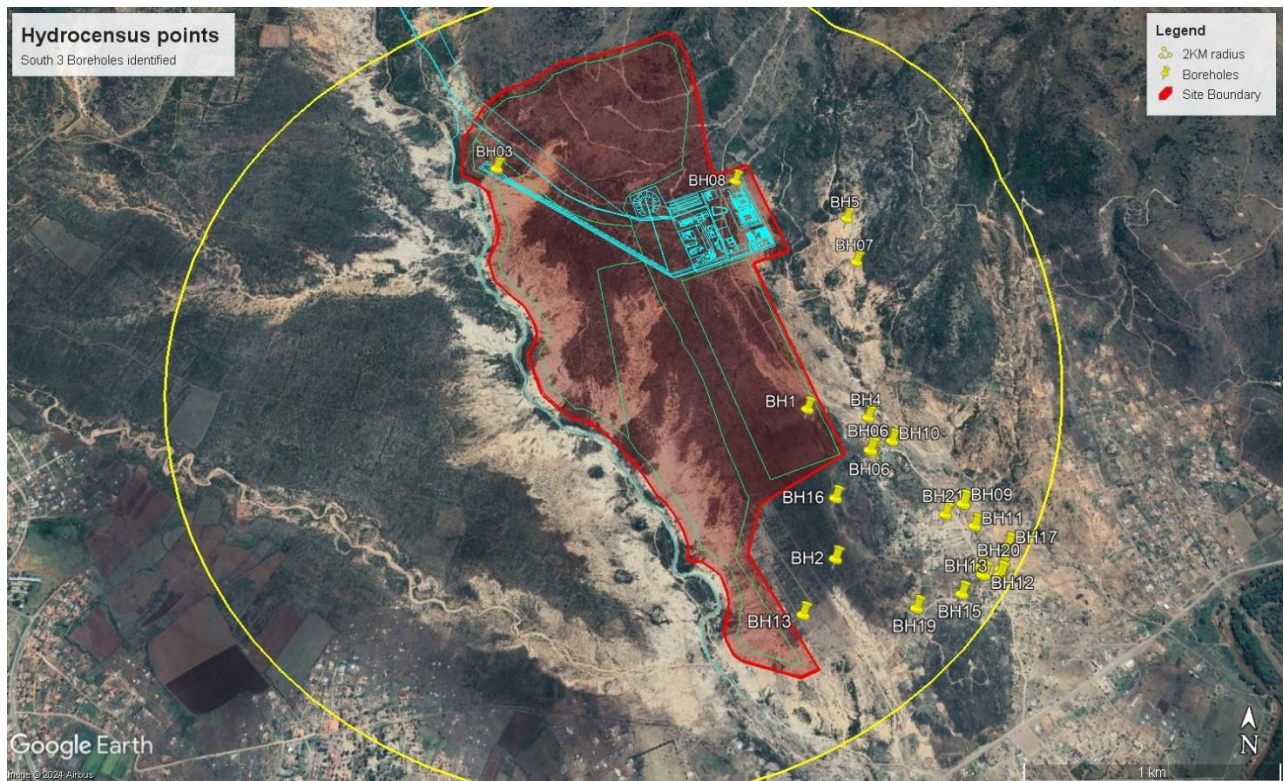


Figure 6.1: Hydrocensus points

## 6.2 Water Levels

During the Hydrocensus 5 boreholes were available for groundwater level measurement. The groundwater levels varied between a minimum of 1.15 m and a maximum of 22.85 m below ground level (Table 6.2). This general relationship is useful to make a quick calculation of expected groundwater levels at selected elevations, or to calculate the depth of to the groundwater level (unsaturated zone):

$$\begin{aligned} \text{Groundwater level} &= \text{Elevation} \times \text{gradient} + \text{intercept} \\ \text{Groundwater depth} &= \text{Elevation} - \text{Calculated Groundwater Level} \end{aligned}$$

In general, a good relationship should hold between topography and static groundwater level. This relationship can be used to distinguish between boreholes with water levels at rest, and boreholes with anomalous groundwater levels due to disturbances such as pumping or local hydrogeological heterogeneities.

However, due to the heterogeneity of the subsurface, these relationships should not be expected to hold everywhere under all circumstances, and deviations could thus be expected. Groundwater flow direction should be perpendicular to these contours and inversely proportional to the distance between contours. As can be expected, the groundwater flow is mainly from topographical high to low areas, eventually draining to the local streams.

**Table 6.2: Available Groundwater Statistics**

Groundwater level statistics	
Number of boreholes Available for levels taking	5
Number of boreholes with anomalous water levels	0
Min water level (mbgl)	1.15
Max water level (mbgl)	22.85
Mean water level (mbgl)	11.815

### 6.3 Water Quality

Water samples were collected from seven (7) boreholes around the site during the investigation. The water results are compared with the maximum recommended concentrations for domestic use as defined by the SANS 241-1: 2015 target water quality limits. The SANS 241-1: 2015 standard is applicable to all water services institutions and sets numerical limits for specific determinants to provide the minimum assurance necessary that the drinking water is deemed to present an acceptable health risk for lifetime consumption. Colors of individual cells refer to the drinking water classification of the specific groundwater sample. The results of the screening for groundwater are presented in **Table 6.3** and discussed in the sections below:

#### 6.3.1 Groundwater quality against SANS standards

The groundwater quality against SANS standards for the seven boreholes are summarized as follows:

- Electrical Conductivity and total dissolved solids exceed the SANS standard limits in BH01 and BH12 samples, indicating a high mineralization level on these samples.
- Nitrates exceeds SANS standards in BH06 and BH12 and this may be likely due to nitrogen fixation from the natural vegetation in the area.
- The sample BH01 also have Chloride, Sodium, Zinc and total Manganese values elevated above SANS standards.
- Samples BH06, BH09, and BH13 have Zinc levels above SANS standards.
- Manganese levels are also above SANS standards in samples BH02 and BH06, likely due to local geology.

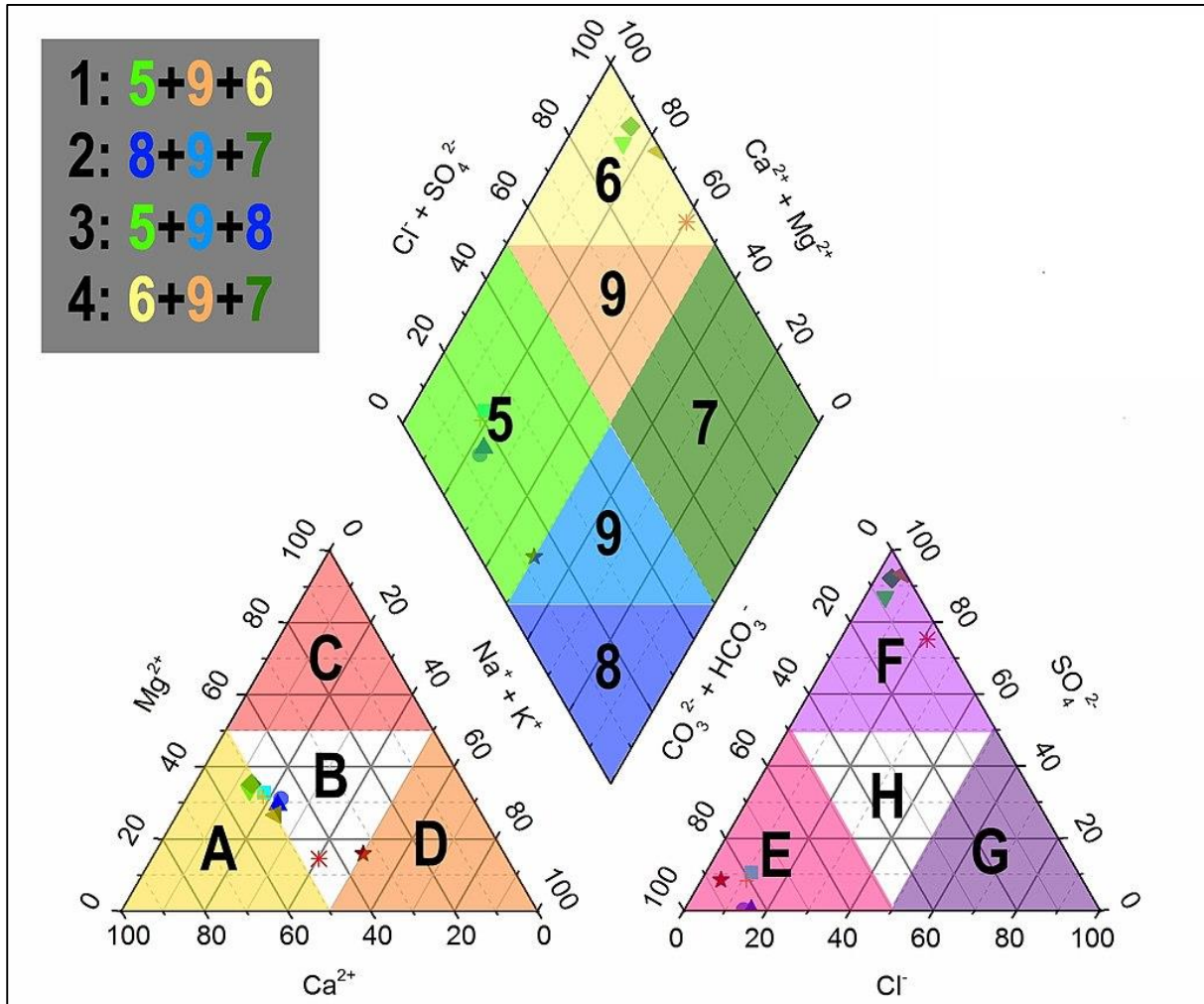
**Table 6.3: Water quality data at South3 project site compared to the applicable limits and standards**

Parameter	Unit	SANS 241: 2015		Risk	Results						
		Recommended Limits			BH01	BH02	BH03	BH06	BH09	BH12	BH13
<b>Physical &amp; Aesthetic determinants</b>											
Electrical conductivity at 25°C	EC	mS/m	≤ 170	Aesthetic	514	80	17.8	135	80	243	81
Total Dissolved Solids	TDS	mg/liter	≤ 1200	Aesthetic	2973	556	91	907	541	1684	560
pH at 25°C		pH units	≥ 5 to ≤9.7	Aesthetic	8.31	8.21	8.30	7.87	8.34	8.34	8.00
<b>Chemical Determinants - Macro determinants</b>											
Nitrate as N	NO <sub>3</sub>	mg/liter	≤ 11	Acute Health	0.5	1.7	<0.2	29.0	7.6	257.6	1.4
Sulphate	SO <sub>4</sub>	mg/liter	Acute Health ≤500; Aesthetic ≤250	Acute Health/Aesthetic	19.8	36.3	4.4	107.0	45.5	195.2	36.9
Fluoride	F	mg/liter	≤1.5	Chronic Health	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
Chloride	Cl	mg/liter	≤ 300	Aesthetic	150.4	36.9	7.9	157.4	24.2	53.6	287.7
Sodium	Na	mg/liter	≤ 200	Aesthetic	1218.7	30.5	9.0	72.4	54.1	106.7	28.2
Zinc	Zn	mg/liter	≤5	Aesthetic	6	4	<3	17	14	5	6
Total Iron	Fe	mg/liter	Acute Health ≤ 2.0; Aesthetic	Acute/Aesthetic	0.21	0.64	0.02	<0.02	<0.02	<0.02	<0.02

			≤0.3								
Total manganese	Mn	mg/liter	Acute Health ≤0.4; Aesthetic ≤0.1	Acute/Aesthetic	0.23	0.24	0.032	0.27	<0.002	0.006	<0.002
Aluminum	Al	µg/liter	≤ 300	Operational	<20	<20	<20	<20	<20	<20	<20
<b>Concentration deemed to present an unacceptable health risk for lifetime consumption.</b>											

### 6.3.2 Spatial analysis of groundwater quality

The geochemical evolution of groundwater can be understood by plotting the concentration of major cations and anions in the Piper trilinear diagram (Piper, 1944). Major cations are plotted in the two base triangles as major cations ( $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ , and  $\text{Na}^{+}$  plus  $\text{K}^{+}$ ), and major anions as ( $\text{Cl}^{-}$ ,  $\text{SO}_4^{2-}$  and  $\text{CO}_3^{2-}$  plus  $\text{HCO}_3^{-}$ ) in milliequivalent percentages. Piper diagrams are very useful in making quick comparisons between waters from different sources and presents the data in a convenient manner for visual inspection. **Figure 6.2** below gives the general description of Hydrochemical facies in piper diagrams.



**Figure 6.2: Hydrochemical facies in a Piper diagram**

According to Figure 6.2 above, the Piper diagram can be separated into Hydrochemical facies as follows:

- A: Calcium type;
- B: No dominant type;
- C: Magnesium type;
- D: Sodium and potassium type;
- E: Bicarbonate type;
- F: Sulphate type;

- G: Chloride type;
- 1: Alkaline earths exceed alkalies;
  - 2: Alkalies exceed alkaline earths;
  - 3: Weak acids exceed strong acids;
  - 4: Strong acids exceed weak acids;
  - 5: Magnesium bicarbonate type;
  - 6: Calcium chloride type;
  - 7: Sodium chloride type;
  - 8: Sodium bicarbonate type;
  - 9: Mixed type

### 6.3.3 Baseline Hydrochemical facies and water classification at the South 3 Site

The plot in **Figure 6.3** indicates the classification of groundwater at the South3 site using a Piper plot. The plot shows that groundwater from BHo1 is of sodium chloride type with dominant chloride anions and sodium-potassium type cations. This suggest that the groundwater chemistry is mainly controlled by a mixing and ion exchange processes (Ahmed *et al.*, 2010).

Groundwater from BHo2, BHo3 and BHo9 can be classified as magnesium bicarbonate type dominated by bicarbonate ions, with no dominant cations, indicating enriched water quality associated with water rock interaction. The BHo3 Borehole is located upstream of the project site whereas the BH2 and BHo9 are located downstream of the project site and this indicates that magnesium bicarbonate groundwater types are found in areas covering the downstream and upstream sessions of the proposed project site.

Groundwater from BHo6 is a mixed type, dominated by calcium cations, with no dominant anions. Similarly, water from BH13 is also a mixed type, and also dominated by calcium type cations, however the bicarbonates were also found as dominant anions in this sample. Groundwater from BH12 can be can be classified as well-mixed water with no dominant cations and anions. The three boreholes namely BHo6, BH12 and BH13 containing mixed water types are located downstream of the project area.

In general, the water quality at the proposed project can be described as dominated by mixed and magnesium bicarbonate types with alkaline earths metals generally exceeding alkalies.

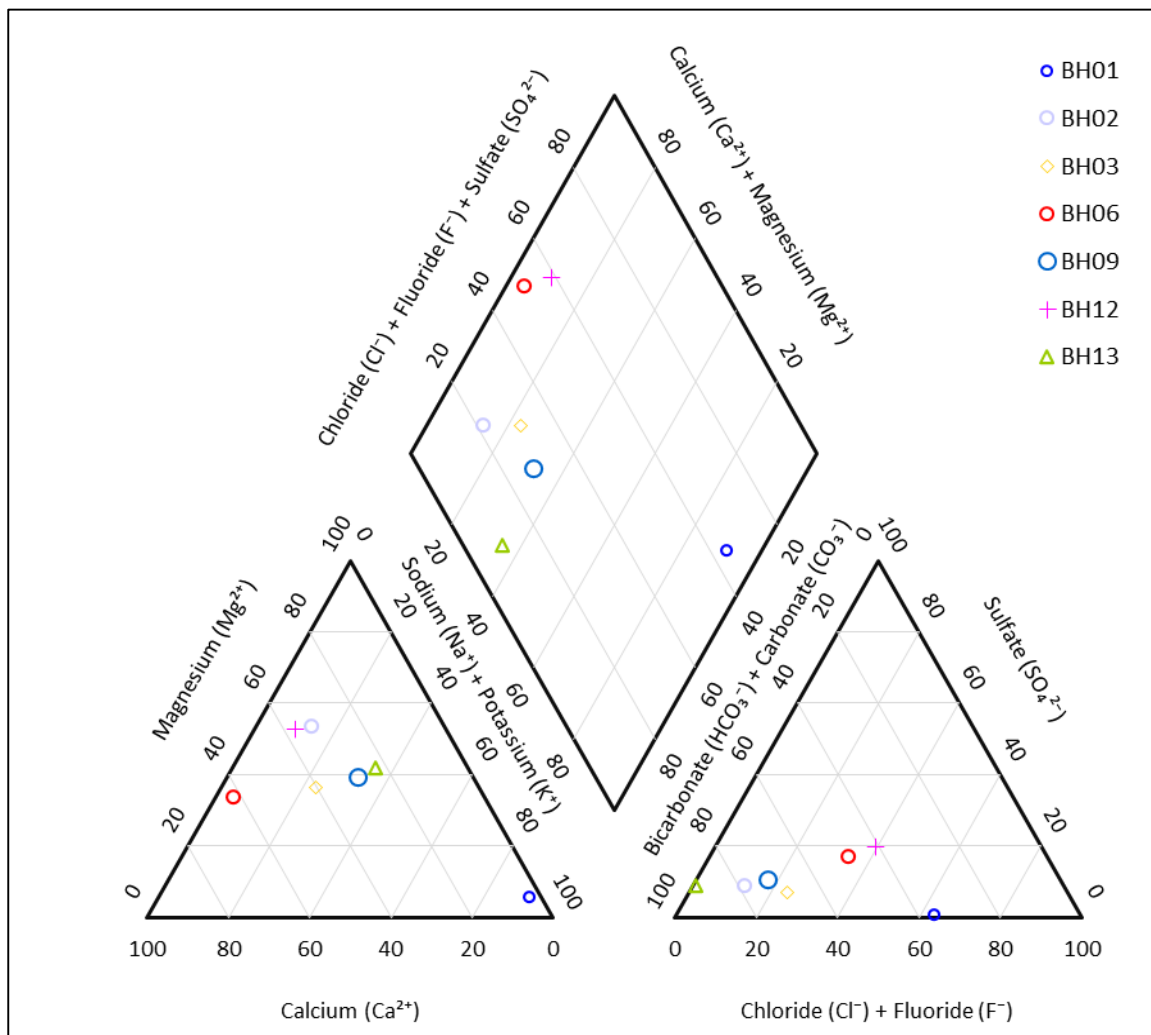


Figure 6.3: Groundwater classification at the South3 Site

## 7. AQUIFER CHARACTERIZATION

An aquifer is described as a strata or group of interconnected strata comprising of saturated earth material capable of conducting groundwater and of yielding usable quantities of groundwater to boreholes and/or springs (Vegter, 1994). In the light of South Africa’s limited water resources, it is important to discuss the aquifer sensitivity in terms of the boundaries of the aquifer, its vulnerability, classification and finally protection classification, as this will help to provide a framework in the groundwater management process.

### 7.1 Aquifer Vulnerability

Aquifer vulnerability assessment indicates the tendency or likelihood for contamination to reach a specified position in the groundwater system after introduction at some location above the uppermost aquifer. In other words, it is a measure of the degree of insulation that the natural and manmade factors provide to keep contamination away from groundwater.

- Vulnerability is high if natural factors provide little protection to shield groundwater from contaminating activities at the land surface.
- Vulnerability is low if natural factors provide relatively good protection and if there is little likelihood that contaminating activities will result in groundwater degradation.

The following factors have an effect on groundwater vulnerability:

- **Depth to groundwater:** Indicates the distance and time required for pollutants to move through the unsaturated zone to the aquifer.
- **Recharge:** The primary source of groundwater is precipitation, which aids the movement of a pollutant to the aquifer.
- **Aquifer media:** The rock matrices and fractures which serve as water bearing units.
- **Soil media:** The soil media (consisting of the upper portion of the vadose zone) affects the rate at which the pollutants migrate to groundwater.
- **Topography:** Indicates whether pollutants will run off or remain on the surface allowing for infiltration to groundwater to occur.
- **Impact of the vadose zone:** The part of the geological profile beneath the earth's surface and above the first principal water-bearing aquifer. The vadose zone can retard the progress of the contaminants (DWS,1995).

The Groundwater Decision Tool (GDT) was used to quantify the vulnerability of the aquifer underlying the site using the below assumptions.

- Depth to groundwater below the site was estimated from water levels measured during the Hydrocensus inferred to be at mean of 11.84 mbgl.

The aquifer vulnerability for a contaminant released from surface to a specified position in the groundwater system after introduction at some location above the uppermost aquifer was determined using the criteria described below and assuming a worst-case scenario:

- **Highly vulnerable** (> 60), the natural factors provide little protection to shield groundwater from contaminating activities at the land surface.
- **Medium Vulnerable** = 30 to 60%, the natural factors provide some protection to shield groundwater from contaminating activities at the land surface, however based on the contaminant toxicity mitigation measures will be required to prevent any surface contamination from reaching the groundwater table.
- **Low Vulnerability** (< 30 %), natural factors provide relatively good protection and if there is little likelihood that contaminating activities will result in groundwater degradation.

## 7.2 Aquifer Classification

The aquifer(s) underlying the subject area were classified in accordance with "A South African Aquifer System Management Classification, December 1995." The main aquifers underlying the area were classified in accordance with the Aquifer System Management Classification

document. The aquifers were classified by using the following definitions:

- **Sole Aquifer System:** An aquifer which is used to supply 50% or more of domestic water for a given area, and for which there is no reasonably available alternative sources should the aquifer be impacted upon or depleted. Aquifer yields and natural water quality are immaterial.
- **Major Aquifer System:** 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 (Electrical Conductivity of less than 150 mS/m).
- **Minor Aquifer System:** These can be fractured or potentially fractured rocks which do not have a high primary permeability, or other formations of variable permeability. Aquifer extent may be limited and water quality variable. Although these aquifers seldom produce large quantities of water, they are important for local supplies and in supplying base flow for rivers.
- **Non-Aquifer System:** These are formations with negligible permeability that are 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, although imperceptible, does take place, and needs to be considered when assessing the risk associated with persistent pollutants.

Based on information collected during the Hydrocensus it can be concluded that the aquifer system in the study area can be classified as a medium. In order to achieve the Aquifer System Management and Second Variable Classifications, as well as the Groundwater Quality Management Index, a point scoring system as presented in **Table 7.2** was used.

**Table 7.1: Ratings – Aquifer System Management and Second Variable Classifications**

<b>Aquifer System Management Classification</b>		
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	-
<b>Second Variable Classification (Weathering/Fracturing)</b>		
Class	Points	Study area
High:	3	3
Medium:	2	-
Low:	1	-

**Table 7.2: Ratings-Groundwater Quality Management (GQM) Classification System**

<b>Aquifer System Management Classification</b>		
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	-
<b>Aquifer Vulnerability Classification</b>		
Class	Points	Study area
High:	3	-
Medium:	2	2
Low:	1	-

As part of the aquifer classification, a Groundwater Quality Management (GQM) Index is used to define the level of groundwater protection required. The GQM Index is obtained by multiplying the rating of the aquifer system management and the aquifer vulnerability.

The vulnerability, or the likelihood for contamination to reach a specified position in the groundwater system after introduction at some location above the uppermost aquifer, in terms of the above, is classified as medium level.

The level of groundwater protection based on the Groundwater Quality Management Classification:

$$\begin{aligned} \text{GQM Index} &= \text{Aquifer System Management} \times \text{Aquifer Vulnerability} \\ &= 2 \times 2 = 4 \end{aligned}$$

**Table 7.3 : 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	

### 7.3 Aquifer Protection Classification

A Groundwater Quality Management Index of medium was estimated for the study area from the ratings for the Aquifer System Management Classification. According to this estimate a medium level groundwater protection is required for the aquifer. Reasonable and sound groundwater protection measures based on the modelling will therefore be recommended to ensure that no cumulative pollution affects the aquifer, even in the long term. DWA's water quality management objectives are to protect human health and the environment. Therefore, the significance of this aquifer classification is that measures must be taken to limit the risk to the following environments: The protection of the underlying aquifer and Protection of potential groundwater users.

## 8. CONCEPTUAL MODEL

The conceptual model describes the hydrogeological environment and was used to design and construct the numerical model to represent simplified, but relevant conditions of the groundwater system. The conditions were chosen in view of the specific objective of the modelling for the project. The conceptual model is based on the source-pathway-receptor principle. From the baseline assessment and available data, the following conceptual model was derived.

### 8.1 Source

The main potential on-site contamination sources area:

- The opencast workings
- The Pollution Control Dams (PCD's)
- Waste rock dump

### 8.2 Pathway

From the reviewed information the conceptual Model consists of two hydrogeological units:

- Weathered aquifer network
- Fractured aquifer network

The weathered layer has a thickness of approximately 30 m and is comprised of residual soils and weathered formations. Groundwater levels generally following topography and hydrocensus groundwater levels have an average groundwater level of 11.84 mbgl. Hydraulic conductivity values are estimated to be in the order of  $10^{-2}$  m/d.

The underlying aquifer network is a deep fractured aquifer. Fracturing mainly occurs in the top of this unit and decreases with depth. Hydraulic conductivity typically decreases with depth and is estimated to range between  $10^{-2}$  m/d in the upper layers and  $10^{-4}$  m/d for the lower layers.

Based on the conceptual model, possible pathways for on-site contaminations are:

- The surface water streams; and
- The weathered and fractured aquifers

### 8.3 Receptor

Potential receptors as seen in are:

Streams:

- One perennial stream (Tubatsane) running along the western boundary.
- Non-Perennial streams of Tubatsane River.

Springs:

- No spring sources were found down gradient of the project

Privately owned boreholes (abstraction):

- No privately-owned boreholes were found down gradient which are used for abstraction.

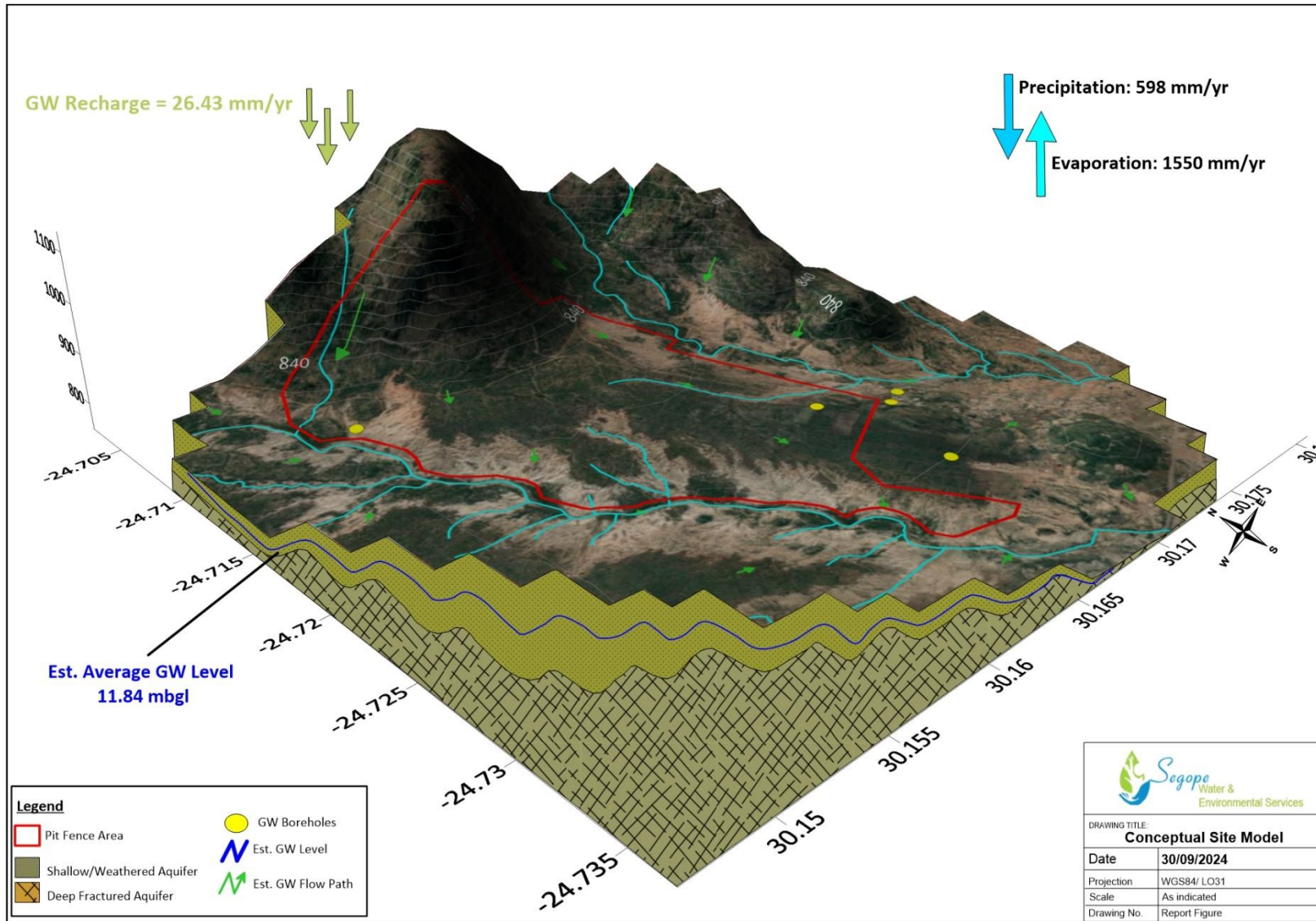


Figure 8.1 Geohydrological Conceptual Model

## 9. NUMERICAL MODELLING

Following the characterisation of the aquifers, contaminant sources and groundwater receptors, the conceptual model was transformed into a numerical model so that the groundwater flow conditions, and mass transport can be solved numerically. This section outlines the translation of the conceptual model into a numerical flow model.

### 9.1 Objectives

The numerical groundwater flow model is required to aid in decision making processes and environmental management. The groundwater regime of the study area is heterogeneous and this influence the groundwater flow patterns. Constructing a groundwater flow model with all the detail is close to impossible; however, assumptions are made based on data gathered in the field and used to simulate different scenarios to conclude with management protocol.

Therefore, the purpose of the numerical model is to develop a tool than can be used to assess the impact of the proposed mine *i.e.* dewatering volumes associated with the proposed mine during the operational phase and simulation of the impacts associated with potential pollution sources.

### 9.2 Model Limitations and Exclusions

Groundwater flow models are inherently simplified mathematical representations of complex aquifer systems. The simplification limits the accuracy with which groundwater systems can be simulated in general. There are numerous sources of error and uncertainty in groundwater flow models. Model error commonly stems from practical limitations of grid spacing, time discretisation, parameter structure, insufficient calibration data, and the effects of processes not simulated by the model.

The calibration of the model developed was mainly based on available groundwater levels focussing on the Bushveld Complex deposits in which the site is situated. Assumed is a homogenous rock matrix for the Bushveld aquifers. The calculated inflows represent the correct order of magnitude, and the most likely range of inflow variation based on the uncertainties of the model used will be presented.

Transmissivity, hydraulic conductivity and storage values were estimated from information from other studies in the vicinity of the site. Additional aquifer testing with multiple-level monitoring in the weathered and fractured aquifers on the site would increase the confidence of the hydrogeological parameters used as input for the numerical modelling. Therefor, site-specific aquifer testing is recommended.

### 9.3 Modeling Code

The numerical model for the project was constructed using GMS 10.4.2 GUI, a pre- and post-processing package for MODFLOW and MT3D. MODFLOW is a modular three-dimensional groundwater flow model and MT3D a modular three-dimensional solute transport model published by the United States Geological Survey. MODFLOW and MT3D uses 3D finite differences discretization and flow codes to solve the governing equations. MODFLOW and MT3D is a widely used simulation code, which is well documented.

## 9.4 Model Setup

The conceptual model is translated into a numerical model during the model setup. Setting up the numerical model entails:

- Selecting the model domain;
- Defining the model boundary and initial conditions;
- Spatially and temporally discretizing the project data; and
- Preparing the model input data.

The above conditions were used to simulate the groundwater flow in the model domain for pre-mining steady state conditions.

## 9.5 Model Domain and Boundary Conditions

The model domain is defined by the drainage systems between the Molawetse River and the Steelpoort River. The two rivers both merge downstream south of the project area.

Further, the model should be defined by natural geological and hydrogeological boundary conditions, i.e. the model domain should preferably encompass entire hydrogeological structures. The model consists of two layers to represent the weathered and fractured aquifers. The weathered aquifer consists of 30 m thick layer represented by an unconfined aquifer. The lower fractured aquifer consists of 60 m thickness layer represented as a confined aquifer.

From the conceptual point of view, it was essential to meet two criteria to the maximum extent possible:

- The modelled area should be defined by natural geological and hydrogeological boundary conditions, i.e. the model domain should preferably encompass entire hydrogeological structure.

Boundary conditions express the way in which the considered domain interacts with its environment. In other words, they express the conditions of known water flux, or known variables, such as the hydraulic head. Different boundary conditions result in different solutions, hence the importance of stating the correct boundary conditions. Boundary condition options in MODFLOW can be specified either as:

- Specified head or Dirichlet; or
- Specified flux or Neumann; or
- Mixed or Cauchy boundary conditions

Local hydraulic boundaries were identified for model boundaries. They were represented by local perennial and non-perennial water courses and topographical highs and delineated the entire model domain. These hydraulic boundaries were selected far enough from the area of investigation to not influence the numerical model behaviour in an artificial manner. The model boundaries and model grid are shown in Figure 9.1 and provides a summary of the boundaries, boundary descriptions and boundary conditions specified in the hydrogeological model. Hydraulic boundaries were identified for the model, which are summarised in Table 9.1.

**Table 9.1 Model Boundary Conditions**

<b>Boundary</b>	<b>Description</b>	<b>Condition</b>
Top	Top Surface of water table	Mixed type: River cells for rivers; drains for non-perennial streams. Recharge is constant for the model area. Recharge flux is applied to the highest active cell.
North	River and no-flow boundary condition	Tubatsane tributary and Topographical high
East	River boundary condition	Steelpoort Tributary
South	River boundary condition	Steelpoort River
West	River boundary condition	Molawetse River

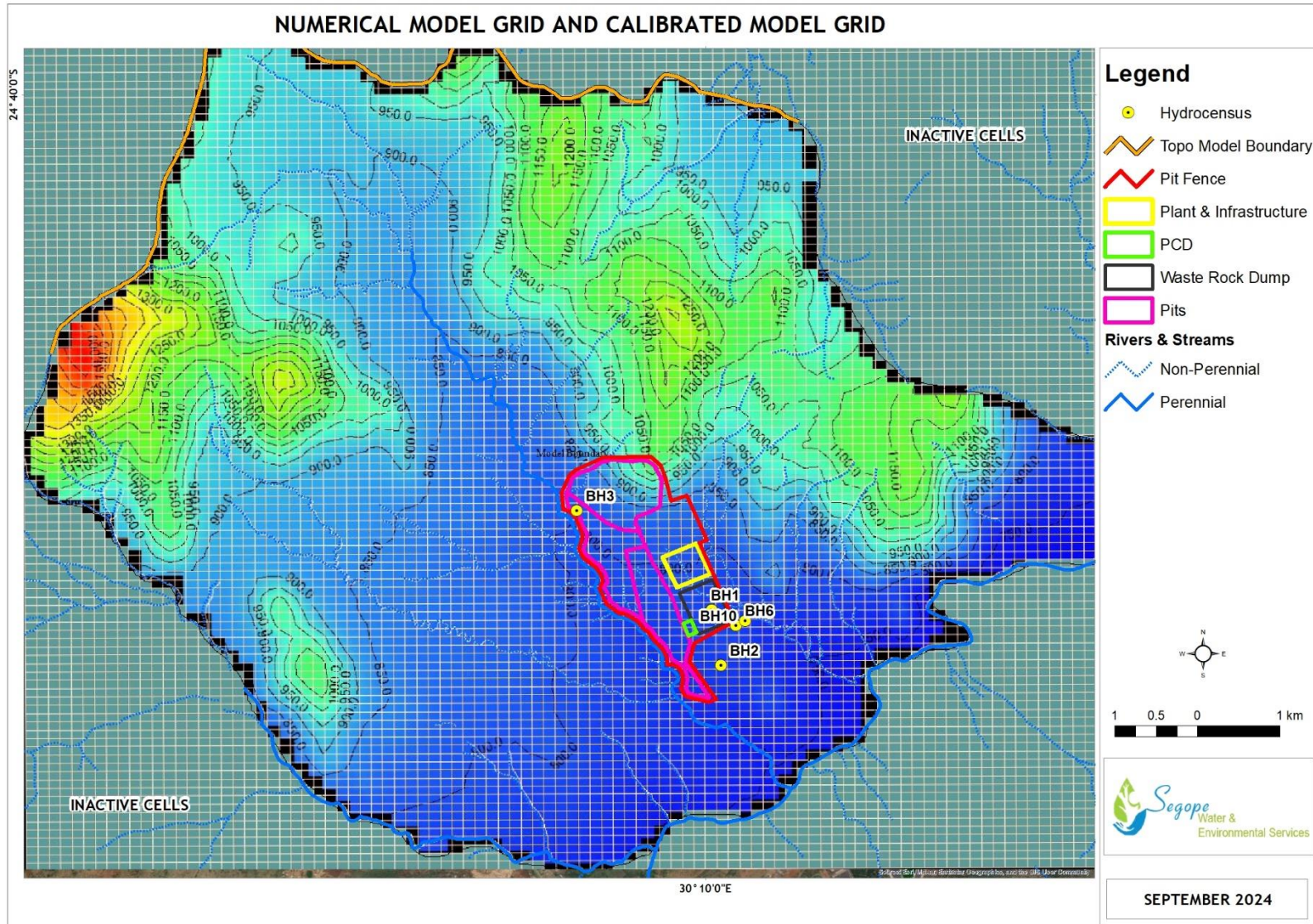


Figure 9.1: Model Boundary

## 9.6 Model Input Parameters

Model input parameters for this flow model are divided into two groups:

- Hydrogeological parameters
- Initial conditions

The initial head conditions, specified in the steady state model, were estimated from topography. Initial transient model heads were derived from the steady state model results. The objective of the steady state model was to simulate the undisturbed groundwater system in the region prior to mining.

One percent (1 %) recharge of MAP was applied, which is ~ 5.9 mm per annum (mm/a). Due to the homogeneous nature of the geology in the study area, similar parameter values were assigned to the entire model domain.

## 9.7 Calibration

Calibration is the process of finding a set of boundary conditions, stresses and hydrogeological parameters that produce result that most closely matches field measurements of hydraulic heads and flows. In a regional groundwater flow model, a difference between calculated and measured heads of up to several meters can be tolerated and is usually expressed as a function of the total range of observations.

For calibration of a pre-mining steady state, the most recent groundwater levels for hydrocensus locations were used. A total of 5 observation boreholes were used for the steady state model calibration where water level measurements was available. These boreholes are partially uniformly distributed across the model domain.

After model calibration, an acceptable correlation with  $R^2 = 0.99$  (equivalent to a correlation of 99%) was obtained between the simulated and observed groundwater elevation. The calibration was deemed acceptable with a Mean Residual Head of 2.1 and a Root Mean Square Error (RMSE) of 3.3.

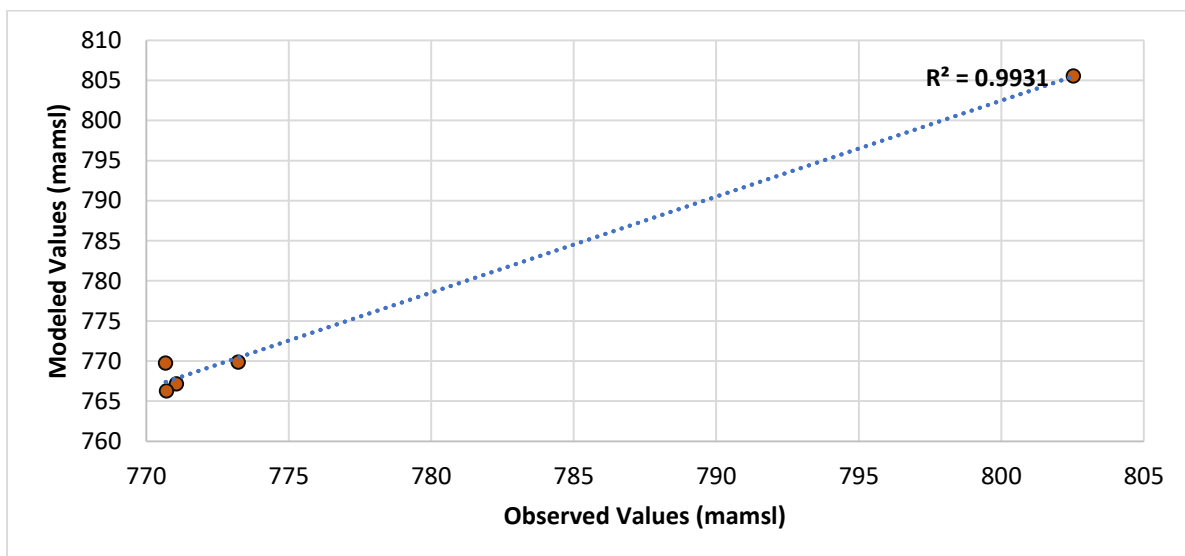


Figure 9.2: Steady State Model Calibration

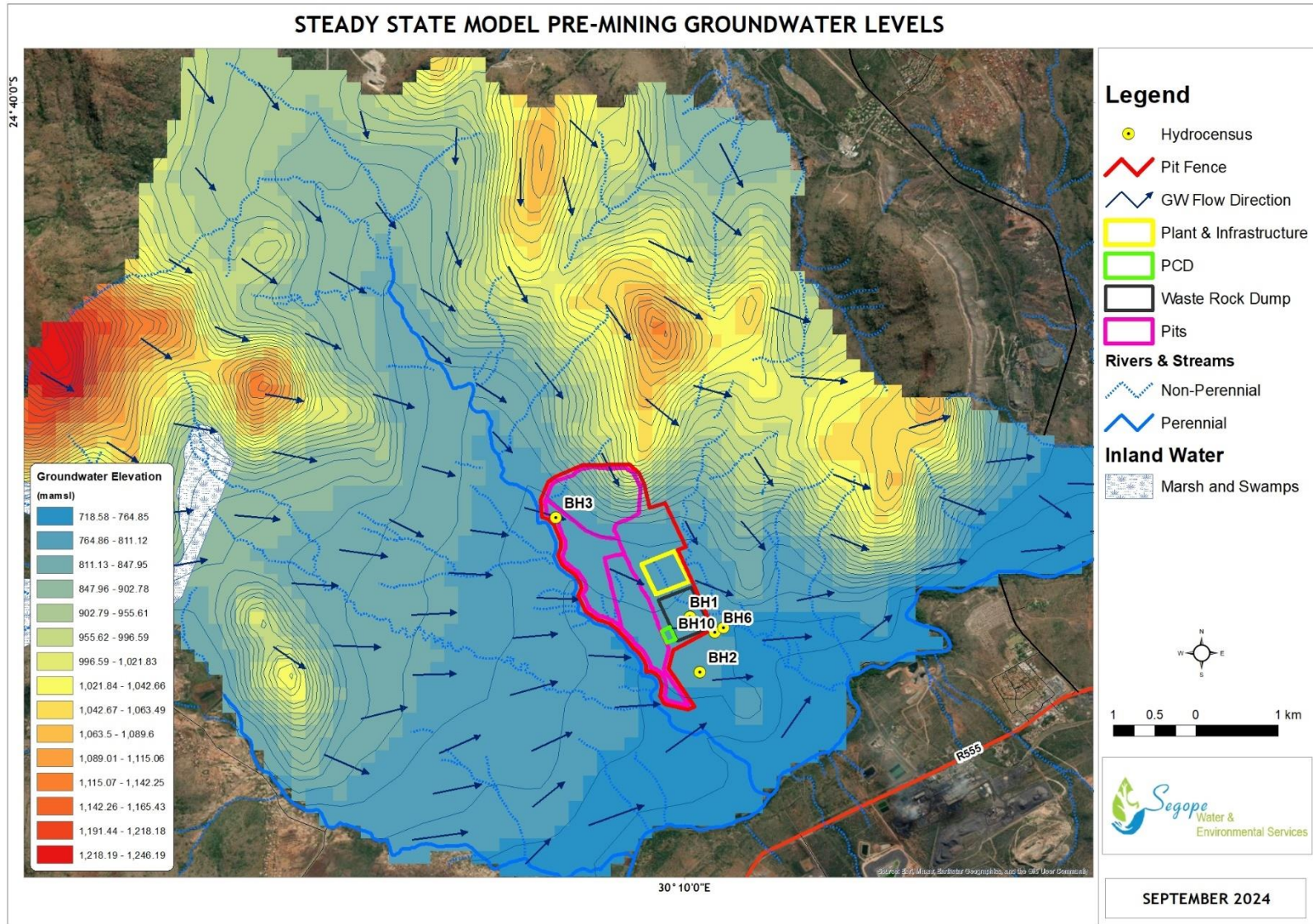


Figure 9.3: Calibrated Flow Model

## 9.8 Specified Hydraulic Conductivity

For the purpose of this study, the subsurface was envisaged to consist of the following hydrogeological units. The initial head conditions, specified in the steady state model, were estimated from topography. Initial transient model heads were derived from the steady state model results.

- The upper few meters below surface consists of rock outcrops, sandy gravel and red clay in places; being the product of partially to complete weathered mafic bedrock. This layer is anticipated to have a low hydraulic conductivity due to the high clay content, and in general unsaturated. However, a seasonal aquifer perched on the bedrock probably does form in this layer, especially after high rainfall events. Flow in this perched aquifer is expected to follow the surface contours closely.
- The next few tens of meters are slightly to moderately weathered fractured bedrock with a moderate to low hydraulic conductivity. The permanent groundwater levels mostly reside in this unit and is about 25 meters below ground level. The groundwater flow direction in this units rather influenced by regional topography and for the site it would be in a general easterly direction as also confirmed by modelling.
- Below a few tens of meters, the fracturing of the aquifer is less frequent and the fractures less open due to increased pressure. This results in an aquifer of low hydraulic conductivity and very slow groundwater flow velocities. As in the previous unit, the flow direction is expected to be mostly easterly. This trend was confirmed by modelling.

### 9.8.1 Groundwater source and sinks

Although the most relevant aquifer parameters are optimized by the calibration of the model, many parameters are calculated and/or judged by conventional means. The following fixed assumptions and input parameters were used for the numerical model of this area:

- Horizontal Hydraulic Permeability of the bedrock = 0.5 m/d as an initial value, declining with depth by an order of magnitude with depth due to decreasing weathering of the bedrock and increased pressure that tend to close fractures.
- Vertical Hydraulic Anisotropy (KH/KV) of the bedrock = 10. By nature of the pronounced horizontal layering, this value is commonly used in the Bushveld.
- The effective porosity value of the bedrock was taken as 0.3, declining gradually to
- 0.03 at a depth of 150 meters. This value could not be determined directly and was taken as typical of the fractured bedrock.
- Longitudinal dispersion was taken as 50 meters, which is about 10% of expected plume dimensions, as recommended in various modelling guidelines.
- Transverse and vertical dispersion was taken as 5 meters and 0.5 meter respectively as recommended in various textbooks, being about 10% of the expected plume dimensions.
- The Open pit was simulated as a drain, with a conductance of 0.001 m<sup>2</sup>/day/m<sup>2</sup>.

## **9.9 Transient State Simulation**

The impacts of mining activities were assessed in a transient model using different stress periods to simulate changes related to model parameters over time. The transient model setup entails selecting the appropriate time-dependent parameters such as artificial recharge (if any) and mine dewatering. The solution of the calibrated steady-state model was used as initial hydraulic head distribution of the transient model.

After the completion of the transient state model setup, the mine plan was incorporated into the model. This was done to estimate the groundwater inflow rates over time.

### **9.9.1 Mass Transport Simulation**

In most cases, contaminant transport is driven by advection, i.e. groundwater flow is the main mechanism controlling the movement of solutes in groundwater. Advection implies that contaminants migrate at a rate similar to the groundwater flow velocity and in the same direction as the hydraulic gradient. Therefore, knowledge of groundwater flow patterns and hydraulic parameters can be used to predict solute transport under advection.

## 10. PREDICTED GROUNDWATER IMPACTS

The aim of this chapter is to assess the likely hydrogeological impact that the proposed mine might have on the receiving environment. The typical operational stages that will be considered in this section are:

- **Construction Phase:** Preparations at the specific site before actual operations commence.
- **Operational Phase:** The conditions expected to prevail during the operation of the site.
- **Decommissioning Phase:** The closing of operations as well as site clean-up and rehabilitation.
- **Post-mining Phase:** This relates to the steady-state conditions following site-closure. A period will be considered after which it is assumed that impacts will steadily decrease and the system will commence its return to the natural state.

### 10.1.1 Construction Phase Impacts

It is accepted for the purposes of this document that the construction phase will consist of preparations for the proposed mine, which is assumed to consist mainly of infrastructure on site, and the mobilisation of earth moving equipment.

### 10.1.2 Impacts on groundwater quantity

This phase is not expected to influence the groundwater levels.

### 10.1.3 Impacts on groundwater quality

This phase should cause very little additional impacts in the groundwater quality. It is expected that the current status quo will be maintained. With the exception of lesser oil and diesel spills, there are also no activities expected that could impact on regional groundwater quality.

### 10.1.4 Groundwater management

Pollution prevention starts in the planning phase of an operation through evaluation of plans and, is aimed at understanding the potential impacts of alternative working methodologies and a conscious effort to select, design and implement the alternatives that maximise the ability to prevent pollution. Pre-establishment of an operation, typical pollution prevention considerations include those shown below:

- Before operation, a plan that includes explicit consideration of closure and rehabilitation issues must be prepared and approved. These plans should define the sequence and nature of operations and detail the methods to be used in closure and restoration. The plans as well as the numerical should be updated regularly (every 3 to 5 years) during operation with available monitoring data. All operational planning and activities should be undertaken with eventual closure in mind, such that operations can end in a manner that minimizes the final risks and liabilities in the post-closure phase.
- Waste residue deposits should be located as far as possible from the:
  - Tubatsane and Mofafa Rivers

- Water management facilities should be designed to intercept and contain as much contaminated runoff and/or seepage as possible. The following facilities should be lined up.
  - Return Water Dam
  - Pollution Control Dam
- Apply effective storm water management principles to ensure that clean runoff is maximised and diverted to the receiving water resource, while contaminated runoff is minimised and contained for reuse within the operation.
- Apply passive water management measures within the operations that are aimed at minimising the potential for water quality deterioration due to the oxidation of sulphide minerals by reducing the available contact time between water and exposed sulphide minerals.
- Monitoring boreholes as discussed in the following sections will be required in strategic locations near the pollution source, to obtain information on the groundwater regime as well as for future monitoring purposes.
- Construct detailed water and salt balances that take account of climatic and operational variability, as a planning tool to ensure that all pollution control dams are adequately sized and that they are integrated into a robust water reuse and reclamation strategy to ensure that captured contaminated water is effectively reused within the mining operations and that system spillages to the environment are avoided.
- Proper storage, handling and monitoring of fuel and chemicals used on site to minimize the risk of spillages to the environment.
- Institute detailed monitoring systems that are capable of detecting pollution at the earliest possible stage, at all facilities where significant pollution potential exists, in order that this can lead to rapid and effective management actions to address the pollution source and minimize it to the full extent possible.
- Safety measures such as freeboard allowances etc. should be included in designs of storm water control facilities to allow for sufficient storage capacity and to ensure that risks of overflows or spillages are minimized and environmental impacts are therefore avoided.
- Design, construct, maintain and operate any clean water system at the mine or activity so that it is not likely to spill into any dirty water system more than once in 50 years;
- Design, construct, maintain and operate any dirty water system at the mine or activity so that it is not likely to spill into any clean water system more than once in 50 years;
- Design, construct and maintain all water systems in such a manner as to guarantee the serviceability of such conveyances for flows up to and including those arising as a result of the maximum flood with an average period of recurrence of once in 50 years.
- Design and operate the MRDs to minimise the evaporative losses, e.g. by limiting the size of the supernatant pool on the MRD surface.

### 10.1.5 Key considerations

There are four key considerations prior to development:

- Pollution prevention consideration: Deterioration of water quality must be prevented wherever possible and minimized where complete prevention is not possible.
- Conservation consideration: Losses of water and consumptive use of water must be minimized.
- Water users within the mine must be provided with water of a quality as poor as possible but good enough quality that it does not cause significant user, water quality, product quality or process related problems (scaling *etc.*).
- The plan must be sustainable over the life cycle of the mine and over different hydrological cycles.

### 10.2 Operational Phase Impacts

The operational phase is interpreted as the active mining of the proposed mine. It is inevitable that these effects will impact on the groundwater regime. The potential impacts that will be considered are the groundwater quantity and quality. The mining depth was assumed to be at the depth of the ore body.

#### 10.2.1 Groundwater level drawdown

The proposed mining is partially below the regional groundwater levels thus causing groundwater inflows into the open mining areas from the surrounding aquifer during operation. The mining areas will have to be actively dewatered to ensure dry working conditions.

Pumping of water that seeps into the open mining areas will cause dewatering of the surrounding aquifer and an associated decrease in groundwater levels within the zone of influence of the dewatering cone. The zone of influence of the dewatering cone depends on several factors including the depth of mining below the regional groundwater level, recharge from rainfall to the aquifer, the size of the mining area and the aquifer transmissivity, amongst others.

During the operational phase it is expected that the main impact on the groundwater environment will be dewatering of the surrounding aquifer. A numerical groundwater flow model was used to simulate the development of the drawdown cone over time on the Project Site and surrounding area. The potential cone of drawdown is largest at over time of mining (2044) and extends to a maximum radius of ~470 m around the opencasts.

#### 10.2.2 Drawdown mitigations

The drawdown impacts as a consequence of the opencast pits is expected to result in a minor impact. To reduce the impact further the mining footprint should be kept as small as possible, mining should progress as quickly as possible, and dewatering activities should cease as soon as possible after mining has been completed.

Frequent groundwater level monitoring should be carried out throughout the operational phase to discern trends in water levels and comparison with calculated drawdowns. Based on the simulations no third-party sources, wellfields or other groundwater abstractions are present

within the zone of influence and as such it is unlikely there will be an impact on third party abstraction sources.

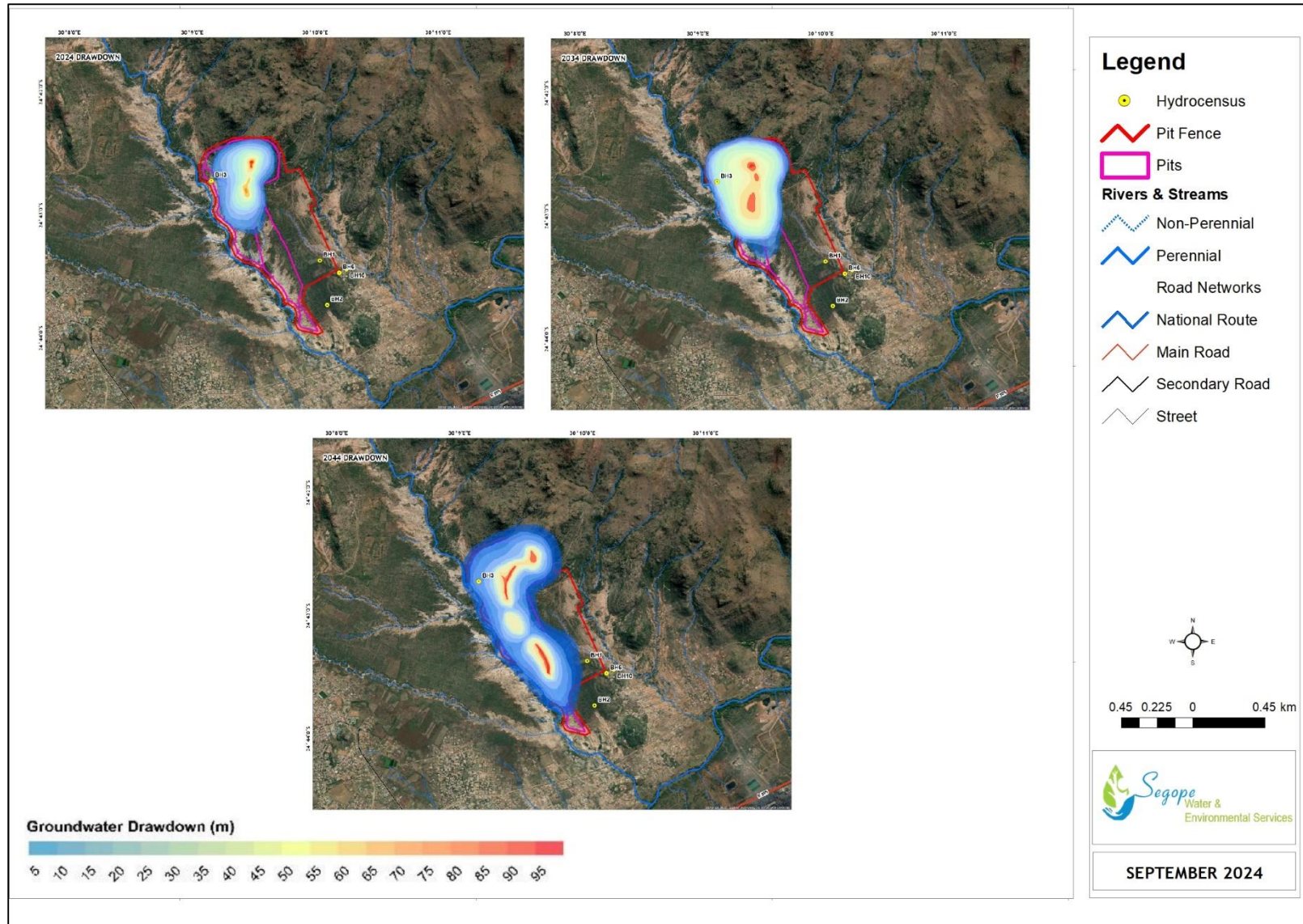


Figure 10.1: Simulated Groundwater Cone of Drawdown Extent

### 10.2.3 Impacts on groundwater quantity

During the operational phase, it is expected that the main impact on the groundwater environment will be de-watering of the surrounding aquifer. Water entering the mining areas will have to be pumped out to enable mining activities. This will cause a lowering in the groundwater table in- and adjacent to the mine.

The dewatering of the aquifer has been calculated for the proposed mine using the calibrated numerical model as described above. A worst-case scenario has been modelled, assuming that all opencasts would be dewatered. This will obviously not be the case, and the actual drawdown could thus be less. However, as the recovery of groundwater is expected to be very slow, it could well be that the first opencast is still in an early stage of recovery. Thus, the worst-case scenario could also be close to the actual scenario.

- The calculated drawdown of the worst-case scenario is predicted, as contours of drawdown for all the mines being dewatered simultaneously. There are no identified privately owned boreholes in the potential affected area that might experience a decline in water levels of approximately 5 m or more.

Despite the modelled predictions, it must again be stressed that structures of preferred groundwater flow have not been modelled. The computed total inflow into mine assuming that all areas in the mine are dewatered simultaneously, was calculated.

However, these figures are overestimations and probably reflect worst-case scenarios. The actual inflow will depend on the area being mined at any one moment in time. It is important to view these numbers for the water make of the mine in relation to natural evaporation, as listed in the table. Illustrative volumes are included in the table as if the evaporation will take place over the whole opencast, for comparative purposes. As the whole opencast will not be open at any one time, this is obviously an overestimate. Nevertheless, it is illustrative that evaporation can contribute considerably to the removal of groundwater seepage into the opencast.

Furthermore, it should be realised that evaporation is a seasonal effect. Direct recharge from rainfall will in turn add to these volumes. The amount of direct recharge will depend on the season as well as the mining layout and storm water management. It is suggested that this is calculated as part of the surface water study.

It must be cautioned that these calculations have been performed using simplified assumptions of homogeneous aquifer conditions. The reality could deviate substantially from this and the model should thus be updated as more information becomes available.

The predicted groundwater inflows into the opencasts within a year (based on worst-case scenario) ranges at ~800 m<sup>3</sup>/d to 1000 m<sup>3</sup>/day, mainly due to that the opencasts have a surface area of ~1578841 m<sup>2</sup>.

The inflow calculations based on the groundwater model represent the worst-case scenario which is indicated in Table 10.1. These calculations were performed excluding evaporation from the opencasts.

**Table 10.1: Simulated Groundwater Inflows - All Mining Areas**

Total Opencasts Area (m <sup>2</sup> )	Maximum Drawdown (m)	Max Cone of Depression (m)	Inflow Volume (m <sup>3</sup> /day)	Estimated Inflow (m <sup>3</sup> /yr.)
1578841	90	470	850	310250

### 10.2.4 Groundwater quantity mitigations

Mining of all of the proposed areas should progress as swiftly as possible to reduce the period of active dewatering. In addition, the extent of the mining areas should be kept to a minimum to reduce dewatering impacts. The dewatering of the open pits should stop as soon as mining activities cease.

The dewatering volumes should be monitored frequently throughout the LoM to note deviations from the predicted inflows as soon as they are identified.

### 10.3 Impacts on groundwater quality

As some waste disposal facilities will be present on the mine (waste rock dumps, settling dam, ROM stockpile, processing plant and PCD), outflow from these facilities could be contaminated as a result of mine drainage. As sulphate is normally a significant solute in drainage from mines, sulphate concentration from the facilities has been modelled as a conservative (non-reacting) indicator of mine drainage pollution. A starting concentration of 50 mg/litre has been assumed as a worst-case scenario based on the leach testing performed for the study.

The migration of contaminated water from the mining area has been modelled as described, in terms of the extent of the pollution plume after 25 years of mine operation.

The results must be viewed with caution as a homogeneous aquifer has been assumed. Heterogeneities in the aquifer are unknown and the effect of this cannot be predicted. Furthermore, no chemical interaction of the leachate with the minerals in the surrounding bedrock has been assumed. As there must be some interaction and retardation of the plume, this calculation will represent a worst-case scenario.

### 10.4 Impacts on surface water

Although surface water as such is not part of this study, the impact of the proposed mine on streams in the area can be estimated qualitatively from the model in so far as the groundwater component (base flow) of the stream is concerned. Such an impact assessment will not include possible surface runoff influences caused by mining, but merely addresses the base flow component due to gaining (or losing) of groundwater by the stream. It can be deduced from the calculated figures that the cumulative groundwater drawdown at the streams/wetlands close to the mine will not have an impact.

### 10.5 Water management

The following water management options are recommended during operations:

#### a) General

- Identify and where possible, maximise areas of the mine that will result in clean storm water runoff as well as infrastructure associated with the mine (for example office areas) and ensure that runoff from these areas is routed directly to natural watercourses and not contained or contaminated.
- Ensure that clean storm water is only contained if the volume of the runoff poses a risk, if the water cannot be discharged to watercourses by gravitation, for attenuation purposes, or when the clean area is small and located within a large dirty area. This contained clean water should then be released into natural watercourses under controlled conditions.
- Ensure the minimisation of contaminated areas, reuse of dirty water wherever possible and planning to ensure that clean areas are not lost to the catchment unnecessarily.
- Ensure that seepage losses from storage facilities (such as polluted dams) are minimised and overflows are prevented.
- Ensure that all possible sources of dirty water have been identified and that appropriate collection and containment systems have been implemented and that these do not result in further unnecessary water quality deterioration.
- Ensure that less polluted water or that: moderately polluted water is not further polluted. Where possible less and more polluted water should be separated. This will assist in the reuse water strategy and improve possibilities for reuse based on different water quality requirements by different mine water uses.
- Where contaminants are transported along construction roads, emergency containment and mitigation measures must be developed to minimize impacts should accidental spillages occur along the transport routes.
- Store all potential sources of contamination in secure facilities with appropriate Storm Water management systems in place to ensure that contaminants are not released to the water resource through Storm Water runoff.
- Separate and collect all storm water that has a quality potentially poorer than the water quality specified and negotiated for the specific catchment into dirty water storage facilities for reuse within the mining operations.
- Ensure that all storm water structures that are designed to keep dirty and clean water separate can accommodate a defined precipitation event. (The magnitude of the precipitation event used in such an objective statement must, as a minimum, adhere to the relevant legal requirements.)
- Route all clean storm water directly to natural watercourses without increasing the risk of a negative impact on safety and infrastructure, e.g. loss of life or damage to property due to an increase in the peak runoff flow.
- Ensure that the maximum volume of clean water runoff is diverted directly to watercourses and the minimum amount of storm water reports to the pit floor of an open cast mine.
- Develop and implement proper environmental management and auditing systems to ensure that pollution prevention and impact minimisation plans and measures developed in the design and feasibility stages are fully implemented.
- The size of unrehabilitated areas (pit, spoils, unvegetated areas) that produce contaminated runoff should be minimised.
- Rehabilitation should be planned to promote free drainage and to minimise or eliminate

ponding of storm water. On-going rehabilitation as mining operations progress is required.

- The clean and dirty water flow areas on a mine site should be identified.
- Every effort should be made to maximise the clean area and minimise the dirty area when locating the diversion berms, channels and dams. In the case of a new mine, the maximisation of the clean areas should have an influence in overall mine planning and the location of the mine infrastructure
- The mine planning should consider concurrent rehabilitation of mine workings and waste management facilities, to maximise the areas of clean runoff that can be discharged to the natural watercourses.

#### **b) Waste rock deposits and pollution control dams**

- Monitoring of water storage facilities, particularly pollution control dams, is imperative to manage the risk of spillage from the dams. Stage-storage (elevation- capacity) curves are useful tools to monitor the remaining capacity within a water storage facility.
- Prevent the erosion or leaching of materials from any residue deposit or stockpile from any area and contain material or substances so eroded or leached in such area by providing suitable barrier dams, evaporation dams or any other effective measures to prevent this material or substance from entering and polluting any water resources.
- Water quantity and quality data should be collected on a regular, ongoing basis during mine operations. These data will be used to recalibrate and update the mine water management model, to prepare monitoring and audit reports, to report to the regulatory authorities against the requirements of the IWMP and other authorisations and as feedback to stakeholders in the catchment, perhaps via the CMA.
- Water that has been in contact with residue, and must therefore be considered polluted, must be kept within the confines of the MRD until evaporated, treated to rendered acceptable for release, or re-used in some other way.
- All water that falls within the catchment area of the MRD must be retained within that area. Foremost MRDs the catchment can be divided into component catchments,
- as follows:
  - The top area of the MRD together with any return water storage dams which have been connected to the top area of the MRD by means of an outfall penstock, and
  - The faces of the MRD together with the catchment paddocks provided to receive run-off from the faces and any additional catchment dams associated with the faces and catchment paddocks.
- The design, operation and closure of MRDs should incorporate consideration of the risk of changes in the mining and plant operations, and hence the mine water balance, through the lifecycle of the mine.
- A system of storm water drains must be designed and constructed to ensure that all water that falls outside the area of the MRD is diverted clear of the deposit. Provision must be

made for the maximum precipitation to be expected over a period of 24 hours with a probability of once in one hundred years. A freeboard of at least 0.5 m must be provided throughout the system above the predicted maximum water level. This requirement applies to all MRDs, both fine and coarse-grained MRDs.

- Ensure that the water use practices on and around the MRD do not result in unnecessary water quality deterioration, e.g. use of the return water dam for storage of poorer quality water.
- Should the above be insufficient to capture polluted surface and groundwater moving towards the tributaries of the Tubatsane and Mofafa Rivers, interception trenches can be designed as follows:
  - The depth of the trench should be at least 4 mbgl (or 2 m below the groundwater level) to intercept polluted seepage that resulted from the WRD;
  - The design of the trench gradient must be such that the water is free-flowing without eroding the channel;
  - The water from the trench must be captured, retained and managed within the mine water systems.

### C. Opencast pits

- Mining should aim to remove as much of the ore body (acid generating material) as possible.
- Should private boreholes decrease in yield the mine should supply the owners with a volume of water as agreed upon between the parties involved.
- The capacity to rapidly pump water out of the pit into storage dams should be maintained. This will assist in minimising water quality deterioration due to long-term retention of storm watering contact with materials that may cause water quality deterioration.
- Berms should be constructed around the opencast pits to minimise the flow of any surface water or floodwater into mine workings. These berms should be constructed to allow free drainage away from the pits.
- Concurrent rehabilitation should take place during the operational phase, where applicable, to:
  - Meet the post-mining topography requirements.
  - Minimise the post-closure water management requirements, by maximising free-draining areas and minimising contamination of clean water.
  - The above water management principles should play a key and decisive role when evaluating and deciding on rehabilitation and closure strategies.
  - Additionally, adding lime to backfill material could be considered to minimise the generation of acidity.
- Water quantity and quality data should be collected on a regular, ongoing basis during

mine operations. These data will be used to recalibrate and update the mine water management model, to prepare monitoring and audit reports, to report to the regulatory authorities against the requirements of the IWMP and other authorisations and as feedback to stakeholders in the catchment, perhaps via the CMA. See the Monitoring Network section.

- If excessive groundwater recharge and rainfall is encountered other than the predicted volumes the water could be managed as follows:
  - Manage in-pit seepage and rainfall through a collection and storage system. Water stored in pit should be utilised locally for dust suppression, as far as possible. Excess pit water should be pumped to surface to be incorporated into the mine water balance,
  - Maximise the abstraction and discharge of clean groundwater ahead of the pit development, through installation of dewatering boreholes surrounding the pit.

***Please note that further investigation will be required for the above especially the siting and pumping rate of the dewatering boreholes.***

## **10.6 Decommissioning and Post-Closure Phase Impacts**

During this phase it is assumed that dewatering of the proposed mine will be ceased, and it will be allowed to flood. The groundwater regime will return to a state of equilibrium once mining has stopped and the removal of water from the mining void has been discontinued.

The rise in groundwater level is predicted to be relatively slow and the water levels are expected to recover in over 100 years. The following possible impacts were identified at this stage:

- Following closure of the mine, the groundwater level will rise to an equilibrium that will differ from the pre-mining level due to the disturbance of the bedrock. However, this change is likely to be minimal due to the depth of mining and no drawdown anticipated close to surface.
- Groundwater within the mined areas is expected to deteriorate due to chemical interactions between the geological material and the groundwater. The resulting groundwater pollution plume is expected to commence with downstream movement.

### **10.6.1 Impacts on groundwater quantity**

After closure, the water table will rise in the mine to reinstate equilibrium with the surrounding groundwater systems. However, the mined areas will have a large hydraulic conductivity compared to the pre-mining situation.

#### **a. Rebound and Potential Decant**

Following the closure of the opencasts and the cessation of the dewatering it is assumed to lead to groundwater rebound.

This estimated rebound time in years for the mines is expected to last more than 100 years. After rebound has reached equilibrium or water in the pit equal to surrounding host rock, decant has the potential to occur due to excessive rainfall and surface water run-off water entering the pit. The percentage of the rainfall/run-off that is recharged into the rehabilitated opencast and potential decant depends on:

- The slope of the rehabilitated pit and its direct surroundings.

- The thickness and composition of the topsoil. i.e. clay content and compaction.
- The vegetation of the rehabilitation and its direct surroundings.
- The amount rainfall and intensity of the rainfall events.
- The size of the ramps and the final voids

Predicted groundwater levels indicate that a rise in groundwater will occur and that decant after rebound in so far as daylighting to surface is unlikely to occur.

### **10.6.2 Impacts on groundwater quality**

Once the normal groundwater flow conditions have been re-instated, polluted water could potentially migrate away from the mining areas.

#### **a. Spread of pollution**

As some discards and exposed reactive mineral surfaces will remain in the mine, this outflow could be contaminated as a result of mine drainage. As sulphate is normally a significant solute in drainage from mines, sulphate concentration from the mine has been modelled as a conservative (non-reacting) indicator of mine drainage pollution. A starting concentration of 50 mg/litre has been assumed as a worst-case scenario. However, geological material is a transient contaminant source and decreases in the concentration of released contaminants are expected over time. A 5% decrease in contaminant concentrations in the mine were incorporated into the transport modelling.

The migration of contaminated water from the mining areas and co-diposal facility was simulated for 25, 50 and 100 years post-closure (Figure 10.2). The maximum extent of the contaminant plume (sulphate >50 mg/l) for the weathered aquifer was calculated to be ~360 m from the mining areas 100 years post-closure.

The contaminant migration indicates that the plumes will mainly flow towards and follow local drainage lines, such as the Tubatsane and Steelpoort river located to the west and south of the opencasts (Figure 10.2). Shallow contaminated seepage may impact on the Tubatsane perennial stream. This impact is however likely to be moderate due to the expected contaminant movement calculated for 100 years post-closure.

### **10.6.3 Groundwater contamination mitigations**

The dewatering of the pits should cease as soon as possible after mining activities are completed to allow for groundwater level recovery. To mitigate the contaminant plume migration the open pits should be properly rehabilitated, including reduction of recharge to these areas by properly top-soiling and vegetating the areas. This will reduce infiltration of water into the groundwater and reduce plume extents.

Continuous water quality measurements for up and downstream of the Tubatsane River should be part of the post-closure plan. If contamination of the surface water is indicated then mitigation measures, i.e. ensuring surface water quality remains within standards prior to flowing into the Steelpoort River, should be implemented. Groundwater may need to be captured or actively lowered in Southern and Main Pit to prevent contaminant plumes to move away from the pits.

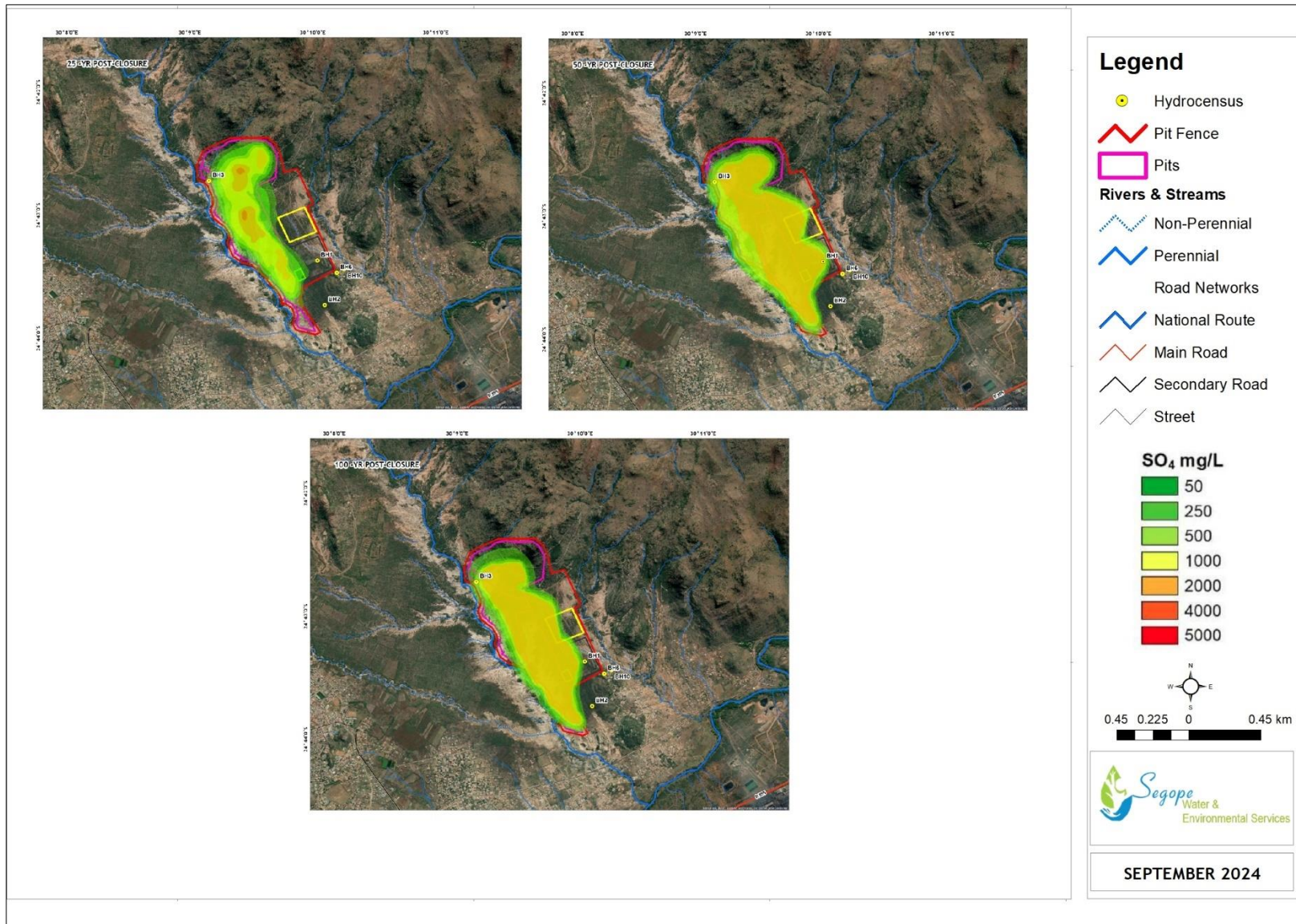


Figure 10.2: Groundwater Contamination Plumes Post-Closure

#### 10.6.4 Cumulative effects

The cumulative pollution impacts of all current and historic mining in addition to the proposed mine could not be calculated as any data on surrounding mines is not available. However, it is highly recommended that a regional study be undertaken to quantify impacts on at least a quaternary scale or a data sharing agreement should be reached with neighbouring mines.

#### 10.6.5 Groundwater management

##### a. Waste rock deposits

- Update the numerical model against monitored data.
- After proper geochemical investigation the ARD (if present in significant concentrations) can be dealt with as follows:
  - Cover and capping research studies and design to reduce water and oxygen reactions
  - Use as waste backfill in open pits
  - Neutralisation (e.g. lime) and treatment (stimulation of sulphate reducing bacteria)
  - Segregation/isolation/encapsulation
  - Passive leachate management and treatment Polluted groundwater can be treated as follows:
  - Reduce hydraulic head by water shedding
- Integrate capture store-release systems
  - Utilise evapotranspiration
  - Cap and cover with capillary break
  - Drainage diversions
  - Neutralisation and detoxification of tails seepage
  - Wetland filtration

#### 10.6.6 Opencast pits

The post-closure groundwater management of the opencast should be done in two phases:

- Phase 1: Immediately after closure
- Phase 2: After Rapid Flooding

Please note that the numerical model must be updated against monitored data during the post-closure phase. Additionally, a geochemical model must be constructed to calculate realistic contaminant transport scenarios.

##### **Phase 1: Immediately after closure**

During mining the acid generating material and non-acid generating material should be separated.

- The acid producing material should be placed as low in the pits as possible, followed by then non-acid generating material.
- Rapid flooding should be done by diverting storm water channels and pumping of available groundwater into the pit until the acid producing material is inundated by the water.

### **Phase 2: After Rapid Flooding**

After the acid producing material is inundated by the water:

- The final backfilled opencast topography should be engineered such that runoff is directed away from the opencast areas.
- The final layer (just below the topsoil cover) should be as clayey as possible and compacted if feasible, to reduce recharge to the opencasts.
- Natural berms should then be constructed to allow free drainage of surface water around the rehabilitated pit.

### **10.7 Assumptions and Limitations**

The modelling was done within the limitations of the scope of work of this study and the amount of data available. Although all efforts have been made to base the model on sound assumptions and has been calibrated to observed data, the results obtained from this exercise should be considered in accordance with the assumptions made. Especially the assumption that a fractured aquifer will behave as a homogeneous porous medium can lead to error. However, on a large enough scale (bigger than the REV, Representative Elemental Volume) this assumption should hold reasonably well.

**Table 10.2: Summary of Potential Impacts during Operation-Dewatering**

<b>Mining area</b>	<b>Potential impacted receptor</b>	<b>Estimated increase in concentrations during operation (mg/ℓ)</b>
Pollution Control Dam	Tubatsane River, Downstream boreholes	Max 50 mg/L
Proposed Process Plant Area	Tubatsane, Downstream boreholes	Max 50 mg/L
RoM & Product Stockpile Area	Tubatsane River, Downstream boreholes	Max 50 mg/L
Settling Dam	Tubatsane River, Downstream boreholes	Max 50 mg/L
Sewerage Treatment Plant	Tubatsane River, Downstream boreholes	Max 50 mg/L

## 11. GROUNDWATER RISK ASSESSMENT

The groundwater 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 therefore aimed at describing and defining the relationship between cause and effect. In the absence of any one of the three components, it is possible to conclude that groundwater risk does not exist.

### 11.1 Source Term(s)

The approach to define the behavior of the source term will always start with the definition of the key questions that need to be answered for the source term:

- **Will any waste material be generated that has a potential to contaminate?**
- **Toxicity of the waste?** The potential for different wastes to pollute water resources differs greatly, depending on the composition of the waste and its potential for degradation over time. South African legislation broadly classifies waste under two categories, namely general and hazardous waste. Between these two categories lies a continuum, with a transition from what could be described as nontoxic to toxic. When referring to a level of toxicity, then the constituent itself must be considered and also the potential user of the water, e.g. human, animal, aquatic life, or irrigation
- **Quantity of waste?** Toxicity and quantity of waste go hand in hand. Experience has shown that it is easier to dispose of, manage and contain small quantities of waste than large quantities. The risk for groundwater pollution is usually greater at large waste disposal facilities, where it is often impossible to prevent groundwater pollution because of the nature and scale of operations.
- **Potential for leachate generation?** It is theoretically possible, by using synthetic liners, to completely contain leachate from a waste site. This is, however, mostly impractical and very costly. It is also now generally accepted that all liners leak to a greater or lesser (or to some) extent. In reality, therefore, leachate that is generated in a disposal site may eventually reach the groundwater regime.

It needs to be recognised that source terms are dynamic in nature and could exhibit a variable quality over time, due to changes in hydrology and to changes in the chemistry. An impact assessment that defines the source term as a static constant feature over time is unlikely to be realistic and would be inappropriate for anything other than the most basic screening level assessment. A definition of the identified source terms is shown in Table.

### 11.2 Pathways

With respect to potential impacts on the water resource, the groundwater pathways through which contaminants could move are the following:

- Movement through the vadose (unsaturated) zone;

- Movement through an aquifer;
- Decant to surface
- Movement through mining voids.

Within the context of defining the pathways it is important to note that the pathways may have the following features:

- Hydraulic conduit (pathway) for the mobilization and movement of the contaminants of concern from the source term to the receptor.
- Attenuation of contaminants, release of new contaminants and alteration of the chemistry of the discharge from the source term through a variety of chemical reactions.
- Habitat for receptors.

A definition of the groundwater pathways is shown in Table.

### **11.3 Receptors**

As the final component of the risk assessment, the receptors in the context of the water resource would be users of the water resource itself. The following receptors were found:

- Groundwater user abstracting contaminated groundwater through a borehole for domestic use, livestock watering or irrigation.
- Aquatic fauna and flora in a receiving watercourse.
- Any water user abstracting water from an impacted watercourse

## **12. GROUNDWATER ENVIRONMENTAL MANAGEMENT PROGRAMME (EMP)**

Table 12.1 summarizes all the groundwater related EMP's and should be implemented during the various phases of mining. The EMP's were developed in accordance with the DWA Best Practice Guideline series.

### **12.1 Groundwater Impact Assessment Criteria**

The criteria for the description and assessment of groundwater impacts were drawn from the EIA Regulations, published by the Department of Environmental Affairs and Tourism (April 1998) interims of the NEMA. In order to determine the significance of an impact, the following criteria would be used: extent, duration, intensity and probability. The extent and probability criteria have five parameters, with a scaling of 1 to 5. Intensity also has five parameters, but with a weighted scaling.

The assessment of the intensity of the impact is a relative evaluation within the context of all

the activities and other impacts within the framework of the project. The intensity rating is weighted as 2 since this is the critical issue in terms of the overall risk and impact assessment (thus the scaling of 2 to 10, with intervals of 2). The intensity is thus measured as the degree to which the project affects or changes the environment.

The level of detail as depicted in the EIA regulations was fine-tuned by assigning specific values to each impact. In order to establish a coherent framework within which all impacts could be objectively assessed, it was necessary to establish a rating system, which was applied consistently to all the criteria. For such purposes, each aspect was assigned a value, ranging from one (1) to five (5), depending on its definition. This assessment is a relative evaluation within the context of all the activities and the other impacts within the framework of the project. An explanation of the impact assessment criteria is defined below in **Table 12.1**.

**Table 12.1: Explanation of the EIA criteria**

Criteria	Description
Nature	Includes a description of what causes the effect, what will be affected and how it will be affected.
Extent	The physical and spatial scale of the impact.
Duration	The lifetime of the impact is measured in relation to the lifetime of the development.
Intensity	Examining whether the impact is destructive or benign, whether it destroys the impacted environment, alters its functioning, or slightly alters the environment itself.

Probability	This describes the likelihood of the impacts actually occurring. The impact may occur for any length of time during the lifecycle of the activity, and not at any given time.
Status	Description of the impact as positive, negative or neutral.
Significance	A synthesis of the characteristics described above and assessed as low, medium or high. A distinction will be made for the significance rating without the implementation of mitigation measures and with the implementation of mitigation measures.
Confidence	This is the level of knowledge/information that the environmental impact practitioner or a specialist had in his/her judgement.
Reversibility	Examining whether the impacted environment can be returned to its pre-impacted state once the cause of the impact has been removed.
Replaceability	Examining if an irreplaceable resource is impacted upon
Cumulative	Synthesis of different impacts in concert, considering the knock-on impacts thereof.

## 12.2 Nature and Status

The nature of the impact is the consideration of what the impact will be and how it will be affected. This description is qualitative and gives an overview of what is specifically being considered. That is, the nature considers 'what is the cause, what is affected, and how is it affected. The status is thus given as being positive, negative or neutral, and is deemed to be either direct or indirect in impact.

## 12.3 Extent

The physical and spatial scale of the impact is classified in Table 12.1.

## 12.4 Duration

The lifetime of the impact is measured in relation to the lifetime of the project, as per Table 12.3.

## 12.5 Intensity

This will be a relative evaluation within the context of all the activities and the other impacts within the framework of the project, as per Table 12.4.

## 12.6 Probability

This describes the likelihood of the impacts actually occurring. The impact may occur for any length of time during the lifecycle of the activity, and not at any given time.

## 12.7 Level of Significance

The level of significance is expressed as the sum of the area exposed to the risk (extent), the length of time that exposure may occur over in total (duration), the severity of the exposure (intensity) and the likelihood of the event occurring (probability). This leads to a range of significance values running from 'no impact' to 'extreme'. The significance of the impacts has been determined as the consequence of the impact occurring (reflection of chance of occurring, what will be affected (extent), how long will it be affected, and how intense is the impact) as affected by the probability of it occurring, this translates to the following formula:

$$\text{Significance value} = (\text{Extent} + \text{Duration} + \text{Intensity}) \times \text{Probability}$$

Each impact is considered in turn and assigned a rating calculated using the results of this formula, and presented as a final rating classification according to Table 19. A distinction will be made for the significance rating of (a) without the implementation of mitigation measures, and, (b) with the implementation of mitigation measures.

## 12.8 Identifying Potential Impacts with Mitigation Measures

In order to gain a comprehensive understanding of the overall significance of the impact, after implementation of the mitigation measures, it will be necessary to re-evaluate the impact. Significance with mitigation is rated on the following scale as contemplated in Table 12.4 below.

**Low (L):** The impact is mitigated to the point where it is of limited importance.

**Medium (M):** Notwithstanding the successful implementation of the mitigation measures, to reduce the negative impacts to acceptable levels, the negative impact will remain of significance. However, taken within the overall context of the project, the persistent impact does not constitute a fatal flaw.

**High (H):** The impact is of major importance. Mitigation of the impact is not possible on a cost-effective basis. The impact is regarded as high importance and taken within the overall context of the project, is regarded as a fatal flaw. An impact regarded as high significance, after mitigation could render the entire development option or entire project proposal unacceptable.

## 12.9 Impact Assessment and Management Options

Based on the impact assessment criteria as detailed in the preceding paragraph an impact rating is given. The table also summarizes all the groundwater related EMP's and should be implemented during the operation and closure of the mine.

# 13. MONITORING PROGRAMME

## 13.1 Groundwater Monitoring Network

A groundwater monitoring system has to adhere to the criteria mentioned below. As a result, the system should be developed accordingly.

### 13.1.1 Source, plume, impact and background monitoring

A groundwater monitoring network should contain monitoring positions which can assess the groundwater status at certain areas. The boreholes can be grouped classification according to the following purposes:

- **Source monitoring:** Monitoring boreholes are placed close to or in the source of contamination to evaluate the impact thereof on the groundwater chemistry.
- **Plume monitoring:** Monitoring boreholes are placed in the primary groundwater plume's migration path to evaluate the migration rates and chemical changes along the pathway.
- **Impact monitoring:** Monitoring of possible impacts of contaminated groundwater on sensitive ecosystems or other receptors. These monitoring points are also installed as early warning systems for contamination break-through at areas of concern.
- **Background monitoring:** Background groundwater quality is essential to evaluate the impact of a specific action/pollution source on the groundwater chemistry.

### 13.1.2 System Response Monitoring Network

**Groundwater levels:** The response of water levels to abstraction is monitored. Static water levels are also used to determine the flow direction and hydraulic gradient within an aquifer. Where possible all of the above-mentioned borehole's water levels need to be recorded during each monitoring event.

### 13.1.3 Monitoring Frequency

In the operational phase and closure phase, quarterly monitoring of groundwater quality and groundwater levels is recommended. Quality monitoring should take place before after and during the wet season, i.e. during September and March. It is important to note that a groundwater- monitoring network should also be dynamic. This means that the network should be extended over time to accommodate the migration of potential contaminants through the aquifer as well as the expansion of infrastructure and/or addition of possible pollution sources.

### 13.1.4 Monitoring Parameters

The identification of the monitoring parameters is crucial and depends on the chemistry of possible pollution sources. They comprise a set of physical and/or chemical parameters (e.g. groundwater levels and predetermined organic and inorganic chemical constituents). Once a pollution indicator has been identified it can be used as a substitute to full analysis and therefore save costs. The use of pollution indicators should be validated on a regular basis in the different sampling positions. The parameters should be revised after each sampling event; some metals may be added to the analyses during the operational phase, especially if the pH drops.

### 13.1.5 Abbreviated analysis (pollution indicators)

#### *Physical Parameters:*

- Groundwater levels

***Chemical Parameters:***

- Field measurements:
  - pH, EC
- Laboratory analyses:
  - Major anions and cations (Ca, Na, Cl, SO<sub>4</sub>)
  - Other parameters (EC)

**13.1.6 Full analysis**

***Physical Parameters:***

- Groundwater levels

***Chemical Parameters:***

- Field measurements:
  - pH, EC
- Laboratory analyses:
  - Anions and cations (Ca, Mg, Na, K, NO<sub>3</sub>, Cl, SO<sub>4</sub>, F, Fe, Mn, Al, & Alkalinity)
  - Other parameters (pH, EC, TDS)
  - Petroleum hydrocarbon contaminants (where applicable, near workshops and petroleum handling facilities)
  - Sewage related contaminants (E.coli, faecal coliforms) in borehole in proximity to septic tanks or sewage plants.

**13.1.7 Mine monitoring**

DWAF (1998) states that “A monitoring hole must be such that the section of the groundwater most likely to be polluted first, is suitably penetrated to ensure the most realistic monitoring result.”<sup>14</sup>

Currently a monitoring network does not exist for the proposed mine. The recommended boreholes are listed in Table 26 and the areas to site these monitoring boreholes are shown in Figure 25. These boreholes can be utilised for water level monitoring during operations, as well as groundwater quality monitoring after decommissioning of the site.

However, a monitoring network should be dynamic. This means that the network should be extended over time to accommodate the migration of contaminants through the aquifer as well as the expansion of infrastructure and/or addition of possible pollution sources. An audit on the monitoring network should be conducted annually.

## **14. CONCLUSIONS AND RECOMMENDATIONS**

This section will briefly summarise the current groundwater conditions in the area of the proposed mine, the expected impacts on the groundwater environment and the recommendations to minimise the effect of the operation on the groundwater.

### **14.1 Topography and Drainage**

The area is characterised by a mountainous topography and in the area of the mining site the slope is more or less in the order of 18:100 (0.18). Locally drainage is towards South West to the Steelpoort River

### **14.2 Geology**

The investigated area falls within the 2430 Pilgrims Rest 1:250 000 geology series maps and is situated approximately 22 km North West of Burgersfort, Limpopo. The proposed mining areas fall within the Rustenburg Layered Suite of the eastern limb of the Bushveld Complex. The rocks of the Dwarsriver Subsuite underlie the proposed mining area. All these rocks dip slightly to the south west, following the emplacement geometry of the Bushveld Complex. Also present in the area are Quaternary sediments.

The Dwarsriver Subsuite is composed of medium- to coarse-grained norite and anorthosite (upper part); medium- to coarse-grained pyroxenite (lower part); Merensky reef; chromitite layer (upper group; middle group; lower group) and a pyroxenite layer. A number of linear features which have been inferred by aeromagnetic data can be found in the area surrounding the proposed mine. These may be dykes or faults.

### **14.3 Hydrogeology**

The Rustenburg Layered Suite rocks typically act as secondary aquifers (intergranular and fractured rock aquifers) (Haupt, C.J). However, the multi-layered weathering system present on these rocks could prove to have up to two aquifer systems present in the form of a shallow, saprolitic aquifer with a weathered, intergranular soft rock base associated with the contact of fresh bedrock and the weathering zone; and a fractured bedrock aquifer. These aquifer systems are discussed below:

#### **14.4 Shallow, saprolitic aquifer**

The main source of recharge into the shallow aquifer is rainfall that infiltrates the aquifer through the unsaturated (vadose) zone. Vertical movement of water is faster than lateral movement in this system as water moves predominantly under the influence of gravity. This aquifer may contain coarse, anorthositic sediment or turf clay sediment when underlain by anorthosite or gabbro-norite respectively. The hydraulic conductivity of this aquifer ranges between  $10^{-8}$  and  $10^{-2}$  m.day<sup>-1</sup> and porosity ranges between 0.4 and 0.7 for turf clay sediments. The hydraulic conductivity of the coarse, anorthositic sediment can reach up to 20m/day with porosities ranging between values of 0.25 to 0.5.

#### **14.5 Shallow weathered aquifer**

This aquifer, which is recharged by rainfall, is often perched and due to the impermeable clay horizons, that might have developed. The recharge to this aquifer is estimated to be in the order of 3 - 5% of the annual rainfall. The well-developed clay layers in this aquifer restrict the downward filtration of recharged rainwater into the main fractured aquifer. The largest accumulation of water is normally confined to the contact between the weathered and “fresh” bedrock. The borehole yields in this aquifer appear to be high due to the sandy / gritty nature of the weathered pyroxenite.

#### **14.6 Fractured, bedrock aquifer**

Groundwater movement is predominantly associated with secondary structures in this aquifer (fractures, faults, dykes, etc.). The average water level depth in the area ranges between 5 and 40m bgl<sup>3</sup>. Borehole yields in the Rustenburg Layered Suite fractured aquifers are generally low and can be expected to be between 0.1 and 2 l/s with regional flow resembling flow in the porous medium (i.e. obeying Darcy's law). These formations contain limited quantities of water resources due to the poor storage capacity of the igneous rock. Groundwater quality in the area is also expected to be intermediate to poor with EC values ranging from 4.4 to 120mS/m and possibly elevated Ca, Mg, Cl, and SO<sub>4</sub> as well as carbonate alkalinity concentrations.

Both the porosity and the hydraulic conductivity of the Rustenburg Layered Suite fractured aquifers are known to be low. The commonly expected values of porosity and permeability for igneous rock types, similar to those present in the Rustenburg Layered Suite, are 0.05 (porosity) and  $10^{-5}$  m.d<sup>-1</sup> (hydraulic conductivity) respectively (Kruseman & de Ridder, 1994). Movement of groundwater in this aquifer will be preferential in secondary structures such as joints, faults and fractures.

#### **14.7 Deeper fractured aquifer**

Groundwater occurrence is controlled by the presence of zones of weathering and fracturing within the country rock. Groundwater is generally restricted to depths of 40 – 70m below surface, with most water strikes occurring in fracturing below the weathering. The deepest water strikes (70m) are associated with the contact zones of the main SW – SE trending dykes. Zones of high transmissivity are known to be associated

with the dolerite dykes and borehole yields varying from 2- 20 l/s have been obtained in the general area. Aquifers are confined, anisotropic and secondary with limited storage.

#### 14.8 Aquifer protection classification

A Groundwater Quality Management Index of 4 was estimated for the study area from the ratings for the Aquifer System Management Classification. According to this estimate a **medium level groundwater protection** is required for the aquifer. Reasonable and sound groundwater protection measures based on the modelling will therefore be recommended to ensure that no cumulative pollution affects the aquifer, even in the long term.

### 14.4 Groundwater Impacts

#### 14.4.1 Construction phase

##### a. Impacts on groundwater quantity

This phase is not expected to influence the groundwater levels. With the exception of lesser oil and diesel spills, there are also no activities expected that could impact on regional groundwater quality.

##### b. Impacts on groundwater quality

It is noted that the PCD is planned to be constructed on one of the non-perennial tributaries of the Moopetsi River. It is recommended that the placement of this structure be re-evaluated to minimise contamination impacts from potential leakages or spills on the surface water of the area.

##### c. Groundwater Management

- Before operation, a plan that includes explicit consideration of closure and rehabilitation issues must be prepared and approved. These plans should define the sequence and nature of operations and detail the methods to be used in closure and restoration. The plans as well as the numerical should be updated regularly (every 3 to 5 years) during operation with available monitoring data. All operational planning and activities should be undertaken with eventual closure in mind, such that operations can end in a manner that minimizes the final risks and liabilities in the post-closure phase.
- Waste residue deposits should be located as far as possible from the:
  - Tributary of the Moopetsi River
- It is noted that the PCD is planned to be constructed on one of the non-perennial tributaries of the Moopetsi River. It is recommended that the placement of this structure be re-evaluated to minimise contamination impacts from potential leakages or spills on the surface water of the area.

- Apply effective storm water management principles to ensure that clean runoff is maximised and diverted to the receiving water resource, while contaminated runoff is minimised and contained for reuse within the operation.
- Apply passive water management measures within the operations that are aimed at minimising the potential for water quality deterioration due to the oxidation of sulphide minerals by reducing the available contact time between water and exposed sulphide minerals.
- Monitoring boreholes as discussed in the following sections will be required in strategic locations

near the pollution source, to obtain information on the groundwater regime as well as for future monitoring purposes.

- Construct detailed water and salt balances that take account of climatic and operational variability, as a planning tool to ensure that all pollution control dams are adequately sized and that they are integrated into a robust water reuse and reclamation strategy to ensure that captured contaminated water is effectively reused within the mining operations and that system spillages to the environment are avoided.
- Proper storage, handling and monitoring of fuel and chemicals used on site to minimize the risk of spillages to the environment.
- Institute detailed monitoring systems that are capable of detecting pollution at the earliest possible stage, at all facilities where significant pollution potential exists, in order that this can lead to rapid and effective management actions to address the pollution source and minimize it to the full extent possible.
- Safety measures such as freeboard allowances etc. should be included in designs of storm water control facilities to allow for sufficient storage capacity and to ensure that risks of overflows or spillages are minimized and environmental impacts are therefore avoided.
- Design, construct, maintain and operate any clean water system at the mine or activity so that it is not likely to spill into any dirty water system more than once in 50 years;
- Design, construct, maintain and operate any dirty water system at the mine or activity so that it is not likely to spill into any clean water system more than once in 50 years;
- Design, construct and maintain all water systems in such a manner as to guarantee the serviceability of such conveyances for flows up to and including those arising as a result of the maximum flood with an average period of recurrence of once in 50 years.
- Design and operate the MRDs to minimise the evaporative losses, e.g. by limiting the size of the supernatant pool on the MRD surface.

#### 14.4.2 Operational phase

##### **Impacts on groundwater quantity**

There are no identified privately owned boreholes in the potential affected area that might experience a decline in water levels of approximately 5 m or more. It can be deduced from the calculated figures that the cumulative groundwater drawdown at the streams/wetlands close to the mine will not have an impact.

### **Groundwater management**

- Identify and where possible, maximise areas of the mine that will result in clean storm water runoff (for example open veld areas) as well as infrastructure associated with the mine (for example office areas) and ensure that runoff from these areas is routed directly to natural watercourses and not contained or contaminated.
- Ensure that clean storm water is only contained if the volume of the runoff poses a risk, if the water cannot be discharged to watercourses by gravitation, for attenuation purposes, or when the clean area is small and located within a large dirty area. This contained clean water should then be released into natural watercourses under controlled conditions.
- Ensure the minimisation of contaminated areas, reuse of dirty water wherever possible and planning to ensure that clean areas are not lost to the catchment unnecessarily.
- Ensure that seepage losses from storage facilities (such as polluted dams) are minimised and overflows are prevented.
- Ensure that all possible sources of dirty water have been identified and that appropriate collection and containment systems have been implemented and that these do not result in further unnecessary water quality deterioration.
- Ensure that less polluted water or that: moderately polluted water is not further polluted. Where possible less and more polluted water should be separated. This will assist in the reuse water strategy and improve possibilities for reuse based on different water quality requirements by different mine water uses.
- Where contaminants are transported along construction roads, emergency containment and mitigation measures must be developed to minimize impacts should accidental spillages occur along the transport routes.
- Store all potential sources of contamination in secure facilities with appropriate Storm Water management systems in place to ensure that contaminants are not released to the water resource through Storm Water runoff.
- Separate and collect all storm water that has a quality potentially poorer than the water quality specified and negotiated for the specific catchment into dirty water storage facilities for reuse within the mining operations.
- Ensure that all storm water structures that are designed to keep dirty and clean water separate can accommodate a defined precipitation event. (The magnitude of the precipitation event used in such an objective statement must, as a minimum, adhere to the relevant legal requirements.)
- Route all clean storm water directly to natural watercourses without increasing the risk of a negative impact on safety and infrastructure, e.g. loss of life or damage to property due to an increase in the peak runoff flow.
- Ensure that the maximum volume of clean water runoff is diverted directly to watercourses and the minimum amount of storm water reports to the pit floor of an open cast mine.
- Develop and implement proper environmental management and auditing systems to ensure that

pollution prevention and impact minimisation plans and measures developed in the design and feasibility stages are fully implemented.

- The size of unrehabilitated areas (pit, spoils, unvegetated areas) that produce contaminated runoff should be minimised.
- Rehabilitation should be planned to promote free drainage and to minimise or eliminate ponding of storm water. On-going rehabilitation as mining operations progress is required.
- The clean and dirty water flow areas on a mine site should be identified.
- Every effort should be made to maximise the clean area and minimise the dirty area when locating the diversion berms, channels and dams. In the case of a new mine, the maximisation of the clean areas should have an influence in overall mine planning and the location of the mine infrastructure
- The mine planning should consider concurrent rehabilitation of mine workings and waste management facilities, to maximise the areas of clean runoff that can be discharged to the natural watercourses
- Monitoring of water storage facilities, particularly pollution control dams, is imperative to manage the risk of spillage from the dams. Stage-storage (elevation-capacity) curves are useful tools to monitor the remaining capacity within a water storage facility.
- Prevent the erosion or leaching of materials from any residue deposit or stockpile from any area and contain material or substances so eroded or leached in such area by providing suitable barrier dams, evaporation dams or any other effective measures to prevent this material or substance from entering and polluting any water resources.
- Water quantity and quality data should be collected on a regular, ongoing basis during mine operations. These data will be used to recalibrate and update the mine water management model, to prepare monitoring and audit reports, to report to the regulatory authorities against the requirements of the IWMP and other authorisations and as feedback to stakeholders in the catchment, perhaps via the CMA.
- Water that has been in contact with residue, and must therefore be considered polluted, must be kept within the confines of the MRD until evaporated, treated to rendered acceptable for release, or re-used in some other way.
- All water that falls within the catchment area of the MRD must be retained within that area. For most MRDs the catchment can be divided into component catchments, as follows:
  - The top area of the MRD together with any return water storage dams which have been connected to the top area of the MRD by means of an outfall penstock, and
  - The faces of the MRD together with the catchment paddocks provided to receive run-off from the faces and any additional catchment dams associated with the faces and catchment paddocks.
- The design, operation and closure of MRDs should incorporate consideration of the risk of changes in the mining and plant operations, and hence the mine water balance, through the life cycle of the mine.
- A system of storm water drains must be designed and constructed to ensure that all water that

falls outside the area of the MRD is diverted clear of the deposit. Provision must be made for the maximum precipitation to be expected over a period of 24 hours with a probability of once in one hundred years. A freeboard of at least 0.5 m must be provided throughout the system above the predicted maximum water level. This requirement applies to all MRDs, both fine and coarse-grained MRDs.

- Ensure that the water use practices on and around the MRD do not result in unnecessary water quality deterioration, e.g. use of the return water dam for storage of poorer quality water.

Should the above be insufficient to capture polluted surface and groundwater moving towards the tributaries of the Moopetsi River, interception trenches can be designed as follows:

- The depth of the trench should be at least 4 mbgl (or 2 m below the groundwater level) to intercept polluted seepage that resulted from the WRD;
- The design of the trench gradient must be such that the water is free-flowing without eroding the channel;
- The water from the trench must be captured, retained and managed within the mine water systems.
- Mining should aim to remove as much of the ore body (acid generating material) as possible.

Should private boreholes decrease in yield the mine should supply the owners with a volume of water as agreed upon between the parties involved.

- The capacity to rapidly pump water out of the pit into storage dams should be maintained. This will assist in minimising water quality deterioration due to long-term retention of storm water in contact with materials that may cause water quality deterioration.
- Berms should be constructed around the opencast pits to minimise the flow of any surface water or floodwater into mine workings. These berms should be constructed to allow free drainage away from the pits.
- Concurrent rehabilitation should take place during the operational phase, where applicable, to:
  - Meet the post-mining topography requirements.
  - Minimise the post-closure water management requirements, by maximising free-draining areas and minimising contamination of clean water.
  - The above water management principles should play a key and decisive role when evaluating and deciding on rehabilitation and closure strategies.
  - Additionally, adding lime to backfill material could be considered to minimise the generation of acidity.
- Water quantity and quality data should be collected on a regular, ongoing basis during mine operations. These data will be used to recalibrate and update the mine water management model, to prepare monitoring and audit reports, to report to the regulatory authorities against the requirements of the IWMP and other authorisations and as feedback to stakeholders in the catchment, perhaps via the CMA. See the Monitoring Network section.

- If excessive groundwater recharge and rainfall is encountered other than the predicted volumes the water could be managed as follows:
  - Manage in-pit seepage and rainfall through a collection and storage system. Water stored in pit should be utilised locally for dust suppression, as far as possible. Excess pit water should be pumped to surface to be incorporated into the mine water balance,
  - Maximise the abstraction and discharge of clean groundwater ahead of the pit development, through installation of dewatering boreholes surrounding the pit.
- All openings to the mine need to be sealed or have adequate berms surrounding the openings to prevent surface water entering.
- All boreholes should be sealed from the bottom to the top to prevent groundwater entering the hole and feeding into the mine workings.
- All depressions created by mining need to be profiled for self-drainage of surface water away from the workings.
- Should depressions created by mining not be able to be filled, then the areas need to be surrounded by berms to prevent surface water increasing the mine workings.
- Where significant water ingress cannot be prevented, measures should be put in place to intercept ingress water as close as possible to the source in order that it can be pumped out of the mine before its quality can deteriorate through contact with sulphide minerals.
- Properly mark all significant water ingress points encountered during mine construction and development and ensure that their physical location, flowrate and water quality are recorded and incorporated into the existing groundwater model and the mine water and salt balance.
- Properly seal all major water ingress points and ensure that the details of the sealing operation are recorded.
- Ensure that all approved design measures are properly implemented and modify mine plans and drawings to indicate 'as-built' systems wherever they deviate from the original designs, together with motivations on the design variation.
- Institute appropriate water level and water quality monitoring programmes to confirm rate of water rise and water quality as the mine floods.
- Water quantity and quality data should be collected on a regular, ongoing basis during mine operations. These data will be used to recalibrate and update the mine water management model, to prepare monitoring and audit reports, to report to the regulatory authorities against the requirements of the IWMP and other authorisations and as feedback to stakeholders in the catchment, perhaps via the CMA. See the Monitoring Network section.
- Areas that may have subsided or areas of depressions and/or sinkholes should be filled to create free draining surfaces.

#### **14.4.2 Decommissioning/post-mining phase**

##### **Impacts on groundwater quantity**

- Following closure of the mine, the groundwater level will rise to an equilibrium that will differ from the pre-mining level due to the disturbance of the bedrock. However, this change is likely to be minimal due to the depth of mining and no drawdown anticipated close to surface.
- Groundwater within the mined areas is expected to deteriorate due to chemical interactions between the geological material and the groundwater. The resulting groundwater pollution plume is expected to commence with downstream movement.
- Continued groundwater contamination is likely to be released from the tailings facility if it is not removed.
- Predicted groundwater levels indicate that a rise in groundwater will occur and that decant after rebound in so far as daylighting to surface is unlikely to occur.

### **Groundwater management**

- Update the numerical model against monitored data.
- After proper geochemical investigation the ARD (if present in significant concentrations) can be dealt with as follows:
  - Cover and capping research studies and design to reduce water and oxygen reactions
  - Use as waste backfill in open pits
  - Neutralisation (e.g. lime) and treatment (stimulation of sulphate reducing bacteria)
  - Segregation/isolation/encapsulation
  - Passive leachate management and treatment
- Polluted groundwater can be treated as follows:
  - Reduce hydraulic head by water shedding
  - Integrate capture store-release systems
  - Utilise evapotranspiration
  - Cap and cover with capillary break
  - Drainage diversions

The post-closure groundwater management of the opencast should be done in two phases:

- Phase 1: Immediately after closure
- Phase 2: After Rapid Flooding

Please note that the numerical model must be updated against monitored data during the post-closure phase. Additionally, a geochemical model must be constructed to calculate realistic contaminant transport scenarios.

### **Phase 1: Immediately after closure**

During mining the acid generating material and non-acid generating material should be separated.

- The acid producing material should be placed as low in the pits as possible, followed by the non-acid generating material.
- Rapid flooding should be done by diverting storm water channels and pumping of available groundwater into the pit until the acid producing material is inundated by the water.

### **Phase 2: After Rapid Flooding**

After the acid producing material is inundated by the water:

- The final backfilled opencast topography should be engineered such that runoff is directed away from the opencast areas.
- The final layer (just below the topsoil cover) should be as clayey as possible and compacted if feasible, to reduce recharge to the opencasts.
- Natural berms should then be constructed to allow free drainage of surface water around the rehabilitated pit.

## **15. RECOMMENDATIONS**

The following recommendations are put forward:

- Water quantity and quality data should be collected on a regular, ongoing basis during mine operations. These data will be used to recalibrate and update the mine water management model,
- to prepare monitoring and audit reports, to report to the regulatory authorities against the requirements of the IWMP and other authorisations and as feedback to stakeholders in the catchment, perhaps via the CMA.
  - The monitoring as recommended in the report should be established prior to operation.
  - The Hydrocensus and risk assessment should at least be repeated once before closure to evaluate any impacts.

## **16. REFERENCES**

Department of Water and Sanitation (DWS) (2013). Groundwater Resource Directed Measures (GRDM). Version 2.3.2.

Modikwa Platinum Mine, South Shaft 2 Project - Hydrogeological Assessment: October 2010. GCS Report 10-295;

Modikwa Platinum Mine, South Shaft 2 – Evaluation of Excessive Groundwater: February 2012. GCS  
Report 12-064;

Modikwa Platinum Mine, South Shaft 3 – Excessive Groundwater: Site visit: Phase May 2024

# APPENDICES

## APPENDIX A: Water Quality Analysis Lab Results



Element Materials Technology

Unit D2 & D5

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South Africa

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SEGOPE WATER AND ENVIRONMENTAL SERVICES (PTY) LTD

11 Canyon Way  
Crescent Wood Country Estate  
Midrand  
South Africa  
1176



**Attention :** Letladi Maisela  
**Date :** 2nd July, 2024  
**Your reference :**  
**Our reference :** Test Report 24/792 Batch 1  
**Location :** n/a  
**Date samples received :** 18th June, 2024  
**Status :** Final report  
**Issue :** 202407021159

Nine samples were received for analysis on 18th June, 2024 of which nine were scheduled for analysis. Please find attached our Test Report which should be read with notes at the end of the report and should include all sections if reproduced. Interpretations and opinions are outside the scope of any accreditation, and all results relate only to samples supplied.

All analysis is carried out on as received samples and reported on a dry weight basis unless stated otherwise. Results are not surrogate corrected.

Analysis was undertaken at either Element Materials Technology UK, which is ISO 17025 accredited under UKAS (4225) or Element Materials Technology (SA) which is ISO 17025 accredited under SANAS (T0729) or a subcontract laboratory where specified.

NOTE: Under International Laboratory Accreditation Cooperation (ILAC), ISO 17025 (UKAS) accreditation is recognised as equivalent to SANAS (South Africa) accreditation.

The greenhouse gas emissions generated (in Carbon – Co2e) to obtain the results in this report are estimated as:

Scope 1&2 emissions - 16 kg of CO2

Scope 1&2&3 emissions - 37.813 kg of CO2

Authorised By:

**Debbie van Wyk**  
Project Manager

Inorganics Laboratory:

**Aubrey Lindi**  
Technical Signatory (Inorganics)

Please include all sections of this report if it is reproduced

GEOHYDROLOGICAL IMPACT ASSESSMENT OF THE SOUTH 3 OPENCAST MINING PROJECT AT MODIKWA  
PLATINUM MINE, LIMPOPO PROVINCE, SOUTH AFRICA

**Element Materials Technology**

**Client Name:** SEGOPE WATER AND ENVIRONMENTAL SERVICES (PTY) LTD **Report :** Liquid

**Reference:**

**Location:** n/a

**Contact:** Letladi Maisela

**EMT Job No:** 24/792

**Liquids/products:** V=40ml vial, G=glass bottle, P=plastic bottle  
H=H<sub>2</sub>SO<sub>4</sub>, Z=ZnAc, N=NaOH, HN=HNO<sub>3</sub>

EMT Sample No.	1-4	5-8	9-12	13-16	17-20	21-24	25-28	29-32	33-36	Please see attached notes for all abbreviations and acronyms		
Sample ID	BH01	BH02	BH03	BH06	BH09	BH12	BH13	T-UPSTREAM	T-DOWNSTREAM			
Depth												
COC No / misc												
Containers	H HN P	H HN P	H HN P	H HN P	H HN P	H HN P	H HN P	H HN P	H HN P			
Sample Date	<>	<>	<>	<>	<>	<>	<>	<>	<>			
Sample Type	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water			
Batch Number	1	1	1	1	1	1	1	1	1			
Date of Receipt	18/06/2024	18/06/2024	18/06/2024	18/06/2024	18/06/2024	18/06/2024	18/06/2024	18/06/2024	18/06/2024			
										LOD/LOR	Units	Method No.
Dissolved Aluminium <sup>SA</sup>	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	ug/l	SA_TM30/SA_PM14
Dissolved Arsenic <sup>SA</sup>	5.6	5.4	<2.5	6.1	8.5	2.8	<2.5	3.4	4.4	<2.5	ug/l	SA_TM30/SA_PM14
Dissolved Cadmium <sup>SA</sup>	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	ug/l	SA_TM30/SA_PM14
Dissolved Calcium <sup>SA</sup>	35.8	65.1	15.0	143.0	55.8	178.7	60.3	52.1	43.1	<0.2	mg/l	SA_TM30/SA_PM14
Total Dissolved Chromium <sup>SA</sup>	<1.5	<1.5	<1.5	<1.5	7.1	<1.5	<1.5	2.7	3.1	<1.5	ug/l	SA_TM30/SA_PM14
Dissolved Cobalt <sup>SA</sup>	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	ug/l	SA_TM30/SA_PM14
Dissolved Copper <sup>SA</sup>	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	ug/l	SA_TM30/SA_PM14
Total Dissolved Iron <sup>SA</sup>	213	644	22	<20	<20	<20	<20	<20	<20	<20	ug/l	SA_TM30/SA_PM14
Dissolved Lead <sup>SA</sup>	6	<5	<5	<5	<5	<5	<5	<5	<5	<5	ug/l	SA_TM30/SA_PM14
Dissolved Magnesium <sup>SA</sup>	40.5	64.3	8.2	47.3	47.1	153.9	67.3	60.6	50.2	<0.1	mg/l	SA_TM30/SA_PM14
Dissolved Manganese <sup>SA</sup>	229	240	32	270	<2	29	<2	<2	5	<2	ug/l	SA_TM30/SA_PM14
Dissolved Mercury <sup>SA</sup>	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	ug/l	SA_TM30/SA_PM14
Dissolved Molybdenum <sup>SA</sup>	<2	<2	61	<2	<2	<2	<2	<2	<2	<2	ug/l	SA_TM30/SA_PM14
Dissolved Nickel <sup>SA</sup>	<2	3	<2	2	<2	6	<2	<2	<2	<2	ug/l	SA_TM30/SA_PM14
Dissolved Potassium <sup>SA</sup>	5.2	1.2	1.5	3.6	0.2	2.2	0.2	0.5	0.9	<0.1	mg/l	SA_TM30/SA_PM14
Dissolved Selenium <sup>SA</sup>	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	ug/l	SA_TM30/SA_PM14
Dissolved Sodium <sup>SA</sup>	1218.7	30.5	9.0	72.4	54.1	106.7	28.2	28.7	36.7	<0.1	mg/l	SA_TM30/SA_PM14
Dissolved Zinc <sup>SA</sup>	6	4	<3	17	14	5	5	4	5	<3	ug/l	SA_TM30/SA_PM14
Fluoride <sup>SA</sup>	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	mg/l	SA_TM27/SA_PM0
Chloride <sup>SA</sup>	1150.4 <sup>AC</sup>	36.9	7.9	157.4	53.6	287.7 <sup>AB</sup>	22.6	23.5	36.8	<0.3	mg/l	SA_TM27/SA_PM0
Nitrite as NO <sub>2</sub> <sup>SA</sup>	<0.02	0.23	<0.02	0.16	0.12	0.32	0.22	0.11	<0.02	<0.02	mg/l	SA_TM27/SA_PM0
Nitrate as NO <sub>3</sub> <sup>SA</sup>	0.5	1.7	<0.2	29.0	7.6	257.6 <sup>AB</sup>	1.4	108.9 <sup>AA</sup>	21.3	<0.2	mg/l	SA_TM27/SA_PM0
Sulphate <sup>SA</sup>	19.8	36.3	4.4	107.0	45.5	195.2	36.9	38.2	35.4	<0.5	mg/l	SA_TM27/SA_PM0
Ortho Phosphate as PO <sub>4</sub>	<0.03	<0.03	0.47	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	mg/l	SA_TM191/SA_PM31
Ammoniacal Nitrogen as NH <sub>4</sub> <sup>SA</sup>	1.93	<0.03	<0.03	4.61	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	mg/l	SA_TM27/SA_PM0
Hexavalent Chromium*	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	mg/l	UK_TM38/UK_PM0
Total Alkalinity as CaCO <sub>3</sub> <sup>SA</sup>	1036	396	96	384	320	508	396	276	288	<3	mg/l	SA_TM32/SA_PM0
Carbonate Alkalinity as CaCO <sub>3</sub>	88	<3	<3	<3	64	<3	80	96	80	<3	mg/l	SA_TM32/SA_PM0
Bicarbonate Alkalinity as CaCO <sub>3</sub>	948	396	96	384	256	508	316	180	208	<3	mg/l	SA_TM32/SA_PM0
Electrical Conductivity @25C <sup>SA</sup>	5140	800	178	1354	804	2430	810	781	670	<2	uS/cm	SA_TM28/SA_PM0
pH <sup>SA</sup>	8.31	8.21	8.30	7.87	8.34	8.34	8.00	8.18	8.47	<2.00	pH units	SA_TM19/SA_PM0
Total Dissolved Solids <sup>SA</sup>	2973	556	91	907	541	1684	560	536	421	<35	mg/l	SA_TM20/SA_PM31
Total Suspended Solids <sup>SA</sup>	29	152	292	12	14	<10	<10	<10	<10	<10	mg/l	SA_TM37/SA_PM0



## NOTES TO ACCOMPANY ALL SCHEDULES AND REPORTS

EMT Job No.: 24/792

### SOILS and ASH

Please note we are only MCERTS accredited (UK soils only) for sand, loam and clay and any other matrix is outside our scope of accreditation.

Where an MCERTS report has been requested, you will be notified within 48 hours of any samples that have been identified as being outside our MCERTS scope. As validation has been performed on clay, sand and loam, only samples that are predominantly these matrices, or combinations of them will be within our MCERTS scope. If samples are not one of a combination of the above matrices they will not be marked as MCERTS accredited.

It is assumed that you have taken representative samples on site and require analysis on a representative subsample. Stones will generally be included unless we are requested to remove them.

All samples will be discarded one month after the date of reporting, unless we are instructed to the contrary. Asbestos samples are retained for 6 months.

If you have not already done so, please send us a purchase order if this is required by your company.

Where appropriate please make sure that our detection limits are suitable for your needs, if they are not, please notify us immediately.

All analysis is reported on a dry weight basis unless stated otherwise. Limits of detection for analyses carried out on as received samples are not moisture content corrected. Results are not surrogate corrected. Samples are dried at 35°C ±5°C unless otherwise stated. Moisture content for CEN Leachate tests are dried at 105°C ±5°C. Ash samples are dried at 35°C ±5°C.

Where Mineral Oil is quoted, this refers to Total Aliphatics C10-C40.

Where a CEN 10:1 ZERO Headspace VOC test has been carried out, a 10:1 ratio of water to wet (as received) soil has been used.

% Asbestos in Asbestos Containing Materials (ACMs) is determined by reference to HSG 264 The Survey Guide - Appendix 2 : ACMs in buildings listed in order of ease of fibre release.

Sufficient amount of sample must be received to carry out the testing specified. Where an insufficient amount of sample has been received the testing may not meet the requirements of our accredited methods, as such accreditation may be removed.

Negative Neutralization Potential (NP) values are obtained when the volume of NaOH (0.1N) titrated (pH 8.3) is greater than the volume of HCl (1N) to reduce the pH of the sample to 2.0 - 2.5. Any negative NP values are corrected to 0.

The calculation of Pyrite content assumes that all oxidisable sulphides present in the sample are pyrite. This may not be the case. The calculation may be an overestimate when other sulphides such as Barite (Barium Sulphate) are present.

### WATERS

Please note we are not a UK Drinking Water Inspectorate (DWI) Approved Laboratory .

ISO17025 accreditation applies to surface water and groundwater and usually one other matrix which is analysis specific, any other liquids are outside our scope of accreditation.

As surface waters require different sample preparation to groundwaters the laboratory must be informed of the water type when submitting samples.

Where Mineral Oil is quoted, this refers to Total Aliphatics C10-C40.

### STACK EMISSIONS

Where an MCERTS report has been requested, you will be notified within 48 hours of any samples that have been identified as being outside our MCERTS scope. As validation for Dioxins and Furans and Dioxin like PCBs has been performed on XAD-2 Resin, only samples which use this resin will be within our MCERTS scope.

Where appropriate please make sure that our detection limits are suitable for your needs, if they are not, please notify us immediately.

### DEVIATING SAMPLES

All samples should be submitted to the laboratory in suitable containers with sufficient ice packs to sustain an appropriate temperature for the requested analysis. The temperature of sample receipt is recorded on the confirmation schedules in order that the client can make an informed decision as to whether testing should still be undertaken.

### SURROGATES

Surrogate compounds are added during the preparation process to monitor recovery of analytes. However low recovery in soils is often due to peat, clay or other organic rich matrices. For waters this can be due to oxidants, surfactants, organic rich sediments or remediation fluids. Acceptable limits for most organic methods are 70 - 130% and for VOCs are 50 - 150%. When surrogate recoveries are outside the performance criteria but the associated AQC passes this is assumed to be due to matrix effect. Results are not surrogate corrected.

### DILUTIONS

A dilution suffix indicates a dilution has been performed and the reported result takes this into account. No further calculation is required.

### BLANKS

Where analytes have been found in the blank, the sample will be treated in accordance with our laboratory procedure for dealing with contaminated blanks. Please include all sections of this report if it is reproduced

**ABBREVIATIONS and ACRONYMS USED**

**GEOHYDROLOGICAL IMPACT ASSESSMENT OF THE SOUTH 3 OPENCAST MINING PROJECT AT MODIKWA PLATINUM MINE, LIMPOPO PROVINCE, SOUTH AFRICA**

EMT Job No.: 24/792

**NOTE**

Data is only reported if the laboratory is confident that the data is a true reflection of the samples analysed. Data is only reported as accredited when all the requirements of our Quality System have been met. In certain circumstances where all the requirements of the Quality System have not been met, for instance if the associated AQC has failed, the reason is fully investigated and documented. The sample data is then evaluated alongside the other quality control checks performed during analysis to determine its suitability. Following this evaluation, provided the sample results have not been effected, the data is reported but accreditation is removed. It is a requirement of our Accreditation Body for data not reported as accredited to be considered indicative only, but this does not mean the data is not valid.

Where possible, and if requested, samples will be re-extracted and a revised report issued with accredited results. Please do not hesitate to contact the laboratory if further details are required of the circumstances which have led to the removal of accreditation.

Laboratory records are kept for a period of no less than 6 years.

**REPORTS FROM THE SOUTH AFRICA LABORATORY**

Any method number not prefixed with SA has been undertaken in our UK laboratory unless reported as subcontracted.

**Measurement Uncertainty**

Measurement uncertainty defines the range of values that could reasonably be attributed to the measured quantity. This range of values has not been included within the reported results. Uncertainty expressed as a percentage can be provided upon request.

**Customer Provided Information**

Sample ID and depth is information provided by the customer.

**Age of Diesel**

The age of release estimation is based on the nC17/pristane ratio only as prescribed by Christensen and Larsen (1993) and Kaplan, Galperin, Alimi et al., (1996).

Age estimation should be treated with caution as it can be influenced by site specific factors of which the laboratory are not aware.

**Tentatively Identified Compounds (TICs)**

Where Tentatively Identified Compounds (TICs) are reported, up to 10 Tentatively Identified Compounds will be listed where there is found to be a greater than 80% match with the NIST library. The reported concentration is determined semi-quantitatively, with a matrix specific limit of detection. Note, other compounds may be present but are not reported.

#	ISO17025 (UKAS Ref No. 4225) accredited - UK.
SA	ISO17025 (SANAS Ref No.T0729) accredited - South Africa
B	Indicates analyte found in associated method blank.
DR	Dilution required.
M	MCERTS accredited.
NA	Not applicable
NAD	No Asbestos Detected.
ND	None Detected (usually refers to VOC and/SVOC TICs).
NDP	No Determination Possible
SS	Calibrated against a single substance

GEOHYDROLOGICAL IMPACT ASSESSMENT OF THE SOUTH 3 OPENCAST MINING PROJECT AT MODIKWA  
PLATINUM MINE, LIMPOPO PROVINCE, SOUTH AFRICA

SV	Surrogate recovery outside performance criteria. This may be due to a matrix effect.
W	Results expressed on as received basis.
+	AQC failure, accreditation has been removed from this result, if appropriate, see 'Note' on previous page.
>>	Results above quantitative calibration range. The result should be considered the minimum value and is indicative only. The actual result could be significantly higher.
*	Analysis subcontracted to an Element Materials Technology approved laboratory.
CO	Suspected carry over
LOD/LOR	Limit of Detection (Limit of Reporting) in line with ISO 17025 and MCERTS
ME	Matrix Effect
NFD	No Fibres Detected
BS	AQC Sample
LB	Blank Sample
N	Client Sample
TB	Trip Blank Sample
OC	Outside Calibration Range
AA	x2 Dilution
AB	x5 Dilution
AC	x10 Dilution

## Method Code Appendix

ISO 17025 (UKAS/IS ANAS)	MCERTS (UK soils only)	Analysis done on As Received (AR) or Dried (AD)	Reported on dry weight basis
Yes			
Yes			
Yes			
Yes			
Yes			
Yes			
Yes			

## Element Materials Technology

EMT Job No: 24/792

Test Method No	Description	Prep Method No. (if appropriate)	Description
SA_TM19	Determination of pH by bench pH meter	SA_PM0	No preparation is required.
SA_TM19	Orthophosphate as PO4 by Colorimetric Measurement v1	SA_PM3	Sample is filtered
SA_TM20	Modified BS 1377-3: 1990 Gravimetric determination of Total Dissolved Solids	SA_PM3	Sample is filtered
SA_TM27	Major ions by Ion Chromatography	SA_PM0	No preparation is required.
SA_TM28	Determination of Electrical Conductivity with hand held manual conductivity probe	SA_PM0	No preparation is required.
SA_TM30	Determination of Trace Metals by ICP-OES (Inductively Coupled Plasma Optical Emission Spectrometry); WATERS by Modified USEPA Method 200.7, Rev. 4.4, 1994; Modified EPA Method 6010B, Rev.2, Dec 1996; Modified BS EN ISO 11885:2009; SOILS by Modified USEPA Method 3050B, Rev.2, Dec.1996	SA_PM14	Preparation of waters and leachates for metals by ICP OES/ICP MS. Samples are filtered for Dissolved metals, and remain unfiltered for Total metals then acidified
SA_TM32	Determination of Alkalinity by titration of the sample with a standard solution of acid by visual detection of end points.	SA_PM0	No preparation is required.
SA_TM32	Determination of Alkalinity by titration of the sample with a standard solution of acid by visual detection of end points.	SA_PM0	No preparation is required.
SA_TM37	Modified BS EN 872:2005 Gravimetric determination of Total Suspended Solids. Sample is filtered and the resulting residue is dried and weighed.	SA_PM0	No preparation is required.
UK_TM38	Soluble Ion analysis using the Thermo Aquakem Photometric Automatic Analyser. Modified US EPA methods 325.2, 375.4, 365.2, 353.1, 354.1	UK_PM0	No preparation is required.