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Groundwater Impact Assessment Report for the Weltevreden Project, Xivono Mining (Pty) Ltd

Groundwater Impact Assessment

Prepared for:

Xivono Mining (Pty) Ltd

Project Number:



MBU5710

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EXECUTIVE SUMMARY

Digby Wells Environmental (hereafter Digby Wells) was appointed by Xinovo (Pty) Ltd (hereafter Xinovo) to undertake an Environmental Impact Assessment, Integrated Water Use Licence Application and a Mining Right application for the proposed Weltevreden Coal Mine Project (the Project) of which this groundwater impact assessment forms part. It is proposed to mine coal from two pits, OC1 (162 ha footprint) and OC2 (200 ha footprint) using conventional opencast mining methods.

The site is predominantly underlain by the *Vryheid Formation* with a variable thickness over short distances. Outcrops of quartzite of the *Lakenvlei Formation* and diabase sills are present at the eastern half of the site. The presence of dyke-type intrusions were also observed which will likely follow a southwest to northeast orientation.

Geophysical survey lines were interpreted, four drill targets were selected and subsequently four aquifer test/monitoring boreholes were drilled and tested for aquifer parameterisation. Aquifer test results showed that hydraulic conductivities of the weathered and the top of the fractured aquifer is generally low, in the range of 10^{-1} - 10^{-3} m/d, in range of expected values for the Karoo aquifers.

In general groundwater levels are shallow, mostly less than ~10 meters below ground level (mbgl) near the site and mainly located within the shallow weathered aquifer. Groundwater levels mainly follow topography and the main surface water drainage directions with the main groundwater flow direction to the south towards the Nkomati River.

The groundwater in the area is predominantly of a Mg-HCO₃ type, with a few instances of Ca-HCO₃ and Na-SO₄, Na-Cl and Mg-Cl. The groundwater in the area is of good quality with no parameters exceeding any of the limits as per the SANS and WHO drinking water guidelines.

The following aquifer units were discerned in the conceptual model: shallow weathered and fractured rock aquifer units in the Karoo sedimentary lithologies and in the *Dwyka* and *Lakenvlei Formations*. Locally dolerite or diabase sills outcrop at surface where poor aquifers form due to low to moderate weathering of the sills.

The weathered aquifer units are mainly the sandstone, siltstone and shale of the *Vryheid Formation*, quartzite of the *Lakenvlei Formation* and dolerite sills. At the site the weathered rocks are predominantly overlain by orthic soil types and hydromorphic soil types mainly related with wetlands.

The weathered zone depth at the site is expected to be between 3-20 mbgl with an average of ~8 mbgl and hydraulic conductivities in the range of 10^{-1} - 10^{-2} m/d. The fractured rock units mainly consist of the fractured *Vryheid Formation* and pre-Karoo Formations with hydraulic conductivities for the fractured zone in the order of 10^{-2} - 10^{-3} m/d.

Recharge values for Karoo lithologies are generally low, mainly between 1-3% of mean Annual Precipitation (MAP). Recharge rates for the *Vryheid*, *Dwyka*, *Lakenvlei Formations* and sills in the conceptual model are all expected to have relatively low recharge rates with values ranging between ~0.5 to 1.5% of MAP.

Impacts on the groundwater environment, as a consequence of the proposed mining activities will be based on the source-pathway-receptor approach, in which the potential sources for contamination or other impacts will be determined, the routes through which potential impacts, such as contaminants, could migrate from the sources and the receivers of potential impacts. Based on the results from the baseline assessment the following sources, pathways and receptors were discerned:

- Groundwater sources: seepage from the opencast pits into the surrounding aquifer post-closure after the mine dewatering has ceased; and infiltration of contaminated water from the hards stockpiles into the underlying aquifer through recharge infiltrating into the waste rock;
- The pathway: the primary pathway for seepage from the opencast pits and the hard stockpile is the weathered and fractured rock units of the *Vryheid Formation* and faults and fractures that are sufficiently permeable (effectively porous) to allow water flow; and
- Groundwater receptors are mainly third-party groundwater users and groundwater dependant wetlands and streams in the vicinity of the site.

A numerical model was constructed for the Project consisting of three layers to allow for discretisation between the weathered and fractured lithologies. After model calibration a correlation of 96% was obtained between the simulated and observed groundwater elevation (Figure 7.3). The calibration was deemed acceptable with a Mean Residual Head of 0.7, a Mean Residual Absolute Head of 4.9 and a Root Mean Square Error (RMSE) of 5.6.

The following conclusions were made for the site:

- The potential cone of drawdown during the operational phase is largest at the end of life of mine and extends to a maximum radius of ~200 m around the opencasts. The relatively small cone of drawdown is due to the overall shallow depths of the No. 2 coal seam;
- During steady state production the groundwater inflows will likely be in the range of ~500 to ~1 500 m³/d. Most of these abstraction volumes will be drawn from the pit areas and as such the impact on groundwater availability will be minor;
- Based on the simulations no third-party sources, wellfields or other groundwater abstractions are present within the zone of influence. Therefore, it is unlikely there will be an impact on third party abstraction sources by lowering of water levels due to the dewatering activities;
- During the Operational Phase groundwater flow directions will be directed towards the mining areas due to the mine dewatering. Therefore, contamination during the operational phase will be contained within the mining area, and little contamination will be able to migrate away from the mining area

- The limited drawdown impacts as a consequence of the relatively shallow pit depths is expected to result in a minor impact due to the scale and it is unlikely there will be an impact on third party abstraction sources;
- Groundwater levels in the vicinity of the site are expected to take approximately 80 years to recover Post-Closure. However, due to the limited scale of the drawdown cone it is expected that the long-term recovery will have a minor impact;
- It is unlikely that any other privately-owned boreholes or the spring located in the vicinity of the proposed development will be impacted upon. The contaminant migration indicates that the plumes will flow towards and following local drainage lines located between and to the west and the east of the opencast pits.
- The drainage line between the two pits is expected to receive an increased salt load from the contaminant plumes. This is expected to have a moderate impact on the drainage line and associated unchanneled valley bottom wetland;
- Decant from OC1 will flow towards the tributary east of the pit; the decant from OC2 will flow towards the tributary west of the pit. Based on the calculated decant volumes and expected quality of the potential decant indicates a moderate impact if decant would occur and is not mitigated against. Any potential decant flows from the opencast pits should be captured and treated.

The following recommendations are made:

- The waste and coal materials are classified as a Type 3 waste and disposal of the material should therefore be done to a Class C landfill facility or a facility with a similar performing liner system;
- The development of a closure water management plan that assesses the management of a critical water level to minimise contamination of the shallow weathered aquifer. This must be analysed in a financial model to further inform the most effective closure water management options. The groundwater model must be used as a management tool to inform this process;
- Minimise the mining footprint, progress the mining activities as quickly as possible, and cease dewatering activities as soon as possible after mining has been completed;
- Flood the opencast areas as soon as possible to restrict oxygen ingress into the backfill and lower sulphate levels in seepage;
- Monitoring of groundwater abstraction volumes and the rate of water level recovery in the backfilled opencasts and the development of stage curves which will aid in water management during the Post-Closure Phase;
- Installation of a groundwater and surface water monitoring network, with frequent surface and groundwater quality monitoring for the operational phase, and to continue into the post-closure phase, to be able to discern trends in surface water quality;

- If proven that any third-party boreholes will be affected by the mining activities an alternative water supply must be provided;
- Updating of the numerical model once every two-three years or after significant changes in mine schedules or plans by using the measured water ingress and water levels to re-calibrate and refine the impact predictive scenario.
- Options to prevent decant flow from the pits, such as pump and treat, must be considered, alternatives compared and included in a closure plan.

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LIST OF ABBREVIATIONS

Abbreviation	Description
ABA	Acid Base Accounting
AG	Acid Generating
AMD	Acid Mine Drainage
AP	Acid Potential
ARD	Acid Rock Drainage
BH	Borehole
Coeff. Var.	Coefficient of Variance
DEA	Department of Environmental Affairs
DMR	Department of Mineral Resources
DW test	Reagent (Distilled) Water test
DWS	Department of Water and Sanitation
EAP	Environmental Assessment Practitioner
EC	Electrical Conductivity
EIA	Environmental Impact Assessment
EM	Electro Magnetic geophysical survey
EMP	Environmental Management Plan
EMPr	Environmental Management Programme report
ESIA	Environmental and Social Impact Assessment
GMWL	Global Meteoric Water Line
GPS	Global Positioning System
He	Hectares
Hz	Hertz
ICP	Inductively Coupled Plasma
ICP-OES	Inductively Coupled Plasma Atomic Emission Spectroscopy
IPP	Independent Power Producer
IWULA	Integrated Water Use License Application
k	Hydraulic conductivity
kh	Horizontal hydraulic conductivity
kv	Vertical hydraulic conductivity

Abbreviation	Description
km	kilometre
ktpm	Kilotonees per month
L/h	Litre per hour
L/s	Litre per second
LC	Leachable Concentration
LCT	Leachable Concentration Threshold
LoM	Life of Mine
m amsl	metres above mean sea level
m bgl	metres below ground level
m ³	cubic metre
MAE	Mean Annual Evaporation
Mag	Magnetic geophysical survey
mamsl	Meters above mean sea level
MAP	Mean Annual Precipitation
mbgl	Meters below ground level
mg/l	milligrams per litre
mm	millimetre
mm/a	millimetre per annum
ms	milli-seconds
mS/m	milli Siemens per metre
Mtpa	Million ton per annum
NAG	Net Acid Generating
NEMA	National Environmental Management Act, 1998
NEMWA	National Environmental Management: Waste Act, 2008
NNP	Net Neutralising Potential
NP	Neutralising Potential
NPR	Neutralising Potential Ratio
nT	nanoTesla
NTU	Nephelometric Turbidity Units
PAG	Potential Acid Generating
PAN	Potential Acid Neutralising

Abbreviation	Description
PCD	Pollution Control Dam
RMSE	Root Mean Square Error
S	Storativity
SANAS	South African National Accreditation System
SANS	South African National Standards
SPLP	Synthetic Precipitation Leaching Procedure
SS	Sulphide-Sulphur
St. Dev.	Standard Deviation
Sy	Specific yield
T	Transmissivity
T	Transmissivity
TC	Total Concentration
TCT	Total Concentration Threshold
TDS	Total Dissolved Solids
UTM	Universal Transverse Mercator
WHO	World Health Organisation
WMA	Water Management Area
WRD	Waste Rock Dump
wt. %	Weight percentage
XRD	X-Ray Diffraction
XRF	X-Ray Fluorescence

1 Introduction

Digby Wells Environmental (hereafter Digby Wells) was appointed by Xinovo (Pty) Ltd (hereafter Xinovo) to undertake an Environmental Impact Assessment, Integrated Water Use Licence Application and a Mining Right application for the proposed Weltevreden Coal Mine Project (the Project) of which this groundwater impact assessment forms part. It is proposed to mine coal at the project site mine from two pits, OC1 (162 ha footprint) and OC2 (200 ha footprint) using conventional opencast mining methods.

Xivono intends to convert their approved Prospecting Right through completing a Mining Right Application (MRA) in terms of the Minerals and Petroleum Resources Development Act, 2002 (Act No. 28 of 2002) (MPRDA). Concurrently, Xivono will initiate this Integrated Environmental Authorisation and Water Use Licence Application (WULA) process for the MRA to comply with the:

- National Environmental Management Act, 1998 (Act No. 107 of 1998) (NEMA);
- National Environmental Management: Waste Act, 2008 (Act No. 56 of 2008) (NEM: WA); and
- National Water Act, 1998 (Act No. 36 of 1998) (NWA).

The Groundwater Impact Assessment will form part of an Environmental Authorisation (EA) application process in terms of the National Environmental Management Act, 1998 (Act No. 107 of 1998) (NEMA) for the proposed mining activities. Below, a general description of the proposed activities, the methodology, the baseline groundwater assessment, the results for the groundwater modelling and the impact assessment are described.

2 Project Description

The proposed Project Site is located within the eMakhazeni Local Municipality, situated in the Nkangala District Municipality in the province of Mpumalanga. The closest town is Belfast which is approximately 6 km north of the proposed Project Area (Figure 2-1).

The Prospecting Right includes Portions 28, 29, 30 and 40 of the farm Paardeplaats 380 JT, as well as, Portion 2, 3, 10, and Portion of Portions 4, 7, 9, 11, 12, 14 and the Remaining Extent of the farm Weltevreden 381 JT. The Prospecting Right is divided into an east and west section by the R33 which runs in a north-south direction through the site. The proposed Mining Right Area (the Project Area) will only include the farm portions west of the R33 (Figure 2-2). The eastern portion will not be mined nor accommodate any mining-related infrastructure.

Xinovo plans to utilise containers for the mine offices and workshop infrastructure which will occupy a footprint of approximately 0.03 ha (300 m²). Other surface infrastructure proposed for the site includes a pollution control dam (PCD), crushing and screening plant (no washing to take place on site), Run of Mine (RoM) pad, overburden dump, stockpiles, pipelines and lined trenches. The surface infrastructure is expected to have a footprint of approximately 1 ha

(Figure 2-2). It is proposed to mine coal at the project site mine from two pits, OC1 (162 ha footprint) and OC2 (200 ha footprint) using conventional opencast mining methods. The drilling programme showed coal to be present on the north-and southwestern parts of the site. The targeted coal seams for the mine are the No. 2, 3, 4S and 4L seams, with anticipated mining of the No. 2 Seam in OC1 at the south-western part of the site and mining of the No. 2, 3, 4S and 4L Seams in OC2 at the north-western part of the site (Figure 2-3, depth in meters above mean sea level (mamsl)) which are planned to be mined over a Life of Mine (LoM) of 10 years (Figure 2-4). Processing of coal will be carried out on-site and auxiliary infrastructure including a RoM pad, waste rock (hards stockpiles), topsoil dumps and PCDs are proposed.

To attain the required authorisation for the proposed Project a detailed Groundwater Impact Assessment study is required and will provide baseline environmental background (define the groundwater system of the area) and identify and assess potential groundwater impacts that may arise from the proposed development and its associated activities. The objectives of this groundwater specialist report are:

- Carry out a hydrocensus survey and groundwater sampling;
- Baseline groundwater environment description, including:
 - Climate;
 - Topography and drainage;
 - Regional and local geology; and
 - Site Hydrogeology;
- Environmental sensitivity screening;
- Intrusive Fieldwork;
 - Geophysical Surveying of the Project Area;
 - Borehole drilling and supervision;
 - Aquifer testing of hydrogeological boreholes;
- Geochemical assessment and waste classification;
- Setup of a site conceptual hydrogeological model;
- Perform numerical modelling of potential impacts; and
- Carry out a groundwater impact assessment and describe potential mitigations;
- Propose a groundwater monitoring network.

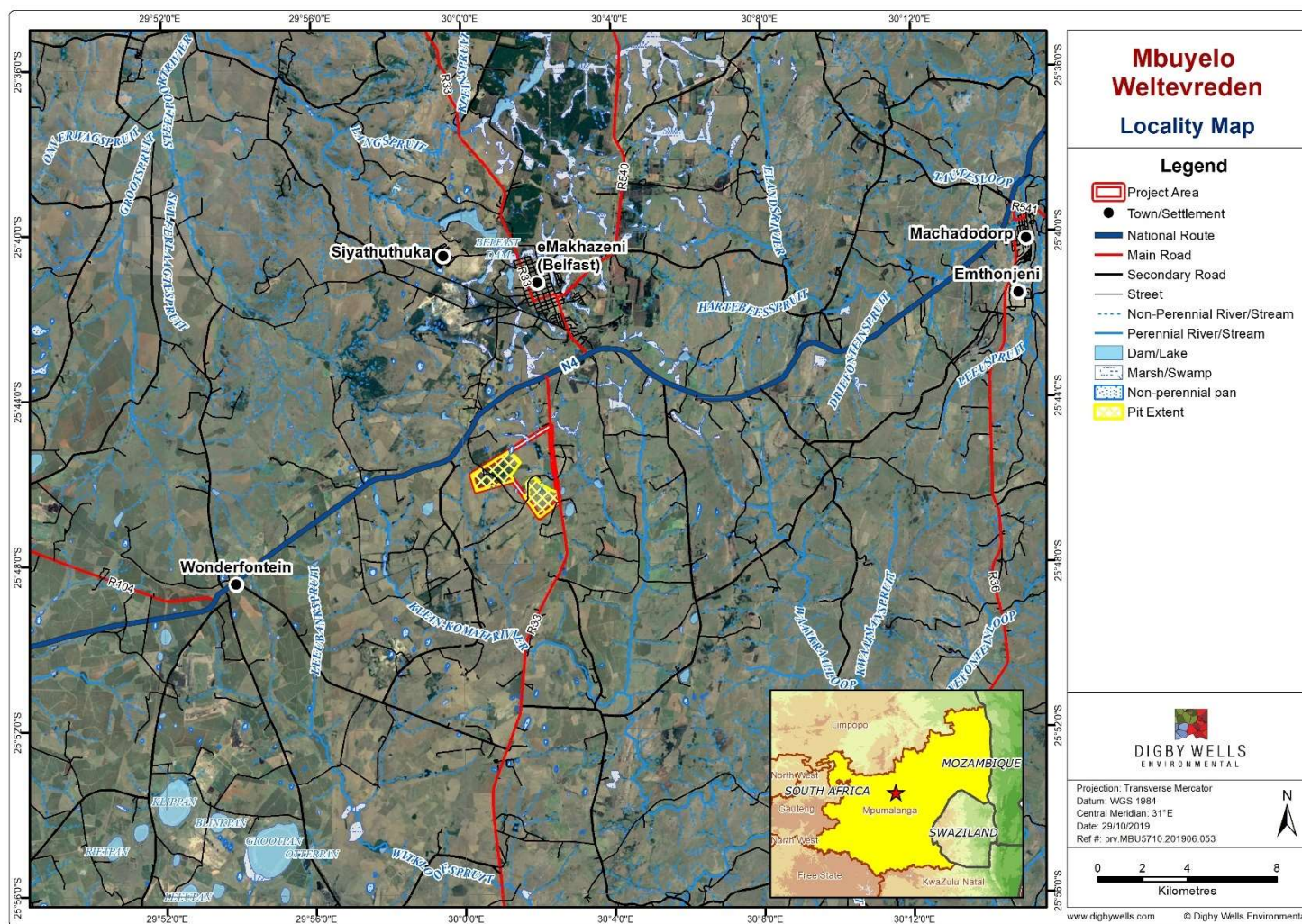


Figure 2-1: Project Location

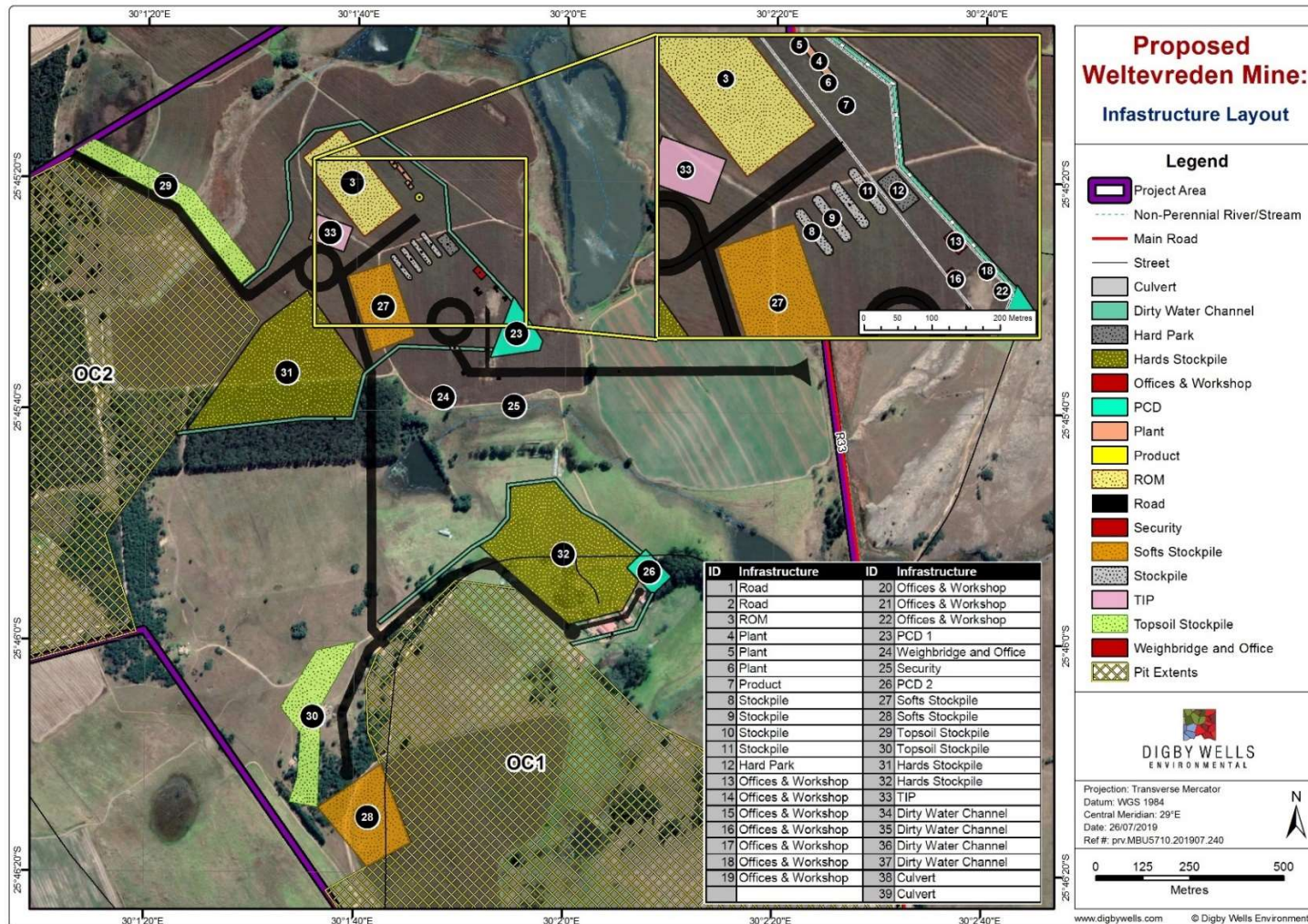


Figure 2-2: Site Layout Showing the Proposed Areas and Surface Infrastructure.

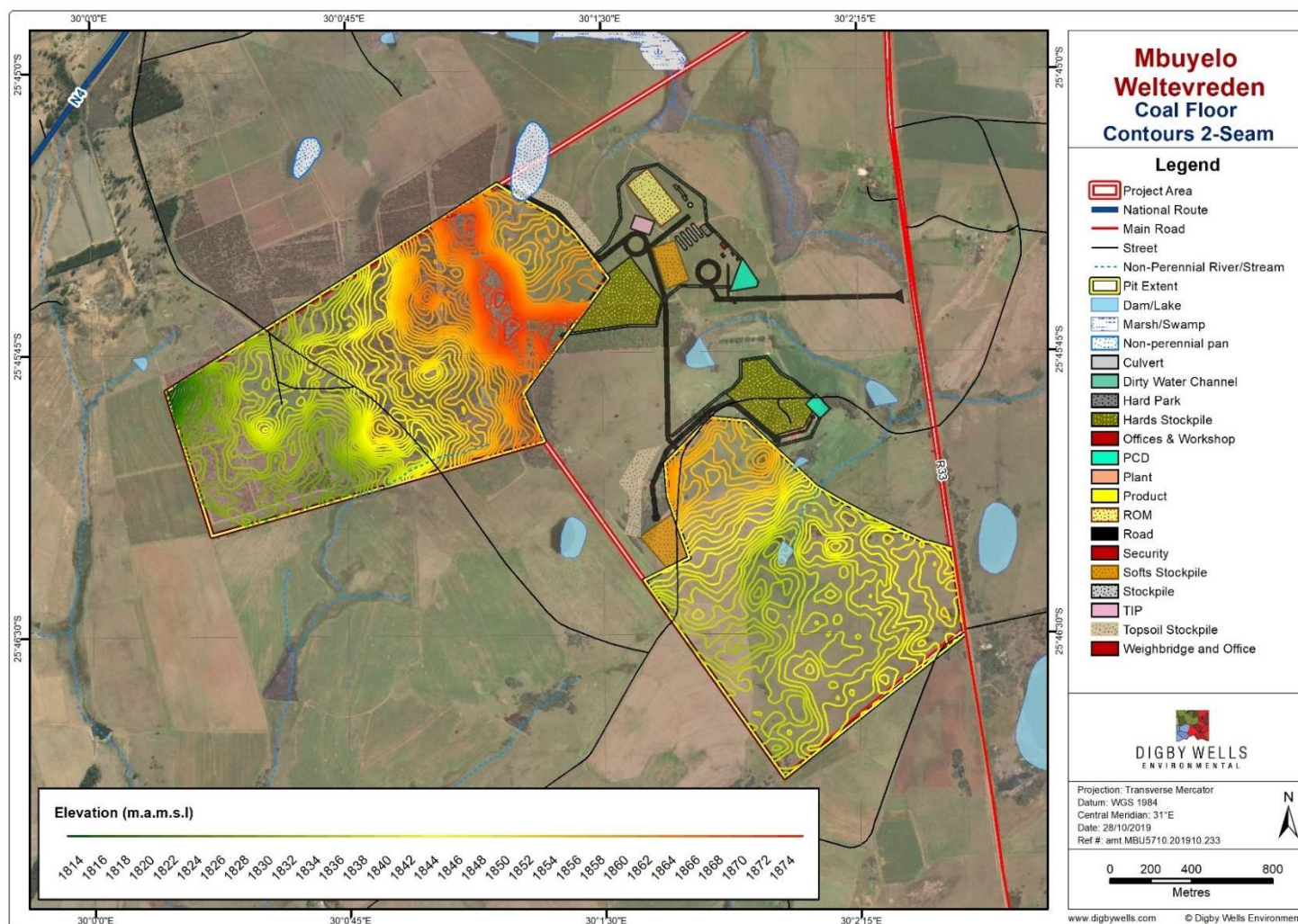


Figure 2-3: Coal Floor Elevation Contours for the No. 2 Seam (mamsl)

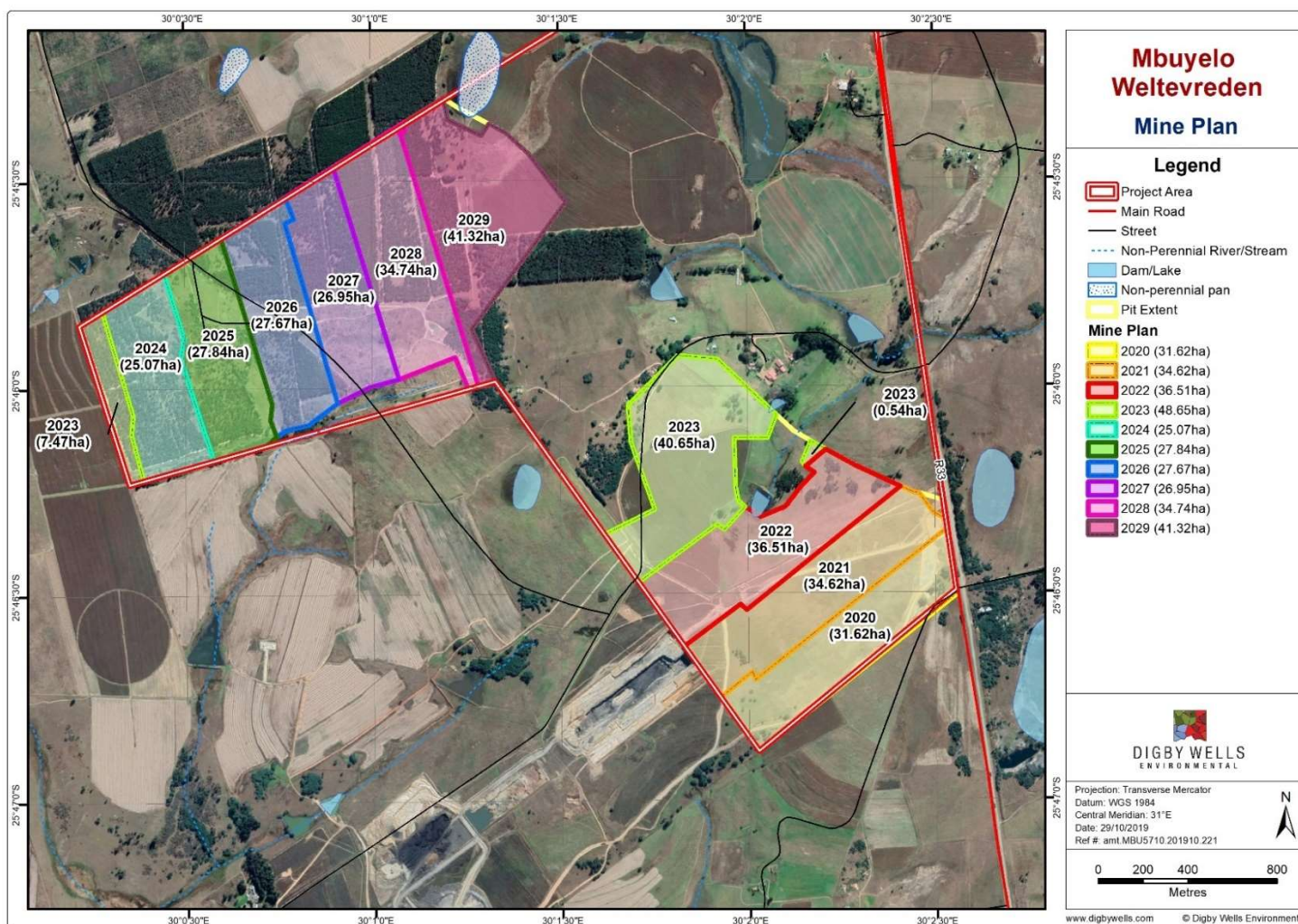


Figure 2-4: Yearly Mine Plan

Methodology

2.1 Baseline Assessment

In depth analyses of all relevant and available secondary data such as reports, data sheets, proposals and maps were utilised to compile a baseline site description that will feed into the EIA specialist report. Part of the assessment was to collate all background information and carry out preliminary fieldwork.

2.1.1 Hydrocensus

A hydrocensus survey was conducted from the 29th of April to the 1st of May 2019. The survey was undertaken to provide an insight in the baseline hydrogeological conditions at and around the proposed Project Site. The survey included visits to communal water supply boreholes, private boreholes and springs.

A total of 22 water supply boreholes and one (1) spring were identified. The following information was collected at each of the field sites (where possible):

- Sampling coordinates (X, Y and Z position);
- Static (or rest) water level;
- Primary groundwater (borehole) use; and
- Field pH, EC and TDS values.

2.1.1.1 Groundwater Sampling

A total of 13 samples were collected for water quality analysis (Section 3.5.4). Samples were collected at 9 third party boreholes and 4 aquifer test/monitoring boreholes. Samples were couriered and submitted to Waterlab laboratories (a SANAS accredited lab) for analysis. The information listed above will be used to define the groundwater baseline condition and will be used as a reference for future water monitoring and impact assessments. The analysis was performed for inorganic constituents such as major cations, anions and metals as show in Table 2-1.

Table 2-1: Analysed parameters

Physical parameters	Nutrients	Dissolved anions	Dissolved metals	Others
pH	Ammonia-N	M Alkalinity	ICP-OES (i.e. major, minor and trace metals)	Total cations
EC in mS/m	Nitrate-N	P Alkalinity		Total anions
Total Suspended Solids	Nitrite-N	Bromide (Br)		% error
Total Dissolved Solids	Total Phosphate (P)	Chloride (Cl)		Total Balance
		Fluoride (F)		Total hardness

Physical parameters	Nutrients	Dissolved anions	Dissolved metals	Others
		Sulphate (SO ₄)		Ca hardness
				Mg hardness

2.1.1.2 Water Level Measurements

The groundwater levels were measured by using a dip meter for identified boreholes. Static groundwater levels were measured through measuring the distance between the borehole collar level on surface and the water table depth within the borehole. The height of the borehole collar was then subtracted from the measured groundwater level to determine the exact groundwater level in metres below ground level (mbgl). The mbgl measurement was subsequently subtracted from the borehole's surface elevation to use a universal unit of metres above mean sea level (mamsl) for all measurements.

2.2 Environmental Sensitivity

Based on the groundwater characteristics, the environmental sensitivity will be qualitatively described for the Project Area and will guide the placement of infrastructure and activities. The sensitivity analysis will include interactions with ecology and hydrology as there are linked to the groundwater environment.

2.3 Fieldwork

Intrusive fieldwork was carried out for the characterisation of the underlying aquifers and to obtain parameters to enable the construction of a conceptual model and to carry out numerical modelling of potential impacts. The fieldwork included the following.

2.3.1 Geophysical Survey

A geophysical survey was carried out between 21st and 26th April and between 13th and 14th June 2019 to identify any anomalies or structures at the Project Area that could indicate aquifers and/or preferential groundwater flow paths. Based in the geophysics results, drill targets were generated to drill aquifer test/monitoring boreholes. The two geophysical methods used were the electromagnetic (carried out by EM34) and magnetic (carried out by Geotron G5) surveys. A total of six (6) survey lines of between 300 m and 1.1 km in length were carried out on site based on the preliminary site layout to site aquifer test/monitoring boreholes.

2.3.1.1 Borehole Drilling

Four (4) aquifer test/monitoring boreholes were drilled in the pit areas to allow for aquifer parameter estimations. The boreholes were drilled into the Karoo lithologies to allow for testing of these hydrostratigraphic units, from which most of the groundwater inflow is expected. The boreholes were drilled at 165 mm (6.5") and installed with plain/slotted casing at 114 mm

(4.5"). The drilling was carried out by SureFocus Drilling. Digby Wells carried out drilling supervision.

2.3.1.2 Aquifer Testing

The boreholes were aquifer tested using submersible pumps. The testing was carried out by In Situ Groundwater Services. Digby Wells carried out aquifer test supervision and interpreted the test data to derive aquifer parameters.

2.3.2 Geochemical Assessment and Waste Classification

Footwall and hanging wall rock and coal samples were collected during drilling of the aquifer test/monitoring boreholes to undertake geochemical testing. In total 6 samples were collected and submitted for geochemical characterisation. The following characterisation tests were conducted:

- Standard static geochemical tests, including:
 - Acid Base Accounting (ABA), sulphur speciation, net acid generation (NAG), paste pH; and
 - Mineralogical (XRD) and elemental composition (XRF).
- The following leach tests as per the National Environmental Management: Waste Act:
 - The Distilled/Reagent water leachate (DW) tests were done to simulate the heavy metal and anion leachate potential of the waste material and waste water left in-situ under normal conditions, with only neutral water allowing leaching to occur. The distilled/reagent water tests were used to evaluate the leachability of materials that will be disposed. Major ions and dissolved metals in each of the leachate tests were quantified.
 - Total concentration values were determined by the aqua regia digestion method to determine the complete chemical make-up of the material before being leached or altered.

2.3.3 Site Conceptual Hydrogeological Model

A conceptual model was developed for the Project using all available information including the baseline assessment, the hydrocensus investigation, water sampling results and mine plans and schedules, as well as the regional geological and hydrogeological setting. The model aims to describe the groundwater environment in terms of the source-pathway-receptor approach:

- Groundwater sources:
 - Precipitation, evapotranspiration;
 - Recharge and discharge areas; and
 - Hydro-chemical contribution to the local aquifer.
- The pathway:

- Aquifers - these are rock units or open faults and fractures within rock units that are sufficiently permeable (effectively porous) to allow water flow;
- Boundaries that result in the change or interruption of groundwater flow;
- Hydro-stratigraphic units - these are formations, parts of formations, or a group of formations displaying similar hydrologic characteristics that allow for a grouping into aquifers and associated confining layers; and
- Groundwater receptors:
 - These include the groundwater users, streams and natural ecosystem that depend on the groundwater.

2.3.4 Numerical Modelling

MODFLOW is internationally recognised groundwater model published by the U.S. Geological Survey and is commonly used by groundwater specialists and environmental scientists. The same software will be used in the updating of the model, utilising the GMS 10.4.2 GUI.

The potential contaminant plumes originating from the various mining activities were simulated using the transport module MT3DMS. MT3DMS is utilised for the simulation of advection, dispersion, and chemical reactions of dissolved constituents in groundwater systems. MT3DMS will be used in updating the existing model in conjunction with MODFLOW in a phased flow and transport simulation approach. The numerical model was used to predict the potential mine impact on the groundwater environment for the construction, operational and post-closure phases.

2.3.5 Impact Assessment

A groundwater impact assessment was carried out based on the outcome of the numerical model, and recommended mitigation measures were given that may be necessary to address groundwater impacts associated with the Project on the environmental receptors, including private boreholes.

The final task of the study was to define a network of observation points and implement a monitoring program that would satisfactorily monitor groundwater conditions (levels and quality) before and after commencement of operations. Existing boreholes drilled during the investigations were identified and additional sites were proposed.

3 Baseline Groundwater Environment

3.1 Climate

The area in which the Project is situated is characterised by warm and temperate climate with dry winters and warm summers. The precipitation of the driest month in winter is less than 1 tenth of the wettest month precipitation in summer (Cannon, 2011). The Mean Annual Precipitation (MAP) of region is 742 mm which is likely to be distributed as indicated in Figure 3-1. The normal rainfall (90% of the event) for the wettest month will likely not exceed 70 mm, while extreme rainfall (10% of the events) will likely not exceed 212 mm. This implies the region experiences high to moderate rainfall.

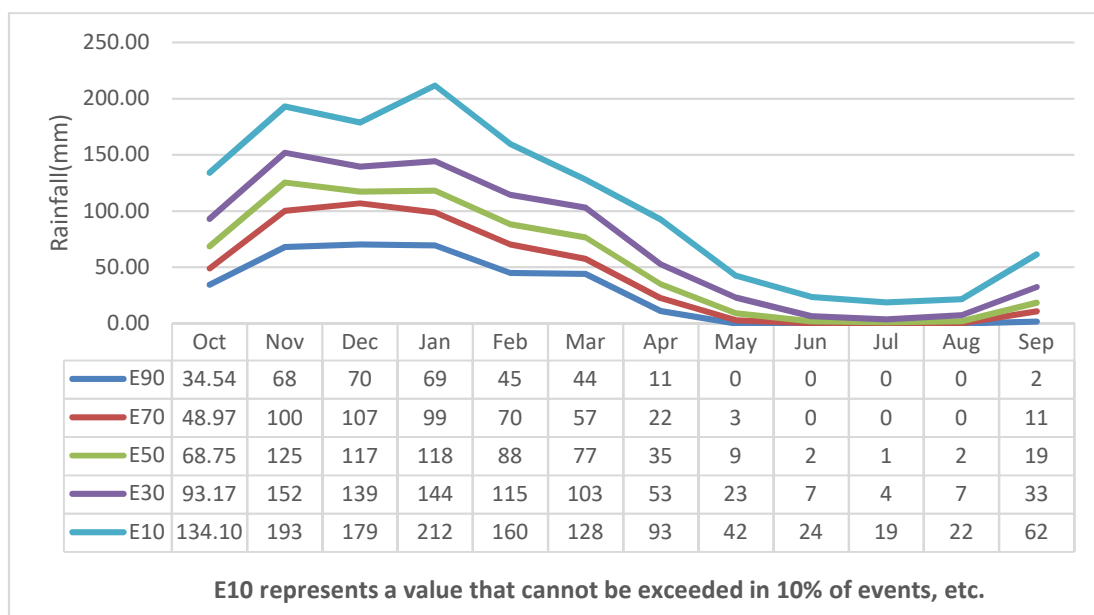


Figure 3-1: Monthly Rainfall distribution for quaternary X11D

3.2 Topography and drainage

The topography of the Project **site** shows higher elevations along the western, northern and eastern site boundaries with gentle slopes ranging directed towards the south-south-eastern part of the site. Elevations range between ~1905 and 1805 mamsl with highest elevations at the north-western part of the site and lowest elevations at the south-eastern part of the site.

The **site** is situated just south of a major catchment divide between the Olifants and Nkomati River. The site is situated within the X11D quaternary catchment which is part of the Nkomati River catchment. Perennial Streams are present at about a 5 km distance west and east of the site, most notably the Klein-Komati and Waarkraalloop streams which flow in a southerly direction. The streams join the **Komati** River about 17 km south-southeast of the site flowing in an eastward direction.

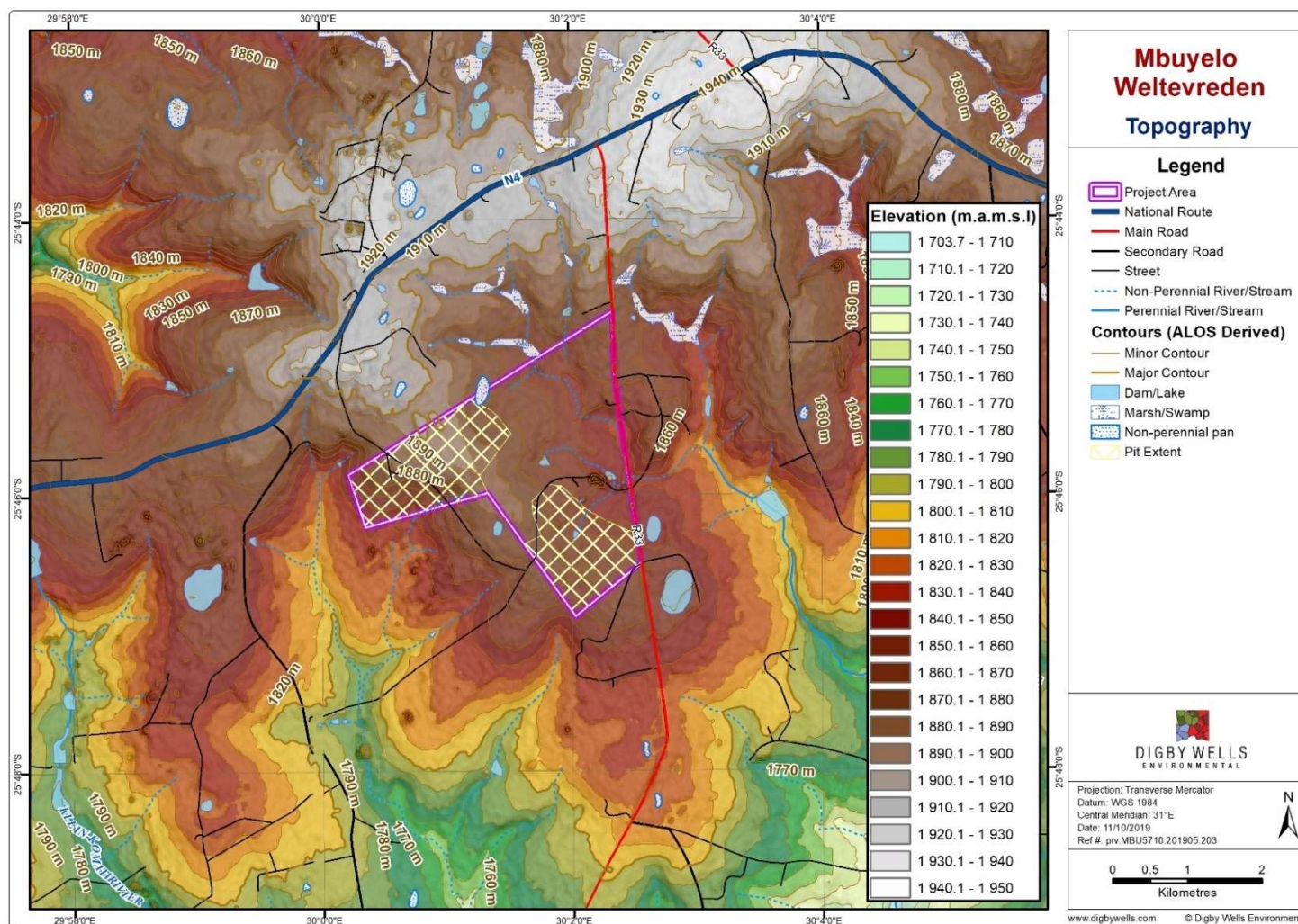


Figure 3-2: Topographical Map

Drainage on-site follows the general topography and consists of a number of farm dams interconnected by two non-perennial streams. These streams flow across the eastern part of the site in a general north to south-eastern orientation (Figure 3-2). The non-perennial streams join and flow off-site near the south-eastern site corner and flow into the Klein-Komati stream south of the site.

3.3 Geology

3.3.1 Regional geology

The site is situated along the northern boundary of the Karoo basin where the major lithostratigraphic units of the Karoo Supergroup crop out. The major formation underlying the Project Area is the *Vryheid Formation* which in the Project Area pinches out towards the north. The uneven pre-Karoo topography along the northern margin of the basin, where the formation overlies the *Dwyka Group* or pre-Karoo rocks, gives rise to marked variations in thickness (Johnson et. al, 2006).

The *Vryheid Formation* consists of alterations of sandstone, siltstone, mudstone, shale including a number of coal seams which are the primary target for coal mining in the area. As the *Vryheid Formation* regionally pinches out towards the north, pre-Karoo rocks outcrop at surface in the region. Generally, the higher topography is underlain by sedimentary rocks of the *Vryheid Formation* whereas the lower lying areas, where these sediments have been eroded away, exposes the pre-Karoo (predominantly metasedimentary) rocks or diamictites of the *Dwyka Group*.

The Project Area is underlain by pre-Karoo rocks with a general SW-NE orientation which mainly belong to the Pretoria Group:

- Steenkampsberg Formation - quartzite with interlayered arenite, shale and conglomerate;
- Nederhorst Formation - hornfels overlain by arenite;
- Lakenvlei Formation - felspathic quartzite with conglomerate and grit;
- Vermont Formation - hornfels with layers of silt and sandstone, carbonate and calc-silicate rocks;
- Magaliesberg Formation - quartzite with some shale layers; and
- Lydenburg member of the Silverton Formation (shale and mudstone with interlayered carbonate layers).

The geological map furthermore indicates potential faulting and/or dykes in a SW-NE orientation and local outcrops of sill-type diabase intrusions.

3.3.2 Local geology

The site itself is predominantly underlain by the Vryheid Formation. Exploration drilling at the site indicates the thickness of the Vryheid Formation is highly variable over short distances with depths between 21 and 81 mbgl for the north-western part of the site and between 16 and 47 mbgl for the south-western part of the site.

The targeted coal seams, as part of the Vryheid Formation, are the No. 2, 3, 4S and 4L seams with the No. 2 seam identified at the south-western part of the site and the No. 2, 3, 4S and 4L seams identified at the north-western part of the site. Depth to coal within the OC1 and OC2 opencast pits are between 12 and 54 mbgl, with the deepest point towards the northern site boundary, and between 6 and 38 mbgl, with the lowest point along the south-western site boundary.

The Vryheid Formation is unconformably underlain by diamictite of the *Dwyka Group*, which in turn unconformably overlies Pre-Karoo rocks and diabase intrusions. It outcrops at surface to the west of the site and was intercepted at depth in most exploration holes.

Based on the exploration borehole logs lithologies underlying the Vryheid Formation were identified as diabase, granite and quartzite. Diabase is similar to dolerite and rocks of this nature indicate sill-type intrusions that occur mainly along bedding planes in the Karoo lithologies and at the contact between Karoo and pre-Karoo rocks. Sill type intrusions were also indicated on geological maps at surface north and northeast of the site (Figure 3-3). Based on the regional geology the presence of basement granites near the site is unlikely, and it could be that coarse-grained diabase or dolerite was interpreted as being granitic rock.

Outcrops of quartzite of the Lakenvlei Formation and diabase sills are present at the eastern half of the site, and exploration drilling shows quartzite underlying the Karoo lithologies along the south-eastern part of the site, in line with the presence of the Lakenvlei formation and the SW-NE orientation of the pre-karoo formations (Refer to Figure 3-3).

The presence of dyke-type intrusions was also observed by the interception of mainly dolerite in some borehole logs. The dykes will likely follow the SW-NE orientation of the geological units and linear features as indicated on the geological map (Figure 3-3).

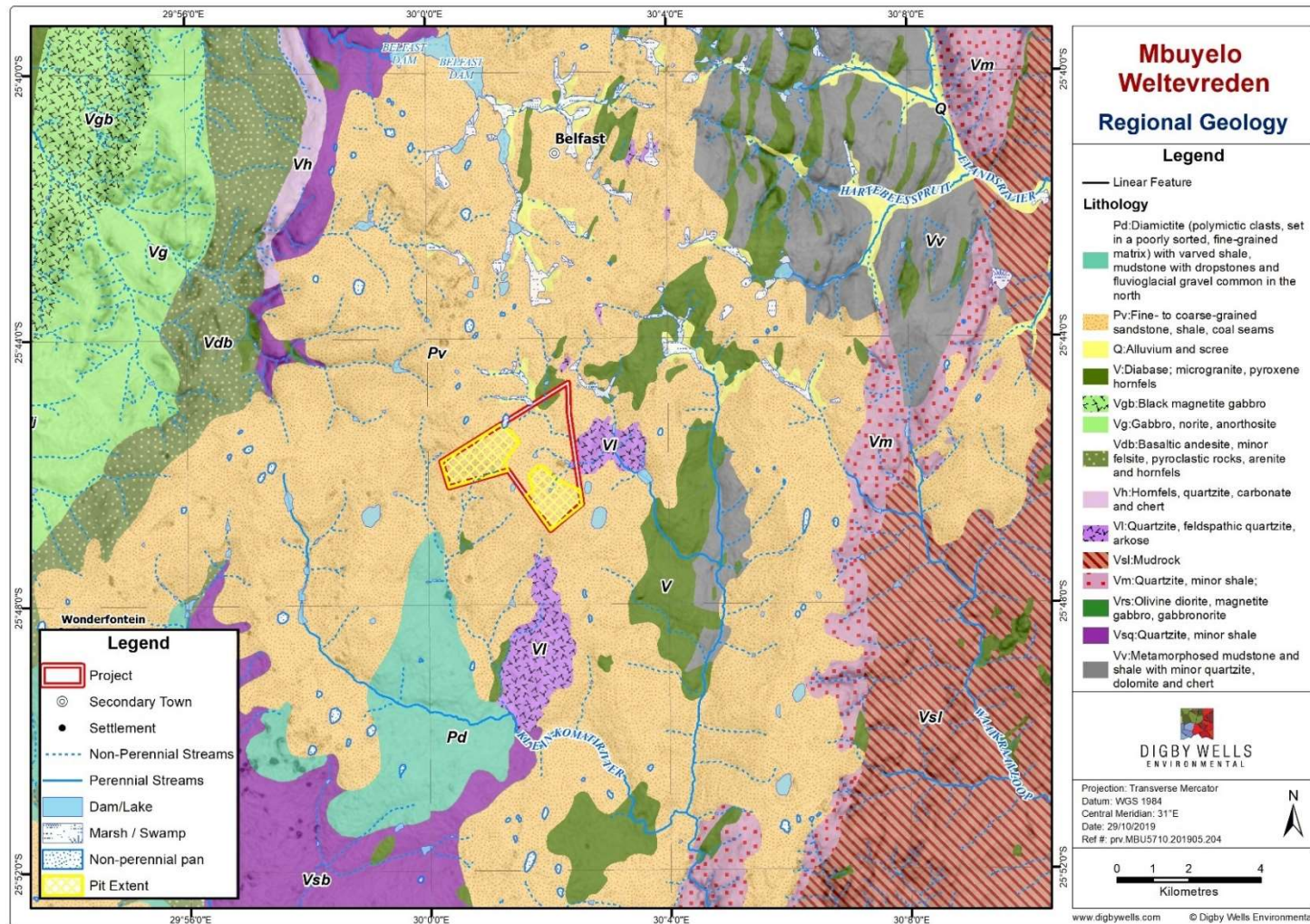


Figure 3-3: Regional Geology

3.4 Hydrogeology

3.4.1 General Aquifer Description

The conceptual hydrogeological model of the area is based on the generally accepted model for the Mpumalanga coal fields. In this model three principal aquifers are identified:

- The weathered Karoo aquifer;
- The fractured Karoo aquifer; and
- The fractured pre-Karoo aquifers (Hodgson and Krantz, 1998).

The Karoo rocks are not known for large scale development of aquifers, but occasional high-yielding boreholes can be present. The aquifers that occur in the area can therefore be classified as minor aquifers (low yielding), but of high importance (Parsons, 1995) and are understood to have a low to medium development potential, mostly used for small-scale domestic purposes or occasionally for large-scale irrigation.

Three distinct superimposed groundwater systems are present within the area (Hodgson and Krantz, 1998, Woodford and Chevallier, 2002) and can be classified as:

- The upper weathered Karoo aquifer (shallow, intergranular type aquifer formed in the weathered zone of the *Vryheid Formation*; can locally form a perched aquifer on top of fresh bedrock);
- The fractured aquifers within the unweathered, fractured Ecca sediments; and
- The aquifer below the *Vryheid Formation* (deeper aquifer formed by fracturing of pre-Karoo sediments and dolerite intrusions).

These types of groundwater systems are common to the groundwater regime in the Karoo environment. The systems do not necessarily occur in isolation and often form a composite groundwater regime that is comprised of one, some, or all of the systems. Based on the exploration drilling at the site all three aquifer types are present at the site.

In general, the shallow Karoo weathered aquifer depth ranges between 5-20 m overlying the fractured Karoo rock formations throughout the region. This is in line with the results from the on-site exploration and monitoring borehole drilling, which indicated the depth of the highly and moderately weathered Karoo aquifer varies between 3 and 20 mbgl with an average of ~8 mbgl.

In terms of pollution risk and/ or susceptibility to pollution, the shallow primary aquifer is understood to be highly susceptible to pollution due to coal mining in the area as the pollutants travel shorter distance to reach the aquifer system (Hodgson and Krantz, 1998). Low-lying wetlands, where groundwater levels are close to surface, can indicate interaction between groundwater and surface water and can also serve as conduits for potential contamination.

The depth of the fractured Karoo aquifer is variable and depth to pre-Karoo lithologies were measured between ~20-80 mbgl for the north-western part of the site and between ~15 and

50 mbgl for the south-western part. Good hydraulic connectivity often exists between the two Karoo aquifers and as such they are treated as a single unit in the modelling of groundwater flow-related systems.

Some of the identified wetlands are associated with changes in geology. East of the proposed mining areas quartzites of the pre-Karoo *Lakenvlei Formation* are close to surface in a low-lying area where the overlying *Vryheid Formation* has been eroded away. The wetland associated with this outcrop indicates the low aquifer potential of the underlying quartzite which is likely causing the local accumulation of water in this area which is then discharged into the associated stream that flows in a general south-south-eastern direction. Another wetland just north of the site is likely associated to an intruded sill. Other wetlands are related to Karoo sediments and were indicated to be related to hillslope seepages and unchanneled valley bottoms.

3.4.2 Geophysical Survey

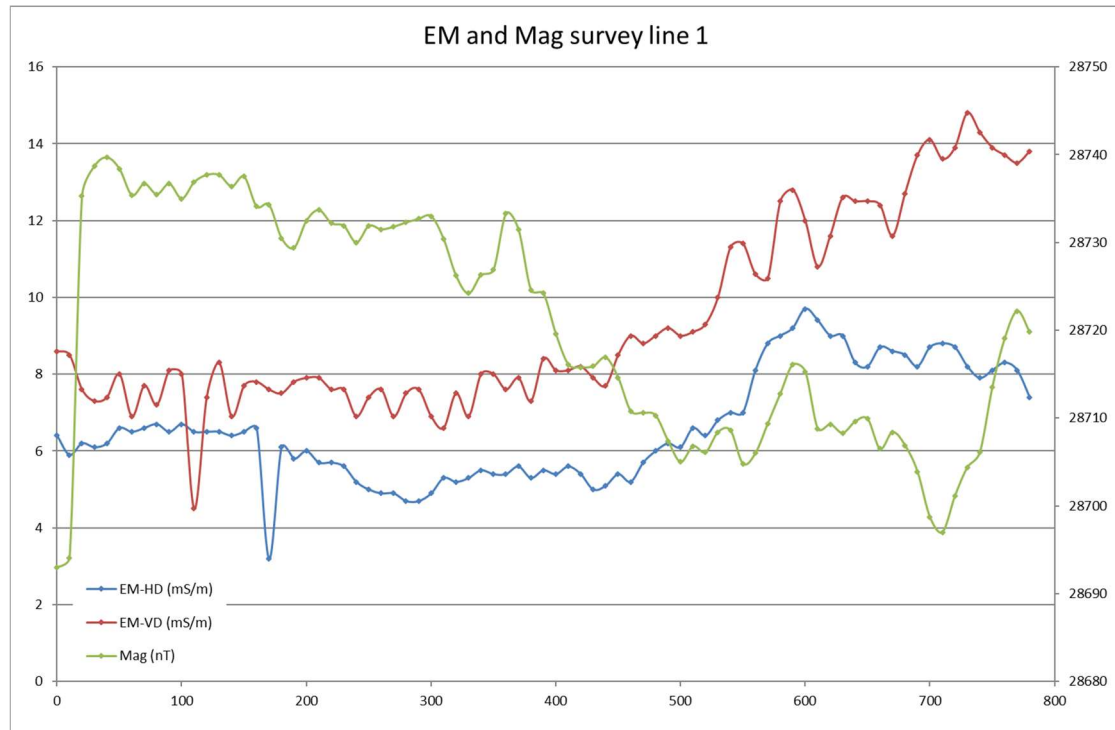
During a geophysical survey, six (6) lines were surveyed close to the two proposed opencast pits (Figure 3-5). The aim of the survey was to characterise the ground conditions in the vicinity of the opencasts, to indicate potential geological structures or preferential flowpaths for groundwater and to generate targets for aquifer test boreholes. The electromagnetic and magnetic survey methods were used.

EM conductivity surveys measure ground conductivity by electromagnetic induction. The electromagnetic system used for the site investigation was the EM 34-3 ground conductivity meters. The system consists of a transmitter and receiver coil spaced at a fixed configuration. Magnetic surveys record spatial variation in the earth's magnetic field, i.e. orientation and strength of the field. The instrument used in magnetic surveying is a magnetometer, in this case a Geomatrix.

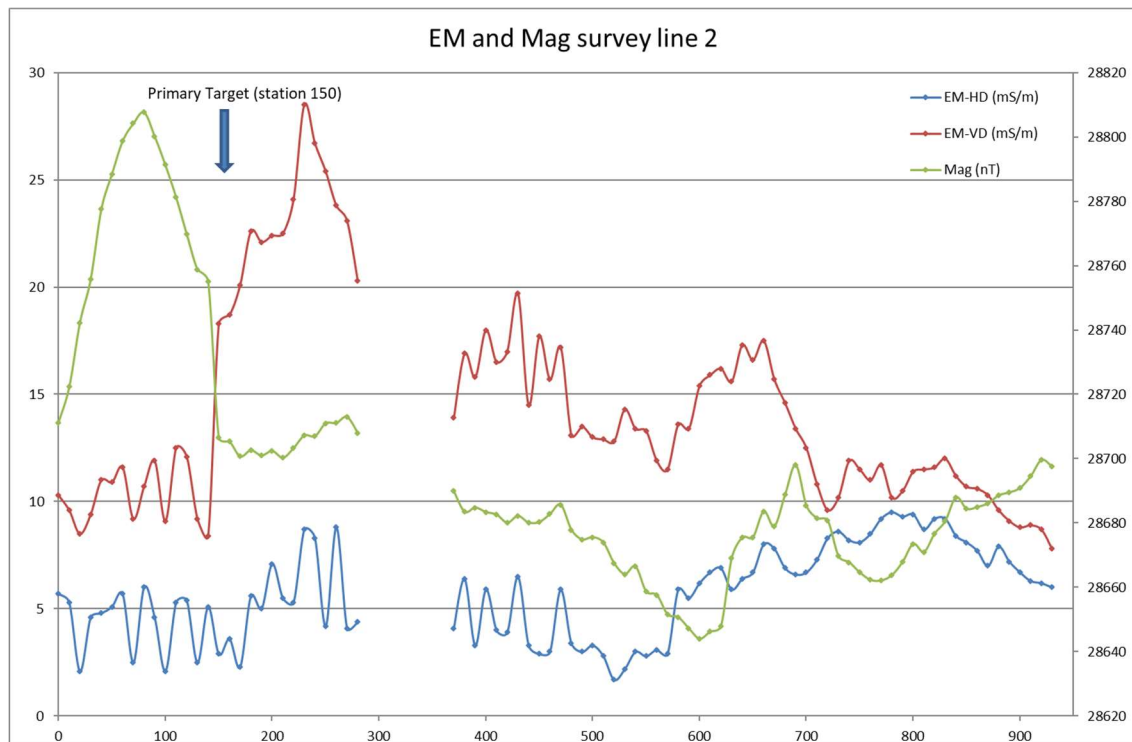
The lines were interpreted based on anomalies in the EM and Mag data in conjunction with lithological units and geological structures as indicated on the regional geological map. The results are shown in Figure 3-4. Five (5) drill targets were identified (Figure 3-4). Based on a field reconnaissance of the targets, four (4) targets were selected. The target on Line 3 was omitted due to access constraints on site. Line 2, target 2 was moved eastward due to access constraints. The area where line 5 was completely inaccessible, and as such drill target 3 had to be moved northward away from the line. Target 3 was eventually chosen based on site access and local farm roads.

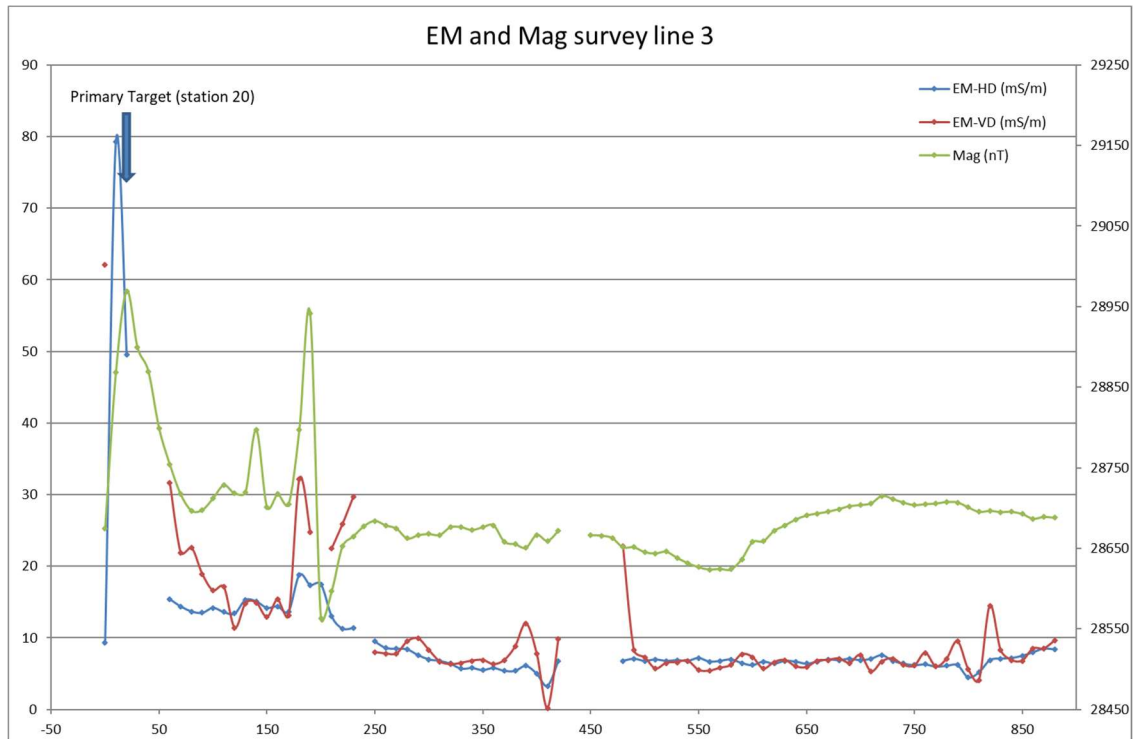
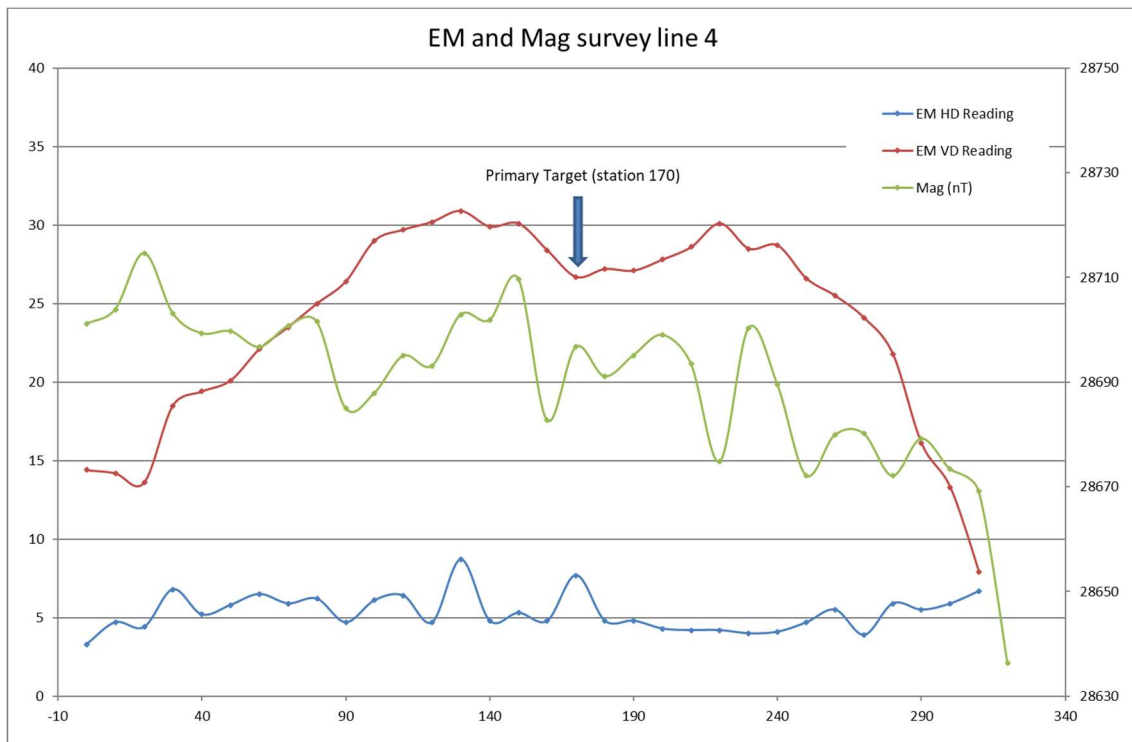


Line 1

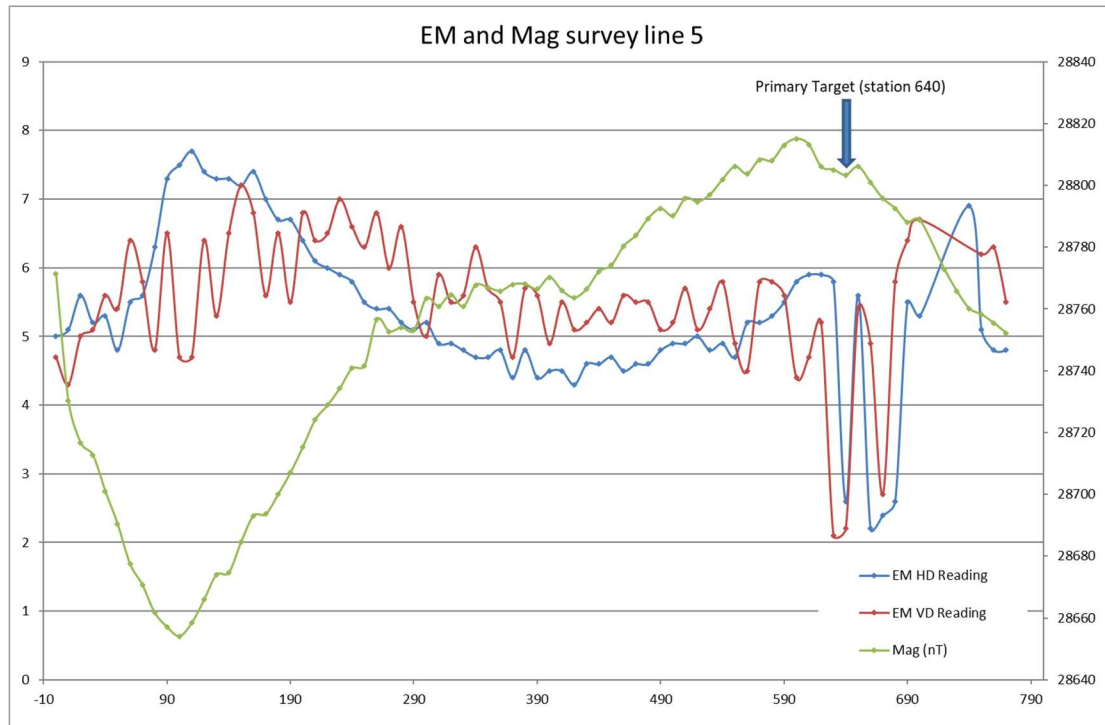


Line 2



Line 3**Line 4**

Line 5



Line 6

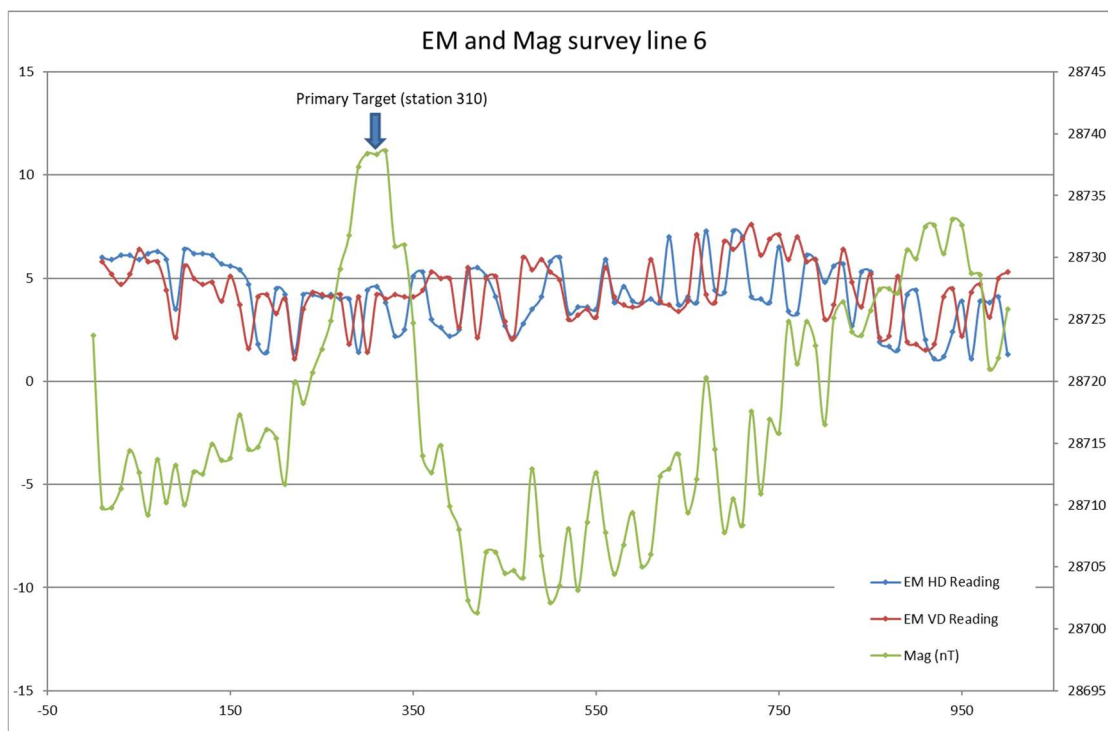


Figure 3-4. Geophysical survey line results

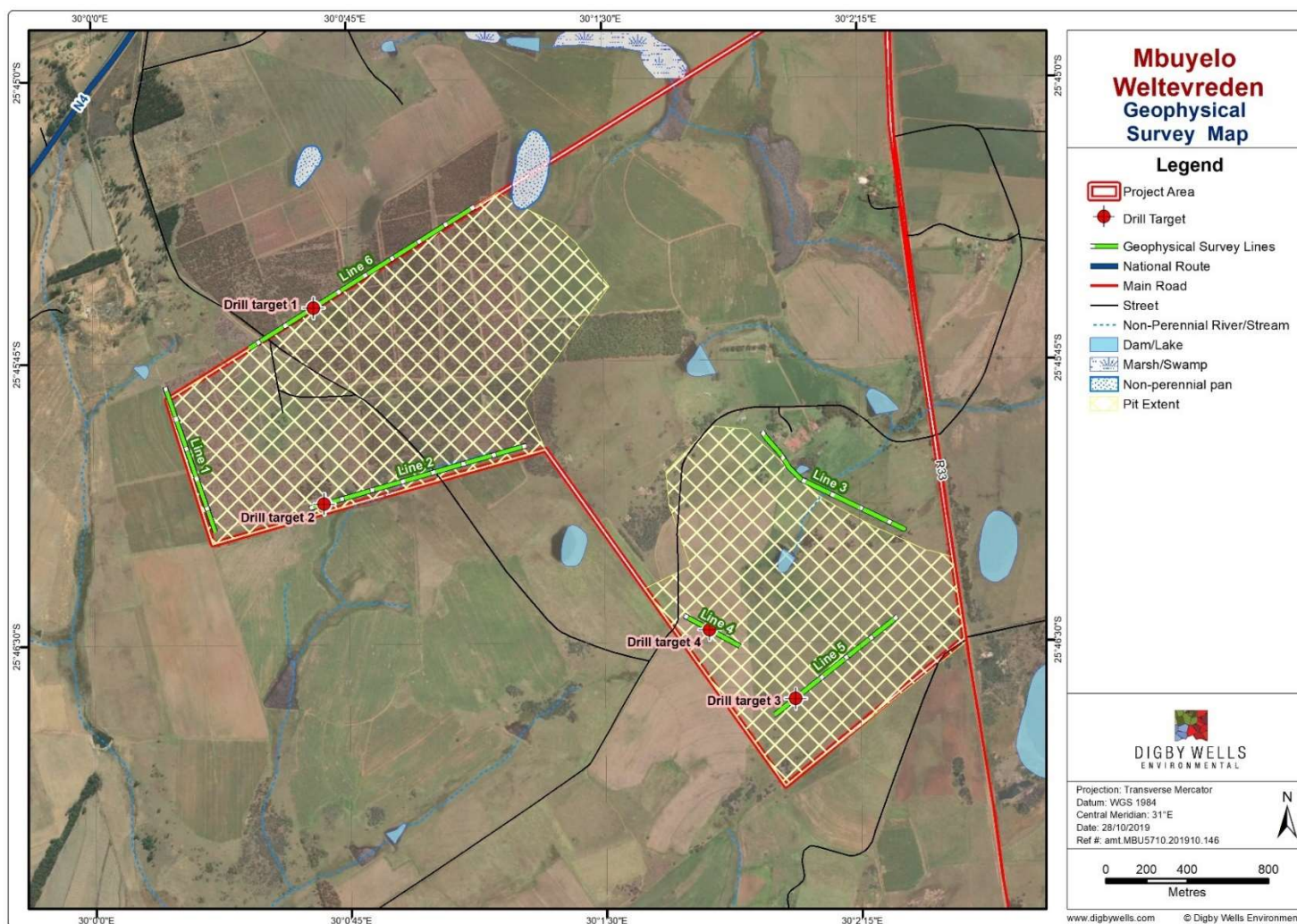


Figure 3-5: Geophysical survey lines and derived drill targets

3.4.3 Borehole Drilling

The drilling of four (4) aquifer test/monitoring boreholes was carried out between 20th and 29th August 2019. The boreholes were drilled to depths between 42 and 51 mbgl. The boreholes construction for all four holes was as follows:

- Percussion drilling at 165 mm (6 inch) open hole diameter;
- Installation of temporary mild steel casing to prevent hole collapse;
- Installation of uPVC casing (60% slotted / 40% plain casing);
- Backfill of the annulus with a gravel pack at the height of the slotted casing, bentonite seal on top of the gravel pack and backfill with arisings;
- Installation of lockable standpipe with concrete plinth.

The boreholes were drilled for the following purposes:

- Description of the encountered lithologies;
- Collection of samples of hangingwall/footwall lithologies and coal samples for geochemical testing;
- Collection of groundwater samples;
- Measurement of groundwater levels; and
- Determining aquifer parameters.

The drilling method used in this programme was rotary-air percussion. The drilling technique was selected for hydrogeological characterisation of the encountered geology, as identification of groundwater inflow and associated air-lift yield can be undertaken during the drilling process. The following information was recorded during the drilling at each drill target:

- Geological information
 - lithology – 1 m intervals;
 - interpreted structure; and
 - depth and degree of weathering.
- Hydrogeological information
 - depth of groundwater strikes and/or seepage; and
 - air-lift yield.
- Other information
 - Penetration rate (indication of weathered/competent rock).

The drill locations are shown on Figure 3-5 and the borehole logs are shown in Appendix A. The main findings of the logging are summarised below, with a summary of the intersected lithology and hydrogeological characteristics summarised in Table 4 3. The monitoring

boreholes were given a code related to the Project Name (Weltevreden) and a number corresponding to the target number (i.e. "Target 1" was renamed "WTVBH1").

Table 3-1. Borehole Construction Summary

BH ID	WTVBH1	WTVBH2	WTVBH3	WTVBH4
Casing	0-9m Solid Casing	0-27m Solid Casing	0-20m Solid Casing	0-27m Solid Casing
	9-12m Perforated Casing	27-42m Perforated Casing	20-36m Perforated Casing	27-42m Perforated Casing
	12-18m Solid Casing		36-39m Solid Casing	
	18-21m Perforated Casing		39-45m Perforated Casing	
	21-33m Solid Casing			
	33-36m Perforated Casing			
	36-42m Solid Casing			
	42-51m Perforated Casing			
Annulus	1.5m Bentonite Seal	1.5m Bentonite Seal	1.5m Bentonite Seal	1.5m Bentonite Seal
	40.5m Gravel Pack	40.5m Gravel Pack	43m Gravel Pack	40.5m Gravel Pack

3.4.3.1 WTVBH1

Drilled on the 29th August 2019, at a topographical elevation of 1 900 mamsl. A reddish brown, dry and fine-grained topsoil was encountered between 0-1 mbgl. This was followed by yellowish brown, dry, coarse- to medium-grained highly weathered sandstone encountered between 1-3 mbgl. Subsequently a brown, damp and fine-grained mudstone was encountered between 3-4 mbgl the top layers are less competent. Between 4-5 mbgl a dark-grey, dry with sub-rounded carbonaceous shale were encountered. A weathered sandstone that is yellowish brown, damp and medium-grained was encountered between 5-7 mbgl. A dark-grey and dry with sub-rounded chips of carbonaceous shale was encountered between 7-8 mbgl. Subsequently a slightly weathered sandstone was encountered between 8-10 mbgl yellowish brown, dry and medium grained.

First competent sandstone that is light-grey, dry and medium grained was encountered between 10-12 mbgl. Between 12-13 mbgl the top half meter was a dark-grey and dry with sub-rounded carbonaceous shale chips and the bottom half meter was coal was encountered. A brown, dry and fine-grained mudstone was encountered between 13-14 mbgl. This was followed by a light-grey, damp and medium grained sandstone was encountered between 14-16 mbgl. Subsequently a siltstone encountered between 16-31 mbgl which is light-grey, dry and fine grained with a gritty texture. A carbonaceous shale, dark-grey and dry with sub-rounded chips encountered between 31-36 mbgl, the shale continues till the top half of 37 mbgl while coal was encountered from the bottom half of 37 mbgl until 38 mbgl. A light-grey, wet and fine-grained with a gritty texture siltstone was encountered between 38-41 mbgl. Subsequently, carbonaceous shale was encountered between 41-47 mbgl, dark-grey, dry with sub-rounded chips. Coal was then encountered again between 47-50 mbgl. A dry and fine-grained mudstone encountered between 50-51 mbgl (end of hole). A water strike was intercepted at 20 mbgl, no blow yield was measured as the borehole was low yielding.

3.4.3.2 WTVBH2

Drilled on the 27th August 2019 with a final depth of 44 mbgl and located at an elevation of 1846 mbgl. A reddish-brown, dry and fine-grained mudstone was encountered between 0-6 mbgl. Followed by a light-grey, damp and fine-grained siltstone with a gritty texture and no chips encountered between 6-9 mbgl. Coal encountered between 9-13 mbgl. Carbonaceous shale encountered between 13-16 mbgl, dark-grey, dry and sub-rounded chips. Subsequently, a light, grey, dry and fine grained with a gritty texture of siltstone encountered between 16-18 mbgl. Brown, dry and fine-grained mudstone was encountered between 20-24 mbgl. Dolerite sill encountered between 24-44 mbgl, greenish grey, dry with sub-angular to angular chips with the level of competence of the rock increasing as the depth increases.

3.4.3.3 WTVBH3

Drilled on the 22nd August 2019 at a depth of 45 mbgl. A brown, dry and fine-grained topsoil layer was encountered between 0-1 mbgl. Followed by yellowish brown, damp and medium-grained weathered sandstone between 1-7 mbgl. There is a reduction of weathering and grain

sizes with the increase in depth. Subsequently, a fresh sandstone that was light-grey, dry and coarse to medium grained without any chips was encountered between 10-12 mbgl. Followed by a light brown, fine grained damp siltstone was encountered between 12-15 mbgl. Dark grey, dry and sub-rounded chips of carbonaceous shale was encountered between 15-19 mbgl. Followed by a very weathered yellowish brown, wet medium grained sandstone where a water strike was also encountered. The deeper drilling continued the fresh light-grey, dry and medium grained sandstone was encountered between 19-33 mbgl. As the drilling continued between 33-36 mbgl, another layer of dark-grey, dry and sub-rounded drill chips of carbonaceous shale was encountered with sub-rounded chips ≤ 1 cm in size. Coal was encountered between 36-39 mbgl. From 39-45 mbgl light-grey, dry and medium grained sandstone was encountered.

3.4.3.4 WTVBH4

Drilled on the 26th August 2019 at a topographical elevation of 1874 mamsl and at a depth of 42 mbgl. First lithology encountered between 0-1 mbgl was a brownish red and damp topsoil with a mixture of pebbles of sandstone and quartz grains. Followed a brown, damp and fine-grained mudstone without any chips encountered between 1-2 mbgl. Siltstone was encountered between 2-4 mbgl it was brown, damp and fine grained with a gritty texture. Subsequently encountered a weathered sandstone that is yellow, damp and medium grained with the presence of chips of quartz < 1 cm. A brown, damp and fine-grained mudstone was encountered between 6-8 mbgl without any chips. From 8-15 mbgl a dark-grey, wet and sub-rounded chips of carbonaceous shale was encountered with the chip size decreasing as the depth increases. Water strike was encountered at 13 mbgl with a blow yield of 1.5 l/s. Mudstone was encountered between 15-25 mbgl, brown, wet and fine-grained. Coal was encountered between 30-33 mbgl. Subsequently encountered carbonaceous shale between 33-41 mbgl dark-grey, dry and sub-rounded chips of 2cm and the sizes reduces as the depth increases. Last encountered lithology was fresh sandstone, light grey, dry and sub-angular chips of plagioclase and quartz < 1 cm.

A summary of the intersected lithology and hydrogeological characteristics is summarised in Table 3-2.

Table 3-2 Drilling Summary

Borehole ID	Borehole Depth (m)	Water Strike (m)	Static Water Level (mbgl)	Final Blow Yield (L/s)	Lithology
WTVBH1	51	19		Low yielding (<0.5 l/s)	Topsoil, Sand, Mud, Shale, Sand, Shale, Mud. Sand, Shale, Coal, Silt, Shale, Coal, Mud
WTVBH2	44		7.60	Low yielding (<0.5 l/s)	Mud, Silt, Sand, Coal, Shale, Silt, Shale, Mud, Dolerite
WTVBH3	45	25	11.75	Low yielding (<0.5 l/s)	Topsoil, Sand, Silt, Sand, Shale, Sand, Sand, Shale, Coal, Sand
WTVBH4	42	13	11.45	1.5	Topsoil, Mud, Silt, Sand, Mud, Shale, Sand, Shale, Coal, Shale, Sand

3.5 Aquifer Testing

The four (4) boreholes were subjected to pumping tests between 17th and 21st September. The aquifer tests consisted of constant discharge tests generally conducted for 8 hour durations, followed by recovery tests, of variable time periods. The objectives of the aquifer testing programme included the determination of the response of the aquifer to an imposed stress (pumping), and estimation of the hydraulic parameters, i.e. the transmissivity, hydraulic conductivity and storativity of the aquifer system. The hydrogeological parameters represent an integral component of the impact assessment concerning potential groundwater inflows and sulphate plume migration.

Prior to each aquifer test, static groundwater levels in the test boreholes were measured from the top of the casing with the use of a dip meter. The following tests were subsequently performed:

- Step tests;
- Constant-rate discharge tests (CRT); and
- Recovery tests (RT).

Calibration and step tests were performed in the boreholes to estimate the pump rates to be used for the CRT. Four (4) hour constant rate tests were proposed. For the four aquifer tests the pump duration varied between 90 and 480 minutes (8 hours), with pumping rates varying between 0.04 and 0.3 l/s. Maximum drawdowns ranged between 7.2 and 42 mbgl. Refer to Table 3-3 for a summary of the aquifer test results.

Recovery tests were performed with recovery durations ranging between 8 and 16 hours. The final recovery water level as a percentage of the pre-pumping water level varied between 76 % and 95 %. A summary of the test programme is presented in Table 3-3.

3.5.1 Data Interpretation

The aquifer test data was analysed with the use of the aquifer testing software Aqtesolv v4.50 - Professional. The Cooper-Jacob (1945) Confined Method, Theis (1935) Unconfined Method and Theis (1935) Recovery Confined Method was used to determine the transmissivity of the groundwater system. Graphs created for each solution are presented in Appendix B. Associated hydraulic conductivity values were subsequently calculated based on the computed transmissivity, borehole saturated thickness and vertical anisotropy ratio.

Although the applied methodology for calculating analytical parameters are based on assumptions which may differ from actual site conditions (e.g. infinite areal extent, homogenous and isotropic aquifer conditions, no delayed gravity response of aquifer), the resulting hydraulic parameter from these calculations are representative of the aquifer system in the vicinity of the tested boreholes. A summary of the hydraulic parameters estimated from the aquifer test analysis is provided in Table 3-3.

The results showed that hydraulic conductivities of the weathered and the top of the fractured aquifer is generally low, in the range of 10^{-1} - 10^{-3} m/d, based on the drawdown reaching pump depth (approx. 40 mbgl) and pumping rates being lower than 0.5 l/s for all four boreholes. The drawdown in borehole WTVBH3 did not reach pump depth with a maximum drawdown of approximately 7.6 m, indicating a higher hydraulic conductivity.

Table 3-3. Aquifer Test Results

BH ID	Depth (mbgl)*	Pump Depth (mbgl)	SWL (mbgl)	Saturated Aquifer thickness (m)	Available Drawdown (m)	Pump yield (L/s)	Total Drawdown (m)	Test duration (min)	Recovery time (min)	Recovery %	Transmissivity (m ² /day)					Hydraulic Conductivity (m/day)
											Cooper-Jacob - early T	Cooper-Jacob - late T	Theis	Theis Recovery	Average	
WTVBH1	51	42.0	7.5	43.5	34.5	0.04-0.11	41.9	90	960	87%	0.18	0.03	0.10	0.04	0.09	0.0020
WTVBH2	44	40.5	6.6	37.4	33.9	0.08-0.15	40.5	150	840	95%	0.27	0.03	0.06	0.02	0.10	0.0026
WTVBH3	45	41.9	9.1	36.0	32.9	0.18-0.27	7.2	480	480	91%	20.36	1.16	0.02	1.49	5.76	0.1601
WTVBH4	42	41.5	9.7	32.3	31.8	0.08-0.3	41.5	300	480	76%	0.49	0.02	0.07	0.04	0.16	0.0049
Average															1.52	0.04
Geometric mean															0.29	0.01
Harmonic mean															0.14	0.004

3.5.2 Groundwater Use

Please refer to a summary of locations identified during the hydrocensus in Table 3-4 and Figure 3-6. The following conclusions were drawn from the hydrocensus:

- Groundwater is the main source of drinking water supply in and around the proposed mining area;
- Groundwater is abstracted with the use of submersible pumps and in one instance a windmill, supplemented by a number of handpumps which are mainly used for domestic purposes by local communities (Table 3-4);
- The windmill as well as submersible pumps are used for domestic, livestock and irrigation purposes (Table 3-4);
- The pH values (Field parameters) measured during the survey ranged between 4.8 at VSTNF1 and 8.8 at GRMBH1 with an average of 6.9, indicating a wide range of acidic to alkaline groundwater present in the vicinity of the site;
- EC values were mostly in the range of between ~800 – 1 100 $\mu\text{S/m}$ which is common for aquifers in the Karoo sediments (Table 3-5).

Table 3-4: Identified boreholes and spring during the hydrocensus

Name	Latitude	Longitude	Status	Comment
BLYBH3	-25.78653	30.0396	Not Sampled	BH is installed with a pump.
BLYBH4	-25.78584	30.03391	Sampled	BH is used for drinking and dairy processing at the farm
PARBH	-25.72007	30.01919	Not Sampled	Artesian well adjacent to the river. The BH is used for domestic purposes at the farm.
PARTP	-25.701666	30.015418	Not Sampled	Residents complain that the water does not taste well. They get their water supply from the nearby Universal Coal mine. Their wind mill has stopped functioning once the nearby mine started operating.
VSTNF1	-25.72526	30.00214	Not Sampled	BH at Alzu farm. The BH is inside a small pump house which and has water overflowing, maybe due to leakages.
HADECBH	-25.7285	30.0095	Not Sampled	Water supply borehole for the villagers at Hadeco/Paardeplaats farm. The distance to the tap is approximately 150-200m

Name	Latitude	Longitude	Status	Comment
HADECBH2	-25.74617	30.00243	Sampled	BH used for domestic purposes at the factory. The farm produces cut flowers for export.
HADECBH3	-25.746146	30.002385	Not Sampled	BH used for domestic purposes
REBH1	-25.74287	30.00819	Sampled	Wind pump is broken and BH is not in use. The BH was previously used for water supply at the village.
ZOEBH	-25.78297	29.992	Sampled	BH is used for domestic, livestock and irrigation purposes as well as for milk production and processing
BLVBH	-25.80862	30.00934	Sampled	BH is used for domestic, livestock and irrigation purposes
DRIBH1	-25.77008	30.00168	Sampled	BH is used for domestic purposes at the farm house
DRIBH2	-25.77664	30.00551	Not Sampled	BH is capped and inaccessible
SACBH	-25.78692	30.01089	Sampled	BH is used for domestic and irrigation purposes at the SA cherries farm
BLY1	-25.81817	30.03196	Not Sampled	BH is used for domestic purposes at the farm house
BLYBH2	-25.78216	30.03944	Not Sampled	BH use is unknown
VOGBH1	-25.78216	30.03944	Not Sampled	BH is used for both domestic and irrigation at the farm
WELBH2	-25.75737	30.0429	Sampled	BH used for domestic purposes at the farm house. BH capped and we could not measure the WL. According to the farm owner the WL is approximately 12 mbgl
ZOEBH2	-25.75424	30.03874	Sampled	BH used for domestic purposes at the farm.
GRMBH1	-25.73594	30.0362	sampled	BH used for domestic purposes at the farm. BH depth is 200 m and the water level is approximately 11-12 m
WELCBH	-25.72482	30.04574	Not Sampled	Community water supply with hand pump
WELBH6	-25.76769	30.02648	Sampled	BH used for water supply at the farm/village for residents. BH has a hand pump installed.

Name	Latitude	Longitude	Status	Comment
Spring	-25.765435	29.999279	Not Sampled.	The spring is used by Komati for commercial bottled water.

Table 3-5: Field parameters

Name	pH	Temperature °C	EC mS/m	TDS mg/L
BLYBH4	7.15	19.5	1028	697
PARBH	8.2	20.2	90.8	62.4
PARTP	7.5	20.6	262	182
VSTNF1	4.8	21.2	544	389
HADECBH	7.2	22.3	223	152
HADECBH2	5.94	17.2	49.4	33.8
HADECBH3	6.2	19.8	96.4	69.5
REBH1	6.1	20.7	897	618
ZOEBH	7.19	16.4	1005	704
BLVBH	6.5	26.6	799	562
DRIBH1	7.14	26	836	594
SACBH	6.08	28.6	848	590
BLY1	6.8	20.8	818	558
BLYBH2	6.67	21.5	828	618
VOGBH1	7.7	21.4	1104	767
WELBH2	6.94	23.7	916	637
ZOEBH2	6.8	26.7	871	588
GRMBH1	8.84	20.6	908	622
WELCBH	8.15	-	986	683
WELBH6	7.5	19.7	941	651

Table 3-6: Groundwater level measurements

Name	GW Level (mbgl)
BLYBH3	5.7
BLYBH4	17.38
HADECBH	28.55

Name	GW Level (mbgl)
REBH1	11.02
ZOEBH	5.48
BLVBH	3.14
DRIBH1	4.65
SACBH	4.93
BLYBH2	5.27
VOGBH1	2.86
ZOEBH2	11.13

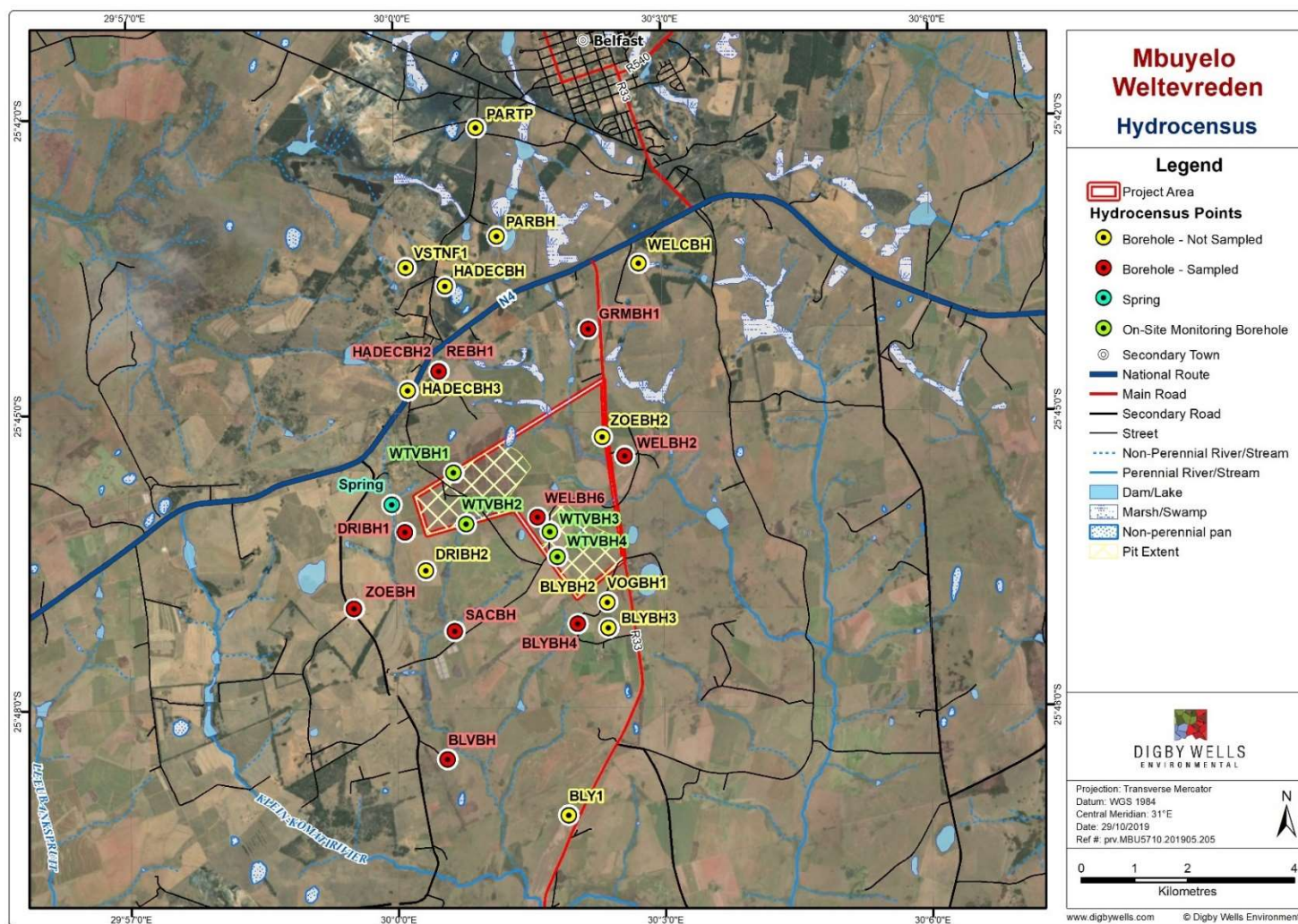


Figure 3-6: Hydrocensus and On-site Monitoring Borehole Map

3.5.3 Groundwater Levels

Groundwater level measurements were taken at eleven (11) boreholes - most of the other boreholes were equipped with a handpump or submersible pump. The groundwater level ranged between 2.9 mbgl at VOGBH1 and 28.6 mbgl at HADECBH1 (Table 3-6).

This indicates that in general groundwater levels are shallow, mostly less than ~10 mbgl near the site and mainly located within the shallow weathered aquifer. Deeper groundwater levels measured at HADECBH1 and BLYBH4 are most likely dynamic water levels due to active pumping from the boreholes.

Monitoring and aquifer test/monitoring boreholes on site indicated groundwater levels between 6.6 and 9.7 mbgl. The shallow groundwater levels at the site indicates there may be interaction between groundwater and surface water. Based on the groundwater levels being close to surface and taking into account identified wetlands and surface water courses (refer to the wetland and surface water impact assessment reports), some of the wetlands, in particular the lower lying wetlands (i.e. floodplains, unchanneled bottom wetlands etc.) are likely to be (partially) groundwater fed.

Groundwater levels were compared to surface elevations and a good correlation between surface elevation and groundwater level was found with a correlation coefficient of 0.97, indicating groundwater flow directions will mainly follow topography and the main surface water drainage directions (Figure 3-7). For the Project Area this indicates the main groundwater flow direction will be to the south towards the Nkomati River.

With the high correlation between topography and groundwater levels and an average groundwater level of ~6 mbgl (if we exclude dynamic groundwater levels) it is anticipated that the shallow groundwater will interact with surface water at lower topographical positions and near drainage courses.

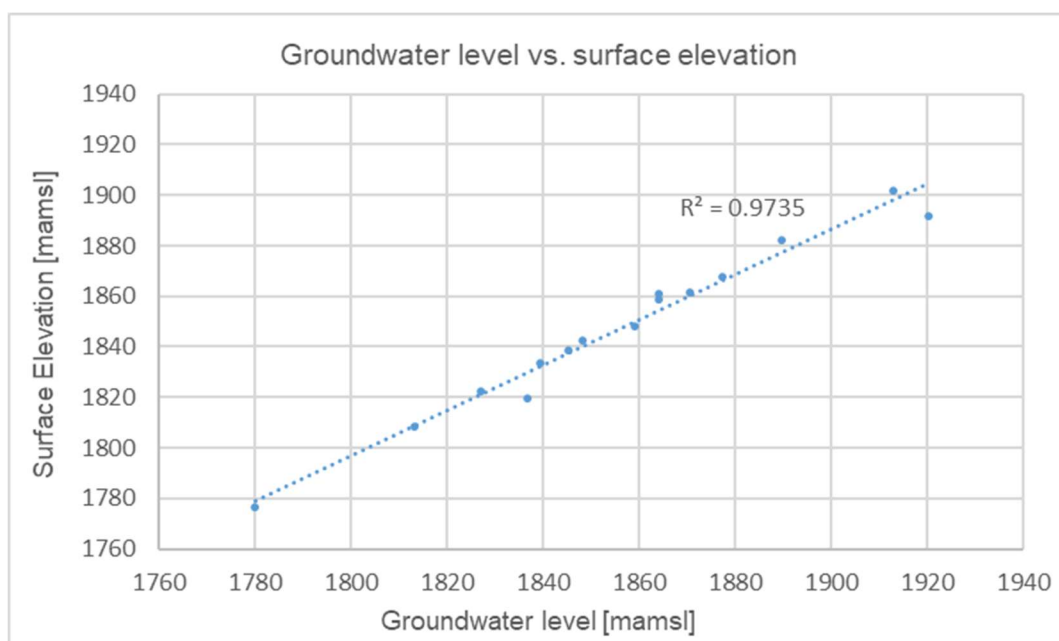


Figure 3-7: Bayesian correlation between surface elevation and groundwater level.

3.5.4 Groundwater Quality

The water quality results for the tested sites are shown in Table 3-7. The results from the baseline water quality data for the groundwater assessment within the Project Area. Samples from nine hydrocensus and four monitoring boreholes were taken for the Project (Refer to Figure 3-6 for the sampled locations) and sent for lab analysis. Based on the water quality results presented in Table 3-7, the following summary can be made for the baseline water quality:

- The groundwater in the area is predominantly of a Mg-HCO_3 type, with a few instances of Ca-HCO_3 and Na-SO_4 , Na-Cl and Mg-Cl (Figure 3-8 and Figure 3-9). This shows overall good groundwater quality and water which has been recently recharged to the shallow aquifer,
- However, water sampled from some boreholes indicate longer residence times allowing for ion exchange and for the groundwater to obtain a more Na-Cl characteristic, although the EC is still low and does not indicate saline water;
- The 13 groundwater samples taken showed the groundwater in the area to be of good quality, with no parameters exceeding any of the limits as per the SANS and WHO drinking water guidelines.

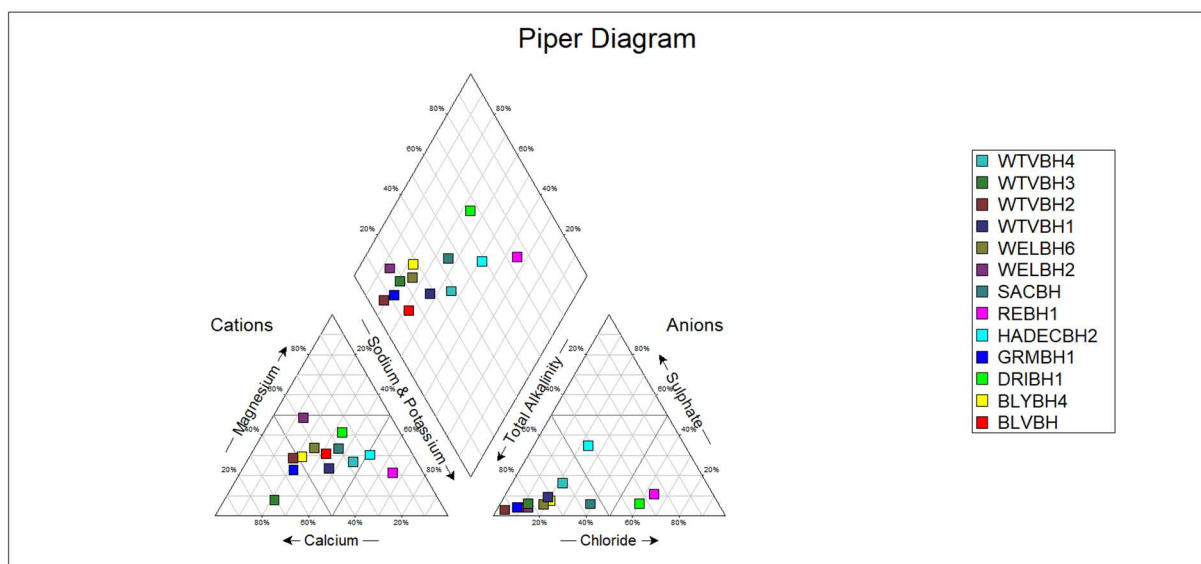


Figure 3-8: Piper Diagram

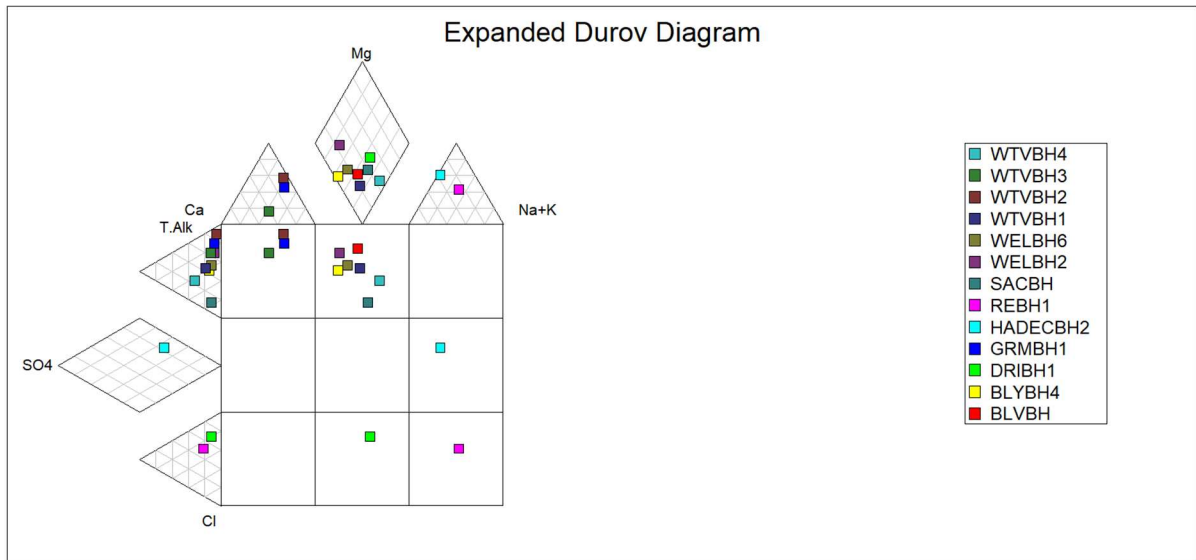


Figure 3-9: Expanded Durov Diagram

Table 3-7: Baseline groundwater quality analysis

Parameter	SANS 241<1 2015 Drinking Water	WHO Drinking Water (2017)	BLVBH	BLYBH4	DRIBH1	GRMBH1	HADECBH2	SACBH	REBH1	WELBH2	WELBH6	WTVBH1	WTVBH2	WTVB03	WTVBH4
Date			02/05/19	02/05/19	02/05/19	02/05/19	02/05/19	02/05/19	02/05/19	02/05/19	02/05/19	23/09/2019	23/09/2019	23/09/2019	23/09/2019
pH in water at 25°C	5<9.7	NS	6.7	7.4	7.1	8.3	6	6.3	5.7	6.8	7	6.5	7.6	7.2	6.4
Total Alkalinity as CaCO ₃	1200	NS	44	72	12	44	<5	20	<5	44	28	16	68	28	8
Conductivity in mS/m	170	NS	11.8	20.6	9.5	10.4	3.7	11.3	5.3	11.7	7.4	4.8	32.2	6.7	10.9
Calcium	NS	NS	7.9	19.2	4.3	11.9	1.1	6.3	1	9.4	5.8	4.724	11.64	9.091	1.954
Magnesium	NS	NS	4.1	7.1	3.5	3.3	1	3.9	1.1	7.2	3.1	1.713	3.846	0.617	1.153
Sodium	200	200	5.9	9.1	5.2	4.6	1.5	6.7	4	3.5	2.9	3.128	3.773	1.598	1.711
Potassium	NS	NS	3.4	2.3	2.1	1	2.1	2.1	3.1	1.3	2.3	3.439	1.875	2.691	3.467
Iron	2	0.3	0.037	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	0.239	0.129	0.049	0.047
Aluminium	0.3	0.1	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	0.639	0.149	<0.1	<0.1
Arsenic	0.01	0.01	< 0.010	< 0.010	< 0.010	0.033	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	<0.01	<0.01	<0.01	<0.01
Boron	2.4	2.4	< 0.010	0.031	0.012	0.087	0.01	< 0.010	< 0.010	< 0.010	< 0.010	0.067	0.072	0.051	0.047
Barium	0.7	0.7	0.04	0.1	0.19	0.01	0.11	0.1	0.15	0.04	0.03	0.096	0.178	0.051	0.113
Beryllium	NS	0.012	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	<0.01	<0.01	<0.01	<0.01
Cadmium	0.003	0.003	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	<0.01	<0.01	<0.01	<0.01
Cobalt	NS	NS	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	<0.01	<0.01	<0.01	<0.01
Chromium	0.05	0.05	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	<0.01	<0.01	<0.01	<0.01
Copper	2	2	0.051	< 0.010	< 0.010	0.014	0.033	< 0.010	< 0.010	0.0096	< 0.010	<0.01	<0.01	<0.01	<0.01

Parameter	SANS 241<1 2015 Drinking Water	WHO Drinking Water (2017)	BLVBH	BLYBH4	DRIBH1	GRMBH1	HADECBH2	SACBH	REBH1	WELBH2	WELBH6	WTVBH1	WTVBH2	WTVB03	WTVBH4
Manganese	0.4	0.4	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	< 0.025	0.026	< 0.025	< 0.025	0.10	<0.025	0.04	0.06
Molybdenum	NS	NS	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	<0.01	<0.01	<0.01	<0.01
Nickel	0.07	0.07	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	<0.01	<0.01	<0.01	<0.01
Lead	0.01	0.01	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	<0.01	<0.01	<0.01	<0.01
Antimony	NS	NS	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	<0.01	<0.01	<0.01	<0.01
Selenium	0.04	0.04	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	<0.01	<0.01	<0.01	<0.01
Tin	NS	NS	< 0.010	0.026	< 0.010	0.01	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	<0.01	<0.01	<0.01	<0.01
Vanadium	NS	NS	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	<0.01	<0.01	<0.01	<0.01
Zinc	5	4	2.66	0.057	0.05	0.044	0.248	0.047	0.08	0.089	0.43	0.08	0.03	0.03	0.04
Chloride	300	250	4	15	15	3	2	10	9	5	5	3	2	3	2
Fluoride	1.5	1.5	0.2	0.2	0.2	0.2	0.2	0.2	0.2	<0.2	0.2	<0.2	0.2	0.2	<0.2
Nitrate as N	11	NS	0.2	1	2	0.2	1	4.9	1	0.3	0.1	0.6	<0.1	0.4	1.7
Nitrite as N	0.9	3	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Sulphate	500	250	2	7	2	<2	4	<2	<2	2	<2	2	<2	<2	<2
Mercury	0.006	0.006	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	<0.01	<0.01	<0.01	<0.01
Ammonia as N	1.5	35	0.2	0.1	0.1	0.1	0.2	0.2	0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1

4 Geochemical Assessment and Waste Classification

Below follows a summary of the geochemical assessment and waste classification that was carried out as part of this hydrogeological investigation. Please refer to Appendix C for the full assessment.

4.1 Mineralogy and Acid Mine Drainage

Waste rock material samples were taken from floor and roof lithologies from exploration borehole cores, and coal material was collected from the main coal seam to be mined (2, 3, 4S and 4L) to determine mineralogy and the potential for Acid Mine Drainage (AMD) as a result of the Project proceeding. The mineralogy results are summarised in Table 4-1.

The mineralogy of the waste rock samples (based in the XRD results) indicate that sample BT1 HW comprises predominantly by kaolinite at 38.79 weight percentage (wt. %) followed by quartz at 27.3 wt. %. Whereas BT1 FW is dominated by quartz at 42.91 followed by kaolinite at 35.11 wt. %. Amorphous minerals are also detected in BT1 HW at 10.51 wt. % indicating the presence of organic material. Sulphide mineral pyrite was detected in BT1 HW at 1.44 wt. %. The elemental composition (XRF) data correlates with the XRD data with the first example that both methods detect the presence of clay minerals such as kaolinite which contains aluminium, and subsequently the results indicate a high Aluminium Oxide (Al_2O_3) content. A minor Iron Oxide (Fe_2O_3) content was also detected in support of the presence of biotite and chlorite minerals. A high Silicon Oxide (SiO_2) content was detected as expected, as this forms part of all the minerals except calcite. The mentioned mineralogy is typical of the **Vryheid Formation** with sedimentary sequences of siltstone, sandstone, carbonaceous shale and mudstone dominating the area.

The XRD results for the four coal samples indicate that the samples comprise predominantly of amorphous minerals which in the case of these samples will be the coal or carbon material that was lost on ignition during the test work. The presence of pyrite is detected in all samples apart from BT4 ranging between 0.39-3.38 wt. %. This is above 0.3 wt. % indicating this sample could be potentially be acid generating. There are neutralising potential minerals in one sample (BT1), compared to samples that have sulphide minerals, such as calcite and ankerite at 1.46 wt. % and 4.45 wt. % respectively.

The AMD potential of materials is determined by assessing the Acid Potential (AP), Neutralising Potential (NP) and the relationship between these two reactions by calculating the net neutralising potential ($\text{NNP} = \text{NP} - \text{AP}$) and Neutralising Potential Ratio ($\text{NPR} = \text{NP}/\text{AP}$). The above reactions and potentials are driven by the mineralogy of the materials. Certain minerals are acid buffering/neutralising and others such as pyrite are acid producing. Sulphide content is the main driver of acid production and AMD under aerobic conditions and that is why the Sulphide-Sulphur (SS%) content of material is also assessed. The test work with the main parameters and results are shown in Table 4-2.

Table 4-1: XRD results for waste rock and coal materials

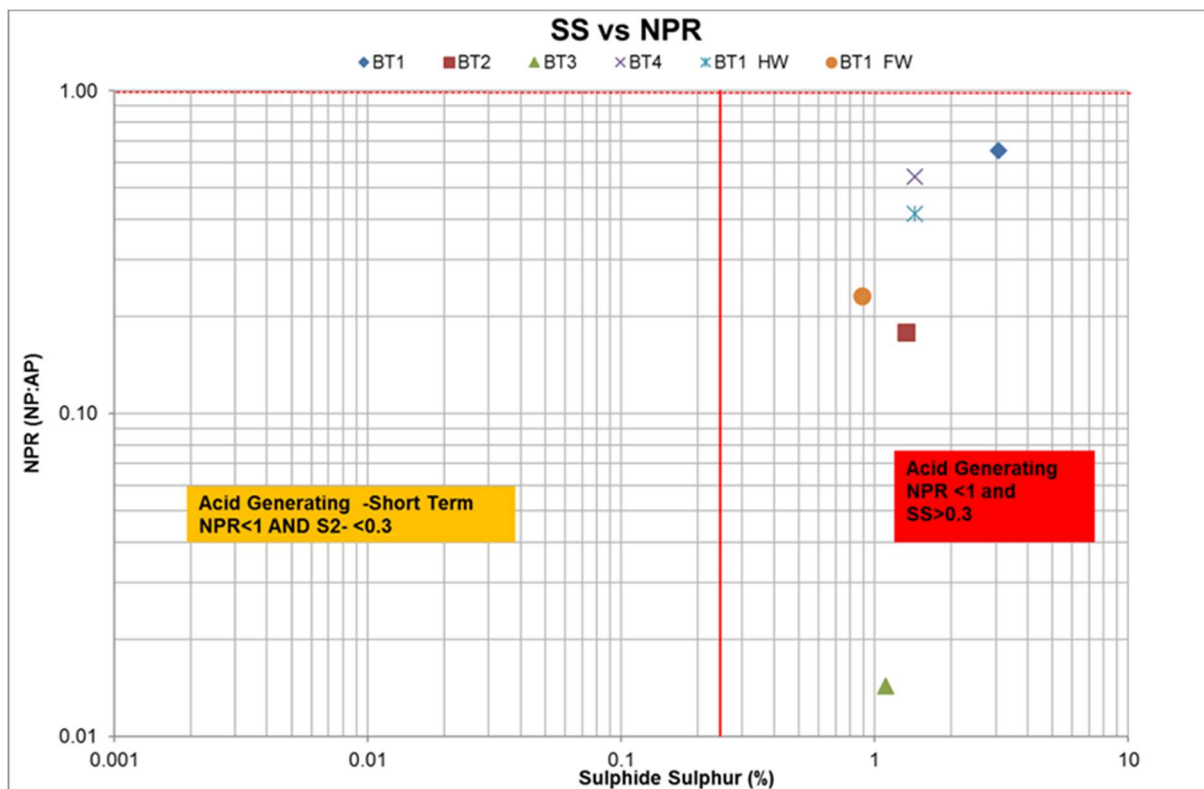
Mineral composition per sample (%)						
Mineral	BT1 HW	BT1 FW	BT1	BT2	BT3	BT4
Amorphous	10.51		66.21	66.47	59.3	68.16
Kaolinite	38.79	35.11	14.17	20.84	17.73	15.41
Microcline	6.51	14.87				2.92
Muscovite	7.01	7.11				2.45
Quartz	27.3	42.91	10.33	11.76	22.58	10.9
Pyrite	1.44		3.38	0.93	0.39	
Siderite	8.44					
Ankerite			4.45			
Calcite			1.46			0.16

The main values used to classify materials as Potential Acid Generating (PAG) or Non-Acid Forming (NAF) are the NPR and sulphide-sulphur content. If the NPR is below 1 there is a potential to generate acid, if the NPR is above 3 there is no potential to generate acid and when the NPR is between 1 and 2, a balance exists between the buffering and acid producing reactions and a clear conclusion cannot be based on the NPR only. If the SS% is above 0.3 it is generally accepted that this material will be acid generating.

The XRD and XRF results indicate presence of sulphide minerals with the potential to form acid. ABA, NAG and SS% results indicate that all waste rock samples are Potentially Acid Generating (PAG), similarly, with the coal samples. Based on this, all coal samples have AMD potential (Figure 4-1).

Table 4-2: ABA and Sulphur Speciation Results

Sample ID	NAG pH	Net Neutralization Potential (NNP) = NP – AP (kg CaCO ₃ /t)	Neutralising Potential Ratio (NPR) (NP: AP)	Total Sulphur (%) (LECO)	Sulphate (SO ₄ ²⁻) Sulphur (%)	Sulphide- (S ²⁻) Sulphur (%)	Acid Generating Potential
BT1	1.9	-34.00	0.65	3.14	0.06	3.08	PAG
BT2	2.2	-35.30	0.18	1.39	0.06	1.33	PAG
BT3	2.3	-25.50	0.01	1.13	0.03	1.1	PAG
BT4	3.9	-21.00	0.54	1.47	0.03	1.44	PAG
BT1 HW	4.3	-26.30	0.42	1.43	0.05	1.38	PAG
BT1 FW	2.9	-21.50	0.23	0.90	0.01	0.89	PAG

**Figure 4-1: Waste rock and coal material AMD – NPR vs SS%**

4.2 Waste Classification

The waste classification conducted on the coal and waste material is a geochemical classification done in accordance with the National Environmental Management: Waste Amendment Act 2014 (Act No. 26 of 2014) (NEM:WA) and no physical material or engineering characterisation was undertaken. A Leachable Concentration Threshold (LCT) and Total Concentration Threshold (TCT) test were undertaken. The LCT means the leachable concentration threshold limit for certain elements and chemical substances in waste, expressed as mg/L, and the TCT means the total concentration thresholds limits for particular elements or chemical substances in a waste, expressed as mg/kg (prescribed in NEM:WA).

GN R 634 identifies waste classes (Waste Types 0 to 4) ranging from high risk to low risk, based on comparison of the Total Concentration (TC) and Leachable Concentration (LC) of individual constituents in the waste against the following threshold limits. Waste is assessed by comparison of the total and leachable concentration of elements and chemical substances in the waste material to TCT and LCT limits as specified in the National Norms and Standards for Waste Classification and the National Norms and Standards for Disposal to Landfill from the NEM:WA.

The coal and waste rock materials that were tested are classified as a Type 3 waste and need to be disposed at a Class C landfill site or a facility with a similarly performing liner system. Figure 4-2 shows a conceptual design for a Class C liner as an example. The Type 3 waste classification is only due to the leachate concentration results being above the LCT0 guideline values. LCT0 values are derived from human health effect values for drinking water, as published by the Department of Water and Sanitation (DWS), South African National Standards (SANS), World Health Organization (WHO) or the United States Environmental Protection Agency (USEPA). According to the test methodologies followed and the results of the leachable concentrations, the risk of elements leaching into the receiving environment from the Class C waste facility is low.

Class C Landfill:

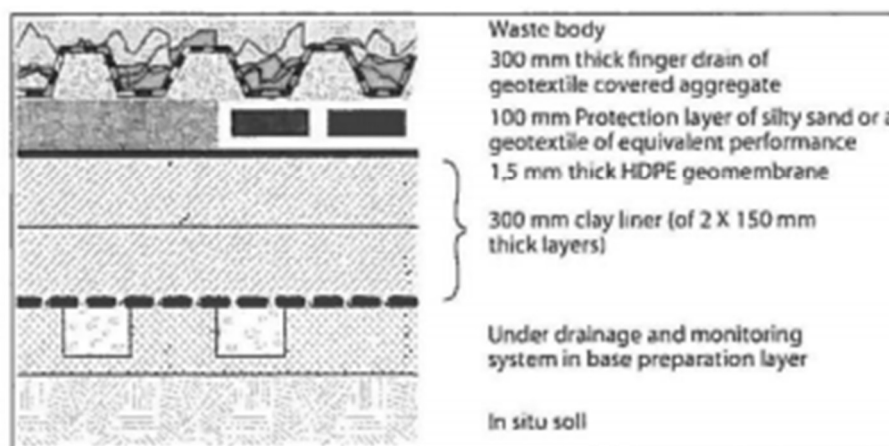


Figure 4-2: Class C liner conceptual design

5 Site Conceptual Hydrogeological Model

The conceptual model describes the hydrogeological environment and is used to design and construct the numerical model to represent simplified, but relevant conditions of the groundwater system. The conditions should be chosen in view of the specific objective of the modelling and might not be relevant for other modelling objectives. The conceptual model is based on the source-pathway-receptor principle.

5.1 Aquifers

The following aquifer units were discerned in the conceptual model: shallow weathered and fractured rock aquifer units in the Karoo sedimentary lithologies and in the *Dwyka Group* and *Lakenvlei Formation*. Locally dolerite or diabase sills outcrop at surface where poor aquifers form due to low to moderate weathering of the sills.

The weathered aquifer units are mainly the sandstone, siltstone and shale of the Vryheid Formation, quartzite of the Lakenvlei Formation and dolerite sills. At the site the weathered rocks are predominantly overlain by orthic soils such as the deeper Hutton, Clovelly and Griffin types and the shallow Mispah and Glenrosa types in areas where the underlying geology (sub)outcrops. Hydromorphic soil types are mainly related with identified wetlands and range from deep Avalon, Bloomsdale, Glencoe and Pinedene forms to shallow Avalon, Westleigh, Longlands and Katspruit Forms associated with the lower slopes and lower midslopes, to structured and gleyed soil forms (Katspruit) associated with the alluvial floodplains (ESS, 2019).

The weathered zone depth at the site is expected to be between 3-20 mbgl with an average of ~8 mbgl, overlying the fractured rock formations. The hydraulic conductivity for the weathered zone is in the range of 10^{-1} - 10^{-2} m/d. The fractured rock units mainly consist of the fractured Vryheid Formation and pre-Karoo Formations, at the site underlying the Vryheid Formation. Based on this the fractured unit was subdivided in an upper fractured aquifer in the Vryheid Formation and a lower fractured zone in the Pre-Karoo Formations. Hydraulic conductivities for the fractured zone are in the order of 10^{-2} - 10^{-3} m/d.

Linear structures were indicated on the regional geological map with a southwest to northeast orientation and it is likely that the high yielding WTVBH3 targeted such a structure or fault zone. It was assumed that the hydraulic conductivity of 0.16 m/d determined for WTVBH3 is an indicative value for the hydraulic conductivity for fault zones, whereas the hydraulic conductivities for the other three boreholes, all in the order of 10^{-3} m/d, are representative for the bulk hydraulic conductivity for the fractured aquifer in the Vryheid Formation.

5.2 Groundwater Recharge

Recharge values for Karoo lithologies are generally low, mainly between 1-3% of MAP. Recharge rates for the Vryheid, Dwyka, Lakenvlei and sills in the conceptual model are all expected to have relatively low recharge rates with values ranging between ~0.5 to 1.5% of MAP.

5.3 Groundwater Levels

Groundwater levels are shallow and located at the bottom of the shallow weathered aquifer. Groundwater levels mainly follow topography and the main surface water drainage directions which are the Klein-Komati and Waarkraalloop streams which flow in a southerly direction towards the Nkomati River.

5.4 Sources, Pathways and Receptors

The following sources, pathways and receptors were discerned:

- Groundwater sources:
 - Seepage from the opencast pits into the surrounding aquifer post-closure after the mine dewatering has ceased; and
 - Infiltration of contaminated water from the hards stockpiles into the underlying aquifer through recharge infiltrating into the waste rock.
- The pathway:
 - The primary pathway for the opencast pits is the weathered and fractured rock units of the Vryheid Formation and faults and fractures that are sufficiently permeable (effectively porous) to allow water flow; and
 - The primary pathway for seepage from the hards stockpiles into the weathered/fractured aquifer units below the stockpile.
- Groundwater receptors:
 - Groundwater receptors are mainly third-party groundwater users in the surrounding area. Boreholes and springs identified during the hydrocensus were mainly for domestic use and livestock watering for single households and small communities; and
 - Groundwater dependant wetlands and streams in the vicinity of the site.

6 Numerical Modelling

6.1 Model Setup

During model setup, the conceptual model is translated into a numerical model. This stage entails selecting the model domain, defining the model boundary conditions, discretizing the data spatially and over time, defining the initial conditions, selecting the aquifer type, and preparing the model input data. The above conditions together with the input data are used to simulate the groundwater flow in the model domain for pre-mining steady state conditions.

MODFLOW, a modular three-dimensional groundwater flow model developed by the United States Geological Survey (Harbaugh et al., 2000) was used for modelling purposes. MODFLOW uses 3D finite difference discretisation and flow codes to solve the governing equations of groundwater flow. MODFLOW NWT (Niswonger et al., 2011) was used in the simulation of the groundwater flow model. Both are widely used simulation codes and are well documented. GMS 10.4.2, a pre- and post- processing package for the MODFLOW modelling code was used for the construction of the numerical model.

6.2 Model Domain

The model domain (Figure 6-1) is irregularly shaped with dimensions of 12 km by 16 km. A rectangular mesh was generated for the model domain, consisting of 1 129 rows and 779 columns. The mesh was refined in the model domain to cell sizes of 25 m by 25 m in the area surrounding the Project Site, with cells gradually coarser further away from the mining area (resulting in a total of 160,332 active cells for the three layers modelled). Although a smaller grid size may result in prolonged running time, it was important to refine the model close to the Project Site to properly delineate geological units and to calculate the groundwater gradient and pollution plumes more accurately in the direct vicinity of the activities.

The model consists of three layers to allow for discretisation between the weathered and fractured lithologies. The weathered zone consisted of one layer of 10 m thickness. The fractured zone was divided into two layers to allow for discretisation of lithological units with depth. This subdivision will also allow for more accurate inflow calculations for the Opencast pits.

6.3 Boundary Conditions

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

Boundary condition options in MODFLOW can be specified either as:

- a. specified head or Dirichlet; or
- b. specified flux or Neumann; or
- c. mixed or Cauchy boundary conditions.

Local hydraulic boundaries were identified for model boundaries. They were represented by local perennial and non-perennial water courses and topographical highs and delineated the entire model domain. These hydraulic boundaries were selected far enough from the area of investigation to not influence the numerical model behaviour in an artificial manner. The model boundaries and model grid are shown Figure 6-1. Table 6-1 provides a summary of the boundaries, boundary descriptions and boundary conditions specified in the hydrogeological model.

Table 6-1: Identification of real-world boundaries and adopted model boundary conditions.

Boundary	Boundary Description	Boundary Condition
Top	Top surface of water table	Mixed type: Drain cells for non-perennial streams. Recharge is constant for the whole model domain. Recharge flux is applied to the highest active cell.
North	Topographical boundary condition	No flow boundary
East	Drainage boundary – non-perennial stream	Drain boundary
South	Stream boundary condition – perennial stream	River boundary
West	Stream boundary condition – perennial stream	River boundary

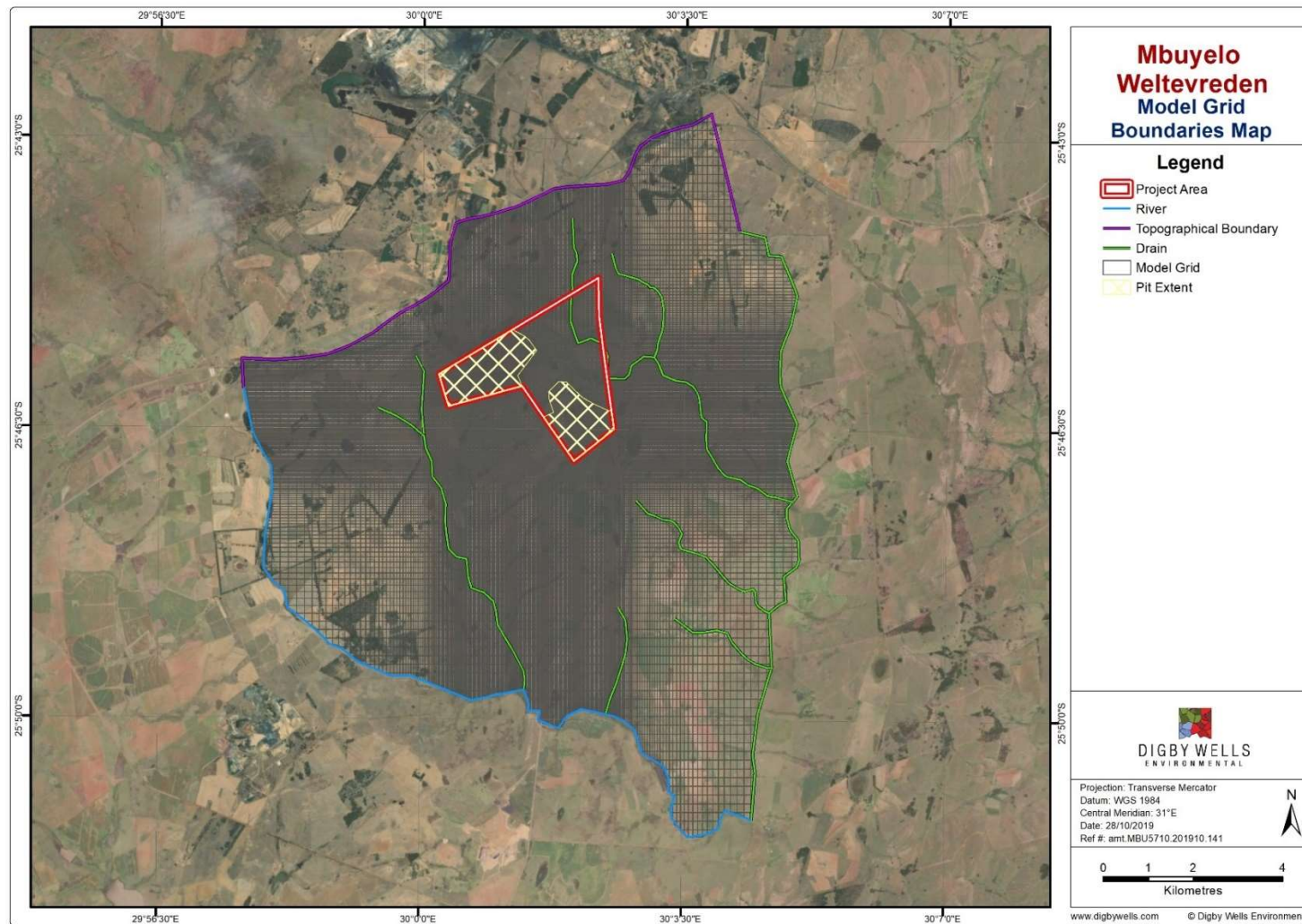


Figure 6-1: Numerical Model Domain, Grid and Boundaries

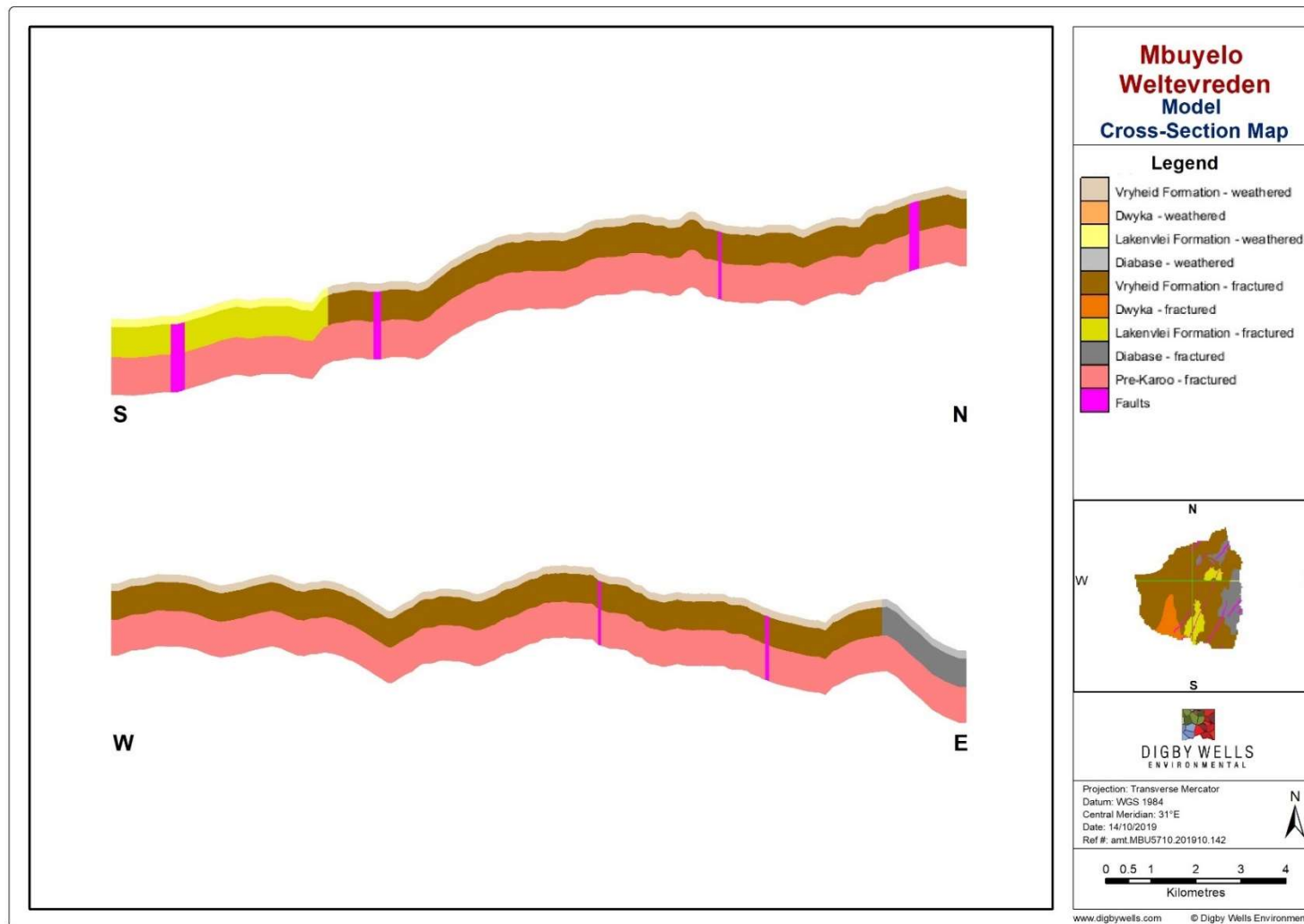


Figure 6-2: Numerical Model Cross Sections

6.4 Steady State Simulation

Prior to the simulation of the mining and dewatering activities, a baseline (pre-mining) steady state groundwater flow model was set-up and calibrated. The objective of the steady state model was to simulate the undisturbed groundwater system in the region for the current situation (2019). The impacts of mining activities for the operational and post-closure phases will then be determined by comparing the transient state results with the steady state results.

6.4.1 Steady State Calibration

Digby Wells collated the most recent borehole data and hydrocensus information available for the Project Site. The steady state model was calibrated with this data to produce a model simulating the baseline groundwater conditions. A total of 32 observation boreholes were used for the steady state calibration, based on the most recent groundwater level data.

The model was calibrated by varying model input data over realistic ranges of values until a satisfactory match between simulated and observed water level data was achieved.

Since recharge and permeability are dependent on each other via the measured heads, the model was not calibrated by changing the permeability and recharge simultaneously. The permeability was calibrated based on the aquifer test results, while the recharge value was adjusted manually until a best fit was obtained.

The Modflow-NWT package was used to solve the partial differential equations. Convergence criteria of a head change of 10^{-3} m were selected. After model calibration a correlation of 96% was obtained between the simulated and observed groundwater elevation (Figure 7.3). The calibration was deemed acceptable with a Mean Residual Head of 0.7, a Mean Residual Absolute Head of 4.9 and a Root Mean Square Error (RMSE) of 5.6.

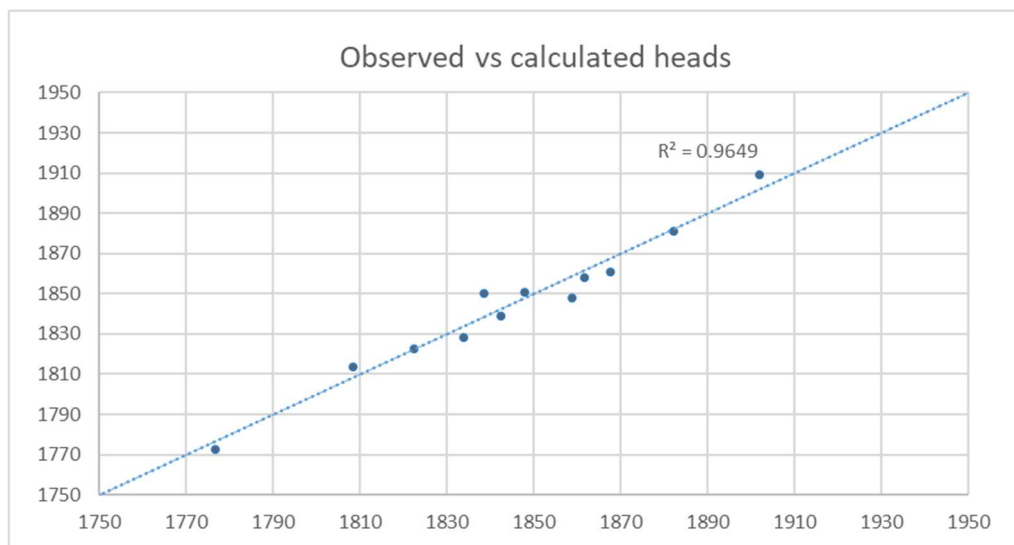


Figure 6-3: Correlation between observed and calculated heads.

A water balance error (all flows into the model minus all flows out of the model) of less than 0.5% is regarded as an accurate balance calculation. The steady state mass balance for entire model domain presented in Figure 6-1 achieved a water balance error of less than 0.002% (Table 6-2).

Table 6-2: Mass balance of steady state model.

	Flow In (m ³ /day)	Flow Out (m ³ /day)
Rivers	246.0	-732.4
Drains	0	-2006.3
Recharge	2492.7	0
TOTAL FLOW	2738.7	-2738.7
Summary	In – Out	% difference
Total	-0.0427	-0.003

6.4.2 Aquifer Hydraulic Conductivity

Initial estimates of the hydraulic conductivity for the different geological units were obtained from the slug test data collected as part of this investigation and based on expert knowledge from other nearby model sites. These hydraulic conductivity values were assigned to hydrogeological layers within the model area. The initial estimates were used for a combination of PEST and manual calibration. The resulting calibrated hydraulic conductivity and transmissivity values for each layer as summarised in Table 6-3.

Table 6-3: Calibrated values of horizontal and vertical hydraulic conductivities

Parameter	Description	PEST code	Layer	Value
Horizontal Hydraulic Conductivity	Vryheid Formation - weathered	HK_100	1	0.0900
Horizontal Hydraulic Conductivity	Dwyka - weathered	HK_200	1	0.0800
Horizontal Hydraulic Conductivity	Lakenvlei Formation - weathered	HK_300	1	0.0800
Horizontal Hydraulic Conductivity	Diabase - weathered	HK_400	1	0.0700
Horizontal Hydraulic Conductivity	Vryheid Formation - fractured	HK_500	2	0.0060
Horizontal Hydraulic Conductivity	Dwyka - fractured	HK_600	2	0.0050
Horizontal Hydraulic Conductivity	Lakenvlei Formation - fractured	HK_700	2	0.0050
Horizontal Hydraulic Conductivity	Diabase - fractured	HK_800	2	0.0040

Parameter	Description	PEST code	Layer	Value
Horizontal Hydraulic Conductivity	Pre-Karoo - fractured	HK_900	3	0.0020
Horizontal Hydraulic Conductivity	Faults	HK_1000	2-3	0.1800

6.4.3 Other model parameters

Recharge values were re-estimated as part of the steady state flow model calibration. An effective large-scale annual recharge value of between 0.57 and 1.1% of MAP (amounting to 1.14×10^{-5} – 2.23×10^{-5} m/d) was estimated for the model which is deemed acceptable for the hydrogeological units present for the Project Site and surrounding area. Other model parameters used in the calibrated model were as follows:

- Non-perennial streams:
 - Drain level at surface level;
 - Drain conductance of 0.2 m²/d/m².
- Rivers:
 - Head level at surface level;
 - River bottom level at 2 m below surface level;
 - River conductance of 0.2 m²/d/m².
- Mine drains:
 - Drain conductance of 0.2 m²/d/m².
- Vertical hydraulic conductivity:
 - 0.1 x horizontal conductivity.
- Specific yield:
 - Weathered zone: 0.03;
 - Fractured zone: 0.01;
 - Low fractured zone (pre-Karoo): 0.001;
 - Faults: 0.01
- Specific storage:
 - Weathered zone: 0.003 m⁻¹;
 - Fractured zone: 0.001 m⁻¹;
 - Low fractured zone (pre-Karoo): 0.0001 m⁻¹;
 - Faults: 0.001 m⁻¹

6.4.4 Sensitivity Analysis

A sensitivity analysis was carried out on the calibrated model. The purpose of the sensitivity analysis was to quantify the uncertainty in the calibrated model caused by the uncertainty in the estimates of aquifer parameters. During the sensitivity analysis horizontal conductivity and recharge were assessed. The sensitivities for the parameters the model results are most sensitive to can be seen in Figure 6-4. Results of the sensitivity analysis indicate that the water levels in the model are mainly sensitive to changes in recharge of the Vryheid Formation and the hydraulic conductivity for the Vryheid fractured aquifer, and to a lesser extent recharge to the Dwyka and Lakenvlei aquifers and hydraulic conductivities of the Vryheid weathered aquifer and the Pre-Karoo fractured aquifers.

Based on these results it is recommended that groundwater monitoring should focus on the weathered zones of the geological units at the site and its surroundings to provide improved data regarding the parameters for these aquifer units. Continued time series groundwater level data and from selected shallow groundwater monitoring boreholes, and chloride mass balance calculations on samples taken from selected boreholes will benefit future model updates the most.

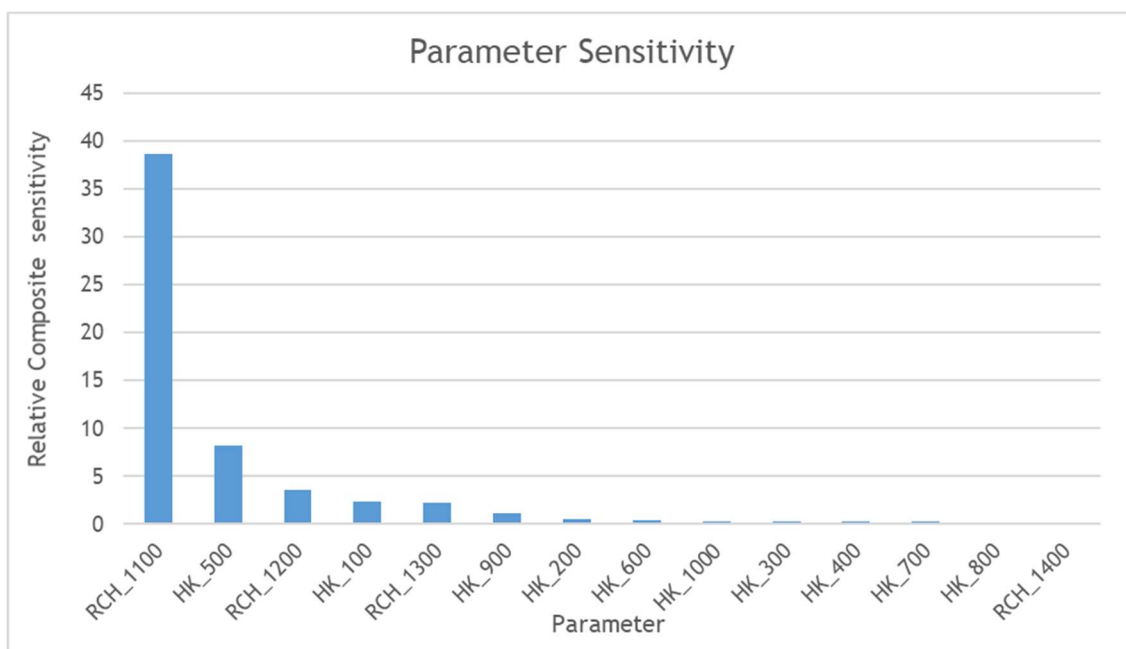


Figure 6-4: Model Parameter Relative Composite Sensitivity.

6.4.5 Simulated Water Levels and Flow Direction

The simulated groundwater levels for the current situation are shown in Figure 6-5. The groundwater levels show the general south to southeastern flow direction of groundwater as previously discussed, with highest groundwater levels along the northern model boundary at the topographical divide, and lowest groundwater levels at the southern end of the model, where the hydrological outflow point for the model is situated.

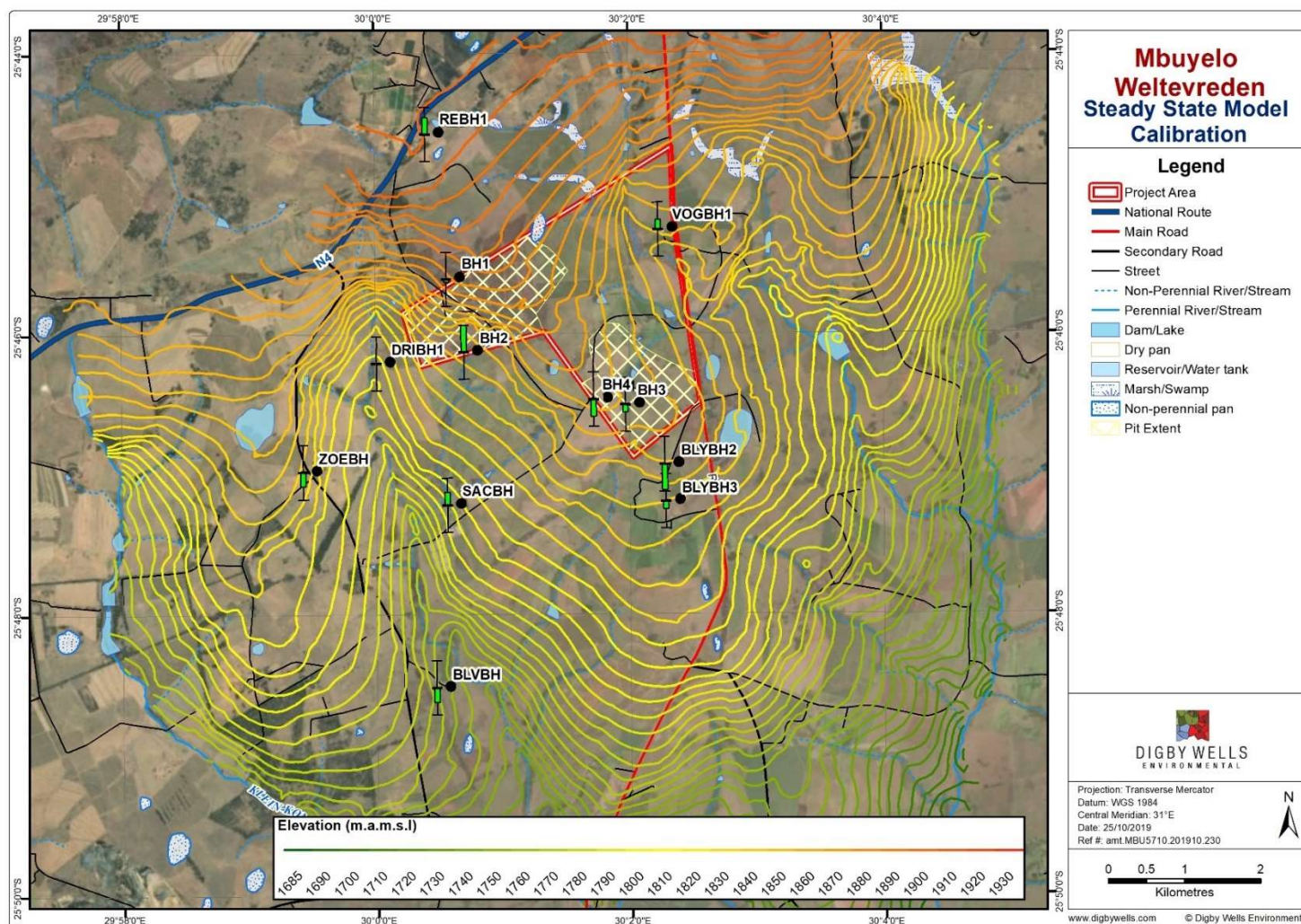


Figure 6-5: Steady-state groundwater levels and calibration results

6.5 Transient State Flow Simulation

Transient flow simulation was carried out to estimate groundwater drawdown for the operational phase and groundwater recovery in the post-closure phase. The transient flow model was based on coal seam floor depths (Figure 2-3) and the latest mine schedule as provided by Xinovo Mining (Figure 2-4). The current LoM is five years in total.

In addition, increased seepage was modelled for the backfilled opencasts and proposed hards stockpiles. Seepage from these stockpiles was estimated based on experience at similar coal mines in a similar geological setting, and a recharge rate of ~12% of MAP was assigned to the hards stockpiles and ~6.5% of MAP for the backfilled, rehabilitated opencast areas for the post-closure phase.

6.6 Mass Transport Simulation

Mass transport calculations were carried out for the opencast pits and the hards stockpiles. Contamination from the opencasts can occur when contaminated water from the backfill infiltrates into the surrounding aquifer. This will most likely only occur post-closure when water levels return to approximate pre-mining conditions. A modelling scenario assuming full backfill and rehabilitation of topsoil and vegetation within the opencast areas was carried out to calculate the expected plume extent.

Contamination from the hards stockpiles can occur through seepage into the waste rock materials, infiltrating into the underlying aquifers. This can occur during the LoM, but more importantly, can continue into the post-closure phase.

6.6.1 Dispersion and Diffusion

No in-field verification of dispersion was available for this study. However, representative, generic values for dispersion and parameters have been used as input into the numerical model. The longitudinal dispersion was set at 50 m, with the following ratios applied for transverse dispersion:

- Horizontal transverse dispersion/longitudinal dispersion: 0.1; and
- Vertical transverse dispersion/longitudinal dispersion: 0.01.

6.6.2 Effective Porosity and Specific Yield

The specific yield was kept equal to the effective porosity. Effective porosity input values were as follows:

- Weathered zone: 0.03;
- Highly fractured zone: 0.01; and
- Low fractured zone: 0.001.

These values are based on previous investigations in similar geological settings.

6.6.3 Selection of the Contamination

As the main source of contamination with coal mining is the weathering of pyrite, the contaminant of choice is sulphate that is released, together with acidity, due to the solution of pyrite. The input concentrations were based on the results of the geochemical assessment, which indicated sulphate levels could increase to over 1 200 mg/l. Conservatively a value of 1 250 mg/l was used as input and is assumed a reasonable concentration as based on the geochemical composition of the coal materials (Section 4).

7 Impact Assessment

The aim of an impact assessment is to strive to avoid damage or loss of ecosystems and services that they provide, and where they cannot be avoided, to reduce, and mitigate these impacts (DEA, 2014). Offsets to compensate for the loss of habitat are regarded as a last resort, after all efforts have been made to avoid, reduce, and mitigate.

The potential impacts of the proposed activities on groundwater resources are shown below per phase of the mine; the impacts were derived based on previous experience and literature review. The impacts shown below take into account the worst-case scenario, however these impacts need to be considered during the planning phase.

1.1 Construction Phase

The construction phase will consist of building of the surface infrastructure of the mine, the construction of box cuts for the two opencasts. The following potential impacts could result from these on-site activities (Table 7-1 and Table 7-2):

- Project Site contamination of groundwater due to hydrocarbon spillages and leaks from construction vehicles; and
- Small-scale dewatering during the construction of box cuts and stripping of topsoils and softs within the opencast areas.

However, these activities are of small magnitude and will only pose Project Site specific groundwater risks. Therefore, the impact of these activities is expected to be low.

7.1.1 Mitigations

Mitigation measures for the construction phase are as follows:

- Regular service of vehicles in designated repair bays;
- Refuelling of vehicles only in designated areas;
- Keep the stripping time as short as possible; and
- If the groundwater level is intercepted the extent and depth of the stripped area should be as minimal as possible while still allowing access into the opencast pits.

Table 7-1. Impacts during the Construction Phase - Spillages

Dimension	Rating	Motivation	Significance
Activity and Interaction: Fuel storage, construction vehicles causing potential groundwater contamination			
Impact Description: site contamination of groundwater due to hydrocarbon spillages and leaks from construction vehicle			
Prior to Mitigation/Management			
Duration	1	Any occurrence could be reversed within a months' time	Negligible (negative) -10
Extent	1	Impacts will be limited to specific isolated parts of the site.	
Intensity	2	Expected minor impacts on the biological or physical environment; damage can be rehabilitated internally.	
Probability	3	There is a possibility of this impact to occur	
Nature	Negative		
Mitigation/Management Actions			
<ul style="list-style-type: none">Regular service of vehicles must take place in designated repair baysRefuelling of vehicles should take place only in designated areas			
Post-Mitigation			
Duration	1	Any occurrence could be reversed within a months' time	Negligible (negative) -6
Extent	1	Impacts will be limited to specific isolated parts of the site.	
Intensity	2	Expected minor impacts on the biological or physical environment; damage can be rehabilitated internally.	
Probability	1	With mitigation measures in place it is not expected to happen	
Nature	Negative		

Table 7-2. Impacts during the Construction Phase - Stripping.

Dimension	Rating	Motivation	Significance
Impact Description: Small scale dewatering during construction /stripping			
Prior to Mitigation/Management			
Duration	1	Any occurrence could be reversed within a months' time	Negligible (negative) -8
Extent	1	Impacts will be limited to specific isolated parts of the site.	
Intensity	2	Expected minor impacts on the biological or physical environment; damage can be rehabilitated internally.	
Probability	2	There is a possibility of this impact to occur if the box cuts go below the groundwater table	
Nature	Negative		
Mitigation/Management Actions			
<ul style="list-style-type: none">Keep the stripping time as short as possible.If the groundwater level is intercepted the extent and depth of the box-cut should be as minimal as possible while still allowing access into the opencast pits.			
Post-Mitigation			
Duration	1	Any occurrence could be reversed within a months' time	Negligible (negative) -6
Extent	1	Impacts will be limited to specific isolated parts of the site.	
Intensity	2	Expected minor impacts on the biological or physical environment; damage can be rehabilitated internally.	
Probability	1	Expected not to happen if box cut depth can be limited	
Nature	Negative		

1.2 Operational Phase

7.1.2 Groundwater level drawdown

The lowest coal floor elevations (refer to Figure 2-3) of the No. 2 Seam are partially below the regional groundwater levels thus causing groundwater inflows into the opencast mining areas from the surrounding aquifer during operation. The mining areas will have to be actively dewatered to ensure dry working conditions. Pumping of water that seeps into the opencast mining areas will cause dewatering of the surrounding aquifer and an associated decrease in groundwater levels within the zone of influence of the dewatering cone. The zone of influence of the dewatering cone depends on several factors including the depth of mining below the regional groundwater level, recharge from rainfall to the aquifer, the size of the mining area and the aquifer transmissivity, amongst others.

During the operational phase it is expected that the main impact on the groundwater environment will be dewatering of the surrounding aquifer. A numerical groundwater flow model was used to simulate the development of the drawdown cone over time on the Project Site and surrounding area. The mine plan includes mining for a period of 10 years in total. The potential cone of drawdown is largest at the end of life of mine and extends to a maximum radius of ~200 m around the opencasts.

7.1.3 Mitigations

The limited drawdown impacts as a consequence of the relatively shallow pit depths is expected to result in a minor impact due to the scale. To reduce the impact further the mining footprint should be kept as small as possible, mining should progress as quickly as possible, and dewatering activities should cease as soon as possible after mining has been completed. Frequent groundwater level monitoring should be carried out throughout the operational phase to discern trends in water levels and comparison with calculated drawdowns. Based on the simulations no third-party sources, wellfields or other groundwater abstractions are present within the zone of influence and as such it is unlikely there will be an impact on third party abstraction sources.

Table 7-3. Impacts during the Operational Phase – Groundwater Drawdown.

Dimension	Rating	Motivation	Significance
Activity and Interaction: Mine dewatering causing lowering of groundwater levels			
Impact Description: Active mine dewatering will be required to ensure dry working conditions in the opencast pits. The dewatering will cause ground levels to be drawn down in the vicinity of the mining area.			
Prior to Mitigation/Management			
Duration	6	Expected for LoM	Minor (negative) - 42
Extent	2	Limited to OC1, OC2 and surroundings.	
Intensity	3	Moderate, short-term effects but not affecting ecosystem function.	
Probability	6	It is likely that this impact will occur	
Nature	Negative		
Mitigation/Management Actions			
<ul style="list-style-type: none">▪ Mining should progress as swiftly as possible to reduce the period of active dewatering▪ The mining area extent should be kept to a minimum▪ Dewatering of the opencast pits should stop should as soon as the mining activities cease▪ Groundwater levels surrounding the pits should be monitored on a regular basis throughout the LoM to verify the extent of the cone of drawdown			
Post-Mitigation			
Duration	5	Expected for LoM	Minor (negative) - 39
Extent	2	Limited to OC1, OC2 and surroundings.	
Intensity	3	Moderate, short-term effects but not affecting ecosystem function.	
Probability	6	It is likely that this impact will occur	
Nature	Negative		

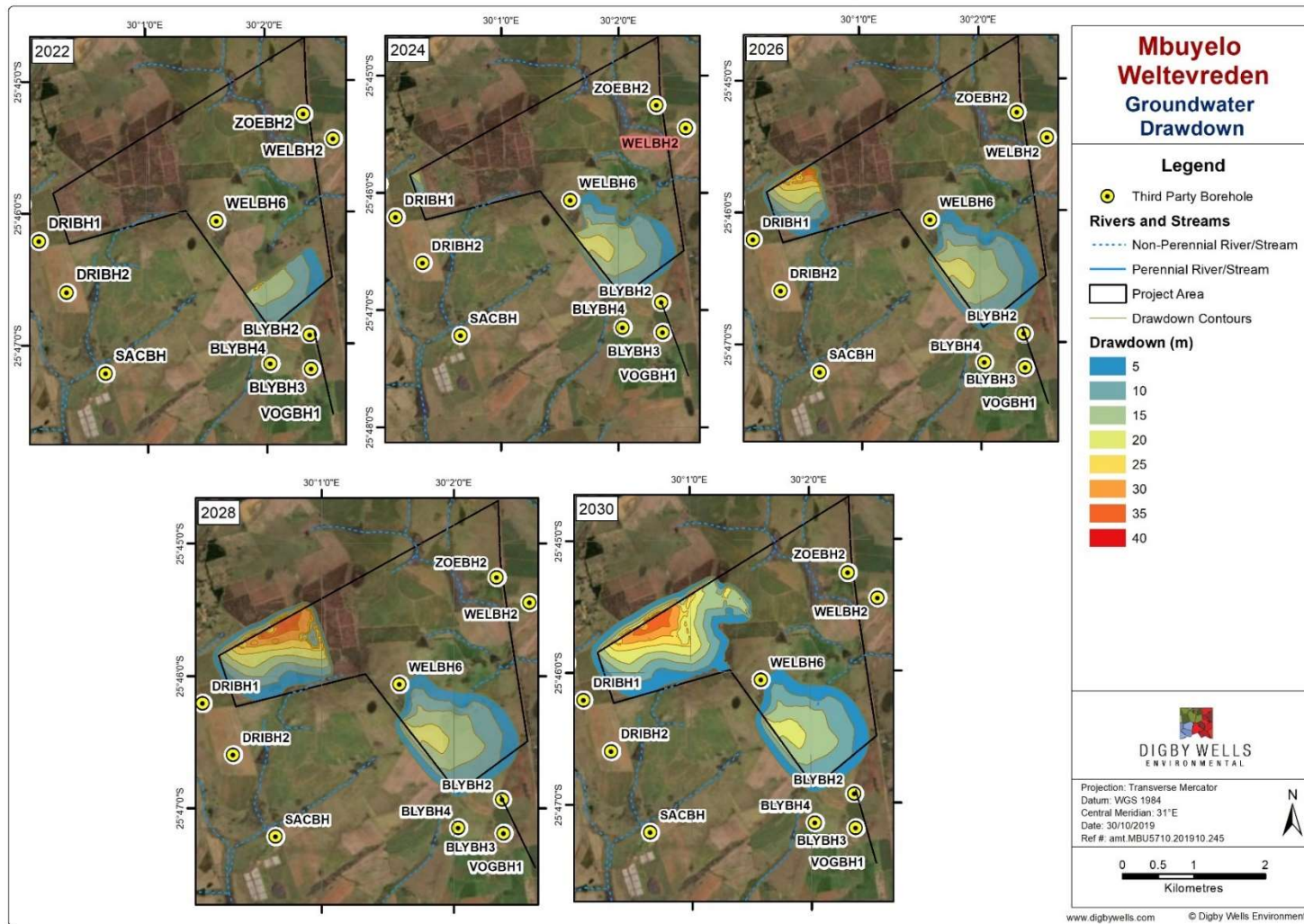


Figure 7-1: Groundwater cone of drawdown during the operational phase

7.1.4 Impact on aquifer yield (groundwater abstraction volumes)

The numerical model was used to predict groundwater inflows into the proposed mine. The computed inflow into the opencast workings was calculated based on the provided mine schedules and assumptions of the numerical model (refer to Section 6). For the first five years of the operational phase the groundwater inflow increases due to the increase in annual production from OC1. During steady state production the groundwater inflows will likely be in the range of ~500 to ~1 500 m³/d (Figure 7-2). Most of these abstraction volumes will be drawn from the pit areas, however, the drainage line now flowing from the area where OC1 will be located, may be impacted upon due to lower flow conditions. Therefore, the impact on groundwater availability will be minor. Dewatering volumes should be monitored frequently throughout the Operational Phase to note any deviations from predicted inflows.

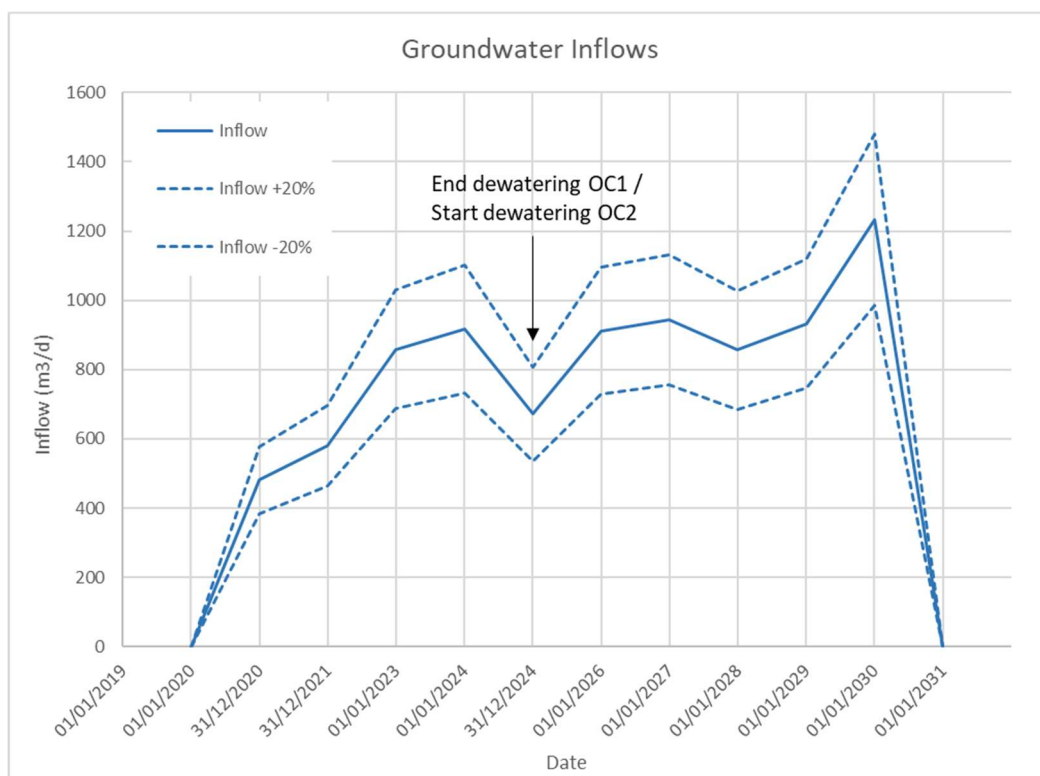


Figure 7-2. Simulated groundwater inflows into the opencast pits

Table 7-4. Impacts during the Operational Phase – Groundwater Abstraction

Dimension	Rating	Motivation	Significance
Activity and Interaction: Mine dewatering causing a decrease in groundwater reserves			
Impact Description: Due to active mine dewatering required to ensure dry working conditions in the opencast pits, certain groundwater volumes will be extracted from the opencast pits, limiting the groundwater resource.			
Prior to Mitigation/Management			
Duration	6	Expected for LoM and a short period post-closure	Minor (negative) - 36
Extent	2	Limited to OC1, OC2 and surroundings.	
Intensity	3	Moderate, short-term effects but not affecting ecosystem function.	
Probability	4	It is probable that this impact will occur	
Nature	Negative		
Mitigation/Management Actions			
<ul style="list-style-type: none">▪ Mining should progress as swiftly as possible to reduce the period of active dewatering▪ The mining area extent should be kept to a minimum▪ Dewatering of the opencast pits should stop should as soon as the mining activities cease▪ Dewatering volumes should be monitored frequently throughout the LoM to note deviations from the predicted inflows as soon as possible			
Post-Mitigation			
Duration	5	Expected for LoM	Negligible (negative) -33
Extent	2	Limited to OC1, OC2 and surroundings.	
Intensity	3	Moderate, short-term effects but not affecting ecosystem function.	
Probability	4	It is probable that this impact will occur	
Nature	Negative		

7.1.5 Groundwater Quality (Potential contamination of groundwater)

The current mining schedule for the Project Site includes 10 years of mining. This allows sufficient time for chemical reactions to take place in the mined-out areas and other potential pollution sources to produce AMD conditions. Groundwater flow directions will be directed towards the mining areas due to the mine dewatering. Therefore, contamination during the operational phase will be contained within the mining area, and little contamination will be able to migrate away from the mining area.

Discard material, if any, should be placed in discard dumps. Any pollution control dams and/or ROM coal stockpile areas should be lined, thereby preventing contamination of the underlying aquifers. During the operational phase clean water and rainwater needs to be diverted away from these surface infrastructures as much as possible to reduce seepage to groundwater.

Contamination from workshops, sewage treatment plant, wash bay or waste collection areas, if any, should be contained as much as possible by proper construction of hardstanding and bunded areas.

Table 7-5. Impacts during the Operational Phase – Groundwater Quality

Dimension	Rating	Motivation	Significance
Activity and Interaction: AMD formation in the opencast pits and hards stockpile causing groundwater contamination			
Impact Description: Due to AMD taking place within the opencast pits and in the hards stockpile, potential groundwater contamination with sulphate and a lower pH could occur, which would have an impact on the groundwater quality.			
Prior to Mitigation/Management			
Duration	6	Expected for LoM and post-closure	Negligible (negative) -22
Extent	2	Limited to OC1, OC2 and surroundings.	
Intensity	2	Negligible effects due to drawdown cone preventing contaminants from spreading	
Probability	3	With current limited data available and based on previous experience this impact is probable	
Nature	Negative		
Mitigation/Management Actions			
<ul style="list-style-type: none">Groundwater abstraction should continue for the LoM to maintain a cone of drawdownMonitoring of groundwater quality in the area surrounding the pits should continue throughout the LoMGroundwater levels surrounding the pits should be monitored on a regular basis throughout the LoM to verify the extent of the cone of drawdown			
Post-Mitigation			
Duration	5	Expected for LoM	Negligible (negative) -18
Extent	2	Limited to OC1, OC2 and surroundings.	
Intensity	2	Negligible effects due to drawdown cone preventing contaminants from spreading	
Probability	2	With current limited data available and based on previous experience this impact is likely to occur but reduced with mitigations in place	
Nature	Negative		

1.3 Post-Closure Phase

7.1.6 Groundwater level recovery

After the end of life of mine pumping of groundwater from the opencast pits will cease, the voids will be backfilled and groundwater levels are allowed to recover. Groundwater levels in the surrounding area which were drawn down due to the dewatering will subsequently return to close to the natural, pre-mining state. However, due to the low recharge influx and increased porosity of the backfill materials it will take a long time before groundwater levels will return to pre-mining conditions. The numerical model was used to simulate groundwater rebound and indicated the rebound will indeed be slow. Groundwater levels in the vicinity of the site are expected to take approximately 80 years to recover. However, due to the limited scale of the drawdown cone it is expected that the long-term recovery will have a minor impact.

Table 7-6. Impacts during the Post-Closure Phase – Groundwater Level Recovery

Dimension	Rating	Motivation	Significance
Activity and Interaction: Mine Dewatering and residual effect on rebounding groundwater levels			
Impact Description: Due to the dewatering activities during the Operational Phase, groundwater levels surrounding OC1 and OC2 will be subdued at the start of the Post Closure Phase, after it will gradually recover towards pre-mining levels.			
Prior to Mitigation/Management			
Duration	6	Reduced groundwater levels will be fully recovered within 100 years, but will be sufficiently recovered approximately 80 years post-closure to not affect any areas surrounding the mine void	Minor (negative) - 42
Extent	2	OC1, OC2 and surrounding area.	
Intensity	3	Moderate, short-term effects are expected	
Probability	6	This impact is likely to occur	
Nature	Negative		
Mitigation/Management Actions			
<ul style="list-style-type: none">Dewatering of the opencast pits should cease as soon as possible after mining activities are completed to allow for groundwater level recoveryGroundwater level recovery should be frequently monitored to identify deviations from the predicted recovery rate Groundwater quality should be frequently sampled to establish if a contaminant plume will migrateClean water and runoff should be diverted where possible towards the opencast pits voids to flood areas as fast as possible after mining has stopped.			
Post-Mitigation			
Duration	5	Reduced groundwater levels will be fully recovered within 100 years, but will be sufficiently recovered approximately 80 years post-closure to not affect any areas surrounding the mine void	Minor (negative) - 39
Extent	2	Limited to OC1, OC2 and local surroundings.	
Intensity	3	Moderate, short term effects are expected	
Probability	6	This impact is likely to occur	
Nature	Negative		

7.1.7 Groundwater contamination

Once the mining has ceased, AMD is still likely to form given the partially unsaturated conditions and the consequent contact of water and oxygen in the backfilled pits and hards stockpiles. Groundwater contaminants could migrate from these areas once groundwater levels in the opencast pits start to recover.

The migration of contaminated water from the opencast pits and the hards stockpiles was simulated for 50 and 100 years post-closure (Figure 7-3). The maximum extent of the contaminant plume (sulphate >50 mg/l) was calculated to be ~850 m from the backfilled opencast pits at 100 years Post-Closure. The migration of pollutants will mainly be in a north-easterly direction from OC1 and in a south-westerly and easterly direction from OC2.

Based on the contaminant transport simulations for the opencast pits, borehole DRIBH1 is projected to be within the zone of contamination and may experience increased sulphate concentrations 40 years Post-Closure. It is recommended to install a monitoring borehole close to DRIBH1 and to continuously monitor the groundwater quality during the Operational Phase and into the Post-Closure Phase. If proven this borehole will be affected by the mining activities an alternative water supply should be provided.

It is unlikely that any other privately-owned boreholes or the spring located in the vicinity of the proposed development will be impacted upon. The contaminant migration indicates that the plumes will flow towards and following local drainage lines located between and to the west and the east of the opencast pits.

According to the simulations the plumes will only reach the drainage lines west and east of the pits after 50 years, and after 100 years the anticipated sulphate concentrations are still below the SANS drinking water standards aesthetic limit of 250 mg/l and are therefore only expected to slightly increase salt load to the drainage lines. This impact is therefore considered to be low. Frequent water quality monitoring should be carried out for the Operational Phase and continue into the Post-Closure Phase to be able to discern trends in surface water quality.

The drainage line between the two pits is expected to receive an increased salt load from the contaminant plumes and expected sulphate concentrations of the groundwater close to the streams may go up to 1 000 mg/l. This is expected to have a moderate impact on the drainage line and associated unchanneled valley bottom wetland. To mitigate the contaminant plume migration the opencast pits should be properly rehabilitated, including reduction of recharge to these areas by properly top-soiling and vegetating the areas. This will reduce infiltration of water into the groundwater and reduce plume extents.

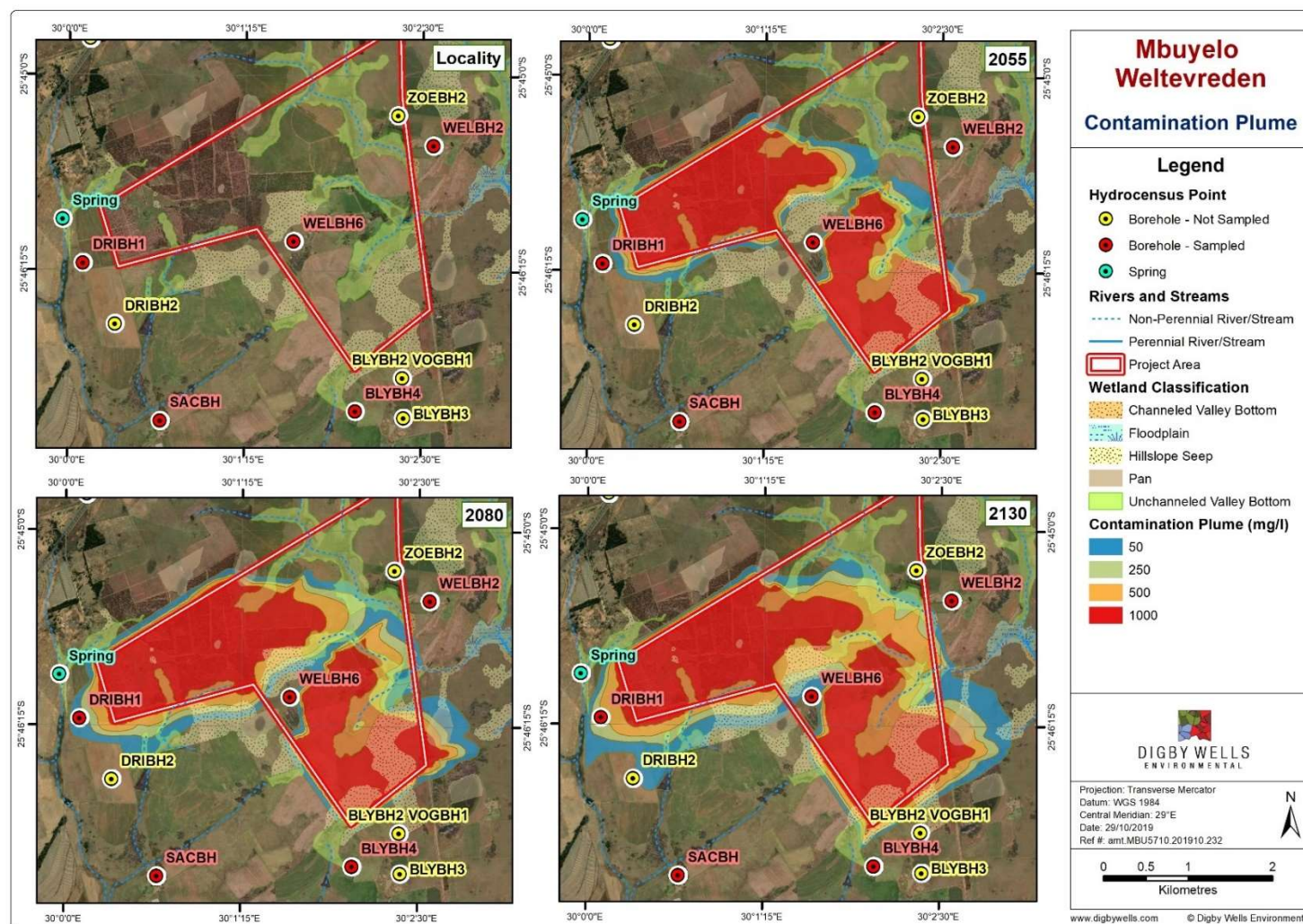


Table 7-7. Impacts during the Operational Phase – Groundwater Quality

Dimension	Rating	Motivation	Significance
Activity and Interaction: AMD in opencast pits and hards stockpiles causing groundwater contamination			
Impact Description: Due to AMD taking place within the backfilled opencast and in the hards stockpile, potential groundwater contamination with sulphate and a lower pH could occur, which would have an impact on the groundwater quality.			
Prior to Mitigation/Management			
Duration	7	The impact will remain long after the life of the Project. The impacts are irreversible.	Moderate (negative) -90
Extent	2	OC1, OC2 and surrounding area.	
Intensity	6	Serious impact on expected on ecosystems and drainage lines within the contaminant plume.	
Probability	6	This impact will likely occur	
Nature	Negative		
Mitigation/Management Actions			
<ul style="list-style-type: none">Dewatering of the pits should cease as soon as possible after mining activities are completed to allow for groundwater level recoveryRehabilitation of the pits and hards stockpiles to reduce infiltration of rainwater into the dump to reduce seepage generationClean water and runoff should be diverted where possible towards the rehabilitated pits as fast as possible after mining has stopped.Groundwater quality should be frequently sampled to establish if a contaminant plume will migrate			
Post-Mitigation			
Duration	7	The impact will remain long after the life of the Project. The impacts are however mitigated in duration if proposed mitigation of faster flooding is implemented	Moderate (negative) -75
Extent	2	Limited to OC1, OC2 and surroundings.	
Intensity	5	Serious impact on expected on ecosystems and drainage lines within the contaminant plume.	
Probability	6	This impact will likely occur	
Nature	Negative		

7.1.8 Mine Decant

For opencast mining the decant point can be established as the lowest topographical point of the pit outline at the end of life of mine. When the active dewatering of the opencast pits has ceased groundwater levels will rebound. As the backfilled opencasts flood, decant will occur when the groundwater level recovers to above the lowest surface elevation of the pit. This can occur long after the end of life of mine and is referred to as the time-to-decant. At the Project Site mining is planned for OC1 and OC2. Based on the proposed mine plans and site topography the potential decant points have been determined for each pit (Figure 7-4).

The volume of the opencast pits at the Project Site was based on the depth and extent of the pit shells. It is assumed the pits will be backfilled as the rollover mining method is being used. Decant calculations were carried out for OC1 and OC2. The porosity of the backfill material was taken to be between 15% and 25% of the total mined volume. A recharge rate of between 6.5% and 20% was used for the time-to-decant and decant volume calculations.

Due to the relative shallow depth of the opencast pits, decant could potentially occur soon after dewatering has ceased, and the estimated time-to-decant may be less than 10 years based on the pit volumes below the respective decant elevations for OC1 and OC2. Decant volume calculations show expected discharge rates of between approximately 220 and 820 m³/d.

Table 7-8 Opencast mine volume calculations

Opencast	Total mined volume m ³ (below decant position)	Void volume (15% effective porosity)	Void volume (25% effective porosity)
OC1	2720551	408082.62	680137.7
OC2	1306042	195906.33	326510.55

Table 7-9 Decant volumes (m³/d).

Opencast	Pit surface area (m ²)	Recharge 6.5%	Recharge 20%
OC1	2015000	266	819
OC2	1645000	217	669

Decant from OC1 will flow towards the tributary east of the pit; the decant from OC2 will flow towards the tributary west of the pit. Based on the calculated decant volumes and expected quality of the potential decant indicates a moderate impact if decant would occur and is not mitigated against. To reduce the impact on surface water quality a water treatment plant will be needed to improve the water quality emanating from the mining areas. Any potential decant flows from the opencast pits should be captured, for instance by an abstraction borehole placed inside the rehabilitated pit area at the decant points. This would locally reduce the groundwater level and prevent decant flow.

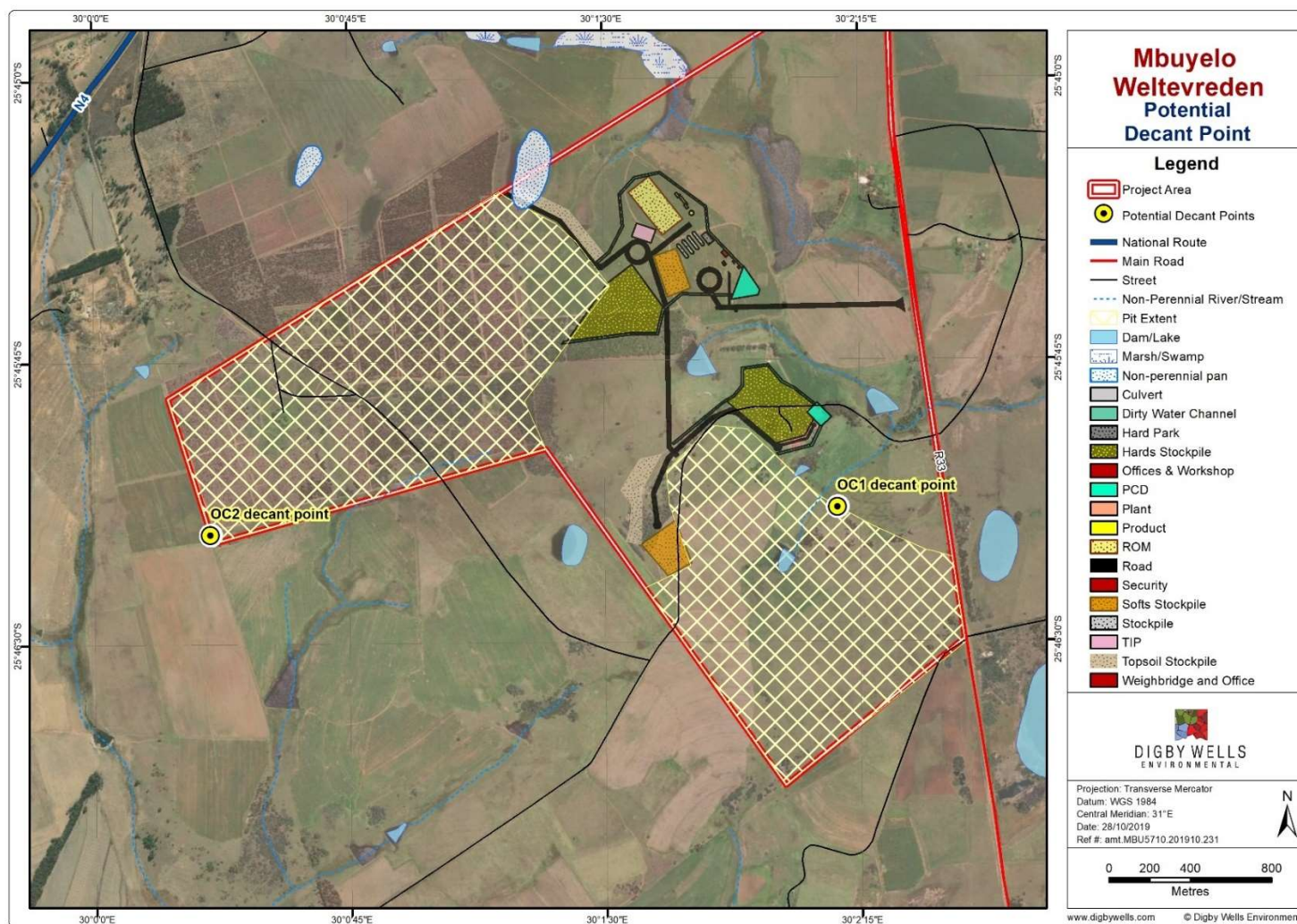


Figure 7-4: Potential decant points

Table 7-10. Impacts during the Operational Phase – Decant

Dimension	Rating	Motivation	Significance
Activity and Interaction: Mine decant causing contamination of groundwater			
Impact Description: If groundwater levels within the opencast pits recover to elevations higher than surface elevations, this water may then flow from the pit areas and cause groundwater contamination down gradient of the mine.			
Prior to Mitigation/Management			
Duration	7	The impact will remain long after the life of the Project. The impacts are irreversible.	Moderate (negative) -84
Extent	2	Decant points and downgradient	
Intensity	6	Serious impact on ecosystems within the contaminant plume.	
Probability	5	This impact may occur	
Nature	Negative		
Mitigation/Management Actions			
<ul style="list-style-type: none">Groundwater level recovery in the rehabilitated opencast pits should be frequently monitored to create stage curves and predict the final water recovery level.Rehabilitation of the pits and hards stockpiles to reduce infiltration of rainwater into the dump to reduce seepage generation.Installation of groundwater abstraction boreholes at decant points to reduce water level and prevent decant flow, and treatment of the abstracted water			
Post-Mitigation			
Duration	6	The impact will remain long after the life of the Project. The impacts are irreversible.	Minor (negative) - 60
Extent	2	Limited to the site only	
Intensity	6	Serious impact on ecosystems within the contaminant plume.	
Probability	2	This impact is unlikely to happen	
Nature	Negative		

8 Groundwater Monitoring Network

The groundwater monitoring network design should comply with the risk-based source-pathway-receptor principle. A groundwater-monitoring network should contain monitoring positions which can assess the groundwater status at certain areas. Both the impact on water quality and water quantity should be catered for in the monitoring system. The boreholes in the network should cover the following: contaminant sources, receptors and potential contaminant plumes. Furthermore, monitoring of the background water quality and levels is also required. Groundwater monitoring should be conducted to assess the following:

- The impact of mine dewatering on the surrounding aquifers. This will be achieved through monitoring of groundwater levels in the monitoring boreholes. If private boreholes are identified within the zone of impact on groundwater levels, these will be included in the monitoring programme;
- Groundwater inflow into the mine workings. This will be achieved through monitoring of groundwater levels in the monitoring boreholes as well as measuring water volumes pumped from mining areas;
- Groundwater quality trends. This will be achieved through sampling of the groundwater in the boreholes at the prescribed frequency; and
- The rate of groundwater recovery and the potential for decant after mining ceases. This can be achieved through measuring groundwater levels in the opencast pits workings. Stage curves will be drawn to assess the inflow into defunct workings.

Groundwater Monitoring should be undertaken according to the schedule presented in Table 8-1. The proposed monitoring network can be seen Table 8-1. It is envisaged that the frequency of monitoring remains on a quarterly basis.

Table 8-1 Groundwater Monitoring Programme

Monitoring position	Sampling interval	Water Quality Standards
Construction, Operational, Decommissioning and Post Closure Phases		
All monitoring boreholes	Quarterly: measuring the depth of groundwater levels	N/A
All monitoring boreholes	Quarterly: sampling for water quality analysis	South African Water Quality Guidelines: Domestic Use
Rainfall	Daily at the mine	N/A

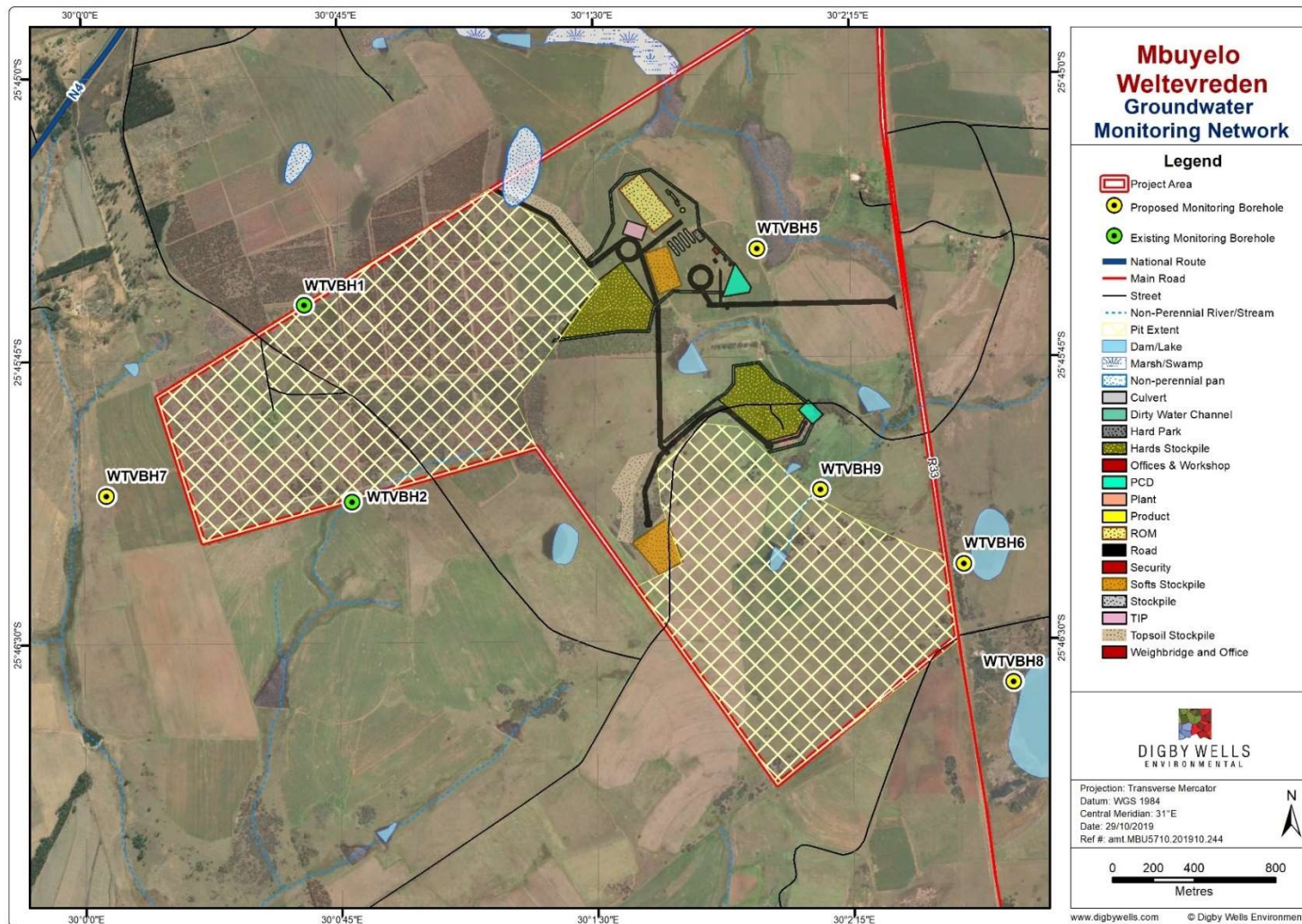


Figure 8-1: Proposed Groundwater Monitoring Network

9 Gaps in Knowledge and Limitations

The following limitations and gaps were identified:

- A model is a simplified representation of reality. This is also the case for numerical groundwater models. Numerical models assume uniform flow within the different aquifer units assigned to the model. In real-life there may be fractured or faulted zones within those units that could enhance groundwater flows. However, the calculated groundwater inflows and drawdowns are considered realistic.
- Porosity values for the aquifers were not available but were chosen based on experience in similar geological settings and values are deemed representative for Karoo strata;
- No in-field verification of dispersion was available for this study. However, representative, generic values for dispersion and parameters have been used as input into the numerical model.
- The model calibration was based on available groundwater levels taken in on-site monitoring and aquifer test holes and accessible third-party boreholes;
- Contaminant plume calculations were based on results from the geochemical assessment on 2 waste rock and 4 coal samples retrieved during the drilling of aquifer test boreholes. Additional coal samples would be recommended to verify the current results and increase the accuracy of the potential seepage concentrations from coal materials.

10 Conclusions and recommendations

10.1 Conclusions

The following conclusions were made for the site:

- The MAP of region surrounding the site is ~740 mm;
- The topography on the site shows higher elevations along the western, northern and eastern site boundaries with gentle slopes ranging directed towards the south-south-eastern part of the site;
- The site is situated within the Nkomati River catchment with drainage in the area surrounding the site mainly flowing in a southerly direction;
- The dominant lithologies present in the area are coal-bearing sandstone, mudstone, siltstone, shale and coal seams of the *Vryheid Formation* with dolerite sill type intrusions of the Karoo dolerite Suite. Pre-Karoo lithologies were also identified on-site. The coal reserve intersected in the Project Area is confined to the western part of the site with outcrops of diabase intrusions and the Lydenburg Member identified at the eastern half of the site;
- Based on the mineralogy and AMD results all coal and waste rock materials are

classed as PAG, potentially leading to AMD development and pollution of groundwater and surface water resources if not mitigated and managed;

- Coal material will be stockpiled for short periods on site before being transported or processed. The potential for pollution development and AMD formation is thus low and can be mitigated to reduce the contamination impact;
- Three principal aquifers are identified for the site: the weathered aquifer; the fractured Karoo aquifer; and the fractured pre-Karoo aquifer. The aquifers that occur in the area can therefore be classified as minor aquifers (low yielding), but of high importance and are understood to have a low to medium development potential, mostly used for small scale domestic purposes or occasionally for large scale irrigation;
- The shallow aquifer depth at the site ranges varies between 3 and 20 mbgl with an average of ~8 mbgl. Depth to pre-Karoo lithologies range between ~20-80 mbgl for the north-western part of the site and between ~15 and 50 mbgl for the south-western part. In terms of pollution risk and / or susceptibility to pollution, the shallow primary aquifer is understood to be highly susceptible to pollution;
- The main source of water supply in and around the proposed mining area is groundwater which is abstracted using submersible pumps, community handpumps and a windmill. Water is mainly used for domestic use and livestock watering, but also for cut flower and cherry production;
- Groundwater depth mostly ranges between ~3-11 mbgl, with groundwater levels deeper than 17 mbgl likely representing dynamic water levels for boreholes which are in use. Groundwater flow directions generally follow topography and drainage directions;
- The predominant groundwater type found was Mg-HCO₃ with a few instances of Ca-HCO₃ and Na-SO₄, Na-Cl and Mg-Cl. The groundwater is of good quality as no exceedances over the SANS or WHO drinking water guidelines were observed;
- The potential cone of drawdown during the operational phase is largest at the end of life of mine and extends to a maximum radius of ~200 m around the opencasts. The relatively small cone of drawdown is due to the overall shallow depths of the No. 2 coal seam;
- For the first five years of the Operational Phase the groundwater inflow increases due to the increase in annual production from OC1. During steady state production the groundwater inflows will likely be in the range of ~500 to ~1 500 m³/d;
- Based on the simulations no third-party sources, wellfields or other groundwater abstractions are present within the zone of influence. Therefore, it is unlikely there will be an impact on third party abstraction sources by lowering of water levels due to the dewatering activities;
- During the Operational Phase groundwater flow directions will be directed towards the mining areas due to the mine dewatering. Therefore, contamination during the

operational phase will be contained within the mining area, and little contamination will be able to migrate away from the mining area;

- The limited drawdown impacts as a consequence of the relatively shallow pit depths is expected to result in a minor impact due to the scale and it is unlikely there will be an impact on third party abstraction sources;
- During steady state production the groundwater inflows will likely be in the range of ~500 to ~1 500 m³/d. Most of these abstraction volumes will be drawn from the pit areas and as such the impact on groundwater availability will be minor;
- Groundwater levels in the vicinity of the site are expected to take approximately 80 years to recover Post-Closure. However, due to the limited scale of the drawdown cone it is expected that the long-term recovery will have a minor impact;
- It is unlikely that any other privately-owned boreholes or the spring located in the vicinity of the proposed development will be impacted upon. The contaminant migration indicates that the plumes will flow towards and following local drainage lines located between and to the west and the east of the opencast pits;
- The drainage line between the two pits is expected to receive an increased salt load from the contaminant plumes. This is expected to have a moderate impact on the drainage line and associated unchanneled valley bottom wetland; and
- Decant from OC1 will flow towards the tributary east of the pit; the decant from OC2 will flow towards the tributary west of the pit. Based on the calculated decant volumes and expected quality of the potential decant indicates a moderate impact if decant would occur and is not mitigated against. Any potential decant flows from the opencast pits should be captured and treated.
- Considering the limited extent of expected impacts on the groundwater environment, and taking into account the mitigations as recommended in this report, the proposed activities can be authorised.

10.2 Recommendations

The following recommendations are made, and should be included in the EMP_r and EA:

- The waste and coal materials are classified as a Type 3 waste and disposal of the material should therefore be done to a Class C landfill facility or a facility with a similar performing liner system;
- The development of a closure water management plan that assesses the management of a critical water level to minimise contamination of the shallow weathered aquifer. This must be analysed in a financial model to further inform the most effective closure water management options. The groundwater model must be used as a management tool to inform this process;
- Minimise the mining footprint, progress the mining activities as quickly as possible, and cease dewatering activities as soon as possible after mining has been completed;

- Flood the opencast areas as soon as possible to restrict oxygen ingress into the backfill and lower sulphate levels in seepage;
- Proper rehabilitation of the opencast pits, including the installation of a proper cover that reduces recharge to these areas including a proper top-soil layer and vegetation;
- Monitoring of groundwater abstraction volumes and the rate of water level recovery in the backfilled opencasts and the development of stage curves which will aid in water management during the Post-Closure Phase;
- Installation of a groundwater and surface water monitoring network, with frequent surface and groundwater quality monitoring for the operational phase, and to continue into the post-closure phase, to be able to discern trends in surface water quality;
- If proven that any third-party boreholes will be affected by the mining activities an alternative water supply must be provided;
- Updating of the geochemical assessment with dynamic testing and geochemical modelling to assess the long-term development of AMD;
- Updating of the numerical model once every two-three years or after significant changes in mine schedules or plans by using the measured water ingress and water levels to re-calibrate and refine the impact predictive scenario.
- Options to prevent decant flow from the pits, such as pump and treat, must be considered, alternatives compared and included in a closure plan.

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Appendix A: Borehole Logs



DIGBY WELLS ENVIRONMENTAL



Fern Isle, Section 10,
359 Pretoria Avenue
2125, Randburg
Tel: +27 (0)11 789 9495

CLIENT Mbuyelo Coal Mine

Province Mpumalanga
Location Belfast
Site
Project Name **Mbuyelo Group**
Project No. MBU5710
Drilled By Sure Focus Drilling
Date Drilled 29/08/2019

BOREHOLE ID WTVBH1

X-coordinate
Y-coordinate
Z-coordinate (mams)
Coordinate System
Final Depth (m) 51
Water Level (mbgl)
Collar Height (m)
Logged By Kgagelo Thobejane

PERCUSSION DRILL LOG

LITHOLOGICAL DESCRIPTION	GEOLOGICAL PROFILE	DEPTH mbgl	Weathering			Penetration rate (mm/sec/m)	WATER STRIKE mbgl	BLOW YIELD L/s (measure at every water strike and rock change)	DEPTH mbgl	BOREHOLE DESCRIPTION	BOREHOLE CONSTRUCTION
			Slight	Moderate	Very Complete						
Alluvium		0				31.91			0		
Highly Weathered Sandstone						33.52					
Mudstone						33.45					
Shale						34.52					
Sandstone						35.10					
Shale						33.89					
Weathered Sandstone						33.26					
Sandstone						37.76					
Shale and coal						35.54					
Mudstone						52.60					
						45.17					
						45.36					
						51.21					
						42.16					
						50.59					
						51.09					
						51.80					
						52.00					
						52.36					
						55.34					
						80.34					
						65.73					
						47.53					
						62.14					
						52.44					
						49.92					
						68.93					
						73.23					
						70.57					
						69.76					
						74.06					
						62.52					
						91.51					
						82.83					
						79.71					
						100.11					
						62.15					
						40.15					
						77.99					
						94.14					
						81.76					
						105.27					
						91.03					
						73.65					
						79.87					
						77.16					
						78.98					
						50.16					
						51.23					
						50.96					
						49.88					

Comment:



DIGBY WELLS ENVIRONMENTAL



Fern Isle, Section 10,
359 Pretoria Avenue
2125, Randburg
Tel: +27 (0)11 789 9495

CLIENT Mbuyelo Coal Mine

Province Mpumalanga

Location Belfast

Site

Project Name **Mbuyelo Group**

Project No. MBU5710

Drilled By Sure Focus Drilling

Date Drilled 28/09/2019

BOREHOLE ID WTVBH2

X-coordinate

Y-coordinate

Z-coordinate (mams)

Coordinate System

Final Depth (m) 44

Water Level (mbgl)

Colar Height (m)

Logged By Kgaugelo Thobejane

PERCUSSION DRILL LOG

LITHOLOGICAL DESCRIPTION	GEOLOGICAL PROFILE	DEPTH mbgl	Weathering			Penetration rate (mm.sec/m)	WATER STRIKE mbgl	BLOW YIELD L/s (measure at every water strike and rod change)	DEPTH mbgl	BOREHOLE DESCRIPTION	BOREHOLE CONSTRUCTION
			Slight	Moderate	Very Complete						
Mudstone		0				48.29			0	Solid PVC 0 - 6 m	
						47.69					
						43.20					
						45.15					
						41.99					
		5				43.77			5		
						46.32				Perforated PVC 6 - 40 m	
Siltstone						51.60					
						52.12					
		10				41.60			10		
Coal						41.71					
						43.70					
						43.19					
Carbonaceous Shale		15				55.60			15		
						55.17					
						53.30					
Siltstone						53.97					
Carbonaceous Shale		20				41.16			20		
						62.69					
Mudstone						44.60					
						42.53					
		25				52.88			25		
						56.90					
						56.02					
						68.20					
		30				69.68			30		
						69.94					
						59.58					
						69.60					
		35				54.72			35		
						71.42					
						74.34					
						61.55					
						62.00					
		40				61.54			40		
						68.08					
						74.88					
						75.23					
						75.50					
		45				90.90			45		
						77.37					
						79.44					
						101.68					
						103.99					
		50							50		
		55							55		
		60							60		
		65							65		

Comment:



PERCUSSION DRILL LOG

Comment:	
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Fern Isle, Section 10,
359 Pretoria Avenue
2125, Randburg
Tel: +27 (0)11 789 9495

CLIENT Mbuyelo Coal Mine

Province Mpumalanga
Location Belfast
Site
Project Name **Mbuyelo Group**
Project No. MBU5710
Drilled By Sure Focus Drilling
Date Drilled 26/08/2019

BOREHOLE ID WTVBH4

X-coordinate
Y-coordinate
Z-coordinate (mams)
Coordinate System
Final Depth (m)
Water Level (mbgl)
Collar Height (m)
Logged By Kgaugelo Thobejane

PERCUSSION DRILL LOG

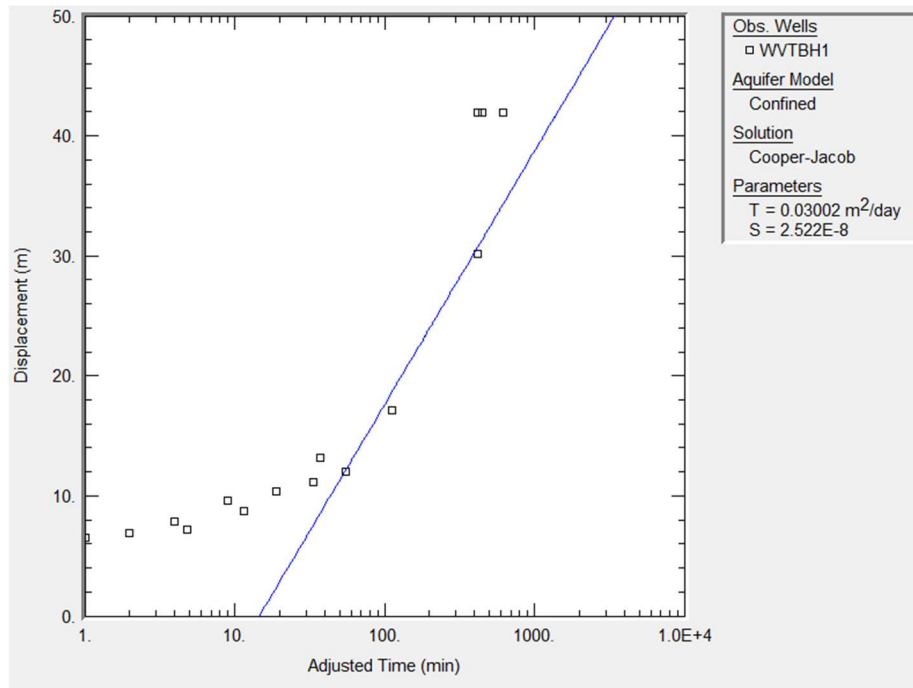
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			Slight	Moderate	Very Complete						
Alluvium		0				40.69			0		
Mudstone						40.20					
Siltstone						42.30					
Weathered Sandstone						32.52					
Mudstone						33.69					
						33.89					
						39.40					
						39.20					
						39.56					
						50.67					
Carbonaceous Shale						48.87					
						49.89					
						49.35					
						49.20					
						54.60					
						51.23					
						53.28					
						51.06					
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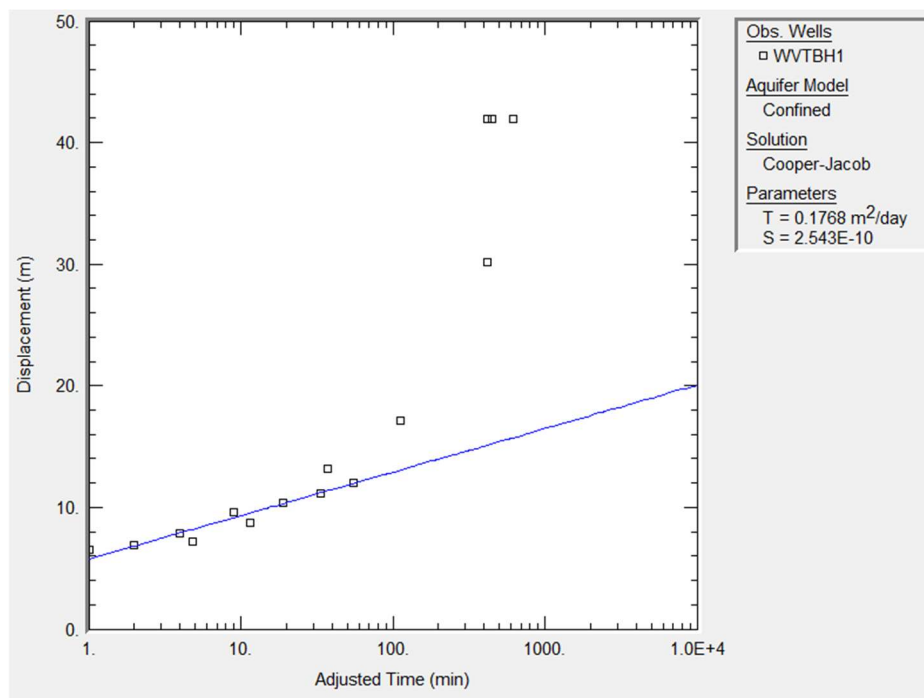


Appendix B: Aquifer Test Results

WTBH01



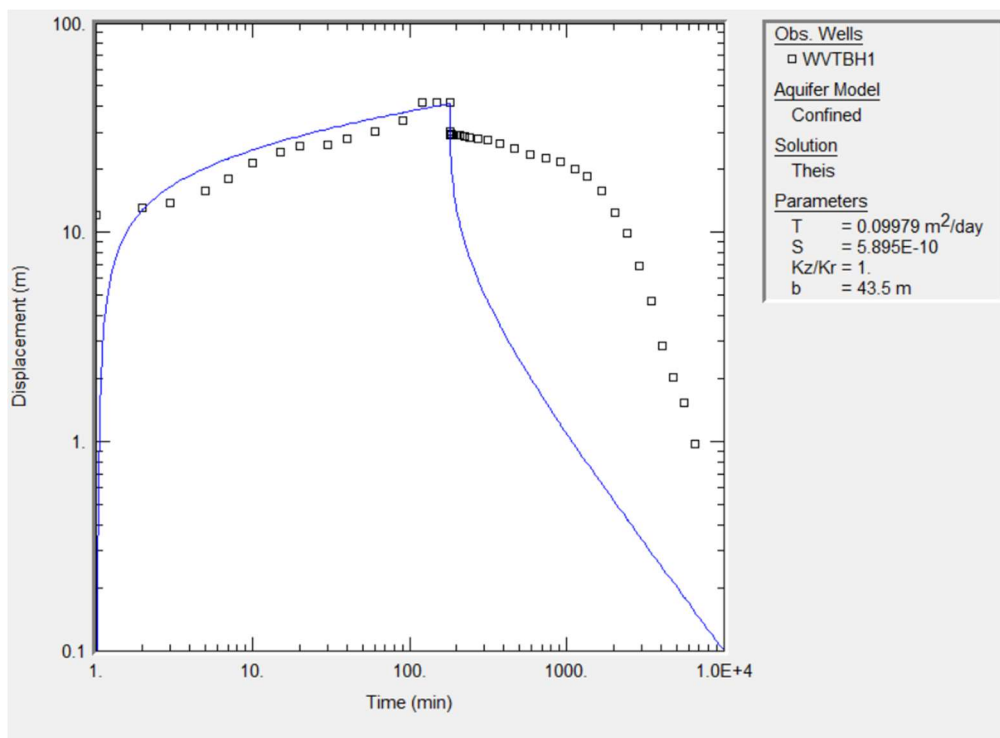
Cooper-Jacob
Early T



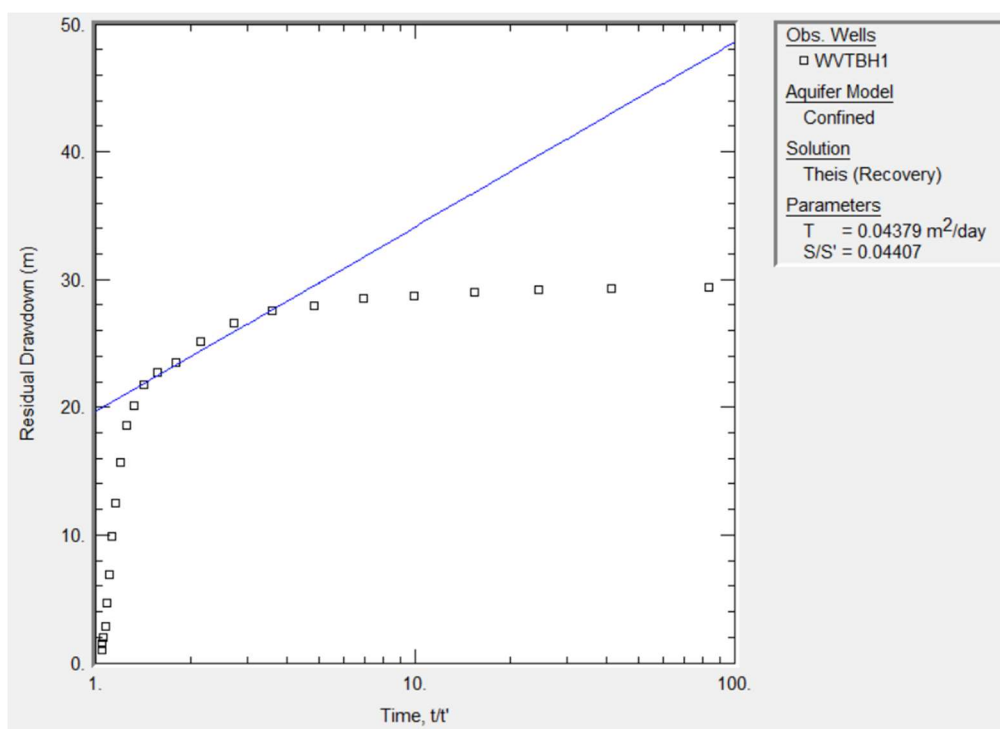
Cooper-
Jacob Late T



DIGBY WELLS ENVIRONMENTAL

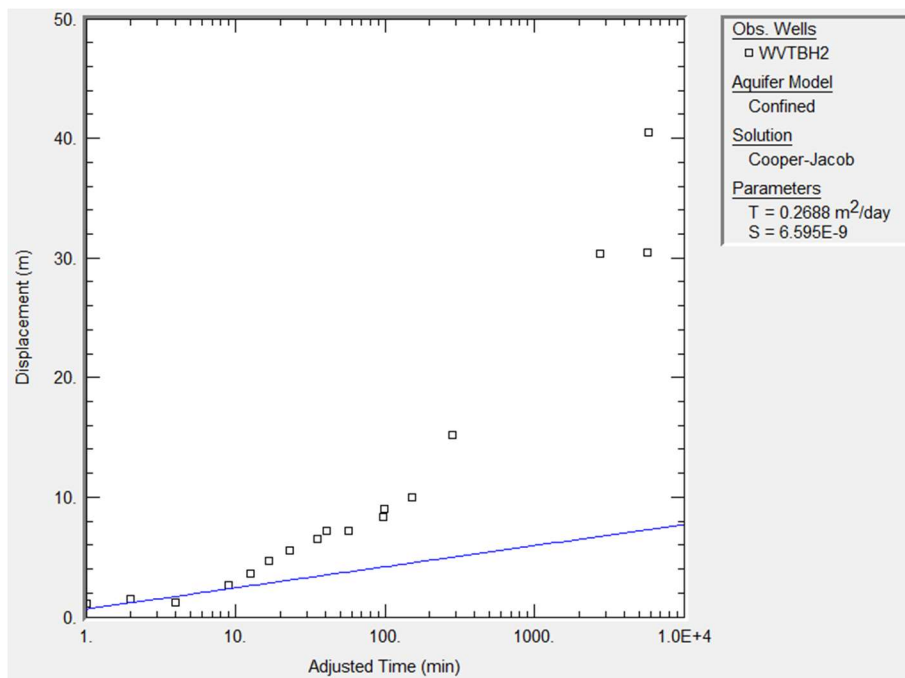


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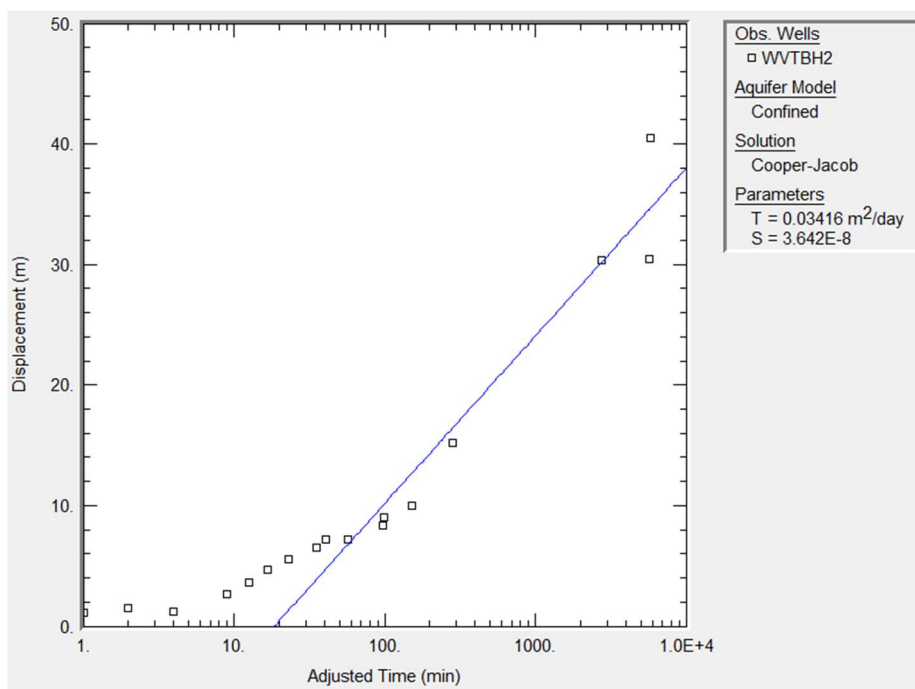


Theis recovery

WTVBH2



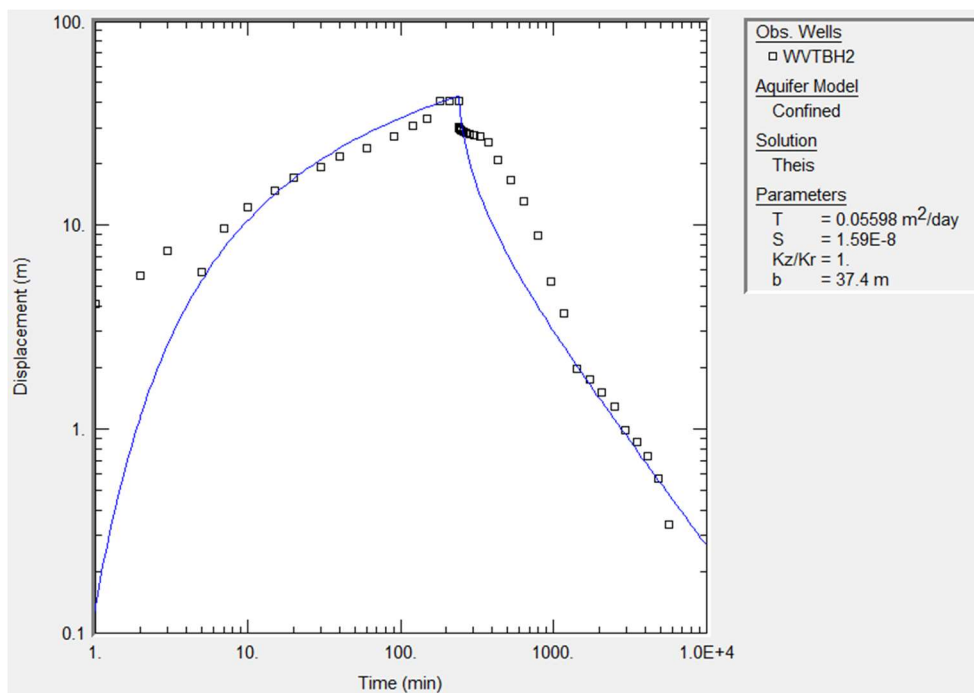
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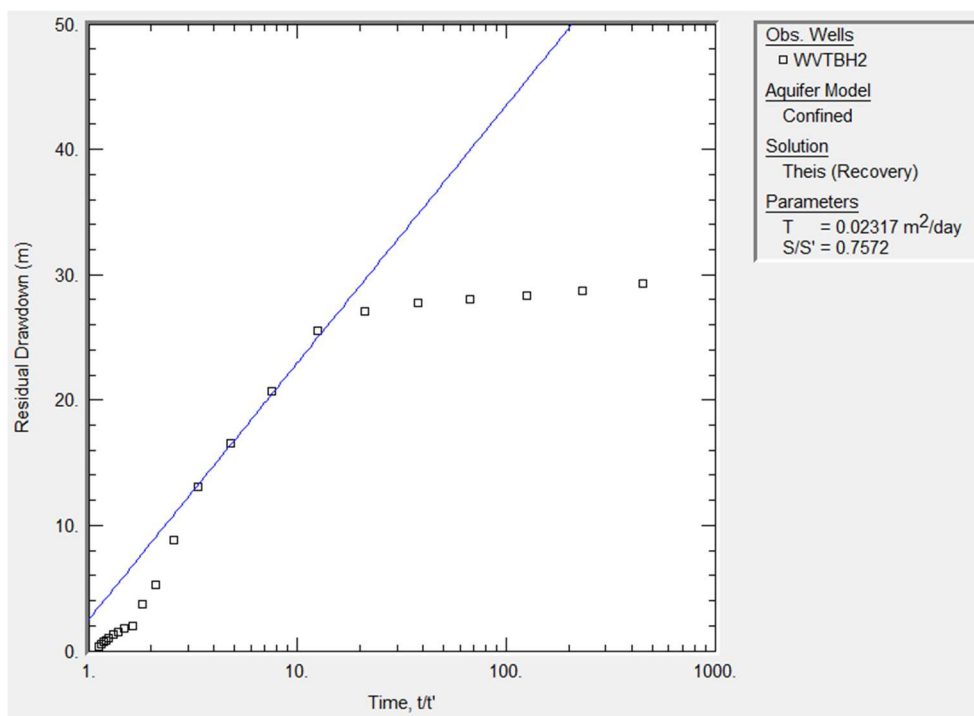
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DIGBY WELLS ENVIRONMENTAL

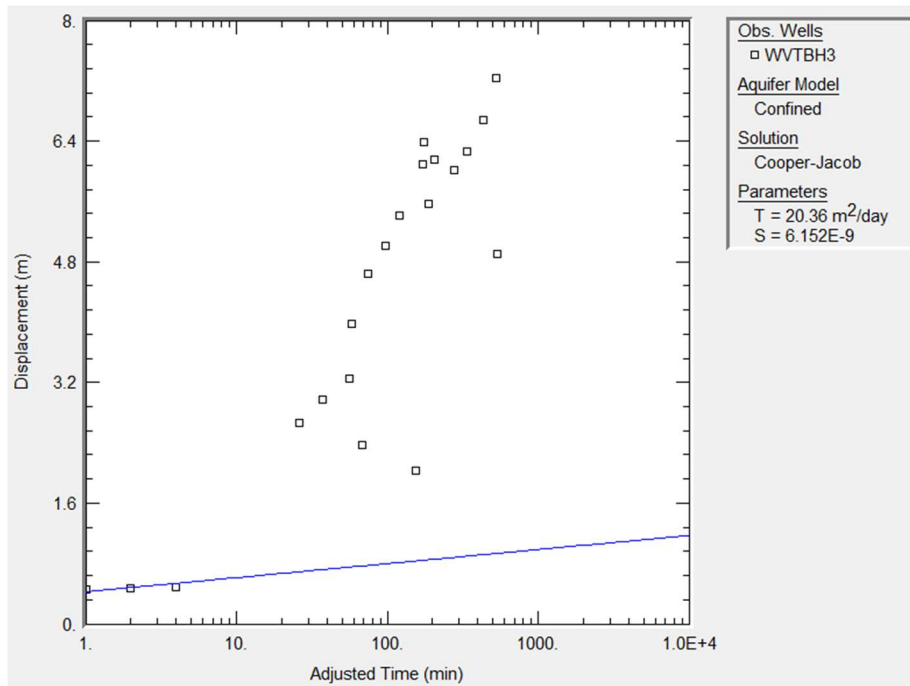


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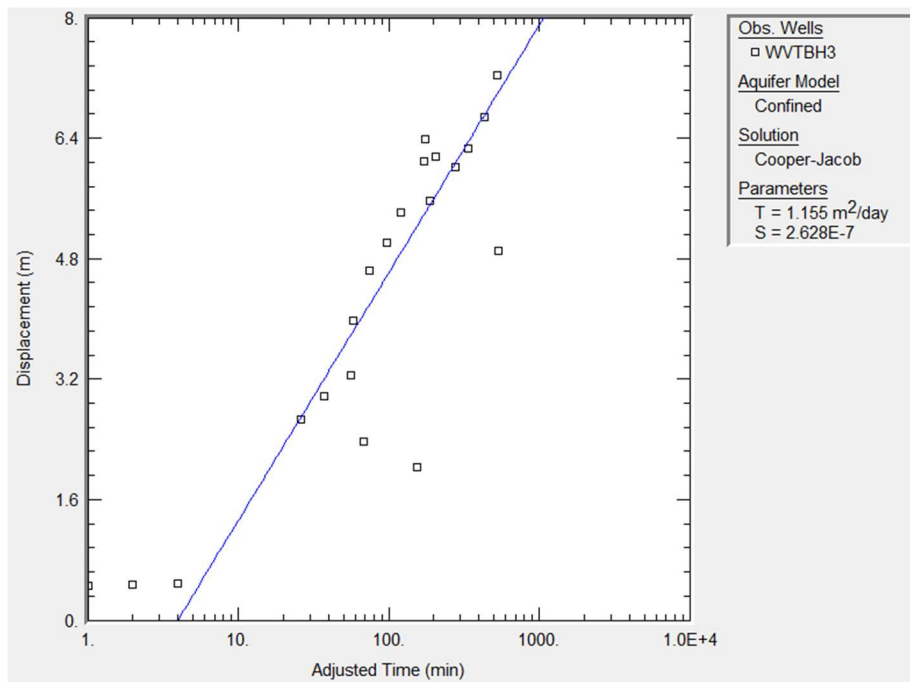


Theis Recovery

WVTBH3



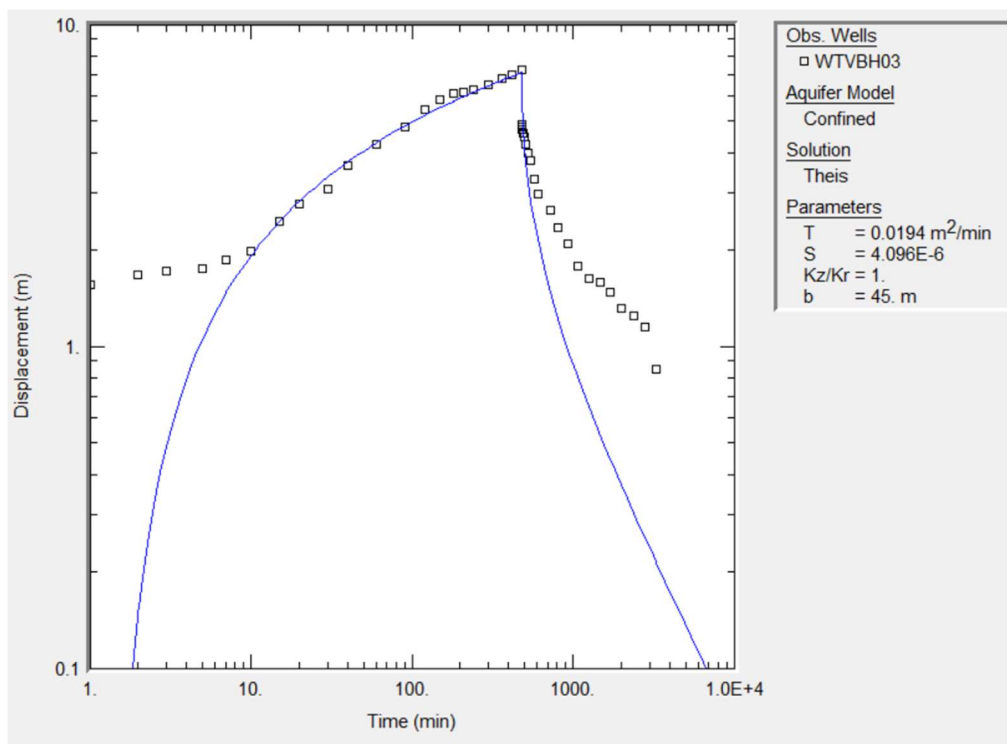
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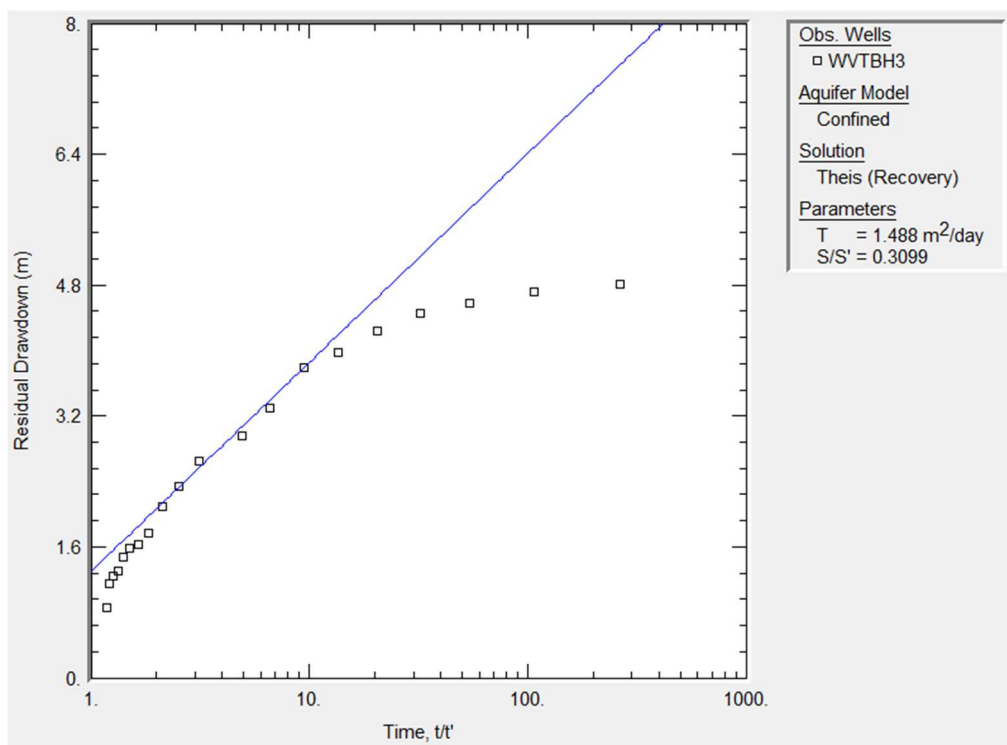
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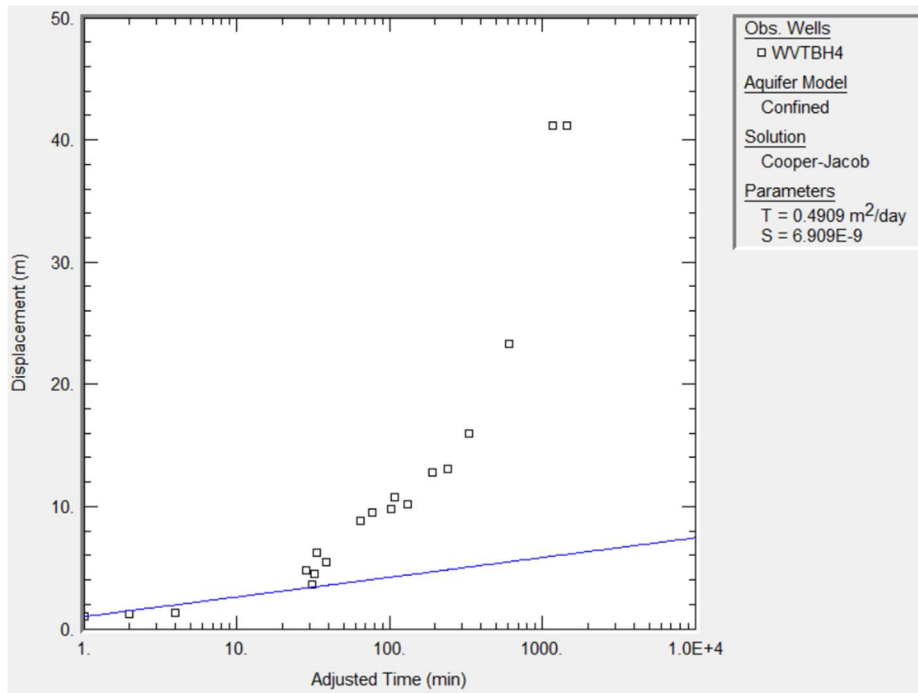


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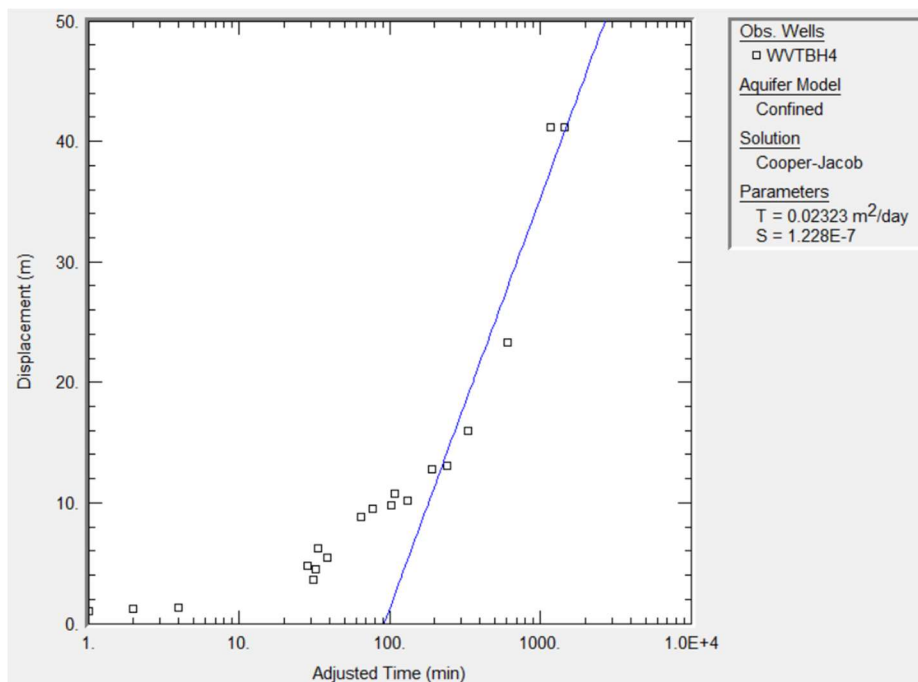


Theis recovery

WVTBH4



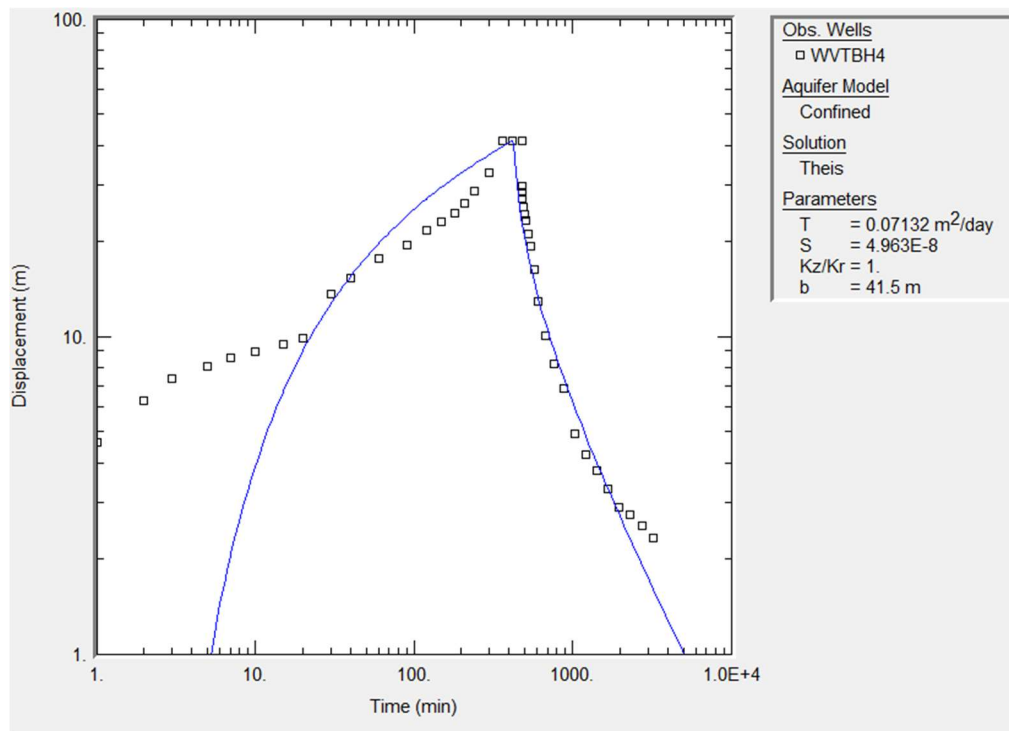
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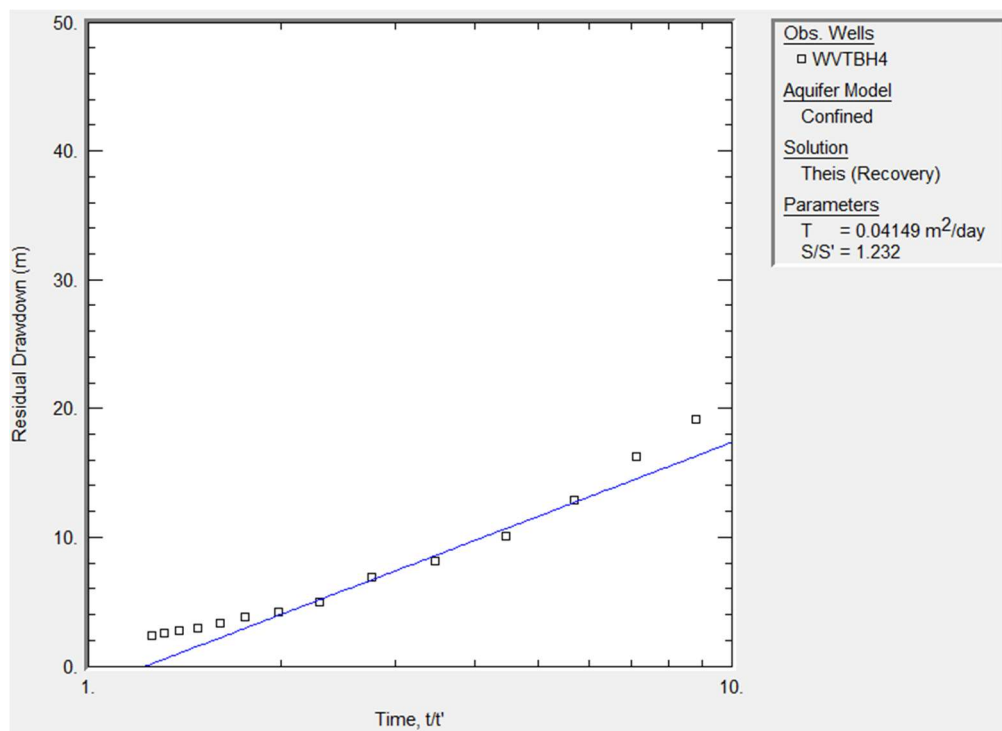
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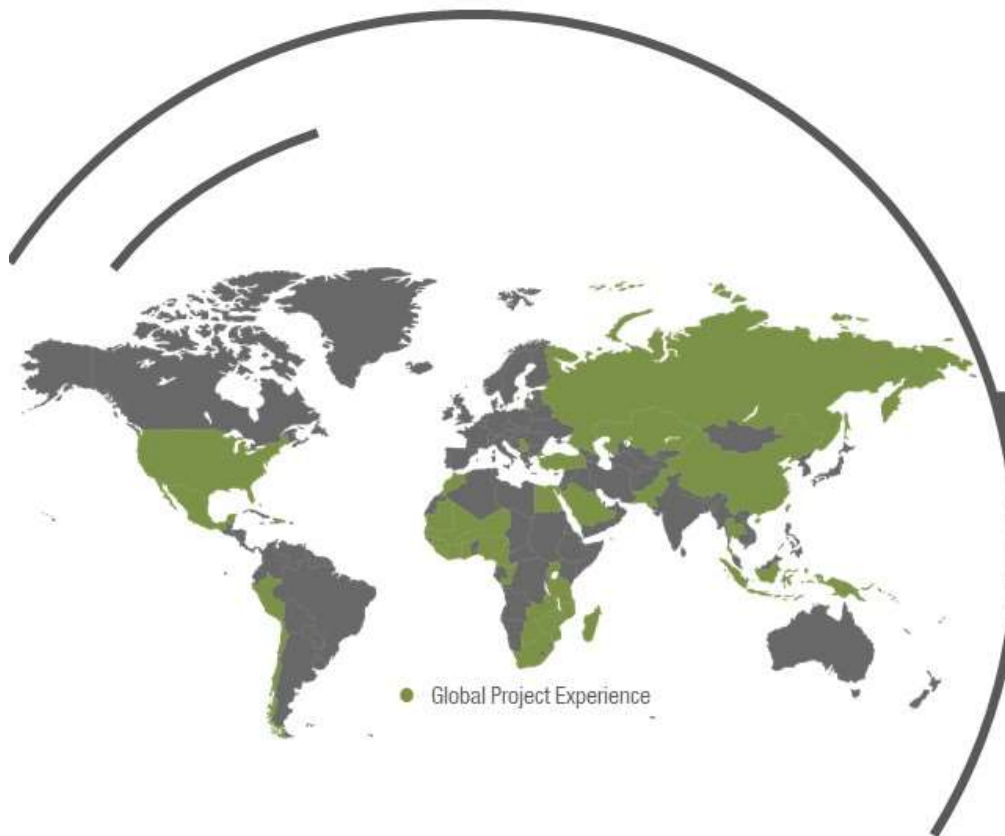
Theis



Theis recovery



Appendix C: Geochemical Assessment and Waste Classification



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Xivono Weltevreden Coal Mining Project near Belfast, Mpumalanga

Geochemistry Assessment and Waste Classification Report

Prepared for:

Xivono Mining (Pty) Ltd

Project Number:




MBU5710

October 2019



This document has been prepared by Digby Wells Environmental.

Report Type:	Geochemistry Assessment and Waste Classification Report
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DECLARATION OF INDEPENDENCE

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I, Kgaugelo Thobejane , as duly authorised representative of Digby Wells and Associates (South Africa) (Pty) Ltd., hereby confirm my independence (as well as that of Digby Wells and Associates (South Africa) (Pty) Ltd.) and declare that neither I nor Digby Wells and Associates (South Africa) (Pty) Ltd. have any interest, be it business, financial, personal or other, in any proposed activity, application or appeal in respect of Xinovo (Pty) Ltd other than fair remuneration for work performed, specifically in connection with the Social Impact Assessment for the Weltevreden Coal Mining Project.

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EXECUTIVE SUMMARY

Digby Wells Environmental (hereafter Digby Wells) was appointed by Xivono Mining (Pty) Ltd (hereafter Xivono) to conduct a geochemical assessment and waste classification to evaluate the acid generation potential of coal and waste material that will be generated as a result of mining.

The waste classification conducted on the coal and waste material is a geochemical classification done in accordance with the National Environmental Management: Waste Act, 2008 (Act No. 59 of 2008) (NEM: WA) and no physical material or engineering characterisation was undertaken.

A total of four coal samples and two waste rock (discard) from exploration boreholes were available for testing with each sample weighing approximately 1 kg. For acid generating potential and waste classification purposes the provided samples were submitted for the following laboratory test work:

- X-ray Diffraction (XRD) and X-Ray Fluorescence (XRF);
- Acid Base Accounting (ABA), Net Acid Generation (NAG) and sulphur speciation tests;
- Aqua regia digestion to determine total concentrations; and
- Distilled (reagent) water leachate tests to determine the leachable concentrations.

The predominant rocks are the sedimentary rocks of the Eccra Group (Karoo Basin), with the Project Area situated in the Vryheid Formation and consists of deltaic mudstones and sandstones, shale and coal (Wilson & Anhaeusser, 1998). The shale is dark-grey in colour due high carbon content and the presence of coal beds (Lavin, 2013). The Witbank coalfield has up to five coal seams contained in the middle Eccra group sediments. The targeted coal seams, as part of the Vryheid Formation, are the 2, 3, 4S and 4L seams with the 2-seam identified at the south-western part of the site and the 2, 3, 4S and 4L seams identified at the north-western part of the site. The mineralogy of the samples collected indicated there were coal materials demonstrated by amorphous minerals, and there was also presence of sedimentary rocks indicated by clay minerals with sample BT1 HW consisting of ~10% of amorphous mineral. There are acid generating minerals in samples BT1 HW and BT1-BT4.

The Acid Potential (AP) and Neutralising Potential (NP) of a sample is linked to the mineralogy and the reactions formed under aerobic conditions. When these parameters are used to calculate the Net Neutralising Potential ($NNP = NP - AP$) and Neutralising Potential Ratio ($NPR = NP/AP$) an indication of the acid mine drainage potential can be reached. Based on the above-mentioned approach, all waste rock material and coal samples are classified as potentially acid generating and poses a risk for AMD.

The coal and waste materials situated in the boreholes are classified as a Type 3 waste and needs to be disposed at a Class C landfill site or a facility with a similarly performing liner system. The Type 3 waste classification is due to the leachate concentration results being above the LCT0 guideline values. According to the test methodologies followed and the results of the leachable concentrations the risk of elements leaching into the receiving environment from the waste facility is low.

The following mitigation options were proposed to counter metal leach and Acid Mine Drainage (AMD) formation from stockpiles and waste facilities:

- Storm water management and diversion trough trenches and sedimentation dams allowing the capture of dirty water and contaminants to be diverted and pumped to water treatment facilities or pollution control dams;
- The diversion and capturing of dirty water in pollution control dams where water can be treated before being discharged into the environment or allowed to evaporate in evaporation ponds;
- Lining of stockpile areas to minimise potential pollution seepage from coal stockpiles;
- Partial backfilling of the pit with neutralising material and flooding post closure to stop any oxidation processes that will develop AMD;
- If high volumes of AMD water are produced and captured in pollution control dams the water can be treated through lime dosage to buffer the pH and allowing SO₄ and metals to precipitate and settle out before the water is discharged; and
- Monitoring boreholes can help as early warning systems, as well as seepage capturing abstraction holes should groundwater quality decrease.

Based on the geochemical test work findings the following recommendations are made

- Drilling of monitoring boreholes upstream and downstream of hards stockpiles to be incorporated into the groundwater and surface water monitoring program;
- Long term kinetic test work to be done on waste rock samples and coal material to determine the potential of pollution and AMD development over a longer period; and
- Geochemical modelling to allow transient evaluation of the environmental geochemical processes that will be associated with the pit development and pollution sources during the mining processes, as well as the simulation of any chemical mitigation options like lime dosage.

Based on the LCT and TCT results the following recommendations are made for the waste classification:

- The waste and coal materials are classified as a Type 3 waste and disposal of the material should be done to a Class C landfill facility or a facility with a similar performing liner system; and



- The leachate factor of 1:20 used for waste classification is conservative and diluted approach. The leachate results of these tests can lead to a diluted result not always presenting the true concentrations to be expected on site once mining has started. For this reason, the expected sulphate concentration in the seepage water will be more than what has been observed in the results and a conservative approach of SO_4 of more than 1200 mg/L should be used for the contaminant transport modelling in the groundwater assessment.



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1 Introduction

Digby Wells Environmental (hereafter Digby Wells) was appointed by Xivono Mining (Pty) Ltd (hereafter Xivono) to conduct a geochemical assessment and waste classification to evaluate the coal and waste rock materials that will be generated as a result of mining. The aim is to determine if the materials have acid producing potential and to classify the waste materials in terms of the National Environmental: Waste Management Act, 2008 (Act No. 59 of 2008), as amended (hereafter NEM: WA). The following terms of reference were provided:

- Assess the acid generating potential of the coal material that will remain in the opencast pits;
- Assess the leachate potential of the hards stockpile materials as well as the release of heavy metals from the remaining (rehabilitated) opencast pits; and
- Advise on the required liner to be installed for the hards stockpiles.

Refer to Figure 1-1 for the proposed site layout. The methodology applied to the study is in line with the Department of Water Affairs' Best Practice Guideline for Impact Prediction (hereafter BPG: G4) and proposed procedures. With the above in mind, Xivono appointed Digby Wells to conduct X-Ray Fluorescence (XRF), X-Ray Diffraction (XRD), Sulphur Speciation (SS%), Acid Base Accounting (ABA), Net Acid Generation (NAG) and NAG pH, Net Neutralising Potential (NNP) and geochemical leachate tests on the material and advise on its chemical characterisation and potential for Acid Mine Drainage (AMD).

1.1 Scope of Work and Methodology

1.1.1 Site visit and Sampling

Fresh ore and waste samples were collected by a Digby Wells consultant, subsequently the consultant submitted the samples to an accredited laboratory for analysis. Approximately 1 kg per sample of coal and waste rock materials were collected from exploration boreholes. The sampling process is explained in further detail in the sections below.

1.1.2 Laboratory Tests

The following sample preparation and tests were done on the samples submitted as discussed in below:

Coal and Discard Material

Four coal samples and two waste rock (hanging wall and footwall) samples were taken for laboratory analyses. The samples were submitted for the following test work:

- XRD and XRF to determine the mineralogy of each sample;
- ABA, NAG and SS% to determine the acid generating and/or acid neutralising potential of each sample. This allows an evaluation of the potential for AMD;

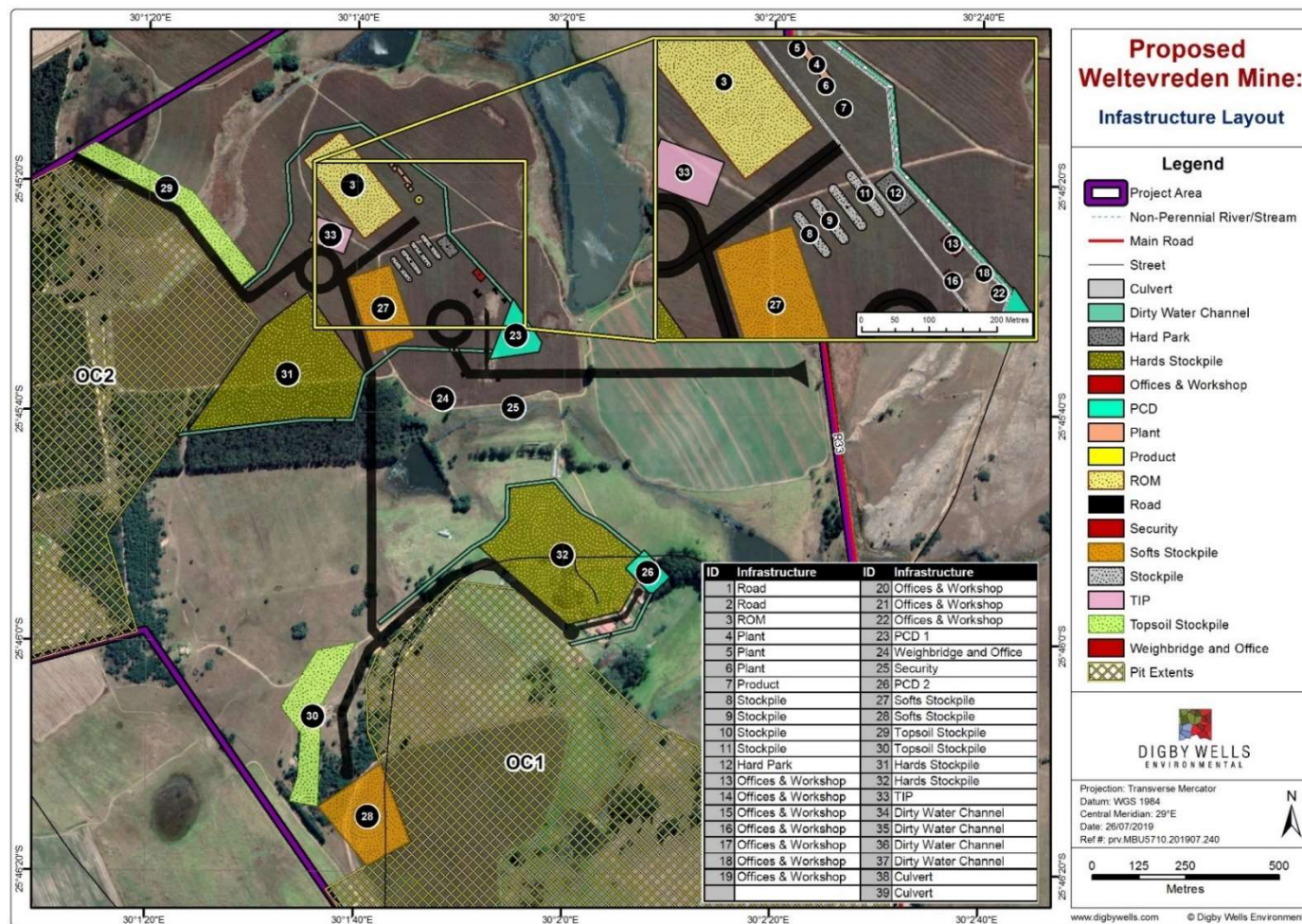


Figure 1-1: Site Layout Showing the Proposed Areas and Surface Infrastructure.

- *Aqua Regia* Digestion with full Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) Quant to evaluate the total chemical makeup of the material and to determine the Total Concentrations (TC) for evaluation against the waste classification Total Concentration Threshold (TCT) guideline values; and
- Distilled water leachate tests at a ratio of 1:20 (solid: liquid) with pH, Electrical Conductivity (EC), Alkalinity, P-Alkalinity (for carbonate and bicarbonate calculations), Total Dissolved Solids (TDS), Fluorine (F), Chlorine (Cl), Nitrate (NO₃), Cyanide (CN), Sulphate (SO₄), Nickel (Ni), Arsenic (As) and Manganese (Mn) to determine the leachable concentrations of the material to compare it to the waste classification Leachable Concentration Threshold (LCT) National Environmental Management: Waste Amendment Act, 2014 (Act No. 26 of 2014) guideline values.

A detailed breakdown of the various test methodologies is provided in Appendix A.

1.2 Deliverables

The following deliverables are provided in this report:

- Laboratory results and interpretations; and
- Conclusions and recommendations on the geochemical characteristics of the material and the handling thereof during operation and backfilling.

1.3 Study Limitations and Assumptions

The following limitations and assumptions apply:

- General Limitation
 - Due to the two waste rock samples sent for analyses, these do not represent the full extent of waste rock materials that will be generated throughout the mining process.
- XRD Results:
 - Mineral names may not reflect the actual compositions of minerals identified, but rather the mineral group;
 - Due to preferred orientation and crystallite size effects, a small percentage error may occur in the mineral distribution, but the general proportion of minerals and their presence is accurate; and
 - Samples contained organic carbon and the results presented were checked by the lab against the amount of material losses on ignition during other static tests.
- Sulphur Speciation:
 - Samples were analysed with Pyrolysis at 550°C, as per the Prediction Manual for Drainage Chemistry from Sulphidic Geological Materials MEND Report 1.20.1; and

- Organic Sulphur is not considered and may be included in the results.
- Leachate Tests and Characterisation
 - The distilled water leachate tests are a static method applied to identify potential elements of concern;
 - Distilled water tests were done at a neutral pH (7) at a solid:liquid ratio of 1:20; and
 - NEM: WA classification thresholds were used as a reference point in characterising the leachate quality. This report is intended to serve as a waste classification and guideline on liner requirements

2 Geology

The project area is located approximately 8km south-west of the town Belfast in Mpumalanga, South Africa, on the far eastern edge of the Witbank coalfield. The coalfield extends about 190km east-west between the towns of Springs and Belfast, and about 60km in a north-south direction between the towns of Middelburg and Ermelo. The Witbank coalfield has up to five coal seams contained in the middle Ecca group sediments of the Karoo Supergroup. The targeted coal seams, as part of the Vryheid Formation are the 2, 3, 4S and 4L seams with the 2-seam identified at the south-western part of the site and the 2, 3, 4S and 4L seams identified at the north-western part of the site

The predominant rocks are the sedimentary rocks of the Ecca Group (Karoo Basin), which is subdivided into several formation units based on the cyclic nature of the sedimentary fills. The Project Area is situated in the Vryheid Formation and consists of deltaic mudstones and sandstones, shale and coal (Wilson & Anhaeusser, 1998). The shale is dark-grey in colour due to high carbon content and the presence of coal beds (Lavin, 2013).

3 Sample Description

The waste rock and coal samples are provided in Table 3-1.

Table 3-1: Sample descriptions and borehole ID

No.	Laboratory ID	Origin/Description	Exploration Boreholes
1	BT1	Coal Sample	WTVBH1
2	BT2	Coal Sample	WTVBH2
3	BT3	Coal Sample	WTVBH3
4	BT4	Coal Sample	WTVBH4
5	BT1 HW (Hanging wall)	Roof Sample of TW006	WTVBH1
6	BT1 FW (Footwall)	Floor sample of TW006	WTVBH1

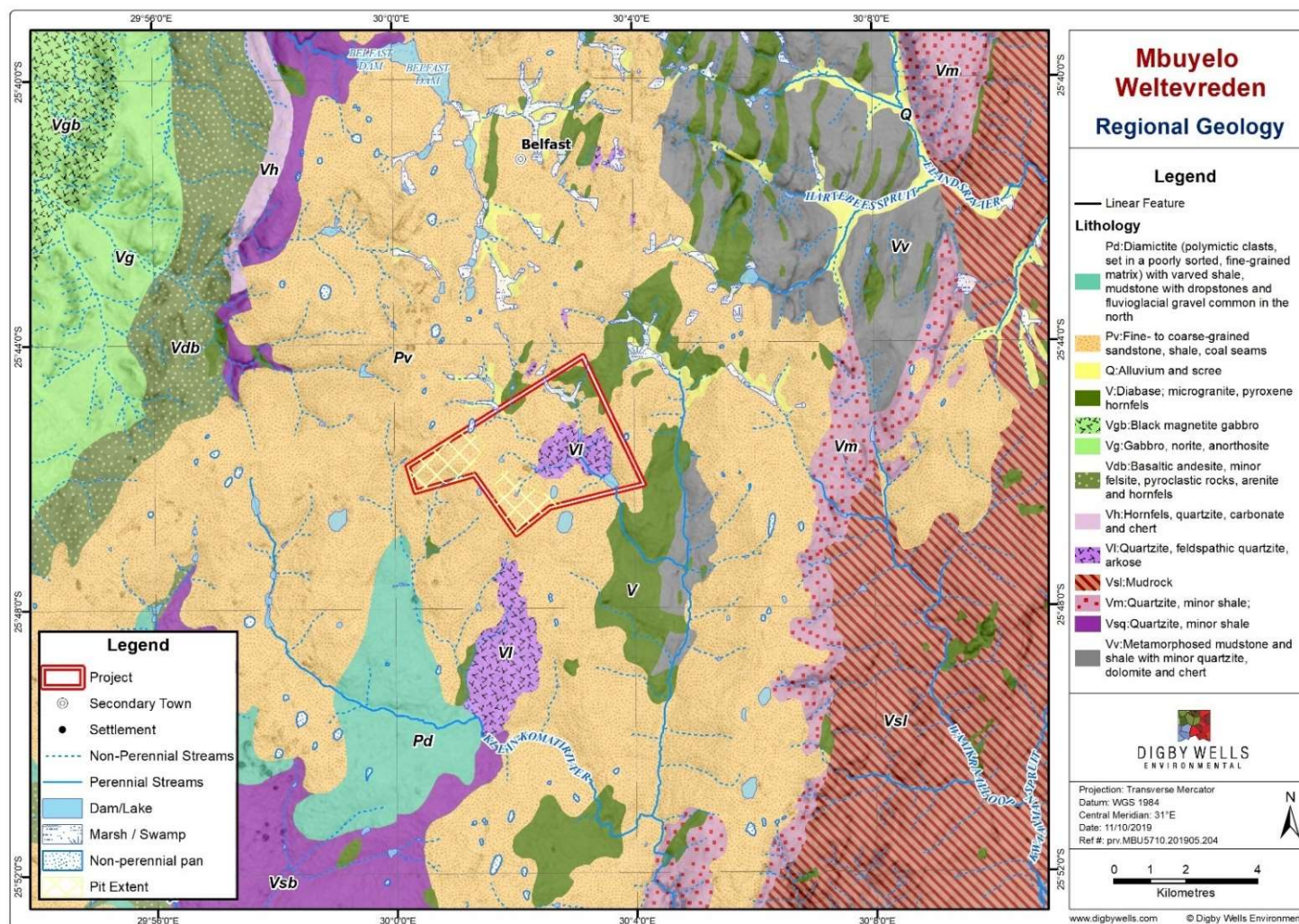


Figure 3-1: Regional geology of the project area

4 Mineralogy and AMD

All laboratory certificates are provided in Appendix A.

4.1 Geochemistry Assessment

4.1.1 Waste Rock

Two samples were taken as representative of the waste rock, one floor and one roof lithologies from exploration borehole WTVBH1. The results are summarised in Table 4-1.

The XRD results indicate that the dominant minerals in both samples BT1 HW and BT1 FW are kaolinite (38.79% and 35.11% respectively) and quartz (27.35% and 42.91% respectively). Both samples are sedimentary rocks with sample BTW1 HW comprising of amorphous material which is either coal or carbon material that was lost on ignition during test work. Pyrite is only detected in the hanging wall (BT1 HW) at concentration of 1.44 % which is above the 0.3 % for acid mine drainage generation. However, there is a presence of an iron rich carbonate mineral siderite (8.44 wt.%) which comprises of neutralising potential. Sample BT1 HW is a carbonaceous shale while BT1 FW is a mudstone.

The XRF results correlates with the XRD, such as high aluminium oxide (Al_2O_3) content which relates with kaolinite and the aluminium in muscovite. High silicon dioxide (SiO_2) which is found in kaolinite, microcline, muscovite and quartz. The iron (III) oxide (Fe_2O_3) also have medium concentration particularly in BT1 HW because of the presence of pyrite and siderite.

Table 4-1: XRD Results for Waste Rock Material

Mineral composition per waste rock sample (%)		
Mineral	BT1 HW	BT1 FW
Amorphous	10.51	
Kaolinite	38.79	35.11
Microcline	6.51	14.87
Muscovite	7.01	7.11
Quartz	27.3	42.91
Pyrite	1.44	
Siderite	8.44	

4.1.2 Coal Material

Four samples were taken as representative of the coal. The results are summarised in Table 4-2.

The XRD results for the four coal samples indicates that these samples consist predominantly of amorphous material which is either coal or carbon material. The second most dominant mineral is kaolinite for all samples with an exception of BT3 where quartz is found. Pyrite is

included in all samples, with an exception of BT4, and it is above 0.3%. BT1 is the only sample encompassing two neutralising potential minerals ankerite (4.45%) and calcite at (1.46 %) while BT4 comprising only the latter at 0.16%.

The XRF results correlate with the XRD results, such as a high SiO₂ content particularly for BT3 due to the highest quartz concentration. The Al₂O₃ concentration is the second highest concentration and it is responsible largely for the formation of kaolinite in these samples with minor minerals such as microcline and muscovite requiring some aluminium especially in sample BT4. The Fe₂O₃ concentration for BT1 is relatively high due to the presence of high pyrite and ankerite concentration.

Table 4-2: XRD Results for Coal Material

Mineral composition per coal sample (%)				
Mineral	BT1	BT2	BT3	BT4
Amorphous	66.21	66.47	59.3	68.16
Ankerite	4.45			
Calcite	1.46			0.16
Kaolinite	14.17	20.84	17.73	15.41
Microcline				2.92
Muscovite				2.45
Pyrite	3.38	0.93	0.39	
Quartz	10.33	11.76	22.58	10.9

4.2 Acid-Base Accounting Results

The AMD potential of materials is determined by assessing the Acid Potential (AP), Neutralising Potential (NP) and the relationship between these two reactions by calculating the Net Neutralising Potential (NNP = NP - AP) and Neutralising Potential Ratio (NPR = NP/AP). The above reactions and potentials are driven by the mineralogy of the materials. Certain minerals are acid buffering/neutralising and others like pyrite are acid producing. Sulphide content is the main driver of acid production and AMD under aerobic conditions and that is why the sulphide sulphur content of the material is also assessed.

The main values used to classify materials as Non-Acid Forming (NAF), Potentially Acid Generating (PAG) are the NPR and sulphide sulphur content. If the NPR is below 1 there is a PAG (red cells), if the NPR is above 3 the sample is NAF (green cells). When the NPR is between 1 and 2, a balance exists between the buffering and acid producing reactions and a clear conclusion cannot be based on the NPR only. When focussing on the Sulphide Sulphur (SS) %, if the SS% is above 0.3 (red cells) it is generally accepted that this material will be PAG. For NAG pH, if pH is less than 3.5 there will be PAG (red cells). The following conclusions were reached from the AMD test work with the main parameters and results shown in Table 4-3 and Figure 4-1

4.2.1 Waste Rock Material

The XRD and XRF results indicate the presence of pyrite in BT1 HW while BT1 FW demonstrates neutral mineralogy. The ABA, NAG and SS% results indicating that both samples are PAG with the following conclusions:

- If NAG pH is greater than or equals to 5.5 it indicates no acid generation potential; however, between 5.5 and 3.5 a low risk acid generation potential is expected. Acid generating potential is expected for NAG pH lower than 3.5. Based on the NAG pH of the samples, BT1 HW NAG pH is at 4.3 which indicates low risk of acid generation and BT1 FW have are PAG with a NAG pH of 2.9;
- A negative NNP indicates an acid generating potential. Based on this, all samples are PAG;
- The NPR is less than 1 for all samples and this means that the samples are PAG, unless sulphide minerals are non-reactive;
- The SS% is above 0.3% and this also confirms they are PAG for all samples; and
- On average all samples can be classified as PAG and therefore have the potential to form AMD.

4.2.2 Coal Material

The XRD and XRF results indicate the presence of pyrite in all samples with an exception of BT4. The following conclusions were reached from the AMD test work:

- NAG pH for BT1-BT3 are below 3.5, indicating a high acid generating potential, while BT4 having a NAG pH of 3.9 which indicates this sample has a low risk of acid generation;
- A negative NNP was indicated for all samples;
- The SS% contents for all samples were above 0.3% with BT1 having the highest concentration of 3.08%; and
- All samples are classified as PAG with a risk of AMD formation.

Table 4-3: ABA and SS% Results

Sample ID	NAG pH	Net Neutralization Potential (NNP) = NP – AP (kg CaCO ₃ /t)	Neutralising Potential Ratio (NPR) (NP: AP)	Total Sulphur (%)	Sulphate (SO ₄ ²⁻) Sulphur (%)	Sulphide (S ²⁻) Sulphur (%)	Acid Generating Potential
BT1	1.9	-34.00	0.65	3.14	0.06	3.08	PAG
BT2	2.2	-35.30	0.18	1.39	0.06	1.33	PAG
BT3	2.3	-25.50	0.01	1.13	0.03	1.1	PAG

Sample ID	NAG pH	Net Neutralization Potential (NNP) = NP – AP (kg CaCO ₃ /t)	Neutralising Potential Ratio (NPR) (NP: AP)	Total Sulphur (%)	Sulphate (SO ₄ ²⁻) Sulphur (%)	Sulphide (S ²⁻) Sulphur (%)	Acid Generating Potential
BT4	3.9	-21.00	0.54	1.47	0.03	1.44	PAG
BT1 HW	4.3	-26.30	0.42	1.43	0.05	1.38	PAG
BT1 FW	2.9	-21.50	0.23	0.90	0.01	0.89	PAG

* Red indicates values are in range to potentially generate acid

4.3 Conclusion

Based on the geochemistry and the AMD results, the following was concluded associated with the potential sources of pollution or AMD on site:

- The coal materials are classed as PAG, with the waste rock material potentially leading to AMD development and pollution of groundwater and surface water resources if not mitigated and managed; and
- Coal material will be stockpiled for short periods on site before being transported or processed. The potential for pollution development and AMD formation is thus low and can be mitigated to reduce the contamination impact.

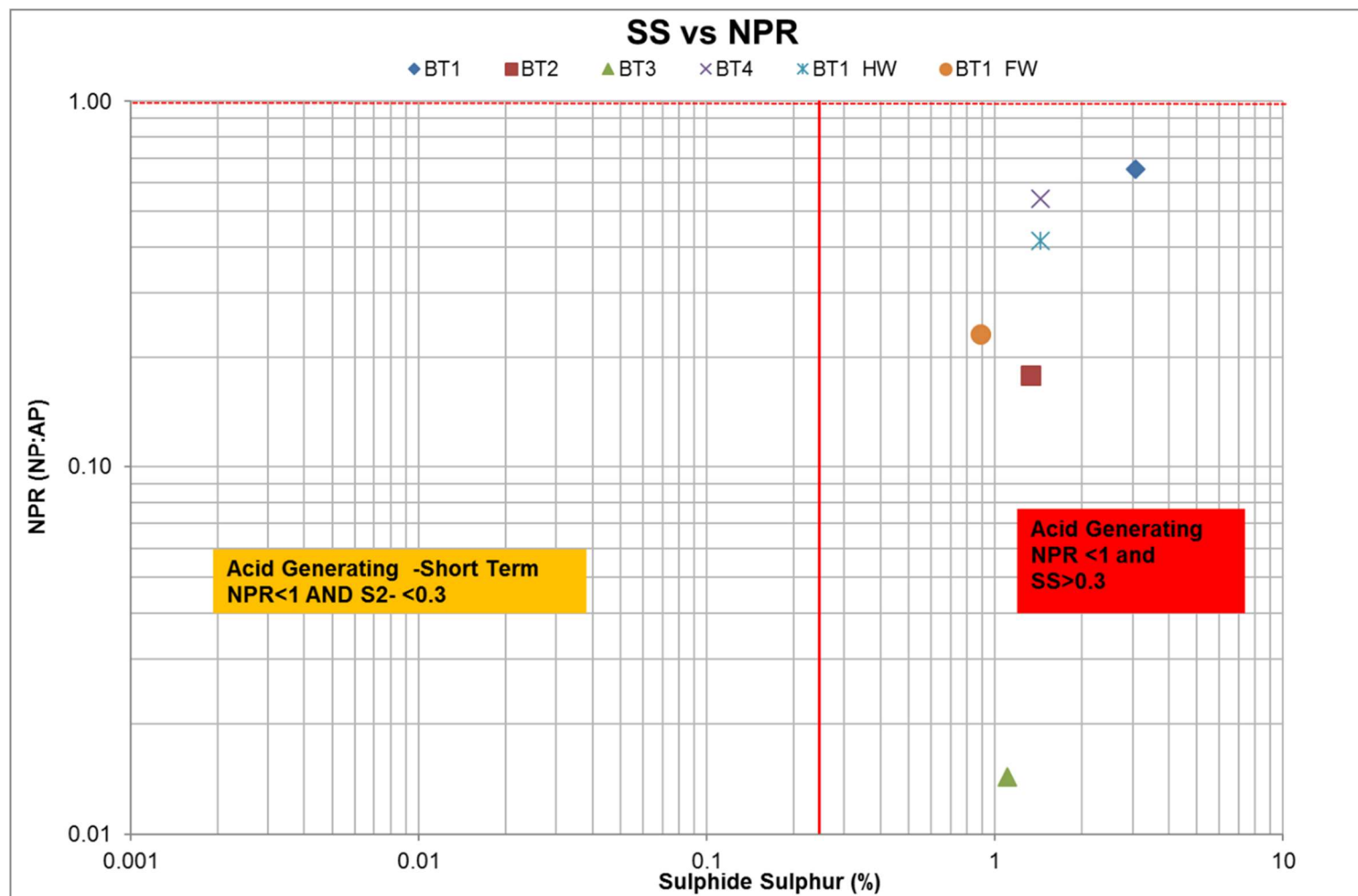


Figure 4-1: Waste rock and coal material AMD – NPR vs Sulphide Sulphur

5 Waste Classification

5.1 Legislative Guidelines

On 2 June 2014, the National Environmental Management: Waste Amendment Act, 2014 (Act No. 26 of 2014) was published, which for the first time included “residue deposits” and “residue stockpiles” under the environmental waste legislation. Previously mining residue was covered under the Mineral and Petroleum Resources Development Act, 2002 (Act No. 28 of 2002) (MPRDA). A new regulation, on the planning and management of residue stockpiles and residue deposits, was included into the NEM: WA in July 2015. The purpose of these regulations is to regulate the planning and the management of residue stockpiles and residue deposits from prospecting, mining, exploration or operation. Residue deposits and residue stockpiles are listed under Schedule 3, under the category “Hazardous Waste”, therefore the understanding is that mine waste is hazardous unless the applicant can prove otherwise.

As residue deposits and residue stockpiles are waste, they are regulated by the following regulations (both promulgated on 23 August 2013):

- GN R 635 – National Norms and Standards for Assessment of Waste for Landfill Disposal; and
- GN R 636 – National Norms and Standards for Disposal of Waste to Landfill.

According to these regulations, waste that is generated must be classified in accordance with South African National Standards (SANS) 10234 within 180 days of generation. SANS 10234 is based on the Globally Harmonised System (GHS). It illustrates a comprehensive classification that is used to determine whether a waste is hazardous based on its physical, health and environmental properties. Classification in terms of SANS 10234 means establishing whether the waste is hazardous based on its properties. The norms and standards specify the waste classification methodologies for determining the waste category, and the specifications for pollution control barrier systems (liners) for each of the waste categories.

The Department of Environmental Affairs (DEA) has published Notice 1005 of 2014 (14 November 2014), Proposed Regulations Regarding the Planning and Management of Residue Stockpiles and Residue Deposits from a Prospecting, Mining, Exploration or Production Operation.

In terms of a waste disposal assessment, these Regulations state that residue stockpiles and residue deposits must be characterised to identify any potential risk to health or safety and environmental impact in terms of physical characteristics, chemical characteristics (toxicity, propensity to oxidise and decompose, propensity to undergo spontaneous combustion, pH and chemical composition of the water separated from the solids, stability and reactivity and the rate thereof, neutralising potential and concentration of volatile organic compounds), and mineral content.

In addition, the quality of seepage from residue facilities needs to be predicted, as contained in Notice 1006 of 2014 (14 November 2014): Proposed Regulations to Exclude a Waste Stream or a Portion of a Waste Stream from the Definition of Waste.

These Regulations state that waste generated from a source listed in Category A of Schedule 3 of NEM: WA may be excluded from being defined as hazardous on demonstration that the waste is non-hazardous in accordance with the Waste Management and Classification regulations. Exclusion of a waste stream from the definition of waste may be considered if it can be demonstrated that any contaminant of concern originating from the waste reaching the receptor will not exceed the acceptable environmental limits for any contaminant of concern for such a receptor. The acceptable environmental limits have not been defined.

5.2 Waste Classification Methodology

In the Regulations, the terms "Total Concentration Threshold" and the abbreviation "TCT" mean the total concentration threshold limit for certain elements or chemical substances in a waste, expressed as mg/kg, prescribed in Section 6 of the Norms and Standards. The terms "Leachable Concentration Threshold" and abbreviation "LCT" mean the leachable concentration threshold limit for certain elements and chemical substances in a waste, expressed as milligrams per litre (mg/L), prescribed in Section 6 of these Norms and Standards.

TCT limits are subdivided into three categories:

- TCT0 limits based on screening values for the protection of water resources, as contained in the Framework for the Management of Contaminated Land (DEA, March 2010);
- TCT1 limits derived from land remediation values for commercial/industrial land (DEA, March 2010); and
- TCT2 limits derived by multiplying the TCT1 values by a factor of 4, as used by the Environmental Protection Agency, Australian State of Victoria.

LCT limits are subdivided into four categories:

- LCT0 limits derived from human health effect values for drinking water, as published by the DWS, SANS, World Health Organization (WHO) or the United States Environmental Protection Agency (USEPA);
- LCT1 limits derived by multiplying LCT0 values by a Dilution Attenuation Factor (DAF) of 50, as proposed by the Australian State of Victoria;
- LCT2 limits derived by multiplying LCT1 values by a factor of 2; and
- LCT3 limits derived by multiplying the LCT2 values by a factor of 4.

GN R 634 identifies waste classes (Waste Types 0 to 4) ranging from high risk (Type 0) to low risk (Type 4), based on comparison of the TCT and LCT of individual constituents in the waste against the following threshold limits. Waste is assessed by comparison of the total and

leachable concentration of elements and chemical substances in the waste material to TCT and LCT limits as specified in the National Norms and Standards for Waste Classification and the National Norms and Standards for Disposal to Landfill as per Table 5-1.

Table 5-1: Waste Classification Criteria

Waste Type	Element or chemical substance concentration	Disposal
0	LC > LCT3 OR TC > TCT2	Not allowed
1	LCT2 < LC ≤ LCT3 OR TCT1 < TC ≤ TCT2	Class A or Hh:HH landfill
2	LCT1 < LC ≤ LCT2 AND TC ≤ TCT1	Class B or GLB+ landfill
3	LCT0 < LC ≤ LCT1 AND TC ≤ TCT1	Class C or GLB- landfill
4	LC ≤ LCT0 AND TC ≤ TCT0 for metal ions and inorganic anions AND all chemical substances are below the total concentration limits provided for organics and pesticides listed	Class D or GLB- landfill

5.3 Results and Classification

Results of the analysis of LC and TC are shown in Table 5-2 and Table 5-3 respectively and compared to threshold concentrations published in the NEM: WA Waste Classification and Management Regulations.

Waste Rock Samples:

- BT1 HW and BT1 FW
 - LCT0 < Chromium (Cr) < LCT1, and LCT0 < Nickel (Ni) < LCT1 values; and
 - Based on total concentrations, all parameters are below the TCT0 values

Coal Samples:

- All coal samples LCT0 < Chromium (Cr) < LCT1, and LCT0 < Nickel (Ni) < LCT1 values; and
- BT1
 - TCT0 < As < TCT1 while the rest of the samples are below the TCT0

5.4 Conclusion

Based on the outcome of leachate concentrations (Table 5-2) Cr and Ni concentrations failed to be below the LCT0 for all samples, and the As concentration was elevated to above the LCT0 limit for two samples. Based on these results the waste rock as well as the coal material are classified as a Type 3 material. If disposed of at a landfill disposal site or alternative site on surface, the material requires a Class C liner or similar performing system demonstrated in Figure 5-1.

Class C Landfill:

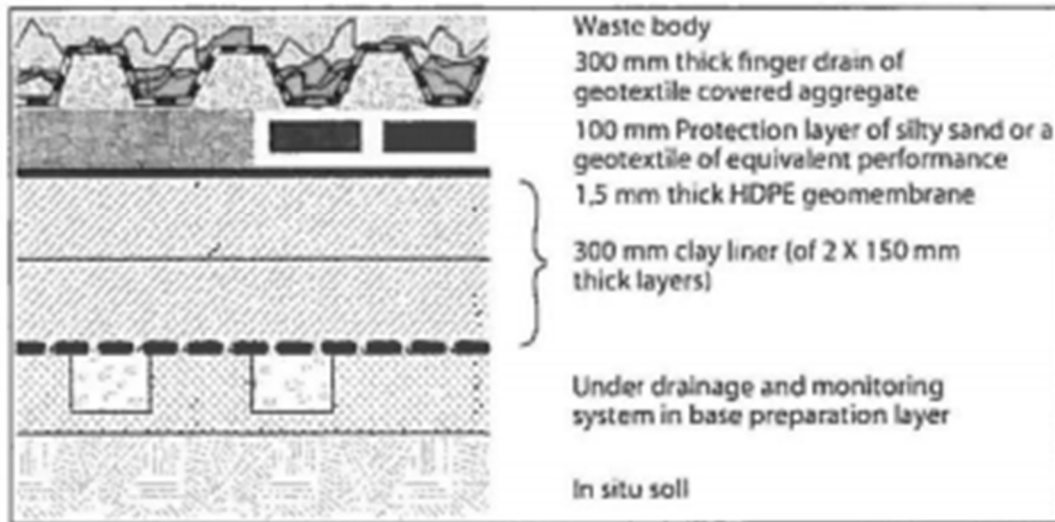


Figure 5-1: Class C Containment Barrier Requirements

Table 5-2: LCT Classification (mg/L) Results

Parameter	Unit	SANS241-2015 Drinking water standards	BT1	BT2	BT3	BT4	BT 1 HW	BT 1 FW	LCT0	LCT1	LCT2	LCT3
As, Arsenic	mg/L	0.01	7.21	2.94	<2.0	<2.0	8.04	<2.0	0,01	0.5	1	4
B, Boron	mg/L	2.4	42	25	23.00	25.00	99	16.14	0,5	25	50	200
Cd, Cadmium	mg/L	0.003	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0,003	0,15	0,3	1,2
Co, Cobalt	mg/L		2.48	1.89	1.98	<0.10	16.82	2.66	0,5	25	50	200
Cr total	mg/L	0.05	0.11	0.11	0.11	0.11	0.11	0.11	0,1	5	10	40
Cu, Copper	mg/L	2	0.12	0.11	0.1	0.11	0.11	0.11	2	100	200	800
Mn, Manganese	mg/L	0.4	0.21	0.27	0.31	0.17	0.18	0.16	0,5	25	50	200
Mo, Molybdenum	mg/L		0.001	<0.001	<0.001	0.01	0.026	0.027	0.07	3.5	7	28
Ni, Nickel	mg/L	0.07	0.11	0.12	0.12	0.11	0.11	0.11	0.07	3.5	7	28
Pb, Lead	mg/L		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.5	1	4
Chloride as Cl	mg/L	300	28	8.91	1.02	0.58	0.64	0.99	300	15000	30000	120000
Parameter	Unit	SANS241-2015 Drinking water standards	BT1	BT2	BT3	BT4	BT 1 HW	BT 1 FW	LCT0	LCT1	LCT2	LCT3

Parameter	Unit	SANS241-2015 Drinking water standards	BT1	BT2	BT3	BT4	BT 1 HW	BT 1 FW	LCT0	LCT1	LCT2	LCT3
Sulphate as SO ₄	mg/L	500	166.85	63.86	9.54	37.02	52.37	42.13	250	12500	25000	100000
Nitrate as N	mg/L	11	<0.1	<0.1	0.31	<0.1	<0.1	<0.1	11	550	1100	4400
F, Fluoride	mg/L	1.5	0.13	<0.1	0.18	0.14	0.45	0.35	1,5	75	150	600
CN total, Cyanide total	mg/L		0.02	0.054	0	0	0.008	0	0,07	3,5	7	28
pH		5 to 9.7	6.40	7.10	6.40	7.30	7.20	7.00				

* Yellow highlight indicates exceedance of LCT0 limit

Table 5-3: TCT Classification (mg/kg) Results

Parameter	Unit	BT1	BT2	BT3	BT4	BT 1 HW	BT 1 FW	TCT0	TCT1	TCT2
As, Arsenic	mg/kg	7.21	2.94	<2.0	<2.0	8.04	<2.0	5,8	500	2000
B, Boron	mg/kg	42	25	23.00	25.00	99	16.14	150	15000	60000
Cd, Cadmium	mg/kg	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	7,5	260	1040
Co, Cobalt	mg/kg	2.48	1.89	1.98	<0.10	16.82	2.66	50	5000	20000
Cr (IV), Chromium (IV)	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	6,5	500	2000
Hg, Mercury	mg/kg	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0,93	160	640
Mo, Molybdenum	mg/kg	1.34	0.49	1.28	0.72	<0.10	<0.10	40	1000	4000

Parameter	Unit	BT1	BT2	BT3	BT4	BT 1 HW	BT 1 FW	TCT0	TCT1	TCT2
Ni, Nickel	mg/kg	14.01	<0.30	<0.30	<0.30	20	<0.30	91	10600	42400
Sb, Antimony	mg/kg	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	10	75	300
Se, Selenium	mg/kg	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	10	50	200
Chloride as Cl	mg/kg	5	<1	<1	<1	10	<1	n/a	n/a	n/a
Sulphate as SO ₄	mg/kg	0.17	0.19	0.09	0.08	0.15	0.03	n/a	n/a	n/a
Nitrate as N	mg/kg	<0.5	0.28	1.16	2.37	0.72	0.29	n/a	n/a	n/a
F, Fluoride	mg/kg	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	100	10000	40000
CN total, Cyanide total	mg/kg	0.7	1.74	2.78	0.86	0.61	1.52	14	10500	42000
pH		8.3	6.7	7.5	8.7	7.1	9.7			

* Yellow highlight indicates exceedance of LCT0 limit

6 Mitigation Options

The following mitigation options were proposed to counter metal leach and AMD formation from stockpiles and waste facilities:

- Storm water management and diversion through trenches and sedimentation dams allowing the capture of dirty water and contaminants to be diverted and pumped to water treatment facilities or pollution control dams;
- The diversion and capturing of dirty water in pollution control dams where water can be treated before being discharged into the environment or allowed to evaporate in evaporation ponds;
- Lining of stockpile areas to minimise potential pollution seepage from coal stockpiles;
- Partial backfilling of the pit with neutralising material and flooding post closure to stop any oxidation processes that will develop AMD;
- If high volumes of AMD water are produced and captured in pollution control dams the water can be treated through lime dosage to buffer the pH and allowing SO_4 and metals to precipitate and settle out before the water is discharged; and
- Monitoring boreholes, as recommended for this Project, can help as early warning systems, as well as seepage capturing abstraction holes should groundwater quality decrease.

7 Recommendations

Based on the geochemical test work findings the following recommendations are made:

- Drilling of monitoring boreholes upstream and downstream of hard stockpiles to be incorporated into the groundwater and surface water monitoring program;
- Long term kinetic test work to be done on waste rock samples and coal material to determine the potential of pollution and AMD development over a longer period; and
- Geochemical modelling to allow transient evaluation of the environmental geochemical processes that will be associated with the pit development and pollution sources during the mining processes, as well as the simulation of any chemical mitigation options like lime dosage.

Based on the LCT and TCT results the following recommendations are made for the waste classification:

- The waste and coal materials are classified as a Type 3 waste and disposal of the material should be done to a Class C landfill facility or a facility with a similar performing liner system;
- The leachate factor of 1:20 used for waste classification is conservative and diluted approach. The leachate results of these tests can lead to a diluted result not always presenting the true concentrations to be expected on site once mining has started. For

this reason, the expected sulphate concentration in the seepage water will be more than what has been observed in the results and a conservative approach of SO₄ of more than 1200 mg/L should be used for the contaminant transport modelling in the groundwater assessment.

8 References

- National Environmental Management: Waste Amendment Act 2014 (Act No. 26 of 2014).
- Wilson, M.G.C. and Anhaeusser, C.R., 1998. The mineral resources of South Africa (Handbook 16).



Appendix A: Laboratory Certificates

M and L Laboratory Services (Pty) Ltd
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Ref. No. : ML-2019-17414

Issued at. : Johannesburg

Date : 10/10/2019

Contract No. : 10887541

Page 1 of 11

Registration Number 1974/001476/07 VAT Number 4780103505

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Certificate/Report

COMPANY NAME : DIGBY WELLS & ASSOCIATES
ADDRESS : PRIVATE BAG X10046 RANDBURG
SUBJECT : ANALYSIS OF 6 SOLID SAMPLES
PROJECT REFERENCE : SOLID SAMPLES 03/09/2019
INSTRUCTED BY : KGAUGELO THOBEJANE
ORDER NUMBER : PN MBU5710
RECEIVED ON : 03/09/2019
ANALYSIS COMPLETED : 10/10/2019
DATE ANALYSED : 03/9/2019 - 26/09/2019

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Laboratory Number			E020320	E020321	E020322
Sampled Date					
Sample Marks			BT 1	BT 2	BT 3
Determinand	Method References	Detection Limit	Result	Result	Result
ANALYSIS WERE CARRIED OUT ON 5% AQUEOUS EXTRACTS OF A SAMPLE AS RECEIVED:METALS					
Silver as Ag(mg/l)*	W044-28-O	0.004	<0.004	<0.004	<0.004
Aluminium as Al(mg/l)*	W044-28-O	0.003	0.088	0.078	0.13
Arsenic as As(mg/l)*	W044-28-O	0.002	0.012	0.007	<0.002
Boron as B(mg/l)*	W044-28-O	0.006	0.049	0.016	<0.006
Barium as Ba(mg/l)*	W044-28-O	0.001	0.29	0.27	0.14
Beryllium as Be(mg/l)*	W044-28-O	0.002	<0.002	<0.002	<0.002
Bismuth as Bi(mg/l)*	W044-28-O	0.005	<0.005	<0.005	<0.005
Calcium as Ca(mg/l)*	W044-28-O	0.05	84	32	2.06
Cadmium as Cd(mg/l)*	W044-28-O	0.001	<0.001	<0.001	<0.001
Cobalt as Co(mg/l)*	W044-28-O	0.001	0.093	0.092	0.098
Chromium as Cr(mg/l)*	W044-28-O	0.003	0.11	0.11	0.11
Copper as Cu(mg/l)*	W044-28-O	0.002	0.12	0.11	0.10
Iron as Fe(mg/l)*	W044-28-O	0.001	0.15	0.16	0.17
Mercury as Hg(mg/l)*	W044-30-C	0.001	<0.001	<0.001	<0.001
Potassium as K(mg/l)*	W044-28-O	0.005	3.84	2.18	2.43
Magnesium as Mg(mg/l)*	W044-28-O	0.01	17.21	12.27	1.13
Manganese as Mn(mg/l)*	W044-28-O	0.001	0.21	0.27	0.31
Molybdenum as Mo(mg/l)*	W044-28-O	0.001	0.001	<0.001	<0.001
Sodium as Na(mg/l)*	W044-28-O	0.02	3.71	2.74	2.06
Nickel as Ni(mg/l)*	W044-28-O	0.003	0.11	0.12	0.12
Lead as Pb(mg/l)*	W044-28-O	0.01	<0.01	<0.01	<0.01
Antimony as Sb(mg/l)*	W044-28-O	0.01	<0.01	<0.01	<0.01
Selenium as Se(mg/l)*	W044-28-O	0.003	<0.003	<0.003	<0.003
Silicon as Si(mg/l)*	W044-28-O	0.007	0.88	0.81	3.00
Tin as Sn(mg/l)*	W044-28-O	0.02	<0.02	<0.02	<0.02
Strontium as Sr(mg/l)*	W044-28-O	0.001	0.96	0.24	0.018
Thorium as Th(mg/l)*	W044-28-O	0.002	<0.002	<0.002	<0.002
Titanium as Ti(mg/l)*	W044-28-O	0.001	<0.001	<0.001	0.005
Thallium as Tl(mg/l)*	W044-28-O	0.009	<0.009	<0.009	<0.009
Uranium as U(mg/l)*	W044-28-O	0.004	<0.004	<0.004	<0.004
Vanadium as V(mg/l)*	W044-28-O	0.002	0.14	0.13	0.12

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Mulalo Mhlanga

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Laboratory Number			E020320	E020321	E020322
Sampled Date					
Sample Marks			BT 1	BT 2	BT 3
Determinand	Method References	Detection Limit	Result	Result	Result
ANALYSIS WERE CARRIED OUT ON 5% AQUEOUS EXTRACTS OF A SAMPLE AS RECEIVED:METALS					
Zinc as Zn(mg/l)*	W044-28-O	0.005	0.094	0.093	0.091
Zirconium as Zr(mg/l)*	W044-28-O	0.001	0.040	0.040	0.040

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Sampled Date					
Sample Marks			BT 4	BT 1 HW	BT 1 FW
Determinand	Method References	Detection Limit	Result	Result	Result
ANALYSIS WERE CARRIED OUT ON 5% AQUEOUS EXTRACTS OF A SAMPLE AS RECEIVED:METALS					
Silver as Ag(mg/l)*	W044-28-O	0.004	<0.004	<0.004	<0.004
Aluminium as Al(mg/l)*	W044-28-O	0.003	0.10	0.13	0.24
Arsenic as As(mg/l)*	W044-28-O	0.002	0.010	0.003	0.006
Boron as B(mg/l)*	W044-28-O	0.006	<0.006	0.063	0.018
Barium as Ba(mg/l)*	W044-28-O	0.001	0.30	0.34	0.33
Beryllium as Be(mg/l)*	W044-28-O	0.002	<0.002	<0.002	<0.002
Bismuth as Bi(mg/l)*	W044-28-O	0.005	<0.005	<0.005	<0.005
Calcium as Ca(mg/l)*	W044-28-O	0.05	22	19.32	14.10
Cadmium as Cd(mg/l)*	W044-28-O	0.001	<0.001	<0.001	<0.001
Cobalt as Co(mg/l)*	W044-28-O	0.001	0.092	0.093	0.092
Chromium as Cr(mg/l)*	W044-28-O	0.003	0.11	0.11	0.11
Copper as Cu(mg/l)*	W044-28-O	0.002	0.11	0.11	0.11
Iron as Fe(mg/l)*	W044-28-O	0.001	0.16	0.17	0.16
Mercury as Hg(mg/l)*	W044-30-C	0.001	<0.001	<0.001	<0.001
Potassium as K(mg/l)*	W044-28-O	0.005	3.45	4.85	4.78
Magnesium as Mg(mg/l)*	W044-28-O	0.01	7.45	8.31	5.24
Manganese as Mn(mg/l)*	W044-28-O	0.001	0.17	0.18	0.16
Molybdenum as Mo(mg/l)*	W044-28-O	0.001	0.010	0.026	0.027
Sodium as Na(mg/l)*	W044-28-O	0.02	2.05	3.20	2.43
Nickel as Ni(mg/l)*	W044-28-O	0.003	0.11	0.11	0.11
Lead as Pb(mg/l)*	W044-28-O	0.01	<0.01	<0.01	<0.01
Antimony as Sb(mg/l)*	W044-28-O	0.01	<0.01	<0.01	<0.01
Selenium as Se(mg/l)*	W044-28-O	0.003	<0.003	<0.003	<0.003
Silicon as Si(mg/l)*	W044-28-O	0.007	1.06	2.15	2.96
Tin as Sn(mg/l)*	W044-28-O	0.02	<0.02	<0.02	<0.02
Strontium as Sr(mg/l)*	W044-28-O	0.001	0.17	0.20	0.13
Thorium as Th(mg/l)*	W044-28-O	0.002	<0.002	<0.002	<0.002
Titanium as Ti(mg/l)*	W044-28-O	0.001	0.001	0.005	0.034
Thallium as Tl(mg/l)*	W044-28-O	0.009	<0.009	<0.009	0.034
Uranium as U(mg/l)*	W044-28-O	0.004	<0.004	<0.004	<0.004
Vanadium as V(mg/l)*	W044-28-O	0.002	0.13	0.13	0.12

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Laboratory Number	E020323		E020324	E020325
Sampled Date				
Sample Marks	BT 4		BT 1 HW	BT 1 FW
Determinand	Method References	Detection Limit	Result	Result
ANALYSIS WERE CARRIED OUT ON 5% AQUEOUS EXTRACTS OF A SAMPLE AS RECEIVED:METALS				
Zinc as Zn(mg/l)*	W044-28-O	0.005	0.092	0.092
Zirconium as Zr(mg/l)*	W044-28-O	0.001	0.040	0.040

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Laboratory Number			E020320	E020321	E020322
Sampled Date					
Sample Marks			BT 1	BT 2	BT 3
Determinand	Method References	Detection Limit	Result	Result	Result
ANALYSIS WERE CARRIED OUT ON 5% AQUEOUS EXTRACTS OF A SAMPLE AS RECEIVED					
Nitrate as NO ₃ (mg/l)*	W044-50-W	0.1	<0.1	<0.1	0.3
Nitrate as N(mg/l)*	W044-50-W	0.1	<0.1	<0.1	0.31
pH value @ 25°C*	W044-27-O		6.40	7.10	6.40
Conductivity mS/m @25°C*	W044-27-O	1.0	48	26	4.30
Chloride, Cl(mg/l)*	W044-50-W	0.1	28	8.91	1.02
Cyanide, CN(mg/l)*			0.020	0.054	0
Total Alkalinity*	W044-50-W	0.01	28	40	<0.01
Fluoride, F(mg/l)*	W044-50-W	0.1	0.13	<0.1	0.18
Sulphate as SO ₄ (mg/l)*			166.85	63.86	9.54

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Laboratory Number			E020323	E020324	E020325
Sampled Date					
Sample Marks			BT 4	BT 1 HW	BT 1 FW
Determinand	Method References	Detection Limit	Result	Result	Result
ANALYSIS WERE CARRIED OUT ON 5% AQUEOUS EXTRACTS OF A SAMPLE AS RECEIVED					
Nitrate as NO ₃ (mg/l)*	W044-50-W	0.1	<0.1	<0.1	<0.1
Nitrate as N(mg/l)*	W044-50-W	0.1	<0.1	<0.1	<0.1
pH value @ 25°C*	W044-27-O		7.30	7.20	7.00
Conductivity mS/m @25°C*	W044-27-O	1.0	18.00	18.80	14.10
Chloride, Cl(mg/l)*	W044-50-W	0.1	0.58	0.64	0.99
Cyanide, CN(mg/l)*			0	0.008	0
Total Alkalinity*	W044-50-W	0.01	38	26	13.10
Fluoride, F(mg/l)*	W044-50-W	0.1	0.14	0.45	0.35
Sulphate as SO ₄ (mg/l)*			37.02	52.37	42.13

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Laboratory Number			E020320	E020321	E020322
Sampled Date					
Sample Marks			BT 1	BT 2	BT 3
Determinand	Method References	Detection Limit	Result	Result	Result
THE ANALYSIS WAS CARRIED OUT ON ACID DISSOLUTION OF A SAMPLE AS RECEIVED					
Silver as Ag(mg/kg)*	W044-28-O	0.40	<0.40	<0.40	<0.40
Arsenic as As(mg/kg)*	W044-28-O	2.0	7.21	2.94	<2.0
Boron as B(mg/kg)*	W044-28-O	0.6	42	25	23
Beryllium as Be(mg/kg)*	W044-28-O	0.20	<0.20	<0.20	<0.20
Bismuth as Bi(mg/kg)*	W044-28-O	0.50	<0.50	<0.50	<0.50
Cadmium as Cd(mg/kg)*	W044-28-O	0.10	<0.10	<0.10	<0.10
Cobalt as Co(mg/kg)*	W044-28-O	0.10	2.48	1.89	1.98
Mercury as Hg(mg/kg)*	W044-30-C	0.10	<0.10	<0.10	<0.10
Molybdenum as Mo(mg/kg)*	W044-28-O	0.10	1.34	0.49	1.28
Nickel as Ni(mg/kg)*	W044-28-O	0.30	14.01	<0.30	<0.30
Antimony as Sb(mg/kg)*	W044-28-O	1.0	<1.0	<1.0	<1.0
Selenium as Se(mg/kg)*	W044-28-O	3.0	<3.0	<3.0	<3.0
Tin as Sn(mg/kg)*	W044-28-O	2.0	<2.0	<2.0	<2.0
Thorium as Th(mg/kg)*	W044-28-O	0.20	<0.20	<0.20	<0.20
Titanium as Ti(mg/kg)*	W044-28-O	0.10	<0.10	<0.10	<0.10
Thallium as Tl(mg/kg)*	W044-28-O	0.90	<0.90	<0.90	<0.90
Uranium as U(mg/kg)*	W044-28-O	0.40	<0.40	<0.40	<0.40

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T0040



M & L LABS

Registration Number 1974/001476/07 VAT Number 4780103505

Consulting Industrial Chemists, Analysts

CONFIDENTIAL

Certificate/Report

Laboratory Number			E020323	E020324	E020325
Sampled Date					
Sample Marks			BT 4	BT 1 HW	BT 1 FW
Determinand	Method References	Detection Limit	Result	Result	Result
THE ANALYSIS WAS CARRIED OUT ON ACID DISSOLUTION OF A SAMPLE AS RECEIVED					
Silver as Ag(mg/kg)*	W044-28-O	0.40	<0.40	<0.40	<0.40
Arsenic as As(mg/kg)*	W044-28-O	2.0	<2.0	8.04	<2.0
Boron as B(mg/kg)*	W044-28-O	0.6	25	99	16.14
Beryllium as Be(mg/kg)*	W044-28-O	0.20	<0.20	<0.20	<0.20
Bismuth as Bi(mg/kg)*	W044-28-O	0.50	<0.50	<0.50	<0.50
Cadmium as Cd(mg/kg)*	W044-28-O	0.10	<0.10	<0.10	<0.10
Cobalt as Co(mg/kg)*	W044-28-O	0.10	<0.10	16.82	2.66
Mercury as Hg(mg/kg)*	W044-30-C	0.10	<0.10	<0.10	<0.10
Molybdenum as Mo(mg/kg)*	W044-28-O	0.10	0.72	<0.10	<0.10
Nickel as Ni(mg/kg)*	W044-28-O	0.30	<0.30	20	<0.30
Antimony as Sb(mg/kg)*	W044-28-O	1.0	<1.0	<1.0	<1.0
Selenium as Se(mg/kg)*	W044-28-O	3.0	<3.0	<3.0	<3.0
Tin as Sn(mg/kg)*	W044-28-O	2.0	<2.0	<2.0	<2.0
Thorium as Th(mg/kg)*	W044-28-O	0.20	<0.20	<0.20	<0.20
Titanium as Ti(mg/kg)*	W044-28-O	0.10	<0.10	<0.10	<0.10
Thallium as Tl(mg/kg)*	W044-28-O	0.90	<0.90	<0.90	<0.90
Uranium as U(mg/kg)*	W044-28-O	0.40	<0.40	<0.40	<0.40

Ndileka Bangani

Mulalo Mhlanga

BDL - Below Detection Limit

* Denotes test method not accredited to ISO 17025

Denotes test method is outsourced

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Certificate/Report

Laboratory Number			E020320	E020321	E020322
Sampled Date					
Sample Marks			BT 1	BT 2	BT 3
Determinand	Method References	Detection Limit	Result	Result	Result
THE ANALYSIS WERE CARRIED OUT ON A DRIED MILLED SAMPLE					
pH Value @ 25°C (on a saturated paste)*	W044-27-O		8.3	6.7	7.5
Chloride, Cl(mg/kg)*	ASTM 150696a	1	5	<1	<1
Sulfate, SO ₄ (%)*	GRAVIMETRIC	0.01	0.17	0.19	0.09
Total Nitrate as NO ₃ (mg/kg)*			<0.5	1.25	5.15
Total Nitrate as N(mg/kg)*			<0.5	0.28	1.16
Fluoride, F(mg/kg)*	ASTM D3761-96	0.10	<0.10	<0.10	<0.10
Hexavalent chromium as Cr6+(mg/kg)*	EPA 3060A	0.1	<0.1	<0.1	<0.1
Total cyanide as CN(mg/kg)*	MICRO DIST 10-	0.1	0.70	1.74	2.78

Ndileka Bangani

Mulalo Mhlanga

BDL - Below Detection Limit

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Certificate/Report

Laboratory Number			E020323	E020324	E020325
Sampled Date					
Sample Marks			BT 4	BT 1 HW	BT 1 FW
Determinand	Method References	Detection Limit	Result	Result	Result
THE ANALYSIS WERE CARRIED OUT ON A DRIED MILLED SAMPLE					
pH Value @ 25°C (on a saturated paste)*	W044-27-O		8.7	7.1	9.7
Chloride, Cl(mg/kg)*	ASTM 150696a	1	<1	10	<1
Sulfate, SO ₄ (%)*	GRAVIMETRIC	0.01	0.08	0.15	0.03
Total Nitrate as NO ₃ (mg/kg)*			10.50	3.20	1.30
Total Nitrate as N(mg/kg)*			2.37	0.72	0.29
Fluoride, F(mg/kg)*	ASTM D3761-96	0.10	<0.10	<0.10	<0.10
Hexavalent chromium as Cr ⁶⁺ (mg/kg)*	EPA 3060A	0.1	<0.1	<0.1	<0.1
Total cyanide as CN(mg/kg)*	MICRO DIST 10-	0.1	0.86	0.61	1.52

Ndileka Bangani

Mulalo Mhlanga

BDL - Below Detection Limit

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T0040



M & L LABS

Certificate/Report

RESULTS REPORTED RELATED ONLY TO ITEMS TESTED

COMPANY NAME : DIGBY WELLS & ASSOCIATES (SA) PTY LTD

ADDRESS : PRIVATE BAG X10046

SUBJECT : ANALYSIS OF 6 SOLID SAMPLES

MARKED : AS BELOW

INSTRUCTED BY : ARJAN VANT ZELFDE

ORDER NO. : PN MBU 5710

RECEIVED ON : 03/09/2019

LAB NO(S) : E020320-E020325

DATE ANALYSED : 16/09/2019

ACID-BASE ACCOUNTING

Analysis on the dried and milled samples:

SAMPLE MARKS:	LAB NO:	Total Sulphur, S %	Total Acidity Potential as CaCO ₃ kg/ton	Gross Neutralisation Potential as CaCO ₃ kg/ton	Net Neutralisation Potential as CaCO ₃ kg/ton (By Difference)
BT1	E020320	3.14	98	64	-34.0
BT2	E020321	1.39	43	7.7	-35.3
BT3	E020322	1.13	35	9.5	-25.5
BT4	E020323	1.47	46	25	-21.0
BT1 HW	E020324	1.43	45	18.7	-26.3
BT1 FW	E020325	0.90	28	6.5	-21.5

Method Reference:

Lawrence, R.W., Polling, G.P. and Marchant, P.B., 1989. Investigation of predictive techniques or acid mine drainage, Report on DSS Contract No. 23440-7-9178/01-SQ, Energy Mines and Resources, Canada, MEND Report 1.16.1(a). Sobek, A.A., Schuller, W.A., Freeman, J.R. and Smith, R.M., 1978. Field and Laboratory Methods Applicable to Overburden and Mine soils, EPA 600/2-78-054, 203 pp.

Certificate/Report

RESULTS REPORTED RELATED ONLY TO ITEMS TESTED

Analysis on the dried and milled samples:

<u>SAMPLE MARKS:</u>	<u>LAB NO:</u>	<u>Total Sulphur, S</u> %	<u>Sulphide Sulphur as S</u> % (by calculation)	<u>Sulphate Sulphur, S</u> %
BT1	E020320	3.14	3.08	0.06
BT2	E020321	1.39	1.33	0.06
BT3	E020322	1.13	1.1	0.03
BT4	E020323	1.47	1.44	0.03
BT1 HW	E020324	1.43	1.38	0.05
BT1 FW	E020325	0.90	0.89	0.01

Notes:

1. The Sulphate content was determined by a Wet Chemical procedure.

Analysis on the dried and milled samples:

<u>SAMPLE MARKS:</u>	<u>LAB NO:</u>	<u>NAG pH @25°C</u>	<u>NET ACID GENERATION AS</u> <u>H₂SO</u> <u>Kg/tonne</u>
BT1	E020320	1.9	10
BT2	E020321	2.2	125
BT3	E020322	2.3	85
BT4	E020323	3.9	81
BT1 HW	E020324	4.3	2.0
BT1 FW	E020325	2.9	<1.0

Method Reference:

Miller, S., Robertson, A. and Donohue, T. (1997). Advances in Acid Drainage Prediction. Prediction using The Net Acid Generation (NAG) Test. Report on Acid Mine Drainage published in Vancouver, BC., Canada.



Certificate/Report

RESULTS REPORTED RELATED ONLY TO ITEMS TESTED

ANALYSIS:

- Qualitative and Quantitative XRD (mineralogy)
- The samples were prepared according to the standardized Panalytical backloading system, which provides nearly random distribution of the particles.
- The samples were analyzed using a PANalytical Aeris powder diffractometer in θ - θ configuration with an X'Celerator detector and fixed divergence- and receiving slits with Fe filtered Co-K α radiation ($\lambda=1.789\text{\AA}$). The phases were identified using X'Pert Highscore plus software.
- The relative phase amounts (weight %) were estimated using the Rietveld method (Autoquan Program). The quantitative results are listed below.

Comment:

- ☐ The samples seem to be coal samples with a high amorphous content.

Amorphous material is invisible for the Rietveld method and the amount of the crystalline phases will be overestimated.

- ☐ After addition of a standard of 20% Si (Aldrich 99% pure) for determination of amorphous content the overestimation of this phase and of all the other phases can be corrected for.



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RESULTS REPORTED RELATED ONLY TO ITEMS TESTED

Quantitative Results:

	<u>E020325</u>				
	BT 1 FW				
	wt%				
Ankerite	-				
Calcite	-				
Chlorite	-				
Hematite	-				
Kaolinite	35.11				
Magnetite	-				
Microcline	14.87				
Muscovite	7.11				
Plagioclase	-				
Quartz	42.91				
Sepiolite	-				
Siderite	-				
	<u>E020320</u>	<u>E020321</u>	<u>E020322</u>	<u>E020323</u>	<u>E020324</u>
	BT 1	BT 2	BT 3	BT 4	BT1 HW
	wt%	wt%	wt%	wt%	wt%
Amorphous	66.21	66.47	59.3	68.16	10.51
Ankerite	4.45	-	-	-	-
Calcite	1.46	-	-	0.16	-
Kaolinite	14.17	20.84	17.73	15.41	38.79
Microcline	-	-	-	2.92	6.51
Muscovite	-	-	-	2.45	7.01
Pyrite	3.38	0.93	0.39	-	1.44
Quartz	10.33	11.76	22.58	10.9	27.3
Siderite	-	-	-	-	8.44



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RESULTS REPORTED RELATED ONLY TO ITEMS TESTED

Mineral	General Formula
Ankerite	$\text{Ca(Fe, Mg)}(\text{CO}_3)_2$
Calcite	$\text{Ca(CO}_3\text{)}$
Chlorite	$(\text{Mg,Fe})_5\text{Al(AlSi}_3\text{O}_{10})(\text{OH})_8$
Hematite	FeO_3
Kaolinite	$\text{Al}_4(\text{OH})_8(\text{Si}_4\text{O}_{10})$
Magnetite	Fe_3O_4
Microcline	KAlSi_3O_8
Muscovite	$\text{KAl}_3\text{Si}_3\text{O}_{10}(\text{OH})_2$
Plagioclase	$(\text{Na,Ca})(\text{Si,Al})_4\text{O}_8$
Pyrite	FeS_2
Quartz	SiO_2
Sepiolite	$\text{Mg}_8(\text{OH})_4\text{Si}_{12}\text{O}_{30}(\text{H}_2\text{O})_{12}$
Siderite	$\text{Fe(CO}_3\text{)}$

The results were supplied by a sub contracted laboratory



Certificate/Report

RESULTS REPORTED RELATED ONLY TO ITEMS TESTED

ANALYTE	LAB NO	E020320	E020321	E020322	E020323	E020324	E020325
	SAMPLE MARK	BT 1	BT 2	BT 3	BT 4	BT1 HW	BT 1 FW
Fe2O3	%	9.856	4.685	3.086	5.151	9.641	1.587
SiO2	%	49.027	66.759	73.716	62.188	62.828	78.444
Al2O3	%	18.751	25.598	19.107	23.497	22.166	15.010
K2O	%	0.434	0.401	1.567	0.658	2.139	3.505
P2O5	%	0.045	0.078	0.048	0.057	0.100	0.035
Mn3O4	%	0.059	0.091	0.084	0.045	0.186	0.023
CaO	%	8.199	0.570	0.273	2.620	0.436	0.135
MgO	%	3.381	0.369	0.294	1.415	1.108	0.427
TiO2	%	1.215	1.362	1.089	1.142	1.366	0.943
Na2O	%	0.110	0.029	0.071	0.073	0.073	0.168
V2O5	%	0.014	0.012	0.021	0.012	0.022	0.011
BaO	%	0.094	0.055	0.098	0.094	0.091	0.114
SrO	%	0.083	0.034	0.032	0.049	0.020	0.019
ZrO2	%	0.052	0.060	0.052	0.058	0.083	0.081
CuO	%	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
PbO	%	0.008	0.011	0.008	0.009	0.005	0.009
ZnO	%	0.009	0.009	0.012	0.010	0.028	0.021
SO3	%	9.536	0.452	0.268	2.469	0.366	0.325
Total	%	100.895	100.598	99.855	99.568	100.704	100.877
Ash	%	28.425	29.090	39.554	26.591	75.885	93.107

*Ashing done at 815°C. *Samples reported on a dried basis.

*The results relate specifically to the items as tested

The results were supplied by a sub contracted laboratory

Authorised Signature

EXTRACT OF THE BUREAU VERITAS GENERAL TERMS AND CONDITIONS OF BUSINESS

This extract of the Bureau Veritas general terms and conditions of business ("**General Conditions**") shall govern all services, including (but not limited to) laboratory test work, surveys, sampling, site investigations, consultations and opinions, performed for any individual or juristic person (the "**Client**") by M and L Laboratory Services Proprietary Limited, its subsidiary companies and their employees, agents, consultants and subcontractors (collectively referred to as the "**Company**"), whether in terms of a specified contract or not. For the purpose of these General Conditions, the Company and the Client shall collectively be referred to as the "**Parties**" and individually as a "**Party**".

1. QUOTATIONS

Any quotations for Services submitted by the Company to the Client shall be based on information supplied to the Company by the Client and will not under any circumstances be binding on the Company if such information is incorrect or incomplete in any manner.

2. INSTRUCTIONS

The Client will provide the Company with clear and precise written instructions, documents, information and samples prior to the performance of the Services. The Company will not be liable for any error, omission or inaccuracy in the reports or certificates produced by it to the extent that the Company has been given erroneous or incomplete information by the Client. The reports and certificates produced by the Company reflect the findings of the Company at the time of performance of the Services only.

3. SAMPLE MATERIAL

The Client will ensure that all samples/materials submitted by it for test work of any nature are clearly marked and identifiable. Should it be necessary for the Company to carry out any sample preparation, preliminary experimental work, or research prior to carrying out the Services, the Client will be liable for any charges in respect thereof. Unless the Client otherwise instructs in writing, the Company may retain, return to the Client, destroy or dispose of all excess samples, material, specimens or exhibits provided by the Client to the Company as soon as the Services are completed and the results have been reported to the Client. Any destruction or disposal shall exclude normal amounts of reserve sample material which the Company shall retain for a period of three months from date of completion of the Services. If the Client requires the Company to return any samples or materials to it or a third party, all costs associated therewith, including associated telecommunication costs, will be borne and paid for the Client.

4. FEES AND TERMS OF PAYMENT

In consideration for the provision of the Services by the Company, the Client shall pay the fees calculated in accordance with the Company's tariff of fees at the time, copies of which may be requested by the Client at any time. In the event of any changes in the Company's fees, the Company shall provide written notification thereof to the Client within a reasonable time prior to such new fees becoming effective. If the Client does not have an account with the Company, the Client shall be required to pay the whole or part of the fees before the Company will commence the Services or release the results, as the case may be. The Client will pay each valid invoices submitted to it by the Company in full and in cleared funds within 30 days of the date of the invoice. The Company shall be entitled to charge Interest at 2% per month on any amounts not paid on the due date.

5. LIABILITY AND INDEMNITY

Neither Party shall be liable to the other Party for any consequential, indirect, incidental or special losses or damages of any nature whatsoever and howsoever arising. Without prejudice to the foregoing, the total liability of the Company arising out of or in connection with this Agreement or in relation to the Services shall be limited to the fee paid or payable by the Client to the Company for the Services that gave rise to the Company's liability to the Client, if any. The Client indemnifies the Company and holds it harmless against all claims made by third parties for losses, damages or expenses of whatsoever nature and howsoever arising relating to the performance, purported performance or non-performance of any Services to the extent that the aggregate of such claims for any one Service exceeds the limitation of liability set out in this clause 5.

6. PROVISION OF THE SERVICES

The Company shall provide the Services with reasonable care, skill and diligence as expected of a competent body experienced in performing services of a similar nature and under similar circumstances. If the Client is aware of any apparent inaccuracy in any results reported by the Company in respect of the Services, the Client shall immediately advise the Company accordingly, and allow the Company a reasonable opportunity to check such results and amend them if necessary.

7. PUBLICATION OF RESULTS

Any reports or certificates issued by the Company are intended for the exclusive use of the Client and shall not be published, used for advertising purposes, copied or replicated for distribution to any person or entity or otherwise publicly disclosed without the prior written consent of the Company.

8. ALTERATIONS OF TERMS

No employee, agent or representative of the Company is authorised to alter or waive any of the terms contained in these General Conditions unless in writing and signed by or on behalf of the Parties. The performance of any test shall further be subject to any additional special conditions as the Company may impose from time to time. If such special conditions differ from any provisions set out herein, such special conditions shall, to the extent of such difference, take precedence.

9. LAW OF SOUTH AFRICA

These General Conditions shall be governed by and construed in accordance with the laws of the Republic of South Africa. The Parties irrevocably consent to the jurisdiction of the South Gauteng High Court, Johannesburg, if any dispute or claim arises out of or in connection with this Agreement.

For full business terms and conditions please click or visit http://portal.bureauveritas.co.za/downloads/conditions_ml.pdf