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Inorganic Business Unit

Bakubung Platinum Mine
Tailings Storage Facility
Impact Assessment

Knight Piesold Pty Ltd

GPT Ref No:KPBAK-20-5104

Version: Draft V1.1

Offices in: Gauteng, Western Cape,
KwaZulu-Natal & Mozambique

Report Type:	Groundwater Impact Assessment
Project Title:	Bakubung Platinum Mine Tailings Storage Facility Impact Assessment
Site Name:	Bakubung Platinum Mine
Site Location:	Pilanesberg, North West Province
Compiled For:	Knight Piesold Pty Ltd
Compiled By:	Marius Terblanche
GPT Reference:	KPBAK-20-5104
Client Reference:	KPBAK-20-5104
Version:	Draft V1.0
Date:	March 2020
Distribution List (Current Version):	
Reviewed by:	Dr GJ Du Toit

Disclaimer:

The results and conclusions of this report are limited to the Scope of Work agreed between GEM-GPT and the Client for whom this investigation has been conducted. All assumptions made and all information contained within this report and its attachments depend on the accessibility to and reliability of relevant information, including maps, previous reports and word-of-mouth, from the Client and Contractors.

Declaration:

I hereby declare:

- I have no vested interest (present or prospective) in the project that is the subject of this report as well as its attachments. I have no personal interest with respect to the parties involved in this project.
- I have no bias with regard to this project or towards the various stakeholders involved in this project.
- I have not received, nor have I been offered, any significant form of inappropriate reward for compiling this report.

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Marius Terblanche

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Customer Satisfaction:

Feedback regarding the technical quality of this report (i.e. methodology used, results discussed and recommendations made), as well as other aspects, such as timeous completion of project and value of services rendered, can be posted onto GPT's website at www.gptglobal.com.

Declaration of Independence

I, (Marius Terblanche), in my capacity as the specialist (Hydrogeology) consultant under instruction from Geo Pollution Technologies and its Client, hereby declare that I -

- Act as an independent specialist:
- Do not have any financial interest in the undertaking of the activity, other than remuneration for the work performed in terms of the National Environmental Management Act, 1998 (Act 107 of 1998);
- Undertake to disclose, to the competent authority, any material information that has or may have the potential to influence the decision of the competent authority or the objectivity of any report, plan or document required in terms of the National Environmental Management Act, 1998 (Act 107 of 1998);
- As a registered member of the South African Council for Natural Scientific Professions, will undertake my profession in accordance with the Code of Conduct of the Council, as well as any other societies to which I am a member; and
- Based on information provided to me by the project proponent, and in addition to information obtained during the course of this study, have presented the results and conclusion within the associated document to the best of my professional judgement.

26/03/2020

M. Terblanche; B.Sc. Hons, Pr.Sci.Nat
Hhydrogeology
Professional Natural Scientist (No 400081/17)

Date

NEMA Regs (2014) - Appendix 6	Relevant section in report
Details of the specialist who prepared the report	Page i
The expertise of that person to compile a specialist report including a curriculum vita	M. Terblanche, B.Sc. (Hons) Geohydrology (University of thee Free State 2015). Professional Natural Scientist (No 400081/17) (SACNASP)
A declaration that the person is independent in a form as may be specified by the competent authority	Page i
An indication of the scope of, and the purpose for which, the report was prepared	Section 3
The date and season of the site investigation and the relevance of the season to the outcome of the assessment	Section 2.2
A description of the methodology adopted in preparing the report or carrying out the specialised process	Section 4
The specific identified sensitivity of the site related to the activity and its associated structures and infrastructure	Section 8
An identification of any areas to be avoided, including buffers	~
A map superimposing the activity including the associated structures and infrastructure on the environmental sensitivities of the site including areas to be avoided, including buffers;	Figure 3
A description of any assumptions made and any uncertainties or gaps in knowledge;	~
A description of the findings and potential implications of such findings on the impact of the proposed activity, including identified alternatives, on the environment	Section 11
Any mitigation measures for inclusion in the EMPr	Section 13.4
Any conditions for inclusion in the environmental authorisation	Section 15.1
Any monitoring requirements for inclusion in the EMPr or environmental authorisation	Section 14
A reasoned opinion as to whether the proposed activity or portions thereof should be authorised and	Section 13.4
If the opinion is that the proposed activity or portions thereof should be authorised, any avoidance, management and mitigation measures that should be included in the EMPr, and where applicable, the closure plan	
A description of any consultation process that was undertaken during the course of carrying out the study	~
A summary and copies if any comments that were received during any consultation process	~
Any other information requested by the competent authority.	~

EXECUTIVE SUMMARY

Scope of work	Within the scope of work the groundwater study aimed to address the following: • Quantify the current groundwater status quo • Impact Predictions • Groundwater Risk Assessment • Groundwater Management Options and Mitigation Measures
Completed work	Hydrocensus of 66 boreholes Geochemical sampling of waste material Geophysical survey Drilling of 6 boreholes Aquifer testing of 6 boreholes Impact prediction through numerical modelling
Topography and drainage	The planned TSF site is flat and the surface topography slopes slightly in a southerly direction between elevations 1050 m above mean sea level (mamsl) and 1029 mamsl, a slope of 2.4%. The site is situated within the A22F quaternary catchment Locally drainage is towards the Elands River that flows from southwest to northeast to the south of the site. On a larger scale, drainage occurs towards the generalised flow of the Crocodile River which flows from south to north towards the Limpopo River.
Local geology	Indicated by the published geological map of the area, Sheet 2526 Rustenburg (1:250 000), the regional area is underlain by gabbro and norite of the Rustenburg Layered Suite, Bushveld Complex, Vaalian Era. A syenite dyke is indicated to the south of the site, while a north west-south east trending fault is indicated to the west of the site
Hydrogeology	According to Barnard (2000), the rocks of the Rustenburg layered suite are characterized by a well-developed igneous layering. The mainly mafic rocks include norite, gabbro, magnetite gabbro anorthosite an pyroxenite.

	Groundwater occurrence is associated mainly with deeply weathered and fractured mafic rocks. Some of the norite zones weather more easily than other rock types. This characteristic in association with north-south striking dykes that cut through and across the norite, has formed groundwater compartments especially in the area between Rustenburg and Pretoria. The groundwater yield potential is classified as poor as the majority of the boreholes on record produce less than 2l/s. the mafic rocks weather to a clay rich soil that is represented by the well-known black turf. The very low permeability of this soil (in the order of 10-3m/d) is considered to reduce recharge to underlying aquifers. The depth to groundwater rest level is between 5 and 40m below surface.
Hydraulic conductivity	The average saturated hydraulic conductivity in the tested pits is 0.12m/day. As the majority of the site is overlain by black clayey soil which had an average conductivity of 0.09m/day, this value would be more representative of the overall site conditions.
Groundwater levels	A total of 66 boreholes were located during the hydrocensus, with an additional 15 boreholes being drilled on site. The majority of the boreholes reported a water level depth of between 20 and 30mbgl.The depth to water level in these boreholes varied between 1.43 and 65.18mbgl
Potential contaminants	A waste classification was conducted on the waste material which is to be deposited on the planned TSF. The samples exceeded the TCT0 or LCT2 values. Cobalt, copper, manganese, nickel and vanadium exceeded the LCT2 limits.

Groundwater quality	The water quality results for the 6 boreholes drilled by Africon during 2008 are compared with the maximum recommended concentrations for domestic use as defined by the SANS 241-1: 2015 target water quality limits. From this comparison, the following is evident: • Fluoride exceeds the allowable limit in sample FBH03D. • Total iron exceeds the allowable limit in samples FBH02D, FBH03D and FBH05S. • Total manganese exceeds the allowable limit in FBH05S.
Aquifer characterisation	Groundwater Vulnerability: The Groundwater Decision Tool calculated a vulnerability value of 43 %, which is medium.
	Classification: Based on information collected during the hydrocensus it can be concluded that the aquifer system in the study area can be classified as a "Minor Aquifer System".
	Protection required: 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.
Groundwater Impacts	Construction phase: Potential hydrocarbon contamination form construction machinery on the site.
	Operational phase: Potential groundwater contamination resulting from pipe networks and transfer pump stations. Potential groundwater contamination resulting from liner leaks under the TSF during the operation of the facility.
	Decommission/Closure phase: Potential groundwater contamination resulting from liner leaks under the TSF after the decommissioning of the facility.

<table>
<tr>
<td>Recommended monitoring</td>
<td>
The following monitoring boreholes are recommended:
<table>
<tr><th>ID</th><th>Latitude (South)</th><th>Longitude (East)</th><th>Borehole Depth (mbgl)</th><th>Reasoning</th><th>Frequency</th></tr>
<tr><td>PROPMON1</td><td>-26.0999</td><td>28.80192</td><td>30-40</td><td>Impact Monitoring</td><td>Quarterly</td></tr>
<tr><td>PROPMON2</td><td>-26.0924</td><td>28.78402</td><td>30-40</td><td>Impact Monitoring</td><td>Quarterly</td></tr>
<tr><td>PROPMON3</td><td>-26.0995</td><td>28.79728</td><td>30-40</td><td>Impact Monitoring</td><td>Quarterly</td></tr>
<tr><td>PROPMON4</td><td>-26.0965</td><td>28.79587</td><td>30-40</td><td>Impact Monitoring</td><td>Quarterly</td></tr>
<tr><td>PROPMON5</td><td>-26.1025</td><td>28.79169</td><td>30-40</td><td>Impact Monitoring</td><td>Quarterly</td></tr>
</table>
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.
Analyses required: Anions and cations (Ca, Mg, Na, K, NO3, Cl, SO4, F, Fe, Mn, Al, & Alkalinity) Dissolved Cations in Water (5-10) by ICP-OES (Ca, Mg, Na, K, Fe, Si, Mn), pH, EC, TDS, Alkalinity, Anions by Ion Chromatography (IC) (4 to 6), Hexavalent Chromium (Cr6+), Free Cyanide in water, Ammonia by Ion Selective Electrode, Trace Elements in liquids (>30elements) by ICP.
</td>
</tr>
<tr>
<td>Main mitigation measures</td>
<td>
Construction Phase:

Care should be taken to minimize contamination during the construction of the TSF and its associated services. Fuel and storage and service areas should be bunded to minimize groundwater contamination.

Operational phase:

The TSF facility and its PCDs should be lined with an approved Class C or GLB- liner.
Potential leakage from infrastructure such as transfer pipe systems and pump station should be minimized. Pipes should be routed above ground in order to detect and limit leaks.
Groundwater monitoring points should be installed in order to monitor the groundwater quality at the TSF as well as the PCDs.
If contamination is detected, contamination interception measures

</td>
</tr>
</table>

	should be put in place. This should consist of but not be limited to interception trenches (if the groundwater level is shallow enough) or interception boreholes. The water intercepted by these measures should be treated to the RQO of the Elandsriver before being released into the environment. Decommission/Closure phase: • If contamination is detected, contamination interception measures should be put in place. This should consist of but not be limited to interception trenches (if the groundwater level is shallow enough) or interception boreholes. The water intercepted by these measures should be treated to the Resource Quality Objective of the Elands River before being released into the environment.
Proposed further work	• Update the numerical and geochemical model against monitored data during operations. • 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 WUL and other authorisations and as feedback to stakeholders in the catchment, perhaps via the CMA. • The monitoring programme as recommended in the report should be established prior to construction. • The hydrocensus and risk assessment should at least be repeated once before closure to evaluate any impacts.

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LIST OF ABBREVIATIONS

Abbreviation	Explanation
ARD	Acid Rock Drainage
BPG	Best Practice Guidelines
CMS	Catchment Management Strategy
CSM	Conceptual Site Model
EC	Electrical Conductivity
EIA	Environmental Impact Assessment
EMPr	Environmental Management Programme
IWRMP	Integrated Water Resources Management Plan
IWRM	Integrated Water Resources Management
km^2	Square kilometre
L/s	Litres per second
LCT	Leachable Concentration Threshold
mamsl	Metres above mean sea level
Ml/d	Megalitres per day
m	metre
mm	Millimetre
mm/a	Millimetres per annum
mS/m	Millisiemens per metre
m^3	Cubic metre
MAP	Mean Annual Precipitation
MPRDA	Mining and Petroleum Resources Development Act (Act No. 73 of 2002) 1989)
NEMA	National Environmental Management Act (Act No. 107 of 1998)
NWA	National Water Act (Act No. 36 of 1998)
ppm	Parts per million
RDM	Resource Directed Measures
RQO	Resource Quality Objective
RWQO	Resource Water Quality Objective
TDS	Total Dissolved Solids
TCT	Total Concentration Threshold
WMA	Water Management Area
WMP	Water Management Plan

DEFINITIONS

Definition	Explanation
Aquiclude	A geologic formation, group of formations, or part of formation through which virtually no water moves
Aquifer	A geological formation which has structures or textures that hold water or permit appreciable water movement through them. Source: National Water Act (Act No. 36 of 1998).
Borehole	Includes a well, excavation, or any other artificially constructed or improved underground cavity which can be used for the purpose of intercepting, collecting or storing water in or removing water from an aquifer; observing and collecting data and information on water in an aquifer; or recharging an aquifer. Source: National Water Act (Act No. 36 of 1998).
Boundary	An aquifer-system boundary represented by a rock mass (e.g. an intruding dolerite dyke) that is not a source of water, and resulting in the formation of compartments in aquifers.
Cone of Depression	The depression of hydraulic head around a pumping borehole caused by the withdrawal of water.
Confining Layer	A body of material of low hydraulic conductivity that is stratigraphically adjacent to one or more aquifers; it may lie above or below the aquifer.
Dolomite Aquifer	See "Karst" Aquifer
Drawdown	The distance between the static water level and the surface of the cone of depression.
Fractured Aquifer	An aquifer that owes its water-bearing properties to fracturing.
Groundwater	Water found in the subsurface in the saturated zone below the water table.
Groundwater Divide or Groundwater Watershed	The boundary between two groundwater basins which is represented by a high point in the water table or piezometric surface.
Groundwater Flow	The movement of water through openings in sediment and rock; occurs in the zone of saturation in the direction of the hydraulic gradient.
Hydraulic Conductivity	Measure of the ease with which water will pass through the earth's material; defined as the rate of flow through a cross-section of one square metre under a unit hydraulic gradient at right angles to the direction of flow (m/d).
Hydraulic Gradient	The rate of change in the total hydraulic head per unit distance of flow in a given direction.
Infiltration	The downward movement of water from the atmosphere into the ground.
Intergranular Aquifer	A term used in the South African map series referring to aquifers in which groundwater flows in openings and void spaces between grains and weathered rock.
Monitoring	The regular or routine collection of groundwater data (e.g. water levels, water quality and water use) to provide a record of the aquifer response over time.
Observation Borehole	A borehole used to measure the response of the groundwater system to an aquifer test.

Definition	**Explanation**
Porosity	Porosity is the ratio of the volume of void space to the total volume of the rock or earth material.
Production Borehole	A borehole specifically designed to be pumped as a source of water supply.
Recharge	The addition of water to the saturated zone, either by the downward percolation of precipitation or surface water and/or the lateral migration of groundwater from adjacent aquifers.
Recharge Borehole	A borehole specifically designed so that water can be pumped into an aquifer in order to recharge the ground-water reservoir.
Saturated Zone	The subsurface zone below the water table where interstices are filled with water under pressure greater than that of the atmosphere.
Specific Capacity	The rate of discharge from a borehole per unit of drawdown, usually expressed as m3/d•m.
Specific Yield	The ratio of the volume of water that drains by gravity to that of the total volume of the saturated porous medium.
Storativity	The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head.
Transmissivity	Transmissivity is the rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient. It is expressed as the product of the average hydraulic conductivity and thickness of the saturated portion of an aquifer.
Unsaturated Zone (Also Termed Vadose Zone)	That part of the geological stratum above the water table where interstices and voids contain a combination of air and water.
Watershed (Also Termed Catchment)	Catchment in relation to watercourse or watercourses or part of a watercourse means the area from which any rainfall will drain into the watercourses or part of a watercourse through surface flow to a common point or points. Source: National Water Act (Act No. 36 of 1998).
Water Table	The upper surface of the saturated zone of an unconfined aquifer at which pore pressure is equal to that of the atmosphere.

GROUNDWATER IMPACT ASSESSMENT

BAKUBUNG PLATINUM MINE TAILINGS STORAGE FACILITY

1 INTRODUCTION

Geo Pollution Technologies (Pty) Ltd (GPT) was appointed by Knight Piesold (KP) to conduct a groundwater investigation for the proposed Tailings Storage Facility (TSF) Project at the Bakubung Platinum Mine.

The report is structured according to the requirements of the GN 267 Annexure D5 and 2.) GN 982 Appendix 6.

2 GEOGRAPHICAL SETTING

2.1 Site Location, Topography and Drainage

The site located approximately 40 km north-north west of Rustenburg, North West Province. The Pilanesberg National Park is located 4 km north of the study area (Figure 1).

The topography (shown in Figure 2) can normally be used as a good first approximation of the hydraulic gradient in the unconfined aquifer. This discussion will focus on the slope and direction of fall of the area under investigation and features that are important from a groundwater point of view.

The planned TSF site is flat and the surface topography slopes slightly in a southerly direction between elevations 1050 metres above mean sea level (mamsl) and 1029 mamsl, a slope of 2.4%. The site is situated within the A22F quaternary catchment. The planned TSF has an area footprint of 237574m^2, while its two pollution control dams (PCDs) have a combined footprint area of 5296.3m^2 (Figure 3).

Locally drainage is towards the Elands River that flows from southwest to northeast to the south of the site. On a larger scale, drainage occurs towards the generalised flow of the Crocodile River which flows from south to north towards the Limpopo River.

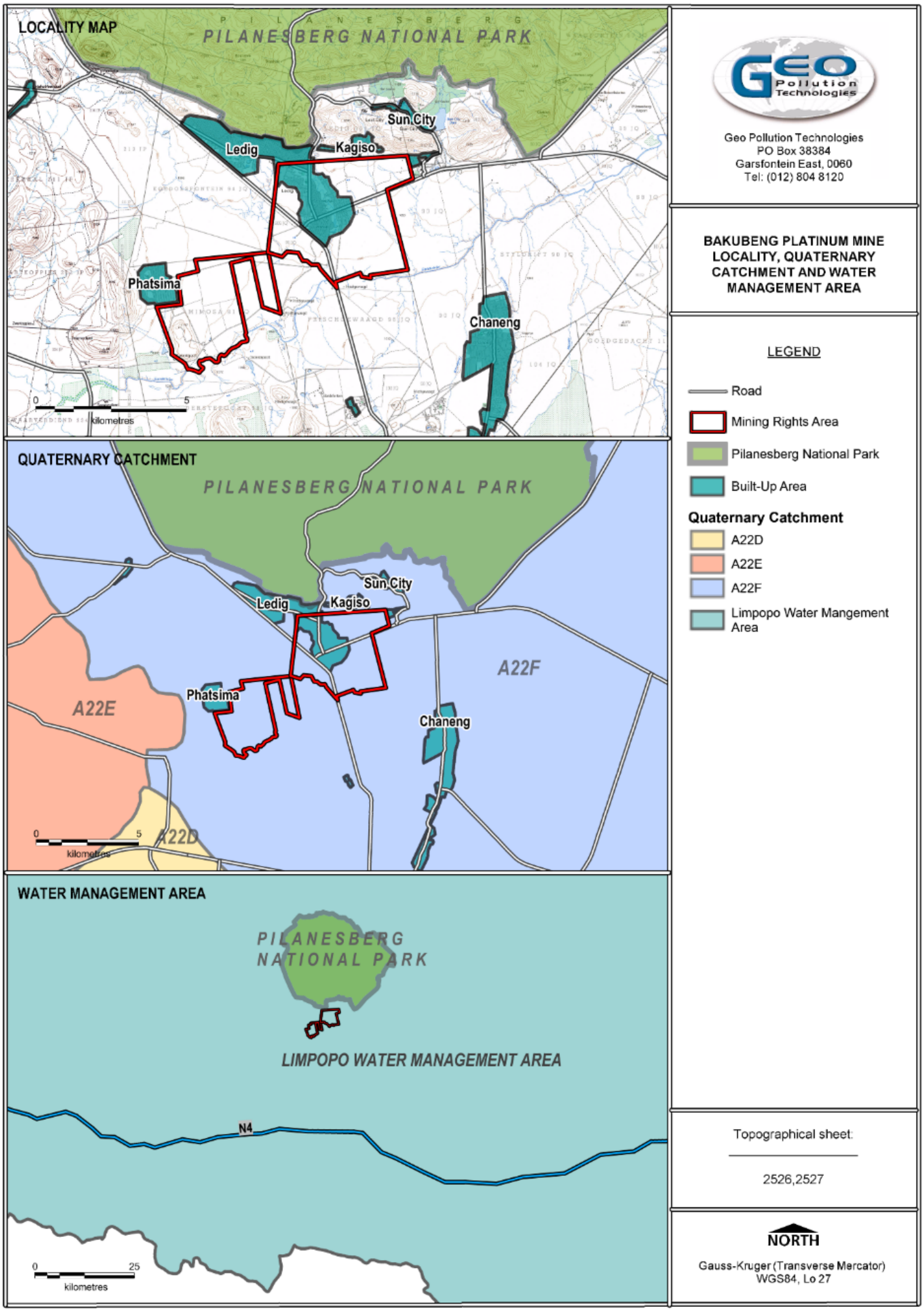


Figure 1: Site Location and Quaternary Catchment Boundaries

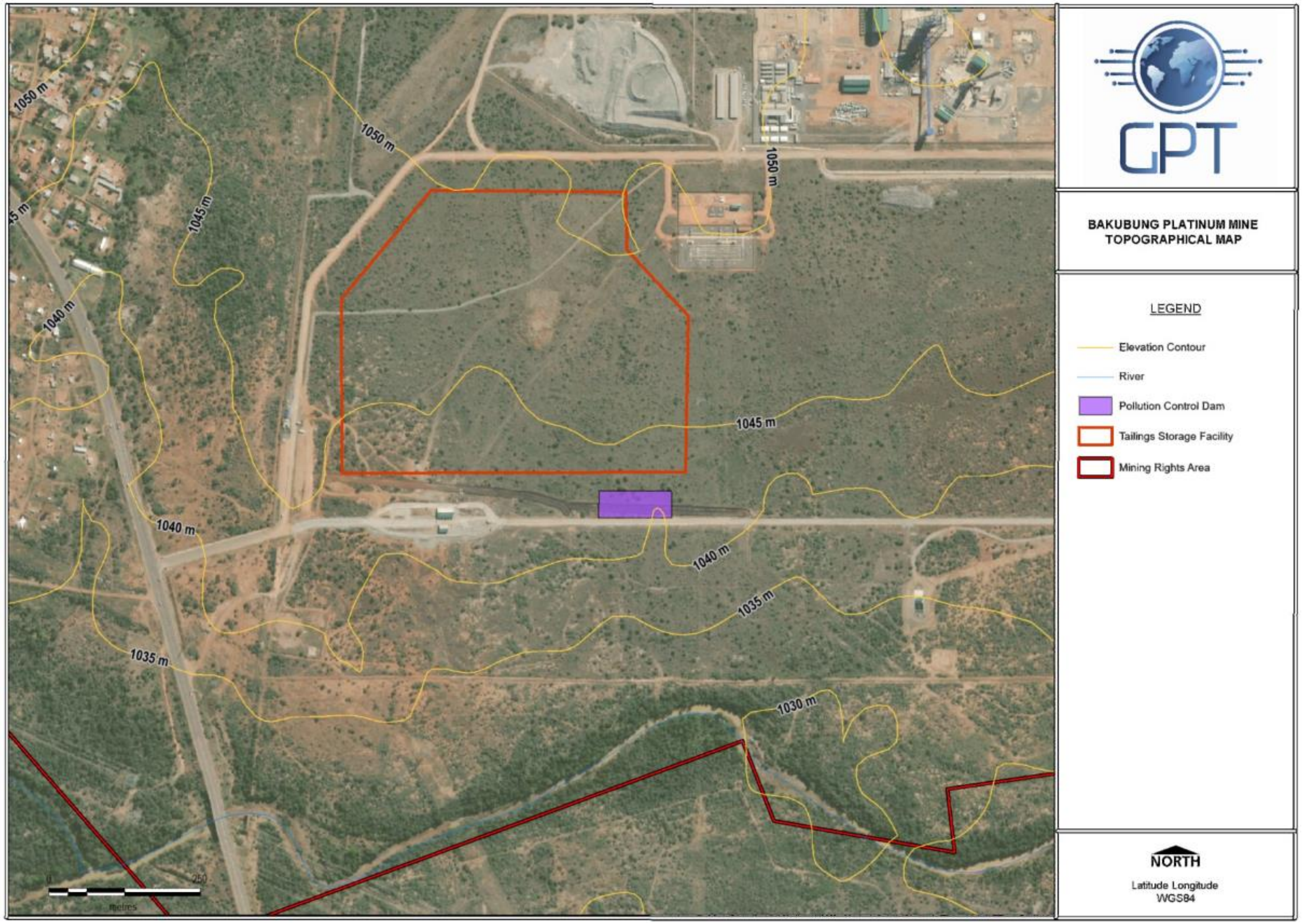


Figure 2: Site Topography

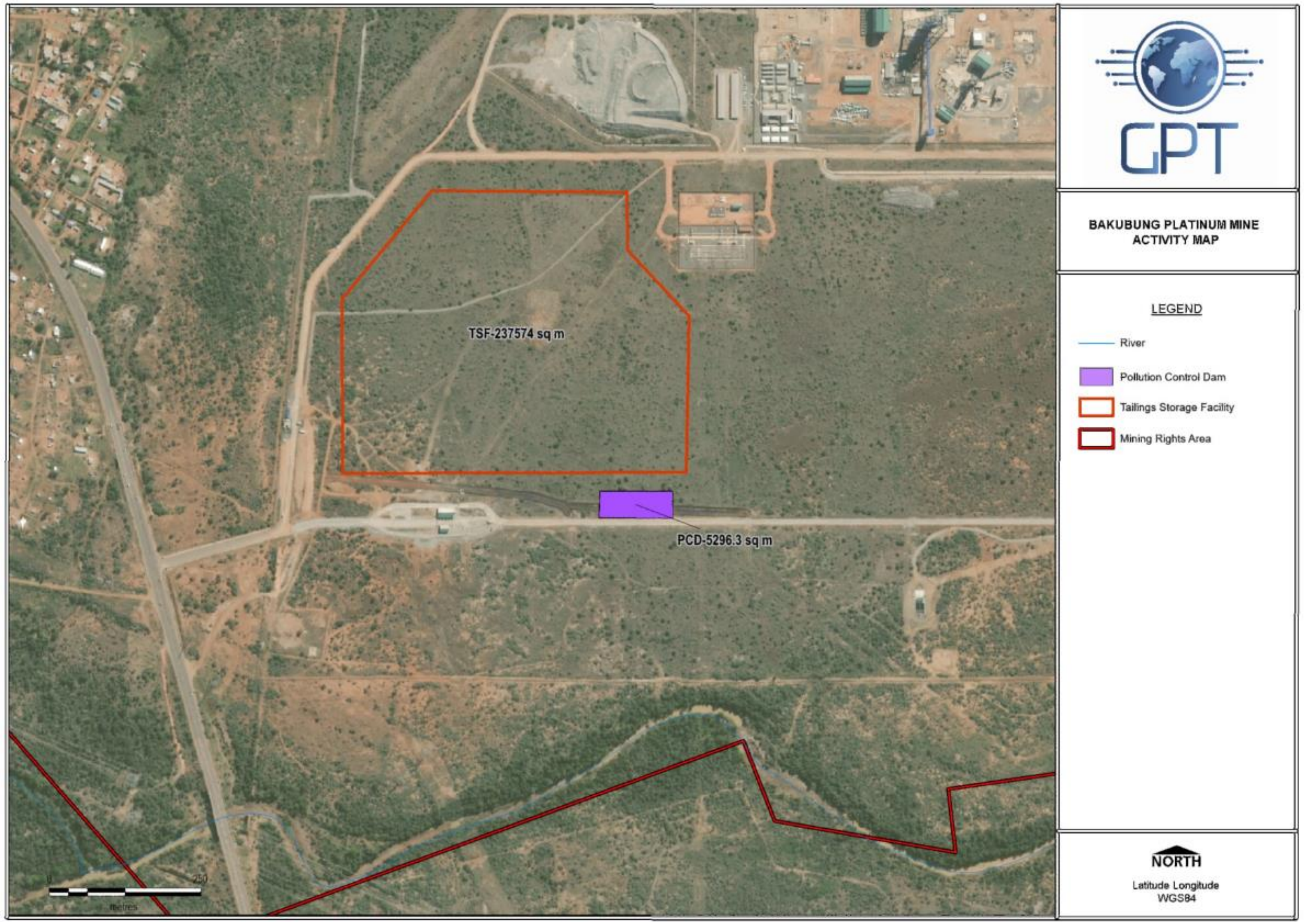


Figure 3: Site Activity Map

2.2 Climate

Climatic data was obtained from the Department of Water and Sanitation weather station Lindleyspoort Dam (rainfall data and evaporation data) (Table 1 and Figure 4)[1]. The site is located in the summer rainfall region of Southern Africa with precipitation usually occurring in the form of convectional thunderstorms. The average annual rainfall (measured over a period of 72 years) is approximately 668.2 mm, with the high rainfall months between October and April.

Table 1: Climatic Data

Month	Average Monthly Rainfall (mm)	Mean Monthly Evaporation (mm)
January	124.3	194
February	97.7	164.7
March	86.5	154.5
April	53.7	119.2
May	19.8	100.6
June	9.2	82.7
July	2.9	91.1
August	4.5	122
September	16.6	163.7
October	49.2	194.6
November	83.4	190.8
December	113.5	197.8
Annual	668.2	1773.9

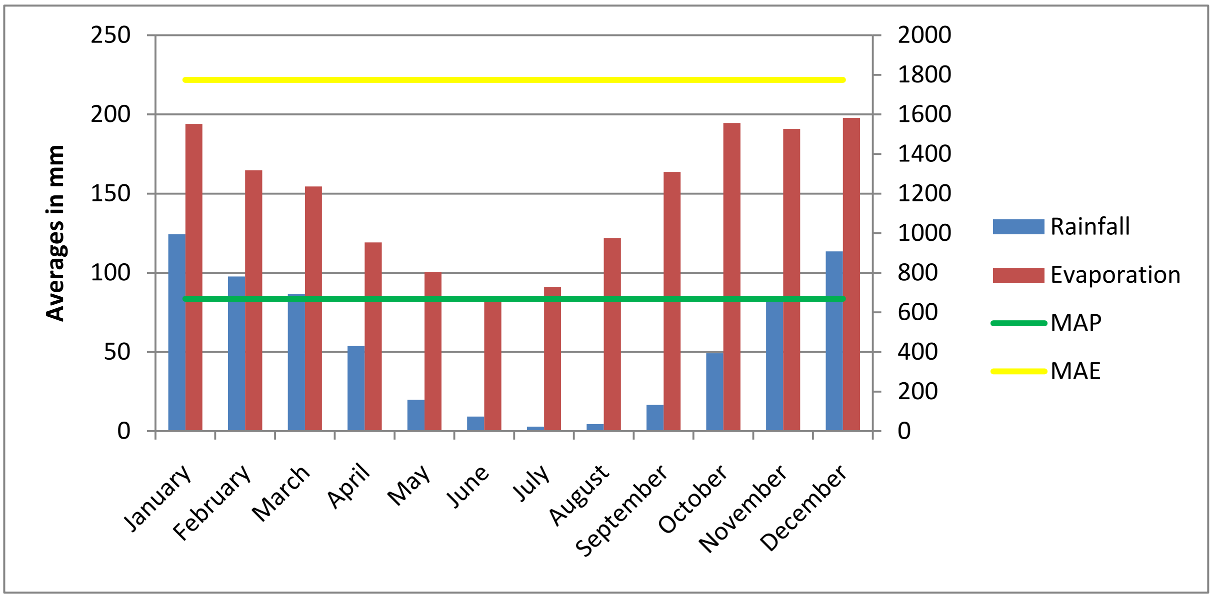


Figure 4: Climatic data representation

[1] Department of Water Affairs (DWA): www.dwa.gov.za

3 SCOPE OF WORK

The purpose of this study is to provide a detailed study on the expected groundwater impacts in support of the water use license application (WULA) and Environmental Management Programme (EMPr) Amendment to be submitted for approval of the proposed TSF.

3.1 Project Objectives

Within the scope of work the groundwater study aimed to address the following:

- Quantify the current groundwater status quo
- Impact predictions
- Groundwater risk assessment
- Groundwater management options and mitigation measures

4 METHODOLOGY

The impact of the planned TSF was investigated through data analyses, the use of numerical models (flow and transport models) and previous reports. The methodology to be followed will be discussed in the headings below.

4.1 Desk study

All available groundwater data (previous reports, site and external databases) crucial to the area, in terms of groundwater was reviewed.

4.2 Hydrocensus

A hydrocensus was conducted by Africon Engineering in 2008, to record private groundwater use in the vicinity of the Bakubung operations. The hydrocensus extended to 1km radius from the mine boundary as well as on the mine property.

4.3 Geophysics

A DC electrical resistivity survey was conducted by Africon engineering in order to identify any geological structures that maybe located on the site.

4.4 Conceptual site model

A conceptual groundwater model was compiled to aid in the understanding of groundwater flow and flow drivers and was used to inform the numerical flow model.

4.5 Modelling

Modelling was performed as a representation of a groundwater flow system and/or geochemical system that attempts to mimic the natural processes. It is therefore a simplified version of the natural system, compiled with geological, hydrogeological, hydrological and meteorological data, which utilises governing equations to incorporate all this data and simulates the hydraulic properties or geochemical properties of the system.

These models were utilised to provide a quantitative understanding of a groundwater system in terms of existing conditions as well as induced stresses, which inherently aids in the identification of cost-effective and efficient solutions to groundwater contamination and management challenges.

4.5.1 Numerical modelling

Numerical groundwater modelling is considered to be the most reliable method of anticipating and quantifying the likely impacts on the groundwater regime.

The numerical model was constructed using MODFLOW and MT3DS. MODFLOW is a modular three-dimensional groundwater flow model, published by the United States Geological Survey. MODFLOW and MT3DS use 3D finite difference discretization and flow codes to solve the governing equations. MODFLOW and MT3DS are widely used simulation codes, which is well documented. MODFLOW is used to simulate groundwater flow rate and direction.

4.5.2 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. MT3DS is superimposed on the MODFLOW simulation results and is used to predict the rate and direction of contaminant movement in the aquifer.

4.6 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). Chapter 4 of the NWA addresses the use of water.

DWS has recognised the 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 were 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
- Hierarchy Series Guidelines
  - H1. Pollution prevention
  - H2. Minimisation of impacts
- General Series Guidelines
  - G3. Water monitoring systems
  - G4. Impact prediction

4.7 Groundwater Recharge Calculations

Recharge to the shallow, unconfined aquifer was calculated using the RECHARGE program developed by the Institute for Groundwater Studies at the University of the Free State, South Africa. The calculated recharge percentage equates to approximately 3% as shown in Table 2.

Table 2: Recharge calculation for the shallow unconfined aquifer

Recharge Estimation			
Method	**mm/a**	**% of rainfall**	**Certainty (Very High = 5 ; Low = 1)**
Soil	38.0	3.0	3
Geology	25.6	3.5	3
Vegter	45.0	2.9	3
Acru	20.0	3.6	3
Harvest Potential	50.0	3.6	3

5 PREVAILING GROUNDWATER CONDITIONS

5.1 Regional Setting

Indicated by the published geological map of the area, Sheet 2526 Rustenburg (1:250 000), the regional area is underlain by gabbro and norite of the Rustenburg Layered Suite, Bushveld Complex, Vaalian Era. A syenite dyke is indicated to the south of the site, while a north west-south east trending fault is indicated to the west of the site (Figure 5).

5.2 Local Setting

The local geology was interpreted from the borehole and test pit logs as set out in Appendix C of the Africon report (Wesiziwe Platinum geohydrological evaluation, March 2008). Locally the area is underlain by gabbro-norite of the Rustenburg layered suite and these units outcrop in the areas around drainages where the covering soil layer has been eroded. The soil cover on the site consists of a dark brown to black, firm loamy clay with abundant vegetation roots. This soil is dispersive and expansive and forms large cracks when moisture is driven off. Locally the soil is referred to as black "turf".

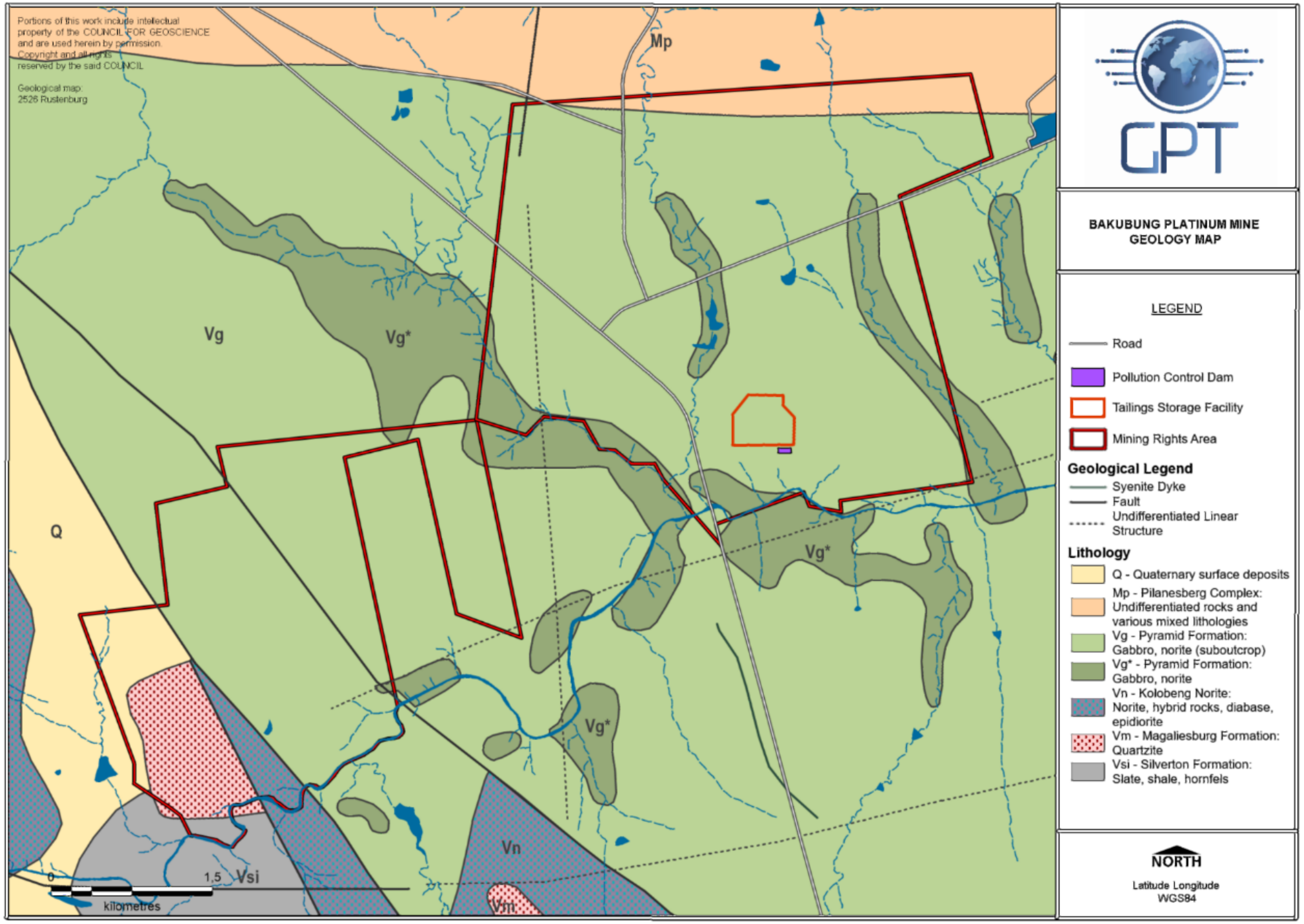


Figure 5: Geology Map of the Study Area.

6 Hydrogeological Setting

The backbone of any groundwater impact prediction or management system is to understand the hydrogeological setting and how the potential stresses will influence the natural groundwater conditions. The hydrogeological setting is described under the headings below.

6.1 Regional Hydrogeological Setting

According to the 1:500 000 hydrogeological map (Johannesburg 2526) (Figure 6) the area of interest is located on a fractured and intergranular aquifer, with a successful borehole yield of between 0.5 l/s and 2.0 l/s.

According to Barnard (2000), the rocks of the Rustenburg layered suite are characterized by a well-developed igneous layering. The mainly mafic rocks include norite, gabbro, magnetite gabbro anorthosite an pyroxenite. Groundwater occurrence is associated mainly with deeply weathered and fractured mafic rocks. Some of the norite zones weather more easily than other rock types. This characteristic in association with north-south striking dykes that cut through and across the norite, has formed groundwater compartments especially in the area between Rustenburg and Pretoria. The groundwater yield potential is classified as poor as the majority of the boreholes on record produce less than 2l/s. the mafic rocks weather to a clay rich soil that is represented by the well-known black turf. The very low permeability of this soil (in the order of 10^{-3}m/d) is considered to reduce recharge to underlying aquifers. The depth to groundwater rest level is between 5 and 40m below surface.

6.2 Hydrocensus

A hydrocensus was conducted by Africon, during March 2008, to record private groundwater use in the vicinity of the operations. A total of 66 boreholes were found. From this survey it was noted that the majority of the boreholes in the area are used for domestic and irrigation purposes. The mean yield in the boreholes was calculated as 1.5l/s.

6.3 Water levels

A total of 66 boreholes were located during the 2008 hydrocensus, with an additional 15 boreholes being drilled on site by Africon during the 2008 baseline groundwater study. The majority of the boreholes reported a water level depth of between 20 and 30mbgl.The depth to waterlevel in these boreholes varied between 1.43 and 65.18mbgl. Groundwater in the area is mainly used for domestic use and irrigation (Africon, 2008).

The waterlevels obtained by Africon in 2008 reported a 87% correlation between groundwater level elevation and topographic elevation, indicating the groundwater mimics the surface topography and that groundwater flows from a high elevation to lower elevation (drainages, rivers etc.).

Groundwater monitoring conducted by the mine indicates that the groundwater levels in the study area remained stable with no significant fluctuation reported (Figure 6). Regionally, groundwater flows in a southerly direction (Figure 7) towards the Elands River.

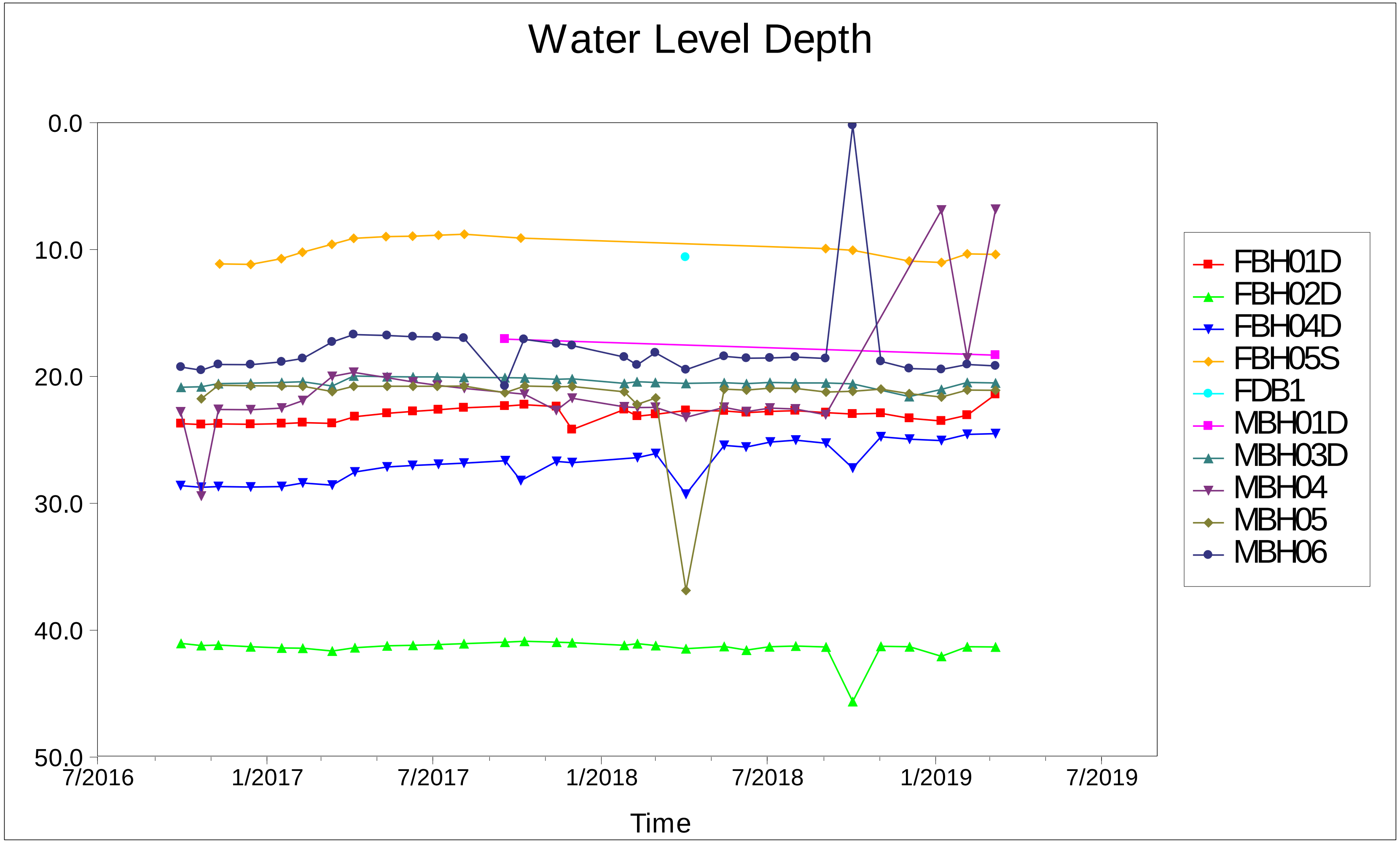


Figure 6: Time series graph of water levels in Wesizwe monitoring boreholes.

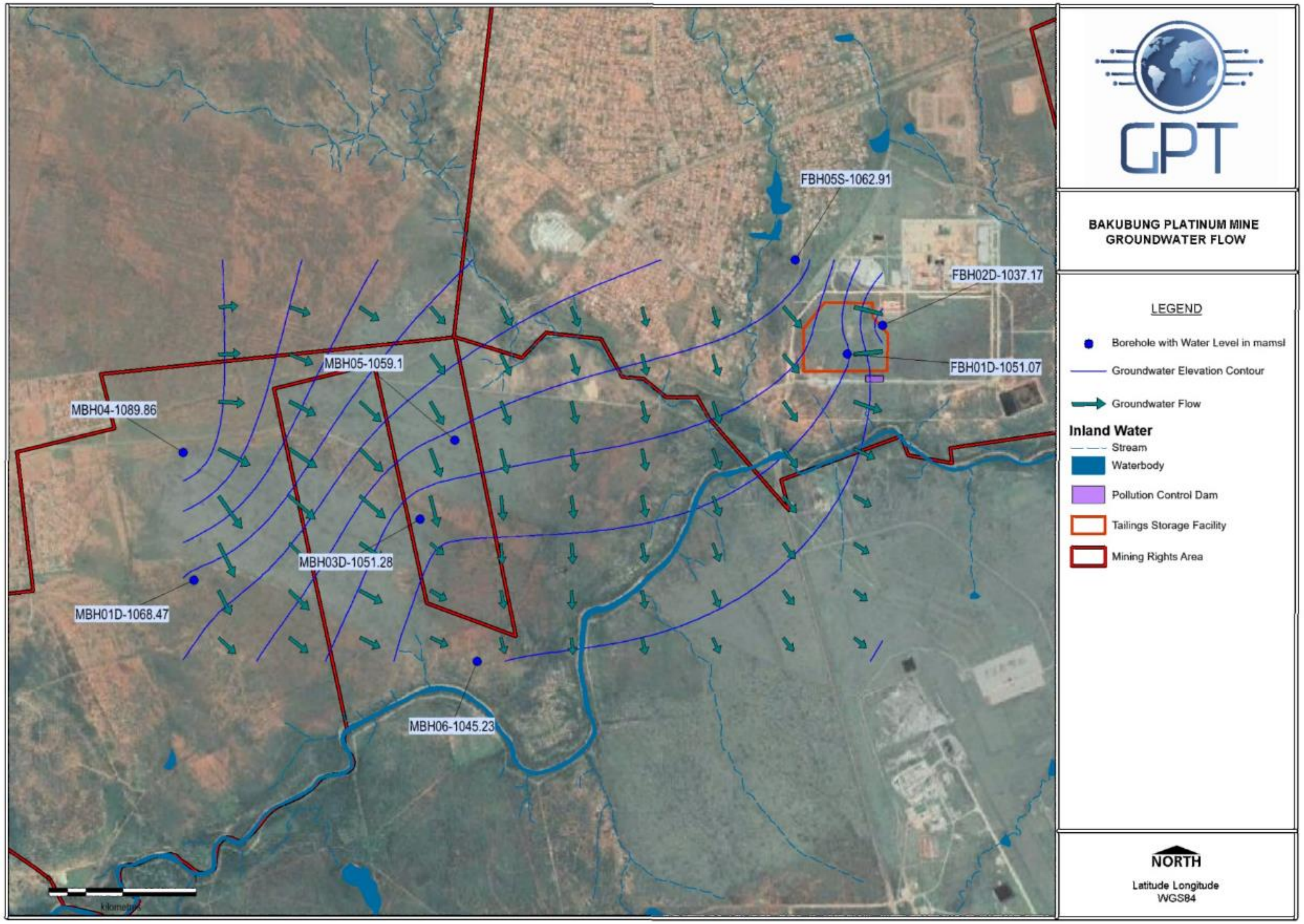


Figure 7: Available water levels and groundwater flow directions

6.4 Water quality

The water quality results for 6 of the boreholes drilled and analysed by Africon during 2008 were 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. Colours of individual cells refer to the drinking water classification of the specific groundwater sample (Table 3).

From this comparison, the following is evident:

- Fluoride exceeds the allowable limit in sample FBH03D
- Total iron exceeds the allowable limit in samples FBH02D, FBH03D and FBH05S.
- Total manganese exceeds the allowable limit in FBH05S

.

Table 3: Chemical results of the boreholes drilled by Africon compared to the SANS 241:2015 2nd edition Standards

Parameter		Unit	SANS 241: 215 Recommended Limits	Risk	Results					
					FBH01D	FBH02D	FBH03D	FBH04D	FBH05D	FBH05S
Physical & Aesthetic Determinants										
Electrical conductivity at 25C	EC	mS/m	≤ 170	Aesthetic	75	34	31	71	96	97
Total Dissolved Solids	TDS	mg/liter	≤ 1200	Aesthetic	75	34	31	71	96	97
pH at 25C		pH units	≥ 5 to ≤9.7	Aesthetic	8.25	8.8	9.33	8.18	8.12	8.12
Chemical Determinants - Macro Determinants										
Nitrate as N	NO_3	mg/liter	≤ 11	Acute Health	0.3	0.1	0.1	0.1	3.9	0.1
Sulphate	SO_4	mg/liter	Acute Health ≤500; Aesthetic ≤250	Acute Health/Aesthetic	20.9	9.1	25.8	10.6	62	66.4
Fluoride	F	µg/liter	≤1500	Chronic Health	500	700	1600	600	500	700
Chloride	Cl	mg/liter	≤ 300	Aesthetic	20	7.2	46.4	46.5	99.3	82.7
Sodium	Na	mg/liter	≤ 200	Aesthetic	1.6	1.4	2.2	2.5	4.3	3.2
Total Iron	Fe	mg/liter	Acute Health ≤ 2; Aesthetic ≤0.3	Acute/Aesthetic	0.03	1.96	0.6	0.03	0.03	0.4
Total manganese	Mn	mg/liter	Acute Health ≤0.4; Aesthetic ≤0.1	Acute/Aesthetic	0.01	0.04	0.01	0.09	0.09	0.4
Concentration deemed to present an unacceptable health risk for lifetime consumption.										

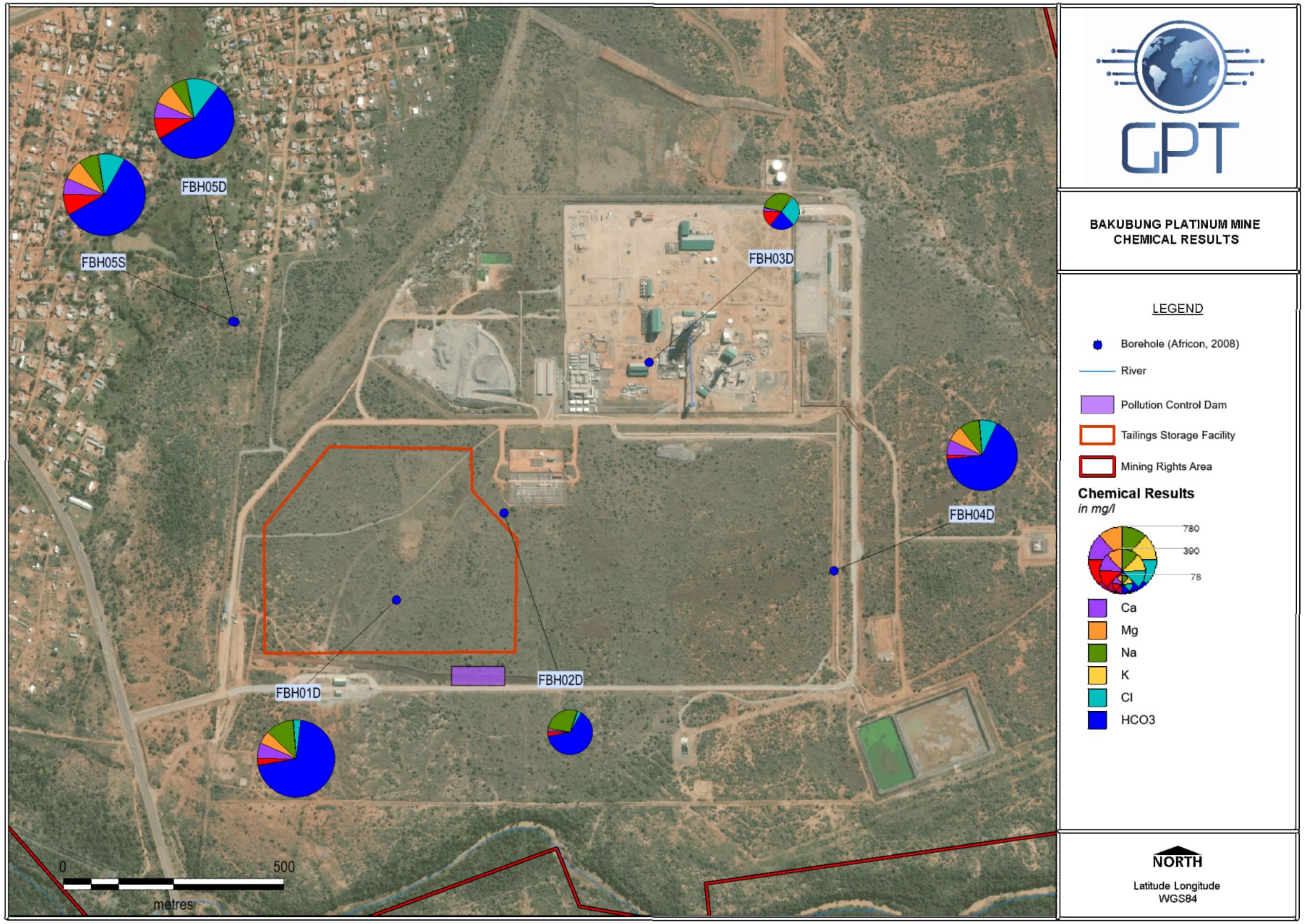


Figure 8: Chemistry map of the sampled Africon 2008 boreholes

6.5 Geophysical Investigations

A geophysical survey was conducted in 2008 by Africon Engineering. The findings of geophysical work are summarised in the paragraphs below.

6.5.1 DC Resistivity (ERT) survey

Electrical Resistivity Imaging/Tomography (ERT), sometimes referred to as electrical resistivity, DC resistivity techniques or vertical electric sounding were used to measure earth resistivity by driving a direct current (DC) signal into the ground and measuring the resultant potentials (voltages) created in the earth. The electrical properties of the sub-surface are derived from this data.

The electrical resistivity varies between different geological materials, depends mainly on variations in water content and dissolved ions in the groundwater. Resistivity investigations thus are used to identify zones with different electrical properties, which can then be referred to different geological strata. Resistivity is also called specific resistance, which is the inverse of conductivity or specific conductance. The most common mineral-forming soils and rocks have very high resistivity in a dry condition; therefore, the resistivity of soils and rocks is normally a function of the amount and quality of water in pore spaces and fractures, as well as the degree of tropical weathering of the formation. Consequently, the variation may be more limited to a confined geological area and variations in resistivity, within a certain soil or rock type, will reflect variations in physical properties. Sand, gravel and sedimentary rock may also have very low resistivities, provided that the pore spaces are saturated with saline water.

Fresh crystalline rock is highly resistive, despite the fact that it may contain certain conductive ore minerals; however, weathering commonly produces highly conductive clay-rich saprolite. Variation in characteristics within one geological material type necessitates calibration of resistivity data against geological documentation, from, for example, surface mapping, test pit exposures or drilling. However, this applies to all geophysical methods.

The degree of saturation will affect the resistivity; the resistivity above the groundwater level will be higher than that below this level, i.e. if the material is similar. Consequently, this method can be used to determine the depth to the water table, where a distinct water table exists. However, if the content of fine-grained material is significant, the water content above the groundwater surface, held by hygroscopic and capillary forces, may be large enough to dominate the electrical behaviour of the material. The resistivity of the pore water is determined by concentrations of ions in solution, the type of ions and temperature. The presence of clay minerals strongly affects the resistivity of sediments and weathered rock. The clay minerals may be regarded as electrically conductive particles, which can absorb and release ions and water molecules on its surface through an ion exchange process.

An Abem Lund Terrameter system was employed to collect the resistivity data. Resistivity measurements are obtained by injecting a current into the ground through two electrodes and measuring the resulting potential between another electrode pair. By systematically increasing the electrode separation around a common point a picture is obtained of resistance variations with depth, whilst a set of adjacent soundings as collected, known as CVES (continuous vertical electrical sounding), provides a resistivity image, or cross section. The ABEM Lund automates the collection of such data sets (Africon Engineering International, March 2008).

It is important to note that the inversion process that translates raw resistivity data into a resistivity cross section is non-unique. The inversion program chooses the smoothest, least heterogeneous, solution. This solves the mathematical problem of non-uniqueness, but produces a slightly blurred image of the actual geology. Abrupt transitions between layers become gradational transitions in the resistivity section. Secondly, the data are collected along a line and inverted assuming two-dimensional geologic structure. This assumption is reasonable for a layered earth or for dipping layers if the data are collected perpendicular to strike.

6.6 Aquifer tests

A brief overview of the aquifer tests conducted at Wesizwe Platinum Mine is described below:

Only one of the boreholes drilled by Africon in 2008 had a significant yield. This borehole was pump tested. Falling head tests were conducted on the remaining boreholes. The results for the aquifer tests can be seen in Table 4 below.

Table 4: Information obtained from aquifer tests conducted [2].

BH ID	Analysis Method	Hydraulic Conductivity (m/day)	Transmissivity (m^2/day)
FBH01D	Bower & Rice	1.50×10^{-2}	~
FBH02D	Bower & Rice	1.36×10^{-5}	~
FBH03D	Bower & Rice	5.75×10^{-5}	~
FBH04D	Bower & Rice	4.2×10^{-2}	~
FBH05D	Bower & Rice	1.39×10^{-2}	~
FBH05S	Bower & Rice	4.18×10^{-3}	~
MBH01D	Bower & Rice	2.73×10^{-1}	~
MBH02S	Bower & Rice	8.81×10^{-2}	~
MBH03D	Bower & Rice	1.2×10^{-2}	~
MBH04D	Bower & Rice	3.48	~
MBH04D	Cooper-Jacob	1.47	60.5
MBH04D	Theis	1.32	54.2
MBH04D	Theis Recovery	1.46	60.0
Mean		6.29×10^{-1}	58.2

Borehole MBH04D had a significantly higher K-value compared to the remaining boreholes which would indicate that this borehole was drilled into a preferential groundwater pathway.

6.7 Double ring infiltrometer tests

The permeability of the soil horizon was ascertained during the study conducted in 2008 by Africon. The results of these test can be seen in Table 5 below.

[2] **(Africon Engineering International, March 2008)**

Table 5: Double Ring Infiltrometer Test Results (Africon 2008)

Test No	Material	Infiltration rate (cm/h)	Saturated hydraulic conductivity (m/day)
MTP2	Clayey Material	0.38	0.09
MTP6	Dry loamy clay	0.38	0.09
MTP7	Loose clayey silty sand	0.79	0.19
Mean		0.51	0.12

The average saturated hydraulic conductivity in the tested pits is 0.12m/day. As the majority of the site is overlain by black clayey soil which had an average conductivity of 0.09m/day, this value would be more representative of the overall site conditions.

7 POTENTIAL CONTAMINANTS

7.1 Waste Classification

A composite sample was taken of the overburden, soft material and hard material was taken and submitted to a laboratory Waterlab Pty Ltd for analysis for waste classification purposes. The laboratory results are contained in Appendix I. The sample represents the material used for back-fill material.

The waste classification was done in terms of Regulation R.635 – National Norms and Standards for the Assessment of Waste for Landfill Disposal published under Section 7(1)(c) of the National Environmental Management: Waste Act, 2008 (Act No. 59 of 2008).

7.1.1 Methodology

Sampling and analysis of waste collected determined the total concentrations (TC) and leachable concentrations (LC) of the elements and chemical substances in the waste product. Samples were analysed against inorganic suites.

The TC and LC values of the samples were compared to the threshold limits of the specific elements and in accordance with the prescribed limits published in the Norms and Standards to determine the total concentrations (TCT limits).

7.1.2 LCT and TCT Limits

The Leachable Concentration Threshold (LCT) and Total Concentration Threshold (TCT) of elements were determined by an accredited SANAS Laboratory. Results of exceedances were recorded as follows:

TCT Inorganic Analysis

- Cobalt exceeded TCT0 in the Solid sample;
- Copper exceeded TCT0 in the solid sample;
- Manganese exceeded TCT0 in the Solid sample

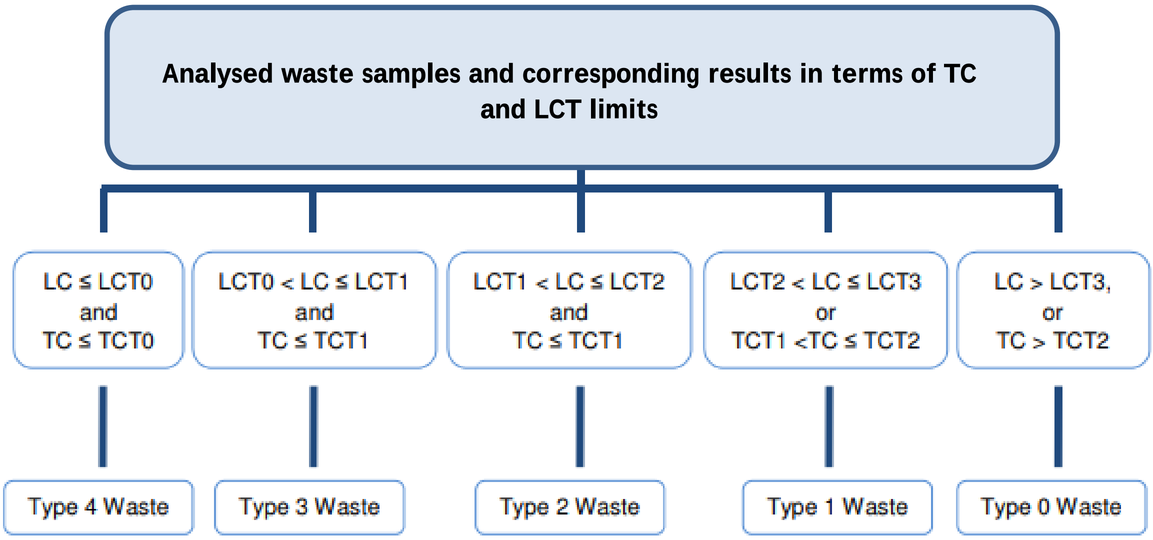
- Nickel exceeded TCT0 in the Solid sample
- Vanadium exceeded TCT0 in the Solid sample

LCT Inorganic Analysis

- No exceedances were report for the LCT inorganic analysis

7.1.3 Waste Type for Landfill Disposal

Waste destined for disposal are determined by comparing TC and LC of the elements with the TCT and LCT limits.



Considering the results presented in Appendix I the waste is classified as a Type 3 waste. The samples exceeded TCT0 or LCT2 values. Cobalt, copper, manganese, nickel and vanadium exceeded the LCT2 limits.

Type 3 waste in terms of the Waste Act should be disposed of in a Class C or GLB- lined facility.

8 AQUIFER CHARACTERISATION

The term aquifer refers to 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.

8.1 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. Stated in another way, 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.

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 after drilling of the new boreholes to be at mean of ~21.36 mbgl.
- Groundwater recharge of ~20 mm/a (4% recharge),
- Sandy clay Loam soil vadose zone
- Gradient of 1.2 % were assumed and used in the estimation.

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
- The GDT calculated a vulnerability value of 43 %, which is medium.

8.2 Aquifer Classification

The aquifer(s) underlying the subject area were classified in Aquifer Management Classification methodology[3]

The main aquifers underlying the area 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 “Minor Aquifer System”, based on the fact that although these aquifers seldom produce large quantities of water, they are important for local supplies and in supplying base flow for rivers.

In order to achieve the Aquifer System Management and Second Variable Classifications, as well as the Groundwater Quality Management Index, a points scoring system as presented in Table 6 and Table 7 was used.

Table 6: Ratings – Aquifer System Management and Second Variable Classifications

[3] Department of Water Affairs and Forestry & Water Research Commission (1995). A South African Aquifer System Management Classification. WRC Report No. KV77/95.

Aquifer System Management Classification		
Class	Points	Study area
Sole Source Aquifer System:	6	
Major Aquifer System:	4	
Minor Aquifer System:	2	2
Non-Aquifer System:	0	
Special Aquifer System:	0 – 6	
Second Variable Classification (Weathering/Fracturing)		
Class	Points	Study area
High:	3	
Medium:	2	2
Low:	1	

Table 7: Ratings - Groundwater Quality Management (GQM) Classification System

Aquifer System Management Classification		
Class	Points	Study area
Sole Source Aquifer System:	6	
Major Aquifer System:	4	
Minor Aquifer System:	2	2
Non-Aquifer System:	0	
Special Aquifer System:	0 – 6	
Aquifer Vulnerability Classification		
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 GQM index for the study area is presented in Table 8.

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

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

GQM Index = Aquifer System Management x Aquifer Vulnerability

= 2 x 2 = 4

Table 8: 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	

8.3 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.

DWS'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.
- The protection of the Elandsriver and its tributaries

9 CONCEPTUAL SITE MODEL (CSM)

9.1 Conceptual site model

The conceptual model is a simplified representation of the conditions at and in the vicinity of the TSF and will provide the framework during the development of the risk assessment and numerical flow and transport model (Figure 9 and Figure 10).

9.2 Water Levels & Flow directions

The groundwater flow around the planned TSF is towards the south east to the Elands River. The water levels on the northern western part of the site is shallower than the south eastern area in the vicinity of the river.

9.3 Hydraulic Conductivities

The average hydraulic conductivity (K) of the clayey soils is in the region of 0.09 m/d. The shallow weathered aquifer has a hydraulic conductivity of between $1.2x10^{-2}$ and $5.75x10^{-5}$. These values are given in the geohydrological assessment report (Africon 2008) and was measured in situ on site using double ring infiltrometer tests and falling head tests respectively. The K-value for the preferential pathway encountered in MBH04D was 1.47m/d. The higher K-value could act as a preferential pathway for groundwater and contaminant migration.

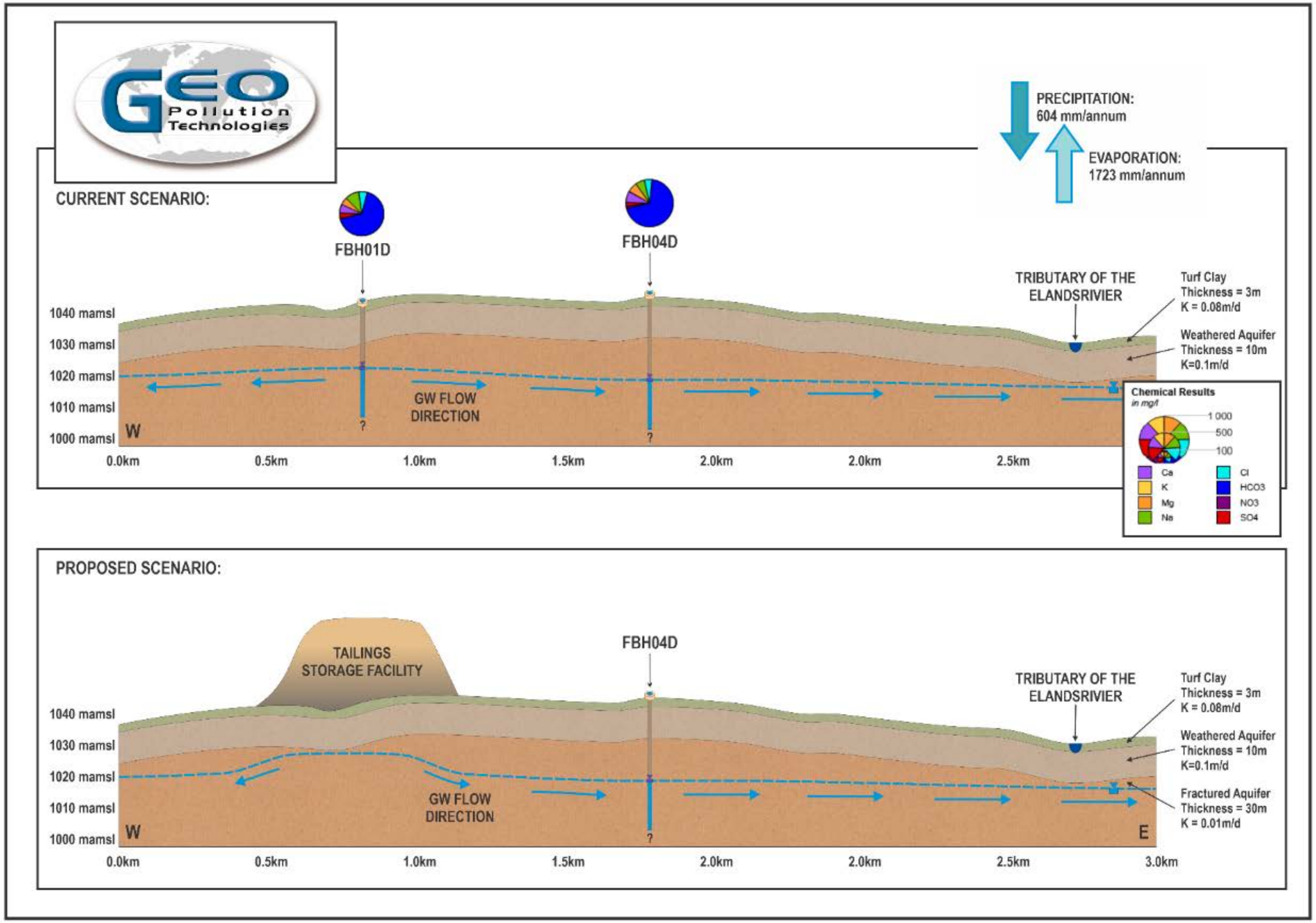


Figure 9: Conceptual Site Model (Not to scale)

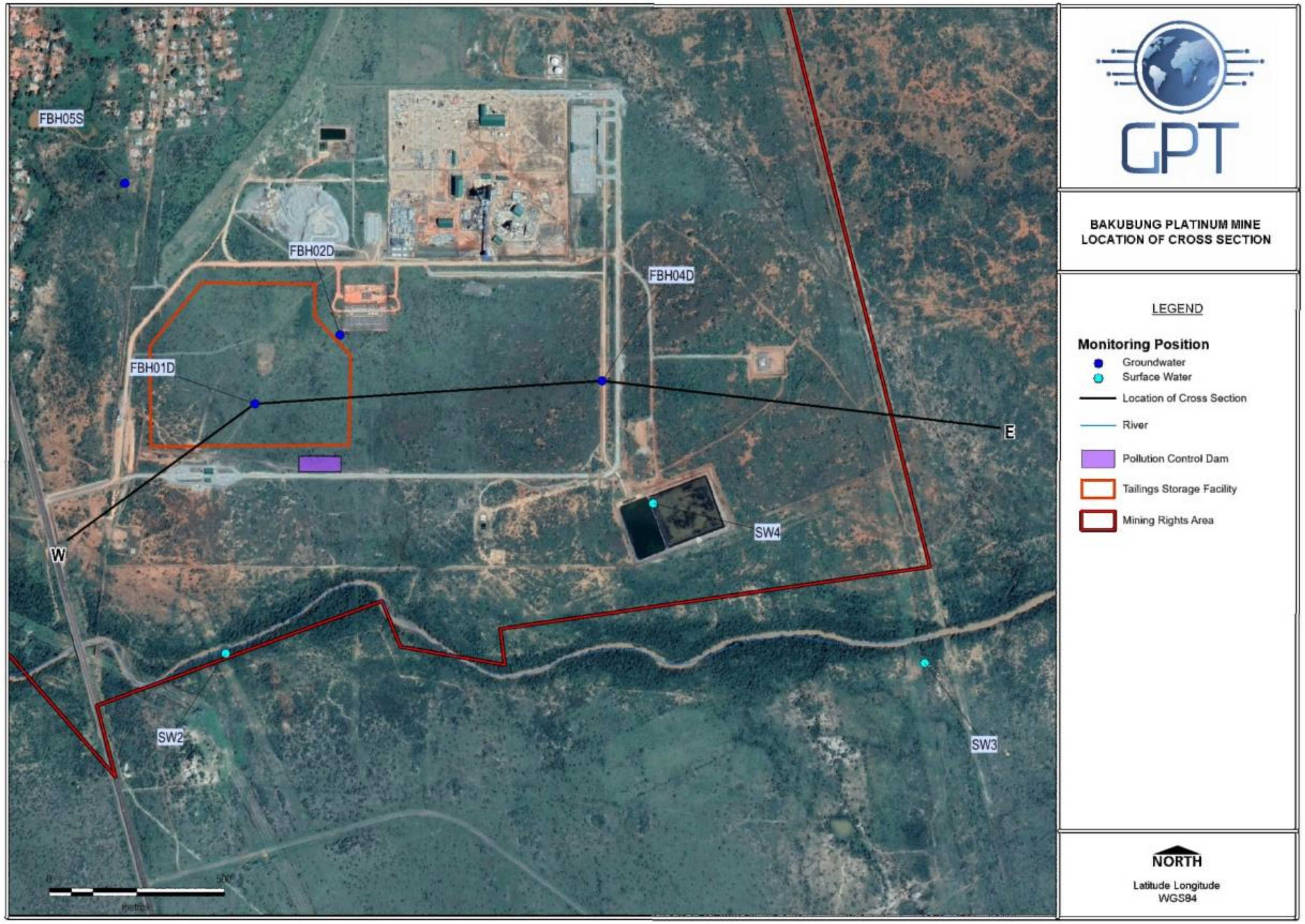


Figure 10: Location of the Cross Section

10 GROUNDWATER FLOW AND TRANSPORT MODELLING

The numerical groundwater flow model is constructed and simulated to aid in decision making processes and environmental management.

The groundwater regime of the study area is highly heterogeneous due to complex faulting and intrusions, which ultimately influences 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.

10.1 Software Model Choice

The finite difference numerical model was created using AquaVeo's Groundwater Modelling System (GMS10) 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 eight overall updates since. The latest update (Modflow-NWT) incorporates several improvements extending its capabilities considerably, the most important being the introduction of the Newton formulation of Modflow. This dramatically improved the handling of dry cells that has been a problematic issue in Modflow in the past.

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.

10.2 Model Set-up and Boundaries

Boundaries were chosen to include the area where the groundwater pollution plume could reasonably be expected to spread and simultaneously be far enough removed from site boundaries not to be affected by groundwater abstraction. These boundaries are described in Table 9.

These boundaries resulted in an area of about 7 to 14 km around the proposed development, which is considered far enough for the expected groundwater effects not to be influenced by boundaries.

10.3 Groundwater Elevation and Gradient

The calibrated static water levels as modelled have been contoured (Figure 13). 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.

10.4 Geometric Structure of the Model

The geometric structure of the model is discussed in Appendix II, with only the conceptual model input and fixed aquifer parameters discussed below.

10.5 Groundwater source and sinks

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

Table 9: Input parameters to the numerical flow model

Model Parameter	Value	Unit	Reason
Recharge to the aquifer	0.00005	m/d	Calculated as 3% of recharge
Recharge to the tailings facility	0.00003 to 0.0003	m/d	Dry deposition, rainwater only. Modelled scenarios
Evapotranspiration	0.005	m/d	Calculated from E-pan evaporation data
Boundaries	Topographic water divides	-	Existing water divide (no flow) boundary conditions present at the site
Refinement	20	m	Based on the scale of the TSFs
Grid dimensions	300 x 250	Cell count	Product of the grid refinement
Preliminary hydraulic conductivity	0.05	m/d	Geohydrological baseline study, pump tests (Stroebel, L, Africon 2008)
Hydraulic anisotropy (vertical)	10	-	Anderson et al. (2015)
Effective porosity	20 for regolith, 5 for fractured rock	%	Wang et al. (2009)
Layers	3	Count	Hydrogeological decision
Longitudinal dispersion	50	m	Schulze-Makuch (2005)
Head error range	10	m	Calculated as 10% of the difference between the maximum and minimum calculated head elevations

10.6 Conceptual model input

For the purpose of this study, the subsurface was envisaged to consist of the following hydrogeological units.

- The upper few metres below surface consist of residual mafic rock, completely weathered to turf clay. This layer is anticipated to have a low hydraulic conductivity, but in general unsaturated.
- The next few tens of metres comprise of moderately weathered, highly fractured mafic rock. The permanent groundwater level resides in this unit and is about 1 to 60 metres below ground level. The groundwater flow direction in this unit is influenced by regional topography and for the site flow would be in general from high lying areas to the Elands River.
- Below this, the fracturing of the aquifer is less frequent and fractures less significant due to increased pressure. This results in an aquifer of lower hydraulic conductivity. The flow direction is expected to be mostly southerly. This trend was confirmed by modelling.

10.7 Calibration of the Numerical Model

Water level and quality data obtained during the previous 2008 hydrocensus as well as groundwater level monitoring data obtained from the client was used to calibrate the steady state numerical groundwater flow model. The hydraulic conductivity of the layers was calibrated, while keeping the unsaturated clay layer constant at the double infiltrometer value. All other parameters were also kept unchanged at calculated values, as listed in the paragraphs above.

A reasonably good calibration was obtained. However, the boreholes at the site could not be fitted adequately as the water levels in them are unusually deep. A similar tendency was found in the baseline study conducted by Africon, (2008). A distinction between water levels shallower than 30 metres below ground level and those deeper than 30 metres was made, but without any explanation. The following graph was copied from the baseline report (Figure 11):

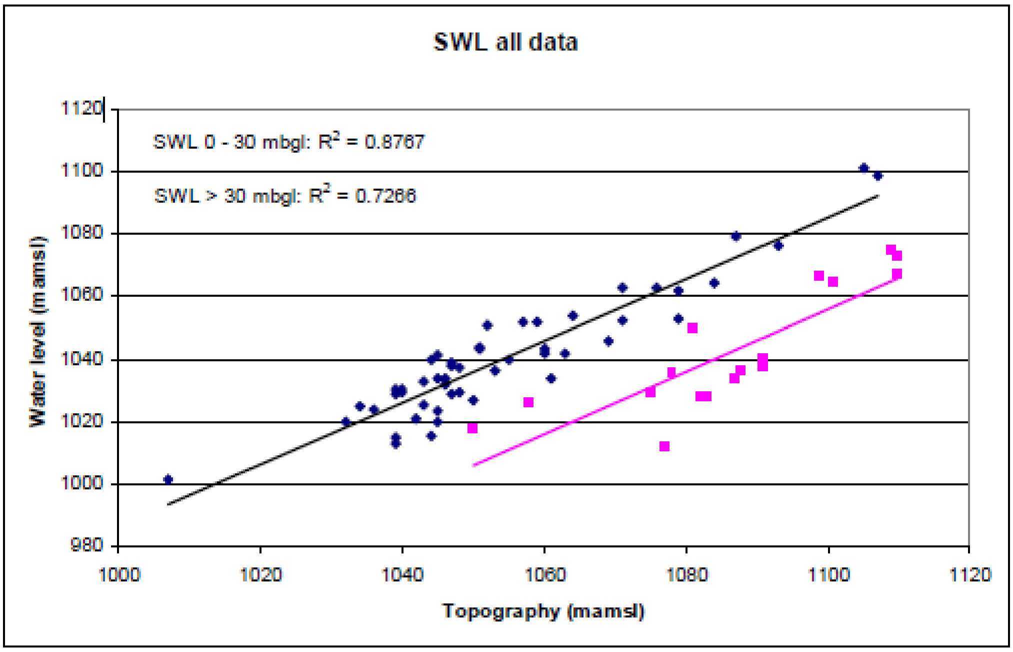


Figure 11: Water level elevation vs topographical elevation [From Stroebel, L., 2008. Geohydrological Evaluation]

Due to time and budget constraints, this apparent difference in groundwater levels was accepted as-is, but it is highly recommended that the reason for this be investigated as soon as possible, as it could influence the modelled groundwater flow at the site, and thus the impact of the Tailings Facility.

The calibration error statistics can be seen in Table 10. The mean residual head error is below 1 metre, which can be regarded as good. A good fit was also obtained for the measured groundwater levels and concentrations (Figure 12 to Figure 13).

Table 10: Optimal Calibrated Aquifer Parameters

Aquifer	Model layer	Layer thickness (m)*	Porosity (%)	Hydraulic conductivity (m/d)
Clay Layer	Layer 1	3	30	0.12**
Shallow Weathered Aquifer	Layer 2	10	20	0.1
Fractured Aquifer	Layer 3	30	5	0.01

*Derived from borehole logs in Africon baseline study

**Obtained from the baseline study double infiltrometer tests

Table 11: Calibration Statistics

Description	Value
Mean Residual (Head)	0.31
Mean Absolute Residual (Head)	5.72
Root Mean Squared Residual (Head)	7.25

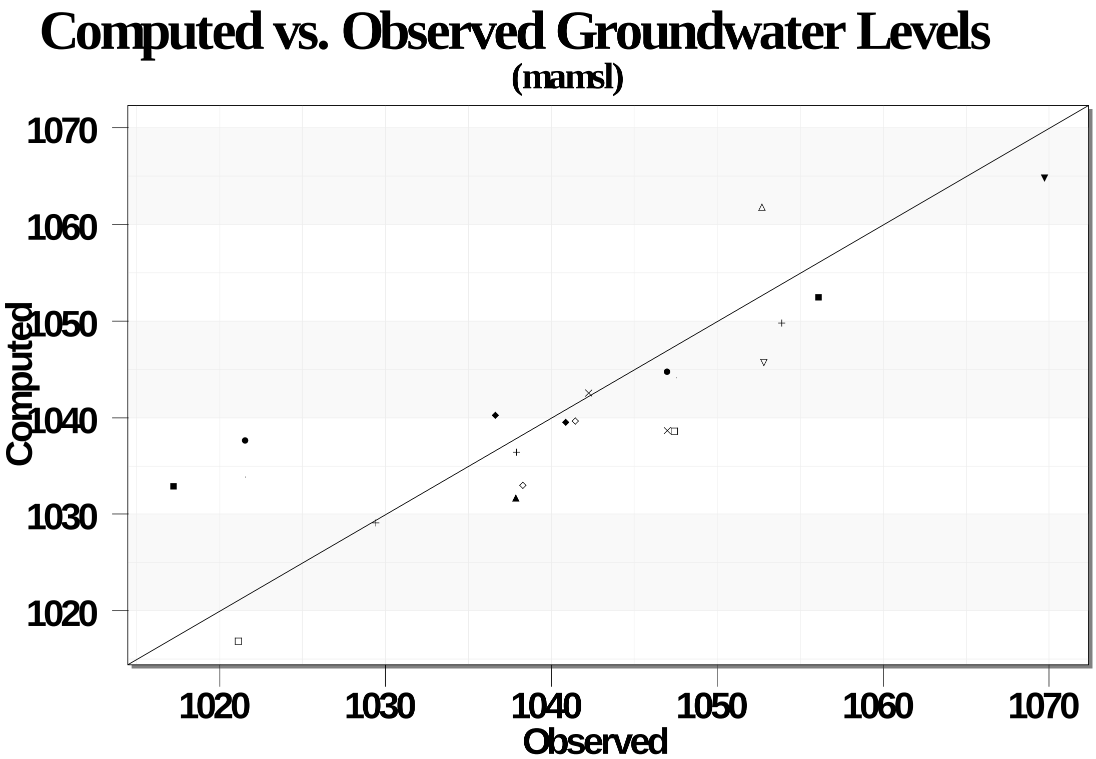


Figure 12: Water level Calibration Graph

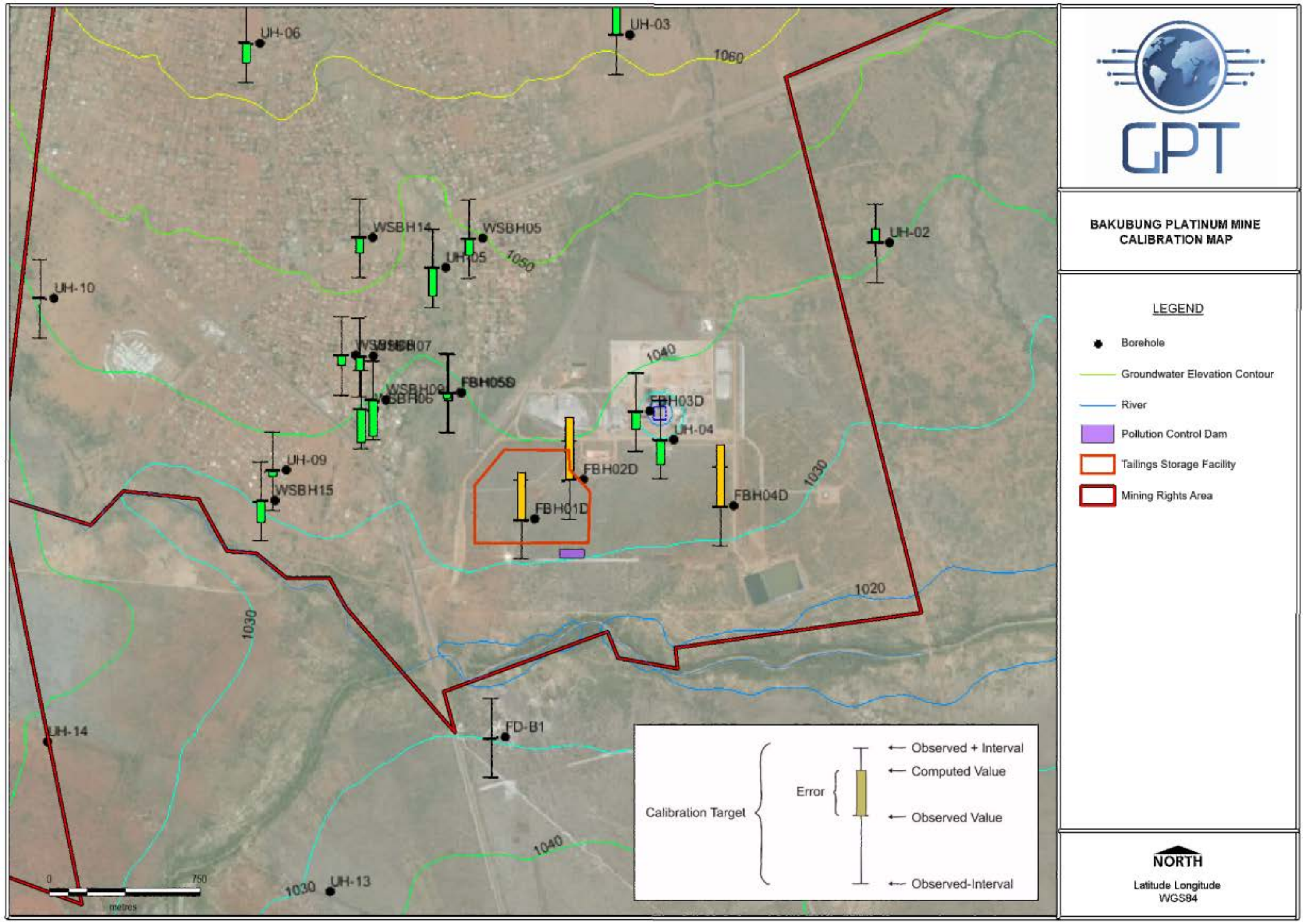


Figure 13: Water Level Calibration Map (bars 10 m head interval)

10.8 Scenarios Modelled

It is understood that the TSF will be lined using a Class C barrier system. The typical barrier system includes the following layers from excavation level upwards[4]:

- Substrate preparation layer: The substrate will be ripped and re-compacted to 95% MOD AASHTO with a moisture content of -2 to +2% of optimum moisture content.
- Subsoil Drainage Layer: A drainage layer is installed below the barrier system to relieve pressure that may be caused by shallow ground water. It also collects any leakage that may penetrate the barrier system.
- Primary low permeability layer: 2 x 150 mm layers of clay compacted to 98% Standard Proctor with a moisture content of +1 to +3% of optimum moisture content in order to have a permeability co-efficient (k) of less than 1x10 cm/s.
- Primary geomembrane layer: 1.5 mm High-density polyethylene (HDPE) geomembrane layer.
- Protection layer: 100 mm layer of fine sand that will protect the geomembrane against damage.
- Leachate collection layer: 300 mm thick finger drains of geotextile covered aggregate with HDPE pipe drainage network.

Should the lining remain undamaged, no impact on groundwater receptors can be expected. But linings are often damaged during construction or operations and leakage to the subsurface are thus possible. Three scenarios were modelled to cater for leakage, namely a 10% and 50% and 100% leakage. As dry deposition of material will be done, the only flow to the TSFs is recharge from rainwater. Recharge from rainfall to the TSF was estimated at 20% of mean annual rainfall. The scenarios modelled were thus:

Table 12: Scenarios modelled

Scenario	Leakage (%)	Effective recharge* (mm/year)	Effective recharge (m/day)
Minor liner leakage	10	12	0.00003
Major liner leakage	50	60	0.00016
No liner	100	120	0.0003

*Numbers are based on an annual rainfall of 590mm/year and 20% recharge to the TSF.

Table 13: Calculated Leakage volumes

Scenario	Leakage (%)	Effective recharge (m/day)	Option 1 leakage volume (m^3/day)	Option 2 Leakage Volume (m^3/day)	Option 3 Leakage Volume (m^3/day)
Minor liner leakage	10	0.00003	6.95	5.8	11.5

[4] Knight Piésold Consulting, July 2019. Wesizwe Platinum Bakubung Storage Facility Feasibility Design Report.

Scenario	Leakage (%)	Effective recharge (m/day)	Option 1 leakage volume (m^3/day)	Option 2 Leakage Volume (m^3/day)	Option 3 Leakage Volume (m^3/day)
Major liner leakage	50	0.00016	37.1	31.0	61.4
No liner	100	0.0003	69.5	58.2	115.1

11 HYDROGEOLOGICAL IMPACTS

It is the aim of this chapter to assess the likely hydrogeological impact that the proposed TSF and its PCDs might have on the receiving environment. The scenarios modelled in this section are those described in Table 12 above.

As in the previous Africon model, a conservative tracer was specified in the groundwater transport model with a concentration of 100 (%) and predicting its concentration in space over time. Contamination over time is depicted for every scenario at 10, 25, 50 and 100 years after the TSFs became operational. The Elands River is the only sensitive receptor in close vicinity to these sources, and impacts will be assed in relations to the river.

11.1 Minor Liner Leakage

The groundwater contamination for a minor leakage of the liner is depicted in Figure 14 below. It follows from these figures that:

- Plume movement is very slow due to the low hydraulic conductivity and flat groundwater level, about 2 meter per year on average.
- At this leakage rate the TSF has limited contamination impact and the plume does not reach the Elands River, even in 100 years.

11.2 Major Liner Leakage

The groundwater contamination for a minor leakage of the liner is depicted as Figure 15 below. It follows from these figures that:

- Plume movement has accelerated somewhat to about 4 meter per year due to increased ponding of groundwater underneath the TSF.
- Groundwater contamination from the TSF could now reach the Elands River, albeit in low concentrations and only after 100 years.

11.3 No Liner

This option is not considered at this stage, but the results are presented here just for comparative purposes (Figure 16). It nevertheless confirms that an unlined scenario is unfavourable as the plume migration rate is significantly increased due to the increased ponding underneath the TSF.

11.4 Conclusions from Modelling Results

Based on the various scenarios modelled, it is concluded that:

- The proposed TSF locality is suitable, but the integrity of the liner will be important. Only minor leaks can be allowed if no impact on the river is desired.
- However, the hitherto unexplained deep groundwater levels could mean that the Elands River is unconnected to the groundwater level. In this scenario, the modelled contamination movement will not reach the river. This is an aspect that is worth further investigation.

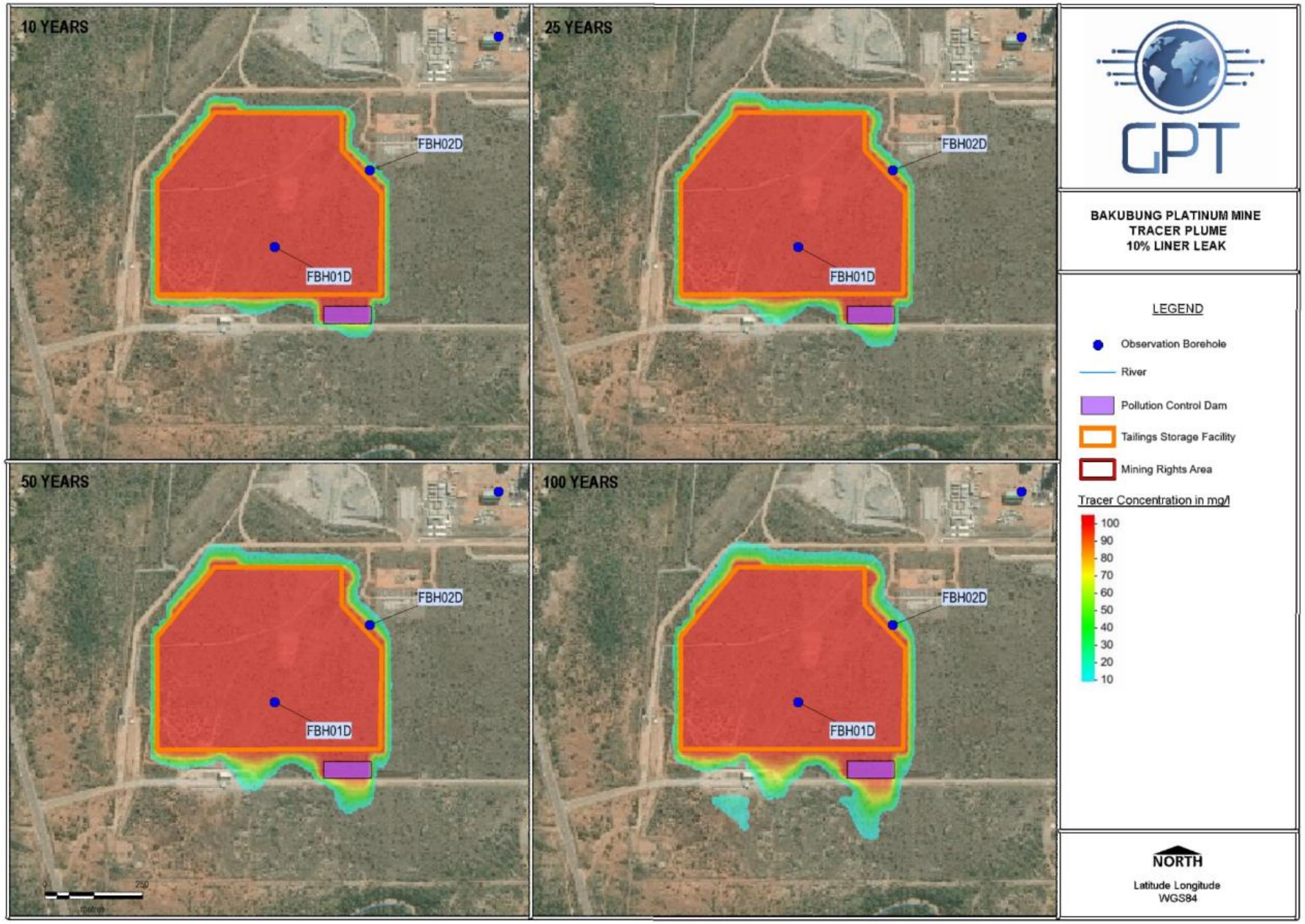


Figure 14: Impacts on the Elands River - Minor Leakage

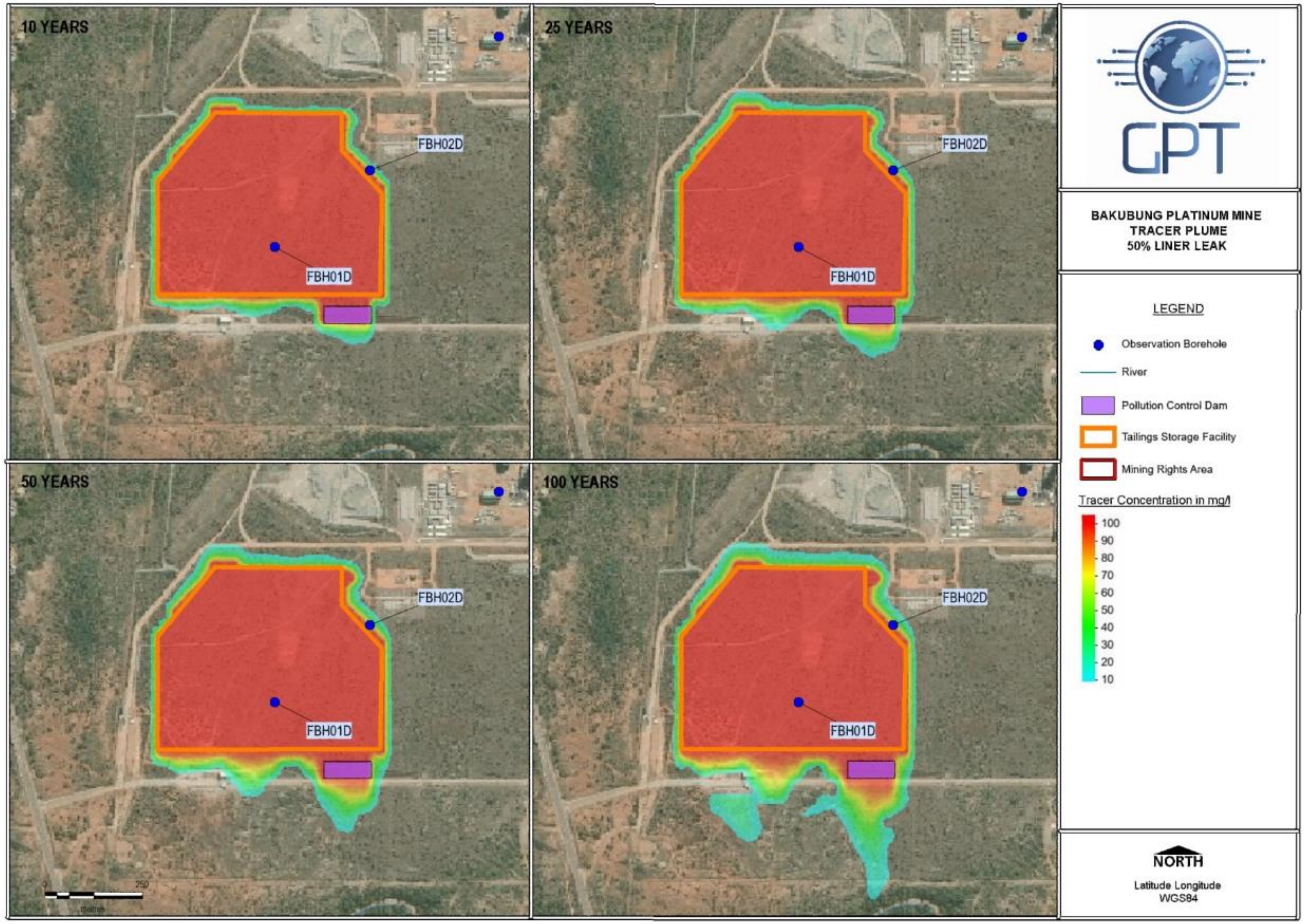


Figure 15: Impacts on the Elands River - Major Leakage

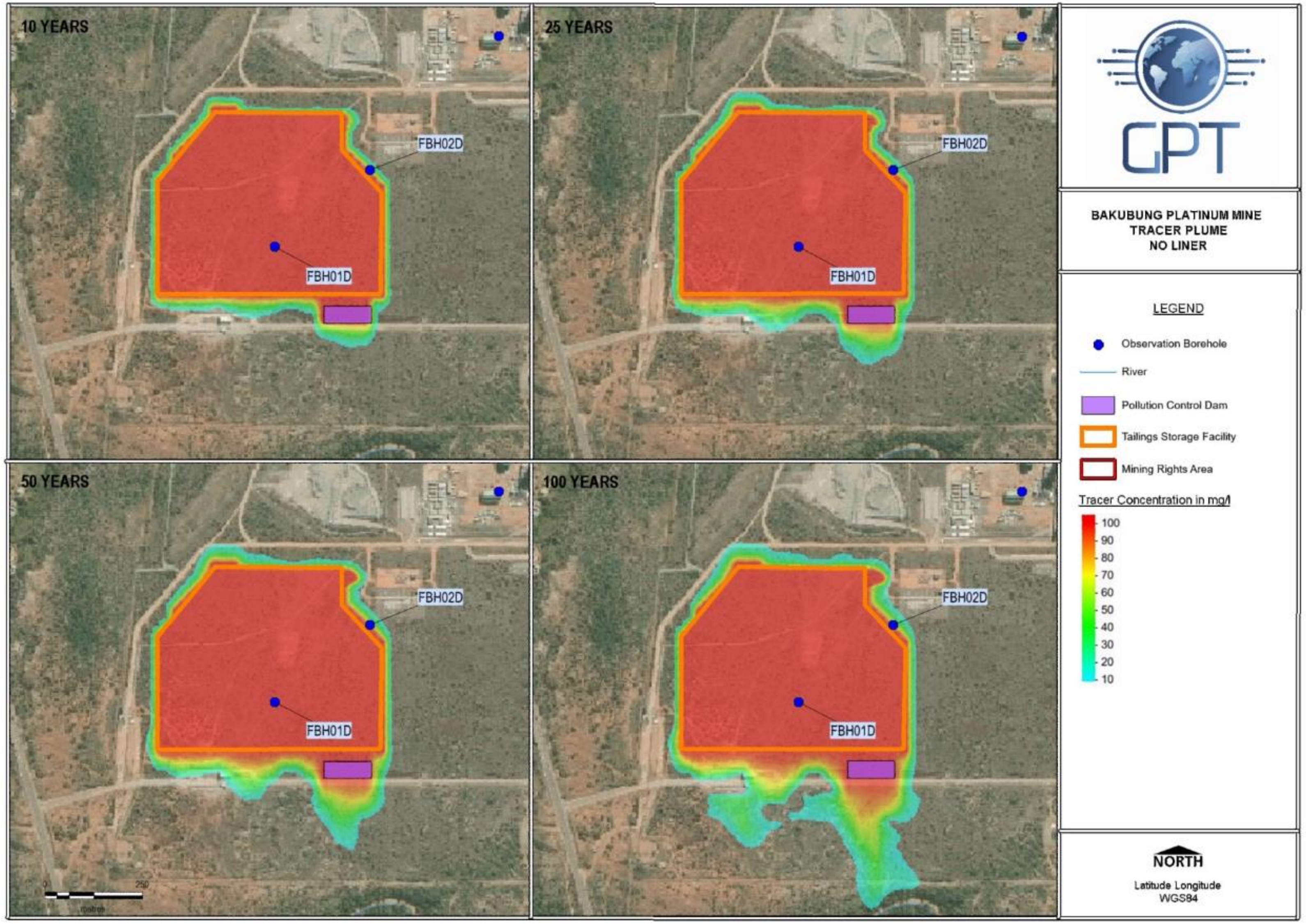


Figure 16: Impacts on the Elands River - No Liner

12 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.

12.1 Source term(s)

The approach to define the behaviour of the source term is detailed below.

- Waste material will be generated that has the potential to contaminate.
- The waste is deemed to have a negative impact on the environment
- Based on the existing TSF there is 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 generally accepted that all liners leak to a greater or lesser (or to some) extent. In reality, therefore, leachate that is generated at the planned TSF 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.

12.2 Pathways

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

- Movement through the regolith which has a thickness of ±3 m and low hydraulic conductivity of 0.09 m/day.
- Movement through the weathered aquifer which has a thickness of ±10 m and moderate hydraulic conductivity of 0.1 m/day.
- Movement through the fractured aquifer which has a hydraulic conductivity of 0.01 m/day. Preferential pathways in the form of fractures have been shown to have hydraulic conductivities of 1.5m/d in this unit.

12.3 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. During the hydrocensus as done by Africon (2008) some groundwater users were found within a 3km radius of the planned TSF area. The groundwater was used for domestic and irrigation purposes. The Elands River is located in close proximity to the planned TSF and therefore the potential receptors of contamination are substantial.

13 IMPACT ASSESSMENT

The impact assessment was conducted according to the impact assessment matrix developed by Knight Piesold. This matrix is developed to accurately determine the significance of the predicted impact on, or benefit to, the surrounding natural and/or social environment.

Nonetheless, an impact assessment will always contain a degree of subjectivity, as it is based on the value judgment of various specialists and Environmental Assessment Practitioners. The evaluation of significance is thus contingent upon values, professional judgement, and dependent upon the environmental and community context. Ultimately, impact significance involves a process of determining the acceptability of a predicted impact to society.

The purpose of impact assessment is to identify and evaluate the likely significance of the potential impacts on identified receptors and resources according to defined assessment criteria, to develop and describe measures that will be taken to avoid, minimise, reduce or compensate for any potential adverse environmental effects, and to report the significance of the residual impacts that remain following mitigation.

13.1 Defining the Nature of the Impact

An impact is essentially any change to a resource or receptor brought about by the presence of the proposed project component or by the execution of a proposed project related activity. The terminology used to define the nature of an impact is detailed in Table 14 below.

Table 14: Impact Nature

Nature of impact	
Term	**Definition**
Positive (+)	An impact that is considered to represent an improvement on the baseline or introduces a positive change.
Negative (-)	An impact that is considered to represent an adverse change from the baseline or introduces a new undesirable factor.
Direct impact (D)	Impacts that result from a direct interaction between a planned project activity and the receiving environment/receptors (e.g. between occupation of a site and the pre-existing habitats or between an effluent discharge and receiving water quality).
Indirect impact (I)	Impacts that result from other activities that are encouraged to happen as a consequence of the Project (e.g. in-migration for employment placing a demand on resources).
Cumulative impact (C)	Impacts that act together with other impacts (including those from concurrent or planned future third-party activities) to affect the same resources and/or receptors as the Project.

13.2 Assessing the Significance

The Knight Piésold impact significance rating system is based on the following equation:

Significance of Environmental / Social Impact = Consequence x Probability

- The consequence of an impact can be derived from the following factors:
- Severity / Magnitude – the degree of change brought about in the environment
- Reversibility - the ability of the receptor to recover after an impact has occurred
- Duration - how long the impact may be prevalent
- Spatial Extent - the physical area which could be affected by an impact.

The severity, reversibility, duration, and spatial extent are ranked using the criteria indicated in Table 15 and then the overall consequence is determined by adding up the individual scores and multiplying it by the overall probability (the likelihood of such an impact occurring). Once a score has been determined, this is checked against the significance descriptions indicated inTable 16.

Table 15: Ranking Criteria

Ranking criteria				
Severity / magnitude (M)	**Reversibility (R)**	**Duration (D)**	**Spatial extent (S)**	**Probability (P)**
5 – Very high – The impact causes the characteristics of the receiving environment/ social receptor to be altered by a factor of 80 – 100 %	**5 – Irreversible** – *Environmental* - where natural functions or ecological processes are altered to the extent that it will permanently cease. *Social* - Those affected will not be able to adapt to changes and continue to maintain-pre impact livelihoods.	**5 – Permanent** - Impacts that cause a permanent change in the affected receptor or resource (e.g. removal or destruction of ecological habitat) that endures substantially beyond the Project lifetime.	**5 – International** - Impacts that affect internationally important resources such as areas protected by international conventions, international waters etc.	**5 – Definite** - The impact will occur.
4 – High – The impact alters the characteristics of the receiving environment/ social receptor by a factor of 60 – 80 %		**4 – Long term** - impacts that will continue for the life of the Project, but ceases when the Project stops operating.	**4 – National** - Impacts that affect nationally important environmental resources or affect an area that is nationally important/ or have macro-economic consequences.	**4 – High probability** – 80% likelihood that the impact will occur
3 – Moderate – The impact alters the characteristics of the receiving environment/ social receptor by a factor of 40 – 60 %	**3 – Recoverable** *Environmental* - where the affected environment is altered but natural functions and ecological processes may continue or recover with human input. *Social* - Able to adapt with some difficulty and maintain pre-impact livelihoods but only with a degree of support or intervention.	**3 – Medium term** - Impacts are predicted to be of medium duration (5 – 15 years)	**3 – Regional** - Impacts that affect regionally important environmental resources or are experienced at a regional scale as determined by administrative boundaries, habitat type/ecosystem.	**3 – Medium probability** – 60% likelihood that the impact will occur u
2 – Low – The impact alters the characteristics of the receiving environment/ social receptor by a factor of 20 – 40 %		**2 – Short term** - Impacts are predicted to be of short duration (0 – 5 years)	**2 – Local** - Impacts that affect an area in a radius of 2 km around the site.	**2 – Low probability** - 40% likelihood that the impact will occur
1 – Minor – The impact causes very little change to the characteristics of the receiving environment/ social receptor and the alteration is less than 20 %	**1 – Reversible** *Environmental* - The impact affects the environment in such a way that natural functions and ecological processes are able to regenerate naturally. *Social* - People/ communities are able to adapt with relative ease and maintain pre-impact livelihoods.	**1 – Temporary -** Impacts are predicted to intermittent/ occasional over a short period.	**1 – Site only** - Impacts that are limited to the site boundaries.	**1 – Improbable** - 20% likelihood that the impact will occur

Table 16: Significance Definitions

Significance		
Score According to Impact Assessment Matrix	**Colour Scale Ratings**	
	Negative Ratings	**Positive Ratings**
Between 0 and 29 significance points indicate **Low Significance**	**Low**	**Low**
Between 30 and 59 significance points indicate **Moderate Significance**	**Moderate**	**Moderate**
60 to 100 significance points indicate **High Significance**	**High**	**High**

13.3 Quantification of Groundwater Impacts

By using the matrix as discussed above, the expected impacts were assessed and quantified. The assessment can be seen in Table 17. From this assessment it can be concluded that there are three possible phases where groundwater contamination can occur at the planned TSF. These phases are:

- Construction phase impacts
- Operational Phase Impacts
- Decommissioning Phase Impacts

The possible impacts during all of the phases have also been identified and can be summed up as follows:

- Construction phases impacts Potential hydrocarbon contamination form construction machinery on the site
- Operational Phase Impacts Potential groundwater contamination resulting from pipe networks and transfer pump stations
- Operational Phase Impacts Potential groundwater contamination resulting from liner leaks under the TSF during the operation of the facility
- Decommissioning phase impacts Potential groundwater contamination resulting from liner leaks under the TSF after the decommissioning of the facility

Each of the expected impacts have been assessed using the matrix and a significance rating for each impact pre- and post-mitigation have been calculated.

Table 17: Groundwater contamination Impact Assessment

Project activity or issue	Potential impact	Nature of impact		Significance before mitigation							Significance after mitigation as per EMP						
		+ / -	D/I/C	M	R	D	S	P	TOTAL	SP	M	R	D	S	P	TOTAL	SP
Groundwater																	
GW Contamination during Construction	Hydrocarbon spills from machinery	-	D	3	3	2	2	3	30	**M**	1	3	1	1	2	12	**L**
GW Contamination during Operation	GW contamination from liner leakage	-	D	4	3	3	3	3	39	**M**	2	3	3	2	2	20	**L**
GW Contamination during Operation	GW contamination from leaking infrastructure	-	D	3	3	2	2	3	30	**M**	2	3	2	1	2	16	**L**
GW Contamination after decommissioning	GW contamination from liner leakage	-	D	3	3	2	2	3	30	**M**	2	3	3	2	2	20	**L**

13.4 Mitigation measures

By applying the necessary mitigation measures as described in the DWS's Best Practice guidelines the expected impact can be reduced. The principal of pollution prevention as defined by the Best Practice Guidelines (BPG H2: Pollution Prevention and Minimization of Impacts) [5] is explained below:

The fundamental principle of pollution prevention is to apply a planning and design process to prevent, inhibit, retard or stop the hydrological, chemical, microbiological, radioactive or thermodynamic processes, which result in the contamination of the water environment, at or as close to the point where the deterioration in water quality originates (i.e. source reduction), or to implement physical measures to prevent or retard the transport of the generated contaminants to the water resource (i.e. recycling, treatment and/or secure disposal).

In the context of this principle, the following key terms are defined:

Source reduction reduces or eliminates the quantity or hazardous nature of pollutants and waste at the point of generation. Source reduction includes strategies to predict the occurrence of acid-forming materials, contaminants and toxic metals likely to be mobilized by mining activities and design operations to avoid or minimize contact with these materials and/or assure their isolation. Source reduction can also include such strategies as substitution of hazardous processes by cleaner processes - such as prohibition of mercury processes for gold recovery.

Impact minimisation would first call for recycling of water and waste streams that might otherwise be released into the environment and then treating and thereafter securely disposing of hazardous substances, pollutants, and materials that could degrade the environment.

Again, it is important to emphasize that source reduction should form the core of any pollution prevention strategy for the mining sector; recycling, treatment and secure disposal are not adequate substitutes for a strong source reduction program.

Recycling provides for the use or reuse of waste and waste water as a substitute for a commercial product or material. It can include strategies such as closed-loop processes for handling acids and cyanides, and maximizing the reclamation/reuse of tailings water.

Treatment is any method, technique, or process that changes the physical, chemical or biological characteristics of waste materials in a way that eliminates harmful characteristics, recovers energy or useful materials in the waste materials, leaves them capable of being reused or safely contained, or reduces their volume. It can include such strategies as decontamination of tailings.

Secure disposal is any method, technique or process that prevents residual wastes from posing a threat to the environment. This includes use of designed disposal units to prevent sulphide materials from coming into contact with air and water and generating acid mine drainage. It may include placement of tailings in engineered structures with appropriate management and diversion of water to prevent mobilization and migration of pollutants.

In light of the above, the following mitigation measures should be put in place:

[5] Best Practice Guidelines:H2 – Pollution Prevention and Minimization of Impacts. Department of Water Affairs and Forestry, July 2008.

- Care should be taken to minimize contamination during the construction of the TSF and its associated services. Fuel and storage and service areas should be bunded to minimize groundwater contamination.
- The TSF facility and its PCDs should be lined with a Class C or GLB- liner
- Potential leakage from infrastructure such as transfer pipe systems and pump station should be minimized. Pipes should be routed above ground in order to detect and limit leaks
- Groundwater monitoring points should be installed in order to monitor the groundwater quality at the TSF as well as the PCDs.
- If contamination is detected, contamination interception measures should be put in place. This should consist of but not be limited to interception trenches (if the groundwater level is shallow enough) or interception boreholes. The water intercepted by these measures should be treated to the RQO of the Elands River before being released into the environment (Table 18)

Table 18: Summary of RQOs for Groundwater in the Crocodile River Catchment - Elands River[6]

Component	Narrative RQO	Indicator Measure	Numerical Criteria
Quantity	Groundwater flow directions in the resource unit should not be reversed from it natural flow directions towards the drainage systems.	Continuous flow measurement at EWR C7.	6.18 % nMAR.
Aquifer	No negative trend between peak drawdowns during dry seasons. Seasonal fluctuation to stay within natural range.	Water level - Depth to Groundwater Level at active monitoring boreholes using Groundwater Monitoring Guidelines*.	
Quality	Groundwater quality should be based on background groundwater quality. Sites that exceed the water use requirement# should not be allowed to deteriorate in water quality. Salinity levels should not increase. Concentrations must	Background water quality per borehole/spring using Groundwater Monitoring Guidelines*. Salts – Electrical Conductivity. Bi-annual monitoring.	Electrical Conductivity ≤ 60 mS/m (based on quality dataset) 2

[6] Department of Water and Sanitation, December 2016. Classes of water resources and resource quality objectives for the catchments of the Nkomati.

Component	Narrative RQO	Indicator Measure	Numerical Criteria
	be maintained a levels to support domestic and ecological water users.		

14 GROUNDWATER MONITORING SYSTEM

14.1 Groundwater Monitoring Network

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

14.1.1 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.

14.1.2 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.

14.1.3 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.

14.1.4 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.

14.1.5 Abbreviated analysis (pollution indicators)

Physical Parameters:

- Groundwater levels

Chemical Parameters:

- Field measurements:

    14.2 pH, EC

- Laboratory analyses:

    14.3 Major anions and cations (Ca, Na, Cl, SO4)

    14.4 Other parameters (EC)

14.4.1 Full analysis

Physical Parameters:

- Groundwater levels

Chemical Parameters:

- Field measurements:

    pH, EC

- Laboratory analyses:

    Anions and cations (Ca, Mg, Na, K, NO3, Cl, SO4, F, Fe, Mn, Al, & Alkalinity) Dissolved Cations in Water (5-10) by ICP-OES (Ca, Mg, Na, K, Fe, Si, Mn), pH, EC, TDS, Alkalinity, Anions by Ion Chromatography (IC) (4 to 6), Hexavalent Chromium (Cr6+), Free Cyanide in water, Ammonia by Ion Selective Electrode, Trace Elements in liquids (>30 elements) by ICP

    ICP-MS (0.001ppm det limit)- including Hg

    Other parameters (pH, EC, TDS)

14.5 Monitoring Boreholes

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."[7]

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[7] Department of Water Affairs and Forestry (DWAF). (1998). Minimum Requirements for the Water Monitoring at Waste Management Facilities. CTP Book Printers. Cape Town.

Currently a monitoring network does not exist for the planned TSF. The recommended boreholes are listed in Table 19 and the areas to site these monitoring boreholes are shown in Figure 17. These boreholes can be utilised for water level monitoring during operations, as well as groundwater quality monitoring after decommissioning of the site.. All of the boreholes should be sited using geophysical methods.

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. A review on the monitoring network should be conducted annually.

Table 19: Proposed Monitoring Positions (New boreholes to be sited using geophysics)

ID	Latitude (South)	Longitude (East)	Owner	Borehole Depth (mbgl)	Reasoning	Frequency	Existing/ New
PROPMON1	-26.0999	28.80192	Bakubung	30-40	Impact Monitoring	Quarterly	New
PROPMON2	-26.0924	28.78402	Bakubung	30-40	Impact Monitoring	Quarterly	New
PROPMON3	-26.0995	28.79728	Bakubung	30-40	Impact Monitoring	Quarterly	New
PROPMON4	-26.0965	28.79587	Bakubung	30-40	Impact Monitoring	Quarterly	New
PROPMON5	-26.1025	28.79169	Bakubung	30-40	Impact Monitoring	Quarterly	Existing

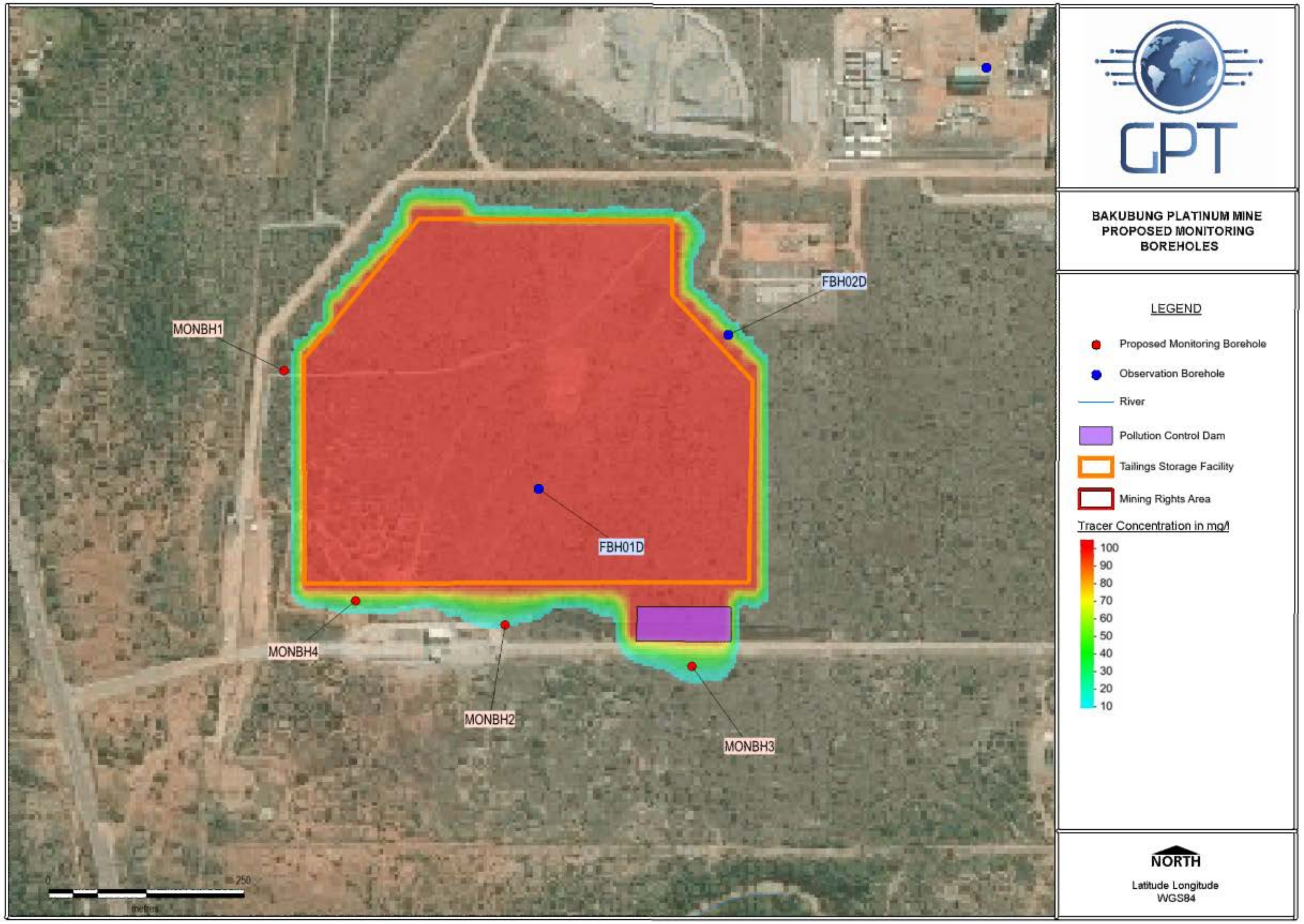

Figure 17: Proposed monitoring positions (new boreholes to be sited by geophysics)

15 CONCLUSIONS AND RECOMMENDATIONS

Geo Pollution Technologies (Pty) Ltd (GPT) was appointed by Knight Piesold (KP) to conduct a groundwater investigation for the proposed Tailings Storage Facility (TSF) Project at the Bakubung Platinum Mine. The report is structured according to the requirements of the GN 267 Annexure D5 and 2.) GN 982 Appendix 6.

The site located approximately 40 km north-north west of Rustenburg, North West Province. The Pilanesberg National Park is located 4 km north of the study area.

The planned TSF site is flat and the surface topography slopes slightly in a southerly direction between elevations 1050 m above mean sea level (mamsl) and 1029 mamsl, a slope of 2.4%. The site is situated within the A22F quaternary catchment

Locally drainage is towards the Elands River that flows from southwest to northeast to the south of the site. On a larger scale, drainage occurs towards the generalised flow of the Crocodile River which flows from south to north towards the Limpopo River.

Climatic data was obtained from the DWS weather station Lindleyspoort Dam (rainfall data and evaporation data). The site is located in the summer rainfall region of Southern Africa with precipitation usually occurring in the form of convectional thunderstorms. The average annual rainfall (measured over a period of 72 years) is approximately 668.2 mm, with the high rainfall months between October and April.

Indicated by the published geological map of the area, Sheet 2526 Rustenburg (1:250 000), the regional area is underlain by gabbro and norite of the Rustenburg Layered Suite, Bushveld Complex, Vaalian Era. A syenite dyke is indicated to the south of the site, while a north west-south east trending fault is indicated to the west of the site.

The local geology was interpreted from the borehole and test pit logs as set out in Appendix C of the Africon report (Wesiziwe Platinum geohydrological evaluation, March 2008). Locally the area is underlain by gabbro-norite of the Rustenburg layered suite and these units outcrop in the areas around drainages where the covering soil layer has been eroded. The soil cover on the site consists of a dark brown to black, firm loamy clay with abundant vegetation roots. This soil is dispersive and expansive and forms large cracks when moisture is driven off. Locally the soil is referred to as black "turf".

According to the 1:500 000 hydrogeological map (Johannesburg 2526) (Figure 5) the area of interest is located on a fractured and intergranular aquifer, with a successful borehole yield of between 0.5 l/s and 2.0 l/s.

A total of 66 boreholes were located during the 2008 hydrocensus, with an additional 15 boreholes being drilled on site by Africon during the 2008 baseline groundwater study. The majority of the boreholes reported a water level depth of between 20 and 30mbgl.The depth to waterlevel in these boreholes varied between 1.43 and 65.18mbgl. Groundwater in the area is mainly used for domestic use and irrigation.

The water quality results for the 6 boreholes drilled by Africon during 2008 are compared with the maximum recommended concentrations for domestic use as defined by the SANS 241-1: 2015 target water quality limits.

From this comparison, the following is evident:

- Fluoride exceeds the allowable limit in sample FBH03D
- Total iron exceeds the allowable limit in samples FBH02D, FBH03D and FBH05S.
- Total manganese exceeds the allowable limit in FBH05S

The GDT calculated a vulnerability value of 43 %, which is medium for the aquifer which is classified as medium. 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.

The conceptual model is a simplified representation of the conditions at and in the vicinity of the TSF and will provide the framework during the development of the risk assessment and numerical flow and transport model. The groundwater flow around the planned TSF is towards the south east to the Elands River. The water levels on the northern western part of the site is shallower than the south eastern area in the vicinity of the river. The average hydraulic conductivity (K) of the clayey soils is in the region of 0.09 m/d. The shallow weathered aquifer has a hydraulic conductivity of between 1.2x10-2 and 5.75x10-5. These values are given in the geohydrological assessment report (Africon 2008) and was measured in situ on site using double ring infiltrometer tests and falling head tests respectively. The K-value for the preferential pathway encountered in MBH04D was 1.47m/d. The higher K-value could act as a preferential pathway for groundwater and contaminant migration.

The following conclusions are drawn from the modelling results:

Minor Liner leakage

- Plume movement is very slow due to the low hydraulic conductivity and flat groundwater level, about 2 meter per year on average.
- At this leakage rate the TSF has limited contamination impact and the plume does not reach the Elands River, even in 100 years.

Major Liner Leakage

- Plume movement has accelerated somewhat to about 4 meter per year due to increased ponding of groundwater underneath the TSF.
- Groundwater contamination from the TSF could now reach the Elands River, albeit in low concentrations and only after 100 years.

No Liner

This option is not considered at this stage, but the results are presented here just for comparative purposes. It nevertheless confirms that an unlined scenario is unfavourable as the plume migration rate is significantly increased due to the increased ponding underneath the TSF.

The proposed TSF locality is suitable, but the integrity of the liner will be important. Only minor leaks can be allowed if no impact on the river is desired.

However, the hitherto unexplained deep groundwater levels could mean that the Elands River is unconnected to the groundwater level. In this scenario, the modelled contamination movement will not reach the river. This is an aspect that is worth further investigation.

From the risk assessment it can be concluded that there are three possible phases where groundwater contamination can occur at the planned TSF. These phases are:

- Construction phase impacts
- Operational Phase Impacts
- Decommissioning Phase Impacts

The possible impacts during all of the phases have also been identified and can be summed up as follows:

- Construction phases impacts Potential hydrocarbon contamination form construction machinery on the site
- Operational Phase Impacts Potential groundwater contamination resulting from liner leaks under the TSF during the operation of the facility
- Operational Phase Impacts Potential groundwater contamination resulting from liner leaks under the TSF during the operation of the facility
- Decommissioning phase impacts Potential groundwater contamination resulting from liner leaks under the TSF after the decommissioning of the facility

In light of the above, the following mitigation measures should be put in place:

- Care should be taken to minimize contamination during the construction of the TSF and its associated services. Fuel and storage and service areas should be bunded to minimize groundwater contamination.
- The TSF facility and its PCDs should be lined with a Class C or GLB- liner
- Potential leakage from infrastructure such as transfer pipe systems and pump station should be minimized. Pipes should be routed above ground in order to detect and limit leaks
- Groundwater monitoring points should be installed in order to monitor the groundwater quality at the TSF as well as the PCDs.
- If contamination is detected, contamination interception measures should be put in place. This should consist of but not be limited to interception trenches (if the groundwater level is shallow enough) or interception boreholes. The water intercepted by these measures should be treated to the RQO of the Elands River before being released into the environment.

15.1 Recommendations

The following actions are recommended:

- Update the numerical and geochemical model against monitored data during operations.
- 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 WUL 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

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APPENDIX I: WASTE CLASSIFICATION

APPENDIX II: NUMERICAL MODEL METHODOLOGY AND SETUP

In this paragraph the setup of the flow model will be discussed in terms of the conceptual model as envisaged for the numerical model, elevation data used, boundaries of the numerical model and assumed initial conditions.

ELEVATION DATA

Elevation data is crucial for developing a credible numerical model, as the groundwater table in its natural state tend to follow topography.

The best currently available elevation data is derived from the STRM (Shuttle Radar Tomography Mission) DEM (Digital Elevation Model) data. The SRTM consisted of a specially modified radar system that flew on board the Space Shuttle Endeavour during an 11-day mission in February of 2000, during which elevation data was obtained on a near-global scale to generate the most complete high-resolution digital topographic database of Earth[8]. Data is available on a grid of 30 metres in the USA and 90 metres in all other areas.

Several studies have been conducted to establish the accuracy of the data, and found that the data is accurate within an absolute error of less than five metres and the random error between 2 and 4 metres for Southern Africa[9]. Over a small area as in this study, the relative error compared to neighbouring point is expected to be less than one metre. This is very good for the purpose of a numerical groundwater model, especially if compared to other uncertainties; and with the wealth of data this results in a much improved model.

[8] http://www2.jpl.nasa.gov/srtm/

[9] Rodriguez, E., et al, 2005. An assessment of the SRTM topographic products. Technical Report JPL D-31639, Jet Propulsion Laboratory, Pasadena, California.

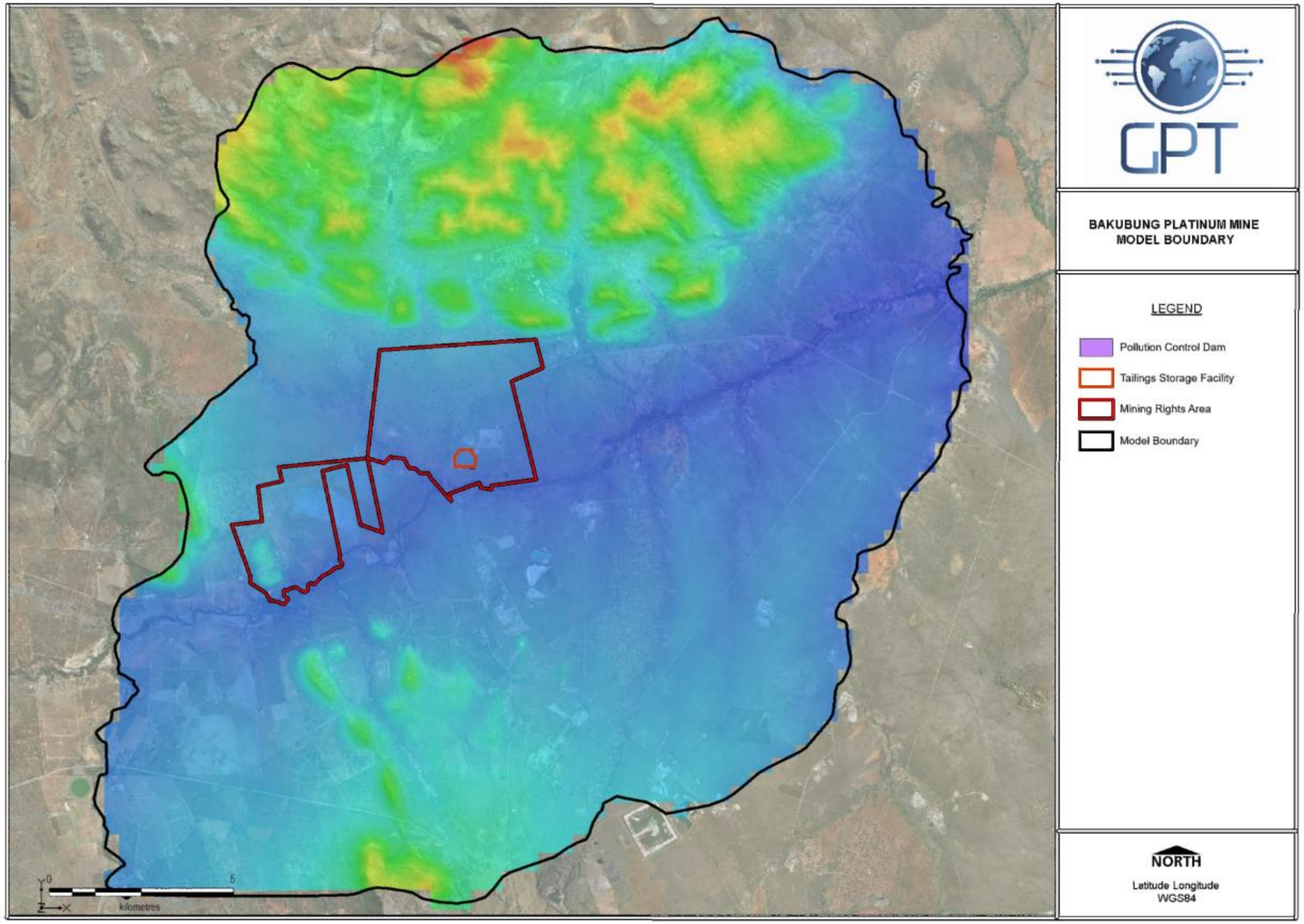

Figure 18: Model Boundaries

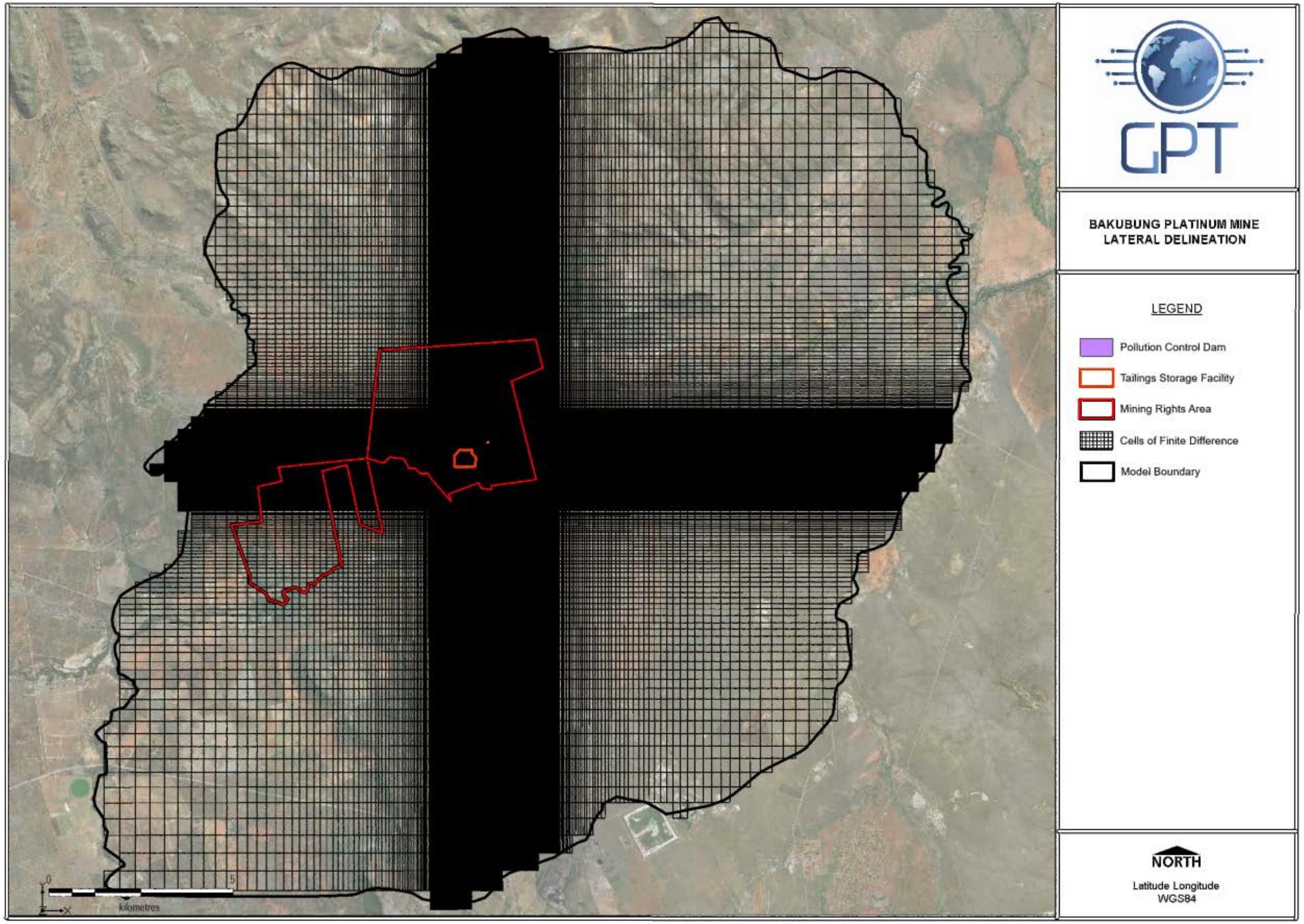

Figure 19: Lateral Delineation of the Regional Model

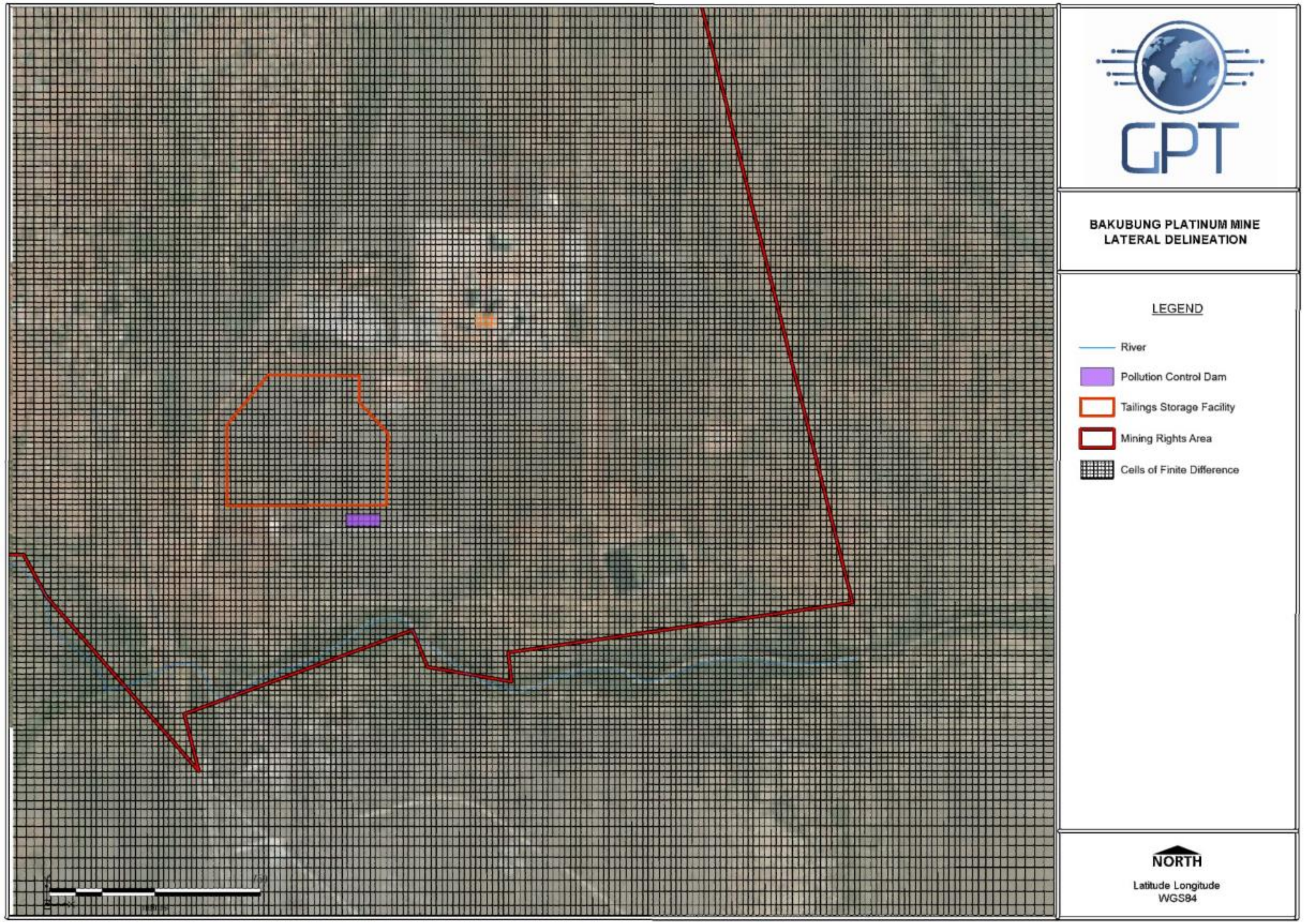

Figure 20: Lateral Delineation In The Mining Area

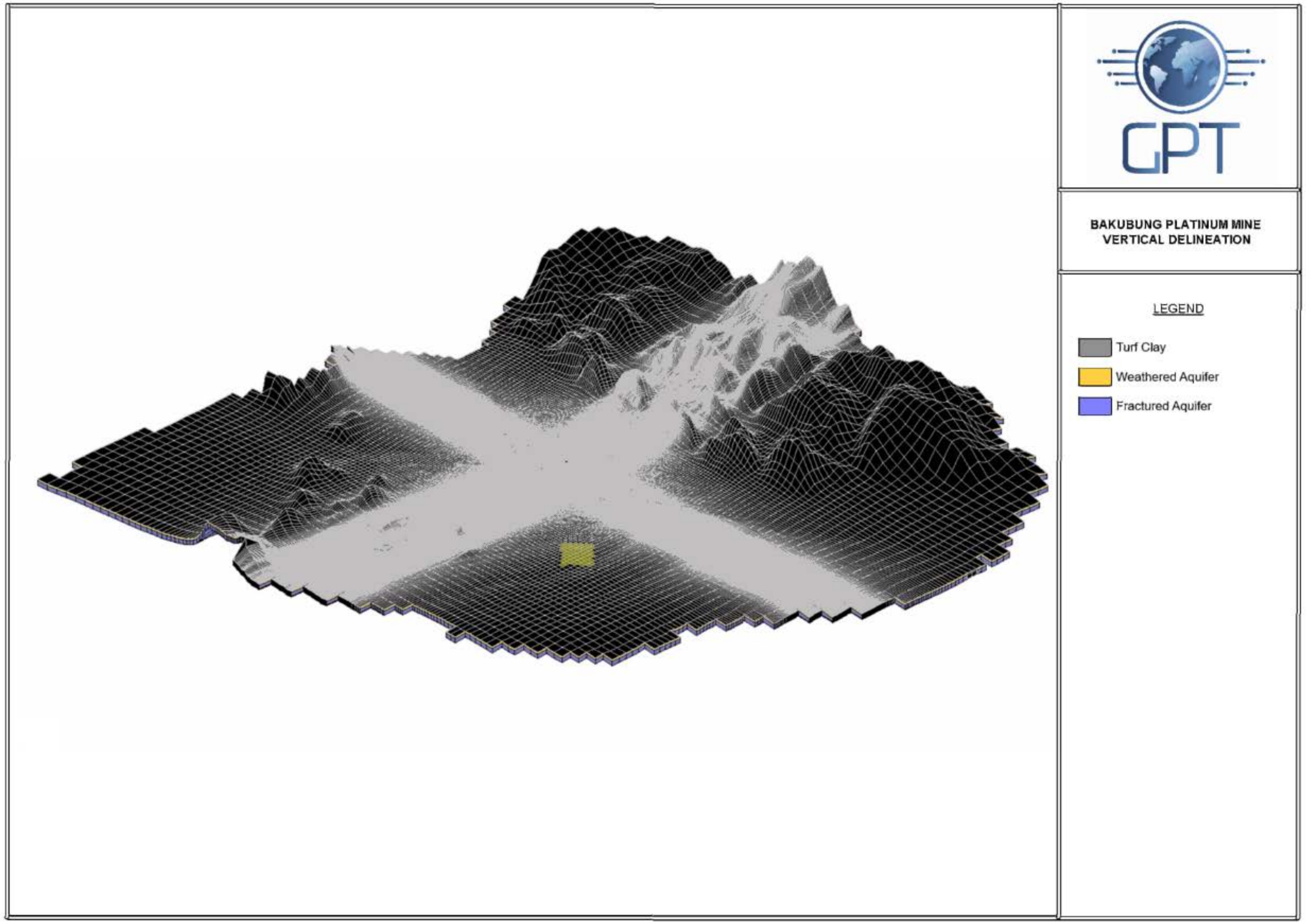

Figure 21: Vertical Delineation of the Modelled Area