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Proposed Development of an Underground Coal Mine and Associated Infrastructure, near Hendrina, Mpumalanga

Groundwater Assessment Report

Project Number:

XST3791

Prepared for:

Umcebo Mining (Pty) Ltd

October 2016

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DECLARATION

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I, Robel Gebrekristos 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 Umcebo Mining (Pty) Ltd, other than fair remuneration for work performed, specifically in connection with the proposed development of an underground coal mine and associated infrastructure, located near Hendrina, Mpumalanga Province.

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EXECUTIVE SUMMARY

Digby Wells Environmental was contracted by Umcebo Mining (Pty) Ltd (Umcebo), to conduct an environmental impact assessment for its proposed underground mine, near Hendrina, Mpumalanga Province. This specialist groundwater study was conducted as part of the overall environmental authorisation process to assess the potential impacts and mitigation plans on the groundwater environment.

The scope of the groundwater study included a desktop study, hydrocensus, geophysical assessment, geochemical study, waste classification, borehole drilling, aquifer testing and numerical modelling.

Baseline Findings

A total of 190 percussion boreholes were recorded during the hydrocensus and from the national groundwater archive. Of these:

- 31 (16%) are used for drinking only;
- 6 (3%) are used for drinking and livestock watering;
- 2 (1%) is used for drinking, livestock and irrigation;
- 31 (16%) is used for irrigation;
- 47 (25%) are used for livestock watering only;
- 17 (9%) are not used for any purpose; and
- The remaining 56 (29%) could not be confirmed.

The baseline groundwater quality is generally clean. Ten of the 13 boreholes sampled are suitable for human consumption. The sulfate concentrations for the sampled boreholes are currently less than 20.6 mg/L. Since sulfate is expected to be an element of concern in coal mines, the values obtained during this study can be used for future contamination comparisons. Three of the 13 boreholes fell within the unacceptable category water quality range. These are either due to fluoride or manganese, both of which are suspected to be due to natural dissolution from the host rocks, particular from the pre-Karoo intrusive rocks.

The aquifers within the project site are characterised with limited permeability, ranging between 10^{-5} m/d and $7x10^{-2}$ m/d. The low permeability was also evident during the drilling programme as no water strikes with measurable blow yields were detected. The water level took up to two weeks to recover to the static position following the drilling. The only exception is BKBH6 (located in Hendrina South) where a water strike of 2 L/s was recorded at a depth of 10 m, in the weathered sandstone. The borehole was pump tested while the rest of them were slug tested.

Potential Impacts

The geochemical analysis conducted on the rock samples confirmed that the site geochemistry is heterogeneous. The mineralogy, sulfur speciation and acid-base accounting analysis showed that the rocks from TFBH1 are potentially acid generating while those from BKBH6 are potentially acid neutralising. Borehole BKBH6 is located in Hendrina South and TFBH1 is located in Mooivley East. The two mine zones will not be connected hydraulically and are expected to have different geochemical properties. While the water in the Mooivley East is expected to be acidic, the water in Hendrina South is likely to be neutral. It should, however, be noted that this is based on limited number of samples that does not include the Mooivley West.

If for any reason the waters of the underground mines are mixed, it will in overall be acidic. This is due to the average net neutralisation potential of all of the samples being -7.7 kg $CaCO_3$/tonne, indicating that overall the acid generating potential of the samples is more than the neutralisation potential and the samples are likely to generate acid.

Mine dewatering will result in the lowering of the water table in the coal seam aquifer. Considering the limited vertical and horizontal conductivities of the aquifers, together with the coal seam depth, such impacts are estimated to be within the mine footprint area. The maximum drawdown in the top weathered aquifer (where majority of the boreholes are located) is estimated to be less than 1 m and will not be significant unless subsidence occurs or blasting related fractures are formed and that the vertical permeability is enhanced. However, deep boreholes intersecting the coal seam aquifer could potentially be impacted by the lowering of the water table. The lateral extent of the no-go zone created by the cone of depression is predicted to be within the mine footprint area, constrained due to the limited aquifer permeability. As a result, any impact will be on the boreholes located within the mine zones.

The mining is likely to alter the natural geochemistry by exposing the sulfides for oxygenation. This could result in sulfate contamination as observed in the coal mines in the region, where the concentration could reach up to 2500 mg/L. Any contamination plume during the mine operation will predominantly be intercepted at the underground sumps due to the dewatering programme. No contamination is expected to reach the rivers during operation, due to the hydraulic gradient being towards the mining and abstraction areas.

After mine closure, however, the dewatering will cease and the groundwater will recover and start to flow towards the rivers and streams. The contamination plume will be transported with the groundwater flow. The size of plume will be controlled by the rock permeability and is predicted to remain in the vicinity of the mine zones.

Model simulations and hydrostatic calculations show that the mine is likely to decant after closure. The decanting is expected to occur through the proposed shaft in Mooivley East starting after about 30 years after closure and will reach a maximum of 7 m^3/d. As discussed previously this mine zone is expected to be acidic. Once the contamination plume reaches the streams, it can migrate at a higher rate compared to groundwater flow and could have a negative impact on the down-gradient riverine ecosystem and land owners unless it is managed properly. It should be noted that the possibility of subsidence has not being considered in the decant simulation. Any unsealed exploration boreholes or rock fractures enhanced by mine blasting or subsidence could also be decant zones if their topographic elevation is lower than the hydraulic head.

Mitigation Plans

The recommended mitigation plans include:

- Dewatered water should be stored in pollution control dams with sufficient storage volumes. Mine water should only be discharged to the environment after being treated to the recommended standards;
- Monthly groundwater monitoring should be conducted to record the water level, water quality and dewatering rates. Management solutions will be provided upon agreement between Umcebo and the affected stakeholders;
- If sinkholes from subsidence are formed during operation, they should be rehabilitated as soon as possible to minimise water and oxygen inflow from the atmosphere and to minimise acid mine drainage;
- Nitrate-based explosives should be avoided to minimise groundwater contamination;
- Overburden and topsoil stockpiles should be managed to minimise infiltration of contaminants to the groundwater. Mitigation methods that should be considered include the vegetation of the stockpile and covering them with soil to minimise rainfall infiltration and mobilisation of dissolved metals.
- Due to the geochemical heterogeneity, the six rock samples are not expected to provide conclusive and representative information on the long-term acid generation potential of the entire mine site. More samples are recommended to be tested from a number of boreholes across the entire project site and long-term kinetic test work should be conducted on the overburden, coal seam and underburden to determine the potential of pollution and AMD development over a longer period.
- Update numerical model annually for the first five years as more information becomes available.

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ABA	Acid-Base Accounting
AMD	Acid Mine Drainage
AP	Acid Potential
DEA	Department of Environmental Affairs
DWS	Department of Water and Sanitation
EMP	Environmental management plan
EIA	Environmental Impact Assessment
LC	Leachable Concentration
LCT	Leachable Concentration Threshold
LoM	Life of Mine
MPRDA	Mineral and Petroleum Resources Development Act
NAG	National Groundwater Archive
NEMA	National Environmental Management Act
NEM:WA	National Environmental Management: Waste Act
NNP	Net Neutralisation Potential
NP	Neutralisation Potential
NPR	Neutralisation Potential Ration
ROM	Run of Mine
SANS	South African National Standards
TC	Total Concentration
TCT	Total Concentration Threshold
XRD	X-Ray Diffraction
XRF	X-Ray Florescence

1 Introduction

Umcebo Mining (Pty) Ltd (Umcebo), a subsidiary of Glencore Operations South Africa (Pty) Ltd (Glencore) is proposing the development and operation of a new underground coal mine and associated infrastructure at a site situated approximately 3 to 22 kilometres (km) south east of Hendrina in the Mpumalanga Province of South Africa (the project).

Umcebo currently holds two Prospecting Rights (PRs), namely, MP 1265 PR and MP 1266 PR, located within the Ermelo Coal Field. The locality map is given in Figure 1-1.

The total extent of MP 1265 PR (referred to as Mooivley East and Mooivley West) is 3 923 hectares (Ha) and comprise the following farms and portions (Figure 1-1):

- Mooivley 219 IS – Potions 2, 4, 5 and Remaining Extent (RE) of the farm;
- Tweefontein 203 IS – Portions 2, 15, 16, and 17;
- Uitkyk 220 IS – Portions 2 and 3; and
- Orange Vallei 201 IS – Portions 1 and RE of the farm.

The total extent of MP 1266 PR (referred to as Hendrina South) is 2 787 Ha and comprises the following farm and portions:

- Elim 247 IS - RE of the farm;
- Geluksdraai 240 IS – 1 and 2;
- Orpenskraal 238 IS – RE of the farm; and
- Bosmanskrans 217 IS – Potions 1, 3, 4, 6, 8, 9 and RE of the farm.

The project area proposed to be mined (underground) has a combined footprint of 6 714 Ha and is located within the Steve Tshwete Local Municipality and Msukaligwa Local Municipality.

This specialist groundwater study was conducted as part of the overall environmental authorisation process to assess the potential impacts and mitigation plans on the groundwater environment during the construction, operation and closure phases of the mine.

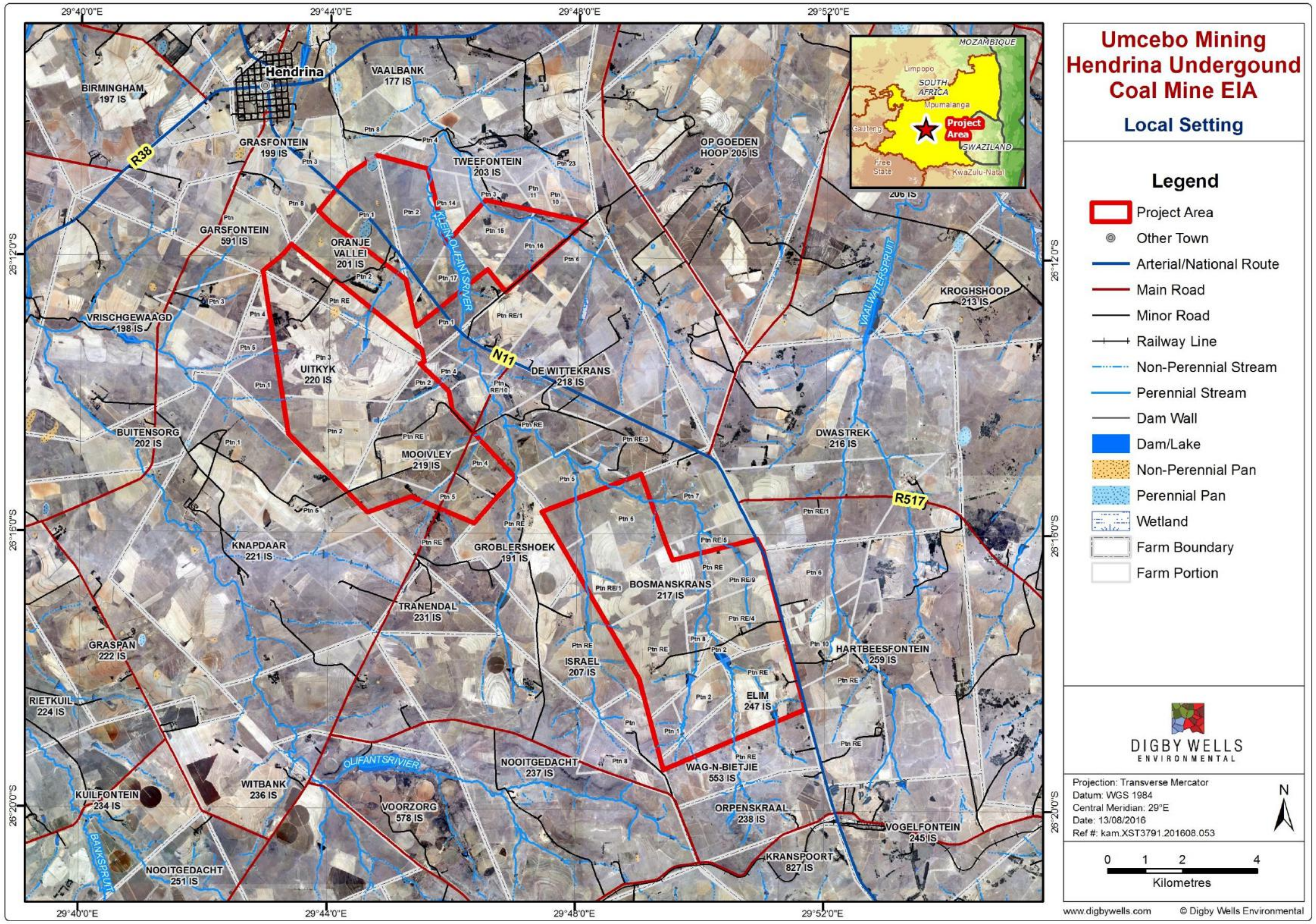

Figure 1-1: Project Site Locality Map

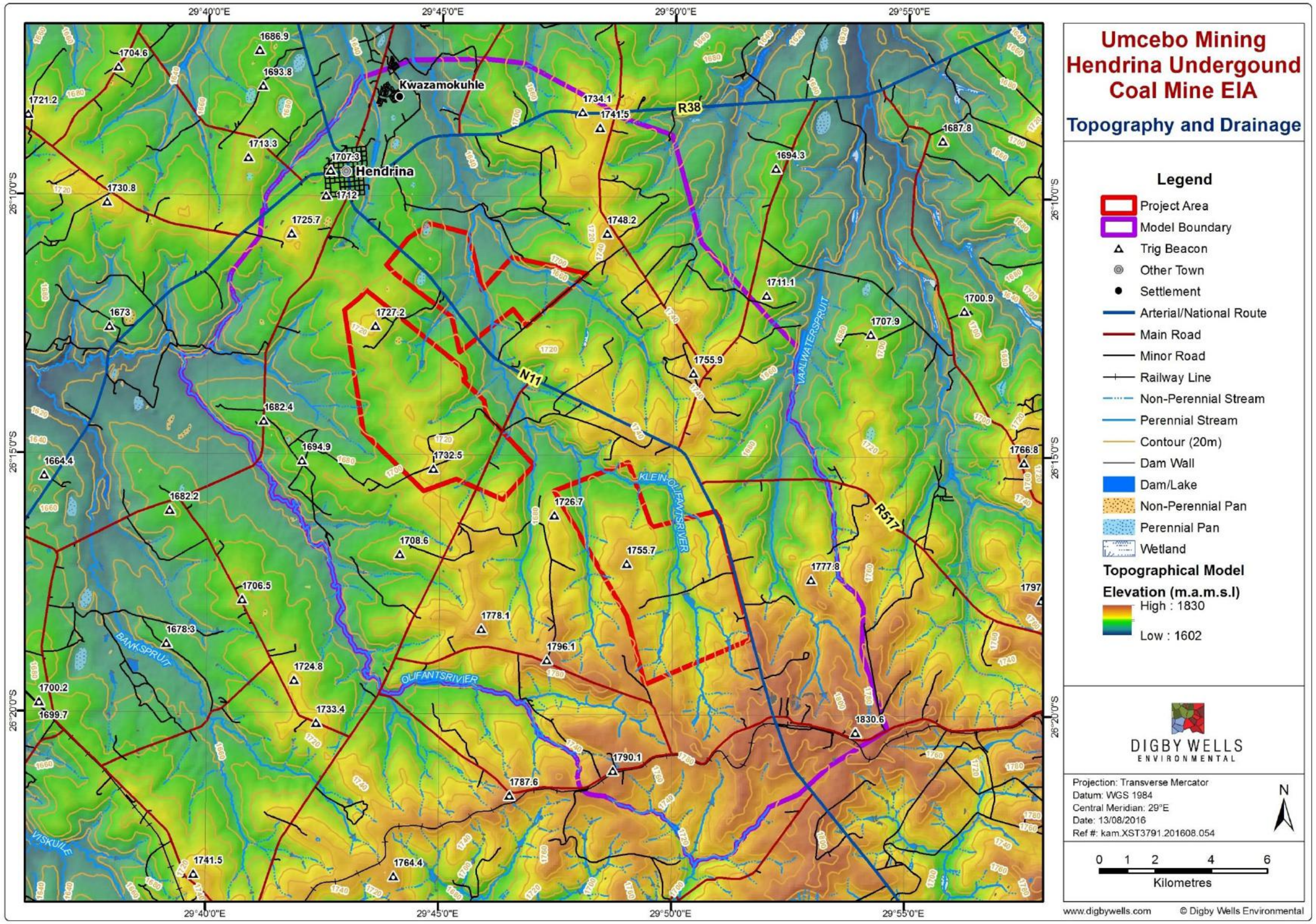

Figure 1-2: Topographic Map

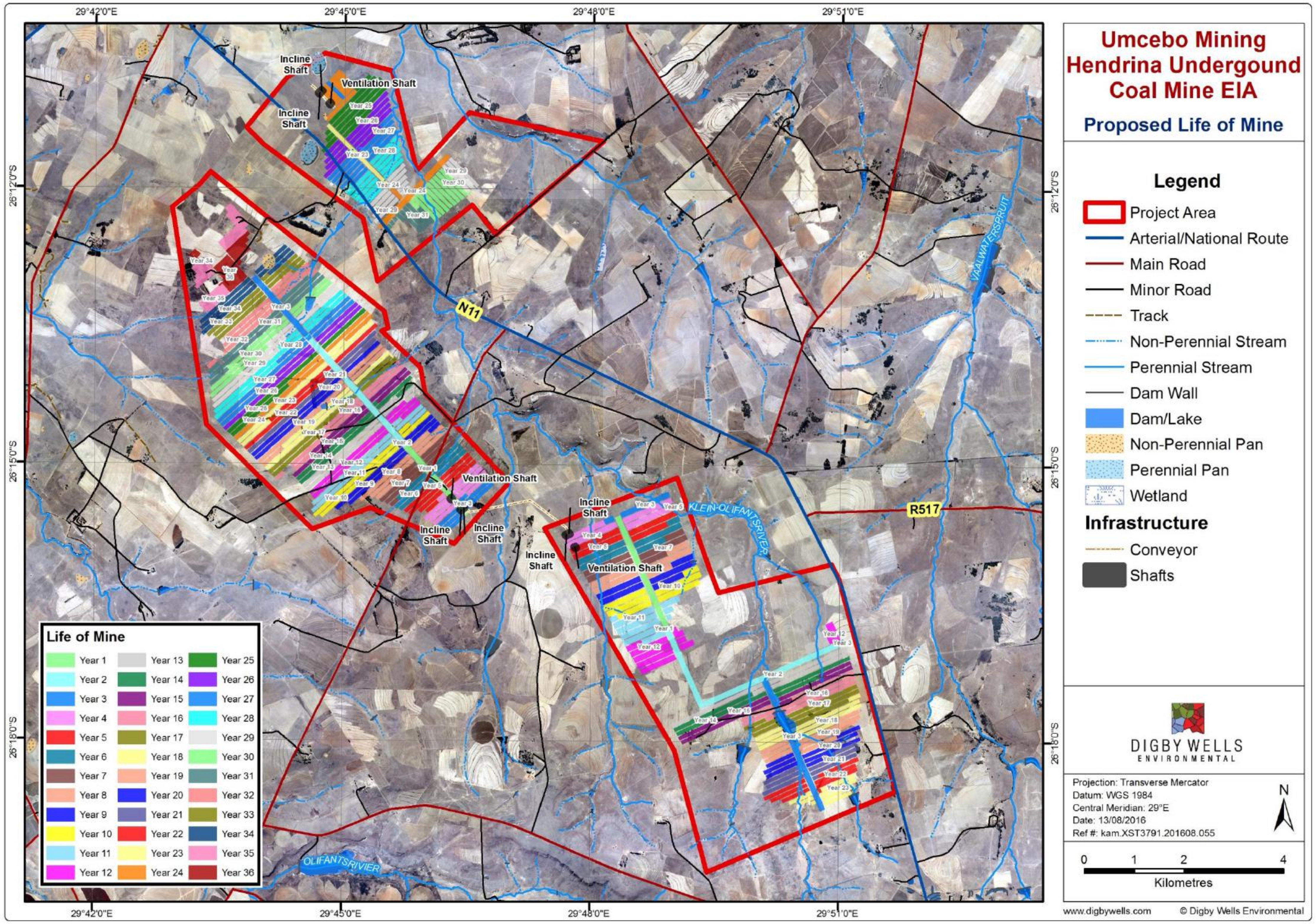

Figure 1-3: Life of Mine

1.1 Project Overview

The project area comprises three underground reserve blocks namely Mooivley East, Mooivley West and Hendrina South. The two Mooivley reserves comprise two shaft areas, which will be developed to gain access to the two underground areas whilst the Hendrina South reserve comprises one shaft area. The positions of the shafts are illustrated in Figure 1-3 and have been included in the groundwater numerical model to evaluate if decant will occur at those positions after mine closure.

Mooivley West and Hendrina South will be mined at the same time. Once completed, Mooivley East mining activities will commence. The Life of Mine (LoM) is illustrated in Figure 1-3 and was incorporated into the groundwater model for inflow estimations and impact assessments. The LoM will be 36 years[1] for all mining areas with a production rate of 2.4 million tonnes per annum at full capacity, with a total of approximately 78 million tonnes of Run of Mine (ROM). The mine will reach full production within the first four years.

The quality of coal makes it suitable for use in the domestic thermal market (Eskom). The coal product will be transported to a nearby Eskom power station (i.e. Kusile, Kendal, Kriel, Grootvlei); via the existing road network.

The project is proposed to commence with construction and development when all required licences and authorisations have been granted.

1.2 Mining Method

Due to the depth of the resource (i.e. 32 m to 128 m below surface), underground mining will be used to access the ore body. Approximately 75 m deep incline shafts (total of three shafts for the project) will be constructed to gain access to the underground resource; this will be done through blasting. Holes will be drilled with a mobile drill rig, and holes charged with either packaged explosives or boosters and Ammonium Nitrate Fuel Oil (ANFO).

The proposed mining method for the extraction of coal will be bord and pillar. In mechanised bord and pillar mining, extraction is achieved by developing a series of roadways (bords) in the coal seam connected by splits (cut-throughs) to form pillars and is done through the use of machinery referred to as a continuous miner. These pillars are left behind as part of a primary roof support system. In partial pillar extraction, every alternative pillar is left behind to support the overburden or all the pillars are extracted to allow the roof to collapse in a controlled manner. There is no plan to extract any of the pillars for this project. It is expected that there will be dolerite intrusions and a dyke development section will be deployed for the purpose of mining through these and preparing new mining sections.

[1] The MRA will be made for an initial period of 30 years, the maximum allowed in terms of the provisions of Section 23 of the MPRDA. At the end of this period an application for renewal of the mining right will be made for any remaining reserves.

Any overburden material extracted will be stockpiled and used to rehabilitate the incline shafts once mining is completed.

1.3 Associated Mine Infrastructure

All proposed mine infrastructure has been reflected on Plan 1 and includes the following:

- Crushing and Screening Plant;
- Overburden and Product Stockpiles;
- Access and Service Roads (with weighbridge);
- Overland Conveyors;
- Three Access Points to the Underground Reserve;
- Three Ventilation Shafts;
- Office Complex (change house, workshop, offices);
- Three Pollution Control Dams (PCD) and water pipelines;
- Five Aboveground Storage Tanks for the storage of diesel;
- Three Waste Bins per Shaft;
- Site Fencing located around the Conveyer Belt and each Mining Complex;
- Diesel Generator and Sub-station;
- Water Treatment Plant; and
- Package Sewage Treatment Plant.

1.4 Terms of Reference

The scope of the groundwater assessment included:

- Conceptual model development: This phase entails the understanding of the three components of a hydrogeological conceptual model: the groundwater sources, pathways and receptors; as well as their interconnections. The following activities were conducted to complete the site conceptual model:
  - Desktop study: This task involved a review of available hydrogeological, geochemical and geological data. Available data was selected and stored into a Windows Interpretation System for Hydrogeologists (WISH) database. This was later used to develop a site conceptual model that was used for numerical modelling, impact assessment and mitigation planning.
  - Hydrocensus: A site visit that included a hydrocensus of existing boreholes (community and/or private boreholes) was conducted following the desktop study. This was carried out to initiate the project and define the baseline groundwater

usage in the area, as well as to gain/collect information on activities and general groundwater related infrastructures.

- Geophysical Survey: Available aeromagnetic data was interpreted for the delineation of dolerite dykes and/or other geological structures that could potentially control the groundwater flow. In areas of uncertainty, a ground magnetic survey was conducted to refine the anomaly and delineate the suspected dyke with more accuracy.
- Percussion Drilling: Based on the interpretation of the geophysical survey, site geology and mine plans, six percussion boreholes were drilled. The drilling programme was aimed in refining the hydrogeological understanding of the site.
- Aquifer Testing: The drilled boreholes were aquifer tested to determine responses and to calculate the parameters presenting the aquifer hydro-dynamics underlying the investigation area. The boreholes were also sampled for baseline groundwater quality assessment.
- Acid-base Accounting: This was conducted to evaluate the acid-mine drainage (AMD) potential of the rock materials. Samples were collected from the overburden, coal seam and underburden for an AMD assessment. Sulfur speciation was also investigated to determine in what oxidation state the sulfur is found.
- Waste Classification: This was conducted to classify the leachate characteristics of the proposed overburden stockpile. No other waste material was classified as there will be no discard dump on site. The waste classification of the overburden stockpile was done according to the National Environmental Management: Waste Act 59 of 2008 (as amended by the National Environmental Management: Waste Amendment Act 26 of 2014) (NEM: WA). This process requires laboratory analysis to determine the leachate quality, mineralogical and chemical nature of the material and the potential to have a negative impact on the environment.

- Numerical Model: A local numerical model was developed and used as a tool for the groundwater impact predictions. Transient state simulation was conducted to quantify the impacts of the proposed underground mine on the groundwater quality of the local aquifers and receptors over time (construction, operational, decommissioning and post-closure phases). Impacts on the streams, private boreholes and farms were also addressed. The numerical model was also used as a dynamic tool to test the effectiveness of recommended management and mitigation options, inducing the positioning of the proposed monitoring boreholes.
- Impact Assessment and Mitigation Planning: The model output was used to assess the potential impact of the proposed mine on the groundwater and nearby streams during the life of mine. During this task, the environmental impacts are rated based on their significance scoring before and after mitigation methods are implemented. The recommended mitigation and management options to further minimise

environmental impacts on the groundwater environment are also addressed during this task. The impact assessment was compiled in light with the South African legislation for environmental authorisations. These include:

- National Environmental Management Act, 1998 (Act No. 107 of 1998), (NEMA) as amended;
- EIA Regulations, 2014;
- National Environmental Management Waste Act, 2008 (Act No. 59 of 2008), (NEM: WA);
- National Water Act, 1998 (Act No. 36 of 1998) (NWA);
- Mineral And Petroleum Resources Development Act, 2002 (Act No. 28 of 2002) (MPRDA); and
- NWA amendment as per Regulation 704 (GN 704, (1999)) on use of water for mining and related activities aimed at the protection of water resources.

2 Details of the Specialist

The groundwater impact assessment was conducted by Dr Robel Gebrekristos. Robel is a senior groundwater modeller and the hydrogeology Department Manager at Digby Wells, with more than 15 years of experience, both as a corporate consultant and as researcher. He achieved his Doctorate in Hydrogeology in 2007 from the University of the Free State.

Robel's experience with groundwater modelling includes using finite difference (PMWIN and VMOD) and finite element (FEFLOW) software packages, tailings seepage modelling (using SEEP/W), water balance evaluations (using GoldSim or Excel Spreadsheet), hydrogeological database management, appraisals of mining and industrial impact assessments, and monitoring and analysis of contaminants (both organic and inorganic) in groundwater.

Robel has solid background on GIS mapping and is familiar with Surfer, QGIS, ArcGIS, Global Mapper, Map Source, WISH and Voxler 3D modelling. He is competent in VB.net and C++ computer programming and is able to design databases. Robel has written more than 18 papers and documents on his field of expertise.

Recent assignments include various hydrogeological specialist and EIA investigations for mining and industrial projects in South Africa and other African countries. Robel was the principal groundwater modeller for the EIA studies of Glencore's Zandbanken Mine in 2013 and Nooitgedacht Mine in 2014.

The CV of the specialist is attached in Appendix A.

3 Aims and Objectives

Mining activities associated with the proposed project have the potential to impact on local groundwater resources over the short and long-term through the exposure, disturbance and/or deposition of geological and waste materials. The objectives of this study are to:

- Investigate the current groundwater conditions (water levels and quality). This represents the baseline groundwater conditions for the site considered to be used for potential future liability claims and preparation to final closure application;
- Establish the current groundwater flow characteristics in the aquifer, considering the aquifer properties, recharge and discharge areas;
- Develop a conceptual and numerical model. This model forms the basis for the groundwater impact assessment, feeding into the overall EIA and IWULA applications;
- Perform Acid-base accounting (ABA) studies to evaluate the acid generation and acid neutralisation potential of the coal seam, the rock immediately above and below the coal seam that could be exposed to oxidation after mining;
- Estimate the inflow rates into the underground workings over the life of mine;
- Estimate the likely impact of the mine on the receiving environment and estimate the size of the cone of dewatering;
- Simulate the contaminant plumes that could potentially be released from the mining activities;
- Evaluate the post-closure groundwater recovery rates and assess the long-term fate and transport of the contamination plume;
- Predict post closure decanting rates and positions; and
- Recommend groundwater monitoring, management and pollution mitigation methods to minimise any potential impacts associated with the proposed mining activities.

4 Methodology

The methodology followed to refine the groundwater conceptual model and develop a numerical model is discussed in this section. All coordinates in this report are expressed in decimal degree projection and WGS84 datum.

4.1 Desktop Study

This task involved a review of available hydrogeological, geotechnical, geochemical, mine plans and geological data. Available data was selected and stored in a Water Interpretation System for Hydrogeologists (WISH) database.

Hydrogeological information from the publicly available National Groundwater Archive (NGA) was reviewed. A total of 134 boreholes have been identified from the NGA as shown in Figure 4-1. This provided valuable information in terms of initial conceptual understanding, groundwater levels, borehole usage and water quality.

An aeromagnetic map was purchased form the Council for Geosciences for delineating geological structures. In addition to this, a number of hydrogeological reports and mine plans were reviewed to define regional and local hydrogeological conditions. These reports are listed in the Reference section of this report.

4.2 Hydrocensus

The hydrocensus was conducted between 14 and 18 March 2016. It was carried out within a 3 km radius of the proposed mining area; depending on site accessibility. There were land access issues in the southern and western portion of the project area and the size of the surveyed area is dependent on this.

During the hydrocensus important data pertaining to the current groundwater conditions and use were collected. These include:

- Borehole locality;
- Owner and property details;
- Borehole depth;
- Rest water level;
- Borehole usage;
- Borehole status, drilling date and equipment;
- Groundwater abstraction rates; and
- Electrical conductivity, pH and groundwater sample details.

To locate and access all known boreholes and surface water sites in the area, the relevant owners were visited by Digby Wells and the land owners then assisted in locating the sites. The coordinates of each site was recorded on a handheld Garmin GPS. The equipment and borehole protection zone was noted and recorded. Access for the dip meter was determined and the water level was measured if possible. The water use was recorded after interviewing the land owners.

A total of 56 boreholes were located within the area of interest as shown in Figure 4-1, with seven being selected for quality analysis. The sites selected for sampling were chosen in an attempt to best represent the area within and bordering the mine site.

Samples were taken using single valve, decontaminated bailers, in the case of accessible boreholes and from pumps or taps in the case of boreholes which were in use; in which case a grab sample was taken. Standard 1 litre (L) sample bottles were used and filled to the top. Samples were delivered to Aquatico Laboratories in Pretoria for analysis.

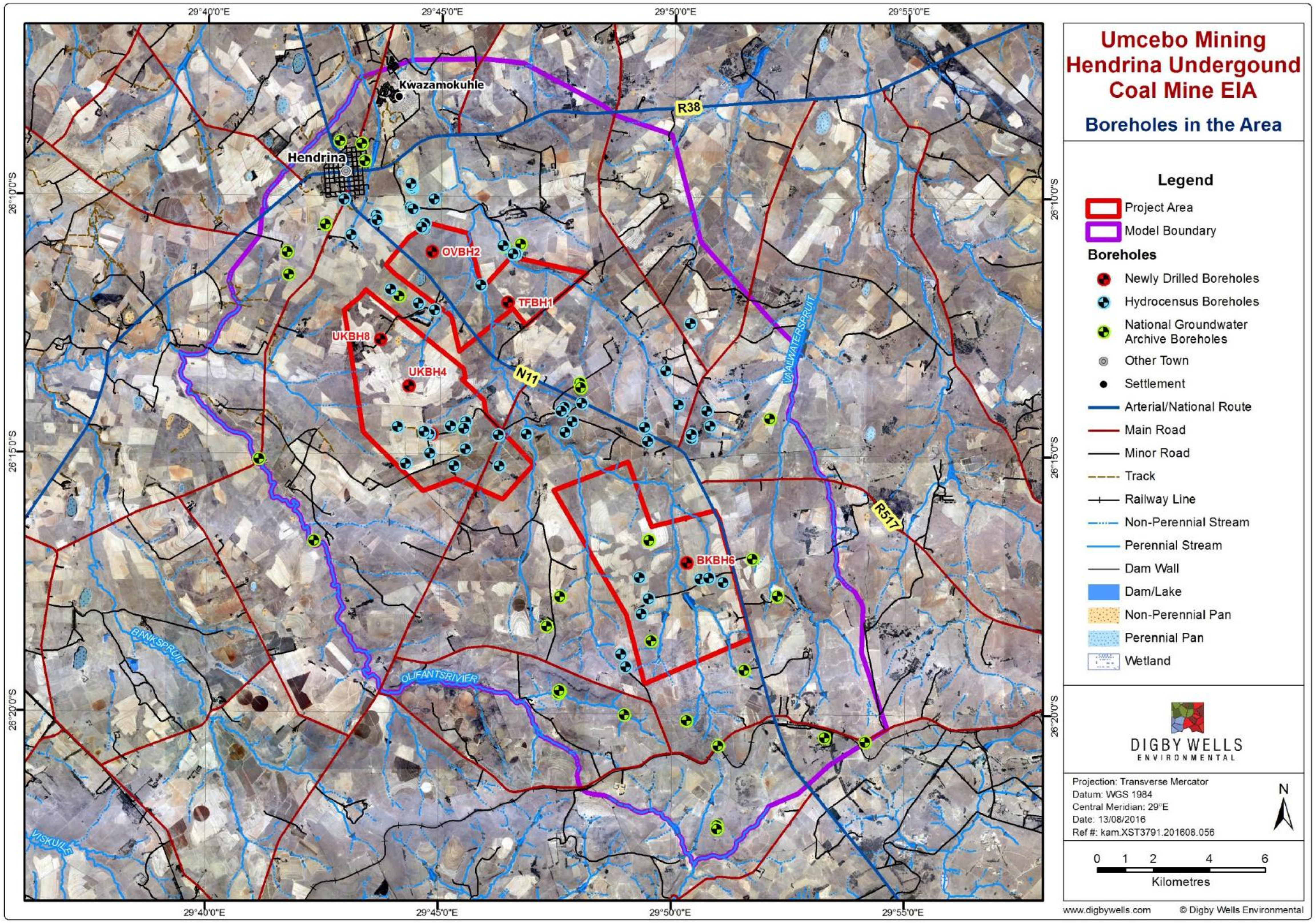

Figure 4-1: Boreholes in the Project Area

4.3 Geophysical Surveying

An aeromagnetic map of the project area (Figure 6-3) was interpreted for possible subsurface geological structures, such as dykes.

A ground magnetic geophysical survey was conducted by Digby Wells between 7 and 8 April 2016. This was carried out along selected lines to further refine the aeromagnetic map and identify any small-scale anomalies.

4.4 Borehole Drilling

Following the review of the mine plans, geological data and geophysical maps, percussion boreholes were drilled for aquifer characterisation. The boreholes were placed across the area in order to gain a representative understanding of the project area, considering the mine plan and geological information. Although 15 percussion boreholes were proposed considering the project size and data availability, only six were drilled due to site inaccessibility and budget constraints. The position of the boreholes in relation to the project area is shown in Figure 4-1 and listed in Table 4-1.

The drilling programme was carried out between 1 and 6 June 2016 and was supervised by a hydrogeologist from Digby Wells. The drilling was performed using a rotary air percussion method with an internal diameter of 165 mm. The boreholes were divided into two: shallow and deep. The shallow boreholes were drilled to a maximum of 36 m to target the top weathered aquifer. The deep boreholes were drilled to approximately 5 m below the coal seam and range in depth between 85 and 135 m.

The borehole logs are provided in Appendix B. The information recorded during drilling includes:

- Lithological profile at 1 m intervals;
- Degree of rock weathering, as weathering may indicate groundwater content;
- Penetration rates;
- Positions of water strikes and corresponding blow yields;
- Details of the borehole construction;
  - The first couple of metres (usually 6 to 12 m depending on the weathered zone depth) of each borehole was drilled using conventional percussion drilling of 203 mm diameter;
  - A starter casing of 203 mm outside diameter was installed across this zone at which point drilling at a diameter of 165 mm was commenced to the final borehole depth;
  - A 165 mm (internal diameter) steel casing was installed across the top section of the borehole; across the unconsolidated and unstable sections of the geology to avoid borehole collapse.

- Rest water level; and
- Final borehole blow yield.

Table 4-1: Coordinates of the newly drilled percussion boreholes

BH ID	Longitude	Latitude	Elevation (mamsl)	BH Depth (m)	Comment
OVBH2	29.74674	-26.1848	1681	36	Shallow
MVBH3	29.747	-26.2436	1711.93	105	Deep
BKBH6	29.83847	-26.2847	1703.45	135	Deep
UKBH8	29.72848	-26.2131	1705.75	110	Deep
UKBH4	29.73867	-26.2281	1696.3	36	Shallow
TFBH1	29.77395	-26.2011	1685.91	85	Deep

4.5 Aquifer Testing

All of the new boreholes were aquifer tested to calculate the hydraulic permeability and storativity values presenting the aquifer hydro-dynamics underlying the investigation areas. Depending on the borehole yield measured during construction, the boreholes were either pump tested or slug tested. The test records are given in Table 4-2.

4.5.1 Pump Testing

Only one of the newly drilled boreholes (UKBH6) yielded more than 0.5 L/s based on the information collected during the percussion drilling (as indicated in Table 4-2). The borehole was therefore pump tested.

- The borehole was first step tested by pumping at increasing rates. The borehole was tested for 4 hours (each step being 1 hour long). This was followed by a recovery test of 4 hours long during which a 90% recovery to the static water level was achieved.
- Following the response of the boreholes to the step test, an 8-hour constant discharge test was performed in the borehole. This was again followed by 90% recovery of the static water level.
- The borehole was sampled for baseline water quality analysis.

4.5.2 Slug Testing

The rest of the boreholes yielded below 0.5 L/s and were slug tested. The test was conducted by instantaneously adding 60 L of water to the borehole. The water level response was then measured and recorded automatically using electronic water level logging devices. The recovery rate was measured for 2 hours after the addition of the slug or until a 90% recovery was achieved.

Table 4-2: Aquifer test decision record of the tested boreholes

BH ID	Water level (m)	Water strike (m)	Blow yield at water strike (L/s)	Final blow yield (L/s)	Slug test	Step-drawdown test	Constant discharge test
BKBH6	11.78	10	2.0	2.0		x	x
MVBH3	25.32	71	seepage	seepage	x		
OVBH2	9.05	28	seepage	seepage	x		
TFBH1	35.78		dry	seepage	x		
UKBH4	5.45	12	seepage	seepage	x		
UKBH8	11.09		dry	seepage	x		

4.6 Acid-base Accounting

Six rock samples that are considered to be representative of the project area were collected for Acid Mine Drainage (AMD) assessment. The samples were collected from two of the newly drilled boreholes, namely BKBH6 and TFBH1. This means that three samples were collected from each of the boreholes. The description of the samples is available in Table 4-3 and their positions illustrated in Figure 4-1.

The six samples represent:

- Two samples from the coal seam;
- Two samples from the overburden (rocks immediately above the coal seam that could be exposed after mining; and
- Two samples from the underburden (rocks immediately below the coal seam that could be exposed after mining.

Table 4-3: Rock samples collected for ABA and leachate tests

Sample ID	From (m)	To (m)	Lithology
BKBH6_O	127	128	sandstone (overburden)
BKBH6_C	128	130	Seam B
BKBH6_U	130	131	sandstone (underburden)
TFBH1_O	77	78	shale (overburden)
TFBH1_C	78	80	Seam B
TFBH1_U	80	81	sandstone (underburden)

The samples were submitted to M&L Labilities in Johannesburg for analysis. The test consisted of:

4.6.1 XRD and XRF

XRF (X-Ray Florescence) is used to determine the elemental composition of a material that allows for the evaluation of a material's chemical compound distribution, as well as the various trace element concentrations.

XRD (X-Ray Diffraction) allows for the measurement of the crystal structures within a sample to determine the mineralogical composition of the material and assists in determining whether any reactive solids will lead to environmental risks through the study of the various minerals.

4.6.2 Leachate Tests

Reagent water leachate tests are done to simulate the metal and anion leachate potential of the overburden stockpile under normal conditions, with only neutral water allowing leaching to occur. No discard dump or other rock waste will be disposed on site and were not exposed to leach test. These tests simulate and evaluate the potential of any heavy metal or ion contamination from the waste material that will be produced. The deionised /reagent water tests are used to evaluate the leachability of material that will be mono-disposed.

4.6.3 Total Elemental Analysis

The objective of the multi-element analysis is to provide a measure of the solid-phase levels of various mineral-forming cations that may be of environmental concern. Combined with the metal leachate test, these levels allow for the calculation of metal depletion times and can be used as a screening tool to detect constituents which occur in anomalously high concentrations and may, under unfavourable geochemical conditions, be of concern as a constituent in AMD.

4.6.4 Paste pH

The paste pH is a type of ABA used to provide a preliminary estimation on the acid generation potential of a rock sample. The sample is placed in a plastic beaker and 10 mL of distilled water is added to make a paste. The paste is stirred with a wooden spoon to wet the powder. This way, a quick measure of the relative acid-generating ($pH<4$) or acid-neutralizing ($pH>7$) potential of the waste material can be evaluated (Sobek *et al*. 1978).

4.6.5 Sulfur Speciation

The objective of sulfur analysis is to identify and measure the concentration of different sulfur species present in the sample. Sulfide minerals are the primary sources of acidity and leaching of trace metals and their measurement is a critical requirement for acid drainage chemistry prediction.

A set of rules, which has been derived based on several of the factors calculated in ABA, was reported by Soregaroli and Lawrence (1998). It has been shown that for sustainable long-term acid generation, at least 0.3% Sulfide–S is needed. Values below this can yield acidity, but this is likely to be only of short-term significance.

4.6.6 Net Neutralisation Potential (NNP)

The difference between the Neutralisation Potential (NP) and the Acid Potential (AP) is defined as the Net Neutralization Potential of the sample (NNP):

NP – AP = NNP

A positive NNP would indicate that there is more neutralising material than acid forming material in that sample, i.e.:

- NNP < 0 = potential to generate acid;
- 0<NNP<20 = uncertain sample; and
- NNP >20 = potential to neutralise acid.

4.6.7 Neutralisation Potential Ratio

Similar to the NNP, the Neutralisation Potential Ratio (NPR) is used to identify and separate potentially acid generating from not potentially acid generating materials. The NPR is calculated by dividing the NP by the AP.

The potential for acid generation was evaluated by using the screening criterion set by Price (1997) as shown in Table 4-4.

Table 4-4: Criteria for interpreting ABA results (Price, 1997)

Potential for ARD	Criterion	Comments
Likely	NPR<1	Potentially acid generating, unless sulfide minerals are non-reactive
Possible	1<NPR<2	Possibly acid generating if NP is insufficiently reactive or is depleted at a rate faster than sulfides
Low	2<NPR<4	Not potentially acid generating unless significant preferential exposure of sulfide
None	NPR>4	Non-acid generating

4.7 Waste Classification

The overburden samples from boreholes BKBH6 and TFBH1 were analysed in order to classify the overburden stockpile material in accordance with the NEM: WA Regulations, by comparison with Total Concentration Threshold (TCT) and Leachable Concentration Thresholds (LCT).

Leachable concentrations were determined using reagent water to simulate the metal and anion leachate potential of the overburden stockpile under normal conditions, with only neutral water allowing leaching to occur. Total Concentrations were determined by *aqua regia* digestion while the leachable concentrations were prepared by a leachate of aqueous extraction.

Total Concentration Threshold limits are subdivided into three categories as follows:

- 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.

Leachable Concentration Threshold (LCT) limits are subdivided into four categories as follows:

- LCT0 limits derived from human health effect values for drinking water, as published by the Department of Water and Sanitation (DWS) and South African National Standards (SANS);
- 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 R634 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 as shown in Table 4-5. 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 per Table 4-6.

Table 4-5: 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

Table 4-6: Total and leachable concentration threshold limits

Parameter	Unit	TCT0	TCT1	TCT2	Unit	LCT0	LCT1	LCT2	LCT3
As, Arsenic	mg/kg	5,8	500	2000	mg/l	0,01	0.5	1	4
B, Boron	mg/kg	150	15000	60000	mg/l	0,5	25	50	200
Ba, Barium	mg/kg	62,5	6250	25000	mg/l	0,7	35	70	280
Cd, Cadmium	mg/kg	7,5	260	1040	mg/l	0,003	0,15	0,3	1,2
Co, Cobalt	mg/kg	50	5000	20000	mg/l	0,5	25	50	200
Cr total	mg/kg	46000	800000	N/A	mg/l	0,1	5	10	40
Cr (IV), Chromium (IV)	mg/kg	6,5	500	2000	mg/l	0,05	2.5	5	20
Cu, Copper	mg/kg	16	19500	78000	mg/l	2	100	200	800
Hg, Mercury	mg/kg	0,93	160	640	mg/l	0,006	0,3	0,6	2,4
Mn, Manganese	mg/kg	1000	25000	100000	mg/l	0,5	25	50	200
Mo, Molybdenum	mg/kg	40	1000	4000	mg/l	0.07	3.5	7	28
Ni, Nickel	mg/kg	91	10600	42400	mg/l	0.07	3.5	7	28
Pb, Lead	mg/kg	20	1900	7600	mg/l	0.01	0.5	1	4
Sb, Antimony	mg/kg	10	75	300	mg/l	0.02	1	2	8
Se, Selenium	mg/kg	10	50	200	mg/l	0.01	0.5	1	4
V, Vanadium	mg/kg	150	2680	10720	mg/l	0.2	10	20	80
Zn, Zinc	mg/kg	240	160000	640000	mg/l	5	250	500	2000
Chloride as Cl	mg/kg	n/a	n/a	n/a	mg/l	300	15000	30000	120000

Parameter	Unit	TCT0	TCT1	TCT2	Unit	LCT0	LCT1	LCT2	LCT3
Sulfate as SO_4	mg/kg	n/a	n/a	n/a	mg/l	250	12500	25000	100000
Nitrate as N	mg/kg	n/a	n/a	n/a	mg/l	11	550	1100	4400
F, Fluoride	mg/kg	100	10000	40000	mg/l	1,5	75	150	600
CN total, Cyanide total	mg/kg	14	10500	42000	mg/l	0,07	3,5	7	28

Notes: n/a: no threshold values

4.8 Numerical Modelling

A numerical model was developed to evaluate the potential impact of the proposed mine on the groundwater environment. Steady and transient state flow and transport model simulations were conducted to estimate the groundwater flow direction, groundwater inflow rates into the mine, and size of the contamination plumes at various stages of the life of the mine. Impacts on the streams, private boreholes and farms over time (construction, operational, decommissioning and post-closure phases) have also being addressed. Scenario modelling was carried out to evaluate if and when decanting will take place after mine closure.

The software code chosen for the numerical modelling work was the modular 3D finite-difference groundwater flow model MODFLOW. MODFLOW is internationally recognised groundwater model published by the U.S. Geological Survey and is commonly used by groundwater specialists and environmental scientists. Processing MODFLOW Pro (v8.0) was used as a user interface.

The potential contaminant plumes originating from the underground mine is simulated using the transport module MT3DMS. The MT3DMS is utilised for the simulation of advection, dispersion, and chemical reactions of dissolved constituents in groundwater systems.

4.9 Impact Assessment and Mitigation Plans

The model output was used to assess the potential impact of the proposed underground mine on the groundwater and nearby receptors during construction, operation and after mine closure. In this phase, the environmental impacts are rated based on their significance scoring before and after mitigation methods are implemented.

The long-term fate and transport of the contamination plume is assessed as it spreads from the mine footprint.

Finally, the recommended mitigation and management options to further minimise environmental impacts on the groundwater environment are presented.

5 Assumptions and Limitations

A numerical model was used to predict the potential impact of the proposed mine on the groundwater environment. Numerical models are commonly used to simulate and develop hydrogeological management solutions, i.e. the prediction of contaminant plume migration; groundwater inflow rate and groundwater level changes over time. However, groundwater systems are often complex and the data input requirements are not practical to evaluate in detail. A model, no matter how sophisticated, will never describe the investigated groundwater system without deviation of model simulations from the actual physical process (Spitz, 1996). Therefore, it is necessary to make some assumptions to simplify the complex, real world hydrogeological conditions into a simplified, manageable model.

All numerical modelling simulations require assumptions to be made during the translation of the numerical code into a site-specific model. These assumptions, which reflect data gaps in the conceptual model regarding the aquifer distribution and the aquifer parameters, can result in areas of uncertainty in the model output and predictions.

The following are lists of assumptions and limitations associated with the groundwater impact assessment:

- The southern and western boundary of the project site is owned by a different company and this area was not accessible for hydrocensus or baseline assessments. The water level, groundwater flow direction and baseline water quality in the area could not be confirmed;
- Discard dumps are one of the main sources of groundwater contamination during operation and after closure. No discard dump is assumed to exist at the site and has been excluded from the contamination plume simulation;
- Shanduka Coal (May 2012) reported that at least 417 boreholes have been drilled all over the project site for coal seam exploration. It is currently unknown how many of these are properly backfilled and sealed. If some, or all of these holes are open, there is a risk of water from the top weathered aquifer to seep and flood the underlying underground workings;
- The hydraulic properties (such as permeabilities and storage coefficients) of the aquifers outside the mine area, particularly in areas where no field data was available is not known;
- The hydraulic connection between the different aquifer systems and coal seams, expressed by vertical hydraulic conductivity is not known;
- No major faults have been identified during this study. This, however, does not mean that no such structures exist at the site. If faults that have not been detected during the drilling and aquifer testing have been intercepted by the mine, increased inflow rates can be expected more than what have been predicted during this study;

- Although a total of 15 boreholes (five for each mine zone) were proposed to be drilled, only six boreholes were eventually drilled due to accessibility problems and cost issues. This would mean that only one borehole was drilled per 11.19 km^2, considering that the total footprint area of the underground mine is 67.14 km^2. The hydrogeological information obtained from such sparse boreholes (such as aquifer permeability) is assumed to be representative of the entire area. The Karoo aquifer is however not homogenous. The orientation, density and aperture or thickness of fractures and dykes are likely to be different. Sufficient hydrogeological information cannot be obtained from six boreholes only. The model results, including the predicted groundwater ingress rates, decant rates and pollution plumes have a confidence level that is proportional to the model accuracy, estimated to be around 60%; and
- Six rock samples were collected for AMD from two boreholes. The rock chemistry is expected to be heterogeneous and these samples may not be adequate to represent the entire mine area. As the mine starts and more samples become available, additional samples are recommended to be analysed for a long-term AMD assessments.

Based on the conceptual model a best approximation of the ‘real world’ site conditions was simulated and calibrated with available information until a reasonable fit of simulated and measured data was obtained. A model sensitivity analysis was then carried out to give an indication of which assumptions in model input parameters were most likely to affect the model output.

6 Baseline Environment

6.1 Geology

6.1.1 Regional Geology

South Africa’s coal deposits occur in the Karoo Supergroup formations; a thick sequence of sedimentary rocks deposited between 300 and 180 million years ago (McCarthy and Pretorius, 2009). The coalfield is underlain by pre-Karoo strata belonging to the Transvaal Supergroup and Bushveld Igneous Complex. Glacial events at the beginning of the Permian Period resulted in the deposition of tillite (Dwyka Formation) on the basement rocks over most of the area. Within the Karoo sedimentary sequence the Ecca Group rests on top of the Dwyka Formation. The coal seams are found within the Ecca Group.

Although rocks of the Ecca Group are widespread around the country, conditions suitable for the formation of coal did not occur everywhere and the coal deposits are restricted, occurring in the main Karoo basin in an arc. Coal is found in South Africa in 19 coalfields (Figure 6-1), located mainly in KwaZulu-Natal, Mpumalanga, Limpopo, and the Free State Provinces, with lesser amounts in Gauteng, the North West Province and the Eastern Cape.

The project area is located within the Ermelo Coalfield. There are five major coal seams developed in the Ermelo Coalfield, named from the base up: the E, the D, the C, the B and the A seams. Basement topography and the present-day erosional surface control the distribution of the coal seams and not all five seams may be present at any one locality. The D and E Seams are thin to absent over much of the coalfield and only the E seam reaches mineable thicknesses in isolated patches in the northern parts of the coalfield. The B and C seams are widely developed, and to mineable thicknesses, in the coalfield. The A seam has, over large areas of the northern and central areas of the coalfield, been removed by erosion. Although to a lesser extent, the B and C seams have also been removed by erosion.

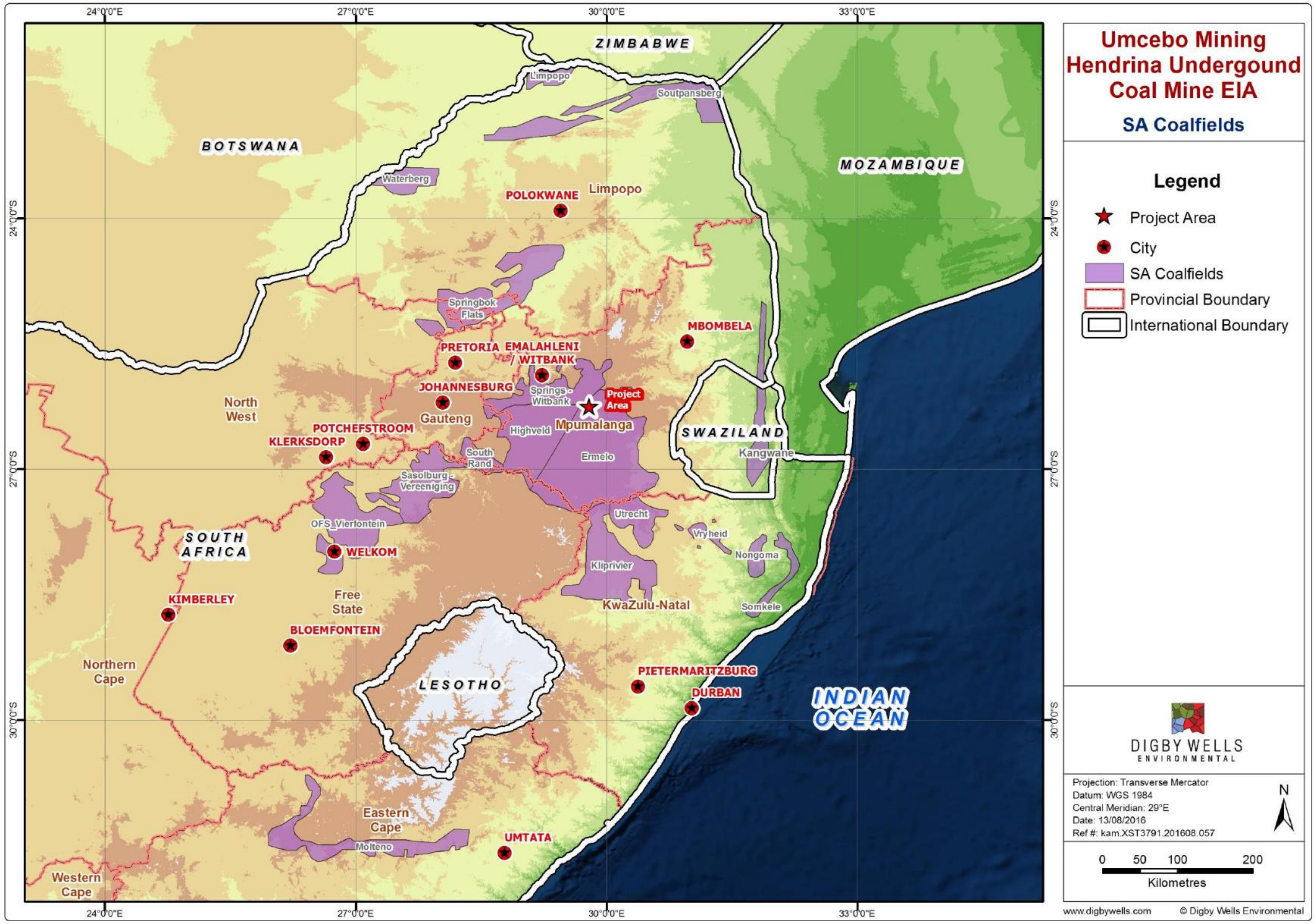

Figure 6-1: South African Coalfields

6.1.2 Local Geology

A geological assessment was undertaken by Shanduka Coal (May 2012) to evaluate the regional and local geology and coal resource within the project area. The exploration results revealed a structurally complex coal reserve with high occurrences of dolerite intrusions in the form of sills and dykes. Although no dolerite was encountered by the boreholes drilled during this study, Shanduka Coal (2012) reported that intrusive dykes and sills, predominately doleritic in composition, are common and devolatilisation of the coal adjacent to the intrusives can be significant.

The E seam has a maximum thickness of over 3 m in the northern part of the coal field. The C seam is traditionally subdivided into the C Lower and C Upper seams. The C Lower seam is normally less than 0.6 m thick. The upper portion of the C Upper Seam is of low grade and may be torbanitic in places. The thickness of the composite seam varies between 0.7 and 4 m. The B seam may reach a thickness of up to 3 m and comprises mainly dull coal. The A seam is normally less than 1 metre thick and of low grade.

The average seam thicknesses of the seams at the project site are summarised in Table 6-1. Considering the coal quality and coal seam thickness, only the B seam will be mined at the project site. The local coal deposit varies in depth between 32 m to 128 m below ground level. A typical geological log at the project site is shown in Figure 6-2.

The aeromagnetic map of the project site is given in Figure 6-3. A number of southwest-northeast trending dykes are traceable. The linear anomalies cross on the eastern tip of the Hendrina South and on the western portion of Mooivley East and West. The Mooivley East and West are characterised by what appears to be disconnected sills having significant difference in magnetic anomaly. Considering the magnetic anomaly, a continuous horizontal sill is expected to exist in the area of the Hendrina South.

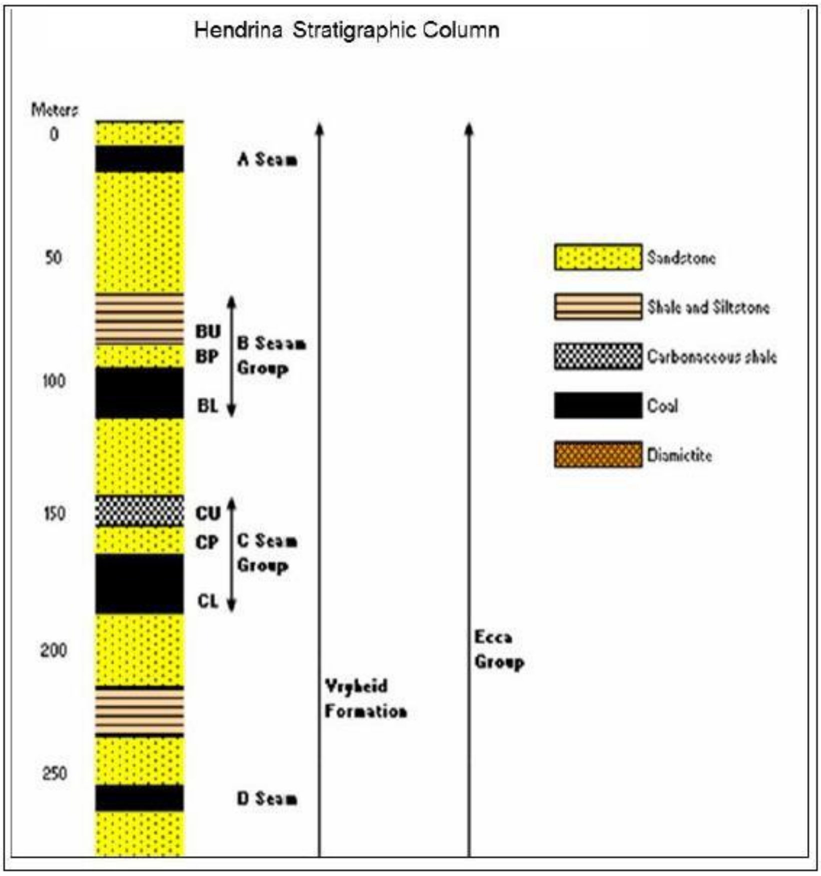

Figure 6-2: Typical Stratigraphic Column for the Project Coal Reserve

Table 6-1: Average coal seam thicknesses

Seam	Average thickness (m)
A	0.65
B	2.27
C	1.91
D	0.24

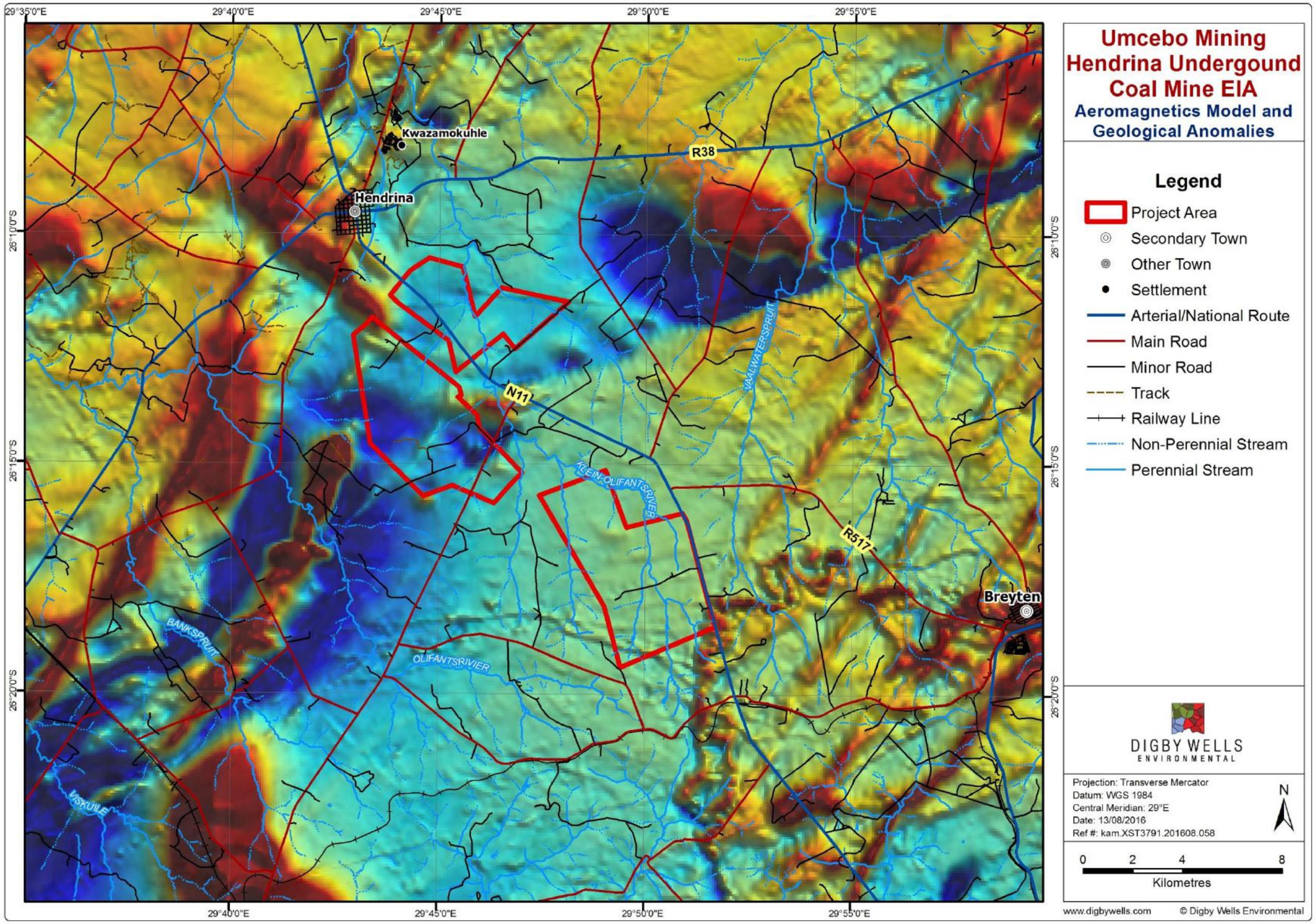

Figure 6-3: Aeromagnetic map of the project area

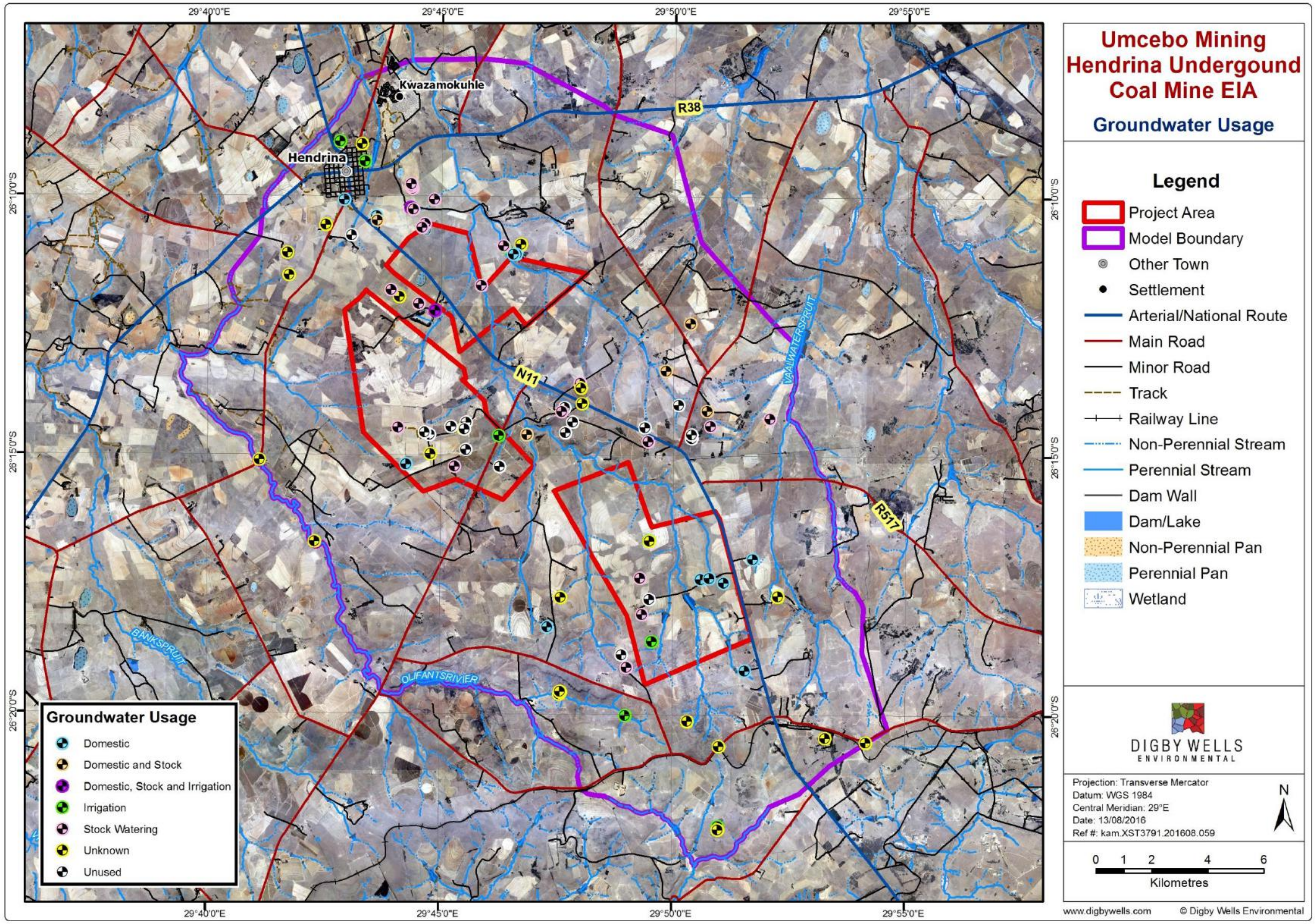

Figure 6-4: Groundwater Usage

6.2 Groundwater Usage

A total of 190 boreholes were recorded during the hydrocensus and from the national groundwater archive. The coordinates and other general information of these boreholes is available in Appendix C.

The groundwater use within the project area is displayed in Figure 6-4 and Figure 6-5. Of the 190 borehole:

- 31 (16%) are used for drinking only;
- 6 (3%) are used for drinking and livestock watering;
- 2 (1%) is used for drinking, livestock and irrigation;
- 31 (16%) is used for irrigation;
- 47 (25%) are used for livestock watering only;
- 17 (9%) are not used for any purpose; and
- The remaining 56 (29%) could not be confirmed.

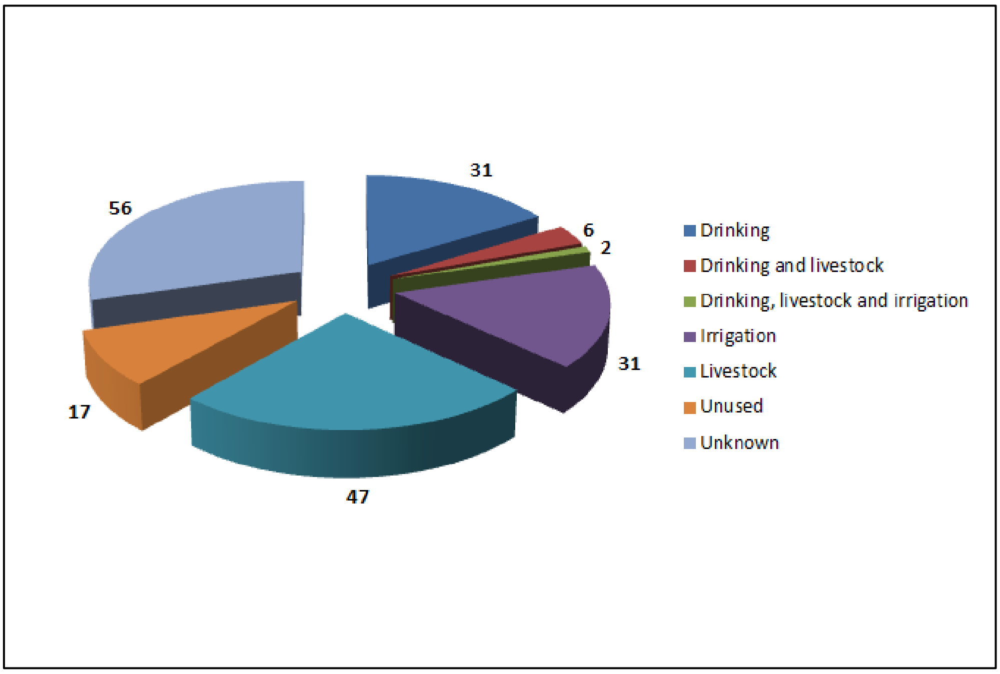

Figure 6-5: Groundwater Usage

6.3 Baseline Groundwater Quality

The groundwater quality results have been compared to the South African National Standards (SANS) 241:2015 Standards for Drinking Water (Table 6-2) and have been grouped into two classes in accordance with the above stated standards. The laboratory result certificates are provided in Appendix D.

According to the SANS 241:2015 standards, water quality can be classified as Acceptable and Unacceptable:

- Concentrations that are below the recommended limits are categorised as Acceptable and are considered of good quality and suitable for human consumption; and
- Concentrations that are above the standards are categorised as Unacceptable and are not desired for human consumption, either due to aesthetic, acute or chronic effects.

6.3.1 Acceptable Quality

Ten of the 13 boreholes sampled are suitable for human consumption. None of the tested parameters exceeded the recommended limits. These boreholes are listed in Table 6-2 (their coordinates given in Appendix C) and displayed in Figure 4-1.

Noteworthy is the current sulfate levels in all boreholes. The recommended sulfate limit is 250 mg/L for aesthetic reasons and 500 mg/L for acute health reasons. The sulfate concentrations for the sampled boreholes are currently less than 20.6 mg/L. Since sulfate is expected to be an element of concern in coal mines, the values obtained during this study can be used as a baseline for future contamination comparisons.

6.3.2 Unacceptable Quality

Three boreholes (MVBH3, BKBH6 and UKBH8) fell within the unacceptable category based on water quality. These boreholes are listed in Table 6-2 and the parameters that exceed the recommended standard are highlighted in red.

- Borehole BKBH6 indicates a number of parameters with elevated concentrations, particularly chloride (1,694 mg/L) and sodium (2,146 mg/L). These elements are indicative of high residence groundwater; thus old water. As confirmed from aquifer testing, however, the borehole is characterised by a permeability of 0.07 m/d and transmissivity of 9.4 m^2/d and is unlikely to be associated with water of high residence time. The recorded high concentrations could possibly be a result of human or laboratory error. Since this result is from a once-off sampling event, it is not possible to fully explain the observed anomaly. Further monitoring is recommended to better define the water quality associated with borehole BKBH6.
- Borehole UKBH8 has fluoride concentration of 2.14 mg/L. This is probably due to the natural dissolution of the host rocks, particularly the pre-Karoo intrusive rocks.
- Borehole MVBH3 is in the unacceptable category due to an elevated manganese concentration of 0.23 mg/L. The source for these is suspected to be due to the natural dissolution of the host rocks.

6.3.3 Diagnostic Plots

Stiff diagrams (Figure 6-6) were used to characterise the groundwater by analysing the concentration of the major cations (Ca, Mg, Na+K) and anions (SO_4, Cl and HCO_3). In Stiff diagrams, cations are plotted in meq/L on the left side of the zero axis and anions are plotted on the right side. This diagram is useful in making a rapid visual comparison between water of different sources.

The diagram (Figure 6-6) shows that all the samples are enriched in alkalinity and depleted in sulfates. This suggests that no mine-related contamination has taken place, as mine water is typically distinguished by enriched sulfate and depleted alkalinity.

The Na and K content of borehole BKBH6 is around 120 meq/L and is significantly higher than the rest of the boreholes, where it is less than 8 meq/L. The stiff diagram of BKBH6 has been presented separately in Figure 6-7 as their concentrations are not on the same scale. The borehole is different from the others not only due to its high total dissolved solids (TDS), but due to its reduced Mg. This further confirms that the borehole quality is unique from the rest and needs to be investigated further through continuous monitoring.

The water chemistry is also displayed using a Piper diagram as shown in Figure 6-6. A Piper diagram is used to classify the water type by plotting the ratios of the major cations (Ca, Mg, Na and K) and anions (Cl, SO_4 and HCO_3+CO_3) as two points in tri-linear fields. These two points are then extended into the main diamond-shaped field of the Piper diagram to plot as one point.

The Piper diagram also confirms the results observed in the Stiff diagrams. The dominant anion is HCO_3, while the dominant cations range from Ca to Na+K and are suspected to be results of ion exchanges between water of higher residence time and those that are recently recharged. No mine-related impacts are evident in the samples.

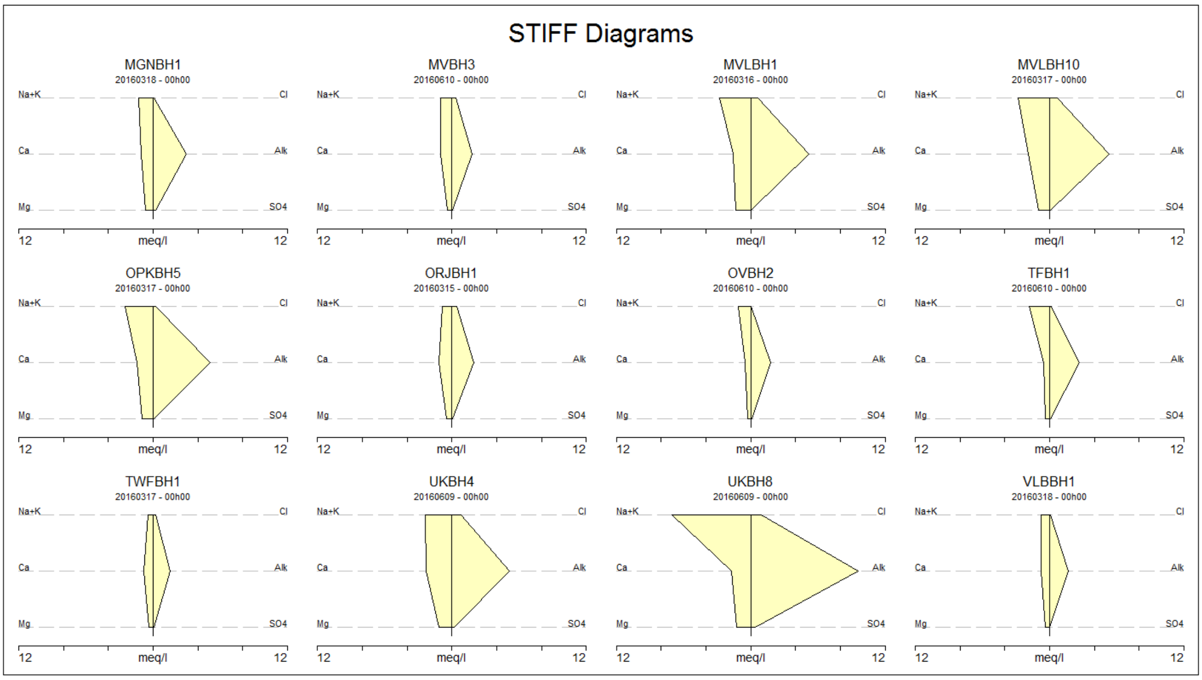

Figure 6-6: Stiff Diagram of the Baseline Water Chemistry

Figure 6-7: Stiff Diagram of the Borehole BKBH6

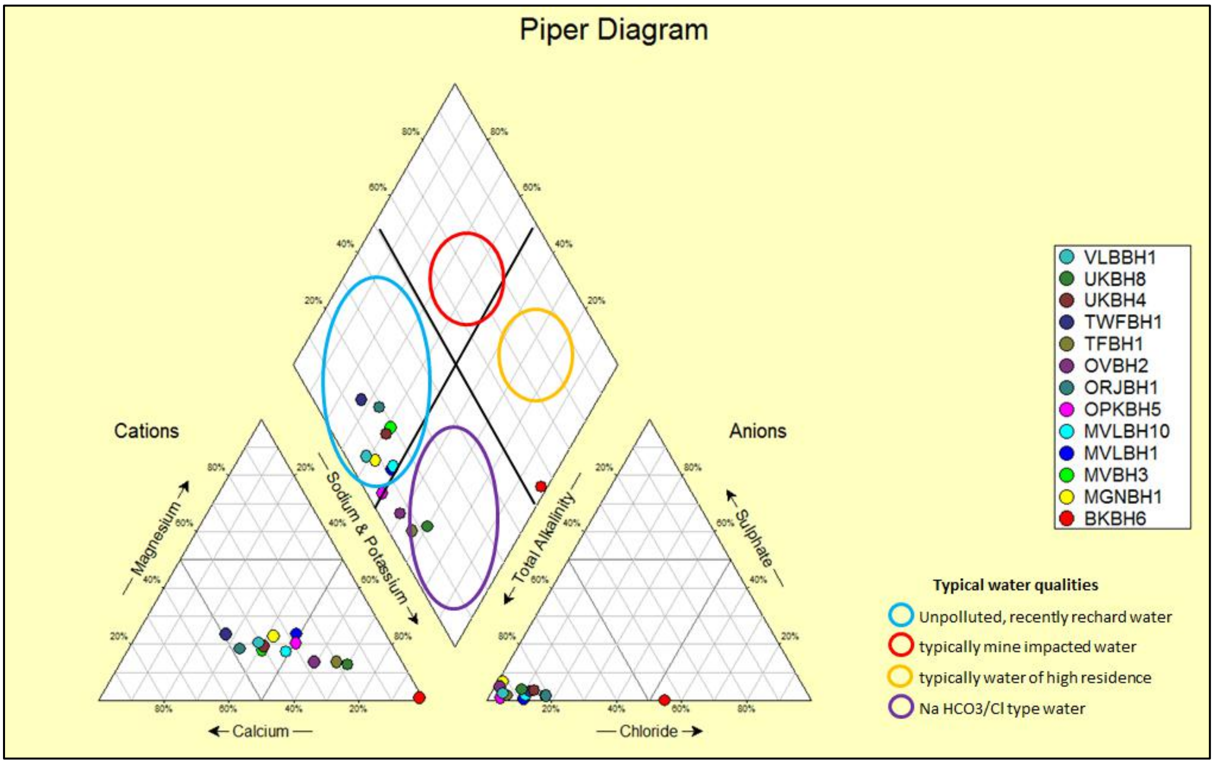

Figure 6-8: Piper Diagram of the Baseline Water Quality

Table 6-2: Baseline water quality as classified based on the SANS 241: 2015

SANS 241: 2015		Total Dissolved Solids	Conductivity at 25° C in mS/m	pH-Value at 25° C	Nitrate NO_3 as N	Chlorides as Cl	Sulfate as SO_4	Fluoride as F	Free and Saline Ammonia as N	Total Alkalinity as $CaCO_3$	Calcium as Ca	Magnesium as Mg	Sodium as Na	Potassium as K	Aluminium as Al	Iron as Fe	Manganese as Mn	Arsenic as As	Lead as Pb
Boreholes	**Date**	**1200**	**170**	**5-9.7**	**11**	**300**	**250**	**1.5**	**1.5**	**N/A**	**N/A**	**N/A**	**200**	**N/A**	**0.3**	**0.3**	**0.1**	**0.01**	**0.01**
MVLBH1	2016/03/16	341	52.50	8.65	0.81	23.60	1.58	0.75	0.41	260	30.70	16.10	62	2.84	-0.002	-0.004	-0.001	-0.010	-0.004
MVLBH10	2016/03/17	348	50.80	8.54	0.87	24.40	5.2	0.95	0.30	268	38.20	11.90	61	4.93	-0.002	-0.004	0.025	-0.010	-0.004
MGNBH1	2016/03/18	219	29.30	8.50	0.74	2.07	10.4	0.32	-0.01	148	21.40	8.50	28	4.08	-0.002	-0.004	-0.001	-0.010	-0.004
OPKBH5	2016/03/17	276	45.30	8.65	0.54	7.49	2.4	0.49	0.97	256	28.80	12.20	56	2.46	-0.002	-0.004	-0.001	-0.010	-0.004
ORJBH1	2016/03/15	182	24.20	8.30	1.69	14.80	1.8	0.28	0.01	96	23.10	5.40	17	4.38	-0.002	-0.004	-0.001	-0.010	-0.004
TWFBH1	2016/03/17	136	17.10	8.22	0.47	7.46	2.8	0.19	-0.01	76	16.80	4.88	9	2.79	-0.002	-0.004	-0.001	-0.010	-0.004
VLBBH1	2016/03/18	155	19.40	8.31	1.61	2.44	2.2	0.21	-0.01	85	15.50	4.75	14	5.14	-0.002	-0.004	-0.001	-0.010	-0.004
TFBH1	2016/06/10	192	25.10	8.18	0.53	5.59	2.5	0.77	0.28	134	11.20	4.60	40	3.73	-0.002	-0.004	-0.001	-0.010	-0.004
OVBH2	2016/06/10	146	19.50	7.71	0.61	1.22	4.4	0.17	0.34	89	9.81	3.03	22	4.75	-0.002	-0.004	-0.001	-0.010	-0.004
MVBH3	2016/06/10	166	24.40	7.08	4.08	13.70	1.9	0.22	0.48	91	19.90	5.27	18	8.66	-0.002	-0.004	0.231	-0.010	-0.004
BKBH6	2016/06/09	4776	823.00	8.02	0.55	1694.00	0.8	2.04	3.40	1969	16.30	11.70	2146	10.70	-0.002	-0.004	-0.001	-0.010	-0.004
UKBH8	2016/06/09	594	87.60	8.38	0.47	34.50	20.6	2.14	0.92	480	34.40	15.50	159	5.23	-0.002	-0.004	-0.001	-0.010	-0.004
UKBH4	2016/06/09	268	53.40	8.05	0.44	28.00	10.3	0.42	0.29	256	46.50	13.70	44	18.80	-0.002	-0.004	-0.001	-0.010	-0.004

Note: "-" values should be read as "<" (e.g. "-1" = "<1")

6.4 Water Level and Flow Direction

The water levels obtained from the NGA and measured during the hydrocensus are shown in Appendix C and ranges between 0.6 m and 50.0 m below ground level (mbgl). This corresponds to a piezometric head of between 1600.2 m and 1814.1 metres above mean sea level (mamsl). The relatively large water level variation over a relatively short distance may indicate that some of the boreholes are groundwater abstraction points measured after pumping and with no sufficient time to recover, or possibly from different aquifers.

A comparison of the water level elevation with topography shows a good correlation of 97.1% (Figure 6-9). This confirms that groundwater elevation mimics the topography and in the project area flows towards the northwest.

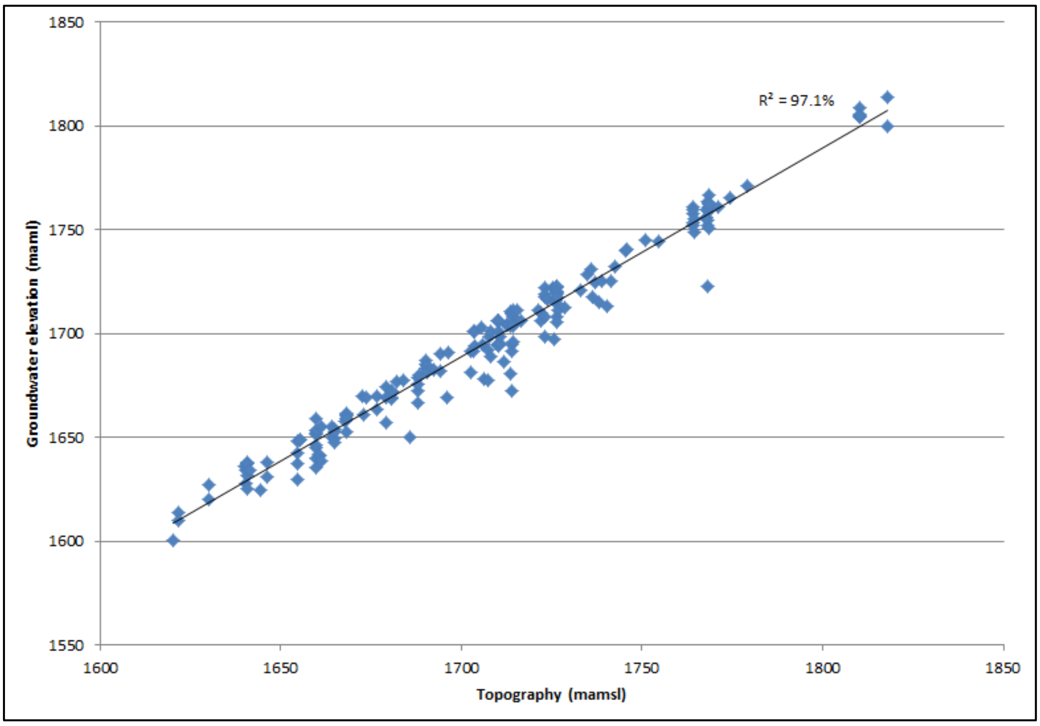

Figure 6-9: Correlation between Topography and Water Level

6.5 Aquifer Permeability

The result of the aquafer test is given in Table 6-3. The permeability is low, ranging between 10^{-5} m/d (borehole TFBH1) and $7x10^{-2}$ m/d (borehole BKBH6). The low permeability was also evident from the drilling results as no water strikes with significant blow yields were detected. The water level took considerable time in all of the boreholes (except for BKBH6) to recover to the static position following the drilling. For example it took more than two weeks for the water level to stabilise in borehole TFBH1.

The only exception is BKBH6 where a water strike of 2.4 L/s was recorded at a depth of 10 m, in the weathered sandstone. The borehole was pump tested while the rest of them were slug tested.

These permeability values were used as input values into the numerical model for impact assessment and groundwater inflow estimations.

Table 6-3: Aquifer test result

BH	Water strike (m)	Blow yield (L/s)	Final blow yield (l/s)	water level (m)	K (m/d)
BKBH6	10	2	2	11.78	0.0712
MVBH3	71	seepage	seepage	25.32	0.0002
OVBH2	28	seepage	seepage	9.05	0.01
UKBH4	12	seepage	seepage	5.45	0.0002
TFBH1		dry	seepage	35.78	0.00001
UKBH8		dry	seepage	11.09	0.00002

6.6 Aquifer Layers

The groundwater systems in the Mpumalanga coalfields have been discussed extensively by Hodgson et al (1998) and Grobbelaar et al (2004). Three distinct superimposed groundwater systems are present. They are the upper weathered Ecca aquifer, the fractured aquifers within the unweathered Ecca sediments and the aquifer below the Ecca sediments. The following aquifer description extracted from the previously stated references is relevant to the project area:

6.6.1 The weathered aquifer

The Ecca sediments are weathered to depths between 5 and 12 m below surface throughout the area. The upper aquifer is associated with this weathered zone and water is often found within a few metres below surface. This aquifer is recharged by rainfall. The percentage recharge to this aquifer is estimated to be in the order of 1% to 3% of the annual rainfall; based on work in other parts of the country by Kirchner *et al*. (1991) and Bredenkamp (1995).

It should, however, be emphasised that in a weathered system, such as the Ecca sediments, highly variable recharge values can be found from one area to the next. This is attributed to the composition of the weathered sediments, which range from coarse-grained sand to fine clay.

Based on the hydrogeological information obtained from the boreholes drilled at Hendrina, the thickness of the weathered zone was approximated to 15 m. The numerical model was calibrated at a recharge of 1% of the mean annual precipitation (which is approximately 670 mm).

6.6.2 Fractured Ecca Aquifer

The pores within the Ecca sediments are well-cemented and do not allow any significant flow of water. All groundwater movement therefore occurs along secondary structures, such as fractures and joints in the sediments. These structures are better developed in competent rocks, such as sandstone; hence the better water-yielding properties of the latter rock type.

It should, however, be emphasised that not all secondary structures are water bearing. Many of these structures are constricted because of compressional forces that act within the earth's crust.

6.6.3 Coal Seam Aquifer

Hodgson *et al*. (1998) states that of all the unweathered sediments in the Ecca, the coal seams often have the highest hydraulic conductivity. Since the aquifer permeability and storativity of the seam will also be enhanced by mine excavation, it has been simulated as a separate aquifer with an approximate permeability of 0.1 m/d. This permeability is in the same order of magnitude estimated for the coal seams by Hodgson *et al*. (1998).

6.7 Acid-base Accounting

The laboratory certificates of the geochemical tests are available in Appendix E. The results show that:

6.7.1 Rock Mineralogy and Composition

The mineralogy of the samples is shown in Table 6-4. Kaolinite and quartz are the primary minerals composing the samples; while microcline and muscovite are secondary. These minerals are common for both of the sampled boreholes (i.e. BKBH6 and TFBH1).

The boreholes are distinct based on their carbonate and pyrite contents. All the samples from borehole BKBH6 (from Hendrina South) are enriched in carbonates (siderite) and have the potential to buffer acid. No pirate is detected in these samples. Siderite is an iron carbonate which will contribute alkalinity to the neutralisation potential; less acidic conditions should be expected in Mooivley West compared, depending on the limited number of samples.

Pyrites is detected in all of the samples from borehole TFBH1 (from Mooivley West) and have the potential to generate acid. No carbonate minerals were detected in these samples. The presence of pyrite and absence of carbonate minerals in borehole TFBH1 may indicate that an acidic environment can be expected in the Hendrina South underground mine. This will be confirmed in line with acid-base accounting analysis discussed in the sections that follow.

The difference in chemical signature between the two boreholes is indicative of mineral heterogeneity and more samples would be required from each proposed mine zone to better define the site geochemistry.

Table 6-4: Mineralogical composition in weight percentage

Minerals	Ideal Composition	BKBH6 O	BKBH6 C	BKBH6 U	TFBH1 O	TFBH1 C	TFBH1 U
Chlorite	$(Mg,Fe)_5Al(AlSi_3O10)(OH)_8$	2.61	6.17	9.08	-	-	-
Kaolinite	$(Na,Ca)(Si,Al)_4O_8$	46.08	44.76	35.24	58.98	55.75	30.3
Microcline	$KAlSi_3O_8$	4.04	7.74	6.31	5.91	6.44	8.82
Muscovite	$KAl_3Si_3O_{10}(OH)_2$	6.52	8.58	9.8	4.3	7.73	10.34
Quartz	SiO_2	36.44	24.85	27.56	27.09	25.95	42.75
Siderite	$FeCO_3$	4.3	6.82	5.23	-	-	-
Rutile	TiO_2	-	1.08	1.1	1.33	1.15	-
Plagioclase	$(Na,Ca)(Si,Al)_4O_8$	-	-	5.68	-	-	5.96
Pyrite	FeS_2	-	-	-	2.38	2.99	0.77
Cristobalite	SiO_2	-	-	-	-	-	-

The elemental composition determined by the XRF analysis is given in Table 6-5. The results are expressed as metal oxides for comparative purposes.

The silica and aluminium in the samples confirm the presence of quartz and kaolinite observed in the XRD analysis. The limited calcium detected in the sample is likely to be due to plagioclase, but not calcite. The S and Fe reported in oxide form combine to form pyrite that is a potential cause of AMD, if exposed to the atmospheric conditions. The relative proportion of the acid forming potential, as well as neutralisation potential of the rocks is discussed in the sections below.

Table 6-5: Elemental composition in weight percentage

Constituents	BKBH6 O	BKBH6 C	BKBH6 U	TFBH1 O	TFBH1 C	TFBH1 U
Al_2O_3	18.432	24.687	22.218	28.336	27.564	18.429
CaO	0.691	0.565	0.714	1.387	1.611	1.145
Fe_2O_3	4.309	7.885	6.592	3.874	4.434	5.637
K_2O	1.707	2.709	3.232	1.233	1.268	2.960
MgO	0.652	1.321	1.544	1.104	1.094	1.203
MnO	0.093	0.146	0.093	0.018	0.017	0.059
Na_2O	0.202	0.340	0.602	0.376	0.354	0.942
P_2O_5	0.095	0.127	0.113	0.065	0.060	0.102
SiO_2	72.286	59.757	63.035	61.256	60.637	68.328
SO_3	0.598	0.340	0.556	1.240	1.424	0.809
Cr_2O_3	0.035	0.020	0.014	0.020	0.018	0.011

Constituents	BKBH6 O	BKBH6 C	BKBH6 U	TFBH1 O	TFBH1 C	TFBH1 U
TiO_2	0.923	1.130	1.018	1.255	1.218	0.798
CuO	0.008	0.010	0.011	0.011	0.009	0.007
PbO	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
As_2O_3	0.005	0.003	0.004	0.005	0.005	0.004
BaO	0.048	0.076	0.098	0.083	0.090	0.097
V_2O_5	0.018	0.023	0.021	0.024	0.021	0.016
NiO	0.006	0.003	0.007	0.004	0.006	0.003
ZrO_2	0.019	0.017	0.027	0.030	0.031	0.024
ZnO	0.009	0.017	0.015	0.009	0.011	0.009
SrO	0.020	0.016	0.016	0.055	0.064	0.034
Ta_2O_5	0.004	0.003	<0.002	0.004	<0.002	0.003
WO_3	0.056	0.022	0.027	0.008	0.008	0.046
Co_3O_4	0.010	0.007	0.009	0.005	0.006	0.011
TOTAL	100.19	99.20	99.93	100.38	99.92	100.65

6.7.2 Paste pH

The paste pH of the samples was found to be slightly alkaline, ranging between 8.3 and 9.2. None of the samples was found to have acidic paste pH, although it is worth noting that borehole BKBH6 is more alkaline than TFBH1.

This may indicate that once the different layers are oxidised, the coal seams, and the underlying and overlying rocks could potentially be acid neutralising, at least in the short-term depending on the sulfide mineral content. However, the paste pH alone is not a conclusive methodology for ABA classification. The sulfide content, and the acid generating and acid neutralisation materials of the samples need to be quantified for more comprehensive ABA evaluations.

Table 6-6: ABA result summary

Sample ID	paste pH	AP ($CaCO_3$ kg/t)	NP ($CaCO_3$ kg/t)	NNP ($CaCO_3$ kg/t)	NPR	Sulfide S%	NAG pH
BKBH6_O	9.2	7.18	12.4	5.22	1.73	0.23	9.2
BKBH6_C	9	2.18	11.9	9.72	5.46	0.07	9
BKBH6_U	9	8.43	14.7	6.27	1.74	0.27	9
TFBH1_O	8.6	45.3	19.3	-26	0.43	1.42	8.6
TFBH1_C	8.6	60.6	16.6	-44	0.27	1.9	8.6
TFBH1_U	8.3	17.2	19.8	2.6	1.15	0.53	8.3

6.7.3 Sulfate Speciation

The Sulfide-S content of the tested samples shows that:

- All three samples (i.e. overburden, coal seam and underburden) of borehole BKBH6 have less than 0.3% S and are unlikely to generate acid sustainably due to the limited sulfide content.
- All three samples (i.e. overburden, coal seam and underburden) of borehole TFBH1 have higher than the 0.3% benchmark required to sustainably generate acid, unless they contain sufficient buffering alkalinity.
- In conclusion, the sulfur results are in line with the mineralogy results. While the rocks in the area of BKBH6 (Hendrina South) are unlikely to sustainably generate acid, the rocks in the area of TFBH1 (Mooivley West) have sufficient sulfide to generate acid. The samples confirmed that the site geochemistry is heterogeneous. More samples are recommended to be tested from a number of boreholes across the entire project site and a long-term kinetic test work should be conducted on the overburden, coal seam and underburden to determine the cumulative potential of pollution and AMD development over a longer period.

6.7.4 Net Neutralisation Potential

As shown in Table 6-6, the samples from borehole BKBH6 have an average NNP of 7.07 kg $CaCO_3$/tonne and could be classified in the uncertain zone. However, the NNP of the samples from TFBH1 have an average NNP of -22.4 kg $CaCO_3$/tonne and is potentially acid generating.

6.7.5 Neutralisation Potential Ratio

The NPR of the samples is plotted in Figure 6-10. The NPR of the rocks from BKBH6 was quantified to be between 1.7 and 5.5, with an average of 3.0. This, together with the limited sulfide amount of less than 0.3%, is indicative of none or low potential of acid generation.

On the other hand, the rocks from TFBH1 are characterised with NPR ranging between 0.3 and 1.9, with average of 0.6. This, along with the sulfide amount of more than 0.3%, is indicative of potential acid generation.

Borehole BKBH6 is located in Hendrina South and TFBH1 is located in Mooivley East. The two mine zones will not be connected hydraulically and are expected to have different geochemical properties. While the water in the Mooivley East is expected to be acidic, the water in Hendrina South is likely to be neutral. It should, however, be noted that this is based on limited number of samples that does not include the Mooivley West. More samples from across the entire project site will be required for a comprehensive conclusion.

Another method for classifying non-potentially acid-generating materials from the potentially acid-generating materials is based on the ratio of NPR versus sulfide-sulfur or total sulfur content (Soregaroli and Lawrence, 1998). Should the NPR be less than 1 and the total sulfur content greater than 0.3%, the sample is considered potentially acid generating. As can be seen in Figure 6-11, the samples from borehole BKBH6 fell into the acid neutralising zone while those from TFBH1 fell in the acid generating zone.

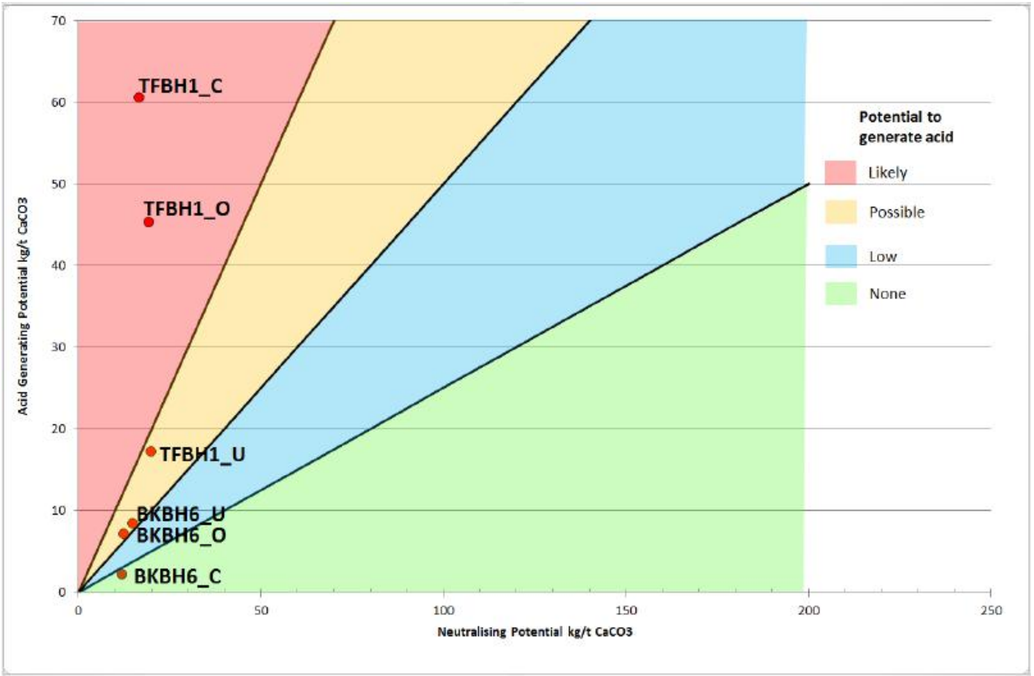

Figure 6-10: Comparison of the Acid Neutralisation and Generation Potential of the Samples

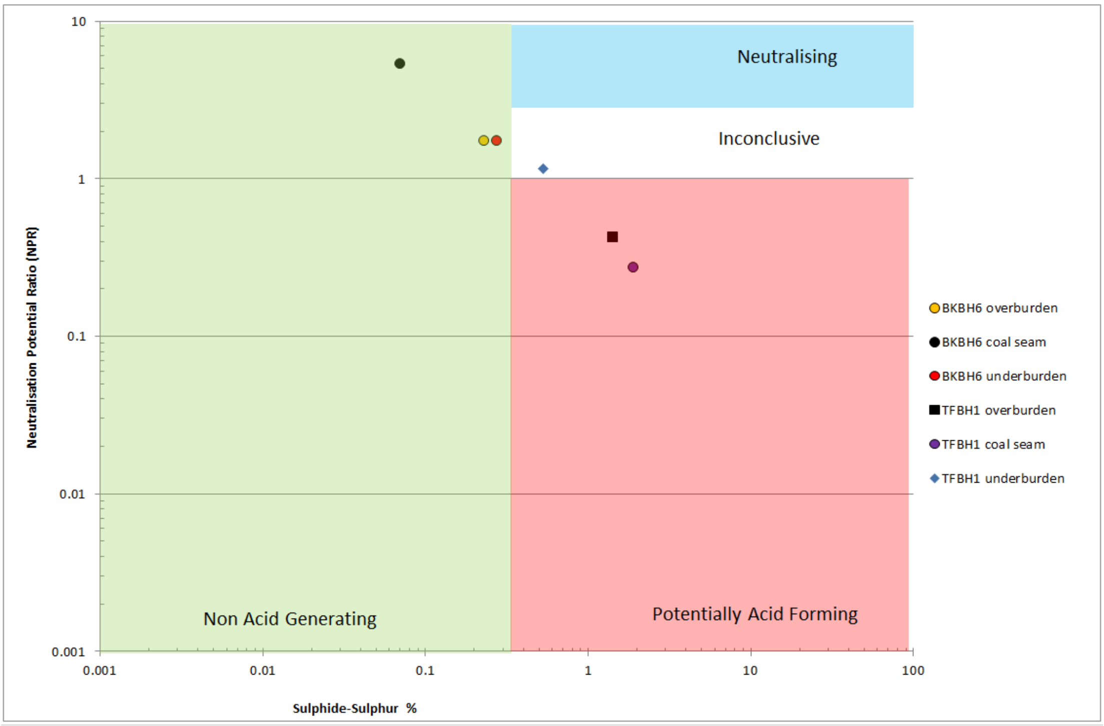

Figure 6-11: Total Sulfur vs NPR

6.8 Waste Classification

As discussed previously, there will be no discard dump on the site. However, there will be an overburden stockpile excavated during the shaft sinking; hence only the overburden samples were subjected to waste classification.

Results of the TC and LC analysis are shown in Table 6-7 and Table 6-8; compared to threshold concentrations published in the NEM: WA Waste Classification and Management Regulations.

6.8.1 Total Concentration Results

The analysis shows that:

- TCT0 threshold values of Ba, Cr and Cu are exceeded in the overburden samples for both BKBH6 and TFBH1;
- TCT0 threshold value for Pb is exceeded in sample BKBH6; and
- Based on the outcome of the total concentration assessment whereby four elements were in excess of the TCT0 limits, the waste material is classified as Type 3 Waste.

6.8.2 Leachable Concentration Results

The analysis shows that none of the samples leached above the LTC0 threshold.

Based on the LCT results only, the residue is classified as Type 4, that need to be disposed on a Class D lined disposal area. However, due to the TCT classification the waste has been classified as Type C.

Table 6-7: TCT classification

Constituents	Total Concentration Thresholds (mg/kg)			Total Concentrations (mg/kg)	
	TCT0	TCT1	TCT2	BKBH6_O	TFBH1_O
			Date	25/07/2016	25/07/2016
Arsenic as As (mg/kg)	5.8	500	2000	-1	-1
Boron as B (mg/kg)	150	15000	60000	50	62
Barium as Ba (mg/kg)	62.5	6250	25000	79	225
Cadmium as Cd (mg/kg)	7.5	260	1040	-0.1	0.28
Cobalt as Co (mg/kg)	50	5000	20000	16	9.4
Chromium VI (mg/Kg)	6.5	500	2000	83	90
Copper as Cu (mg/kg)	16	19500	78000	31	29
Mercury as Hg (mg/kg)	0.93	160	640	-0.1	-0.1
Manganese as Mn (mg/kg)	1000	25000	100000	571	62

Constituents	Total Concentration Thresholds (mg/kg)			Total Concentrations (mg/kg)	
	TCT0	TCT1	TCT2	BKBH6_O	TFBH1_O
			Date	25/07/2016	25/07/2016
Molybdenum as Mo (mg/kg)	40	1000	4000	-0.1	2.5
Nickel as Ni (mg/kg)	91	10600	42400	53	53
Lead as Pb (mg/kg)	20	1900	7600	21	16.7
Antimony as Sb (mg/kg)	10	75	300	-1	-1
Selenium as Se (mg/kg)	10	50	200	-3	-3
Vanadium as V (mg/kg)	150	2680	10720	42	35
Zinc as Zn (mg/kg)	240	160000	640000	67	55

Note: "-" values should be read as "<" (e.g. "-1" = "<1")

Table 6-8: LCT classification

Constituents	Leachable Concentration Thresholds (mg/l)				Leachable Concentrations (mg/l)	
	LCT0	LCT1	LCT2	LCT3	BKBH6_O	TFBH1_O
				Date	25/07/2016	25/07/2016
Arsenic as As (mg/L)	0.01	0.5	1	4	-0.02	-0.02
Boron as B (mg/L)	0.5	25	50	200	0.05	0.35
Barium as Ba (mg/L)	0.7	35	70	280	0.02	0.05
Cadmium as Cd (mg/L)	0.003	0.15	0.3	1.2	-0.001	-0.001
Cobalt as Co (mg/L)	0.5	25	50	200	0.001	-0.001
Chromium as Cr (mg/L)	0.05	2.5	5	20	-0.003	-0.003
Copper as Cu (mg/L)	2	100	200	800	0.007	0.01
Mercury as Hg (mg/L)	0.006	0.3	0.6	2.4	-0.001	-0.001
Manganese as Mn (mg/L)	0.5	25	50	200	0.002	0.002
Molybdenum as Mo (mg/L)	0.07	3.5	7	28	0.02	0.003
Nickel as Ni (mg/L)	0.07	3.5	7	28	-0.003	-0.003
Lead as Pb (mg/L)	0.01	0.5	1	4	-0.01	-0.01
Antimony as Sb (mg/L)	0.02	1	2	8	-0.01	-0.01
Selenium as Se (mg/L)	0.01	0.5	1	4	-0.03	-0.03

Constituents	Leachable Concentration Thresholds (mg/l)				Leachable Concentrations (mg/l)	
	LCT0	LCT1	LCT2	LCT3	BKBH6_O	TFBH1_O
				Date	25/07/2016	25/07/2016
Vanadium as V (mg/L)	0.2	10	20	80	0.004	0.01
Zinc as Zn (mg/L)	5	250	500	2 000	-0.005	-0.005
Chloride as Cl (mg/L)	300	15 000	30 000	120 000	5.4	4.2
Sulfate as SO_4 (mg/L)	250	12 500	25 000	100 000	10.3	8
Nitrate as N (mg/L)	11	550	1 100	4 400	0.7	0.6
Flouride as F (mg/L)	1.5	75	150	600	0.3	0.8

6.8.3 Classification

Based on the classification method mentioned in the National Environmental Management: Waste Act, 2008 (Act No. 59 of 2008) NEM: WA, the samples are classified as Type 3 waste because the total concentration of one or more constituent is between the TCT0 and TCT1 threshold values. The leachable concentrations of all constituents are below the LCT0 threshold value though. Disposal is therefore required at a Class C or GLB- lined waste facility, unless an exemption is granted from the relevant authorities. The Type C waste rock dump is to be designed as illustrated in Figure 6-12.

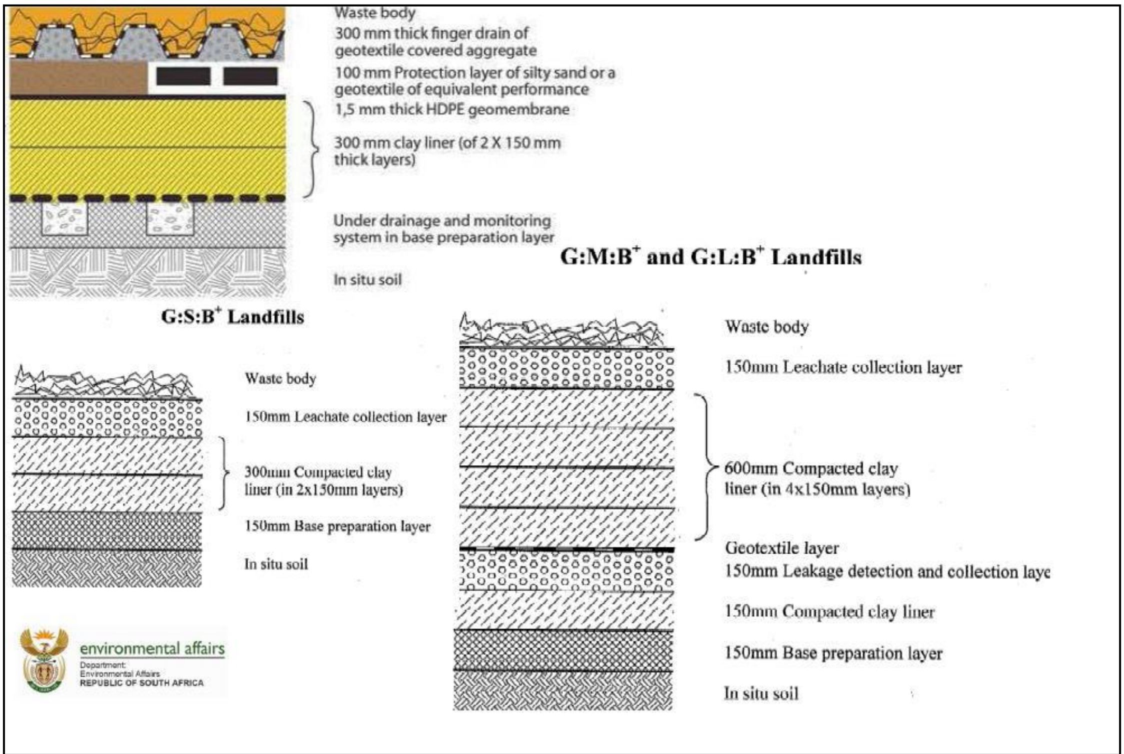

Figure 6-12: Class C Containment Barrier Requirements

7 Numerical Modelling

Following the characterisation of the aquifers, contaminant sources and groundwater receptors, the conceptual model was transformed into a numerical model so that the groundwater flow conditions and mass transport can be solved numerically. A conceptual model is a simplified, but representative description of the groundwater system that illustrates the interaction of the sources, pathways and receptors at the site.

- The sources represent any entity that contributes to the groundwater quantity and/or quality;
- The pathways are the aquifers through which the groundwater and contaminants migrate; and
- The receptors are humans, rivers or natural ecosystems that depend on the groundwater and will be impacted negatively if the water is depleted by dewatering or is contaminated.

As illustrated in Figure 7-1, an environmental risk exists only if the three components of a conceptual model (source, pathway and receptor) are linked.

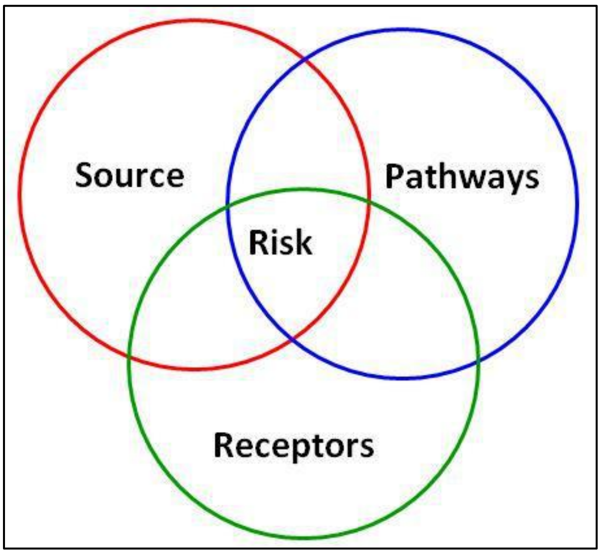

Figure 7-1: A Conceptual Model Based Environmental Risk

7.1 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.

7.2 Model Domain

The model domain (Figure 7-2) is irregularly shaped with dimensions of 29.0 km by 25.3 km. A rectangular mesh was generated over the model domain, consisting of 580 rows and 507 columns. The mesh was refined in the entire model domain to cell sizes of 50 m by 50 m (resulting in a total of 882,180 cells considering the three layers modelled). Although a smaller grid size may result in prolonged running time, it was important to refine the model, so that the groundwater gradient and pollution plumes can be calculated more accurately.

7.3 Boundary Conditions

The boundary conditions are illustrated in Figure 7-2 and are defined by:

- No-flow on the southeast boundary to represent the watershed along the topographic highs of the quaternary catchment;
- General-head boundary on the north and northeast to simulate the in or outflowing groundwater; and
- Drain package on the southern and western boundaries to represent the groundwater convergence along the stream channels. The drain package was also used to simulate the steams within the model domain.

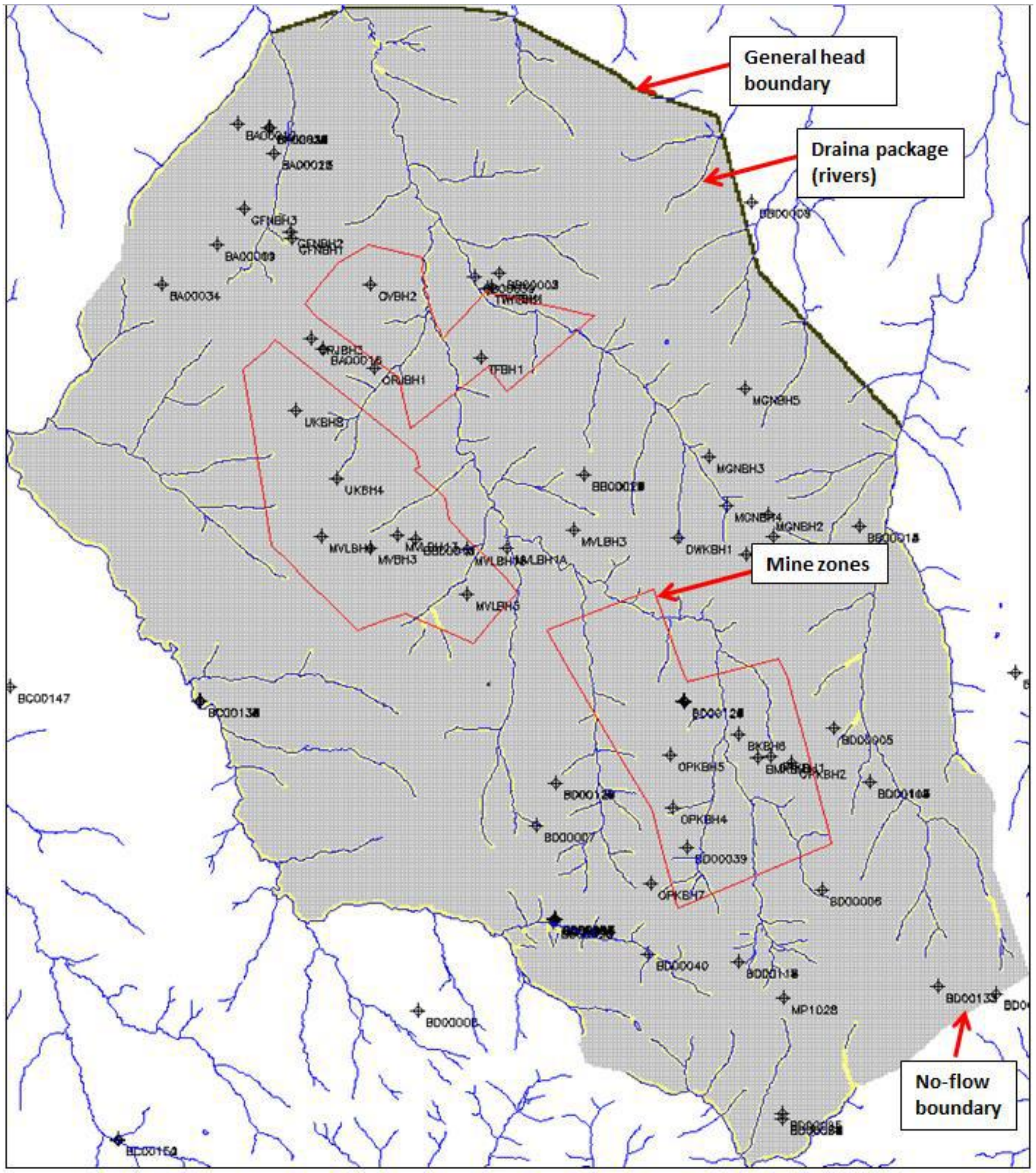

Figure 7-2: Hendrina Groundwater Model Domain

7.4 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 prior to commencement of mine dewatering. The impacts of mining activities can then be determined by comparing the transient state results with the steady state results.

7.4.1 Steady State Calibration

Digby Wells collated the newly drilled borehole data, NGA data and hydrocensus information into a centralised MS Excel database; in WISH (Windows Interpretation System for Hydrogeologists) format. The steady state model was calibrated with this data to produce a model simulating the baseline groundwater conditions. A total of 194 observation boreholes were used for the steady state calibration. Where more than one water level measurement is available, either the mean or one of the values was used.

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 and literature reviews (Hodgson *et al*, 1998), while the recharge value was adjusted manually until a best fit was obtained.

The PCG2 package was used to solve the partial differential equations. Convergence criteria of a residual flux of 10^{-3} m^3/day and a head change of 10^{-3} m were selected.

After model calibration, an acceptable correlation of 98.6% was obtained between the simulated and observed groundwater elevation (Figure 7-3).

7.4.2 Simulated Water Levels and Flow Direction

The steady state (pre-mining) groundwater elevation is illustrated in Figure 7-4. The overall groundwater flow direction is towards the topographic low in the north. Locally, however, the flow direction could be different depending on the drainage patterns of the local streams and orientation of the weathered zones and fractures that act as preferential groundwater flow paths.

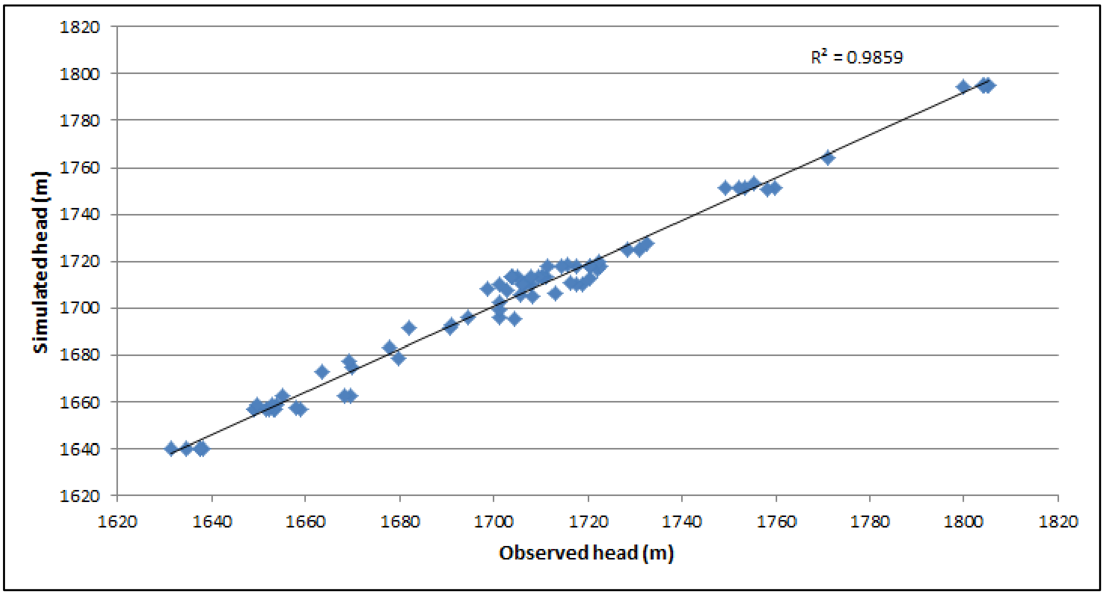

Figure 7-3: Correlation between Observed and Simulated Heads

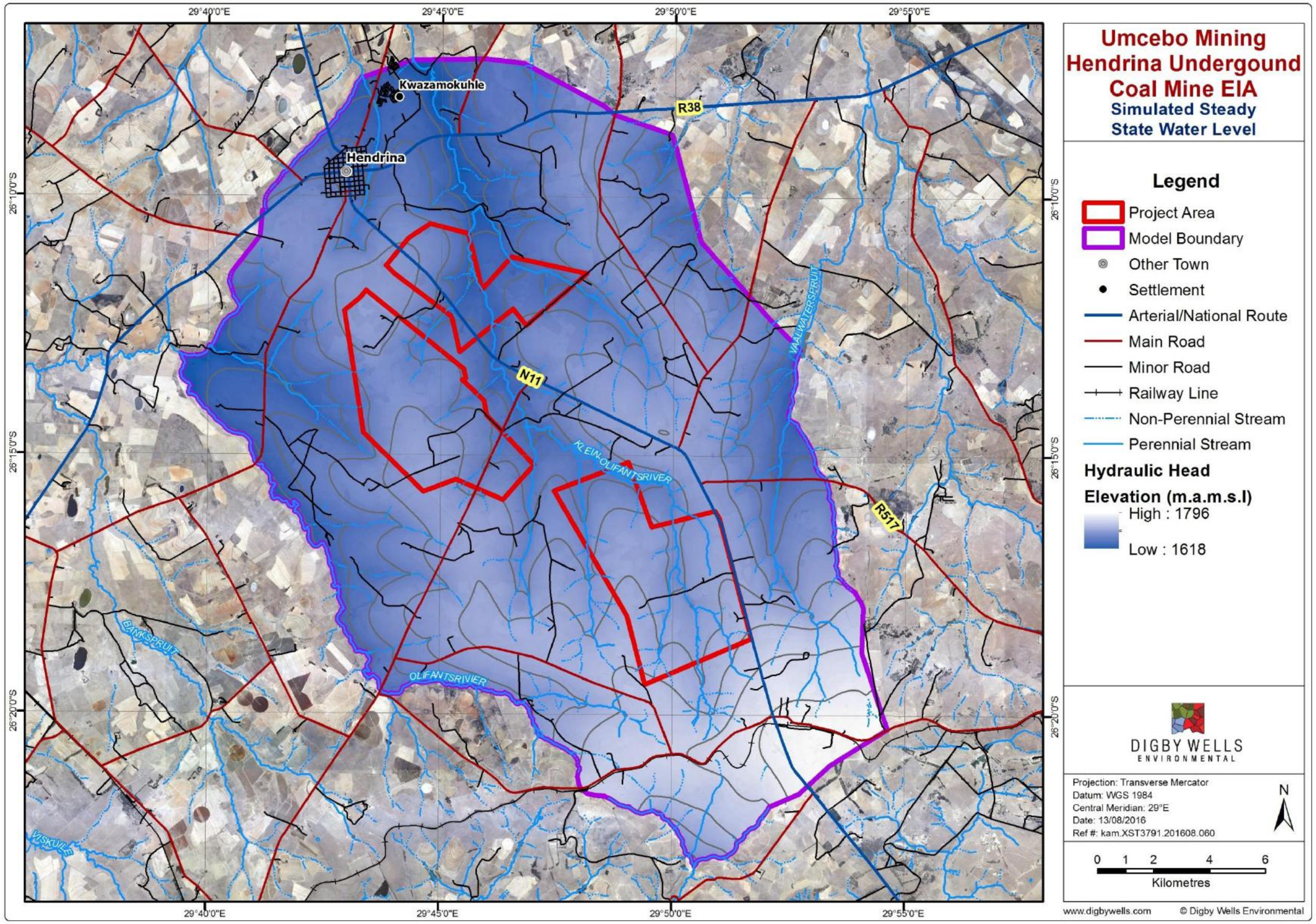

Figure 7-4: Simulated Water Level and Flow Direction

7.5 Transient State Flow Simulation

The impact of mine activities is assessed in a transient model with different stress periods over time to simulate changes related to model parameters and mining progress with time.

During the model setup, the steady state model is converted into a transient model. This stage entails selecting the appropriate time-dependent parameters such as artificial recharge (if any), well field abstraction and mine dewatering. The geometry of the model domain, boundaries, top and bottom of the layers, mesh size, layer type, aquifer permeability and natural recharge remain as defined in the steady state model. The solution of the calibrated steady-state model is used as initial hydraulic head distribution of the transient model.

After the completion of the transient state model setup, the mine plan (Figure 1-3) was incorporated into the model. This was done to estimate the inflow rates, predict the cone of dewatering and contamination plume originating from the mine. Results of the transient state modelling are discussed as part of the Impact Assessment in Section 9.3.

7.6 Mass Transport Simulation

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

7.6.1 Dispersion and Diffusion

Dispersion of contaminants in groundwater is also important in terms of contaminant transport. Dispersive transport is caused by the tortuous nature of pores or fracture openings that result in variable flow velocity distributions within an aquifer and movement of contaminants due to the difference in concentration gradient.

Dispersion has two components: longitudinal and transversal dispersivities. The longitudinal dispersivity is scale dependent and is usually approximately 10% of the travel distance of the plume (Fetter, 1993). The transversal dispersivity is approximately 10% of the longitudinal dispersivity. The higher the dispersivity, the smaller the maximum concentration of the contaminant, as dispersion causes a spreading of the plume over a larger area.

A number of streams flow across the project area, and it is postulated that the streams would be the main receptors of potential contaminant plumes; a longitudinal dispersivity of zero metres is estimated.

A diffusion coefficient of $1x10^{-5}$ m^2/day was selected, acceptable for Karoo sedimentary rocks (Gebrekristos *et al*, 2008).

7.6.2 Effective Porosity and Specific Yield

The percentage of void volume that contributes to groundwater flow is expressed by the term “porosity”. Not all pores are interconnected and therefore cannot contribute equally to groundwater flow, leading to the derivation of the term “effective porosity”, used to express the interconnected void volume that effectively contributes to groundwater flow and therefore contaminant transport. The higher the effective porosity, the slower the contamination migration rate, because more pore voids have to be filled.

The specific yield of a unit volume aquifer is the quantity of water that can be released or drained as a result of gravity. This implies that the specific yield is either equal or less than the effective porosity.

No site specific field measurement of porosity is available, but assumed to be 10%; acceptable for Karoo rocks (Van der Voort, 2001). A specific yield of 0.08 was applied across the entire model domain.

7.6.3 Selection of the contaminant of concern

The potential contamination plumes from the proposed mine sites have been simulated using a relative concentration of 100% at the sources. If, for example, the concentration of sulfate or total dissolved solids from the underground workings is 10 mg/L, a contour value of 50% indicates a concentration value of 5 mg/L, and a contour value of 10% indicates that a concentration value of 1 mg/L. A constant input concentration of 100% is, therefore, assumed from the beginning of operation. As per the Department of Water and Sanitation’s best practice for impact prediction, the plume simulation has been conducted for up to 100 years after mine closure.

8 Sensitivity Analysis and No-go Areas

The proposed mining could potentially impact the groundwater quantity and quality.

8.1 Cone of Dewatering

Mine dewatering will result in the lowering of the water table in the coal seam aquifer. Considering the limited vertical and horizontal conductivities of the Karoo Aquifers and the fact that the majority of the groundwater users tap from the top shallow aquifer, dewatering in the coal seam aquifer is not expected to impact the Klein Olifants River or the boreholes in the top shallow aquifer. However, deep boreholes intersecting the coal seam aquifer could potentially be impacted by the lowering of the water table.

After mine closure and decommissioning of the dewatering programme, the water level will start to recover. The cone of dewatering will therefore be at its maximum at the end of operation.

The cone of dewatering at the end of operation in the coal seam aquifer is given in Figure 8-1. In this study, the size of the no-go area is defined by a drawdown of 5 m. If the water table is lowered by less than 5 m, the impact is not considered to be significant and is not shown in the figure. The maximum drawdown in the top weathered aquifer is estimated to be less than 1 m and will not be significant unless subsidence occurs and that the vertical permeability is enhanced. The streams are generally fed by groundwater as a baseflow. The lowering of the groundwater level could therefore potentially lower the amount of water fed by the groundwater.

The no-go area is predominantly within the mine zones. The no-go size is predicted to be largest in Hendrina South due to the relatively higher rock permeability detected from the pump testing.

8.2 Contamination Plume

Mining is likely to alter the natural geochemistry by exposing the sulfides for oxygenation. This could result in sulfate contamination as observed in the coal mines in the region, where the concentration could reach up to 2500 mg/L.

Contaminant plumes predominantly migrate as a result of advection (i.e. with the flow of the groundwater). Any contamination plume during the mine operation will predominantly be intercepted at the underground sumps due to the dewatering programme. No or limited contamination is expected to reach the rivers during operation, due to the hydraulic gradient being towards the mining and abstraction areas.

After mine closure, however, the dewatering will cease and the groundwater will recover and start to flow towards the rivers and streams. The contamination plume will be transported with the groundwater flow, but due to the limited hydraulic permeability of the region, the plume is expected to remain in the vicinity of the mine zones.

The numerical model was used to predict the size and shape of the contamination plume 100 years after closure and is illustrated in Figure 8-1.

As discussed in Section 7.6.3, a relative source-term concentration of 100% has been simulated and the no-go concentration area has been defined by 0.1%. The plume is not expected to reach and contaminate rivers during mine operation or after closure. However, Adit 3 (located in Mooivley East) could potentially decant after closure at 7 m^3/d and could have a negatively effect on the river quality if not properly managed.

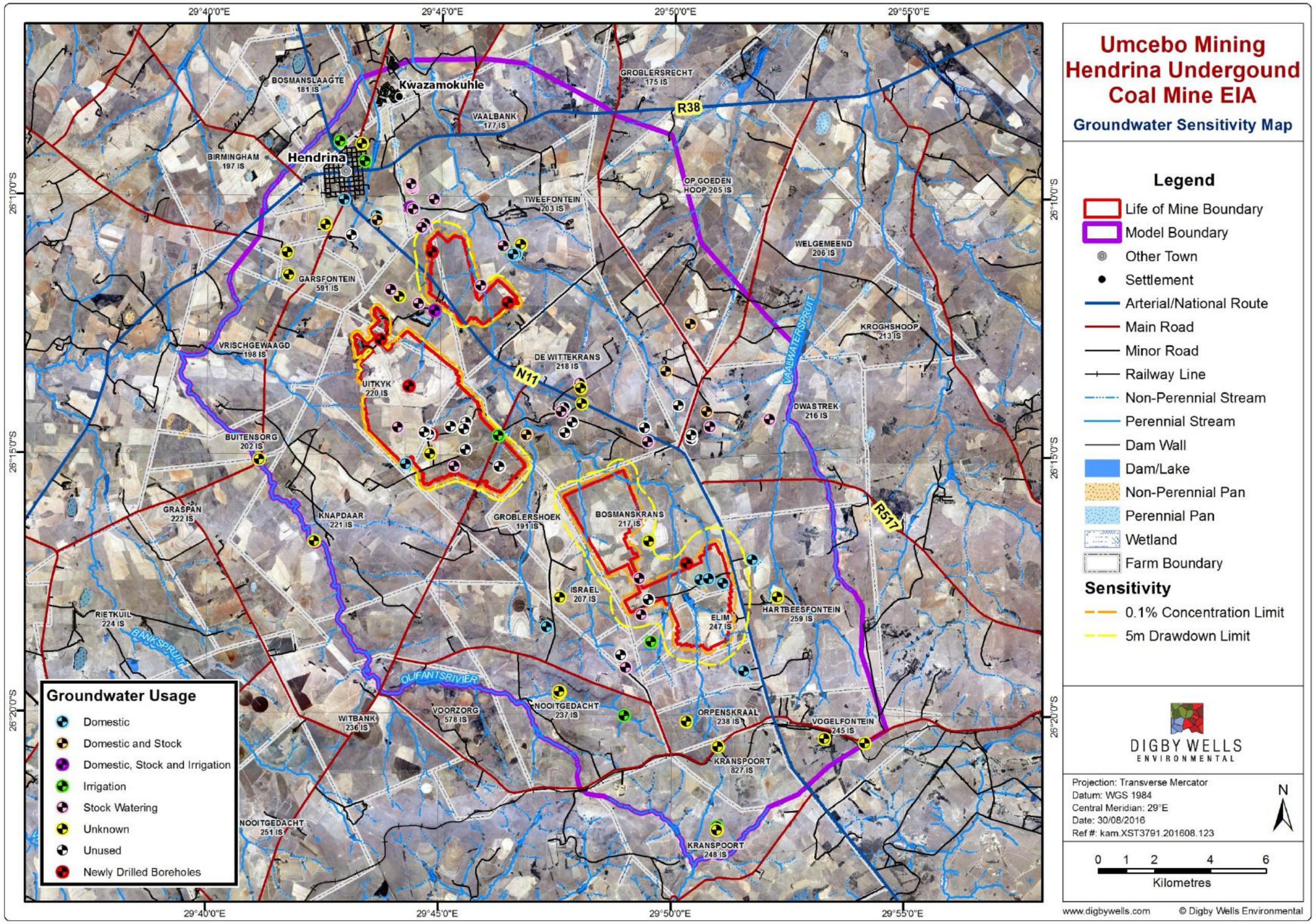

Figure 8-1: Groundwater Sensitivity Map

8.3 Model Sensitivity

The sensitivity of the model to the various hydraulic parameters was evaluated to quantify the uncertainty in the calibrated model caused by input parameters. Input parameters (vertical and horizontal permeabilities, recharge, specific storage and specific yield) were varied within a factor of 0.5 and 2 of the calibrated value and the corresponding groundwater inflow rate was measured.

Figure 8-2 presents the results of the sensitivity analyses for the various steady and transient state parameters. The model is more sensitive to the specific yield than the rest of the parameters. The vertical hydraulic conductivity is the second most influential to the model results. This means that changes in specific yield and vertical hydraulic conductivity will have a greater impact on the model output than the other less sensitive parameters (i.e. horizontal hydraulic conductivity, recharge and specific storage).

Since the model is most sensitive to the specific yield, any future groundwater study is recommended to focus on and refine this parameter of the aquifer, followed by the vertical conductivity.

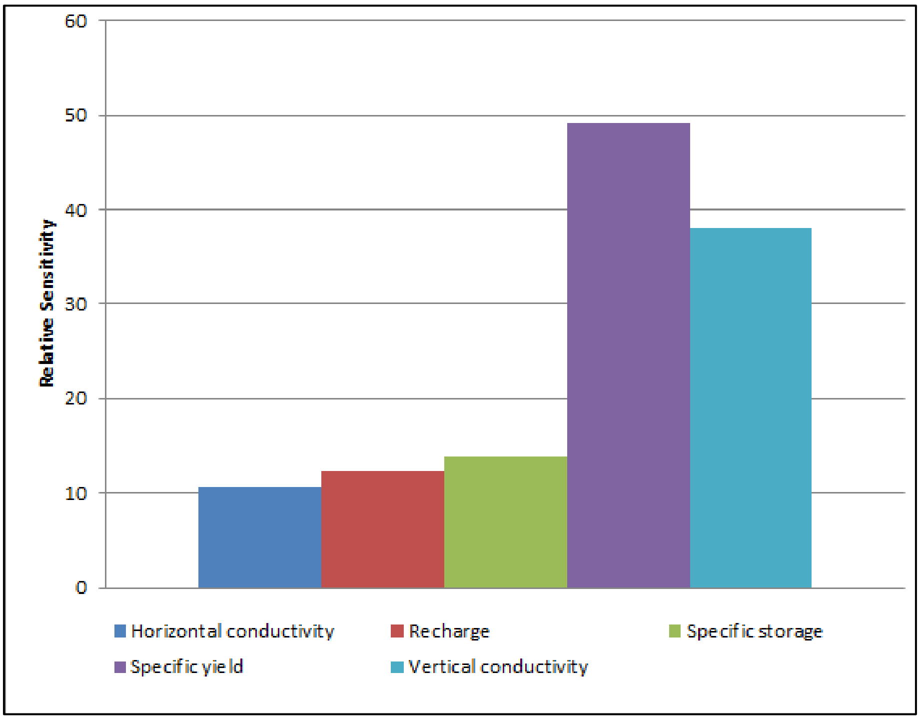

Figure 8-2: Model Sensitivity to the Hydraulic Parameters

9 Impact Assessment

9.1 Introduction

Details of the impact assessment methodology used to determine the significance of physical, bio-physical and socio-economic impacts are provided below.

The significance rating process follows the established impact/risk assessment formula:

Significance = Consequence x Probability x Nature

Where

Consequence = Intensity + Extent + Duration

And

Probability = Likelihood of an impact occurring

And

Nature = Positive (+1) or negative (-1) impact

Note: In the formula for calculating consequence, the type of impact is multiplied by +1 for positive impacts and -1 for negative impacts.

The matrix calculates the rating out of 147, whereby Intensity, Extent, Duration and Probability are each rated out of seven as indicated in Table 9-3. The weight assigned to the various parameters is then multiplied by +1 for positive and -1 for negative impacts.

Impacts are rated prior to mitigation and again after consideration of the mitigation measures proposed in this EIA/EMP Report. The significance of an impact is then determined and categorised into one of eight categories, as indicated in Table 9-2; which is extracted from Table 9-1. The description of the significance ratings is discussed in Table 9-3.

It is important to note that the pre-mitigation rating takes into consideration the activity as proposed, i.e. there may already be certain types of mitigation measures included in the design (for example due to legal requirements). If the potential impact is still considered too high, additional mitigation measures are proposed.

Table 9-1: Impact Assessment Parameter Ratings

Rating	Intensity/Replacability		Extent	Duration/Reversibility	Probability
	Negative Impacts (Nature = -1)	**Positive Impacts (Nature = +1)**			
7	Irreplaceable loss or damage to biological or physical resources or highly sensitive environments. Irreplaceable damage to highly sensitive cultural/social resources.	Noticeable, on-going natural and / or social benefits which have improved the overall conditions of the baseline.	International The effect will occur across international borders.	Permanent: The impact is irreversible, even with management, and will remain after the life of the project.	Definite: There are sound scientific reasons to expect that the impact will definitely occur. >80% probability.
6	Irreplaceable loss or damage to biological or physical resources or moderate to highly sensitive environments. Irreplaceable damage to cultural/social resources of moderate to highly sensitivity.	Great improvement to the overall conditions of a large percentage of the baseline.	National Will affect the entire country.	Beyond project life: The impact will remain for some time after the life of the project and is potentially irreversible even with management.	Almost certain / Highly probable: It is most likely that the impact will occur. <80% probability.

Rating	Intensity/Replacability		Extent	Duration/Reversibility	Probability
	Negative Impacts (Nature = -1)	**Positive Impacts (Nature = +1)**			
5	Serious loss and/or damage to physical or biological resources or highly sensitive environments, limiting ecosystem function. Very serious widespread social impacts. Irreparable damage to highly valued items.	On-going and widespread benefits to local communities and natural features of the landscape.	Province/ Region Will affect the entire province or region.	Project Life (>15 years): The impact will cease after the operational life span of the project and can be reversed with sufficient management.	Likely: The impact may occur. <65% probability.
4	Serious loss and/or damage to physical or biological resources or moderately sensitive environments, limiting ecosystem function. On-going serious social issues. Significant damage to structures / items of cultural significance.	Average to intense natural and / or social benefits to some elements of the baseline.	Municipal Area Will affect the whole municipal area.	Long term: 6-15 years and impact can be reversed with management.	Probable: Has occurred here or elsewhere and could therefore occur. <50% probability.

Rating	Intensity/Replacability		Extent	Duration/Reversibility	Probability
	Negative Impacts (Nature = -1)	**Positive Impacts (Nature = +1)**			
3	Moderate loss and/or damage to biological or physical resources of low to moderately sensitive environments and, limiting ecosystem function. On-going social issues. Damage to items of cultural significance.	Average, on-going positive benefits, not widespread but felt by some elements of the baseline.	Local Local extending only as far as the development site area.	Medium term: 1-5 years and impact can be reversed with minimal management.	Unlikely: Has not happened yet but could happen once in the lifetime of the project, therefore there is a possibility that the impact will occur. <25% probability.
2	Minor loss and/or effects to biological or physical resources or low sensitive environments, not affecting ecosystem functioning. Minor medium-term social impacts on local population. Mostly repairable. Cultural functions and processes not affected.	Low positive impacts experience by a small percentage of the baseline.	Limited Limited to the site and its immediate surroundings.	Short term: Less than 1 year and is reversible.	Rare / improbable: Conceivable, but only in extreme circumstances. The possibility of the impact materialising is very low as a result of design, historic experience or implementation of adequate mitigation measures. <10% probability.

Rating	Intensity/Replacability		Extent	Duration/Reversibility	Probability
	Negative Impacts (Nature = -1)	**Positive Impacts (Nature = +1)**			
1	Minimal to no loss and/or effect to biological or physical resources, not affecting ecosystem functioning. Minimal social impacts, low-level repairable damage to commonplace structures.	Some low-level natural and / or social benefits felt by a very small percentage of the baseline.	Very limited/Isolated Limited to specific isolated parts of the site.	Immediate: Less than 1 month and is completely reversible without management.	Highly unlikely / None: Expected never to happen. <1% probability.

Table 9-2: Probability/Consequence Matrix

Significance

Probability 7	-147	-140	-133	-126	-119	-112	-105	-98	-91	-84	-77	-70	-63	-56	-49	-42	-35	-28	-21	21	28	35	42	49	56	63	70	77	84	91	98	105	112	119	126	133	140	147
6	-126	-120	-114	-108	-102	-96	-90	-84	-78	-72	-66	-60	-54	-48	-42	-36	-30	-24	-18	18	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120	126
5	-105	-100	-95	-90	-85	-80	-75	-70	-65	-60	-55	-50	-45	-40	-35	-30	-25	-20	-15	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105
4	-84	-80	-76	-72	-68	-64	-60	-56	-52	-48	-44	-40	-36	-32	-28	-24	-20	-16	-12	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68	72	76	80	84
3	-63	-60	-57	-54	-51	-48	-45	-42	-39	-36	-33	-30	-27	-24	-21	-18	-15	-12	-9	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54	57	60	63
2	-42	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42
1	-21	-20	-19	-18	-17	-16	-15	-14	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
	-21	-20	-19	-18	-17	-16	-15	-14	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21

Consequence

Table 9-3: Significance Rating Description

Score	Description	Rating
109 to 147	A very beneficial impact that may be sufficient by itself to justify implementation of the project. The impact may result in permanent positive change	Major (positive) (+)
73 to 108	A beneficial impact which may help to justify the implementation of the project. These impacts would be considered by society as constituting a major and usually a long-term positive change to the (natural and / or social) environment	Moderate (positive) (+)
36 to 72	A positive impact. These impacts will usually result in positive medium to long-term effect on the natural and / or social environment	Minor (positive) (+)
3 to 35	A small positive impact. The impact will result in medium to short term effects on the natural and / or social environment	Negligible (positive) (+)
-3 to -35	An acceptable negative impact for which mitigation is desirable. The impact by itself is insufficient even in combination with other low impacts to prevent the development being approved. These impacts will result in negative medium to short term effects on the natural and / or social environment	Negligible (negative) (-)
-36 to -72	A minor negative impact requires mitigation. The impact is insufficient by itself to prevent the implementation of the project but which in conjunction with other impacts may prevent its implementation. These impacts will usually result in negative medium to long-term effect on the natural and / or social environment	Minor (negative) (-)
-73 to -108	A moderate negative impact may prevent the implementation of the project. These impacts would be considered as constituting a major and usually a long-term change to the (natural and / or social) environment and result in severe changes.	Moderate (negative) (-)
-109 to -147	A major negative impact may be sufficient by itself to prevent implementation of the project. The impact may result in permanent change. Very often these impacts are immitigable and usually result in very severe effects. The impacts are likely to be irreversible and/or irreplaceable.	Major (negative) (-)

9.2 Project Activities

The list of project activities that are relevant to the groundwater impact assessment are presented in Table 9-4.

Table 9-4: Description of Activities to be assessed

Project Phase	Project Activity	Project Structures
Construction	Site Clearance	Topsoil Stockpiles
	Blasting and Excavation	Two Shafts per mining right area
	Water Abstraction and Use	Water Tanks and Pipes
	Waste Generation and Disposal	Waste Skips
	Power Generation	Diesel Generator
Operations	Underground Blasting and Mining	Heavy Machinery and Equipment
	Stockpiling	Waste Rock Berms Product Stockpile
	Plant and Equipment Operations	Workshop and Diesel Storage Tanks
	Waste Generation and Storage	Sewage Treatment Plant Waste Skips
	Power Generation	Diesel Generator
	Mine Dewatering	Underground Pumps and Pipes
Mine Decommissioning and Closure	Waste Generation and Disposal	Waste Skips

9.3 Impact Assessment

The proposed underground mine has the potential to impact the groundwater environment negatively through the depletion of the groundwater resource and possible release of undesired contamination plumes. The leach test conducted on the sampled rocks during this study indicated sulfate concentrations of less than 10.3 mg/L (Table 6-8 and Appendix E). However, the groundwater quality at most of the coal mines in the country is characterised by sulfate concentrations in the order of 2500 mg/L. Similar impacts could also occur at the Hendrina project site and management plans should be put in place with this assumption.

Potential impacts are assessed in this section considering the construction, operational and closure phases. The list of project activities can be found in Table 9-4. Only project activities that are likely to result in a groundwater impact are assessed below.

9.3.1 Construction Phase

9.3.1.1 Project Activities Assessed

Mine activities during the construction phase that could result in groundwater impacts include:

- Site clearance and topsoil removal across the project area;
- The construction of overburden stockpile areas; and
- The construction of PCDs.

Table 9-5: Interactions and impacts during the construction phase

Interaction	Impact
Site clearing	Lowering of the water table, if the site clearing will take place below the water table
PCD and stockpile construction	Lowering of the water table, if the construction activities are going to take place below the water table

9.3.1.1.1 Impact Description

The water table within the proposed mine area is shallow, ranging between 0.37 m and 15 m below ground surface. Any site clearing or construction activities that would involve excavation below the water table depth will have a potential impact on the groundwater quantity and quality.

9.3.1.1.2 Management Objectives

The following are management objectives defined for the construction phase:

- Site clearance and construction activities should take place above the water table, if applicable. No impact on the groundwater is expected if the activities take place above the water table; and
- Site clearance should be kept to a minimum area and short duration, if possible.

9.3.1.1.3 Management Actions and Targets

The following actions and targets are required:

- Restrict areas that must be cleared of vegetation for construction activities to those of absolute necessity;
- Avoid constructing below the water table as far as possible;
- If trenches are going to be excavated below the water level, dewatering of the aquifer to lower the water table locally can be considered to ensure that the construction takes place above the groundwater level and the water quality remains acceptable.

The abstracted water can be utilised for dust suppression, vegetation irrigation or discharged to pollution control dams for evaporation. Since the groundwater is not expected to be polluted at this stage, the utilisation of the water for activities such as dust suppression or irrigation will not cause negative environmental impacts; and

- Install long term monitoring boreholes. The positions of the monitoring boreholes are provided in Section 12.3.

9.3.1.1.4 Construction Phase Impact Ratings

The significance rating of the potential impacts before and after mitigation is provided in Table 9-6.

Table 9-6: Potential Impacts during the Construction Phase

Activity & Interaction: Site clearing for the development of surface infrastructure through the removal of the top soil and weathered rocks			
Dimension	**Rating**	**Motivation**	**Significance**
Impact Description: Lowering of the water table			
Prior to mitigation/ management			
Duration	Short term (2)	Construction activities are expected to be short-lived (i.e. during the construction phase)	Negligible (negative) – 18
Extent	Limited (2)	Site clearing will only occur within and immediately around the Project site	
Intensity x type of impact	Minor - negative (-2)	Any dewatering will have minor environmental significance	
Probability	Unlikely (3)	Dewatering during the construction phase (if any) is unlikely to cause environmental impact considering limited rock permeability, the duration and excavation depth.	
Mitigation/ Management actions			
▪ If any trenches are excavated below the water table for any, dewatering of the aquifer to locally lower the water table can be considered to ensure that the construction takes place in a dry environment and the water quality remains acceptable. The abstracted water can be utilised for dust suppression, vegetation irrigation or discharged to local stream (if quality permits). Since the groundwater is not expected to be polluted at this stage, the utilisation of the water for activities such as dust suppression or irrigation will not cause negative environmental impacts. ▪ Install long term monitoring boreholes.			
Post- mitigation			

Activity & Interaction: Site clearing for the development of surface infrastructure through the removal of the top soil and weathered rocks			
Dimension	**Rating**	**Motivation**	**Significance**
Duration	Short term (2)	Any lowering of the water table during the construction phase is expected to be shallow and recover relatively quickly	Negligible (negative) – 15
Extent	Limited (2)	Only the area in the site clearing area will be affected	
Intensity x type of impact	Minimal - negative (-1)	Considering that the construction phase will be for a short period, the intensity will be minimal	
Probability	Unlikely (3)	It is unlikely for groundwater impact to occur during the construction phase, especially with the implementation of the above proposed management plan	

9.3.2 Operational Phase

9.3.2.1 Project Activity Assessed

The mine activities associated with the operational phase that could result in negative groundwater impact include:

- Groundwater dewatering;
- PCDs; and
- Overburden and topsoil stockpiling.

Table 9-7: Interactions and impacts during the operation phase

Interaction	Impact
Groundwater dewatering	Water level lowering
Pollution control dams	Groundwater contamination due to seepage from the dams
Topsoil and overburden stockpile	Groundwater contamination due to seepage

9.3.2.1.1 Impact Description

Mine dewatering is crucial to keep the mine workings dry for safe working conditions. Dewatering is recommended to start with the starting of the excavations. This, however, can potentially impact the groundwater environment negatively by lowering the water level and creating a cone of depression in the coal seam aquifer. This however is unlikely to impact the top weathered aquifer where the interaction occurs with the surface water bodies and where the majority of private boreholes are located. This is due to the limited vertical permeability and relatively deep underground mine.

The estimated groundwater inflow rate at various stages of the life of mine is listed in Table 9-8 and illustrated in Figure 9-1. The total inflow rate is expected to increase as the mine area increases to a maximum inflow of 1,010 m^3/d. It should be noted that this estimate is based on permeability studies conducted on 6 boreholes only. Due to this, together with the other limitations stated in Section 5, the inflow rate should be considered with a certainty of around 60%.

Inflow rate is not only a function of the aquifer properties, but also the mine plan (mined area, depth and excavation rate). The area expected to be impacted by mine dewatering is graphically illustrated in Figure 9-2 (for the top weathered aquifer) and Figure 9-3 (for the coal seam aquifer).

Table 9-8: Estimated groundwater inflow rates

Year	Mined Area	Mooivley West		Hendrina South		Mooivley East		Total Inflow	
	km^2	m^3/d	L/s	m^3/d	L/s	m^3/d	L/s	m^3/d	L/s
0	0.0	0	0.0	0	0.0	-	-	0	0.0
3	2.9	86.3	1.0	338.8	3.9	-	-	425.0	4.9
6	5.8	116.8	1.4	309.4	3.6	-	-	426.2	4.9
9	8.9	157.8	1.8	322.6	3.7	-	-	480.4	5.6
12	12.4	192.7	2.2	394.7	4.6	-	-	587.3	6.8
15	16.0	230.2	2.7	455.8	5.3	-	-	686.0	7.9
18	19.4	265.0	3.1	496.0	5.7	-	-	761.0	8.8
21	22.6	293.5	3.4	532.4	6.2	0.0	0.0	825.8	9.6
24	25.6	314.1	3.6	517.2	6.0	91.0	1.1	922.4	10.7
27	29.5	364.8	4.2	460.2	5.3	157.0	1.8	982.0	11.4
30	32.5	408.1	4.7	438.6	5.1	182.5	2.1	1029.2	11.9
33	35.7	446.4	5.2	422.2	4.9	126.6	1.5	995.2	11.5
36	37.4	495.7	5.7	408.8	4.7	109.2	1.3	1013.7	11.7

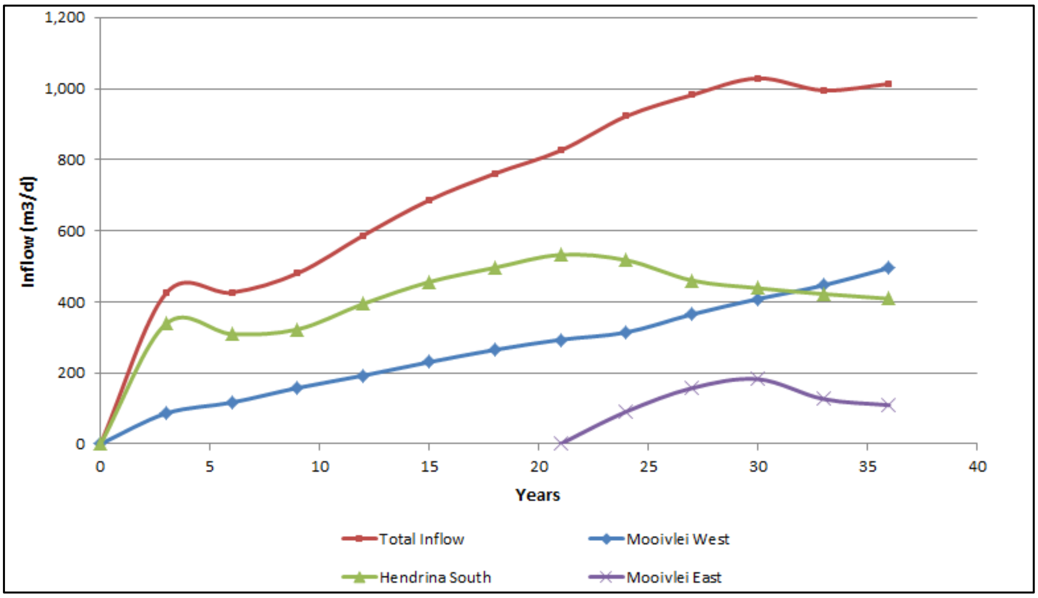

Figure 9-1: Estimated Groundwater Inflow Rates

Although the static leach tests conducted on the sampled rocks did not show contaminants of concerns, a study of various coal mines show that saline water with acidic or alkaline pH can be released from the mine workings and stockpiles once the coal and rocks are exposed to oxygen and moisture. This is also true in the nearby mines in Mpumalanga where the sulfate contamination is at around 2500 mg/L. It is therefore reasonable to assume that such contamination could occur at the project site.

During operation any contaminants that will originate from the mine workings will be pumped out as part of the mine dewatering process. No or limited contaminants are expected to migrate away from the mine area into streams or private boreholes (the limited migration is expected to occur due to diffusion, which is a result of concentration gradient).

9.3.2.1.2 Management Actions and Targets

The following actions and targets are required:

- Contain the contamination plume to within the mine area, by dewatering the underground void; and
- Minimise the impact associated with the lowering of the water table. Always keep the dewatering level close to the coal seam floor, not deeper.

9.3.2.1.3 Operational Phase Impact Ratings

The significance rating of the potential impacts before and after mitigation plans is provided in Table 9-9.

Table 9-9: Potential impacts during the operational phase

Activity & Interaction: Mine dewatering and creation of cone of dewatering			
Dimension	**Rating**	**Motivation**	**Significance**
Impact Description: Lowering of the water table			
Prior to mitigation/ management			
Duration	Beyond Project Life (6)	The water level will remain below its natural level for some time after the life of a project	Minor (negative) – 40
Extent	Limited (2)	The radius of influence will be limited to the coal seam aquifer within the site and to limited extent to the aquifer above	
Intensity x type of impact	Minor - negative (-2)	Mine dewatering will result in lowering of the water table within the site, but no impact on the wetlands and streams are foreseen due to the limited aquifer permeability and depth of the underground mine	
Probability	Almost likely (4)	It is almost certain that there will be a cone of drawdown formed due to the mine dewatering	
Mitigation/ Management actions			
▪ Store the dewatered water in pollution control dams and ensure that the dams will have sufficient storage volume. If that is not possible, re-introduce treated water into the streams after ensuring that they meet the required standards as per specified by the WUL. ▪ Management solutions should be provided following an agreement with the farmers with impacted groundwater levels. ▪ Monitoring of groundwater water levels and groundwater inflow rates. ▪ Update numerical model annually for the first 5 years as more information becomes available.			
Post- mitigation			
Duration	Beyond project life (6)	The water level will remain below its natural level for some time after the life of a Project.	Minor (negative) – 27
Extent	Limited (2)	With the above stated mitigation methods, the extent is expected to be limited.	

Activity & Interaction: Mine dewatering and creation of cone of dewatering			
Dimension	**Rating**	**Motivation**	**Significance**
Intensity x type of impact	Minor - negative (-1)	If the abstracted water is stored in PCDs or treated and re-introduced to the streams, the environmental significance is rated as minor.	
Probability	Unlikely (3)	With the application of the proposed mitigation plans, the probability of the impact will be unlikely.	

Activity & Interaction: Groundwater contamination as a result of underground mining and, seepage from the PCD and waste stockpiling			
Impact Description: Contamination plume in the groundwater			
Prior to mitigation/ management			
Duration	Beyond project life (6)	Groundwater contamination due to mine disturbance will occur during the operational phase and is expected to persist even after closure.	Minor (negative) – 40
Extent	Limited (2)	The contaminated groundwater is unlikely to feed the rivers and will not contaminate an area larger than the mine footprint.	
Intensity x type of impact	Minor – negative (-2)	The mine dewatering is expected to maintain the hydraulic head of the mine area to be below the regional groundwater level, thus containing the contamination plume to within the mine property.	
Probability	Probable (4)	The impact is likely to occur, although the plume is unlikely to not migrate beyond the mine area during the operational phase.	
Mitigation/ Management actions			

Activity & Interaction: Groundwater contamination as a result of underground mining and, seepage from the PCD and waste stockpiling			
Impact Description: Contamination plume in the groundwater			

▪ If subsidence is formed during operation, it should be rehabilitated as soon as possible to minimise water and oxygen inflow from the atmosphere.
▪ Management solutions should be provided following an agreement with the farmers with impacted groundwater or mine purchase land.
▪ Nitrate-based explosives should be avoided to minimise groundwater contamination.
▪ Overburden and topsoil stockpiles should be managed to minimise infiltration of contaminants to the groundwater. Mitigation methods that should be considered include the vegetation of the stockpile and covering them with soil to minimise rainfall infiltration and mobilisation of dissolved metals.
▪ The following management activities can be implemented to minimise contamination that originates from the pollution control dam:
  ▪ Avoid placement of the pollution control dams on areas with the potential for increased infiltration to groundwater, such as over fault zones.
  ▪ Implementation of adequate storm water management to contain all waste water and/or volatile organic compounds, for treatment and recycling.
  ▪ Pollution control dams should be lined to pro-actively prevent infiltration of contaminated seepage water.
  ▪ Pollution control dams should be operated in such a way that it will not overflow more than once in 50 years.			

Post management			
Duration	Beyond project life (6)	Groundwater contamination due to mine disturbance will occur during the operational phase and is expected to persist even after closure	Negligible (negative) – 30
Extent	Limited (2)	With the implementation of the above stated mitigation methods, the impact extent can be minimised to the site only	
Intensity x type of impact	Minimal – negative (2)	The dewatering of the underground mine will contain the pollution plume during the operational phase, with minor effects on the groundwater environment	
Probability	Unlikely (3)	The impact is unlikely to be significant with the implementation of the above stated mitigation methods	

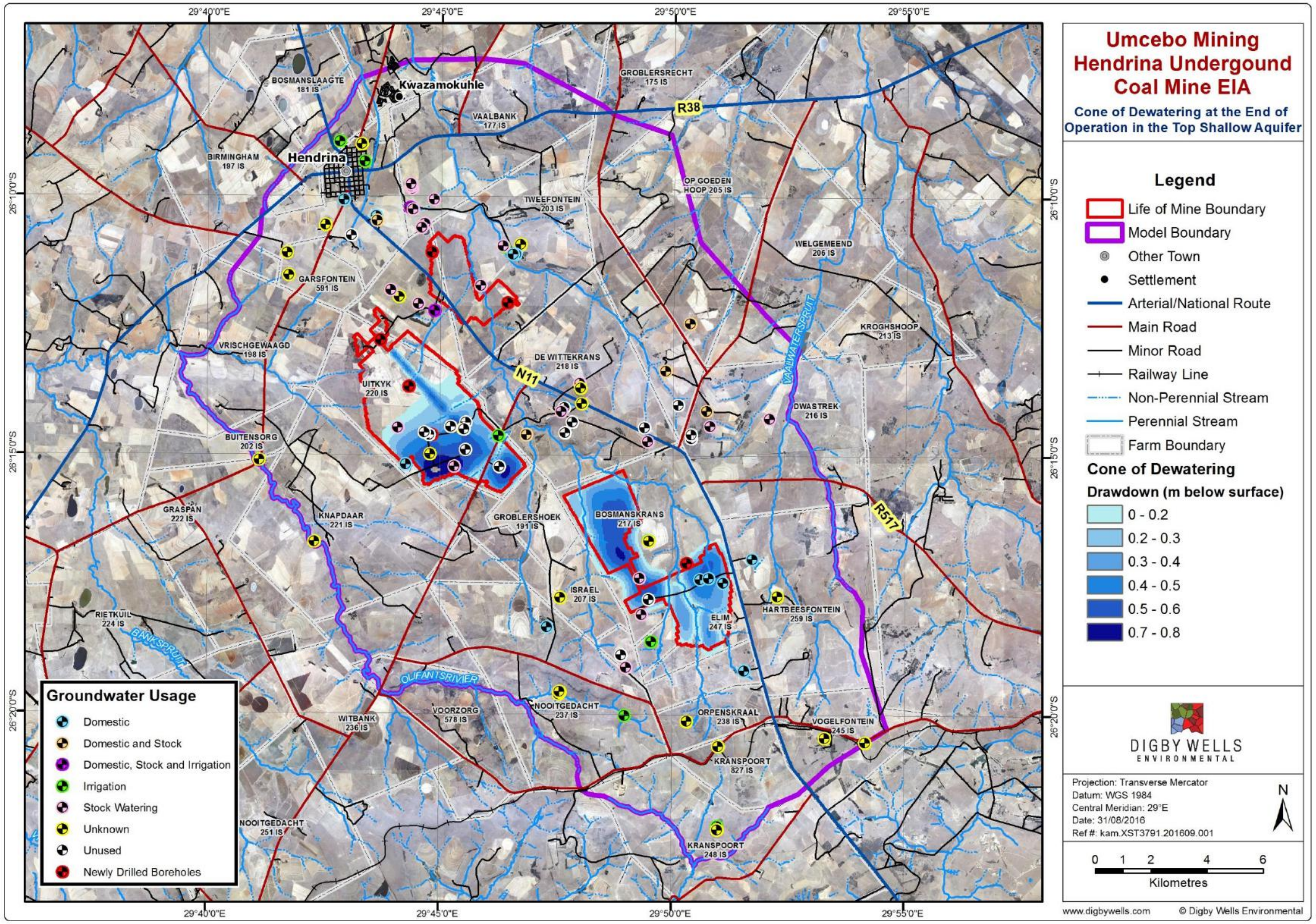

Figure 9-2: Predicted Cone of Dewatering at the end of Operation in the Top Weathered Aquifer

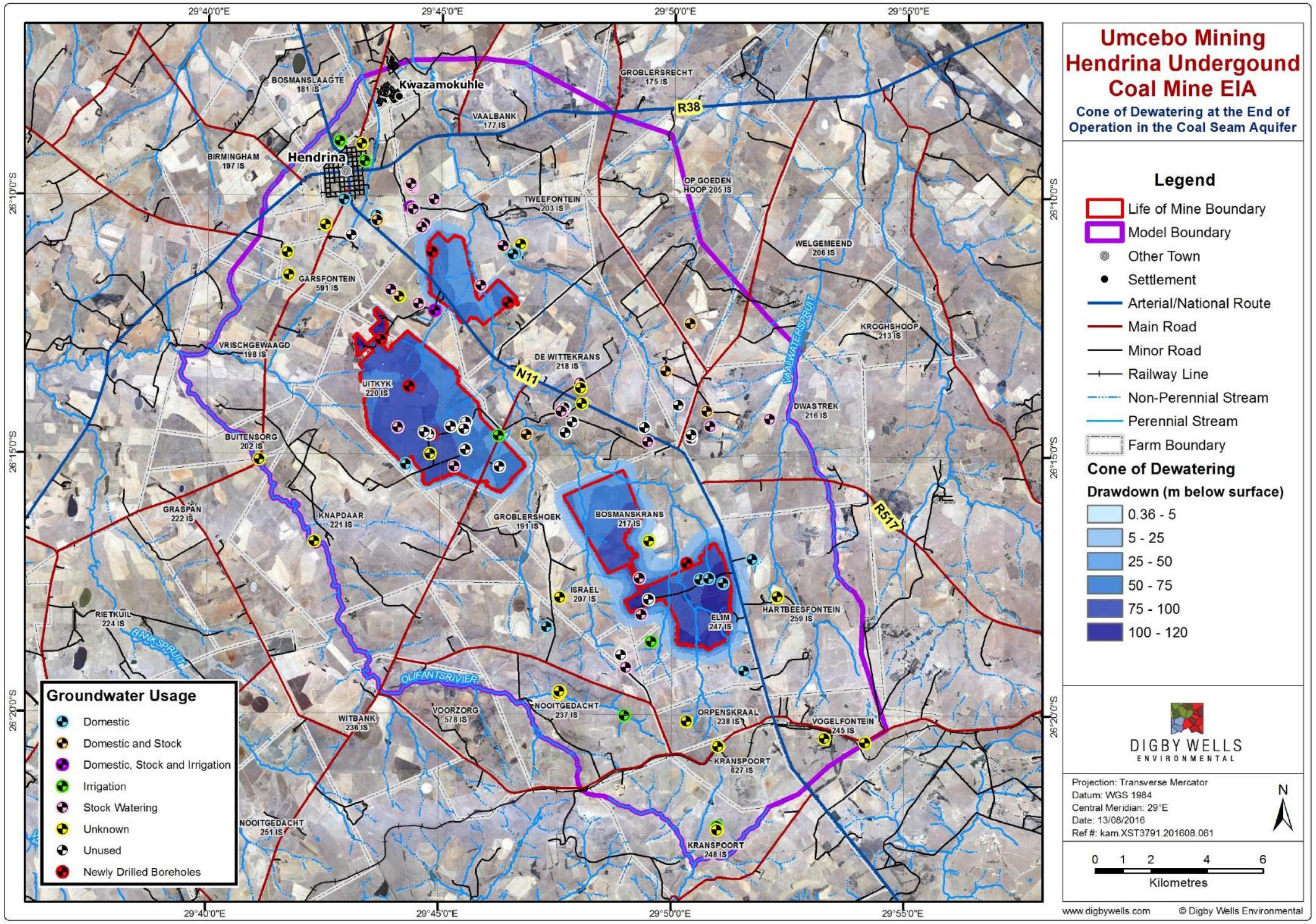

Figure 9-3: Predicted Cone of Dewatering at the end of Operation in the Coal Seam Aquifer

9.3.3 Decommissioning and Post-Closure Phases

9.3.3.1 Project Activity Assessed

The following project activities are likely to cause an impact to groundwater during the decommissioning and post closure phases:

- Groundwater contamination; and
- Mine decant.

Table 9-10 provides the activity interaction and the resultant impact after mine closure.

Table 9-10: Interactions and Impacts during the Decommissioning and Post-Closure Phase

Interaction	Impact
Mine contamination	Groundwater and stream contamination
Mine decanting	Surface water contamination

9.3.3.1.1 Impact Description

Once the mine is closed and dewatering ceases, groundwater will start to recover to its pre-mining level. Following full recovery (expected to be around 30 years after closure as shown in Figure 9-5) the contaminants will start to migrate away from the mine site. The simulated contamination plumes 100 years after closure are displayed in Figure 9-4. This plume is for the coal seam aquifer; the plume is not expected to migrate vertically to the top weathered aquifer.

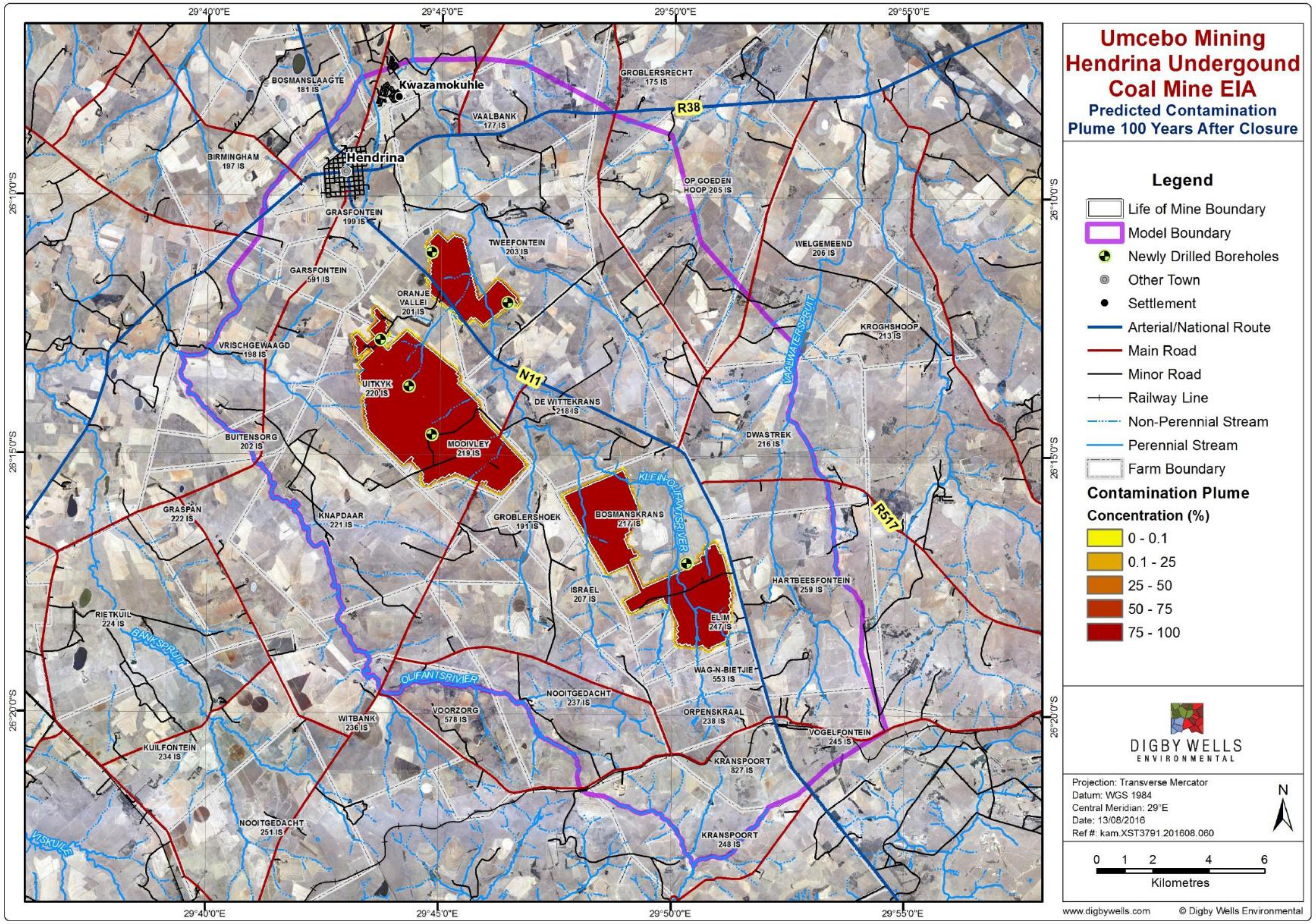

Figure 9-4: Predicted Contamination Plume in the Coal Seam Aquifer, 100 years after Mine Closure

Model simulations and hydrostatic calculations show that the mine is likely to decant after closure. The decanting is expected to occur through the proposed adit in Mooivley East. None of the other adits are foreseen to decant.

- The decanting will start 30 years after mine closure, at a rate of 7 m^3/d as shown in Figure 9-5; and
- Once the contamination plume reaches the stream, it can migrate at a higher rate compared to groundwater flow and could have a negative impact on the down-gradient riverine ecosystem and land owners.

It should be noted that the possibility of subsidence has not being considered in the decant simulation. Should subsidence be formed at elevations lower than the hydraulic head, decanting is likely to occur at those points as well. Any unsealed exploration boreholes or geological fractures enhanced by mine blasting could also be decant zones if their topographic elevation is lower than the hydraulic head. It is impossible to inform at this moment if and when such structures will be formed. Annual monitoring for subsidence followed by rehabilitation will be required.

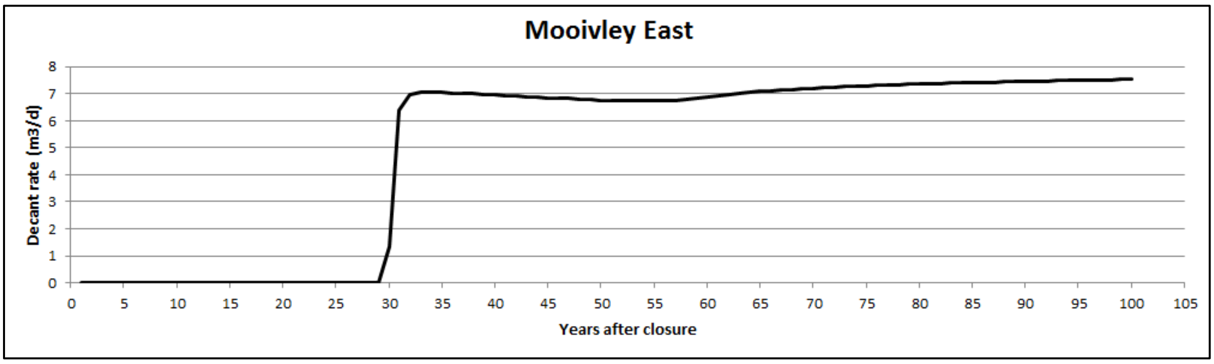

Figure 9-5: Predicted Decanting Period and Rate

9.3.3.1.2 Management Objectives

The following are management objectives defined for decommissioning and post-closure phase:

- To minimise or avoid the potential impact by decant on the rivers; and
- To minimise or avoid the groundwater contamination plume migration, as well as potential stream impacts as a result of groundwater base flow.

9.3.3.1.3 Post-Closure Phase Impact Ratings

The significance rating of the potential impacts during the decommissioning and post-closure is provided in Table 9-11.

Table 9-11: Potential Impacts after Mine Closure

Activity & Interaction: Mine decanting and contamination of surface water bodies			
Dimension	**Rating**	**Motivation**	**Significance**
Impact Description: Decanting of the closed mine			
Prior to mitigation/ management			
Duration	Permanent (7)	Once the mine starts to decant, it is not expected to stop naturally	Moderate (negative) – 105
Extent	Local (3)	The decant is likely to flow to the Klein Olifants River and associated tributaries and affect the surface water quality negatively	
Intensity x type of impact	Serous- negative (-5)	The decant is expected to have a significant impact and require effective management and rehabilitation measures to prevent irreplaceable impacts. The predicted decant rate is, however, relatively low at 7 m^3/d	
Probability	Certain (7)	Based on analytical and numerical modelling, it is certain that there will be a decant after mine closure	
Mitigation/ Management actions			
▪ Capture decant before joining the streams; treat it and re-introduce it into the streams. As experienced from other coal mines, the decant quality could be up to 2500 mg/L of sulfate. ▪ Management solutions should be provided by Umcebo following an agreement with the farmers or communities with impacted rivers. ▪ Monitoring of groundwater water levels in the weathered and coal seam aquifers. ▪ If sinkholes from subsidence are formed after closure, they should be rehabilitated as soon as possible to minimise water and oxygen inflow from the atmosphere. ▪ Update numerical model and decant rates annually for the first 5 years with the monitoring data.			
Post- mitigation			
Duration	Permanent (7)	The decant is expected to continue for the foreseeable future	Negligible (negative) – 30
Extent	Limited (2)	With the re-introduction of the treated water into the surface water system, the extent of impact will be limited	

Activity & Interaction: Mine decanting and contamination of surface water bodies			
Dimension	**Rating**	**Motivation**	**Significance**
Intensity x type of impact	Minimal - negative (-1)	Once the decanted water is treated and re-introduced to the streams, the environmental significance is rated as minimal to no loss	
Probability	Unlikely (3)	If the decant is treated to the SANS or river quality objectives, its impact is unlikely	

Activity & Interaction: Groundwater contamination as a result of underground mining			
Impact Description: Contamination plume in the groundwater			
Prior to mitigation/ management			
Duration	Beyond project life (6)	Groundwater contamination due to potential acid mine drainage or dissolution of heavy metals will occur even after the mine closure	Minor (negative) – 48
Extent	Local (3)	The contaminated groundwater can feed deep boreholes intersecting the coal seam aquifer	
Intensity x type of impact	Moderate – negative (-3)	Overall the streams are gaining from groundwater baseflow. There will be a risk of contaminants migrating from the underground mine to the Klien Olifants and its tributaries	
Probability	Likely (4)	The impact is likely to occur since the groundwater will recover after closure and start to decant	
Mitigation/ Management actions			
▪ Groundwater will flow away from the mine footprint if the hydraulic head within the mine is higher than the surrounding elevation. Ensure (through dewatering or decant management) that the hydraulic head in the mine void is always lower than that of the river or the regional head. ▪ Management solutions should be sought for upon agreement with the farmers or communities with impacted groundwater or mine purchase land. ▪ Monitoring of groundwater water levels and mine inflow rates. ▪ Update numerical model and decant rates annually as aquifer information becomes available.			
Post management			

Activity & Interaction: Groundwater contamination as a result of underground mining			
Impact Description: Contamination plume in the groundwater			
Duration	Beyond project life (6)	Groundwater contamination due to mine disturbance will continue even after mine closure	Negligible (negative) – 30
Extent	Limited (2)	With the implementation of the above stated mitigation methods, the impact extent can be minimised to the site only	
Intensity x type of impact	Minor – negative (2)	If the decanting spot is managed properly, the contaminant plume can be contained, with minor effects on the groundwater environment	
Probability	Unlikely (3)	The impact is unlikely to occur if the above stated mitigation plans are implemented	

10 Cumulative Impacts

Although there are no mines in the immediate surroundings of the project site, a couple of mines and industrial plants operate within a radius of 30 km.

As discussed previously, the maximum water level drawdown at the project site will occur in the coal seam aquifer at the end of the operational phase as illustrated in Figure 9-3. The figure shows that the impact of the dewatering activities will not extend beyond the project site. The potential contamination plume 100 years after mine closure (Figure 9-4) also shows the same result.

However, depending on the mine size, depth, life of mine and mining method, the cone of dewatering from the existing or future mines could possibility reach the project site. Considering the distance between the mines and the limited rock permeability, however, this is an unlikely scenario.

As discussed in Section 9.3.3, decanting is expected to occur at the Mooivley East mine zone after mine closure. Decanting is also possible to occur at any of the mines in the catchment. The project site is within the Kliein Olifants River catchment; a tributary of the Olifants River. All the mines within this catchment could potentially have a cumulative impact on the streams and surface water bodies. This river is essential for water supply and the ecological well-being of the environment. Cumulative impacts that could occur include:

- Deterioration of water quality in the Olifants River; and
- Decrease in the catchment yield, hence the total runoff flow.

Depending on the decant quality, each of the mines are recommended to seal or treat the decant water before joining the streams to minimise the cumulative impact on a regional scale.

11 Unplanned Events and Low Risks

The unplanned events that may happen at the project site and the proposed mitigation plan are listed in Table 11-1.

Table 11-1: Unplanned Events, Low Risks and their Management Measures

Unplanned event	Potential impact	Mitigation / Management / Monitoring
Hydrocarbon spills from bulk storage tanks, vehicles and heavy machinery or hazardous materials or waste storage facilities.	▪ Hydrocarbon contamination of the groundwater	▪ Hydrocarbons and hazardous materials must be stored in bunded areas and refuelling should take place in contained areas; ▪ Ensure that oil and silt traps are well maintained; ▪ Vehicles and heavy machinery should be serviced and checked in a demarcated area on a regularly basis to prevent leakages and spills; ▪ Hydrocarbon spill kits must be available on site at all locations where hydrocarbon spills could take place; ▪ Monitoring boreholes, particularly those located within the construction area, have to be monitored for both water level and quality to detect any changes in quality; and ▪ If a considerable amount of fluid is accidentally spilled, the contaminated soil should be scraped off and disposed of at an acceptable dumping facility. The excavation should be backfilled with soil of good quality.
Spills / leaks from the dewatering pipeline.	▪ Contamination of groundwater	▪ Regular inspections of the pipeline for any leaks. Seeping pipeline should be sealed; and ▪ Ensure that storm water management structures are put in place to capture all spills and to convey to the PCD.

Unplanned event	Potential impact	Mitigation / Management / Monitoring
Contamination from the ROM and overburden stockpile.	▪ Infiltration to the subsurface and groundwater quality deterioration	▪ Ensure the implementation of clean and dirty water separation; ▪ Overburden and topsoil stockpiles should be managed to minimise infiltration of contaminants to the groundwater; ▪ Management of the stockpile shape to control the ease with which water can run off from the facility; and ▪ Ensure that storm water management structures are put in place to capture all runoff from the ROM and overburden dumps and to convey to the PCD.

12 Environmental Management Plan

The objective of an Environmental Management Plan (EMP) is to present mitigation measures that (a) manage undue or reasonably avoidable adverse impacts associated with the development and (b) to enhance potential positives.

12.1 Project Activities with Potentially Significant Impacts

Potentially significant impacts that require mitigation or management are listed in Table 12-1.

Table 12-1: Potentially Significant Impacts

Activity	Aspects	Potential Significant Impacts
Site clearing	Water table	▪ Lowering of the water table if excavation during the site clearing process is going to take place below the water table.
Overburden rock and topsoil stockpile	Groundwater	▪ Groundwater contamination.
Pollution control dam	Groundwater	▪ Groundwater contamination.
Underground mine development	Dewatering	▪ Depletion of the groundwater; ▪ Reduction of the flow rate of the streams; and ▪ Lowering of water tables in private boreholes.
	Groundwater contamination	▪ AMD and dissolution of heavy metals.
Mine decant	Surface water	▪ Deterioration of surface water quality and riverine ecosystem.

12.2 Summary of Mitigation and Management

Table 12-2 to Table 12-4 provide a summary of the proposed project activities, environmental aspects and impacts on the receiving environment. Information on the frequency of mitigation, relevant legal requirements, recommended management plans, timing of implementation, and roles / responsibilities of persons implementing the EMP.

Table 12-2: Impacts

Activities	Phase	Size and scale of disturbance	Mitigation Measures	Compliance with standards	Time period for implementation
Site clearing	Construction	<0.5 km^2	▪ Fill the area with soil if it is low-laying and is below the water table. This will ensure that the construction takes place above the water table. ▪ If trenches are going to be excavated below the water level, dewatering of the aquifer to locally lower the water table can be considered to ensure that the construction takes place above the groundwater level and the water quality remains acceptable. The abstracted water can be utilised for dust suppression, vegetation irrigation or discharged to pollution control dams for evaporation. Since the groundwater is not expected to be polluted at this stage, the utilisation of the water for activities such as dust suppression or irrigation is not expected to cause environmental impacts. ▪ Groundwater monitoring.	N/A	▪ Groundwater monitoring must commence from the start of the construction phase ▪ Protection of the water table and groundwater quality should commence with the start of the construction phase
Overburden and topsoil stockpile	Operation	<1km^2	▪ Overburden and topsoil stockpiles should be managed to minimise infiltration of contaminants to the groundwater. ▪ The vegetation of the stockpile and covering them with soil to minimise rainfall infiltration and mobilisation of dissolved metals. ▪ Groundwater monitoring.	▪ DWS Best Practice Guideline G4: Impact prediction	▪ Stockpile design should be completed before the construction starts. ▪ Groundwater monitoring must commence from the start of the construction phase.
Pollution control dam	Operation	<0.5 km^2	▪ Avoid placement of the pollution control dams on areas with the potential for increased infiltration to groundwater, such as over fault zones. ▪ All contaminant, storm water, waste and hazardous waste storage facilities and other contaminated water storage areas (pollution control dams) should be lined to prevent infiltration of contaminated seepage water proactively. ▪ Monitoring of groundwater quality and water levels is recommended with continuous refining and updating of the monitoring network based on the results obtained. ▪ All pollution control dams should be operated in such a way that it does not overflow more than once in 50 years.	▪ DWS Best Practice Guideline A4: Pollution Control Dams	▪ PCD design should be completed before the construction starts. ▪ Groundwater monitoring must commence from the start of the construction phase.
Underground mine development - Dewatering	Operation and post-closure	38 km^2	▪ Mine should supply equal/better amount of water to affected parties. ▪ Monitoring of water levels on a monthly basis. ▪ Updating of the numerical model as aquifer properties become available.	▪ N/A	▪ Mine should supply clean water when contamination is detected in the private boreholes. ▪ Groundwater monitoring must commence from the start of the construction phase. ▪ Model updating should be conducted annually for the first 4 years. Thereafter on 5 years frequency.

Activities	Phase	Size and scale of disturbance	Mitigation Measures	Compliance with standards	Time period for implementation
Underground mine development - Groundwater contamination	Operation and post-closure	38 km^2	▪ No impact to farms is foreseen depending on the available information and numerical model results. However, if any impacts are confirmed through monitoring, the mine should supply equal/better amount of water to affected parties. ▪ Nitrate-based explosives should be avoided to minimise groundwater contamination. ▪ Mine dewatering to intercept the contamination plume to within the mine area. ▪ Monitoring of groundwater quality and water levels. ▪ Update the numerical model as more groundwater information is collected.	▪ SANS. ▪ River quality objectives. ▪ South African water quality guidelines for drinking, irrigation and livestock watering.	▪ Mine should supply clean water when contamination is detected in the private boreholes. ▪ Groundwater monitoring must commence from the start of the construction phase. ▪ Refine the conceptual and numerical models yearly in the first four years and thereafter every five years based on groundwater monitoring results.
Mine decant	Post-closure	7 m^3/d	▪ Capture the decant before joining the streams, treat it and re-introduce it into the streams. ▪ Management solutions should be upon agreement with the impacted stake holders. ▪ Monitoring of groundwater water levels and mine inflow rates. ▪ Update numerical model and decant rates as aquifer information becomes available.	▪ SANS. ▪ River quality objectives. ▪ South African water quality guidelines for drinking, irrigation and livestock watering.	▪ When the decant starts (approximately 30 years after closure).

Table 12-3: Objectives and Outcomes of the EMP

Activities	Potential impacts	Aspects affected	Phase	Mitigation	Standard to be achieved/objective
Site clearing	Groundwater depletion	Groundwater quantity	Construction	▪ Fill the area with soil if it is low-laying and is below the water table. This will ensure that the construction takes place above the water table. ▪ If trenches are going to be excavated below the water level, dewatering of the aquifer to locally lower the water table can be considered to ensure that the construction takes place above the groundwater level and the water quality remains acceptable. The abstracted water can be utilised for dust suppression, vegetation or discharged to pollution control dams for evaporation. Since the groundwater is not expected to be polluted at this stage, the utilisation of the water for activities such as dust suppression or irrigation is not expected to cause environmental impacts. ▪ Groundwater monitoring.	▪ N/A
Hard rock and topsoil stockpile	Groundwater contamination	Groundwater quality	Operation	▪ Overburden and topsoil stockpiles should be managed to minimise infiltration of contaminants to the groundwater. ▪ The vegetation of the stockpile and covering them with soil to minimise rainfall infiltration and mobilisation of dissolved metals. ▪ Groundwater monitoring.	▪ DWS Best Practice Guideline G4: Impact prediction

Activities	Potential impacts	Aspects affected	Phase	Mitigation	Standard to be achieved/objective
Pollution control dam	Groundwater contamination	Groundwater quality	Operation	▪ Avoid placement of the pollution control dams on areas with the potential for increased infiltration to groundwater, such as over fault zones. ▪ All contaminant, storm water, waste and hazardous waste storage facilities and other contaminated water storage areas (pollution control dams) should be lined to pro-actively prevent infiltration of contaminated seepage water. ▪ Monitoring of groundwater quality and water levels is recommended with continuous refining and updating of the monitoring network based on the results obtained.	▪ DWS Best Practice Guideline A4: Pollution Control Dams.
Underground mine development - Dewatering	Groundwater, wetland and surface water depletion	Surface and groundwater quantity	Operation	▪ Mine should supply equal/better amount of water to affected parties. ▪ Monitoring of water levels. ▪ Updating of the numerical model as aquifer properties become available.	▪ N/A.
Underground mine development - Groundwater contamination	Groundwater, wetland and surface water contamination	Surface and groundwater quality	Operation and post-closure	▪ Mine should supply equal/better amount of water to affected parties. ▪ Nitrate-based explosives should be avoided to minimise groundwater contamination. ▪ Mine dewatering to intercept the contamination plume to within the mine area. ▪ Monitoring of groundwater quality and water levels. ▪ Update the numerical model as more groundwater information is collected.	▪ SANS. ▪ River quality objectives. ▪ South African water quality guidelines for drinking, irrigation and livestock watering.
Mine decant	Wetland and surface water contamination	Quality of rivers and streams	Post-closure	▪ Capture the decant water before joining the streams, treat it and re-introduce it into the streams. ▪ Management solutions should be provided upon agreement with the affected stakeholders. ▪ Monitoring of groundwater water levels and mine inflow rates. ▪ Update numerical model and decant rates as aquifer information becomes available.	▪ SANS. ▪ River quality objectives. ▪ South African water quality guidelines for drinking, irrigation and livestock watering.

Table 12-4: Mitigation

Activities	Potential impacts	Aspects affected	Mitigation type	Time period for implementation	Compliance with standards
Site clearing	Groundwater depletion	Groundwater quantity	▪ Fill the area with soil if it is low-laying and is below the water table. This will ensure that the construction takes place above the water table. ▪ If trenches are going to be excavated below the water level, dewatering of the aquifer to locally lower the water table can be considered to ensure that the construction takes place above the groundwater level and the water quality remains acceptable. The abstracted water can be utilised for dust suppression, vegetation or discharged to pollution control dams for evaporation. Since the groundwater is not expected to be polluted at this stage, the utilisation of the water for activities such as dust suppression or irrigation is not expected to cause environmental impacts. ▪ Groundwater monitoring	▪ Groundwater monitoring must commence from the start of the construction phase ▪ Protection of the water table and groundwater quality should commence with the start of the construction phase	▪ N/A
Overburden and topsoil stockpile	Groundwater contamination	Groundwater quality	▪ Overburden and topsoil stockpiles should be managed to minimise infiltration of contaminants to the groundwater. ▪ The vegetation of the stockpile and covering them with soil to minimise rainfall infiltration and mobilisation of dissolved metals. ▪ Groundwater monitoring.	▪ Stockpile design should be completed before the construction starts. ▪ Groundwater monitoring must commence from the start of the construction phase.	▪ DWS Best Practice Guideline G4: Impact prediction

Activities	Potential impacts	Aspects affected	Mitigation type	Time period for implementation	Compliance with standards
Pollution control dam	Groundwater contamination	Groundwater quality	▪ Avoid placement of the pollution control dams on areas with the potential for increased infiltration to groundwater, such as over fault zones. ▪ All contaminant, storm water, waste and hazardous waste storage facilities and other contaminated water storage areas (pollution control dams) should be lined to pro-actively prevent infiltration of contaminated seepage water. ▪ Monitoring of groundwater quality and water levels is recommended with continuous refining and updating of the monitoring network based on the results obtained.	▪ PCD design should be completed before the construction starts. ▪ Groundwater monitoring must commence from the start of the construction phase.	▪ DWS Best Practice Guideline A4: Pollution Control Dams
Underground mine development - Dewatering	Groundwater, wetland and surface water depletion	Surface and groundwater quantity	▪ Mine should supply equal/better amount of water to affected parties. ▪ Monitoring of water levels. ▪ Updating of the numerical model as aquifer properties become available.	▪ Mine should supply clean water when contamination is detected in the private boreholes. ▪ Groundwater monitoring must commence from the start of the construction phase. ▪ Model updating should be conducted annually for the first 4 years. Thereafter on 5 years frequency.	▪ N/A
Underground mine development - Groundwater contamination	Groundwater, wetland and surface water contamination	Surface and groundwater quality	▪ Mine should supply equal/better amount of water to affected parties. ▪ Nitrate-based explosives should be avoided to minimise groundwater contamination. ▪ Mine dewatering to intercept the contamination plume to within the mine area. ▪ Monitoring of groundwater quality and water levels. ▪ Update the numerical model as more groundwater information is collected.	▪ Mine should supply clean water when contamination is detected in the private boreholes. ▪ Groundwater monitoring must commence from the start of the construction phase. ▪ Refine the conceptual and numerical models yearly in the first four years and thereafter every five years based on groundwater monitoring results.	▪ SANS. ▪ River quality objectives ▪ South African water quality guidelines for drinking, irrigation and livestock watering.
Mine decant	Wetland and surface water contamination	Quality of rivers and streams	▪ Capture decant water before joining the streams, treat it and re-introduce it into the streams. ▪ Management solutions should be provided upon agreement with the affected stakeholders. ▪ Monitoring of groundwater water levels and mine inflow rates. ▪ Update numerical model and decant rates as aquifer information becomes available.	▪ When the decant starts (approximately 30 years after closure).	▪ SANS. ▪ River quality objectives. ▪ South African water quality guidelines for drinking, irrigation and livestock watering.

Table 12-5: Prescribed Environmental Management Standards, Practice, Guideline, Policy or Law

Specialist field	Applicable standard, practice, guideline, policy or law			
Groundwater	▪ National Water Act, 1998 (Act No. 36 of 1998). ▪ National Environmental Management Act, 1998 (Act No. 107 of 1998), as amended (NEMA), GNR 544 and GNR 545 (Section 24 (1)). ▪ Water Services Act 108 of 1997. ▪ National Environmental Management: Waste Act, 2008 (Act 59 of 2008) (NEMWA) and List of Waste Management Activities requiring a Waste Management Licence (WML) GN 718 of 2008.	▪ Department of Water and Sanitation (DWS) (formerly DWAF). Government Gazette, No. 704 (GN 704). 1999. Regulations on the Use of Water for Mining and Related Activities Aimed at the Protection of Water Resources (Vol. 408, No. 20119). 4 June 1999. ▪ Hazardous Substances Act (Act 15 of 1973). ▪ Facilities Regulations (GNR 924 of 2004). ▪ Hazardous Chemical Substances Regulations (GN 1179 of 1995).	▪ Department of Water and Sanitation (DWS) (formerly DWAF). 2006. Best Practice Guideline G3: Water Monitoring Systems. ▪ Department of Water and Sanitation (DWS) (formerly DWAF). 2006. Best Practice Guideline G1: Storm Water Management.	▪ Department of Water and Sanitation (DWS) (formerly DWAF). 2006. Best Practice Guideline G2: Water and Salt Balances. ▪ Department of Water and Sanitation (DWS) (formerly DWAF). 2006. Best Practice Guideline A4: Pollution Control Dams.

12.3 Monitoring Plan

Groundwater monitoring has to continue during all phases of the mine operation to identify impacts over time, and that effective measures can be undertaken at the early stage before negative impacts to the environment takes place.

12.3.1 Proposed Monitoring Boreholes

The main objectives in positioning the monitoring boreholes are to:

- Monitor the movement of polluted groundwater migrating away from the mine area; and
- Monitor the lowering of the water table and the radius of influence.

The positions of the recommended monitoring points are listed in Table 12-6 and displayed in Figure 12-1. The points are composed of existing boreholes, with additional recommended boreholes in areas of borehole scarcity.

Considering the project size and closeness of the receiving environment, a total of 24 monitoring points are recommended for the purpose of groundwater monitoring as listed in Table 12-6. The depth of the shallow monitoring boreholes should be approximately 30 m, while the deep boreholes are recommended to intersect the coal seam.

Table 12-6: List of the Proposed Monitoring Boreholes

BHID	X	Y	BH Status
MVBH3	29.74700	-26.24357	Existing Borehole
MVBH3	29.74652	-26.24388	Existing Borehole
HNDBH5	29.84554	-26.29512	Proposed Borehole
BKBH6	29.84427	-26.29721	Proposed Borehole
HNDBH1	29.73462	-26.19919	Proposed Borehole
HNDBH2	29.75292	-26.21360	Proposed Borehole
HNDBH3	29.72800	-26.17404	Proposed Borehole
HNDBH4	29.72792	-26.17534	Existing Borehole
HNDBH21	29.77131	-26.18303	Existing Borehole
HNDBH6	29.77107	-26.21298	Proposed Borehole
HNDBH7	29.71530	-26.19533	Proposed Borehole
HNDBH8	29.71651	-26.19630	Proposed Borehole
HNDBH9	29.70825	-26.21735	Proposed Borehole
HNDBH10	29.72104	-26.25248	Proposed Borehole

BHID	X	Y	BH Status
HNDBH11	29.81138	-26.27271	Proposed Borehole
HNDBH13	29.85865	-26.31804	Proposed Borehole
HNDBH14	29.78661	-26.27304	Proposed Borehole
HNDBH12	29.81122	-26.27465	Proposed Borehole
HNDBH15	29.75822	-26.19540	Proposed Borehole
HNDBH16	29.75725	-26.19631	Proposed Borehole
HNDBH17	29.77155	-26.23387	Proposed Borehole
HNDBH18	29.79648	-26.24294	Existing Borehole
HNDBH19	29.86408	-26.28476	Existing Borehole
HNDBH20	29.82683	-26.27768	Existing Borehole

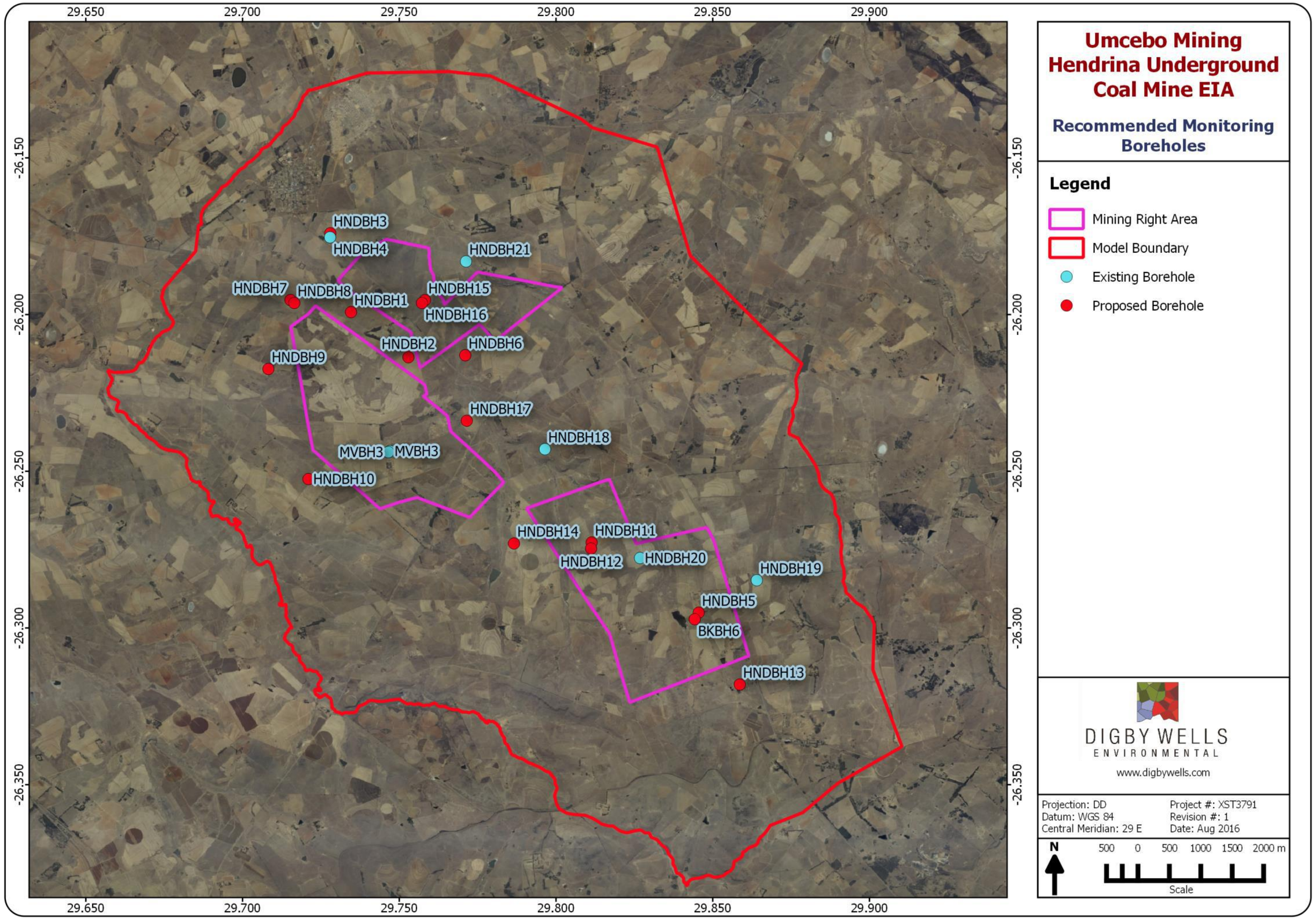

Figure 12-1: Positions of the Proposed Monitoring Boreholes for the Project Area

12.3.2 Water Level

Groundwater levels must be recorded on a monthly basis using an electrical contact tape or pressure transducer, to detect any changes or trends in groundwater elevation and flow direction.

12.3.3 Water Sampling and Preservation

When sampling the following procedures are proposed:

- One litre plastic bottles with a cap are required for the sampling exercises;
- Glass bottles are required if organic constituents are to be tested; and
- Sample bottles should be marked clearly with the borehole name, date of sampling, sampling depth and the sampler's name and submitted to a SANAS accredited laboratory.

12.3.4 Sampling Frequency

Groundwater is a slow-moving medium and drastic changes in the groundwater composition are not normally encountered within days. Considering the proximity of private boreholes and streams to the proposed mine, monitoring should be conducted monthly to reflect influences of wet and dry seasons. The sampling frequency could be adjusted following the trend analysis.

Samples should be collected by using best practice guidelines and should be analysed by a SANAS accredited laboratory.

It is suggested that quarterly samples be collected, extending up to two years post closure and based on the results. Post closure monitoring should continue until a sustainable situation is reached and after it has been signed off by the authorities.

12.3.5 Parameters to be monitored

At coal mining facilities, analyses of the following constituents are recommended:

- Macro Analysis i.e. Ca, Mg, Na, K, SO_4, NO_3, F, Cl;
- Initial full suite metals and then Al, Fe, Mn and other metals identified according to results of the initial analyses;
- pH and Alkalinity; and
- TDS and EC.

12.3.6 Data Storage

During any project, good hydrogeological decisions require good information developed from raw data. The production of good, relevant and timely information is the key to achieve qualified long-term and short-term plans. For the minimisation of groundwater contamination it is necessary to utilize all relevant groundwater data.

The generation and collection of this data is very expensive as it requires intensive hydrogeological investigations and therefore the data has to be managed in a centralised database if funds are to be used in the most efficient way. Digby Wells has compiled a WISH-based database during the course of this investigation and it is highly recommended that the applicant utilise this database and continuously update and manage it as new data becomes available.

13 Consultation Undertaken

As stated in Section 4.2, farmers and relevant land owners were visited by Digby Wells during the hydrocensus programme to locate and access all known boreholes and surface water sites in the area. This was conducted in March 2016.

13.1 Comments and Responses

The comments received from stakeholders and responses provided are listed in Table 13-1.

Table 13-1: Comments and responses

Name of Individual	Consulted	Date of comments received	Issues Raised	EAPs response to issues as mandated by the applicant
Elsabé Engels Smit & Van Wyk Attorneys	Written Comments	20-Apr-16	All the clients I represent are farmers, the concern is largely effect on the farming in the long term especially the water supply.	The baseline groundwater quality is clean. However, there is a potential of groundwater contamination as a result of the proposed underground mine. This contamination is manageable though. Umcebo has put management plans in place (please refer to the groundwater report for details), the groundwater contamination will be managed, including any potential decants. The baseline groundwater quality and water table has been recorded. Any mine impact can be identified by continuous monitoring and comparing with the baseline quality.
Ansie Coetzee Landowner	Landowners Focus Group Meeting	05-May-16	What are the potential impacts we can expect from the project?	The potential impacts on the groundwater are either contamination plume via acid mine drainage or lowering of the water table due to mine dewatering.
Alpheus Pretorius Landowner	Landowners Focus Group Meeting	05-May-16	If it rains, the groundwater volume will increase and also impact the flow of the river. With the flow of this water into the underground cavities, the land capability will be negatively impacted.	The coal seam aquifer and top weathered aquifer are linked by limited vertical permeability. Therefore a limited impact on the top weathered aquifer is foreseen. There is a possibility of mine decanting after closer. This however will be treated to the recommended standards before the decant joins the streams. Annual monitoring will be conducted to identify and rehabilitate any subsidence.
Christo Coetzee Landowner	Landowners Focus Group Meeting	05-May-16	In 2007 prospecting was done by other mines close to existing boreholes I own. Since then the borehole's yield has decreased and it was eventually proven that the decrease was caused by the prospecting activities.	Prospecting activities cannot decrease the yield of boreholes. The yield of the boreholes could potentially be decreased during mining as groundwater will be pumped out as part of the dewatering programme. If such occurs, the mine will communicate with the stakeholders for a solution.
Tielman Landowner	Landowners Focus Group Meeting	05-May-16	Boreholes from other areas i.e., close to Kendal don't provide groundwater anymore due to mining activity.	The yield of the boreholes could potentially be decreased during mining as groundwater will be pumped out as part of the dewatering programme. If such occurs, the mine will communicate with the stakeholders for a solution.
Alpheus Pretorius Landowner	Landowners Focus Group Meeting	05-May-16	Should mining occur and if borehole water depletes as a result of mining, how will water be provided to us and of what quality?	Umcebo will deal with impacted boreholes accordingly.
Manie Prinsloo Landowner	Landowners Focus Group Meeting	05-May-16	How will water be supplied, will it be piped or borehole?	
James Lloyd Landowner	Landowners Focus Group Meeting	05-May-16	What distance from the mine will boreholes be impacted on by mine dewatering?	Please refer to the groundwater report for the sensitivity and no-go areas.
Vincent Shulze Landowner	Landowners Focus Group Meeting	05-May-16	A major concern is that, should mining happen, the water will be affected and we are very reliant on borehole water for our livelihood. On average, what is the impact on borehole water (quality and quantity) from such a project?	The baseline groundwater quality and water levels have been recorded. Any potential impacts will be compared with the baseline value and if an impact is confirmed, Umcebo will deal with the impacted stakeholders accordingly.

14 Conclusions and Recommendations

14.1 Conclusions

14.1.1 Baseline Findings

A total of 190 boreholes were recorded during the hydrocensus and from the national groundwater archive. Of these:

- 31 (16%) are used for drinking only;
- 6 (3%) are used for drinking and livestock watering;
- 2 (1%) is used for drinking, livestock and irrigation;
- 31 (16%) is used for irrigation;
- 47 (25%) are used for livestock watering only;
- 17 (9%) are not used for any purpose; and
- The remaining 56 (29%) could not be confirmed.

Ten of the 13 boreholes sampled are suitable for human consumption. None of the tested parameters exceeded the recommended limits. Noteworthy is the baseline sulfate levels in all of the boreholes. The recommended sulfate limit is 250 mg/L for its aesthetic effect and 500 mg/L for its acute health effect. The sulfate concentrations for the sampled boreholes are currently less than 20.6 mg/L. Since sulfate is expected to be an element of concern in coal mines, the values obtained during this study can be used as a baseline for future contamination comparisons.

Three boreholes fell within the unacceptable category water quality range. These are either due to fluoride or manganese, both of which are suspected to be due to natural dissolution from the host rocks, particular from the pre-Karoo intrusive rocks.

The water level ranges between 0.6 m and 50.0 m below ground level. The relatively large water level variation over a relatively short distance may indicate that some of the boreholes are groundwater abstraction points measured after pumping and with no sufficient time to recover, or possibly from different aquifers. A comparison of the water level elevation with topography shows a good correlation of 97.1%. This confirms that groundwater elevation mimics the topography and in the project area flows towards the northwest.

14.1.2 Potential Impacts

The Sulfide-S analysis shows that the sulfur content of the six samples from the two sampling boreholes (i.e. BKBH6 and TFBH1) is different. While the rocks in the area of BKBH6 (Hendrina South) are unlikely to sustainably generate acid, the rocks in the area of TFBH1 (Mooivley West) have sufficient sulfide to generate acid.

This observation is also confirmed using mineralogical and ABA analysis; where by the rocks from TFBH1 are potentially acid generating while those from BKBH6 are potentially acid neutralising. Borehole BKBH6 is located in Hendrina South and TFBH1 is located in Mooivley East. The two mine zones will not be connected hydraulically and are expected to have different geochemical properties. While the water in the Mooivley East is expected to be acidic, the water in Hendrina South is likely to be neutral. It should, however, be noted that this is based on limited number of samples that does not include the Mooivley West. More samples from across the entire project site will be required for a comprehensive conclusion.

Waste classification conducted on the overburden stockpile showed that the waste material is classified as Type 3 waste because the total concentration of one or more constituents is between the TCT0 and TCT1 threshold values. The leachable concentrations of all constituents are below the LCT0 threshold value. Disposal is therefore required at a Class C or GLB- landfill, unless an exception is granted from the relevant authorities.

Mine dewatering will result in the lowering of the water table in the coal seam aquifer. Considering the limited vertical and horizontal conductivities of the Karoo Aquifers and the fact that the majority of the groundwater users tap from the top shallow aquifer, dewatering in the coal seam aquifer is not expected to impact the boreholes in the top shallow aquifer. However, deep boreholes intersecting the coal seam aquifer could potentially be impacted by the lowering of the water table.

Model simulations and hydrostatic calculations show that the mine is likely to decant after closure. The decanting is expected to occur through the proposed adit in Mooivley East. None of the other adits are foreseen to decant. The decanting will start after 30 years since mine closure at a rate of 7 m^3/d. Once the contamination plume reaches the stream, it can migrate at a higher rate compared to groundwater flow and could have a negative impact on the down-gradient riverine ecosystem and land owners.

14.2 Recommendations

A number of limitations were discussed in Section 5 that reduced the model accuracy and the predicted groundwater impact rating. Further hydrogeological assessments are recommended to gain site specific rock permeability values through borehole drilling and aquifer testing. This will be done to improve the site conceptual model and model accuracy.

The mine dewatering will result in the lowering of the water table. A contamination plume is also likely to be generated from the mine site.

The recommended mitigation plans during the construction phase include:

- The areas that must be cleared of vegetation for construction activities should be restricted to those of absolute necessity;
- Avoid constructing below the water table as far as possible;

- If trenches are going to be excavated below the water level, dewatering of the aquifer to lower the water table locally can be considered to ensure that the construction takes place above the groundwater level and the water quality remains acceptable. The abstracted water can be utilised for dust suppression, vegetation or discharged to pollution control dams for evaporation. Since the groundwater is not expected to be polluted at this stage, the utilisation of the water for activities such as dust suppression or irrigation will not cause environmental impacts; and
- Install long term monitoring boreholes.

The recommended mitigation plans during the operation phase include:

- Dewatered water stored in pollution control dams and the dams should have sufficient storage volume. If that is not possible, re-introduce treated water into the streams;
- Umcebo will communicated with the farmers with impacted groundwater quality and levels to manage the impacts and provide solution provide a solution;
- If sinkholes from subsidence are formed during operation, they should be rehabilitated as soon as possible to minimise water and oxygen inflow from the atmosphere;
- Nitrate-based explosives should be avoided to minimise groundwater contamination;
- Overburden and topsoil stockpiles should be managed to minimise infiltration of contaminants to the groundwater. Mitigation methods that should be considered include the vegetation of the stockpile and covering them with soil to minimise rainfall infiltration and mobilisation of dissolved metals; The following management activities can be implemented to minimise contamination that originates from the pollution control dam:
  - Avoid placement of the pollution control dams on areas with the potential for increased infiltration to groundwater, such as over fault zones.
  - Implementation of adequate storm water management to contain all waste water and/or volatile organic compounds, for treatment and recycling.
  - Pollution control dams should be lined to pro-actively prevent infiltration of contaminated seepage water.
- Monitoring of groundwater water levels and groundwater inflow rates; and
- Update numerical model annually for the first five years as more information becomes available

All the recommended mitigation activities proposed for the operation phase that are relevant to the closure phase should also be applied to the closure phase. These include:

- Continuous groundwater monitoring even after closure, until such time that a steady state is achieved;
- Potential impacts will be monitored and investigated. Management solutions will be provided upon agreement between Umcebo and the affected stakeholders;
- Annual monitoring for subsidence should be conducted after closure. Any subsidence formed as a result of subsidence should be rehabilitated as soon as possible to minimise water and oxygen inflow from the atmosphere; and
- Capture decant before joining the streams; treat it and re-introduce it into the streams. As experienced from other coal mines, the decant quality could be up to 2500 mg/L of sulfate.

It should be noted that the possibility of subsidence has not being considered in the decant simulation. Should subsidence are formed at elevations lower than the hydraulic head, decanting is likely to occur at those points as well. Any unsealed exploration boreholes or geological fractures enhanced by mine blasting could also be decant zones if their topographic elevation is lower than the hydraulic head. It is impossible to inform at this moment if and when such structures will be formed. Annual monitoring for subsidence followed by rehabilitation will be required.

Due to the geochemical heterogeneity, the six rock samples are not expected to provided conclusive and representative information on the long-term acid generation potential of the entire mine site. More samples are recommended to be tested from a number of boreholes across the entire project site and a long-term kinetic test work should be conducted on the overburden, coal seam and underburden to determine the potential of pollution and AMD development over a longer period.

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Appendix A: Curriculum Vitae of the Specialist

CURRICULUM VITAE

Education

- PhD in Hydrogeology, Institute for Groundwater Studies, University of the Free State, South Africa, 2007.
- Honours and MSc in Hydrogeology, Institute for Groundwater Studies, University of the Free State, South Africa, 2004.
- BSc major in Geology and minor in Physics, Geology Department, University of Asmara, Eritrea, 1999.

Employment

- Digby Wells and Associates, Johannesburg, South Africa (October 2011 to current)
- ERM Southern Africa (April 2009 to September 2011)
- Knight Piésold Engineering (July 2007 to March 2009)
- Institute for Groundwater Studies, University of the Free State, South Africa (July 2004 to July 2007)
- Umvoto Africa (Pty) Ltd, Cape Town, South Africa (November 2002 to July 2003)
- Geology Department, University of Asmara, Eritrea (September 1999 to February 2002)

Experience

Robel is a senior groundwater modeller and the hydrogeology unit manager at Digby Wells with more than 13 years of experience, both as a corporate consultant and a researcher.

Robel's experience in hydrogeology includes:

- Hydrogeological field data interpretation and conceptual modelling;
- Groundwater flow and mass transport modelling;
- Unsaturated flow modelling;
- Analytical Modelling;
- Geochemical investigations and interpretations;
- Groundwater monitoring (organic and inorganic);
- Mine dewatering management and EIA/EMP assessments;
- Groundwater resource assessment and management;
- Water and mass balance calculations (with Goldsim);

- Knowledge of Hydrogeology and GIS based software: WISH, Aquifer Test Pro, Surfer, QGIS, ArcView, Global Mapper, Map Source, RockWorks; Blender and Sketchup; and
- Computer programming, particularly C++, VB and SQL languages.

Project Experience

Recent 10 assignments include:

- **Gold One – Geluksdal TSF**: Evaluation of potential impact on the groundwater arising from the construction, operation and closure of the proposed Geluksdal TSF.
- **Anglo Platinum – Bokoni Mine:** Groundwater inflow estimations using analytical methods for two proposed deep shafts in fractured aquifers of Bushveld Complex in the western limb.
- **BHP Energy Coal South Africa (South Africa) – Union Colliery**: Volumetric calculations, mine decanting predictions and long-term water geochemistry assessment as part of the mine closure management plan
- **Anglo Platinum – Bokoni Mine:** Groundwater investigation as part of the EIA study and IWULA applications.
- **Resource Generation – Boikarabelo Mine**: Mass transport modelling to for the long-term assessment of the potential mine impacts in the nearby receptors (streams and private boreholes).
- **Anglo Platinum (South Africa)** Aquifer characterization and numerical modelling for mine feasibility study in the Bushveld Igneous aquifers.
- **Exxaro Mine (South Africa)** Regional numerical modelling for groundwater impact assessment and management planning of existing and proposed pits and associated mine infrastructures such as tailings storage facilities, rock and ash dumps in a coal mine.
- **Sasol Mafutha Project (South Africa)** Regional and local numerical modelling for groundwater impact assessment and management planning of proposed Coal-fired Power Station as well as Coal Mine.
- **Anglo Platinum (South Africa)** Aquifer characterisation and analytical modelling for groundwater management in future underground mine.
- **Sasol Midland Industrial Site (South Africa)** Site characterization and numerical modelling for the evaluation of transport and fate of organic contaminants (particularly DNAPLs) in groundwater.

Professional Affiliations

- Registered Professional Natural Scientist (PrSciNat) with the South African Council for Natural Scientific Professions – Registration Number: 400175/08
- The Geological Society of South Africa: Membership number: 967074
- International Association of Hydrogeologists (IAH)
- Ground Water Division of the Geological Society of South Africa

Publications

Presentations at International Conferences

Gebrekristos, R.A (2015). Packer Testing And Analytical Modelling For Groundwater Inflow Estimation For Proposed Shafts, (*Best Paper at Biennial South African Groundwater Conference, Bloemfontein, 21-23 September 2015).*

Gebrekristos, R.A, Trusler, G., James, A., (2015). Blast curtain optimized with a numerical model for TSF seepage control, Biennial South African Groundwater Conference, Stellenbosch, 21-23 September 2015.

Gebrekristos, R.A, Chesire, P. and Kotze J. (2011). Analytical Modelling Based on Strong Conceptual Site Models. Submitted to the Biennial South African Groundwater Conference, Pretoria, 16 – 18 September 2011.

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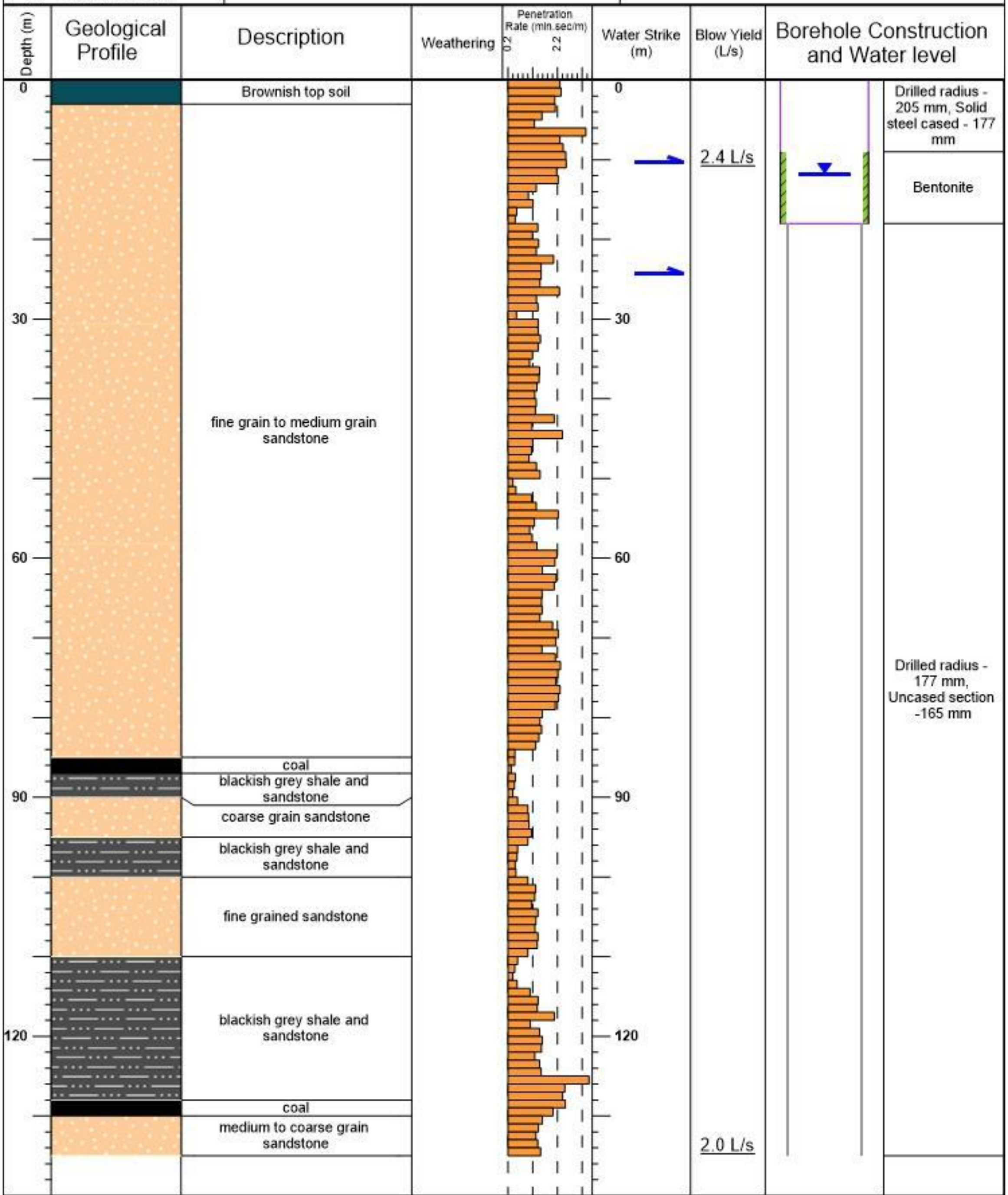
Appendix B: Borehole Logs

DIGBY WELLS ENVIRONMENTAL
Digby Wells House
Turnberry Office Park
48 Grosvenor Road
Bryanston, 2191
Tel: +27(0)11 789 9495

CLIENT:	**Glencore**	**BOREHOLE ID:**	**BKBH6**
Project Name:	Hendrina EIA/EMP	Coordinate System:	WGS84
Project Code:	XST3971	X-Coordinate:	29.83847
Location:	Mpumalanga	Y-Coordinate:	-26.28473
Drilled By:	Ubuntu drilling	Z-Coordinate:	
Date Drilled:	03/06/2016	Final Depth (m):	135
Logged By:	Simango E	Collar Height (m):	0.62

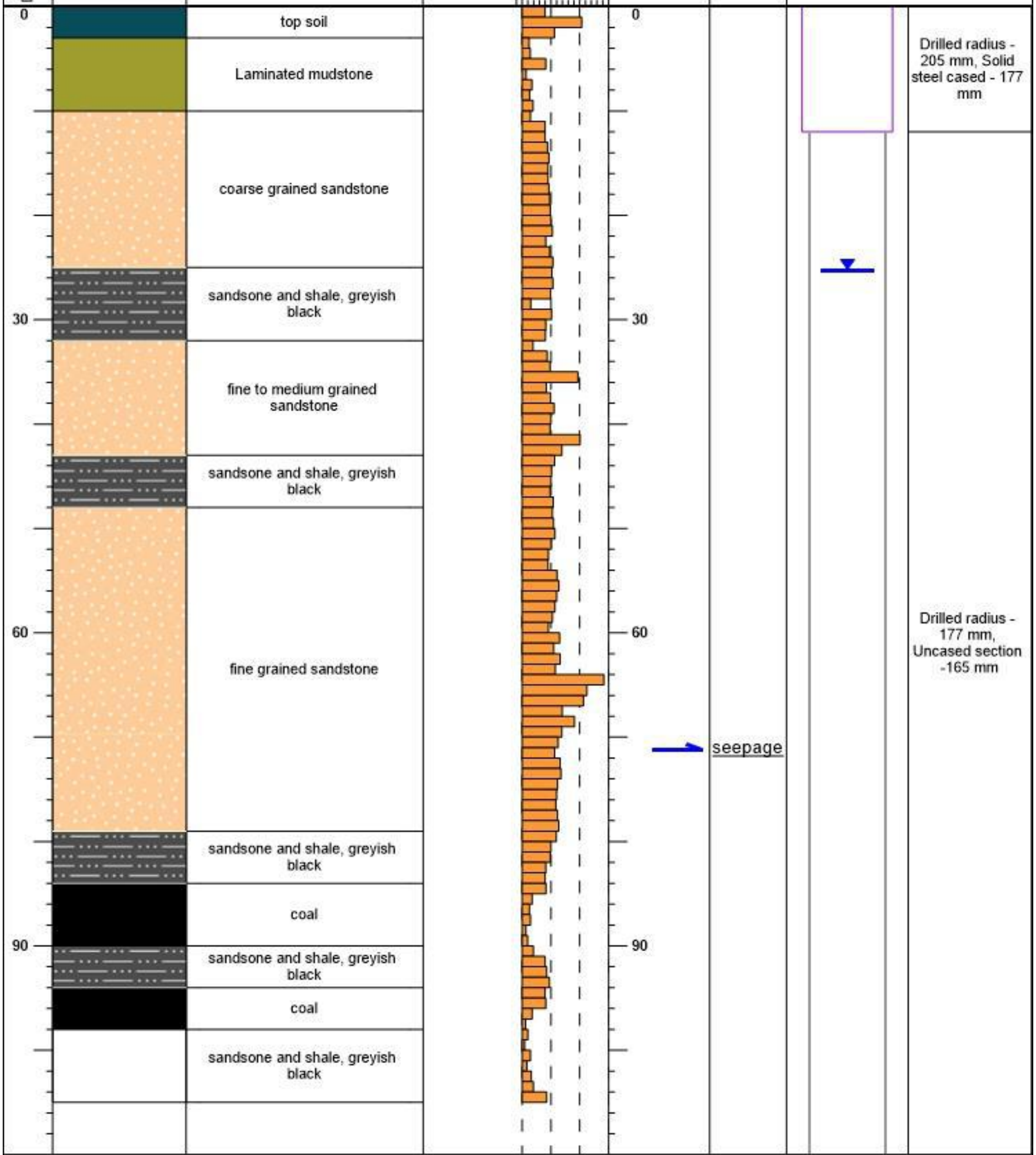


Comment:
INTR =interlaminated

DIGBY WELLS ENVIRONMENTAL
Digby Wells House
Turnberry Office Park
48 Grosvenor Road
Bryanston, 2191
Tel: +27(0)11 789 9495

CLIENT:	**Glencore**	**BOREHOLE ID:**	**MVBH3**
Project Name:	Hendrina EIA/EMP	Coordinate System:	WGS84
Project Code:	XST3971	X-Coordinate:	29.747
Location:	Mpumalanga	Y-Coordinate:	-26.24357
Drilled By:	Ubuntu drilling	Z-Coordinate:	
Date Drilled:	01/06/2016	Final Depth (m):	105
Logged By:	Simango E	Collar Height (m):	0.43

Depth (m) | Geological Profile | Description | Weathering | Penetration Rate (min.sec/m) | Water Strike (m) | Blow Yield (L/s) | Borehole Construction and Water level



Comment:
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Tel: +27(0)11 789 9495

CLIENT:	**Glencore**	**BOREHOLE ID:**	**OVBH2**
Project Name:	Hendrina EIA/EMP	Coordinate System:	WGS84
Project Code:	XST3971	X-Coordinate:	29.74674
Location:	Mpumalanga	Y-Coordinate:	-26.18484
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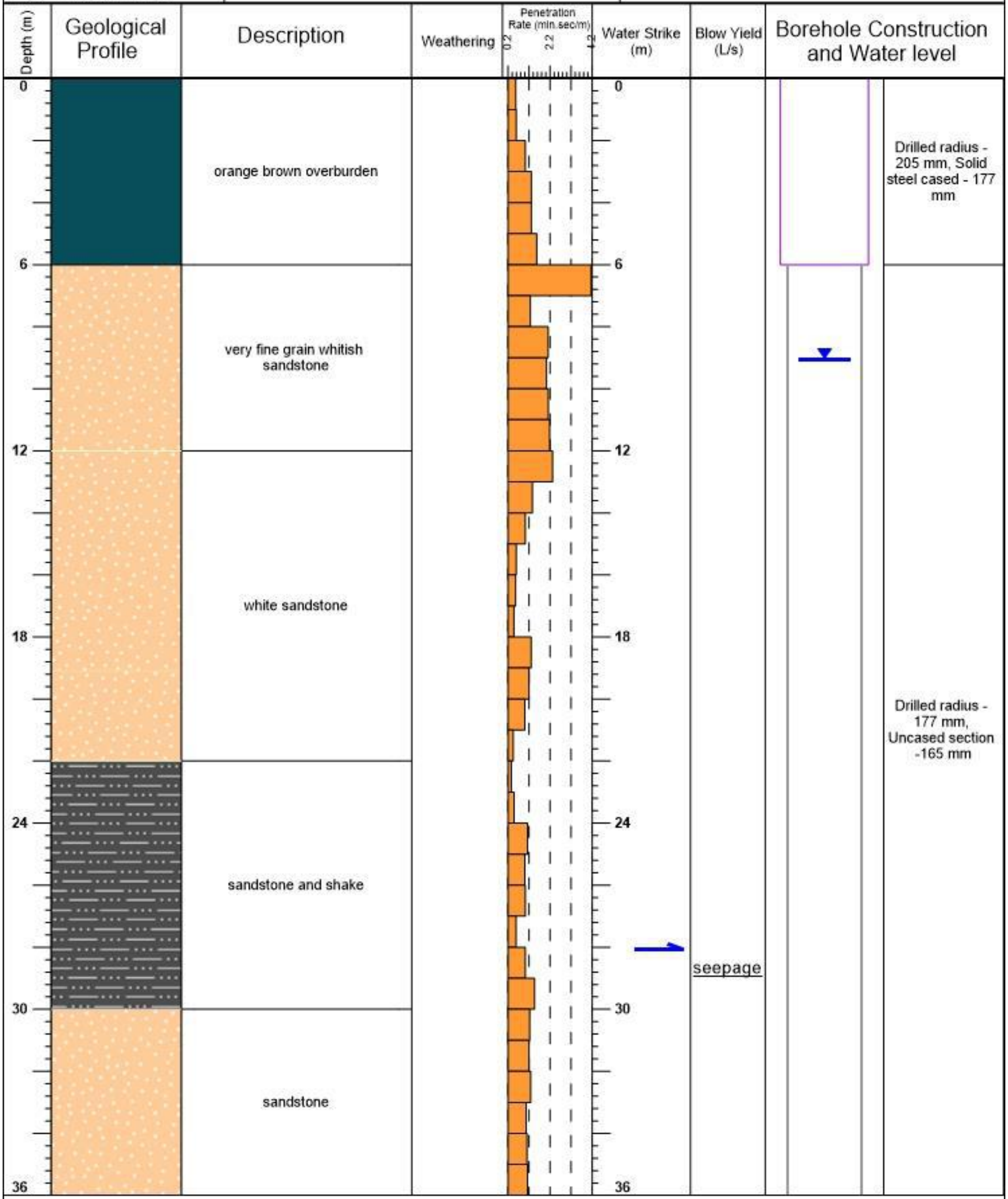

Comment:
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DIGBY WELLS ENVIRONMENTAL
Digby Wells House
Turnberry Office Park
48 Grosvenor Road
Bryanston, 2191
Tel: +27(0)11 789 9495

CLIENT:	**Glencore**	**BOREHOLE ID:**	**TFBH1**
Project Name:	Hendrina EIA/EMP	Coordinate System:	WGS84
Project Code:	XST3971	X-Coordinate:	29.77395
Location:	Mpumalanga	Y-Coordinate:	-26.20106
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Date Drilled:	06/06/2016	Final Depth (m):	85
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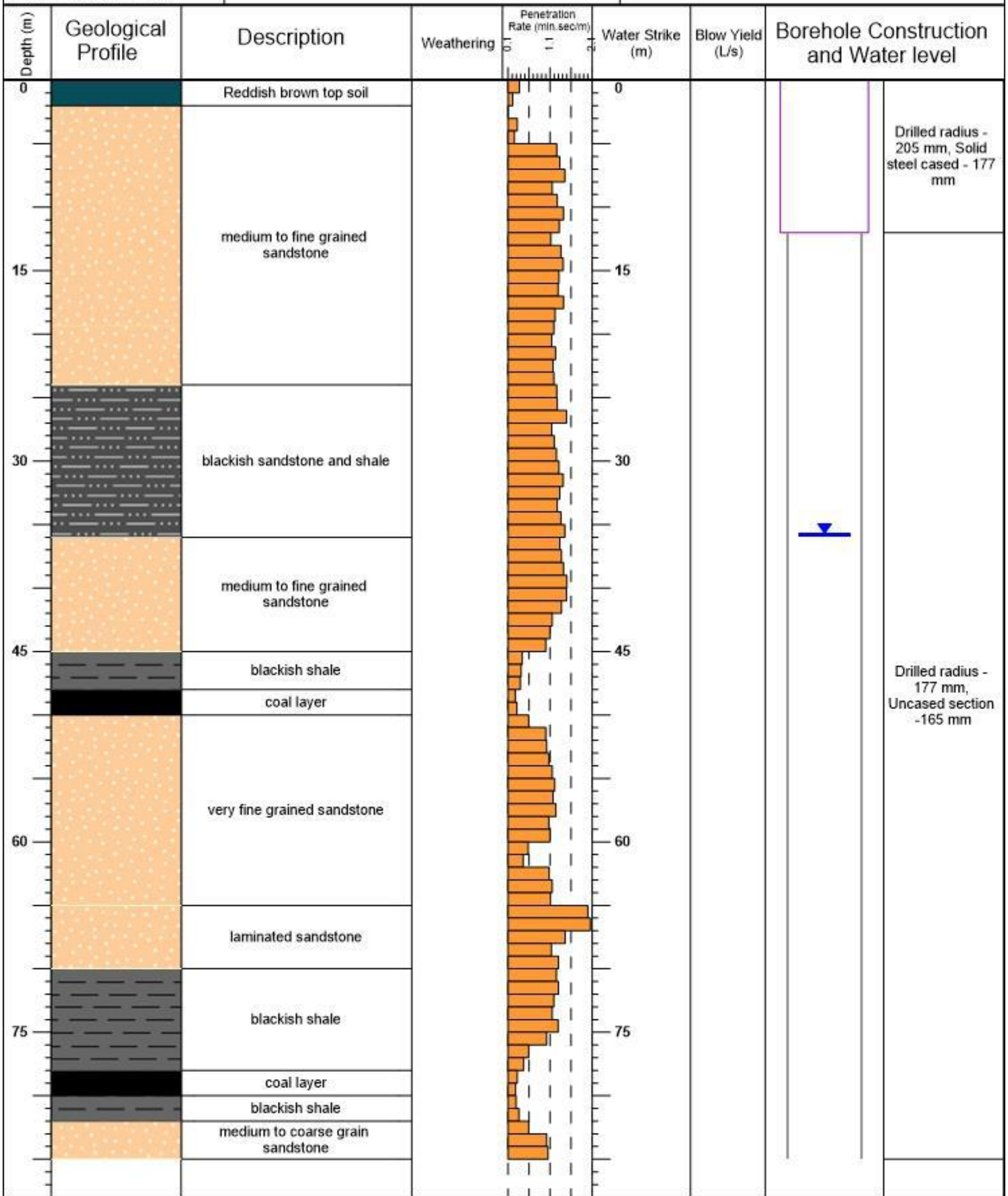

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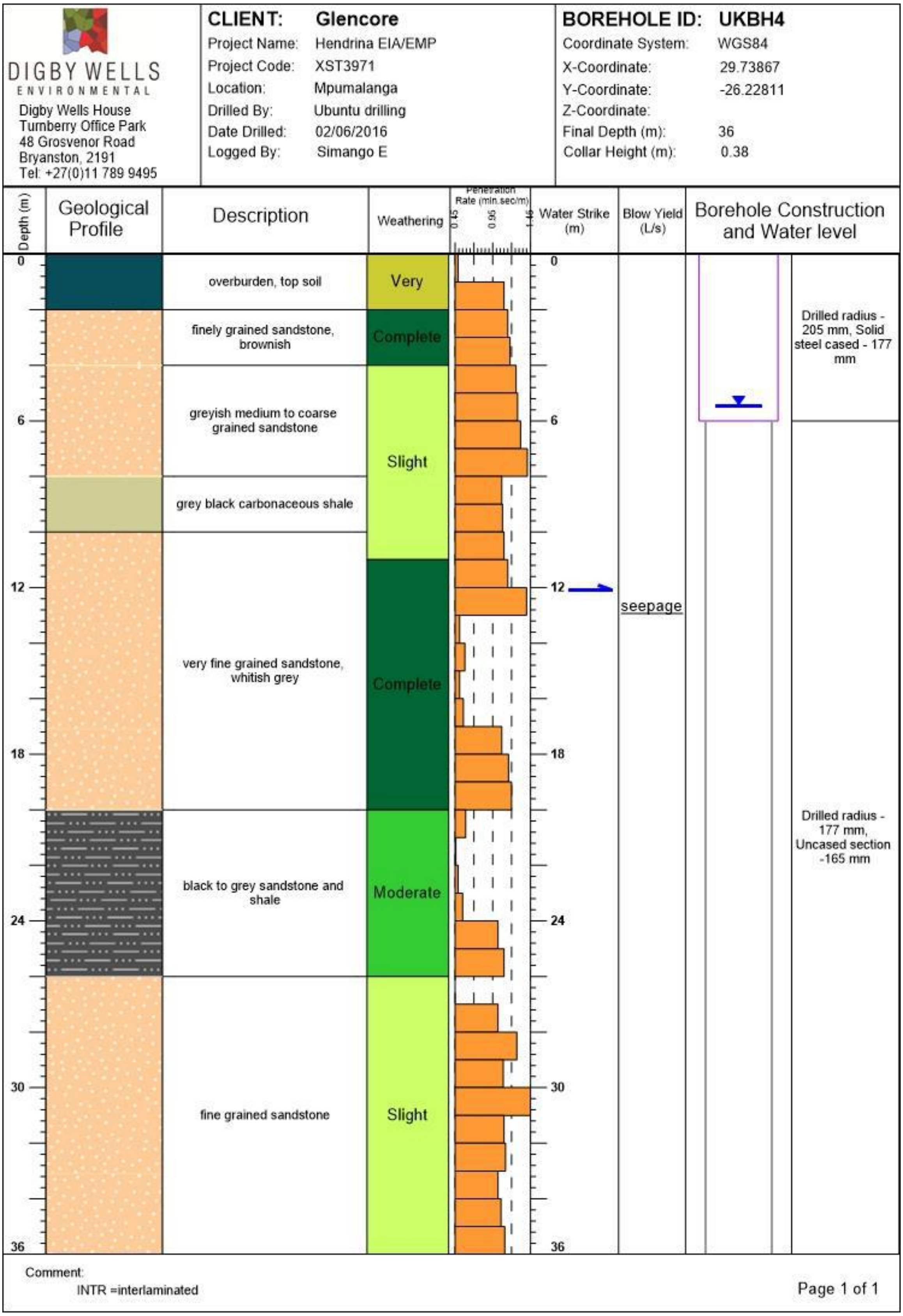
DIGBY WELLS ENVIRONMENTAL
Digby Wells House
Turnberry Office Park
48 Grosvenor Road
Bryanston, 2191
Tel: +27(0)11 789 9495
CLIENT: Glencore
Project Name: Hendrina EIA/EMP
Project Code: XST3971
Location: Mpumalanga
Drilled By: Ubuntu drilling
Date Drilled: 02/06/2016
Logged By: Simango E
BOREHOLE ID: UKBH4
Coordinate System: WGS84
X-Coordinate: 29.73867
Y-Coordinate: -26.22811
Z-Coordinate:
Final Depth (m): 36
Collar Height (m): 0.38
Depth (m)
Geological Profile
Description
Weathering
Penetration Rate (min.sec/m)
0.45
0.95
1.46
Water Strike (m)
Blow Yield (L/s)
Borehole Construction and Water level
0
6
12
18
24
30
36
overburden, top soil
Very
finely grained sandstone, brownish
Complete
greyish medium to coarse grained sandstone
Slight
grey black carbonaceous shale
very fine grained sandstone, whitish grey
Complete
black to grey sandstone and shale
Moderate
fine grained sandstone
Slight
seepage
Drilled radius - 205 mm, Solid steel cased - 177 mm
Drilled radius - 177 mm, Uncased section -165 mm
Comment:
INTR =interlaminated
Page 1 of 1

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Digby Wells House
Turnberry Office Park
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CLIENT:	**Glencore**	**BOREHOLE ID:**	**UKBH8**
Project Name:	Hendrina EIA/EMP	Coordinate System:	WGS84
Project Code:	XST3971	X-Coordinate:	29.72848
Location:	Mpumalanga	Y-Coordinate:	-26.21311
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Date Drilled:	02/06/2016	Final Depth (m):	110
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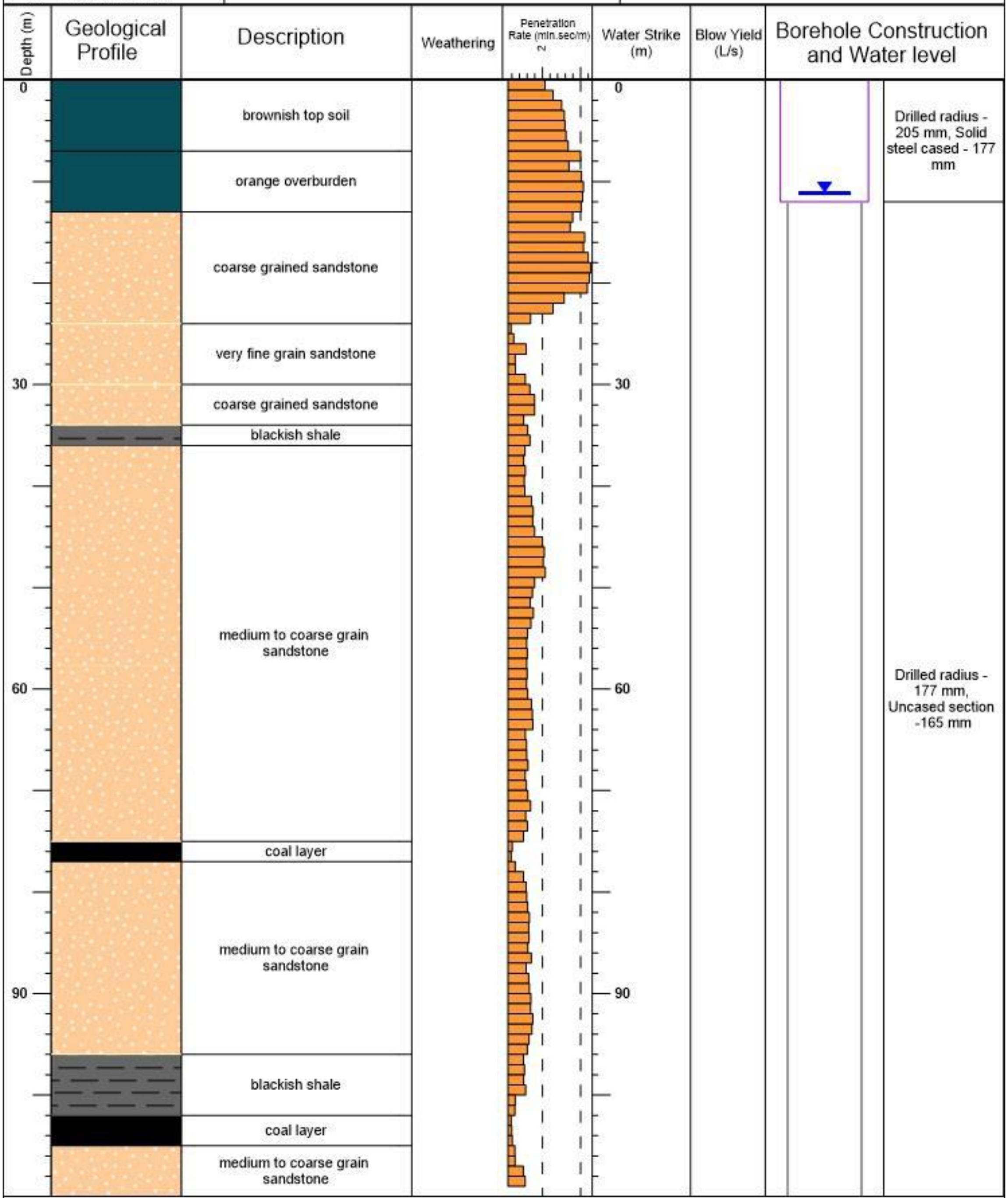

Comment:

Appendix C: List of Hydrocensus and NGA Boreholes

BH ID	X	Y	Zcoord	Survey Date	Farm name	Owner	BH depth	Water level	Abstraction Rate	BH Usage	BH status	Field EC	Field pH	Field TDS	T (0C)	Comment
BMKBH1	29.843224	-26.289934	1,736.42	17/03/2016	Bosmanskrans 217	Christo Coetzee	not known	12.6	not known	Domestic	Hydrocensus	313	7.8	217	18.9	water also used at mechanical workshop , sampled from a tap
DWKBH1	29.823109	-26.241024	1,727.02	16/03/2016	De Wttekrans 218	Vincent Schultze	not known	3.11	not known	Unused	Hydrocensus	-	-	-	-	no sample obtained
DWKBH2	29.824174	-26.245595	1,740.71	16/03/2016	De Wttekrans 218	Vincent Schultze	not known	-	not known	Stock Watering	Hydrocensus	319	7.9	221	19.7	cattle about 50 m from windmill, no water level measured as borehole is completely covered
GFNBH1	29.727008	-26.174588	1,626.45	18/03/2016	Grasfontein 199	Lloyd John James	70	4.5	1000 L/d	Domestic and Stock	Hydrocensus	146	7.7	99.8	27	cattle kraal close to borehole
GFNBH2	29.726659	-26.173194	1,668.22	18/03/2016	Grasfontein 199	Lloyd John James	70	2.7	not known	Domestic	Hydrocensus	89.3	6.76	63.2	184	
GFNBH3	29.715203	-26.16803	1,692.97	18/03/2016	Grasfontein 199	Lloyd John James	70-90	8.71	not known	Domestic	Hydrocensus	75.3	6.57	51.4	24.4	sample taken from tap in the house
GFNSP1	29.717864	-26.179502	1,657.03	18/03/2016	Grasfontein 199	Lloyd John James	0	0	not known	Unused	Hydrocensus	248	7.01	172	24.4	
MGNBH1	29.846552	-26.240602	1,725.68	18/03/2016	Morgenster 204	Adam van Niekerk	not known	7.62	not known	Stock Watering	Hydrocensus	212	7.01	148	19.3	sheep grazing in close proximity of borehole, borehole uncapped
MGNBH2	29.845226	-26.235725	1,743.47	18/03/2016	Morgenster 204	Adam van Niekerk	not known	16.08	not known	Domestic and Stock	Hydrocensus	240	7.31	164	19.8	equipped with a submersible pump
MGNBH3	29.830477	-26.222872	1,717.11	18/03/2016	Morgenster 204	Adam van Niekerk	not known	7.05	not known	Domestic and Stock	Hydrocensus	230	6.95	161	19.1	
MGNBH4	29.835103	-26.23377	1,711.99	18/03/2016	Morgenster 204	Adam van Niekerk	not known	2.76	not known	Unused	Hydrocensus	319	8.03	25	18.4	currently not used, borehole doesnot have a cap
MGNBH5	29.839248	-26.207529	1,741.47	18/03/2016	Morgenster 204	Adam van Niekerk	not known	27.3	not known	Domestic and Stock	Hydrocensus	294	9.07	203	24.1	sample taken from dam
MGNBH6	29.839796	-26.24455	1,749.29	18/03/2016	Morgenster 204	Adam van Niekerk	not known	9.9	not known	Unused	Hydrocensus	-	-	-	-	no sample taken, dead bird remain in borehole
MGNBH7	29.839795	-26.243235	1,755.50	18/03/2016	Morgenster 204	Adam van Niekerk	not known	dry	-	Unused	Hydrocensus	-	-	-	-	borehole dry
MVL SRING	29.800523	-26.233331	1,713.03	16/03/2016	Mooivley 219	Vincent Schultze				Unknown	Hydrocensus					
MVLB6	29.746339	-26.249784	1,724.42	16/03/2016	Mooivley 219	Vincent Schultze				Unknown	Hydrocensus					
MVLBH1	29.780852	-26.243457	1,660.67	16/03/2016	Mooivley 219	Vincent Schultze	not known	6.24	not known	Domestic and Stock	Hydrocensus	9.54 ms/m	8.13	6.66ppt	1961	cattle nearby
MVLBH10	29.744244	-26.242873	1,711.88	17/03/2016	Mooivley 219	Vincent Schultze	not known	-	not known	Unused	Hydrocensus	434	7.55	273	18.3	oily envrionment

BH ID	X	Y	Zcoord	Survey Date	Farm name	Owner	BH depth	Water level	Abstraction Rate	BH Usage	BH status	Field EC	Field pH	Field TDS	T (0C)	Comment
MVLBH11	29.759139	-26.239603	1,698.63	17/03/2016	Mooivley 219	Vincent Schultze	not known	-	-	Unused	Hydrocensus	-	-	-	-	windmill not working, no water level no sample
MVLBH12	29.758472	-26.241844	1,708.17	17/03/2016	Mooivley 219	Vincent Schultze	not known	-	-	Unused	Hydrocensus	-	-	-	-	windmill not working, no water level no sample
MVLBH13	29.753756	-26.240904	1,699.97	17/03/2016	Mooivley 219	Vincent Schultze	not known	26.7	not known	Unused	Hydrocensus	-	-	-	-	borehole not working and disconnected from pump
MVLBH14	29.754938	-26.253811	1,711.63	17/03/2016	Mooivley 219	Vincent Schultze	not known	-	-	Stock Watering	Hydrocensus	-	-	-	-	could not access the dam where borehole pumps water into
MVLBH15	29.759033	-26.248351	1,701.99	17/03/2016	Mooivley 219	Vincent Schultze	not known	-	-	Unused	Hydrocensus	-	-	-	-	broken windmill not working anymore, no sample no water level
MVLBH16	29.770748	-26.243836	1,674.17	17/03/2016	Mooivley 219	Vincent Schultze	not known	11.82	not known	Irrigation	Hydrocensus	137.2	7.5	96.6	17.5	
MVLBH1A	29.780848	-26.243431	1,660.32	16/03/2016	Mooivley 219	Vincent Schultze	not known	6.16	not known	Domestic and Stock	Hydrocensus	-	-	-	-	no sample as borehole is right next to MVLBH1
MVLBH2	29.793198	-26.235941	1,704.69	16/03/2016	Mooivley 219	Vincent Schultze	not known	-	not known	Stock Watering	Hydrocensus	128	7.39	90	22.7	windmill pumps to a small reseivoir used for cattle watering
MVLBH2A	29.79428	-26.234698	1,697.07	16/03/2016	Mooivley 219	Vincent Schultze	not known	-	-	Unused	Hydrocensus	-	-	-	-	broken windmill not working anymore
MVLBH3	29.797232	-26.239329	1,716.17	16/03/2016	Mooivley 219	Vincent Schultze	not known	8.3	-	Unused	Hydrocensus	-	-	-	-	borehole not used
MVLBH4	29.794595	-26.242827	1,682.75	16/03/2016	Mooivley 219	Vincent Schultze	not known	dry	not known	Unused	Hydrocensus	-	-	-	-	dry borehole
MVLBH5	29.771078	-26.253798	1,686.42	16/03/2016	Mooivley 219	Vincent Schultze	not known	6.16	not known	Unused	Hydrocensus	427	6.64	290	19.6	windmill not working
MVLBH7	29.737652	-26.253145	1,699.69	16/03/2016	Mooivley 219	Vincent Schultze	not known	-	not known	Domestic	Hydrocensus	-	-	-	-	no water sample as pump was broken at the time.
MVLBH8	29.734746	-26.241291	1,652.41	17/03/2016	Mooivley 219	Vincent Schultze	not known	2.13	not known	Stock Watering	Hydrocensus	-	-	-	-	no sample taken as wind was not blowing at the moment
MVLBH9	29.746035	-26.24351	1,713.66	17/03/2016	Mooivley 219	Vincent Schultze	not known	-	-	Unused	Hydrocensus	393	7.67	269	18.5	windmill heavily oiled and completely closed no water level was measured
OPKBH1	29.846294	-26.289566	1,730.05	17/03/2016	Orpenskraal 238	Christo Coetzee	not known	3.98	not known	Domestic	Hydrocensus	202	7.77	140	19.7	
OPKBH2	29.851484	-26.29094	1,745.09	17/03/2016	Orpenskraal 238	Christo Coetzee	not known	5.28	not known	Domestic	Hydrocensus	262	8.59	183	18.7	water sample obtained from a jojo tank fed by the borehole
OPKBH3	29.824791	-26.296438	1,736.45	17/03/2016	Orpenskraal 238	Pieter Oosthuysen	not known	dry	-	Unused	Hydrocensus	-	-	-	-	dry borehole

BH ID	X	Y	Zcoord	Survey Date	Farm name	Owner	BH depth	Water level	Abstraction Rate	BH Usage	BH status	Field EC	Field pH	Field TDS	T (0C)	Comment
OPKBH4	29.822219	-26.301249	1,733.58	17/03/2016	Orpenskraal 238	Pieter Oosthuysen	not known	6.36	not known	Stock Watering	Hydrocensus	386	7.66	268	17.9	
OPKBH5	29.821474	-26.289567	1,725.34	17/03/2016	Orpenskraal 238	Pieter Oosthuysen	not known	10.73	not known	Stock Watering	Hydrocensus	357	7.67	252	18.3	
OPKBH6	29.815007	-26.314343	1,768.81	17/03/2016	Orpenskraal 238	Pieter Oosthuysen	not known	-	not known	Unused	Hydrocensus	-	-	-	-	broken windmill not working anymore
OPKBH7	29.816781	-26.318259	1,774.81	17/03/2016	Orpenskraal 238	Pieter Oosthuysen	not known	8.75	not known	Stock Watering	Hydrocensus	580	7.63	400	17.3	
ORJBH1	29.747748	-26.20363	1,565.50	15/03/2016	Oranje vallei 201	Rocky Kane-berman	not known	13.28	not known	Domestic, Stock and Irrigation	Hydrocensus	1233	7.7	6.34ppt	19.5	kraal nearby
ORJBH2	29.741907	-26.201476	1,687.96	15/03/2016	Oranje vallei 201	Rocky Kane-berman	not known	-	-	Stock Watering	Hydrocensus	-	-	-	-	no sample obtained as the wind was not blowing and therefore the windmill was not pumping
ORJBH3	29.731972	-26.196981	1,708.55	15/03/2016	Oranje vallei 201	Rocky Kane-berman	not known	9.12	not known	Stock Watering	Hydrocensus	9.41 ms/m	7.46	6.58 ppt	19.9	generator pump heavily oiled
TWF SP1	29.772185	-26.182712	1,644.81	17/03/2016	Tweefontein 203	Alfeus Pretorius	0	0	not known	Stock Watering	Hydrocensus	131.8	7.73	93.3	19.8	spring flows throughout the year.
TWFBH1	29.776674	-26.185389	1,668.03	17/03/2016	Tweefontein 205	Alfeus Pretorius	78	9.72	not known	Domestic	Hydrocensus	140.6	7.35	98.9	17.6	
TWFBH2	29.775641	-26.185418	1,664.63	17/03/2016	Tweefontein 206	Alfeus Pretorius	96	22.2	not known	Domestic	Hydrocensus	335	7.38	233	19	
TWFSP2	29.764189	-26.195494	1,643.92	17/03/2016	Tweefontein 204	Alfeus Pretorius	0	0	not known	Stock Watering	Hydrocensus	66.3	6.7	45.7	19.2	spring flows throughout the year.
VLBBH1	29.738836	-26.170465	1,681.97	18/03/2016	Vaalbank 177	Lloyd John James	92	-	not known	Domestic, Stock and Irrigation	Hydrocensus	138	7.61	96.1	20.4	apparently itï¿½s a strong borehole
VLBSP1	29.739477	-26.164254	1,678.80	18/03/2016	Vaalbank 177	Lloyd John James	0	0	0	Stock Watering	Hydrocensus	290	5.9	202	29.3	cattle grazing in close proximity of spring
VLBSP2	29.739105	-26.163656	1,679.61	18/03/2016	Vaalbank 177	Lloyd John James	0	0	0	Stock Watering	Hydrocensus	-	-	-	-	no sample taken as they are all in close proximity to VLBSP1 and feeds the same dam
VLBSP3	29.739056	-26.163459	1,679.52	18/03/2016	Vaalbank 177	Lloyd John James	0	0	0	Stock Watering	Hydrocensus	-	-	-	-	no sample taken as they are all in close proximity to VLBSP1 and feeds the same dam
VLBSP4	29.739158	-26.162804	1,679.31	18/03/2016	Vaalbank 177	Lloyd John James	0	0	0	Stock Watering	Hydrocensus	-	-	-	-	no sample taken as they are all in close proximity to VLBSP1 and feeds the same dam
VLBSP5	29.747362	-26.167819	1,659.85	18/03/2016	Vaalbank 177	Lloyd John James	0	0	0	Stock Watering	Hydrocensus	91	7.4	67.9	25.5	spring used for stock watering

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VLBSP6	29.739828	-26.171068	1,675.40	18/03/2016	Vaalbank 177	Lloyd John James	0	0	0	Stock Watering	Hydrocensus	207	6.49	144	21.3	covered with algae
VLBSP7	29.744094	-26.17567	1,663.26	18/03/2016	Vaalbank 177	Lloyd John James	0	0	0	Stock Watering	Hydrocensus	157.8	7.13	109.4	27.2	pumps to a bigger dam, cattle drink from it
VLBSP8	29.742961	-26.176909	1,670.31	18/03/2016	Vaalbank 177	Lloyd John James	0	0	0	Stock Watering	Hydrocensus	255	6.9	182	22.7	pumps water to the house
2629BA0 0001	29.52473	-26.22556	1600							Unknown	NGA					
2629BA0 0002	29.52473	-26.22557	1600							Unknown	NGA					
2629BA0 0003	29.52474	-26.22556	1600	24/01/1984				4	2.220 l/s	Unknown	NGA					
2629BA0 0004	29.52473	-26.22558	1600	18/01/1984				20	0.310 l/s	Unknown	NGA					
2629BA0 0005	29.52475	-26.22556	1600	18/01/1984				4	3.330 l/s	Unknown	NGA					
2629BA0 0006	29.52473	-26.22559	1600							Unknown	NGA					
2629BA0 0007	29.52476	-26.22556	1600	27/10/1937				3.66	0.080 l/s	Irrigation	NGA					
2629BA0 0008	29.52473	-26.2256	1600	11/05/1939				11.58	0.250 l/s	Unknown	NGA					
2629BA0 0009	29.70862	-26.17612	1700	26/06/1984				3.5	0.330 l/s	Unknown	NGA					
2629BA0 0010	29.70863	-26.17612	1700							Unknown	NGA					
2629BA0 0011	29.70862	-26.17613	1700	23/08/1986				12	0.300 l/s	Unknown	NGA					
2629BA0 0012	29.71918	-26.01612	1620							Unknown	NGA					
2629BA0 0013	29.71918	-26.01613	1620	22/05/1984				12	0.530 l/s	Unknown	NGA					
2629BA0 0014	29.69556	-26.19222	1700							Unknown	NGA					
2629BA0 0015	29.735	-26.19917	1700							Unknown	NGA					
2629BA0 0016	29.73501	-26.19917	1700	19/07/1984				28	0.830 l/s	Unknown	NGA					

BH ID	X	Y	Zcoord	Survey Date	Farm name	Owner	BH depth	Water level	Abstraction Rate	BH Usage	BH status	Field EC	Field pH	Field TDS	T (0C)	Comment
2629BA00017	29.72251	-26.15556	1660	12/10/1963				17.07		Domestic	NGA					
2629BA00018	29.72252	-26.15557	1660	02/06/1967				11.89		Domestic	NGA					
2629BA00019	29.71362	-26.14917	1660	08/03/1948				18.29		Irrigation	NGA					
2629BA00020	29.52477	-26.22556	1600	20/01/1984				3	0.590 l/s	Unknown	NGA					
2629BA00021	29.5914	-26.01723	1600	07/11/1919				8.84		Domestic	NGA					
2629BA00022	29.72254	-26.1556	1660	16/10/1937				15.24		Domestic	NGA					
2629BA00023	29.72255	-26.15561	1660	21/09/1937				10.97		Irrigation	NGA					
2629BA00024	29.7214	-26.15	1660	27/02/1948				14.63		Irrigation	NGA					
2629BA00025	29.72141	-26.15001	1660	27/01/1948				13.11		Domestic	NGA					
2629BA00026	29.72142	-26.15002	1660	01/07/1955				6.4		Irrigation	NGA					
2629BA00029	29.72145	-26.15005	1660	25/10/1955				7.32		Unknown	NGA					
2629BA00030	29.72146	-26.15006	1660	26/02/1954				6.1		Domestic	NGA					
2629BA00031	29.72139	-26.14999	1660	21/06/1967				19.5		Domestic	NGA					
2629BA00032	29.72138	-26.14998	1660	06/09/1937				24.38		Domestic	NGA					
2629BA00033	29.69501	-26.18501	1720							Unknown	NGA					
2629BA00034	29.695	-26.185	1720	08/02/1984				4		Unknown	NGA					
2629BA00035	29.5767	-26.09641	1680	05/02/1913				20.73		Irrigation	NGA					
2629BA00036	29.57671	-26.09642	1680	20/01/1913				4.57		Irrigation	NGA					
2629BA00037	29.57672	-26.09643	1680							Unknown	NGA					

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2629BA0 0038	29.57667	-26.09638	1680	17/12/1912				18.9		Irrigation	NGA					
2629BA0 0039	29.57666	-26.09637	1680	04/12/1912				3.66		Domestic	NGA					
2629BA0 0040	29.57665	-26.09636	1680	30/07/1910				12.8		Irrigation	NGA					
2629BA0 0041	29.57664	-26.09635	1680	15/01/1913				4.57		Irrigation	NGA					
2629BA0 0042	29.57668	-26.09639	1680	10/01/1914				5.49		Domestic	NGA					
2629BA0 0043	29.72418	-26.05834	1620	30/04/1928				6.1		Domestic	NGA					
2629BA0 0044	29.71946	-26.10973	1640	20/07/1914				12.19		Domestic	NGA					
2629BA0 0045	29.71947	-26.10974	1640	25/07/1914				6.1		Domestic	NGA					
2629BA0 0046	29.62473	-26.13611	1700	09/04/1913				9.75		Irrigation	NGA					
2629BA0 0047	29.62168	-26.06167	1620	07/08/1914				12.19		Domestic	NGA					
2629BA0 0048	29.62169	-26.06168	1620	18/08/1914				11.89		Irrigation	NGA					
2629BA0 0049	29.6217	-26.06169	1620	27/08/1914				9.14		Stock Watering	NGA					
2629BA0 0050	29.62171	-26.0617	1620	19/09/1914				15.24		Domestic	NGA					
2629BA0 0051	29.62173	-26.06172	1620	12/10/1974				10.97		Irrigation	NGA					
2629BA0 0052	29.62167	-26.06166	1620	29/07/1937				19.81		Irrigation	NGA					
2629BA0 0053	29.62166	-26.06165	1620	24/09/1913				5.33		Irrigation	NGA					
2629BA0 0054	29.62172	-26.06171	1620	30/09/1914				7.62		Stock Watering	NGA					
2629BA0 0055	29.64223	-26.1689	1700	18/02/1911				21.34		Domestic	NGA					
2629BA0 0056	29.64224	-26.16891	1700	02/03/1911				10.97		Irrigation	NGA					

BH ID	X	Y	Zcoord	Survey Date	Farm name	Owner	BH depth	Water level	Abstraction Rate	BH Usage	BH status	Field EC	Field pH	Field TDS	T (0C)	Comment
2629BA0 0057	29.57669	-26.0964	1680	03/01/1914				4.88		Irrigation	NGA					
2629BA0 0058	29.57668	-26.09638	1680	03/10/1913				8.08		Stock Watering	NGA					
2629BA0 0059	29.73637	-26.09415	1660	21/06/1983				25	0.410 l/s	Stock Watering	NGA					
2629BA0 0060	29.73636	-26.09414	1660	06/06/1983				12	1.660 l/s	Stock Watering	NGA					
2629BA0 0061	29.5116	-26.15195	1640	11/09/1913				5.18		Irrigation	NGA					
2629BA0 0062	29.57251	-26.21917	1640	12/11/1920				7.92		Domestic	NGA					
2629BA0 0063	29.59834	-26.16167	1680							Unknown	NGA					
2629BA0 0064	29.59835	-26.16168	1680	21/09/1910				9.14		Domestic	NGA					
2629BA0 0065	29.59836	-26.16169	1680	19/01/1911				21.34		Irrigation	NGA					
2629BA0 0066	29.59837	-26.1617	1680	24/05/1939				12.19		Unknown	NGA					
2629BA0 0067	29.59833	-26.16166	1680	29/05/1939				15.24		Unknown	NGA					
2629BA0 0068	29.73639	-26.09417	1660	25/11/1937				17.37		Domestic	NGA					
2629BA0 0069	29.7364	-26.09418	1660	07/05/1928				6.1		Domestic	NGA					
2629BA0 0070	29.54973	-26.04667	1640	02/10/1914				4.57		Stock Watering	NGA					
2629BA0 0071	29.54974	-26.04668	1640	25/09/1914				3.66		Domestic	NGA					
2629BA0 0072	29.54975	-26.04669	1640	29/04/1913				8.23		Irrigation	NGA					
2629BA0 0073	29.55917	-26.15306	1640	28/04/1910				3.96		Irrigation	NGA					
2629BA0 0074	29.55918	-26.15307	1640	12/05/1910				24.69		Irrigation	NGA					
2629BA0 0075	29.55919	-26.15308	1640	07/07/1910				51.82		Domestic	NGA					

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2629BA0 0076	29.62751	-26.2125	1640	22/04/1913				8.23		Unknown	NGA					
2629BA0 0077	29.62752	-26.21251	1640	05/05/1983				15		Unknown	NGA					
2629BA0 0078	29.51195	-26.09445	1680							Unknown	NGA					
2629BA0 0079	29.51196	-26.09446	1680	05/09/1928				15.54		Irrigation	NGA					
2629BA0 0080	29.51197	-26.09447	1680	30/10/1928				7.01		Irrigation	NGA					
2629BA0 0081	29.51199	-26.09448	1680	17/10/1928				9.75		Irrigation	NGA					
2629BA0 0082	29.512	-26.09449	1680	01/12/1913				10.36		Irrigation	NGA					
2629BA0 0083	29.51194	-26.09444	1680	21/11/1913				4.88		Irrigation	NGA					
2629BA0 0084	29.51193	-26.09443	1680	13/11/1913				10.97		Irrigation	NGA					
2629BA0 0085	29.51192	-26.09442	1680							Unknown	NGA					
2629BA0 0086	29.51191	-26.09441	1680	19/03/1984				6		Unknown	NGA					
2629BA0 0087	29.5119	-26.0944	1680							Unknown	NGA					
2629BA0 0088	29.53695	-26.07667	1660	08/05/1913				15.24		Irrigation	NGA					
2629BA0 0089	29.53696	-26.07668	1660	18/06/1913				4.57		Irrigation	NGA					
2629BA0 0090	29.53697	-26.07669	1660	19/05/1913				12.19		Irrigation	NGA					
2629BA0 0091	29.53698	-26.0767	1660	05/06/1913				7.32		Irrigation	NGA					
2629BA0 0092	29.51861	-26.12529	1640	08/12/1913				13.41		Irrigation	NGA					
2629BA0 0093	29.51862	-26.12528	1640	03/09/1913				10.06		Unknown	NGA					
2629BA0 0094	29.51163	-26.12527	1660	17/12/1913				7.16		Irrigation	NGA					

BH ID	X	Y	Zcoord	Survey Date	Farm name	Owner	BH depth	Water level	Abstraction Rate	BH Usage	BH status	Field EC	Field pH	Field TDS	T (0C)	Comment
2629BB0 0001	29.96501	-26.11528	1660							Unknown	NGA					
2629BB0 0002	29.77834	-26.18223	1660	28/02/1984				9	0.560 l/s	Unknown	NGA					
2629BB0 0003	29.77835	-26.18223	1660	14/05/1984				14	0.530 l/s	Unknown	NGA					
2629BB0 0004	29.7739	-26.04333	1640							Unknown	NGA					
2629BB0 0005	29.7739	-26.04334	1640	23/08/1983				40	0.130 l/s	Unknown	NGA					
2629BB0 0006	29.77391	-26.04333	1640							Unknown	NGA					
2629BB0 0007	29.84059	-26.16584	1660	15/09/1983				20	0.370 l/s	Unknown	NGA					
2629BB0 0008	29.84056	-26.16584	1660	31/07/1972				6	0.250 l/s	Irrigation	NGA					
2629BB0 0009	29.80001	-26.22834	1720							Unknown	NGA					
2629BB0 0010	29.75807	-26.24168	1700	03/07/1920				2.44		Stock Watering	NGA					
2629BB0 0011	29.75806	-26.24167	1700	24/06/1920				9.14		Unknown	NGA					
2629BB0 0012	29.8678	-26.23806	1680	05/03/1938				12.19		Stock Watering	NGA					
2629BB0 0013	29.86779	-26.23806	1680	12/04/1911				7.93		Irrigation	NGA					
2629BB0 0014	29.86779	-26.23807	1680	03/04/1911				11.28		Irrigation	NGA					
2629BB0 0015	29.79973	-26.22703	1720	10/03/1956				18.29		Domestic	NGA					
2629BB0 0016	29.79974	-26.22702	1720	17/03/1956				7.62		Stock Watering	NGA					
2629BB0 0017	29.79975	-26.22701	1720	02/07/1914				7.01		Domestic	NGA					
2629BB0 0018	29.79976	-26.227	1720	25/06/1914				9.14		Domestic	NGA					
2629BB0 0019	29.79977	-26.22699	1720	17/06/1914				9.14		Domestic	NGA					

BH ID	X	Y	Zcoord	Survey Date	Farm name	Owner	BH depth	Water level	Abstraction Rate	BH Usage	BH status	Field EC	Field pH	Field TDS	T (0C)	Comment
2629BB0 0020	29.79978	-26.22698	1720	02/05/1911				4.57		Irrigation	NGA					
2629BB0 0021	29.79979	-26.22697	1720	06/05/1983				4	0.420 l/s	Stock Watering	NGA					
2629BB0 0022	29.7998	-26.22696	1720							Stock Watering	NGA					
2629BB0 0023	29.79981	-26.22695	1720	13/05/1983				21	0.190 l/s	Stock Watering	NGA					
2629BB0 0024	29.9664	-26.16723	1720	24/08/1992				10	9.720 l/s	Irrigation	NGA					
2629BB0 0025	29.82031	-26.04724	1640	04/01/1926				7.92		Irrigation	NGA					
2629BB0 0026	29.8203	-26.04723	1640	09/01/1926				7.31		Irrigation	NGA					
2629BB0 0027	29.82029	-26.04722	1640	09/05/1973				12		Unknown	NGA					
2629BB0 0028	29.7739	-26.09667	1640	28/12/1937				3.66		Domestic	NGA					
2629BB0 0029	29.78806	-26.01334	1620	26/06/1937				14.63		Irrigation	NGA					
2629BB0 0030	29.78807	-26.01335	1620	08/07/1937				11.58		Domestic	NGA					
2629BB0 0031	29.7739	-26.04333	1640	18/01/1926				15.24		Irrigation	NGA					
2629BB0 0032	29.77391	-26.04334	1640	09/08/1939				15.24		Unknown	NGA					
2629BB0 0033	29.77392	-26.04335	1640	06/06/1984				3.5		Unknown	NGA					
2629BB0 0034	29.77393	-26.04336	1640	22/09/1983				4		Unknown	NGA					
2629BB0 0035	29.77394	-26.04337	1640							Unknown	NGA					
2629BB0 0036	29.77389	-26.04332	1640							Unknown	NGA					
2629BB0 0037	29.77388	-26.04331	1640	23/08/1983				40		Irrigation	NGA					
2629BB0 0038	29.77387	-26.0433	1640							Stock Watering	NGA					

BH ID	X	Y	Zcoord	Survey Date	Farm name	Owner	BH depth	Water level	Abstraction Rate	BH Usage	BH status	Field EC	Field pH	Field TDS	T (0C)	Comment
2629BB00039	29.77251	-26.18306	1640	21/04/1994				20	0.500 l/s	Irrigation	NGA					
2629BC00001	29.59139	-26.45612	1700	24/09/1958				4.57	0.760 l/s	Unknown	NGA					
2629BC00004	29.59141	-26.45612	1700							Unknown	NGA					
2629BC00005	29.65529	-26.33667	1660	05/08/1921				7.62	0.010 l/s	Domestic	NGA					
2629BC00006	29.57473	-26.27556	1640	13/07/1918				6.1	0.010 l/s	Domestic	NGA					
2629BC00007	29.6553	-26.33667	1660	19/04/1921				9.14	0.010 l/s	Domestic	NGA					
2629BC00008	29.65529	-26.33668	1660	14/05/1921				7.01	0.010 l/s	Domestic	NGA					
2629BC00009	29.65531	-26.33667	1660	04/06/1921				9.14		Domestic	NGA					
2629BC00010	29.65529	-26.33669	1660							Unknown	NGA					
2629BC00011	29.65533	-26.33667	1660	06/09/1921				6.4		Domestic	NGA					
2629BC00012	29.65532	-26.33667	1660	06/04/1921				15.24		Domestic	NGA					
2629BC00013	29.65529	-26.3367	1660	18/08/1921				9.14	3.940 l/s	Domestic	NGA					
2629BC00014	29.67337	-26.44778	1720							Unknown	NGA					
2629BC00015	29.67336	-26.4478	1720							Unknown	NGA					
2629BC00016	29.52196	-26.47279	1680							Unknown	NGA					
2629BC00017	29.52197	-26.47279	1680							Unknown	NGA					
2629BC00018	29.5164	-26.47279	1680							Unknown	NGA					
2629BC00019	29.52196	-26.4728	1680							Unknown	NGA					
2629BC00020	29.5539	-26.48806	1700	22/03/1910				1.83		Unknown	NGA					

BH ID	X	Y	Zcoord	Survey Date	Farm name	Owner	BH depth	Water level	Abstraction Rate	BH Usage	BH status	Field EC	Field pH	Field TDS	T (0C)	Comment
2629BC00021	29.51556	-26.46306	1680	22/03/1910				10.67	0.010 l/s	Domestic	NGA					
2629BC00022	29.52199	-26.47279	1680	19/05/1921				1.83		Irrigation	NGA					
2629BC00023	29.52196	-26.47282	1680	08/12/1961				0.61	2.030 l/s	Domestic	NGA					
2629BC00024	29.522	-26.47279	1680	13/01/1962				9.14	0.350 l/s	Irrigation	NGA					
2629BC00025	29.52196	-26.47283	1680	20/01/1962				6.71	1.810 l/s	Irrigation	NGA					
2629BC00026	29.52201	-26.47279	1680	29/11/1958				1.22	0.030 l/s	Unknown	NGA					
2629BC00027	29.52196	-26.47284	1680	04/11/1958				3.05	0.180 l/s	Stock Watering	NGA					
2629BC00028	29.52202	-26.47279	1680	24/10/1958				3.05	0.090 l/s	Unknown	NGA					
2629BC00029	29.52196	-26.47285	1680	31/08/1961				6.1	0.540 l/s	Domestic	NGA					
2629BC00030	29.52203	-26.47279	1680	25/11/1961				1.22	0.540 l/s	Irrigation	NGA					
2629BC00031	29.52196	-26.47286	1680	17/08/1961				3.05	1.090 l/s	Domestic	NGA					
2629BC00032	29.52204	-26.47279	1680							Unknown	NGA					
2629BC00033	29.5289	-26.47834	1680							Unknown	NGA					
2629BC00034	29.52205	-26.47279	1680	04/02/1960				7.62	1.630 l/s	Domestic	NGA					
2629BC00035	29.52196	-26.47288	1680	10/02/1960				1.52	0.040 l/s	Domestic	NGA					
2629BC00036	29.52206	-26.47279	1680	15/02/1960				5.49	1.630 l/s	Domestic	NGA					
2629BC00037	29.52196	-26.47289	1680	07/10/1939				7.32	0.030 l/s	Unknown	NGA					
2629BC00038	29.52207	-26.47279	1680	13/10/1939				2.44	0.050 l/s	Unknown	NGA					
2629BC00039	29.52196	-26.4729	1680	06/07/1948				6.4	0.240 l/s	Domestic	NGA					

BH ID	X	Y	Zcoord	Survey Date	Farm name	Owner	BH depth	Water level	Abstraction Rate	BH Usage	BH status	Field EC	Field pH	Field TDS	T (0C)	Comment
2629BC0 0040	29.5164	-26.4728	1680	23/08/1912				9.14	0.040 l/s	Domestic	NGA					
2629BC0 0041	29.52208	-26.47279	1680							Unknown	NGA					
2629BC0 0042	29.52196	-26.47291	1680							Unknown	NGA					
2629BC0 0043	29.52209	-26.47279	1680	05/10/1938				2.13	5.050 l/s	Domestic	NGA					
2629BC0 0044	29.52196	-26.47292	1680	28/04/1939				1.83	5.050 l/s	Unknown	NGA					
2629BC0 0045	29.5221	-26.47279	1680							Unknown	NGA					
2629BC0 0046	29.52196	-26.47293	1680							Unknown	NGA					
2629BC0 0047	29.52211	-26.47279	1680	23/09/1938				3.05	0.190 l/s	Unknown	NGA					
2629BC0 0048	29.52196	-26.47294	1680							Unknown	NGA					
2629BC0 0049	29.52212	-26.47279	1680	28/09/1939				14.63	0.060 l/s	Unknown	NGA					
2629BC0 0050	29.52196	-26.47295	1680	23/09/1966				17.37	0.040 l/s	Unknown	NGA					
2629BC0 0051	29.52213	-26.47279	1680							Unknown	NGA					
2629BC0 0052	29.52196	-26.47296	1680	28/11/1966				8.23	0.910 l/s	Irrigation	NGA					
2629BC0 0053	29.52214	-26.47279	1680	15/03/1952				6.1		Irrigation	NGA					
2629BC0 0054	29.52196	-26.47297	1680	08/04/1952				57.91	0.030 l/s	Unknown	NGA					
2629BC0 0055	29.52215	-26.47279	1680	15/04/1952				7.32	0.880 l/s	Unknown	NGA					
2629BC0 0057	29.52216	-26.47279	1680	27/06/1910				13.72	4.160 l/s	Stock Watering	NGA					
2629BC0 0058	29.52196	-26.47299	1680	27/06/1910				9.45	0.470 l/s	Stock Watering	NGA					
2629BC0 0060	29.52217	-26.47279	1680	19/10/1909				10.06	1.840 l/s	Unknown	NGA					

BH ID	X	Y	Zcoord	Survey Date	Farm name	Owner	BH depth	Water level	Abstraction Rate	BH Usage	BH status	Field EC	Field pH	Field TDS	T (0C)	Comment
2629BC00061	29.52196	-26.473	1680	04/04/1910				10.67	0.010 l/s	Irrigation	NGA					
2629BC00062	29.52218	-26.47279	1680	11/07/1910				4.57	0.020 l/s	Domestic	NGA					
2629BC00063	29.5164	-26.43945	1680							Unknown	NGA					
2629BC00064	29.5164	-26.43946	1680	09/03/1967				4.82	0.030 l/s	Unknown	NGA					
2629BC00065	29.51641	-26.43945	1680	21/03/1967				8	8.020 l/s	Irrigation	NGA					
2629BC00066	29.5164	-26.43947	1680							Unknown	NGA					
2629BC00067	29.51642	-26.43945	1680							Unknown	NGA					
2629BC00068	29.5164	-26.43948	1680							Unknown	NGA					
2629BC00069	29.51643	-26.43945	1680							Unknown	NGA					
2629BC00070	29.5164	-26.43949	1680							Unknown	NGA					
2629BC00071	29.51644	-26.43945	1680							Unknown	NGA					
2629BC00072	29.5164	-26.4395	1680							Unknown	NGA					
2629BC00073	29.51645	-26.43945	1680							Unknown	NGA					
2629BC00074	29.5164	-26.43951	1680							Unknown	NGA					
2629BC00075	29.51646	-26.43945	1680							Unknown	NGA					
2629BC00076	29.5164	-26.43952	1680							Unknown	NGA					
2629BC00077	29.51647	-26.43945	1680							Unknown	NGA					
2629BC00078	29.5164	-26.43953	1680	02/09/1966				3.25	0.010 l/s	Unknown	NGA					
2629BC00079	29.55529	-26.43945	1700	14/12/1955				5.49	0.800 l/s	Domestic	NGA					

BH ID	X	Y	Zcoord	Survey Date	Farm name	Owner	BH depth	Water level	Abstraction Rate	BH Usage	BH status	Field EC	Field pH	Field TDS	T (0C)	Comment
2629BC0 0080	29.5414	-26.43945	1680							Unknown	NGA					
2629BC0 0081	29.54141	-26.43946	1680							Unknown	NGA					
2629BC0 0082	29.54141	-26.43945	1680							Unknown	NGA					
2629BC0 0083	29.54142	-26.43947	1680							Unknown	NGA					
2629BC0 0085	29.57752	-26.41723	1680	04/10/1910				7.32	2.080 l/s	Irrigation	NGA					
2629BC0 0086	29.54695	-26.37834	1620	22/01/1910				7.01	0.840 l/s	Irrigation	NGA					
2629BC0 0087	29.54695	-26.37835	1620	29/11/1955				5.49	0.100 l/s	Irrigation	NGA					
2629BC0 0088	29.54696	-26.37834	1620	06/12/1955				5.49	0.170 l/s	Stock Watering	NGA					
2629BC0 0089	29.63306	-26.30056	1640	23/11/1937				10.06	0.050 l/s	Irrigation	NGA					
2629BC0 0090	29.63306	-26.30057	1640	08/03/1911				3.05	0.370 l/s	Domestic	NGA					
2629BC0 0091	29.6164	-26.26445	1640	21/10/1912				7.01	1.310 l/s	Irrigation	NGA					
2629BC0 0092	29.59973	-26.48389	1700	22/12/1937				22.86	0.210 l/s	Stock Watering	NGA					
2629BC0 0093	29.59974	-26.48389	1700	27/01/1938				15.24	0.040 l/s	Unknown	NGA					
2629BC0 0094	29.59973	-26.4839	1700	27/11/1909				18.9	3.030 l/s	Domestic	NGA					
2629BC0 0095	29.59975	-26.48389	1700	08/11/1909				9.14	3.150 l/s	Domestic	NGA					
2629BC0 0096	29.59973	-26.48391	1700	11/08/1938				2.74	0.380 l/s	Unknown	NGA					
2629BC0 0097	29.59976	-26.48389	1700	14/03/1939				2.44	0.030 l/s	Unknown	NGA					
2629BC0 0098	29.59973	-26.48392	1700	04/04/1939				13.72	0.190 l/s	Unknown	NGA					
2629BC0 0099	29.59977	-26.48389	1700							Unknown	NGA					

BH ID	X	Y	Zcoord	Survey Date	Farm name	Owner	BH depth	Water level	Abstraction Rate	BH Usage	BH status	Field EC	Field pH	Field TDS	T (0C)	Comment
2629BC0 0100	29.59973	-26.48393	1700	22/12/1959				21.34	0.010 l/s	Domestic	NGA					
2629BC0 0101	29.59978	-26.48389	1700	25/01/1962				3.05	0.250 l/s	Irrigation	NGA					
2629BC0 0102	29.59973	-26.48394	1700	17/02/1962				6.1	18.290 l/s	Domestic	NGA					
2629BC0 0103	29.59979	-26.48389	1700							Unknown	NGA					
2629BC0 0104	29.59973	-26.48395	1700	06/06/1952				18.29	1.000 l/s	Irrigation	NGA					
2629BC0 0105	29.5998	-26.48389	1700	10/03/1962				10.67	0.810 l/s	Stock Watering	NGA					
2629BC0 0106	29.71112	-26.41917	1680	30/03/1976				5.3	1.420 l/s	Unknown	NGA					
2629BC0 0107	29.68306	-26.47584	1700							Unknown	NGA					
2629BC0 0108	29.68307	-26.47584	1700							Unknown	NGA					
2629BC0 0109	29.63778	-26.46445	1720							Unknown	NGA					
2629BC0 0110	29.6678	-26.44778	1700							Unknown	NGA					
2629BC0 0113	29.67491	-26.47685	1680							Unknown	NGA					
2629BC0 0114	29.6749	-26.47684	1680							Unknown	NGA					
2629BC0 0115	29.67489	-26.47683	1680							Unknown	NGA					
2629BC0 0116	29.67488	-26.47682	1680	05/09/1957				7.62		Unknown	NGA					
2629BC0 0117	29.67487	-26.47681	1680	29/07/1957				14.63		Unknown	NGA					
2629BC0 0118	29.67486	-26.4768	1680	20/07/1957				12.19		Unknown	NGA					
2629BC0 0119	29.67485	-26.47679	1680	07/01/1957				15.24		Unknown	NGA					
2629BC0 0120	29.67484	-26.47678	1680	10/12/1956				30.48		Unknown	NGA					

BH ID	X	Y	Zcoord	Survey Date	Farm name	Owner	BH depth	Water level	Abstraction Rate	BH Usage	BH status	Field EC	Field pH	Field TDS	T (0C)	Comment
2629BC00121	29.67483	-26.47677	1680	11/06/1957				12.19		Unknown	NGA					
2629BC00122	29.67482	-26.47676	1680	23/10/1973				6.5		Unknown	NGA					
2629BC00123	29.67481	-26.47675	1680	19/03/1974				25		Unknown	NGA					
2629BC00126	29.67478	-26.47672	1680							Stock Watering	NGA					
2629BC00127	29.67477	-26.47671	1680	19/01/1957				13.72		Domestic	NGA					
2629BC00128	29.67476	-26.4767	1680	27/07/1907				6.71		Unknown	NGA					
2629BC00129	29.67475	-26.47669	1680	19/07/1910				11.58		Stock Watering	NGA					
2629BC00130	29.69474	-26.47668	1720	20/12/1910				12.5		Irrigation	NGA					
2629BC00131	29.67473	-26.47667	1680	26/06/1918				12.19		Domestic	NGA					
2629BC00132	29.70506	-26.27811	1640	10/05/1956				15.24		Unknown	NGA					
2629BC00133	29.70505	-26.2781	1640	26/04/1956				3.05		Unknown	NGA					
2629BC00134	29.70504	-26.27809	1640	18/04/1956				2.44		Unknown	NGA					
2629BC00135	29.70503	-26.27808	1640	10/04/1956				9.14		Domestic	NGA					
2629BC00136	29.70502	-26.27807	1640	29/03/1956				3.05		Domestic	NGA					
2629BC00137	29.70501	-26.27806	1640	24/03/1956				6.1		Irrigation	NGA					
2629BC00138	29.66779	-26.44778	1700							Unknown	NGA					
2629BC00139	29.67334	-26.44779	1720							Unknown	NGA					
2629BC00140	29.66779	-26.44779	1700	02/02/1974				10		Unknown	NGA					
2629BC00141	29.67334	-26.4478	1720	23/07/1928				24.38		Irrigation	NGA					

BH ID	X	Y	Zcoord	Survey Date	Farm name	Owner	BH depth	Water level	Abstraction Rate	BH Usage	BH status	Field EC	Field pH	Field TDS	T (0C)	Comment
2629BC0 0142	29.66085	-26.46001	1720	09/03/1954				2.74		Domestic	NGA					
2629BC0 0143	29.67335	-26.44779	1720	10/07/1928				30.48		Unknown	NGA					
2629BC0 0144	29.6517	-26.44391	1700							Unknown	NGA					
2629BC0 0145	29.65171	-26.4439	1700	14/06/1910				3.05		Domestic	NGA					
2629BC0 0146	29.65172	-26.44389	1700	08/03/1910				13.72		Domestic	NGA					
2629BC0 0147	29.65806	-26.27501	1660	01/03/1911				6.71		Domestic	NGA					
2629BC0 0148	29.7114	-26.41945	1680							Unknown	NGA					
2629BC0 0149	29.68531	-26.37615	1680							Unknown	NGA					
2629BC0 0150	29.6853	-26.37614	1680	27/07/1987				22		Unknown	NGA					
2629BC0 0151	29.68529	-26.37613	1680	28/09/1910				10.06		Irrigation	NGA					
2629BC0 0152	29.68528	-26.37612	1680	05/12/1910				4.88		Irrigation	NGA					
2629BC0 0153	29.525	-26.25944	1620	11/08/1994				15	0.200 l/s	Unknown	NGA					
2629BC0 0153	29.525	-26.25944	1620	11/08/1994				15	0.200 l/s	Unknown	NGA					
2629BC0 0154	29.60667	-26.37585	1620	11/08/1994				20	10.000 l/s	Irrigation	NGA					
2629BC0 0154	29.60667	-26.37585	1620	11/08/1994				20	10.000 l/s	Irrigation	NGA					
2629BC0 0155	29.60667	-26.37584	1620	10/08/1994				50	0.110 l/s	Irrigation	NGA					
2629BC0 0155	29.60667	-26.37584	1620	10/08/1994				50	0.110 l/s	Irrigation	NGA					
2629BC0 0156	29.56889	-26.45194	1700							Stock Watering	NGA					
2629BC0 0157	29.57223	-26.44833	1700							Stock Watering	NGA					

BH ID	X	Y	Zcoord	Survey Date	Farm name	Owner	BH depth	Water level	Abstraction Rate	BH Usage	BH status	Field EC	Field pH	Field TDS	T (0C)	Comment
2629BC00158	29.58056	-26.46111	1700							Stock Watering	NGA					
2629BC00159	29.58223	-26.46556	1700							Stock Watering	NGA					
2629BC00160	29.5297	-26.44206	1680							Irrigation	NGA					
2629BC00161	29.52778	-26.44431	1680							Unknown	NGA					
2629BD00001	29.98678	-26.28133	1770	10/12/1991				5.31		Domestic	NGA					
2629BD00002	29.94746	-26.30351	1730	11/12/1991				27.98		Stock Watering	NGA					
2629BD00003	29.9109	-26.26753	1720	11/12/1991				16.02		Domestic	NGA					
2629BD00004	29.9066	-26.27049	1730	11/12/1991				23.15		Domestic	NGA					
2629BD00005	29.8618	-26.28335	1700	11/12/1991				19.11		Domestic	NGA					
2629BD00006	29.85915	-26.31932	1770	11/12/1991				9.17		Domestic	NGA					
2629BD00007	29.78836	-26.30546	1750	12/12/1991				10.2		Domestic	NGA					
2629BD00008	29.75942	-26.34688	1740	12/12/1991				18.38		Domestic	NGA					
2629BD00009	29.92354	-26.40266	1720	12/12/1991				10.19		Domestic	NGA					
2629BD00010	29.922	-26.34677	1770	12/12/1991				10.28		Domestic	NGA					
2629BD00011	29.94128	-26.33674	1760							Domestic	NGA					
2629BD00012	29.90251	-26.34222	1820							Unknown	NGA					
2629BD00013	29.90251	-26.34223	1820	13/04/1957				4.88	0.320 l/s	Stock Watering	NGA					
2629BD00014	29.90252	-26.34222	1820	28/03/1957				5.49	2.130 l/s	Stock Watering	NGA					
2629BD00015	29.90251	-26.34224	1820	14/03/1957				1.52	0.110 l/s	Stock Watering	NGA					

BH ID	X	Y	Zcoord	Survey Date	Farm name	Owner	BH depth	Water level	Abstraction Rate	BH Usage	BH status	Field EC	Field pH	Field TDS	T (0C)	Comment
2629BD00016	29.90253	-26.34222	1820	20/02/1957				6.1	0.090 l/s	Stock Watering	NGA					
2629BD00017	29.90251	-26.34225	1820	06/02/1957				6.1	0.010 l/s	Stock Watering	NGA					
2629BD00018	29.60806	-26.37556	1640	22/01/1969				11.89		Unknown	NGA					
2629BD00019	29.60807	-26.37557	1640							Unknown	NGA					
2629BD00020	29.60808	-26.37556	1640							Unknown	NGA					
2629BD00021	29.60809	-26.37558	1640	22/01/1969				7.62	0.350 l/s	Irrigation	NGA					
2629BD00022	29.94973	-26.345	1760						0.010 l/s	Irrigation	NGA					
2629BD00023	29.90254	-26.34222	1820							Unknown	NGA					
2629BD00024	29.90251	-26.34226	1820						1.140 l/s	Irrigation	NGA					
2629BD00025	29.88306	-26.38389	1800							Domestic	NGA					
2629BD00026	29.79278	-26.32695	1720							Unknown	NGA					
2629BD00027	29.79278	-26.32696	1720	31/10/1988				15	3.660 l/s	Unknown	NGA					
2629BD00028	29.79279	-26.32695	1720	18/11/1988				30	0.170 l/s	Unknown	NGA					
2629BD00029	29.79278	-26.32697	1720							Unknown	NGA					
2629BD00030	29.7928	-26.32695	1720							Unknown	NGA					
2629BD00031	29.79278	-26.32698	1720							Unknown	NGA					
2629BD00033	29.78945	-26.46056	1640							Unknown	NGA					
2629BD00034	29.79334	-26.3264	1720	31/01/1984				9	0.440 l/s	Unknown	NGA					
2629BD00035	29.94112	-26.3714	1700	13/07/1983				16	0.750 l/s	Unknown	NGA					

BH ID	X	Y	Zcoord	Survey Date	Farm name	Owner	BH depth	Water level	Abstraction Rate	BH Usage	BH status	Field EC	Field pH	Field TDS	T (0C)	Comment
2629BD0 0036	29.88917	-26.44111	1700	31/05/1984				11	1.000 l/s	Unknown	NGA					
2629BD0 0038	29.98001	-26.27167	1740	25/04/1907				6.1		Unknown	NGA					
2629BD0 0039	29.82584	-26.31	1740	06/06/1935				5.18		Irrigation	NGA					
2629BD0 0040	29.8164	-26.33389	1740	10/02/1914				12.19		Irrigation	NGA					
2629BD0 0041	29.84973	-26.42501	1740	20/08/1912				13.41		Domestic	NGA					
2629BD0 0042	29.94362	-26.42084	1720	21/02/1910				11.89		Irrigation	NGA					
2629BD0 0043	29.93675	-26.30676	1680							Unknown	NGA					
2629BD0 0044	29.93674	-26.30675	1680							Unknown	NGA					
2629BD0 0047	29.93671	-26.30671	1680	02/11/1950				6.71		Stock Watering	NGA					
2629BD0 0048	29.9367	-26.3067	1680	24/10/1958				4.88		Domestic	NGA					
2629BD0 0049	29.93669	-26.30669	1680	14/07/1950				3.05		Stock Watering	NGA					
2629BD0 0050	29.93668	-26.30668	1680	30/06/1950				6.1		Stock Watering	NGA					
2629BD0 0051	29.93667	-26.30667	1680	13/03/1950				9.14		Irrigation	NGA					
2629BD0 0052	29.90898	-26.47259	1680							Unknown	NGA					
2629BD0 0053	29.90897	-26.47258	1680	16/08/1951				33.53		Unknown	NGA					
2629BD0 0054	29.90896	-26.47257	1680	25/08/1951				27.43		Domestic	NGA					
2629BD0 0055	29.90895	-26.47256	1680	01/09/1951				9.14		Stock Watering	NGA					
2629BD0 0057	29.90893	-26.47254	1680	25/09/1951				10.97		Domestic	NGA					
2629BD0 0058	29.90892	-26.47253	1680	06/07/1912				5.49		Domestic	NGA					

BH ID	X	Y	Zcoord	Survey Date	Farm name	Owner	BH depth	Water level	Abstraction Rate	BH Usage	BH status	Field EC	Field pH	Field TDS	T (0C)	Comment
2629BD0 0059	29.9089	-26.47251	1680	26/06/1912				9.14		Domestic	NGA					
2629BD0 0060	29.93059	-26.36947	1720	19/10/1982				12		Unknown	NGA					
2629BD0 0061	29.93058	-26.36946	1720							Unknown	NGA					
2629BD0 0062	29.93057	-26.36945	1720	12/07/1983				16	0.690 l/s	Unknown	NGA					
2629BD0 0063	29.7917	-26.46087	1640							Unknown	NGA					
2629BD0 0064	29.79169	-26.46086	1640							Unknown	NGA					
2629BD0 0065	29.79168	-26.46085	1640							Unknown	NGA					
2629BD0 0066	29.79167	-26.46084	1640	01/12/1983				16	0.840 l/s	Stock Watering	NGA					
2629BD0 0067	29.88917	-26.43972	1700	30/05/1984				11	0.950 l/s	Stock Watering	NGA					
2629BD0 0068	29.84989	-26.37055	1760							Unknown	NGA					
2629BD0 0069	29.84988	-26.37055	1760							Unknown	NGA					
2629BD0 0070	29.84987	-26.37055	1760							Unknown	NGA					
2629BD0 0071	29.84986	-26.37055	1760							Unknown	NGA					
2629BD0 0072	29.84985	-26.37055	1760	29/11/1919				6.1		Stock Watering	NGA					
2629BD0 0073	29.84984	-26.37055	1760	28/01/1920				5.49		Domestic	NGA					
2629BD0 0074	29.84983	-26.37055	1760	22/04/1920				7.32		Stock Watering	NGA					
2629BD0 0075	29.84982	-26.37055	1760	13/09/1955				1.52		Unknown	NGA					
2629BD0 0076	29.84981	-26.37054	1760	11/08/1913				17.37		Irrigation	NGA					
2629BD0 0077	29.84981	-26.37053	1760	21/08/1913				9.44		Irrigation	NGA					

BH ID	X	Y	Zcoord	Survey Date	Farm name	Owner	BH depth	Water level	Abstraction Rate	BH Usage	BH status	Field EC	Field pH	Field TDS	T (0C)	Comment
2629BD0 0078	29.8498	-26.37052	1760	17/07/1939				45.72		Unknown	NGA					
2629BD0 0079	29.84979	-26.37051	1760	29/09/1919				4.57		Irrigation	NGA					
2629BD0 0080	29.84978	-26.3705	1760	23/10/1919				13.72		Irrigation	NGA					
2629BD0 0081	29.84977	-26.37049	1760	08/11/1919				16.15		Irrigation	NGA					
2629BD0 0082	29.84976	-26.37048	1760	17/05/1920				12.19		Irrigation	NGA					
2629BD0 0083	29.84975	-26.37047	1760	24/08/1955				8.22		Domestic	NGA					
2629BD0 0084	29.84974	-26.37046	1760	10/04/1920				11.58		Irrigation	NGA					
2629BD0 0085	29.84973	-26.36946	1760	04/10/1955				3.05		Irrigation	NGA					
2629BD0 0086	29.79324	-26.3263	1720							Unknown	NGA					
2629BD0 0089	29.79321	-26.32627	1720	23/03/1971				10		Stock Watering	NGA					
2629BD0 0090	29.7932	-26.32626	1720							Unknown	NGA					
2629BD0 0091	29.79319	-26.32625	1720							Unknown	NGA					
2629BD0 0092	29.79318	-26.32624	1720							Unknown	NGA					
2629BD0 0093	29.79317	-26.32623	1720							Unknown	NGA					
2629BD0 0094	29.79316	-26.32622	1720							Unknown	NGA					
2629BD0 0095	29.79315	-26.32621	1720							Unknown	NGA					
2629BD0 0096	29.79314	-26.3262	1720	26/03/1969				3.66		Irrigation	NGA					
2629BD0 0097	29.79313	-26.32619	1720	05/05/1960				19.51		Stock Watering	NGA					
2629BD0 0098	29.79312	-26.32618	1720	07/06/1960				22.56		Stock Watering	NGA					

BH ID	X	Y	Zcoord	Survey Date	Farm name	Owner	BH depth	Water level	Abstraction Rate	BH Usage	BH status	Field EC	Field pH	Field TDS	T (0C)	Comment
2629BD00099	29.79311	-26.32617	1720	11/09/1958				41.45		Irrigation	NGA					
2629BD00100	29.7931	-26.32616	1720	19/12/1969				6.1		Stock Watering	NGA					
2629BD00101	29.79309	-26.32615	1720	11/06/1955				9.14		Unknown	NGA					
2629BD00102	29.79308	-26.32614	1720	27/08/1970				3.05		Unknown	NGA					
2629BD00103	29.79297	-26.32614	1720	15/04/1959				4.27		Stock Watering	NGA					
2629BD00104	29.79306	-26.32613	1720	28/06/1955				10.67		Stock Watering	NGA					
2629BD00105	29.79306	-26.32612	1720	18/06/1956				18.29		Domestic	NGA					
2629BD00106	29.87091	-26.29535	1720							Unknown	NGA					
2629BD00107	29.8709	-26.29534	1720	21/06/1913				14.94		Irrigation	NGA					
2629BD00108	29.87089	-26.29533	1720	12/06/1913				4.27		Irrigation	NGA					
2629BD00109	29.87088	-26.29532	1720	22/10/1955				9.14		Unknown	NGA					
2629BD00110	29.87087	-26.29531	1720	15/10/1955				15.24		Domestic	NGA					
2629BD00111	29.87086	-26.2953	1720	12/08/1955				3.66		Stock Watering	NGA					
2629BD00112	29.87085	-26.29529	1720	08/07/1955				3.66		Irrigation	NGA					
2629BD00113	29.87084	-26.29528	1720	27/06/1913				15.24		Irrigation	NGA					
2629BD00114	29.83867	-26.3356	1760							Unknown	NGA					
2629BD00115	29.83866	-26.33559	1760	20/07/1935				12.19		Unknown	NGA					
2629BD00116	29.83865	-26.33558	1760	07/11/1955				4.57		Domestic	NGA					
2629BD00117	29.83864	-26.33557	1760	19/01/1950				10.67		Stock Watering	NGA					

BH ID	X	Y	Zcoord	Survey Date	Farm name	Owner	BH depth	Water level	Abstraction Rate	BH Usage	BH status	Field EC	Field pH	Field TDS	T (0C)	Comment
2629BD00118	29.83863	-26.33556	1760	29/10/1955				6.1		Unknown	NGA					
2629BD00119	29.83862	-26.33557	1760	15/11/1955				15.24		Stock Watering	NGA					
2629BD00120	29.82478	-26.27756	1720							Unknown	NGA					
2629BD00121	29.82477	-26.27755	1720	28/02/1950				1.22		Stock Watering	NGA					
2629BD00122	29.82476	-26.27754	1720	09/02/1956				24.38		Stock Watering	NGA					
2629BD00123	29.82475	-26.27753	1720	02/02/1956				15.24		Unknown	NGA					
2629BD00124	29.82474	-26.27752	1720	10/05/1911				5.79		Irrigation	NGA					
2629BD00125	29.82473	-26.27751	1720	25/04/1911				4.27		Irrigation	NGA					
2629BD00126	29.79311	-26.29588	1740	24/01/1950				6.1		Unknown	NGA					
2629BD00127	29.7931	-26.29587	1740	28/01/1950				3.66		Domestic	NGA					
2629BD00128	29.79309	-26.29586	1740	11/02/1950				12.19		Unknown	NGA					
2629BD00129	29.79308	-26.29585	1740	20/02/1950				6.1		Stock Watering	NGA					
2629BD00130	29.79307	-26.29584	1740	16/01/1956				9.14		Domestic	NGA					
2629BD00131	29.79306	-26.29583	1740	26/01/1956				15.24		Stock Watering	NGA					
2629BD00132	29.88807	-26.34084	1800	18/07/1913				3.66		Unknown	NGA					
2629BD00133	29.88806	-26.34083	1800	09/07/1913				17.98		Irrigation	NGA					
a10262	29.72143	-26.15003	1660	15/06/1955				7.92		Irrigation	NGA					
a10263	29.72144	-26.15004	1660	21/06/1955				0.61		Unknown	NGA					
a10379	29.57751	-26.41723	1680	22/12/1955				4.57	2.120 l/s	Irrigation	NGA					
a13063	29.67479	-26.47673	1680	25/06/1957				7.62		Unknown	NGA					
a13064	29.6748	-26.47674	1680	12/07/1957				6.1		Unknown	NGA					
a13104	29.67492	-26.47686	1680							Unknown	NGA					

BH ID	X	Y	Zcoord	Survey Date	Farm name	Owner	BH depth	Water level	Abstraction Rate	BH Usage	BH status	Field EC	Field pH	Field TDS	T (0C)	Comment
a14145	29.58584	-26.44362	1690	19/09/1958				9.14	0.370 l/s	Stock Watering	NGA					
a14150	29.59139	-26.45613	1700	29/09/1958				9.14	0.330 l/s	Stock Watering	NGA					
a2239	29.52196	-26.47298	1680	25/06/1948				6.1	1.200 l/s	Irrigation	NGA					
a25157	29.79322	-26.32628	1720	24/03/1971				3.05		Stock Watering	NGA					
a36821	29.79323	-26.32629	1720	10/07/1987				33		Unknown	NGA					
MP10-0027	29.68519	-26.25176	1635							Unknown	NGA					
MP10-0028	29.84996	-26.34368	1780	13/06/2014				8.36		Unknown	NGA					

Appendix D: Laboratory Certificates of the Water Samples

aquatico Laboratories (Pty). Ltd.

Test Report

Client: Digby Wells & Associates
Address: 359 Pretoria Ave, Fern Isle, Section 5, Ferndale, Randburg
Report no: 30223
Project: Digby Wells & Associates

Date of certificate: 12 April 2016
Date accepted: 05 April 2016
Date completed: 12 April 2016
Revision: 0

	Analyses	Unit	Method	253322	253323	253324	253325	253326	253327	253328
	Lab no:			253322	253323	253324	253325	253326	253327	253328
	Date sampled:			16-Mar-16	17-Mar-16	18-Mar-16	17-Mar-16	15-Mar-16	17-Mar-16	18-Mar-16
	Sample type:			Water	Water	Water	Water	Water	Water	Water
	Locality description:			MVLBH1	MVLBH10	MGNBH1	OPKBH5	ORJBH1	TWFBH1	VLBBH1
A	pH @ 25°C	pH	ALM 20	8.65	8.54	8.50	8.65	8.30	8.22	8.31
A	Electrical conductivity (EC) @ 25°C	mS/m	ALM 20	52.5	50.8	29.3	45.3	24.2	17.1	19.4
A	Total dissolved solids (TDS)	mg/l	ALM 26	341	348	219	276	182	136	155
A	Total alkalinity	mg $CaCO_3$/l	ALM 01	260	268	148	256	96.1	76.2	85.2
A	Chloride (Cl)	mg/l	ALM 02	23.6	24.4	2.07	7.49	14.8	7.46	2.44
A	Sulphate (SO_4)	mg/l	ALM 03	1.58	5.22	10.4	2.39	1.76	2.78	2.22
A	Nitrate (NO_3) as N	mg/l	ALM 06	0.813	0.866	0.742	0.543	1.69	0.466	1.61
A	Ammonium (NH_4) as N	mg/l	ALM 05	0.407	0.297	<0.005	0.970	0.011	<0.005	<0.005
N	Ammonia (NH_3) as N	mg/l	ALM 26	0.075	0.040	<0.005	0.175	<0.005	<0.005	<0.005
A	Orthophosphate (PO_4) as P	mg/l	ALM 04	0.049	0.046	0.051	0.042	0.073	0.044	0.067
A	Fluoride (F)	mg/l	ALM 08	0.747	0.953	0.316	0.489	0.275	0.194	0.210
A	Calcium (Ca)	mg/l	ALM 30	30.7	38.2	21.4	28.8	23.1	16.8	15.5
A	Magnesium (Mg)	mg/l	ALM 30	16.1	11.9	8.50	12.2	5.40	4.88	4.75
A	Sodium (Na)	mg/l	ALM 30	61.6	60.8	27.6	55.6	16.5	9.15	14.1
A	Potassium (K)	mg/l	ALM 30	2.84	4.93	4.08	2.46	4.38	2.79	5.14
A	Aluminium (Al)	mg/l	ALM 31	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
A	Iron (Fe)	mg/l	ALM 31	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
A	Manganese (Mn)	mg/l	ALM 31	<0.001	0.025	<0.001	<0.001	<0.001	<0.001	<0.001
A	Chromium (Cr)	mg/l	ALM 31	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
A	Copper (Cu)	mg/l	ALM 31	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
A	Nickel (Ni)	mg/l	ALM 31	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
A	Zinc (Zn)	mg/l	ALM 31	<0.002	0.296	<0.002	<0.002	<0.002	<0.002	<0.002
A	Cobalt (Co)	mg/l	ALM 31	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
A	Cadmium (Cd)	mg/l	ALM 31	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
A	Lead (Pb)	mg/l	ALM 31	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
A	Arsenic (As)	mg/l	ALM 34	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
A	Selenium (Se)	mg/l	ALM 34	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
N	Silicon (Si)	mg/l	ALM 33	15.4	12.5	18.9	2.32	18.5	16.1	19.2
N	Silver (Ag)	mg/l	ALM 32	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

A = Accredited N = Non accredited O = Outsourced S = Sub-contracted NR = Not requested RTF = Results to follow NATD = Not able to determine
The results relates only to the test item tested.
Results reported against the limit of detection.
Results marked 'Not SANAS Accredited' in this report are not included in the SANAS Schedule of Accreditation for this laboratory.
Uncertainty of measurement available on request for all methods included in the SANAS Schedule of Accreditation.

aquatico Laboratories (Pty). Ltd.

Test Report

Client: Digby Wells & Associates
Address: 359 Pretoria Ave, Fern Isle, Section 5, Ferndale, Randburg
Report no: 30223
Project: Digby Wells & Associates

Date of certificate: 12 April 2016
Date accepted: 05 April 2016
Date completed: 12 April 2016
Revision: 0

Lab no:				253322	253323	253324	253325	253326	253327	253328
Date sampled:				16-Mar-16	17-Mar-16	18-Mar-16	17-Mar-16	15-Mar-16	17-Mar-16	18-Mar-16
Sample type:				Water	Water	Water	Water	Water	Water	Water
Locality description:				MVLBH1	MVLBH10	MGNBH1	OPKBH5	ORJBH1	TWFBH1	VLBBH1
	Analyses	**Unit**	**Method**							
N	Boron (B)	mg/l	ALM 33	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
N	Barium (Ba)	mg/l	ALM 33	0.578	0.258	0.004	1.19	0.125	<0.001	0.014
N	Beryllium (Be)	mg/l	ALM 33	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
N	Bismuth (Bi)	mg/l	ALM 32	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
N	Lithium (Li)	mg/l	ALM 32	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
N	Molybdenum (Mo)	mg/l	ALM 33	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
N	Strontium (Sr)	mg/l	ALM 33	1.47	0.630	0.130	0.765	0.180	0.062	0.023
N	Vanadium (V)	mg/l	ALM 33	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
N	Antimony (Sb)	mg/l	ALM 36	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
N	Tin (Sn)	mg/l	ALM 36	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
N	Titanium (Ti)	mg/l	ALM 36	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
A	Anions	meq	ALM 26	6.00	6.28	3.31	5.46	2.52	1.84	1.95
A	Cations	meq	ALM 26	5.64	5.69	3.07	4.99	2.43	1.71	1.91
A	Difference	%	ALM 26	-3.08	-4.90	-3.71	-4.46	-1.83	-3.63	-1.13
N	Acidity	mg $CaCO_3$/l	ALM 60	10.3	15.7	18.1	5.56	6.45	7.06	7.95

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aquatico Laboratories (Pty). Ltd.

ilac-MRA sanas Testing Laboratory T0685

Client: Digby Wells & Associates
Address: 359 Pretoria Ave, Fern Isle, Section 5, Ferndale, Randburg
Report no: 31628
Project: Digby Wells & Associates

Date of certificate: 27 June 2016
Date accepted: 14 June 2016
Date completed: 27 June 2016
Revision: 0

	Lab no:			3548	3549	3550	3551	3552	3553
	Date sampled:			10-Jun-2016	10-Jun-2016	10-Jun-2016	09-Jun-2016	09-Jun-2016	09-Jun-2016
	Sample type:			Water	Water	Water	Water	Water	Water
	Locality description:			TFBH1	OVBH2	MVBH3	BKBH6	UKBH8	UKBH4
	Analyses	**Unit**	**Method**						
A	pH @ 25°C	pH	ALM 20	8.18	7.71	7.08	8.02	8.38	8.05
A	Electrical conductivity (EC) @ 25°C	mS/m	ALM 20	25.1	19.5	24.4	823	87.6	53.4
A	Total Dissolved solids @ 180°C	mg/l	ALM 24	192	146	166	4776	594	268
A	Total alkalinity	mg CaCO3/l	ALM 01	134	88.7	91.0	1969	480	256
A	Chloride (Cl)	mg/l	ALM 02	5.59	1.22	13.7	1694	34.5	28.0
A	Sulphate (SO_4)	mg/l	ALM 03	2.49	4.36	1.94	0.804	20.6	10.3
A	Nitrate (NO_3) as N	mg/l	ALM 06	0.529	0.608	4.08	0.547	0.473	0.436
A	Ammonium (NH_4) as N	mg/l	ALM 05	0.280	0.340	0.475	3.40	0.923	0.290
N	Ammonia (NH_3) as N	mg/l	ALM 26	0.014	0.006	<0.005	0.112	0.072	0.012
A	Orthophosphate (PO_4) as P	mg/l	ALM 04	0.014	0.021	0.008	0.079	0.005	0.004
A	Fluoride (F)	mg/l	ALM 08	0.768	0.170	0.215	2.04	2.14	0.422
A	Calcium (Ca)	mg/l	ALM 30	11.2	9.81	19.9	16.3	34.4	46.5
A	Magnesium (Mg)	mg/l	ALM 30	4.60	3.03	5.27	11.7	15.5	13.7
A	Sodium (Na)	mg/l	ALM 30	40.3	22.2	18.1	2146	159	44.3
A	Potassium (K)	mg/l	ALM 30	3.73	4.75	8.66	10.7	5.23	18.8
A	Aluminium (Al)	mg/l	ALM 31	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
A	Iron (Fe)	mg/l	ALM 31	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
A	Manganese (Mn)	mg/l	ALM 31	<0.001	<0.001	0.231	<0.001	<0.001	<0.001
A	Chromium (Cr)	mg/l	ALM 31	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
A	Copper (Cu)	mg/l	ALM 31	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
A	Nickel (Ni)	mg/l	ALM 31	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
A	Zinc (Zn)	mg/l	ALM 31	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
A	Cobalt (Co)	mg/l	ALM 31	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
A	Cadmium (Cd)	mg/l	ALM 31	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
A	Lead (Pb)	mg/l	ALM 31	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
A	Arsenic (As)	mg/l	ALM 34	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
A	Selenium (Se)	mg/l	ALM 34	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
N	Silicon (Si)	mg/l	ALM 33	12.2	19.8	19.2	4.85	3.74	6.72
N	Silver (Ag)	mg/l	ALM 32	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

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Uncertainty of measurement available on request for all methods included in the SANAS Schedule of Accreditation.

Client: Digby Wells & Associates
Address: 359 Pretoria Ave, Fern Isle, Section 5, Ferndale, Randburg
Report no: 31628
Project: Digby Wells & Associates

Date of certificate: 27 June 2016
Date accepted: 14 June 2016
Date completed: 27 June 2016
Revision: 0

Lab no:				3548	3549	3550	3551	3552	3553
Date sampled:				10-Jun-2016	10-Jun-2016	10-Jun-2016	09-Jun-2016	09-Jun-2016	09-Jun-2016
Sample type:				Water	Water	Water	Water	Water	Water
Locality description:				TFBH1	OVBH2	MVBH3	BKBH6	UKBH8	UKBH4
	Analyses	**Unit**	**Method**						
N	Boron (B)	mg/l	ALM 33	<0.003	<0.003	<0.003	0.700	0.054	0.004
N	Barium (Ba)	mg/l	ALM 33	0.025	<0.001	<0.001	5.64	0.020	0.086
N	Beryllium (Be)	mg/l	ALM 33	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
N	Bismuth (Bi)	mg/l	ALM 32	<0.004	<0.004	<0.004	0.116	<0.004	<0.004
N	Lithium (Li)	mg/l	ALM 32	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
N	Molybdenum (Mo)	mg/l	ALM 33	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
N	Strontium (Sr)	mg/l	ALM 33	0.373	<0.001	0.067	4.38	1.55	0.607
N	Vanadium (V)	mg/l	ALM 33	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
N	Antimony (Sb)	mg/l	ALM 36	0.003	<0.001	<0.001	0.290	<0.001	<0.001
N	Tin (Sn)	mg/l	ALM 36	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
N	Titanium (Ti)	mg/l	ALM 36	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
A	Anions	meq	ALM 26	2.97	1.95	2.55	87.35	11.15	6.19
A	Cations	meq	ALM 26	2.81	1.85	2.48	95.62	10.09	5.88
A	Difference	%	ALM 26	-2.92	-2.65	-1.41	4.52	-4.98	-2.57
N	Acidity	mg CaCO3/l	ALM 60	19.3	14.7	35.1	<0.001	16.1	21.2

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Appendix E: Laboratory Certificates of the Acid-base Accounting and Leachate Tests

M and L Laboratory Services (Pty) Ltd
Reg No. 1974/001476/07 VAT No. 478013505
Proudly level 1 BBBEE company
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Ormonde, 2091
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E: joanne.barton@za.bureauveritas.com
W: www.bureauveritas.com

M&L LABS

Ref.No. : 9362975

Issued at : Johannesburg

Date : 11/07/2016

Certificate/Report

RESULTS REPORTED RELATED ONLY TO ITEMS TESTED

COMPANY NAME	:DIGBY WELLS & ASSOCIATES (SA) PTY LTD
ADDRESS	:PRIVATE BAG X10046 RANDBURG 2125
SUBJECT	:ANALYSIS OF 6 SOLID SAMPLES
MARKED	:AS BELOW
INSTRUCTED BY	:ROBEL GEBREKRISTOS
ORDER NO.	:XST 3791
RECEIVED ON	:10/06/2016
LAB NO(S)	:E34016 - E34021
DATE ANALYSED	:30/06/2016

The Analyses were carried out on 5% Aqueous Extracts of the Dried samples.

LAB NO:	E34016	E34017	E34018	E34019
SAMPLE MARKS	BKBH6 O	BKBH6 C	BKBH6 U	TFBH1 O
pH Value @ 18°C	9.6	9.5	7.9	9.6
Conductivity mS/m @ 25°C	9.2	6.11	5.86	10.8
Total Dissolved Solids	98	114	46	70
Calcium,Ca	0.2	1.1	0.1	0.4
Magnesium, Mg	<0.1	0.1	0.1	0.2
Sodium,Na	19.6	13.9	12.6	25
Potassium,K	0.4	0.3	0.3	0.8
Total Alkalinity as CaCO3	21	15	14	35
P Alk as CaCO3	3	2	Nil	3
Bicarbonate,HCO3	18	13	17	35
Carbonate, CO3	4	2	Nil	4
Chloride,Cl	5.4	8.5	3.9	4.2
Sulfate,SO4	10.3	2.4	1.5	8.0
Nitrate,NO3	2.9	3.0	2.4	2.5
Nitrate as N	0.7	0.7	0.5	0.6
Fluoride,F	0.3	0.4	0.4	0.8
Sum of Cations meq/ℓ	0.873	0.675	0.569	1.144
Sum of Anions meq/ℓ	0.849	0.659	0.481	1.067
% Error	1.390	1.246	8.411	3.512

The results are expressed in mg/l where applicable.

Note: The 1:20 Solid: Aqueous Extractions were carried out using deionised water.

****

Authorised Signature (original blue ink)

ALISON ACKERMAN
OPERATIONAL MANAGER

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RESULTS REPORTED RELATED ONLY TO ITEMS TESTED

Ref.No. : 9362975

Issued at : Johannesburg

Date : 11/07/2016

The Analyses were carried out on 5% Aqueous Extracts of the Dried samples.

LAB NO:	E34020	E34021
SAMPLE MARKS	TFBH1 C	TFBH1 U
pH Value @ 18°C	7.0	7.7
Conductivity mS/m @ 25°C	6.82	8.27
Total Dissolved Solids	42	58
Calcium,Ca	1.6	0.7
Magnesium, Mg	0.4	0.3
Sodium,Na	12.4	17.5
Potassium,K	0.5	1.2
Total Alkalinity as CaCO3	12	24
P Alk as CaCO3	Nil	Nil
Bicarbonate,HCO3	15	29
Carbonate, CO3	Nil	Nil
Chloride,Cl	2.4	3.2
Sulfate,SO4	5.2	5.6
Nitrate,NO3	3.4	3.8
Nitrate as N	0.8	0.9
Fluoride,F	0.4	0.4
Sum of Cations meq/ℓ	0.665	0.852
Sum of Anions meq/ℓ	0.490	0.769
% Error	15.148	5.113

The results are expressed in mg/l where applicable.

Note: The 1:20 Solid: Aqueous Extractions were carried out using deionised water.

Method reference: A list Appended.

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OPERATIONAL MANAGER

****

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M&L LABS

Ref.No. : 9362975
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Date : 11/07/2016

Certificate/Report

RESULTS REPORTED RELATED ONLY TO ITEMS TESTED

COMPANY NAME	:DIGBY WELLS & ASSOCIATES (SA) PTY LTD
ADDRESS	:PRIVATE BAG X10046 RANDBURG 2125
SUBJECT	:ANALYSIS OF 6 SAMPLES OF SOLID
MARKED	:AS BELOW
INSTRUCTED BY	:ROBEL GEBREKRISTOS
ORDER NO.	:XST3791
RECEIVED ON	:10/06/2016
LAB NO(S)	:E34016 - E34021
DATE ANALYSED	:22/06/2016

ACID-BASE ACCOUNTING

Analysis on the dried and milled samples:

SAMPLE MARKS:	LAB NO:	Total Sulphur, S%	Total Acidity Potential as $CaCO_3$ kg/tonne	Gross Neutralisation Potential as $CaCO_3$ kg/tonne	Net Neutralisation Potential as $CaCO_3$ kg/tonne (By Difference)
BKBH6 O	E34016	0.23	7.18	12.4	5.22
BKBH6 C	E34017	0.07	2.18	11.9	9.72
BKBH 6U	E34018	0.27	8.43	14.7	6.27
TFBH1O	E34019	1.45	45.3	19.3	-26.0
TFBH1 C	E34020	1.94	60.6	16.6	-44.0
TFBH1 U	E34021	0.55	17.2	19.8	2.60

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 Minesoils, EPA 600/2-78-054, 203 pp.

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Ref.No. : 9362975

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Date : 11/07/2016

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RESULTS REPORTED RELATED ONLY TO ITEMS TESTED

Analysis on the dried and milled samples:

SAMPLE MARKS:	LAB NO:	Total Sulfur, S %	Sulfate Sulfur as S %	Sulfide Sulfur, S (by calculation) %
BKBH6 O	E34016	0.23	<0.01	0.23
BKBH6 C	E34017	0.07	<0.01	0.07
BKBH 6U	E34018	0.27	<0.01	0.27
TFBH1O	E34019	1.45	0.03	1.42
TFBH1 C	E34020	1.94	0.04	1.90
TFBH1 U	E34021	0.55	0.02	0.53

Notes:

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

****

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Issued at : Johannesburg

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ADDRESS	:PRIVATE BAG X10046 RANDBURG 2125
SUBJECT	:ANALYSIS OF 6 SAMPLES OF SOLID
MARKED	:AS BELOW
INSTRUCTED BY	:ROBEL GEBREKRISTOS
ORDER NO.	:XST3791
RECEIVED ON	:10/06/2016
LAB NO(S)	:E34016 - E34021
DATE ANALYSED	:22/06/2016

Analysis on the dried and milled samples:

SAMPLE MARKS:	LAB NO:	pH Value @ 21°C (on a saturated paste)	NET ACID GENERATION AS H_2SO Kg/tonne
BKBH6 O	E34016	9.2	5.6
BKBH6 C	E34017	9.0	0.73
BKBH6U	E34018	9.0	2.18
TFBH1 O	E34019	8.6	31.8
TFBH1 C	E34020	8.6	23.6
TFBH1 U	E34021	8.3	4.37

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.

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ORDER NO.	:XST3791
RECEIVED ON	:10/06/2016
LAB NO(S)	:E34016 - E34021
DATE ANALYSED	:22/06/2016

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 X'Pert Pro powder diffractometer in θ–θ configuration with an X'Celerator detector and variable divergence- and fixed receiving slits with Fe filtered Co-Kα radiation (λ=1.789Å). The phases were identified using X'Pert Highscore plus software.

The relative phase amounts (weight%) were estimated using the Rietveld method (Autoquan Program). Errors are on the 3 sigma level in the column to the right of the amount. The quantitative results are listed below.

Comment:

- Mineral names may not reflect the actual compositions of minerals identified, but rather the mineral group (i.e "Muscovite" would represent the mineral group "Mica").
- Traces of additional phases may be present.

Quantitative Results:

E34016 BKBH6 O			E34017 BKBH6 C			E34018 BKBH6 U		
	weight%	3 σ error		weight%	3 σ error		weight%	3 σ error
Chlorite	2.61	0.75	Chlorite	6.17	0.93	Chlorite	9.08	0.89
Kaolinite	46.08	1.08	Kaolinite	44.76	1.2	Kaolinite	35.24	1.22
Microcline	4.04	0.45	Microcline	7.74	0.99	Microcline	6.31	0.87
Muscovite	6.52	0.69	Muscovite	8.58	0.69	Muscovite	9.8	0.96
Quartz	36.44	0.81	Quartz	24.85	0.72	Plagioclase	5.68	0.96
Siderite	4.3	0.45	Rutile	1.08	0.36	Quartz	27.56	1.05
			Siderite	6.82	0.51	Rutile	1.1	0.3
						Siderite	5.23	0.54

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E34019 TFBH1 O			E34020 TFBH1 C			E34021 TFBH1 U		
	weight%	3 σ error		weight%	3 σ error		weight%	3 σ error
Kaolinite	58.98	1.05	Kaolinite	55.75	1.17	Cristobalite	1.05	0.54
Microcline	5.91	0.87	Microcline	6.44	0.93	Kaolinite	30.3	1.06
Muscovite	4.3	0.48	Muscovite	7.73	0.75	Microcline	8.82	0.84
Pyrite	2.38	0.3	Pyrite	2.99	0.33	Muscovite	10.34	1.08
Quartz	27.09	0.78	Quartz	25.95	0.84	Plagioclase	5.96	0.87
Rutile	1.33	0.25	Rutile	1.15	0.26	Pyrite	0.77	0.3
						Quartz	42.75	1.26

Note: The XRD analysis was supplied by a Sub Contracted Laboratory.

Ideal Mineral Composition:

Chlorite	(Mg,Fe)5Al(AlSi3O10)(OH)8
Cristobalite	SiO2
Kaolinite	(Na,Ca)(Si,Al)4O8
Microcline	KAlSi3O8
Muscovite	KAl3Si3O10 (OH)2
Plagioclase	(Na,Ca)(Si,Al)4O8
Pyrite	FeS2
Quartz	SiO2
Rutile	TiO2
Siderite	FeCO3

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Authorised Signature (original blue ink)

ALISON ACKERMAN
OPERATIONAL MANAGER

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M&L LABS

Ref.No. : 9362975

Issued at : Johannesburg

Date : 11/07/2016

Certificate/Report

RESULTS REPORTED RELATED ONLY TO ITEMS TESTED

The analysis was carried out on as received basis.

LAB NO:	E34016	E34017	E34018	E34019	E34020	E34021
SAMPLE MARKS	BKBH6 O	BKBH6 C	BKBH6 U	TFBH1 O	TFBH1 C	TFBH1 U
Al2O3 %	18.432	24.687	22.218	28.336	27.564	18.429
CaO %	0.691	0.565	0.714	1.387	1.611	1.145
Fe2O3 %	4.309	7.885	6.592	3.874	4.434	5.637
K2O %	1.707	2.709	3.232	1.233	1.268	2.960
MgO %	0.652	1.321	1.544	1.104	1.094	1.203
MnO %	0.093	0.146	0.093	0.018	0.017	0.059
Na2O %	0.202	0.340	0.602	0.376	0.354	0.942
P2O5 %	0.095	0.127	0.113	0.065	0.060	0.102
Si\O2 %	72.286	59.757	63.035	61.256	60.637	68.328
SO3 %	0.598	0.340	0.556	1.240	1.424	0.809
Cr2O3 %	0.035	0.020	0.014	0.020	0.018	0.011
TiO2 %	0.923	1.130	1.018	1.255	1.218	0.798
CuO %	0.008	0.010	0.011	0.011	0.009	0.007
PbO %	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
As2O3 %	0.005	0.003	0.004	0.005	0.005	0.004
BaO %	0.048	0.076	0.098	0.083	0.090	0.097
V2O5 %	0.018	0.023	0.021	0.024	0.021	0.016
NiO %	0.006	0.003	0.007	0.004	0.006	0.003
ZrO2 %	0.019	0.017	0.027	0.030	0.031	0.024
ZnO %	0.009	0.017	0.015	0.009	0.011	0.009
SrO %	0.020	0.016	0.016	0.055	0.064	0.034
Ta2O5 %	0.004	0.003	<0.002	0.004	<0.002	0.003
WO3 %	0.056	0.022	0.027	0.008	0.008	0.046
Co3O4 %	0.010	0.007	0.009	0.005	0.006	0.011
TOTAL %	100.19	99.20	99.93	100.38	99.92	100.65

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DETERMINANT	METHOD	METHOD REFERENCE
pH value	Electrometric	W044-27-O
Conductivity	Potentiometric	W044-27-O
Total Dissolved Solids	Gravimetric	W044-03-W
Total Solids and loss on ignition	Gravimetric	A.P.H.A. 2540 BE
Total Alkalinity	Titrimetric	W044-50-O
Calcium	Atomic Absorption Spectrophotometry	W044-28-O
Magnesium	Atomic Absorption Spectrophotometry	W044-28-O
Potassium	Atomic Absorption Spectrophotometry	W044-28-O
Sodium	Atomic Absorption Spectrophotometry	W044-28-O
Colour Hazen unit	Lovibond Comparator	B.D.H Nessleriser method
Turbidity N.T.U	Comparator	W044-37-O
Odour	Physical testing	A.P.H.A. 2150 B
Carbonate Hardness	By calculation	A.P.H.A. 2340 A
Chloride	Colorimetric	W044-50-O
Sulfate	Colorimetric	W044-50-O
Sulfite	Titrimetric	A.P.H.A. 4500-SO_3 B
Settle-able solids	Volumetric Measurement	A.P.H.A. 2540-F
Nitrate	Nitrate electrode (Titrimetric)	A.P.H.A. 4500-NO_3 D
Nitrate	Colorimetric	W044-50-O
Nitrite	Colorimetric	W044-50-O
Fluoride	Colorimetric	W044-50-O
Mercury	ICP Scan	W044-28-O
Hexavalent Chromium	Colorimetric	W044-50-O
Total Cyanide	Colorimetric	W044-50-O
Phenolic Compounds as phenol	Colorimetric	W044-50-O
Biochemical Oxygen Demand	Titrimetric	A.P.H.A. 5210 B
Chemical Oxygen Demand	Colorimetric	A.P.H.A. 5220 C
Total Soluble Solids	Gravimetric	A.P.H.A. 2540 D
Soap, Oil and grease	Gravimetric	S.A.B.S. 1051
Sulfide sulphur	Lead Acetate	S.A.B.S. 1056
Sulfide sulphur	Titrimetric	A.P.H.A. 4500-S^2 F
Free and saline ammonia	Colorimetric	W044-50-O
Kjeldahl Nitrogen	Colorimetric	W044-50-O/ A.P.H.A.4500-Nogr B
Acidity/P-Alkalinity	Titrimetric	A.P.H.A. 2310/2320 B
Dissolved Oxygen	Titrimetric	A.P.H.A. 4500-O-C
Oxygen Absorbed (Permanganate value)	Titrimetric	S.A.B.S. 220
Residual/Free Chlorine	Colorimetric	A.P.H.A. 4500-Cl G
Bromide	Colorimetric	A.P.H.A. 4110 C
Calcium Carbonate saturated pH	Potentiometric	P.C.I. 9.28
Free Carbon Dioxide	Titrimetric	A.P.H.A. 4500-CO_2 C
Arsenic, Selenium, Titanium, Aluminium, Nickel, Manganese, Iron, Vanadium, Zinc, Antimony, Lead, Cobalt, Copper, Total Chromium, Silicon, Tin, Zirconium, Bismuth, Thallium, Beryllium, Cadmium, Boron, Phosphorus as Phosphate, Uranium, Molybdenum, Barium, Silver, Thorium, Lithium, (also Ca, Mg, K, Na).	ICP Quantitative Scan	W044-28-O