Palmietkuilen Environmental Impact Assessment

Groundwater Report

Project Number:

CNC4065

Prepared for:

Canyon Coal (Pty) Ltd

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This document has been prepared by Digby Wells Environmental.

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EXECUTIVE SUMMARY

Digby Wells Environmental (hereafter Digby Wells) has been appointed by Canyon Coal (Pty) Ltd (hereafter Canyon) to undertake groundwater specialist studies as part of a Mining Right Application (MRA), Environmental Impact Assessment (EIA) and an Integrated Water Use License Application (IWULA) for their proposed opencast Palmietkuilen Project. Digby Wells conducted a hydrocensus, ground geophysics, drilling of water boreholes, aquifer testing and numerical modelling as part of the hydrogeological study.

In order to have a better baseline understanding of the groundwater qualities around the proposed project area, 10 groundwater samples were collected during the hydrocensus. A total of 7 boreholes were found to be within the recommended SANS 241:2015 drinking guideline values. The water quality in the remaining 3 boreholes was found to be exceeding the acceptable acute health level of NO_3 concentrations when benchmarked against the SANS 241:2015. The high levels of nitrate could be associated with the application of fertilisers by the local farmers or from other natural causes.

A total of 42 boreholes were recorded during the hydrocensus and 6 more were drilled during this study, of these

- 8 (16.6%) are used for drinking only;
- 16 (33.3%) are used for drinking and livestock watering;
- 7 (14.5%) are used as groundwater monitoring points;
- The remaining 17 (35.4%) are unused.

The groundwater level in the project site ranges between 1 m and 73.51 m below ground level (mbgl).

The aquifer test conducted showed that the hydraulic conductivity of the aquifer ranges between 0.007 m/d and 0.154 m/d.

The impact assessment yielded the following results:

- The most extensive cone of depression is experienced at the end of the life of mine; with a maximum drawdown of 63 m and radius of influence extending a total of 3 km from the pit with 1.3 km beyond the project area boundary. Surface water resources i.e. the Verdrietlaagte stream and Dwars-in-die-Wegvlei' wetland/stream could be impacted by dewatering at the pit. This would mean that the wetlands/streams that are gaining in that area may receive less water. The duration, extent and intensity of the impact of the cone of depression on the wetlands/streams could be minimised if dewatered water is treated to the acceptable standards and discharged back to the environment.
- The contamination plume could affect the Verdrietlaagte wetland/stream and Dwars-in-die-Wegvlei' wetland/stream. Wetlands/streams that are gaining in that area may receive water of poor quality (emanating from the contamination plume) resulting in the water quality deterioration at the Wetlands/streams. The impacts of the

contamination plume is expect to occur post-closure and could be reduced by inhibiting acid generating reactions at the source by ensuring that the waste rock material that is high in pyrite content and prone to acid generation are deposited at the base of the rehabilitated pit in such a way that it will be completely flooded with groundwater.

- The contamination plume and cone of depression are not expected to affect any private boreholes (identified during the hydrocensus and desktop study).
- Decant is expected to start 35 years post closure at a rate of 5 L/s.

The following recommendations are made following the groundwater study:

- Geostratum Groundwater and Geochemistry Consult (2016) identified that the waste rock material has a significant potential to generate acid. These materials should be deposited at the base of the rehabilitated pit in such a way that it will be completely flooded with groundwater.
- The mine is predicted to decant after closure. Decant should be captured and treated before joining the tributaries.
- Groundwater should be monitored, to assess the time series water level and quality impacts and trends.
- If impact is confirmed through monitoring, management solutions should be implemented acceptable to the authorities such as the purchase of impacted land or the provision of alternate sources of water.
- With the commencement of mining, more hydrogeological information will be obtained, such as groundwater inflow rates. The numerical model should be updated and calibrated every two years in the first four years to improve its accuracy by incorporating the new information. Thereafter updating of the model every five years is deemed to be sufficient.

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Digby Wells Environmental (hereafter Digby Wells) has been appointed by Canyon Coal (Pty) Ltd (hereafter Canyon) to undertake groundwater specialist studies as part of a Mining Right Application (MRA), Environmental Impact Assessment (EIA) and an Integrated Water Use License Application (IWULA) for their proposed opencast mine.

1.1 Mine Description

In June 2016, Pandospan (Pty) Ltd (Pandospan) concluded a contract with Anglo Operations Limited in support of the acquisition of a Prospecting Right for coal (DMR Ref. No. GP 30/5/1/1/2 (201/10026) PR). The Prospecting Right includes Portions 1, 2, 4, 9, 13 and 19 of the Farm Palmietkuilen 124 IR located in Springs, Sedibeng District, Gauteng Province (Figure 1-1). The mine, and mining-related infrastructure, will be placed on Portion 2 and the proposed future development area is located on Portion 19.

The integrated environmental regulatory processes for the project will be managed by Pandospan on behalf of Anglo Operations Limited (the Applicant), the project applicant. Pandospan forms part of the Canyon Group of Companies for which Canyon Coal functions as the operational division. Canyon Coal is a well-established South African mining company. Since the inception of their first operating mine in 2009, Canyon Coal has brought two additional mines online. The Palmietkuilen project constitutes one of four future mining projects, pending environmental and other authorisations.

This project involves the development of a new opencast coal mine and supporting infrastructure. The raw coal, once extracted, will be transported to a processing plant for crushing, screening and washing. The coal product will either be transported via haul roads from the product stockpile area to the existing Welgedacht siding for distribution by rail or directly to prospective clients by road. The proposed mine will require supporting infrastructure such as water storage, sewage treatment, power supply, fuel storage, haul roads etc.

The current resource is estimated at 125.98 Mt. The life of mine for the project is 53 years including a 2 year ramp-up period. Once the mine has been established a full production rate of 200 000 t / month will be maintained for 51 years. The progression of the mining operation is depicted in the Life of Mine (LoM) plan, in Figure 1-2.

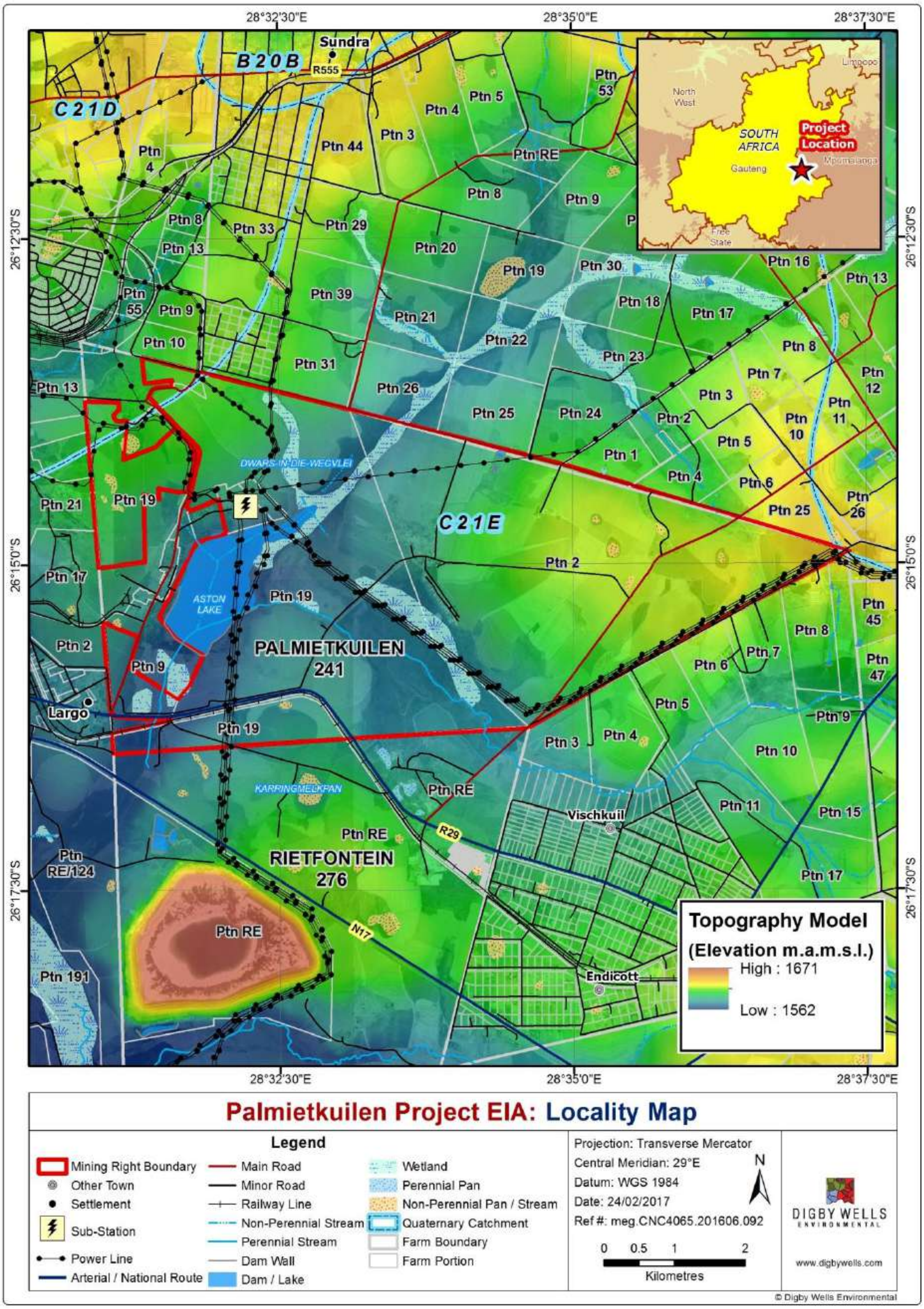

Figure 1-1: Locality map

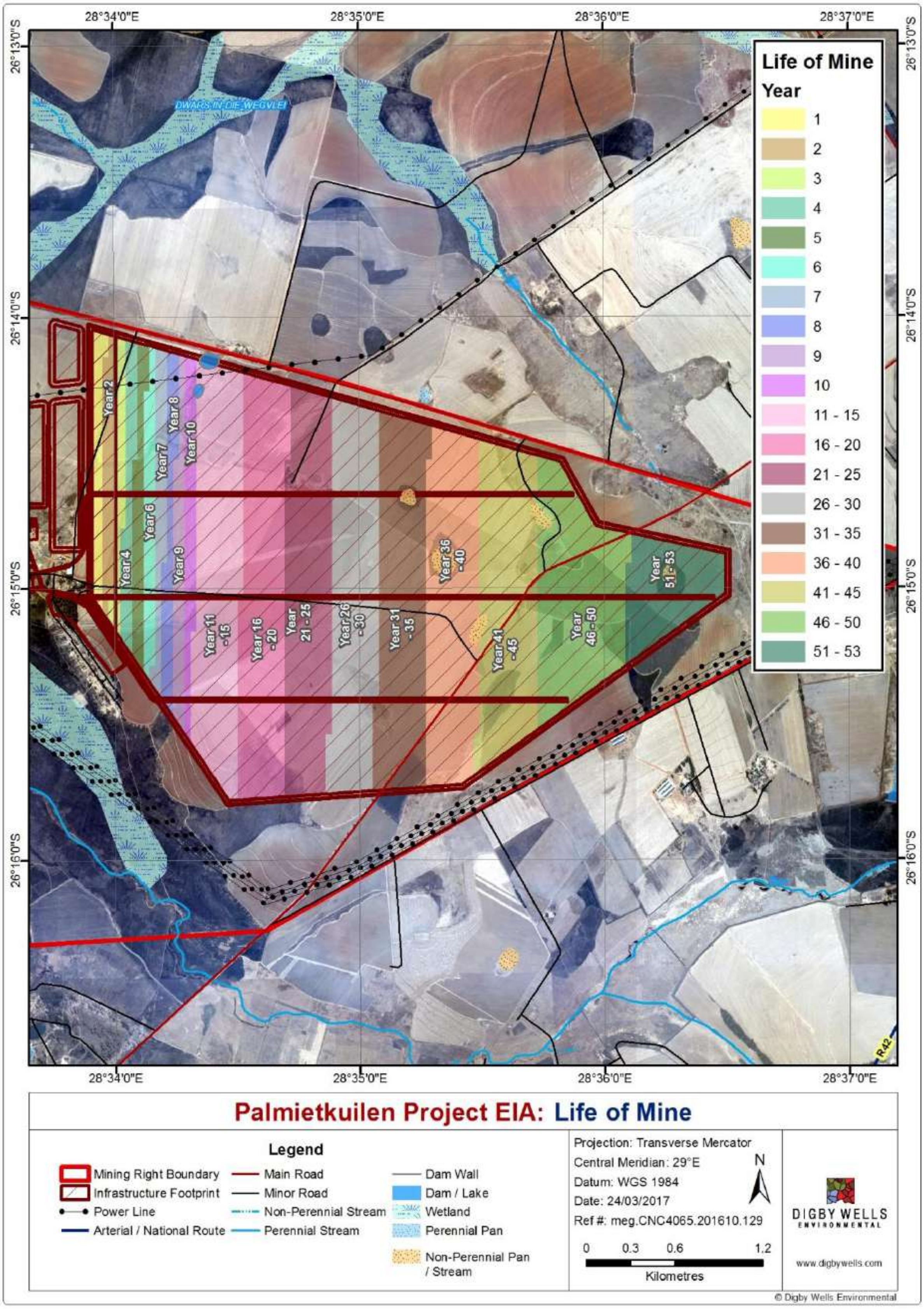

Figure 1-2: Life of mine

1.2 Mining Method

The coal resource will be mined using opencast methods due to the shallow depth of the coal reserve (between 12 and 60 m below the surface). Bench mining and strip mining techniques are proposed. Bench mining involves the development of an opencast pit through a series of benches at varying depths while strip mining involves the movement of overburden laterally to an adjacent empty pit where the mineral has already been extracted. The proposed project will only have one pit.

Topsoil and subsoil will be stripped using an excavator and will be stored in separate stockpile areas on the mining area. Drilling and blasting will be employed for the hard overburden or bedrock to expose the coal seams. Once blasted, the hard overburden will be excavated and stockpiled in the pit for rehabilitation. The mined coal from the opencast will be transported via the haul roads and stored on the Run of Mine (RoM) stockpile area. The coal will be fed into a crushing and washing plant after which the coal product will be temporarily stored at the product stockpile area before being transported to the Welgedacht siding for distribution or directly via truck to the relevant markets. A temporary discard dump containing one year’s capacity will be constructed to store discard before being either rewashed or backfilled into mined out areas. Discard will be placed into the mined pit.

1.2.1 Support Infrastructure

The proposed mine would require additional infrastructure and services to support the proposed mining operation. Figure 1-3 below shows the proposed project infrastructure layout. The supporting infrastructure associated with the proposed Project is discussed in subsections below.

1.2.2 Stockpile Areas

Topsoil, subsoil and overburden material will be excavated and stored on site for rehabilitation. The mined coal will also need to be temporarily stored on a RoM stockpile and a product stockpile area.

1.2.3 Process Plant

1.2.3.1 Screening and Crushing

The RoM will be fed into the process plant by means of a feeder bin at the RoM pad. The feeding capacity of the plant will be 400 tons/hour. Coal will be manually fed into the bin by means of a Front-End Loader. The first stage of the process plant is to screen the coal into various particle sizes. This is done by the use of a 1.5 x 2.5 m primary vibrating grizzly screen fitted with 80 mm bar spacing. The 250 x 80 mm fraction will be discharged into a primary double roll crusher, which will reduce the oversize fraction to 90 mm in size. The primary crusher product will re-join the grizzly undersize fraction which feeds into a secondary 1.8 x 6.0 m double deck screen fitted with 60 and 50 mm bar spacing. The oversize (+75 mm) fraction will be fed to a secondary double roll crusher, the crushed product will be returned to the primary screen feed conveyor belt, in a closed crushing circuit.

1.2.3.2 Coal Washing and Processing

The eventual crushed and screened undersize fraction (-75mm) will be fed to the cyclone, drum and spiral sections of the wash plant which will then be deposited onto a product stockpile. The washing section will operate during daily operational hours.

The slurry from the thickener underflow will report to the filter press and make up 12 % to 15 % of the plant feed. The Dense Media Separation (DMS) plant will be capable of a 95 % organic efficiency with a product yield of 60 %. The remaining 25 % to 28 % solid discard will be placed in the opencast voids.

The plant will produce a product suitable for local and export markets.

1.2.3.3 Product Storage

The coal product will be stored on a product stockpile. The product stockpile conveyor belt will be fitted with a level probe to avoid over filling the stockpile and a mass meter for process accounting purposes.

1.2.4 Water Supply and Management

Possible water sources for use in mining operations include the existing Aston Lake, owned by the Schoeman Boerdery as well as available or new boreholes that are outside the impacted area. These water sources are still to be confirmed by undertaking the relevant feasibility studies. Pipes and pumps will be installed to pump water from these resources directly to the process plant. Process water will be managed and re-used throughout the operations of the project via clean and dirty water separation system, which shall include separate drains that lead into the following dams.

1.2.4.1 Waste Water Dams

Waste water dams will be constructed in the form of a slurry dam and pollution control dams. The purpose of the slurry dam is to collect and separate water from suspended solids and return the water. A slurry dam will be constructed adjacent to the processing plant. The purpose of the pollution control dams is to store process water and stormwater for re-use in the plant. The dams will be designed as per requirements of the Department of Water and Sanitation.

1.2.4.2 Power Supply

The project will obtain power from an existing Eskom distribution power lines. Pandospan are proposing to construct a substation on the project site to connect to existing power line to secure power for the operation of the proposed mine.

Electricity will also be generated by means of diesel generator sets for lighting and pumping of water. Pandospan is also currently investigating the feasibility of using onsite solar power generation as a backup system. The maximum power requirements for the mine will be 5 MVA.

1.2.5 Waste Management

The proposed coal processing activities will result in the generation of slurry waste, which will be stored in the slurry dam. Furthermore, the solid coal discard will be temporarily stored on a discard dump before being taken back to the opencast for final disposal.

A proposed sewage treatment plant is proposed as part of the project to manage sewage. Other wastes including materials and chemicals from maintenance activities and daily operation of the proposed mine will also be generated. All hazardous wastes will be stored and handled appropriately prior to being disposed of by a licensed hazardous waste disposal contractor. General domestic wastes will be managed in accordance with the requirements of the district municipality.

1.2.6 Access and Site Roads

The project site is bordered by an unnamed road to the north that also serves as the boundary between the Gauteng and Mpumalanga Provinces. The R29 serves as a partial southern boundary. There are various farm roads present on the proposed project area that can used to navigate the site.

Access to the site will be from the R29 onto an unnamed farm road heading north. Pandospan intend on using the surrounding road network to haul coal to the existing Welgedacht siding.

1.2.7 Rail Siding

Coal product may be transported via road to the Welgedacht rail siding from where the coal product will be distributed to the intended local and export markets.

1.2.8 Workshop Area

A workshop and office area is proposed which will also include a contractor’s yard where machinery and equipment can be maintained and repaired. It is likely that this area will include offices, a laboratory, wash bays and storage facilities. These buildings are proposed to be approximately 3 m in height.

1.2.9 Hazardous Storage

Diesel storage tanks are proposed to be located in close proximity to the workshop area. This facility will be adequately bunded and have the necessary control systems in place to manage the potential risks of fire and /or explosion.

1.2.10 Vehicles and Equipment

The following vehicles and machinery will be used for the construction and operation of the proposed mine:

- Excavators;
- Dozers to move material;
- Load Haul Dump (LHD);
- Front End Loaders;
- 34 ton interlink haul trucks;
- Mine passenger vehicles;
- Graders for road maintenance;
- Water Bowsers for dust suppression;
- Generators for lighting and water pumping: and
- 2 ton Light Duty Vehicles (LDV).

1.2.11 Relocation of Existing Infrastructure

An existing public gravel road crossing the site in a SW – NE direction would need to be relocated as it currently runs through the proposed opencast area.

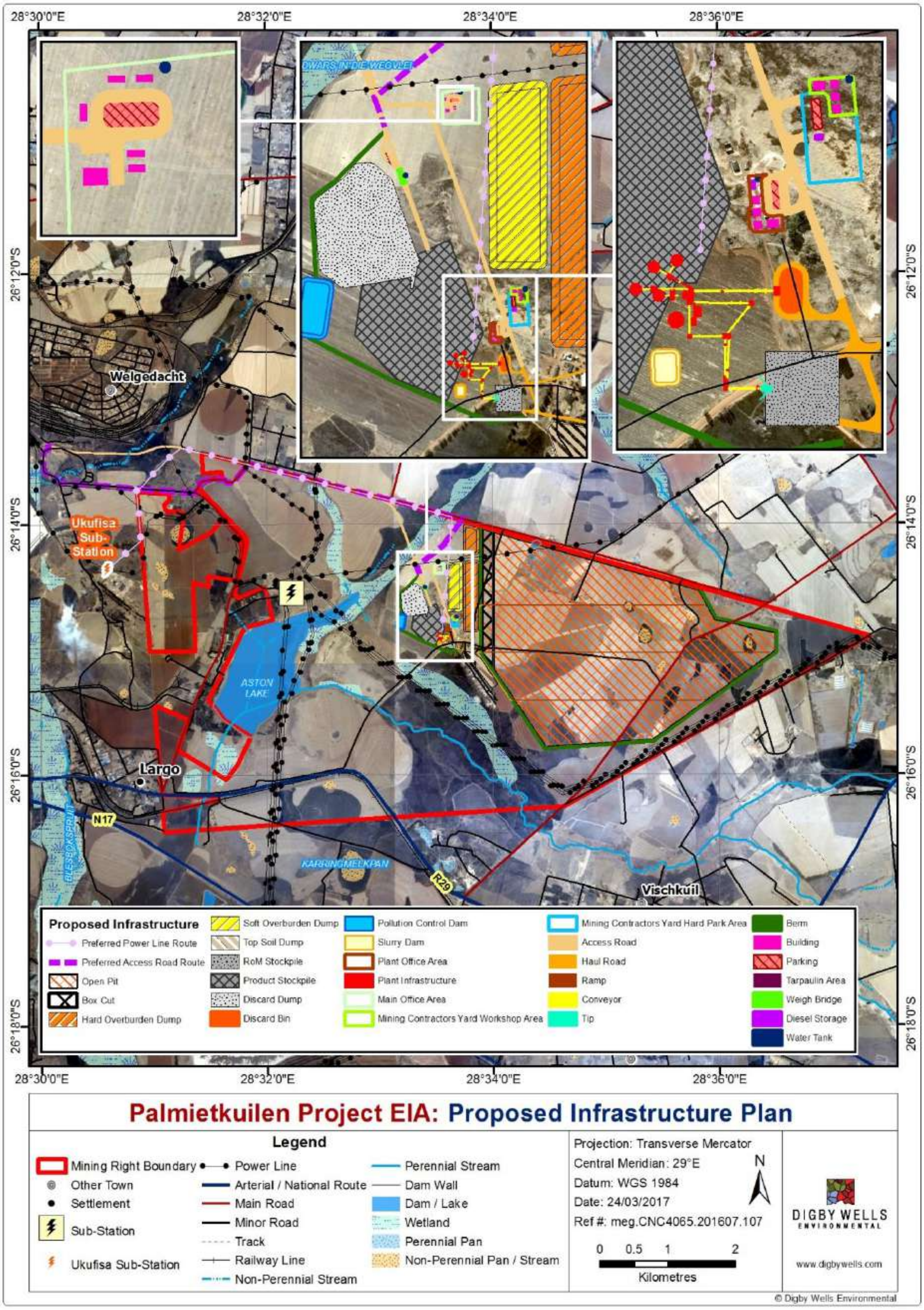

Figure 1-3: Proposed infrastructure

1.3 Topography and Drainage

The elevation of the Palmietkuilen project area ranges from 1637 m above mean sea level (mamsl) on the eastern side to 1600 mamsl on the western side of project boundary.
The slope gradient ranges from 0.9% to 1.1%; influenced by the streams, wetlands and pans surrounding the area. Drainage follows the topography and migrates downstream from east to west.

1.4 Climate

The climatic conditions are described in terms of evaporation and rainfall.

1.4.1 Evaporation

Monthly evaporation data was obtained from the WR2005 manual (WR2005, 2012). Table 1-1 is a summary of the monthly evaporation for the C21E quaternary catchment. The mean annual lake evaporation is observed to be 1 365 mm. From the monthly evaporation, the highest lake evaporation occurs during November, December and January and the lowest evaporation occurs during June, July and May.

Table 1-1: Summary of evaporation data (WR2005, 2012)

Months	Symons Pan Evaporation (mm)	Lake Evaporation Factor	Lake Evaporation (mm)
January	184.60	0.84	155.06
February	152.26	0.88	133.99
March	142.35	0.88	125.27
April	107.58	0.88	94.67
May	87.26	0.87	75.92
June	70.85	0.85	60.22
July	76.54	0.83	63.53
August	110.99	0.81	89.90
September	149.18	0.81	120.83
October	176.31	0.81	142.81
November	176.80	0.82	144.98
December	190.29	0.83	157.94
Total	**1625**	**N/A**	**1365**

1.4.2 Rainfall

The mean annual precipitation (MAP) for quaternary catchment C21E is 691 mm (WR2005, 2012). The average monthly rainfall for this catchment is present in Table 1-2. Based on the data, the average driest months are June, July and August whilst the average wettest months are November, December and January.

Table 1-2: Summary of rainfall data (WRC2005, 2012)

Month	Monthly mean rainfall
January	91.8
February	82.9
March	43.3

Month	Monthly mean rainfall
April	19.1
May	7.4
June	6.4
July	8.1
August	23.4
September	70.7
October	105.4
November	110.1
December	91.8
MAP	**691**

1.5 Study objectives

To main objective of the study is to complete a groundwater impact assessment with a calibrated model. Other objectives include:

- Provide a baseline groundwater quality, water level and flow direction;
- Identify the current groundwater receptors and private boreholes in the area;
- Characterise the groundwater pathways in terms the aquifer hydraulic properties;
- Delineate the radius of influence on groundwater levels as a result of mine dewatering;
- Predict the long-term impact of the mining activities on groundwater quality in terms of contamination plumes;
- Identify the potential impact of mine dewatering on the groundwater receptors (i.e. private groundwater users, as well as rivers and tributaries);
- Calculate the volume of groundwater that may seep into the pit during mining;
- Predict the timing and position of decant from after mine closes;
- Propose optimal management measured to minimise the identified potential impacts.

2 Details of the Specialist

The groundwater impact assessment was conducted by Ayabonga Mpelwane, and consultation was held throughout the process with Dr Robel Gebrekristos.

Ayabonga is a Junior Hydrogeologist employed within the Water Geosciences Department. She holds a BSc degree in Geology, BSc Honours degree in Hydrogeology and MSc in Hydrogeology; all qualifications were attained from the University of the Free State. She joined Digby Wells Environmental in November 2014, as a water geoscience intern. She has been producing numerical and analytical groundwater models which involve groundwater related impact assessments and the development of groundwater management plans.

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.

3 Aims and Objectives

Mining activities associated with the proposed project have the potential to impact on the quality of local groundwater resources over the short and long-term through the exposure, and weathering of overburden and coal waste. The groundwater levels and flow may also be disrupted by the disturbance of geological strata. 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;
- Estimate the inflow rates into the pit 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

4.1 Desktop Study

This phase involved a review of available hydrogeological and geological data. Available data was selected and stored into a WISH database. This was later used to have clear understanding of hydrogeology of the project area.

The reports, plans and database files reviewed as part of this phase included:

- NGA boreholes database;
- Aeromagnetic map purchased from CGS;
- Restigen (Pty) Ltd, Geohydrological investigation on the farm Droogefontein portions 26, 46, 47, November 2013;
- Ngululu resources (Pty) Ltd, Proposed Ngululu Coal Mine final scoping report, January 2015;
- Chanzo environmental management (Pty) Ltd, EIA for the proposed mine on portion 21 and 22 Grootvally 124 IR, October 2009; and
- Lesedi EMF, Environmental Management Framework, 2006.

4.2 Ground Geophysics

The aeromagnetic map of the project area (Figure 4-1) was interpreted for possible subsurface geological contacts and structures such as dykes. Two ground survey geophysical methods were used during this study, the electromagnetic (EM) and magnetic methods. Four lines were surveyed and marked in the field using a handheld GPS for reference and targeting purposes (Figure 4-1). Station spacing was set at ten metres to ensure that possible vertical to sub-vertical features could be detected.

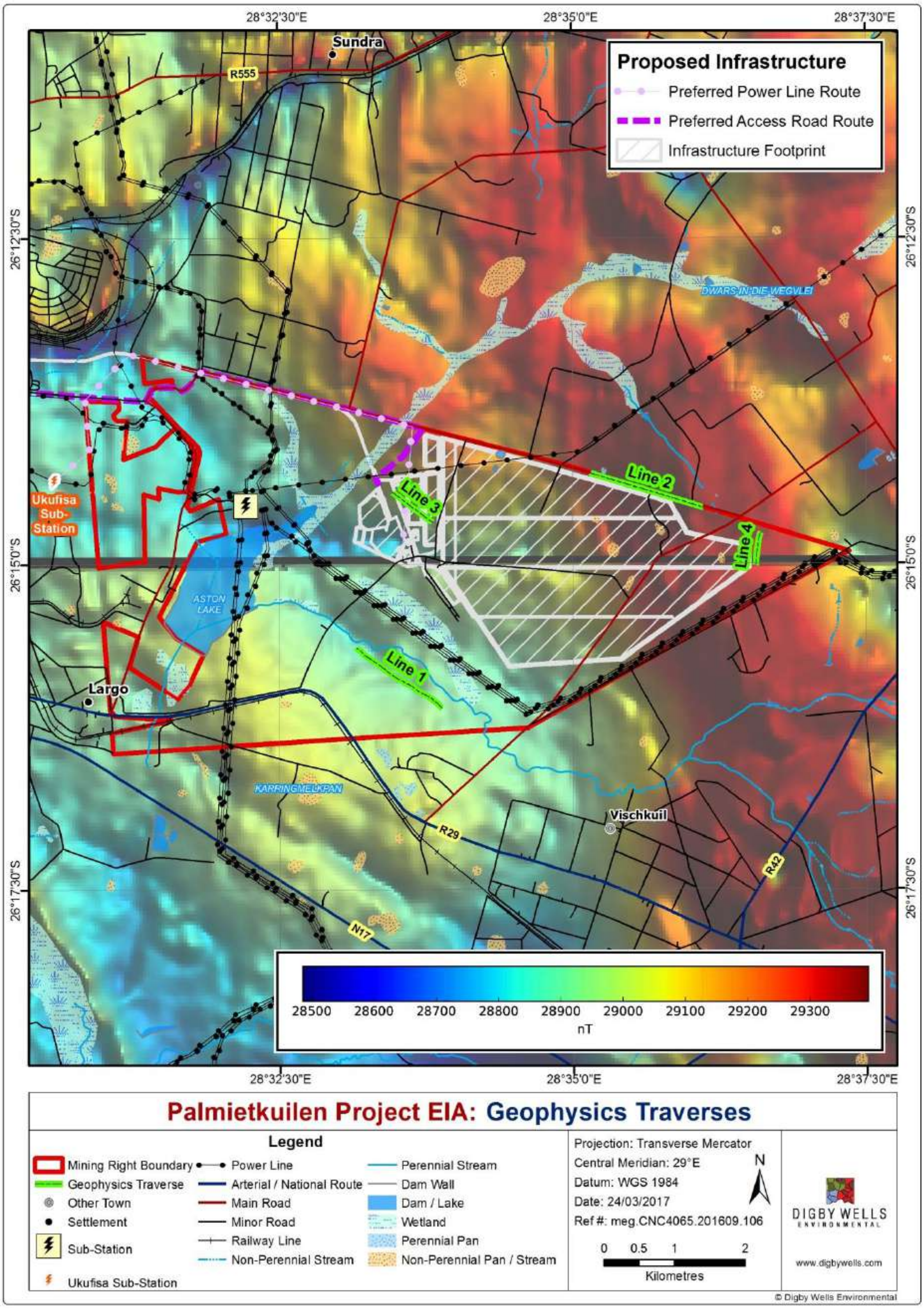

Figure 4-1: Geophysics and traverses

4.3 Borehole Drilling

A percussion drilling programme was initiated to provide an indication of the groundwater hydraulic properties (i.e. aquifer permeability and storage characteristics) of the study area and to be able to monitor contamination and plume migration around the pit area. A total of 7 boreholes were drilled during this study. The boreholes were sited downstream and upstream of the pit and with one borehole in the middle of the pit (Figure 4-2).

The boreholes were drilled at various depths to intersect the coal seam. The shallowest was 40 metres and the deepest was 110 metres.

The drilling programme was undertaken by Diabor Geotechnical & Exploration Drilling Company between 29 November 2016 and 12 December 2016. During the drilling programme a total of 460 m of drilling was advanced. The rotary air-percussion drilling method was used to enable hard rock formations to be penetrated using a hammer drill bit, forced through the rock by compressed air. Borehole finishing included the installation of steel casing, steel lockable cap, black and white marker pole and borehole development (Table 6-3).

Six 165 mm diameter boreholes were drilled, developed and installed under the supervision of Digby Wells (the positions of the boreholes is shown in Figure 4-2). During the drilling supervision the following information was recorded:

- Site identification details (coordinates);
- Penetration rate, colour and drilling chip size at 1 m intervals;
- Vertical geology succession and degree of weathering;
- Depth of drilling and borehole construction; and
- Depth of water strikes, individual water strike yield, final / accumulative blow yield and rest water level after completion.

A summary of the borehole localities and decision record details are given in Table 4-1.

Table 4-1: Borehole locality details

BH	Longitude	Latitude	Comment
BH1	-26.248	28.60959	BH1 drilled on the high magnetic area (Figure 4-1), also ground geophysics done
BH2	-26.2387	28.58661	BH2 drilled on the high magnetic area, both ground and aeromagnetic show the anomaly
BH3	-26.2634	28.5683	BH3 drilled on the moderate magnetic field as confirmed by the aeromagnetic data. Borehole also placed on a possible structure.
BH4	-26.2481	28.55198	BH4 drilled on the low magnetic field to confirm the rock permeability of the lower field.
BH5	-26.2497	28.58318	BH5 drilled on the moderate magnetic area at the centre of the pit to characterise the permeability of the rocks.
BH5A	-26.246392	28.584051	BH5A drilled on the moderate magnetic area at the centre of the pit to characterise the permeability of the rocks
BH6	-26.2336	28.56512	BH6 drilled on the high magnetic area next to the proposed topsoil stockpile.

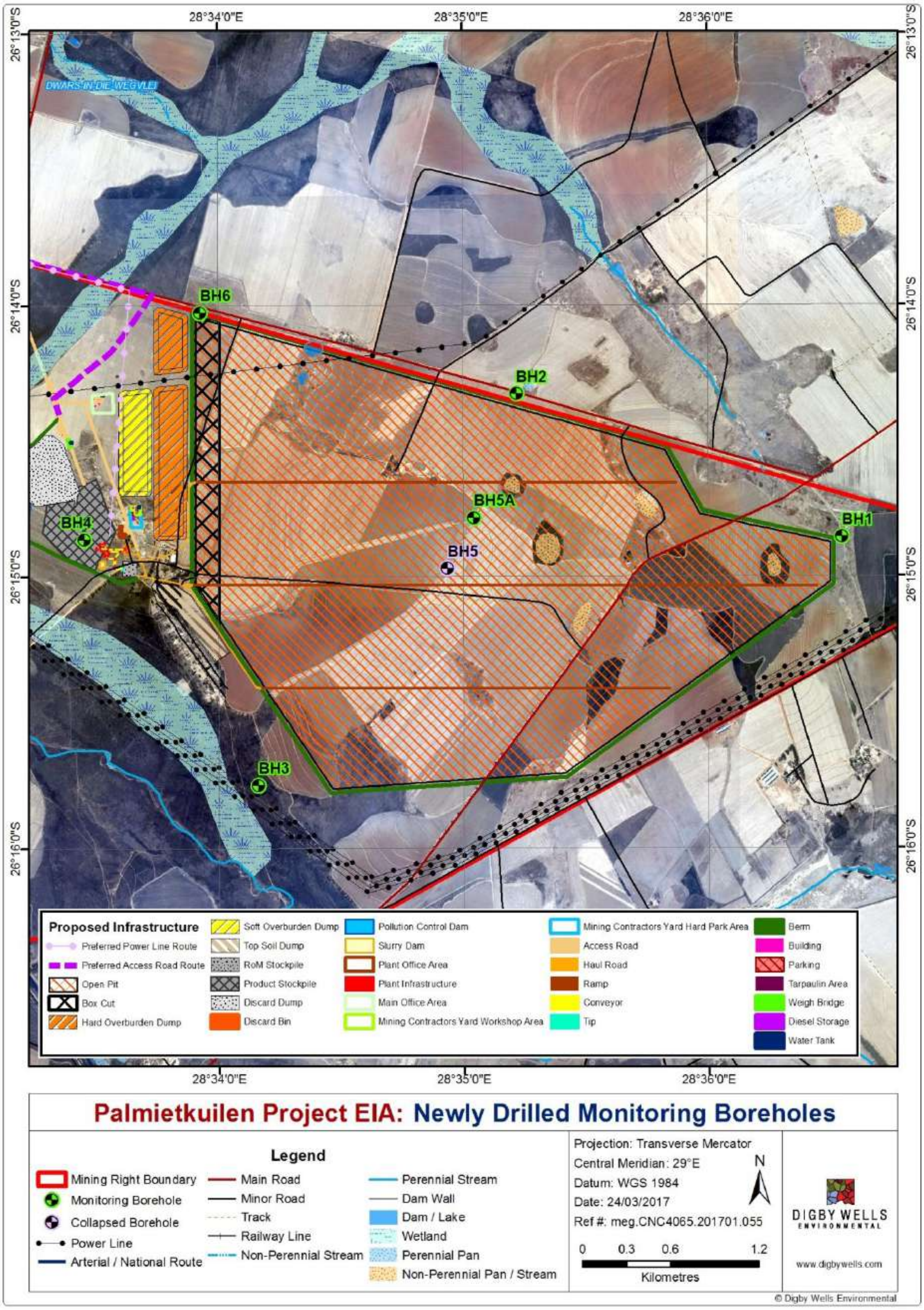

Figure 4-2: Newly drilled boreholes

4.4 Aquifer Testing

Five of the new boreholes were either pump or slug tested to calculate the hydraulic permeability and storativity values presenting the aquifer hydro-dynamics underlying the investigation areas. Digby Wells subcontracted Boegman boreholes testing to conduct the aquifer tests in January 2017. The test was conducted as per the record listed in Figure 4-2.

Three of the newly drilled boreholes (BH2, BH3 and BH5A) yielded more than 0.2 L/s during the percussion drilling (as indicated in Figure 4-2). Out of these two boreholes (BH2 and BH3) were pump tested and BH5A was found to be blocked above the position of the water strike at the depth of 25 m, therefore it was not tested. The following methodologies were used for testing BH2 and BH3:

- The boreholes were first step tested by pumping at increasing rates. They were tested for 4 hours (each step being 60 minutes long). This was followed by a recovery test, reverting back to the static water lever within an hour or reaching 90% recovery to the static water level, whichever was achieved first.
- Following the response of the boreholes to the step test, an 8-hour constant discharge test was performed. This was again followed by 8-hours of recovery measurement or 90% of the static water level recovery.

The remanding three other boreholes (BH1, BH4 and BH6) were slug tested since their blow yield was less than 0.2 L/s. The test was conducted by instantaneously adding 60 L of water to the boreholes. 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.

Borehole BH5 was not tested as it collapsed during the drilling.

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

BH ID	Water Level (m)	Water strike (m)	Final blow yield (L/s)	Slug test	Step drawdown test	Constant discharge test
BH1	4.28	31 & 41	seepage	X		
BH2	4.81	31	0.74		X	X
BH3	1.25	11 & 24	5		X	X
BH4	18.64	44	seepage	X		
BH5	-	26	seepage	Collapsed		
BH5 A	7.88	22 & 38	2.5	No test, borehole blocked		
BH6	2.59	20 & 27	seepage	X		

4.5 Numerical Modelling

The numerical model for the project area was constructed using Processing MODFLOW Pro, a pre- and post- processing package for MODFLOW and MT3DMS. MODFLOW is a modular three dimensional groundwater flow model and MT3D a modular three dimensional solute transport model published by the United States Geological Survey. MODFLOW and MT3DMS use 3D finite difference discretization and flow codes to solve the governing equations. MODFLOW and MT3DMS is a widely used simulation code, which is well documented.

5 Assumptions and Limitations

A numerical groundwater model is a representation of the real system. It is therefore an approximation and the level of accuracy depends on the quality of the data used. This implies that there are always errors associated with groundwater models due to uncertainty in the data and the capability of numerical methods to describe natural physical processes.

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

- No boreholes were found during the hydrocensus in the northern section of the project area. As a result, there is information gap in terms of the current groundwater usage, baseline water quality and water levels;
- There are uncertainties associated with the hydraulic conductivity at the pit area. This was brought about by the obstacles encountered that did not allow for aquifer tests to be conducted at the boreholes located at the pit area (BH5 and BH5A, Section 4.4);
- Private boreholes located within the mining right boundary are not regarded as potential receptors as it is assumed that the mine will then own them as soon as it acquired the mining right; and
- The model accuracy is expected to be around 60% and this needs to be taken into consideration when assessing the model results.

6 Baseline Environment

6.1 Geology

6.1.1 Regional Geology

South Africa's coal deposits occur in the Karoo Supergroup, a thick sequence of sedimentary rocks deposited between 300 and 180 million years ago (McCarthy and Pretorius, 2009).

As shown in Figure 6-1, the Karoo Supergroup is lithostratigraphyically subdivided into the Dwyka, Ecca and Beaufort groups, succeeded by the Molteno, Elliot and Clarens Formations and the Drakensburg Formation (S.A.C.S., 1980). The coals range in age from Early

Permian (Ecca Group) through to Late Triassic (Molteno Formation) and are predominantly bituminous to anthracite in rank, which is a classification in terms of metamorphism under the influence of temperature and pressure.

The East Rand Basin consist of different aquifer systems namely the dual porosity aquifer of the Karoo sequence aquifer, the high yielding Karstic aquifer of the Transvaal Sequence's Malmani dolomites and the fractured aquifer associated with the Pretoria Group and the Witwatersrand Supergroup.

The Karoo sequence is susceptible to preferential weathering. It is softer than either of the two aquifer systems and hosts shallow perched aquifers mainly in the sandstone horizons. The harder layers such as the shale and the tillite could act as barriers upon which the groundwater accumulates. Numerous dolerite intrusions occur in the Karoo Sequence, in the form of dykes and sills. The dolerite intrusions occur along the inherent zones of weakness in the stratigraphic sequence. Most of the flow in this aquifer is found on the contact zones between the sandstones and the shale and provide a favourable target area for drilling of boreholes to abstract groundwater. Recharge in this aquifer is mostly through infiltration of rainfall (Restigen, 2004).

6.1.2 Local Geology

Geological structures are important in establishing hydraulic conductivity between various rock formations, and thereby determining the movement of groundwater.

The Palmietkuilen project is underlain by the Springs – Vischkuil Coalfield. The project also borders the well-known and highly exploited Highveld Coalfield and also underlain by the coal supporting Madzaringwe Formation which forms part of the Karoo Supergroup.

The Palmietkuilen resource consists of the top, mid upper, mid lower and bottom seams. The local geology is obtained from the percussion boreholes that show the rocks are mainly composed of mudstone, sandstone, shale, tillite and coal.

Geological logs of two representative boreholes (BH2 and BH3) are shown in Figure 6-2 and Figure 6-3. The rest of the boreholes' logs are shown in Appendix C.

Borehole BH2 represents the geological profile of those that intersect the dolerite whereas BH3 represents those that do not intersect the dolerite.

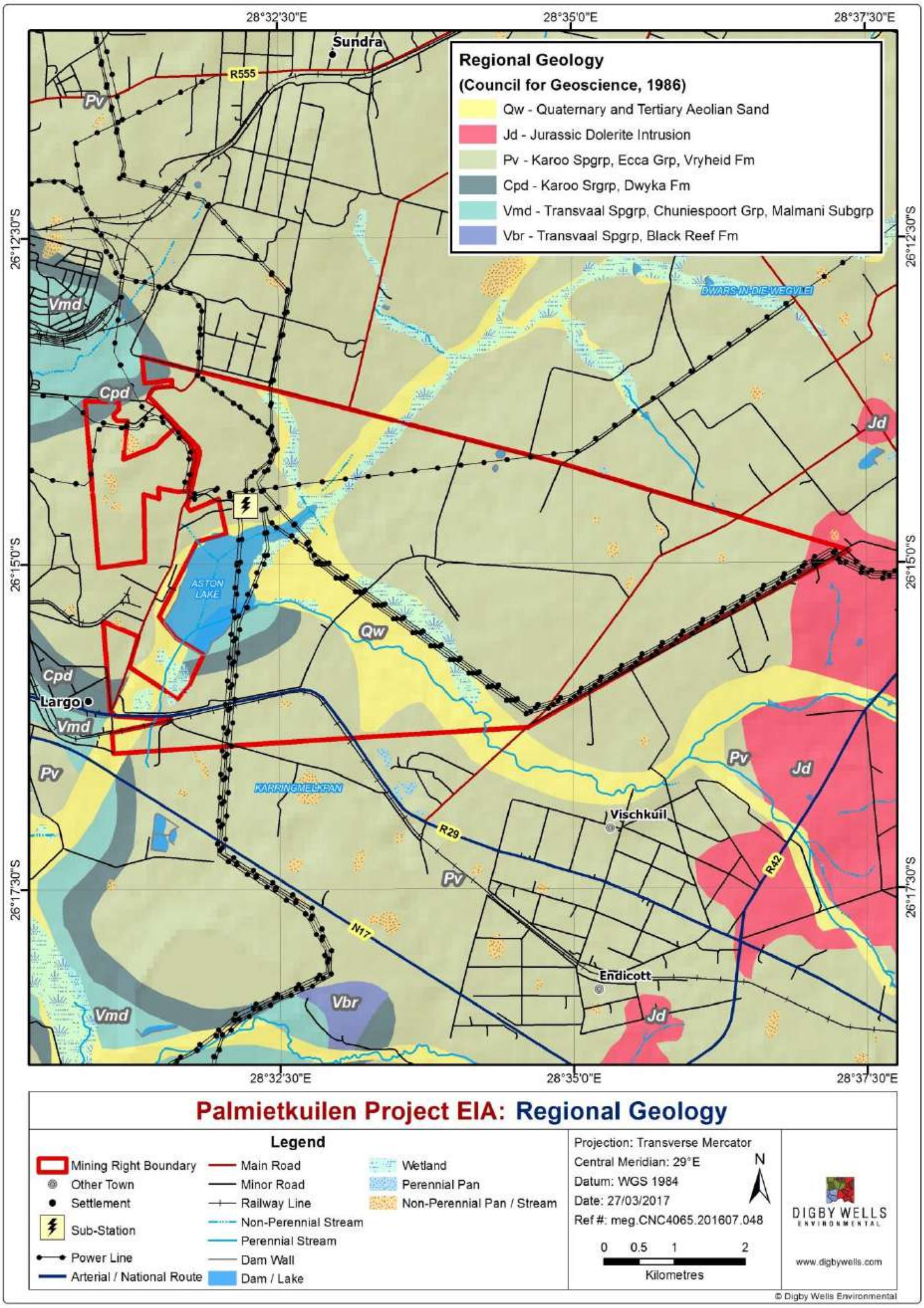

Figure 6-1: Regional geology

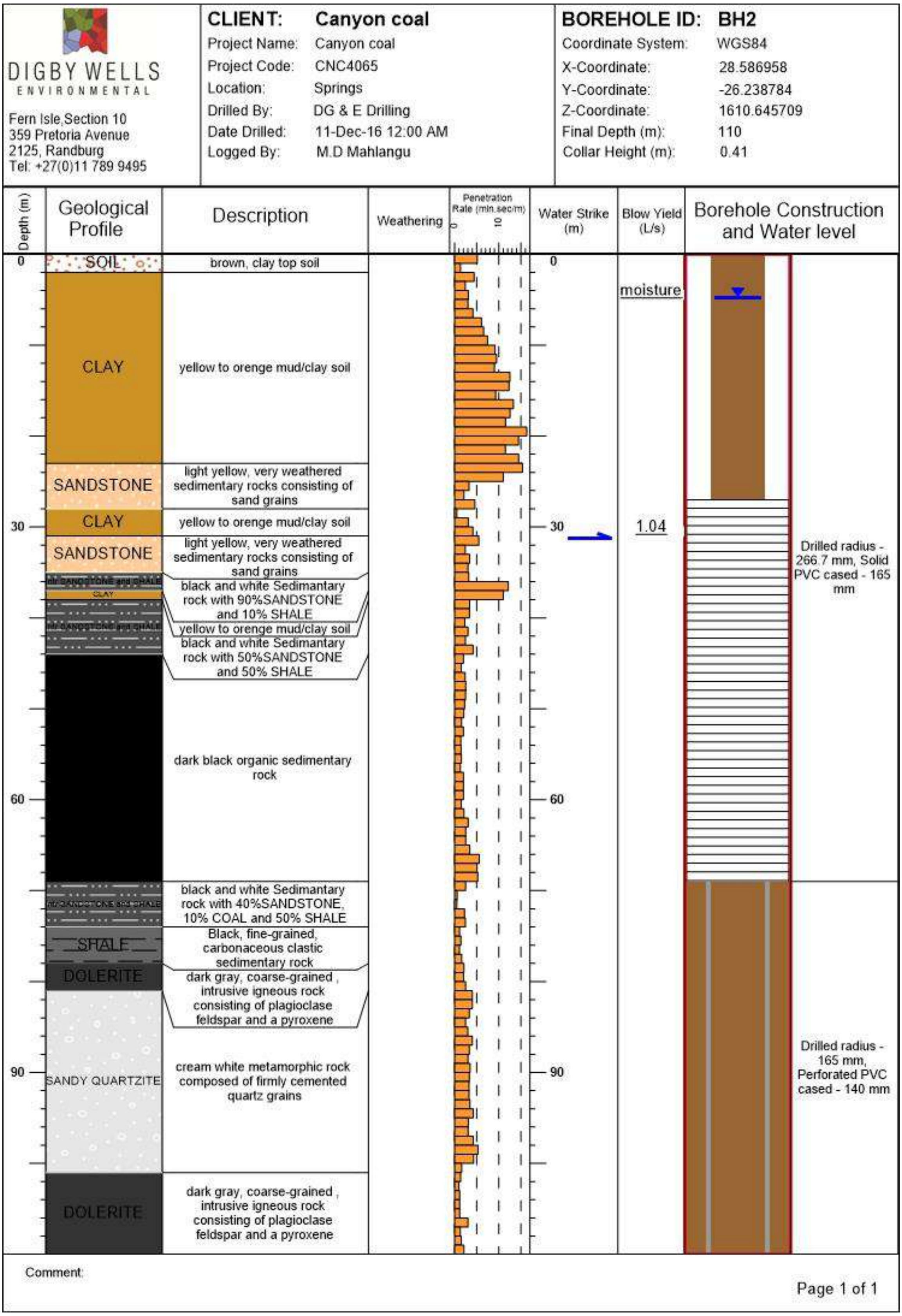

Figure 6-2: Geological profile of borehole BH2

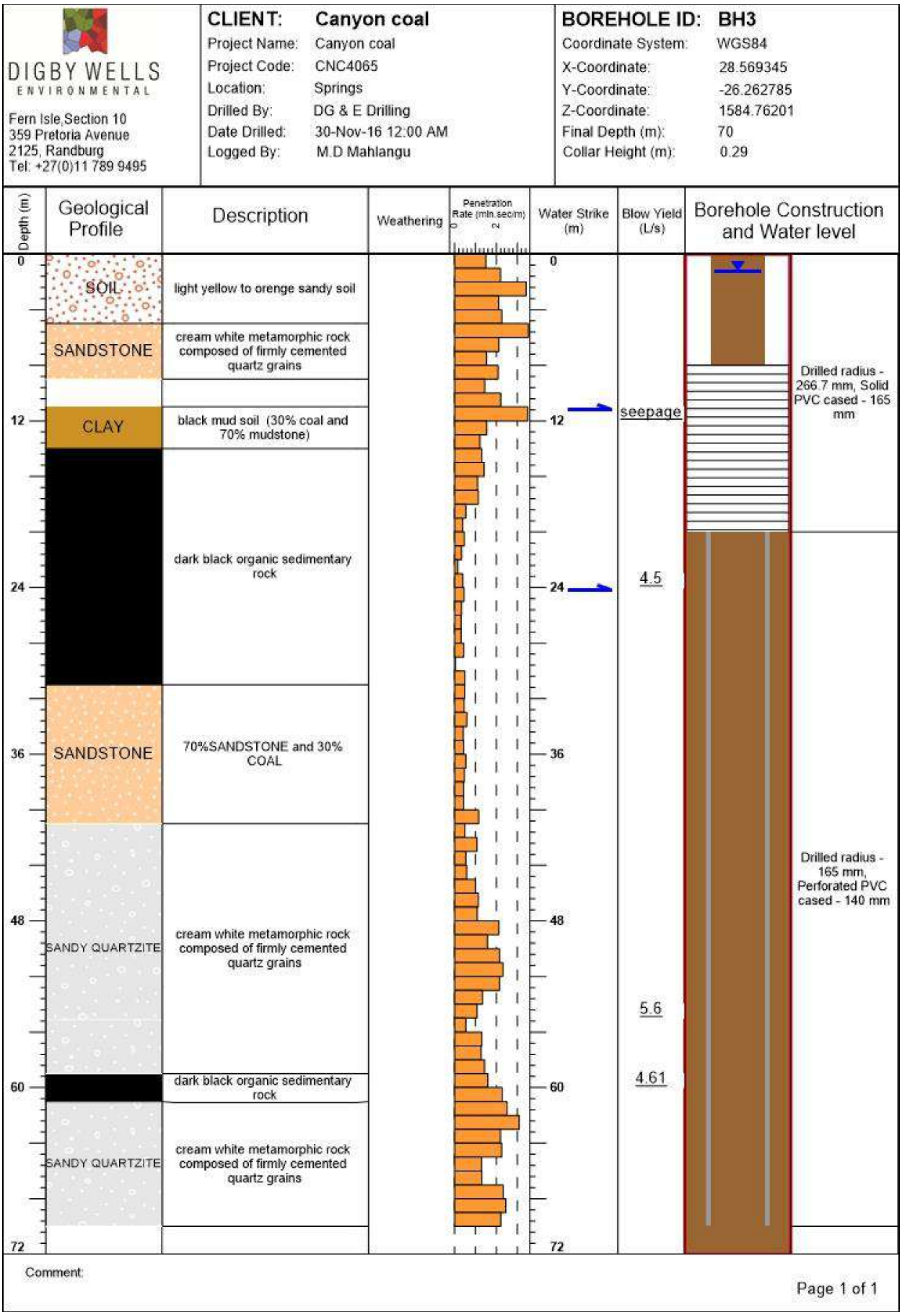

Figure 6-3: Geological profile of borehole BH3

6.2 Baseline Groundwater Quality

The baseline hydrogeological conditions are described in terms of the aquifer classification, borehole yields, groundwater usage, groundwater sources, hydraulic conductivity, groundwater flow patterns, and groundwater quality. This classification can also be described better by means of a conceptual model.

6.2.1 Comparison with the SANS

In order to have a better understanding of the groundwater qualities around the proposed project area, 10 groundwater samples were collected during the hydrocensus and analysed by SANAS accredited laboratory in Pretoria (Aquatico).

The water quality assessment is based on a once off analysis conducted by Digby Wells during the hydrocensus task conducted between 23 August 2016 and 26 August 2016. The laboratory certificate of the water quality is presented in Appendix A.

A summary of the results are presented in Table 6-1 referenced against the South African Bureau of Standards (SABS) (SANS 241:2015) guidelines for drinking water quality since the mine WUL was not available during the task.

Based on the laboratory analysis, the following observations could be made regarding to the compliance with SANS 241:2015 drinking water quality standards:

- A total of 7 boreholes namely: SCHBH1, SCBH05, ALBH01, VLBH2, PL18BH2, PL42BH and PL50BH were found to be within the recommended SANS 241:2015 drinking guideline values. Based on the tested parameters, the water of only these 7 boreholes is considered to be safe for human consumption.
- Groundwater samples from boreholes SCCBH1, WNBH1 and SCBH01 were found to be exceeding the acceptable acute health level of NO_3 concentrations when benchmarked against the SANS 241:2015. Anthropogenic sources are the ones that most often cause the amount of nitrate to rise. The elevated nitrate concentrating from the mentioned boreholes could be resulting from the actions of farmers' fertiliser application or from other natural geological processes.
- Concentration of Total Dissolved Solids (TDS) and electric conductivity (EC) of the sample from WNBH1 were found to be exceeding the maximum allowed aesthetic limits as set by SANS 241:2015. WNBH1 is located south-west of the proposed opencast area, the elevated TDS and EC concentrations at the boreholes is likely to be attributed to its being downgradient of the Grootvlei Gold Mine Shaft .

Table 6-1: Water quality results compared to SANS 241:2015

Sample Date	Sample ID	Total Dissolved Solids	Nitrate NO_3 as N	Chlorides as Cl	Total Alkalinity as $CaCO_3$	Sulphate as SO_4	Calcium as Ca	Magnesium as Mg	Sodium as Na	Potassium as K	Iron as Fe	Manganese as Mn	Conductivity at 25° C in mS/m	pH-Value at 25° C	Aluminium as Al	Free and Saline Ammonia as N	Fluoride as F
	Aesthetic	1200	No limit	No limit	No limit	250	No limit	No limit	200	No limit	0.3	0.1	170	No limit	No limit	6.6	No limit
	Operational	No limit	No limit	No limit	No limit	No limit	No limit	No limit	No limit	No limit	No limit	No limit	No limit	5 to 9,7	0.3	No limit	No limit
	Chronic health	No limit	No limit	300	No limit	No limit	No limit	No limit	No limit	No limit	2	0.4	No limit	No limit	No limit	No limit	1.5
	Acute health	No limit	11	No limit	No limit	500	No limit	No limit	No limit	No limit	No limit	No limit	No limit	No limit	No limit	No limit	No limit
26/08/2016	SCHBH1	245.00	5.68	10.80	180.00	9.37	46.10	21.70	15.70	5.83	0.00	0.00	33.70	8.67	0.00	0.15	-0.26
23/08/2016	SCBH05	207.00	2.09	18.80	138.00	13.40	31.40	14.70	22.60	12.50	0.02	0.00	27.20	8.37	0.00	0.07	0.27
25/08/2016	SCCBH1	345.00	11.80	23.10	196.00	28.50	64.30	24.70	24.70	7.63	0.00	0.00	46.20	8.73	0.00	0.12	-0.26
23/08/2016	ALBH01	282.00	2.41	22.20	171.00	40.30	47.60	22.40	25.60	8.03	0.00	0.00	39.20	8.73	0.00	0.19	-0.26
23/08/2016	VLBH2	380.00	4.82	40.50	225.00	38.90	59.80	25.00	54.90	1.99	0.00	0.00	51.90	8.67	0.00	0.26	0.33
24/08/2016	WNBH1	1446.00	21.80	327.00	227.00	425.00	195.00	102.00	153.00	9.50	0.00	0.00	213.00	8.46	0.00	0.19	0.52
26/08/2016	PL18BH2	104.00	1.07	9.49	73.80	4.25	21.70	6.75	9.15	2.47	0.00	0.00	15.70	8.46	0.00	0.29	-0.26
26/08/2016	PL42BH	273.00	10.40	12.20	185.00	3.30	52.10	24.50	11.40	9.81	0.00	0.00	38.80	8.69	0.00	0.10	-0.26
26/08/2016	PL50BH	338.00	1.06	30.40	228.00	32.00	31.70	19.20	75.80	4.24	0.00	0.00	47.20	8.78	0.00	0.21	0.35
23/08/2016	SCBH01	236.00	24.30	22.30	29.70	21.30	24.90	16.90	18.50	6.53	0.00	0.00	29.60	8.12	0.00	0.13	-0.26

6.2.2 Diagnostic Plots

A Piper diagram (Figure 6-4) was created using the WISH program to characterise the groundwater in the area. A Piper diagram is utilized to characterise water types in a graphical manner and to distinguish between specific water types in the area. The Piper diagram is quartered to simplify this process. The water samples can be grouped into the left, bottom, right and upper quarters. The position of the water sample on the plot is based on the ratio of the various constituents measured in equivalence and is not an indication of the absolute water quality or the suitability thereof for domestic consumption.

The left quarter is characterised by freshly recharged water and is dominated by calcium-magnesium-bicarbonate. The right quarter is associated with stagnant or slow moving groundwater and is dominated by sodium chloride. The bottom quarter is typical of dynamic groundwater flow and is dominated by sodium bicarbonate and the top quarter typically shows contamination by mining activities and is dominated by sulphate.

Groundwater quality results from boreholes ALBH01, VLBH2, SCBH05, PL18BH2, SCCBH1, SCHBH1 and PL42BH plot in the left quarter which is an indication of fresh recharge water that is dominated by calcium-magnesium-bicarbonate. Sample collected at borehole PL50BH plot at the bottom quarter indicating dynamic groundwater flow that is dominated by sodium bicarbonate. The remaining samples (WNBH1 and SCBH01) plot in the top quadrant, indicative of groundwater that is dominated by sulphate water. Elevated sulphur concentrations in groundwater are often characteristic of water that has been impacted by mining related activities. The source of the sulphate concentrations in the WNBH1 and SCBH01 needs further investigation to confirm if historical mining in the area might have contributed for the observed baseline sulphate value.

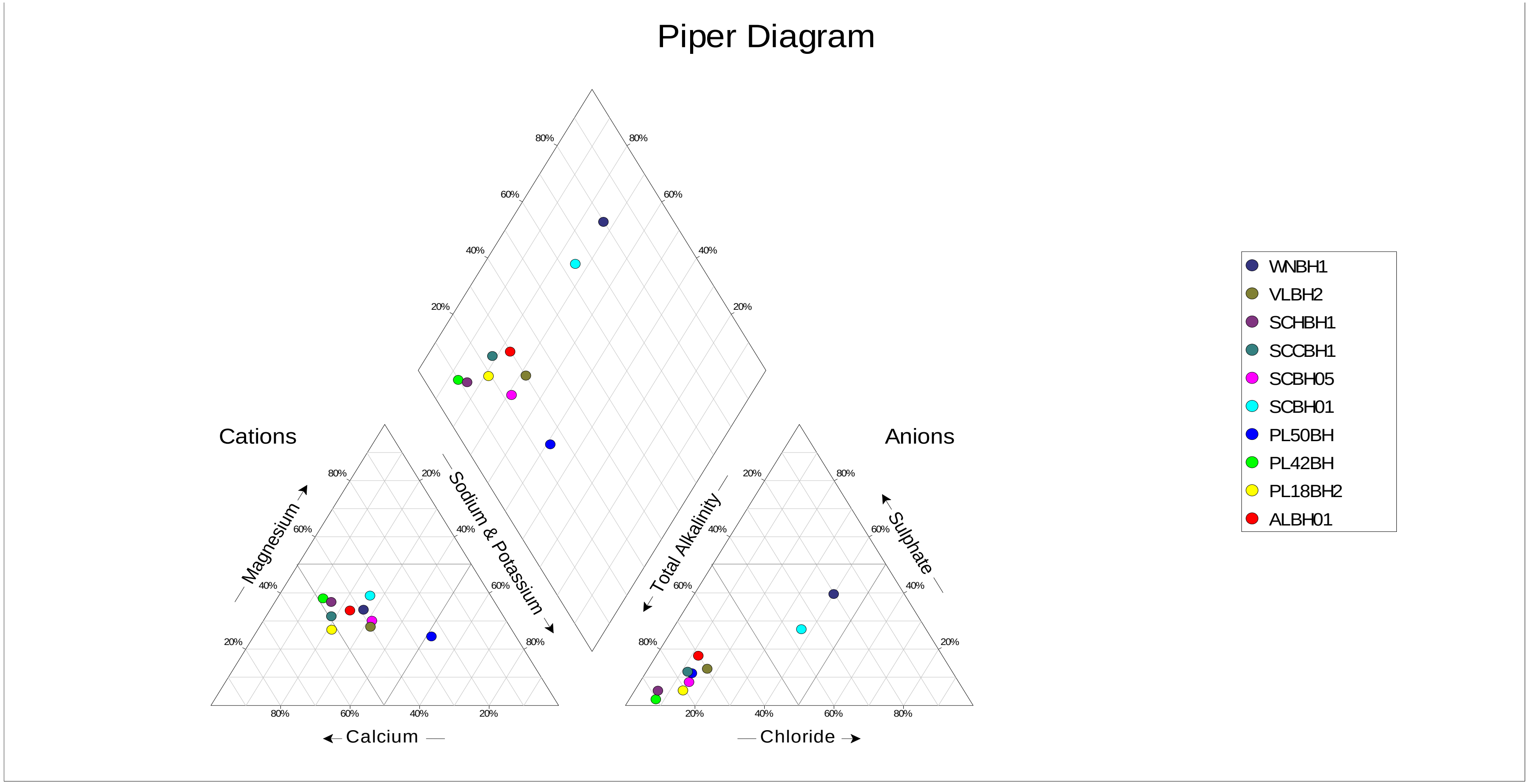

Figure 6-4: Piper diagram of the baseline water chemistry

6.3 Water Level and Flow Direction

The baseline water levels measured during the hydrocensus and the new drilled boreholes are shown in Table 6-2 and ranges between 1 m and 73.51 m below ground level (mbgl). The relatively large water level variation in a relatively short distance indicates groundwater abstraction points as identified during the hydrocensus or possibly from different aquifers.

A comparison of the water level elevation with topography shows a good correlation of 92.64% (Figure 6-5). Only boreholes with static water level measurements were used to plot this figure. The boreholes that are currently in use and their water level is lowered from its natural position were not included.

Figure 6-6 confirms that groundwater elevation mimics the topography and flows towards the Aston Lake and Dwars-in-die-Wegvlei' wetland/stream.

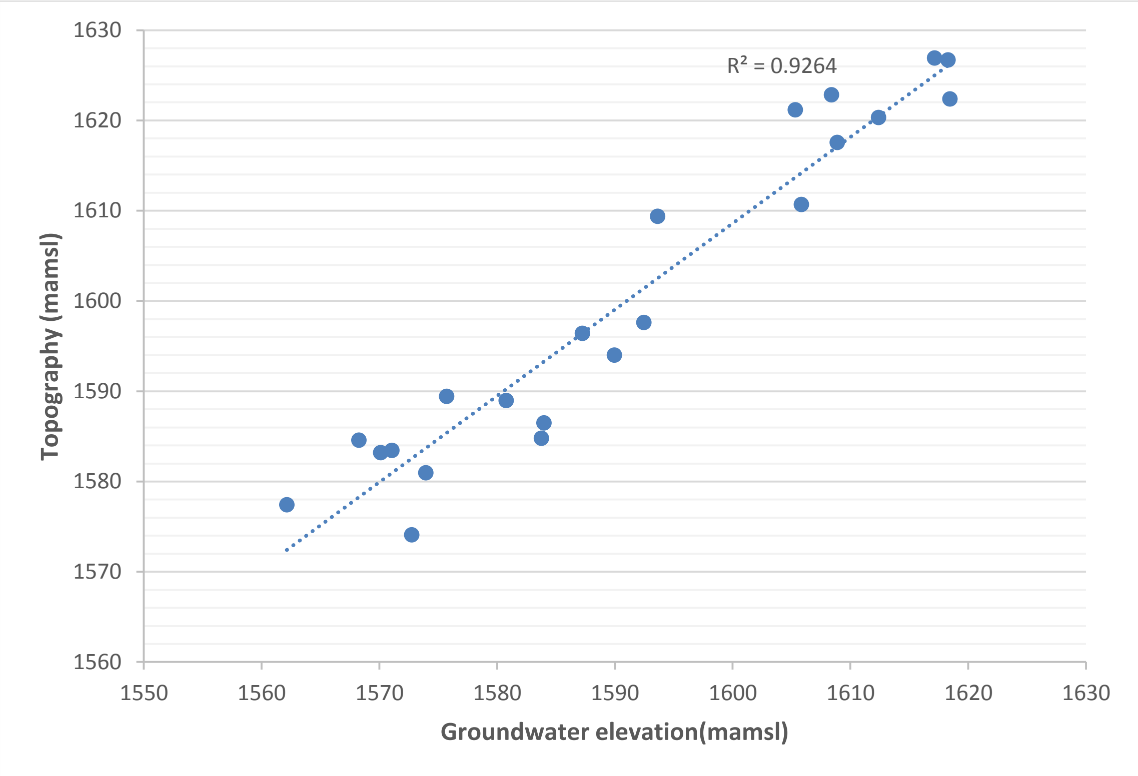

Figure 6-5: Correlation between topography and groundwater level

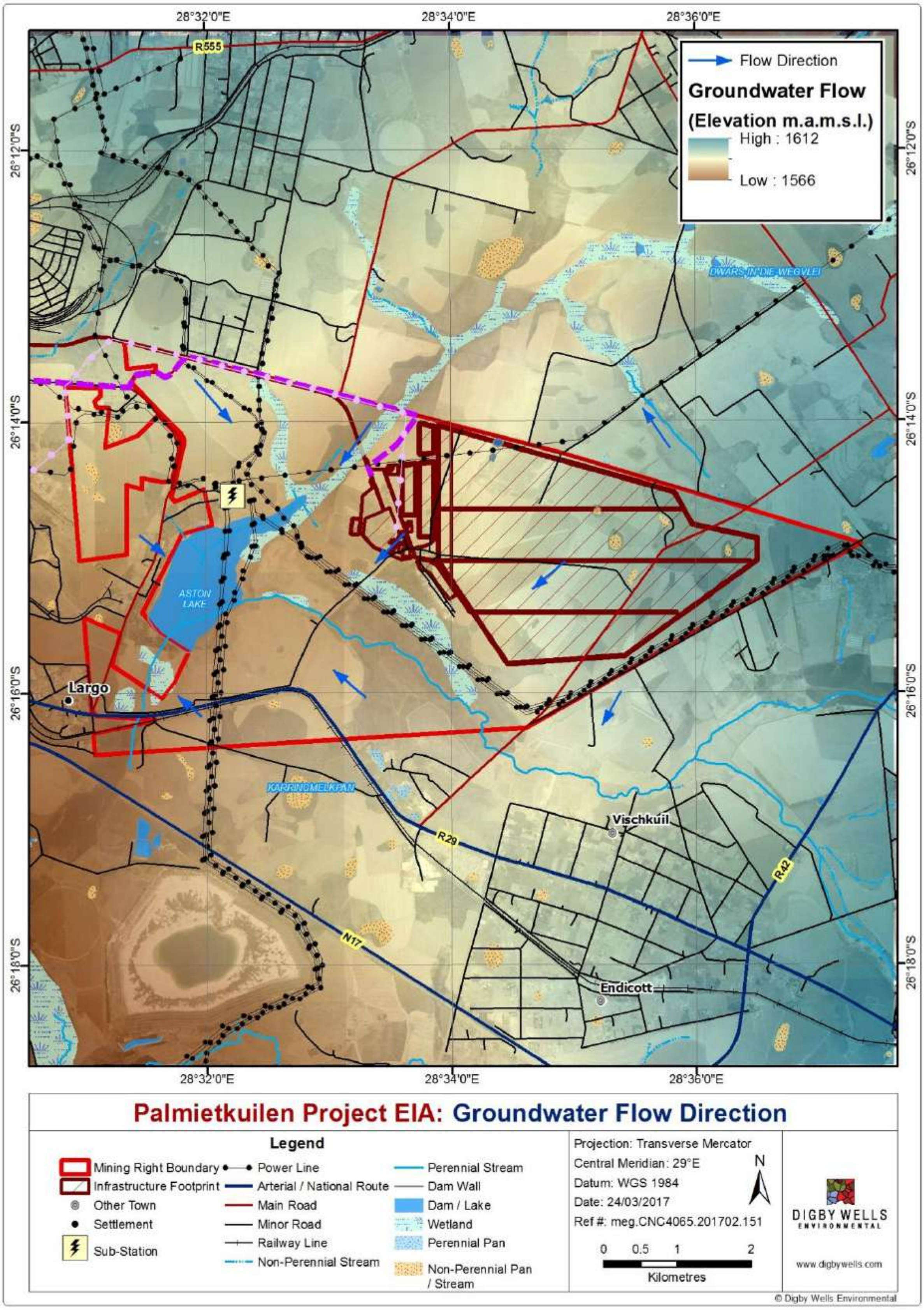

Figure 6-6: Groundwater flow direction

6.4 Current Groundwater Usage

The detailed information obtained during the hydrocensus is shown in Appendix D. The groundwater usage within the hydrocensus area is displayed in Table 6-2 and displayed in Figure 6-7. A total of 42 boreholes were recorded during hydrocensus and 6 new drilled boreholes, of these:

- 8 (16.6%) are used for drinking only;
- 16 (33.3%) are used for drinking and livestock watering;
- 7(14.5%) are used as groundwater monitoring points (6 owned by Canyon and 1 by the Department of Water and Sanitation);
- The remaining 17 (35.4%) are unused.

Table 6-2: Hydrocensus summary

BH ident	Latitude	Longitude	altitude	Water level	BH Usage
BH3	-26.2628	28.56935	1584.762	1	Monitoring
DSBH1	-26.2489	28.48778	1574.05	1.28	Monitoring
BH6	-26.2338	28.56545	1586.477	2.5	Monitoring
BH1	-26.2476	28.6091	1622.365	3.9	Monitoring
VKBH1	-26.2692	28.60483	1593.98	4.02	Stock watering
BH2	-26.2388	28.58696	1610.646	4.81	Monitoring
Scbh1	-26.2484	28.56335	1597.58	5.12	Domestic used
SLBH1	-26.2136	28.48556	1580.94	6.98	Not used
BH5A	-26.2464	28.58405	1620.289	7.88	Monitoring
SCHBH1	-26.2748	28.55877	1588.93	8.15	Drinking water
SPBH5	-26.2459	28.63546	1626.66	8.37	Not used
SCCBH2	-26.2542	28.62081	1617.53	8.63	Stock watering
SCHBH2	-26.275	28.55789	1596.38	9.14	Drinking water
SCCBH1	-26.2554	28.63116	1626.9	9.73	Stock watering
PL53BH	-26.2703	28.51119	1583.41	12.33	Domestic used
PL47BH	-26.2648	28.51385	1583.16	13.04	Not used
PLBH1	-26.2687	28.51282	1589.41	13.7	Not used
SCCBH	-26.2526	28.61391	1622.82	14.43	Domestic used
PL74BH2	-26.2658	28.51583	1577.4	15.25	Not used
SPBH3	-26.2419	28.63443	1609.36	15.73	Not used
SCCBH3	-26.252	28.61971	1621.14	15.8	Drinking water
BH4	-26.2477	28.55755	1584.534	16.27	Monitoring
PL42BH1	-26.2253	28.53105	1622.1	20.45	Domestic used
VLBH2	-26.2669	28.60781	1595.66	22.66	Drinking water
PL57BH1	-26.2257	28.53759	1619.21	51.86	Not used
PL50BH1	-26.2215	28.54138	1621.38	73.51	Drinking water
SPBH1	-26.2448	28.63479	1622.34	-	Not used

BH ident	Latitude	Longitude	altitude	Water level	BH Usage
SPBH4	-26.2407	28.6388	1613.21	-	Used
PL55BH	-26.2243	28.53799	1616.81	Blocked	
PL74BH	-26.266	28.51357	1582.92	Blocked	Not used
SCBH2	-26.2515	28.56251	1591.58	Blocked	Not used
SCBH3	-26.2506	28.5626	1586.77	Blocked	Not used
SCBH4	-26.2559	28.56382	1583.41	Blocked	Not used
Spbh2	-26.2436	28.63552	1615.61	Blocked	Not used
JbBH1	-26.2292	28.50571	1592.06	Dry	Not used
PL50BH2	-26.2223	28.54064	1621.38	Dry	
SPBH6	-26.2462	28.63535	1624.5	Dry	Not used
ALBH1	-26.2494	28.52577	1588.69	Equipped	Domestic used
ELCOBH1	-26.2672	28.50996	1577.16	Equipped	Domestic used
PL18BH1	-26.2833	28.57359	1594.22	Equipped	Domestic used
PL18BH2	-26.2838	28.57454	1598.31	Equipped	Domestic used
PL56BH	-26.2242	28.54096	1611.52	Equipped	Drinking water
PL69BH	-26.2653	28.51626	1594.7	Equipped	Domestic used
PL7BH	-26.2183	28.53654	1612.48	Equipped	Domestic used
PLBH2	-26.2695	28.51703	1586.77	Equipped	Domestic used
SCBH5	-26.2436	28.57787	1613.45	Equipped	Domestic used
WNBH1	-26.2719	28.51715	637.23	Equipped	Drinking water
SPBH7	-26.247	28.63558	1626.42	More than 60 m	Drinking water

The main groundwater uses in the vicinity of the proposed project area are domestic and agricultural. Dwars-in-die-Wegvlei' wetland/stream is likely to be a gaining and losing stream depending on the season. A lowering of the groundwater level could result in a total local reduction of inflow to the wetland impacting its functionality. Furthermore, contaminated surface and groundwater is likely to impact on the 'Dwars-in-die-Wegvlei' water quality. After mine closure, contamination plume emanating from the mine site could potentially migrate towards the stream impacting on its quality. Surface water from the stream flows towards the Aston Lake which is used for recreational activities. If substandard quality migrates into the lake drainage line, the dam may be at risk of water quality deterioration. This could be mitigated by the placement of acid generating material (carbonaceous rock material and sandstone with high pyrite content) at the base of the pits so that the groundwater flow is through weathered material.

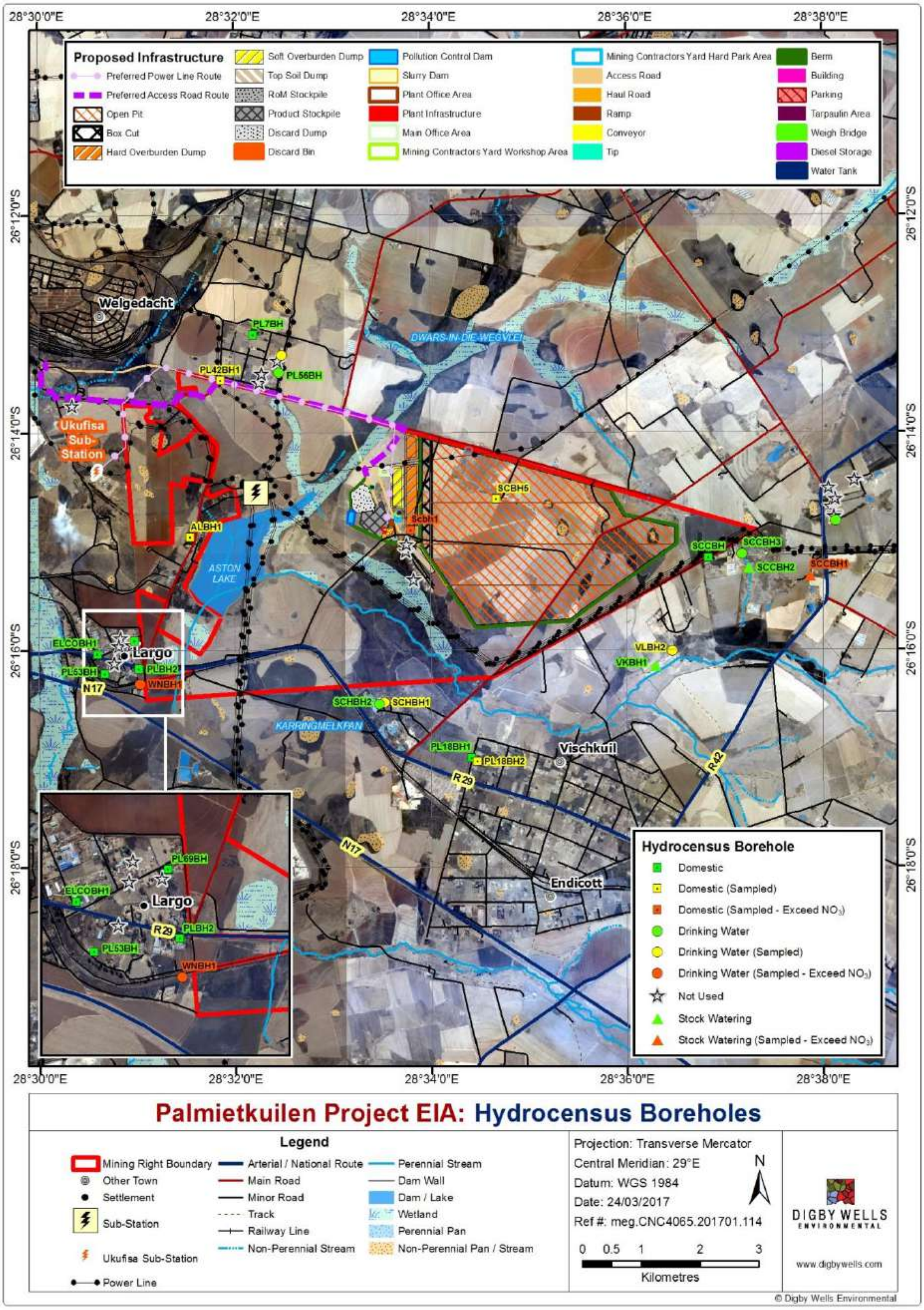

Figure 6-7: Hydrocensus boreholes location

6.5 Geophysical Survey

The results for the four survey lines will be discussed separately. The lines were chosen to cover or surround the proposed pit area by covering anomalies identified from the aeromagnetic map (Figure 4-1).

It is assumed that no major pipe lines were present in the project area as there are no developments on site. Anthropogenic (cultural) influences such as power lines (present at the project area) produce anomalies in the geophysical investigation results. It is important to identify and note the presence of man-made infrastructure that may affect the outcome of the geophysical surveying for interpretation purposes.

6.5.1 Line One

Traverse one was surveyed over a distance of 1.3 km from the southeast to the northwest direction on the 07/09/2016, with both magnetic and electromagnetic methods.

Some anomalies that appear to be caused by the presence of a fence were observed from the results. The negative anomalies observed between stations 750 – 950 and 1110 – 1300 do not seem to be related to any man-made infrastructure and are potentially related to geological structures, therefore drilling at station 820, 1160 and 1220 is recommended to explore the geological structure furthered.

Appendix B depicts the EM and magnetic data for this line section.

6.5.2 Line two

Traverse two (Appendix B) was surveyed on the 09/09/2016 over total distance of 1.5 km in the direction of northwest to southeast. The results of the investigations show that concrete bridges and steel road signs produced some anomalies (Appendix B), the anomalies co-relate to the location of the various infrastructure identified on site. From Appendix B the anomaly observed between station 610 to 950 and the negative anomaly between stations 950 to 1470 is potentially related to the buried geological structure at the surveyed area.

Two high priorities and one optional drilling targets are selected from the geophysics data interpretation, station 80 (high priority), 960 (lower priority) and 1480 (high priority) is proposed to explore the geological structure in details.

6.5.3 Line three

Traverse three (Appendix B) was surveyed over a total distance of 650 m in the direction of north to south on the 09/09/2016. The traverse was shortened to avoid nearby power lines interference with the instruments. No surface man-made infrastructure was observed within the surveyed area. The magnetometer shows two negative anomalies between station 110 to 500 and 520 to 600. The anomalies are not related to any surface anthropogenic (cultural) and can be associated with the buried geological structure within the area.

Three positions for drilling are proposed with only one being of high priority. Station 90 (low priority), 400 (low priority) and 570 (high priority) are proposed targets for drilling to explore the geological structure noted from the magnetometers data.

6.5.4 Line four

Traverse four (Appendix B) was the last one to be surveyed on the 10/09/2016 over a total distance of 500 m from the north direction to south direction. The area surveyed was noticed to be grass land area with no surface infrastructure. Magnetometer data shows negative anomaly between station 30 and 330 and this could be interpreted as the geological structure or a weathered area.

Two positions for drilling are proposed based on priorities. Station 230 is proposed to be drilled as high priority target and station 340 also proposed to be drilled as lower priority target.

6.5.5 Drilling targets

Both ground geophysics survey and aeromagnetic image sourced from the Council of Geosciences were used to select drilling targets as stipulated in Table 6-3.

6.6 Borehole Drilling

The following observations and conclusions were derived from the drilling programme (Table 6-3).

6.6.1 Borehole BH1

BH1 was drilled east of the mine pit to the final depth of 60 metres with the geology of the area consisting mainly of clay. Seepage was encountered at 30 metres and 41 m below surface. The borehole was not developed as it did not have enough water at the end of drilling. The borehole log is attached in Appendix C. The static water level for the borehole was measured as 4.28 mbgl.

6.6.2 Borehole BH2

Borehole BH2 was drilled at the project boundary and north side of the proposed opencast area and the lithology of the area consist mainly of Sandstone.

Seepage was encountered at 5 m and a water bearing structure was encountered 31 m below surface at the contact between clay and sandstone. The borehole was developed for 30 minutes at the end of drilling and the final borehole yield was measured to be 1.04 L/s. The borehole log is attached in Appendix C. The static water level for the borehole was measured as 4.81 mbgl.

6.6.3 Borehole BH3

Borehole BH3 was drilled southern west of the proposed open pin area at the final; depth of 70 m. Seepage was encountered at 11 m below surface and a water bearing structure was encountered 24 m below surface at the contact between clay and sandstone. The borehole was developed for 30 minutes at the end of drilling and the final borehole yield was measured to be 5 L/s. The borehole log is attached in Appendix C.

The static water level for the borehole was measured as 1.25 mbgl.

6.6.4 Borehole BH4

BH4 was drilled on the west side of the proposed opencast area at the final depth of 60 metres below the surface and the geology intersected during the drilling of BH4 was recorded as Mudstone being the dominating rock type in that area.

Seepage was encountered at 44 metres below surface. The borehole was not developed as it did not have enough water at the end of drilling. The borehole log is attached in Appendix C. The static water level for the borehole was measured as 18.64 mbgl.

6.6.5 Borehole BH5A

BH5A was drilled in the middle of the proposed opencast area at the final depth of 70 metres and the borehole lithology was recorded.

Seepage was encountered at 22 metres below surface and a water bearing structure was encountered 38 m below surface where the sandstone was completely weathered. The borehole was developed for 30 min at the end of drilling and the final borehole yield was measured to be 2.5 L/s. The borehole log is attached in Appendix C. The static water level for the borehole was measured as 7.88 mbgl.

6.6.6 Borehole BH6

Borehole Bh6 was drilled North-west of the proposed opencast area to the final depth of 50 metres below the surface.

Seepage was encountered at 20 metres and 27 m below surface. The borehole was not developed as it did not have enough water at the end of drilling. The borehole log is attached Appendix C. The static water level for the borehole was measured as 2.59 mbgl.

Table 6-3: Borehole drilling and construction details

	Borehole ID	BH1	BH2	BH3	BH4	BH5	BH5A	BH6
Borehole Location	x	-26.247584	-26.238784	-26.262785	-26.247744	-26.249522	-26.246392	-26.2338
	y	28.609097	28.586958	28.569345	28.55755	28.582253	28.584051	28.56545
Borehole Data	Borehole Depth (m)	60	110	70	60	40	70	50
	Blow Yield (L/s)	seepage	0.74	5	seepage	seepage	2.5	seepage
	Water Strike depth (m)	31 & 41	31	11 & 24	44	26	22 & 38	20 & 27
	Static Water Level (m bgl)	4.28	4.81	1.25	18.64	collapsed borehole	7.88	2.59
Borehole Construction Data	Solid Steel casing (Diameters -INT mm)	170	170	170	170		170	170
	Depth from, to (m)	0-30	0 - 27	0 - 7	0-19		0 - 19	0 - 18
	Perforated Steel casing (Diameters -INT mm)	170	170	170	170		170	170
	Depth from, to (m)	30-60	27 - 69	7 - 19.5	19 - 43		19 - 37	18 -50

6.7 Aquifer Layers

Summary of the aquifer test results are indicated on Table 6-4 with the graphs on Appendix E.

6.7.1 Shallow unconfined aquifer

A shallow unconfined aquifer occurs within the soil and weathered bedrock zone (between 7 m bgl and 20 m bgl). This unconfined aquifer is formed as a result of the weathering of the top section of the geological sequence. The water will then seep horizontally in a downgradient direction on this contact zone. This layer is sometimes referred to as a weathered aquifer.

6.7.2 Fractured Karoo aquifer

The second aquifer system is an intergranular and fractured, semi-confined Karoo type aquifer of Ecca (shale/sandstone/tillite) origins occurring between 20 and 40 mbgl. Groundwater is confined to joints and fractures. Flow in the matrix rock is insignificant and the matrix usually has very low hydraulic conductivity and low yields. However, high yields do occasionally occur especially where dolerite intrusions (of Karoo age) have resulted in significant fracturing of the host rock. Of all un-weathered sediments in the fractured aquifer, the coal seam often has the highest hydraulic conductivity (Ngululu resources, 1998 Scoping report).

Slug tests were performed on three of the low yield (seepage) boreholes to determine the aquifer parameters of this. Appendix E illustrates the hydraulic data of the tests captured versus time. The slug test data was interpreted using the Bouwer and Rice method (Bouwer and Rice, 1976) and the software package FC_Excel for the determination of aquifer parameters in fractured rock environments.

The transmissivities were calculated using the Theis with Jacob correction method. Average values for hydraulic conductivity and transmissivity were calculated to be 0.04 m/d and 2.44 m^2/d.

The fractured rock aquifer is considered to be a more reliable source of groundwater compared to the shallow weathered zone aquifer (Karoo Groundwater Atlas Volume 2, 2013). The yield from this borehole BH2 and BH3 would be sufficient (between 0.75 L/s and 4 L/s) to supply drinking, sanitation and irrigation (small scale) water for a household

The hydraulic parameters are summarised in Table 6-4 and

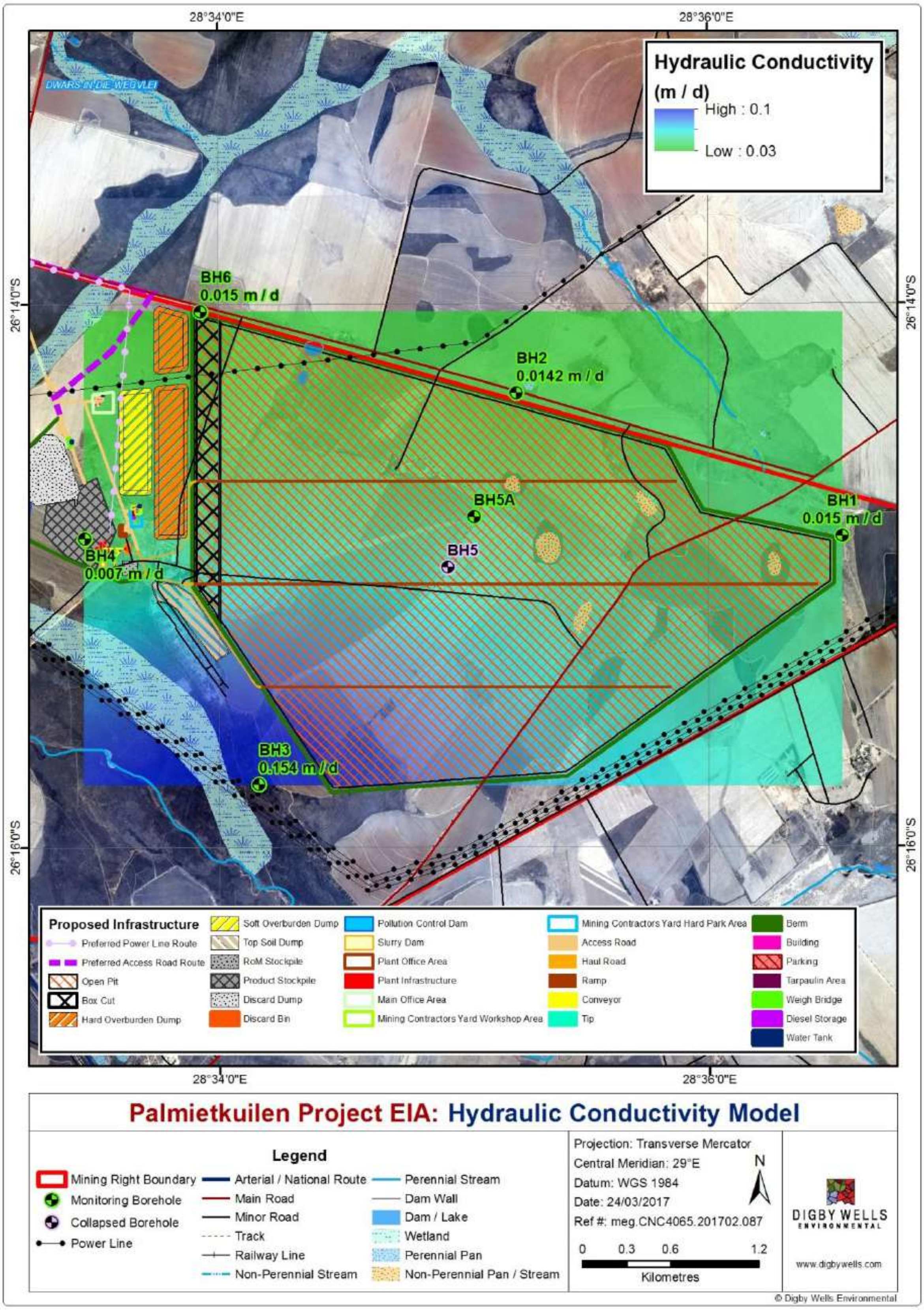

Figure 6-8. Based on the aquifer test results interpretation the area marked with green in the plan shows a high hydraulic conductivity that ranges between 0.014 m/d and 0.154 m/d. This may mean that the aquifers in that area are more vulnerable to contamination than the area that is less permeable. Light blue area in the plan shows aquifers with low hydraulic conductivity ranging between 0.007 m/d and 0.015 m/d.

Table 6-4: Summary of aquifer test results

BH ID	Test Method and period hours	Blow Out Yield, Q (L/s)	Tested Yield, Q (L/s)	FC-Method Transitivity(m^2/d)		Aquifer test pro method		
				Early time	Late Time	T(m^2/d)	K(m/d)	Storativity
BH1	Slug	Seepage	60L Slug	-	-	0.126	0.0150	-
BH4	Slug	Seepage	60L Slug	-	-	0.0151	0.007	-
BH6	Slug	Seepage	60L Slug	-	-	0.122	0.015	-
BH2	Constant test	0.75	0.75	1	1.5	1.36	0.0142	0.00772
BH3	Constant test	5	4.4	8.6	7	10.6	0.154	0.215

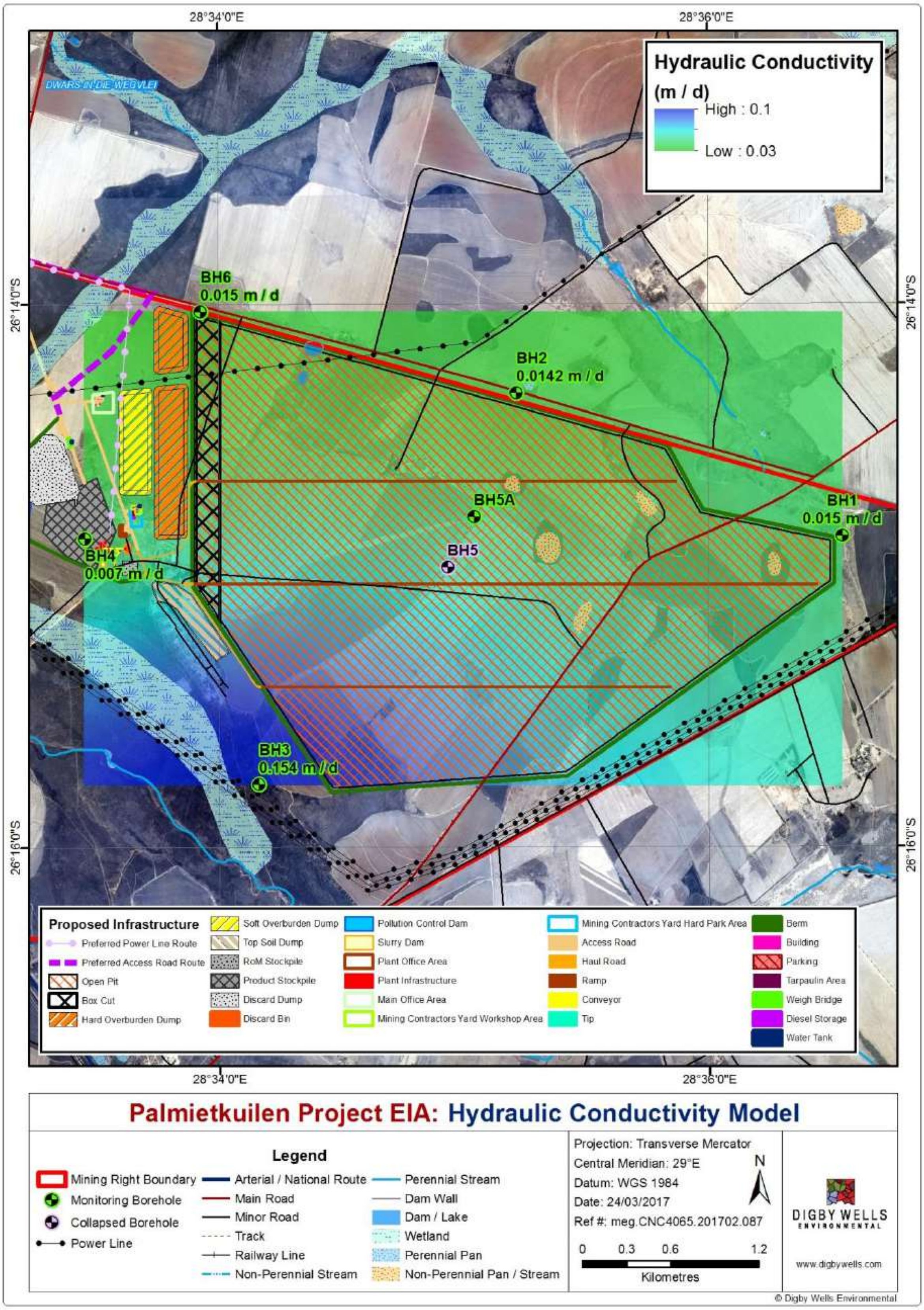

Figure 6-8: Hydraulic conductivity values estimated from the aquifer testing

6.8 Potential Receptors

Any user of a groundwater or surface water resource that is potentially affected by drawdown of the groundwater level or pollution from any of the mentioned potential sources in Section 6.9 is defined as a receptor.

6.9 Potential Sources

There are two types of sources which relate to the hydrogeological environment, namely:

- Sources of groundwater recharge; and
- Sources of contamination.

Both types of sources can be of natural or artificial (anthropogenic) origin.

6.9.1 Sources of Recharge

Mining activities have not yet commenced no artificial groundwater recharge is expected to occur. Once mining commences, seepage from return water dams (if not lined properly), temporary discard dump and backfilled voids could form the main contributors to artificial recharge. Typically rehabilitated areas contain more pore spaces (or less compacted material) allowing for greater recharge potential, with open mine pit often allowing for 100% direct recharge contributions. Rehabilitated land could allow for 8-20% recharge rates. As mining operations have not begun, current recharge is natural and is estimated at around 1-3% of the mean annual precipitation (Hodgson et al, 1998).

6.9.2 Sources of Contamination

Geostratum Groundwater and Geochemistry Consult (2016) state the following from geochemical investigations (acid-base testing) conducted on material expected to be waste rock at the project area:

- Majority of clastic waste rocks (approximately 85% of all waste rock) have very low sulphide content and will not generate acid mine drainage (AMD);
- 10% of the clastic waste rocks have a moderate amount of sulphides and have a moderate potential to generate AMD; and
- 5% of the clastic rocks (some carbonaceous rocks and especially high sulphide containing sandstone adjacent to coal seams) have a significant potential to generate acid and will form localised hot-spots within the backfill.

The backfill will therefore be a heterogeneous mixture of acid generation and non-acid generation rocks.

Potential source of groundwater contamination were identified as the following:

- Opencast;
- Discard dump;

- Stockpiles;
- Mining contractors workshops area;
- Pollution control dam;
- Slurry dam; and
- Diesel storage facilities.

Fuel dispensing areas and waste disposal sites may contribute to the contamination potential of the mine. Hydrocarbons may be found in elevated levels in the soil, groundwater and surface water in the area where they are handled (workshops and fuel dispensing areas). Although waste disposal sites and septic tanks do not contribute largely to the potential contaminant load of the proposed mine, they may impact in localised areas around the sites. The potential impacts include groundwater, surface water and soil.

7 Numerical Model

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 the natural and artificial recharge, temporary discard dumps and mine workings 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.

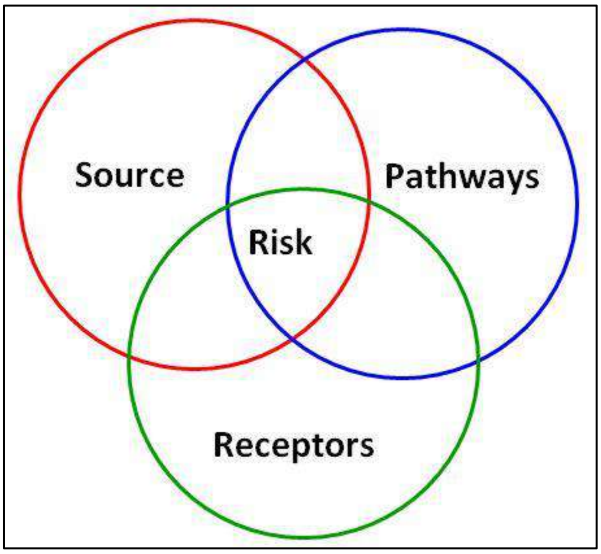

Figure 7-1: A conceptual model based environmental risk

A brief description on the methodology undertaken to construct the numerical model is found in Section 4.5. This section provides a more detailed description of the activities entailed when conducting this task.

7.1 Model Setup

During model setup, the conceptual model described in Section 6 was 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 were used to simulate the groundwater flow in the model domain for pre-mining steady state conditions.

7.1.1 Model Domain

The definition of the numerical model domain was set up considering the surface infrastructure and natural groundwater flow boundaries. The model is a simplified representation of site conditions constructed with as much accurately as possible in order to achieve the highest level of confidence.

The project area is located within the C21E quaternary catchment, in an area of topographical high compared to the majority of the local surrounding area (Figure 1-1). The model boundaries are selected with the consideration of groundwater divides and sub-catchments located far enough not to influence natural or induced groundwater flows within the area of interest.

The model domain is irregularly shaped with dimensions of 19 km by 16 km. A rectangular mesh was generated over the model domain, consisting of 374 rows and 315 columns. The mesh size of the model is 50 m longitudinally and transversely.

7.1.2 Layer Type

The model is simplified into an unconfined/confined aquifer, simulated as one layer, with hydraulic conductivity attained from field investigations (Section 6.7).

The boundary conditions are as described below:

- No flow boundary conditions (Neumann Boundary) around the boundary defined by watershed catchment divides; and
- Drain package for all perennial rivers and their tributaries in and around the project area.

Model domain described above is depicted in Figure 7-2.

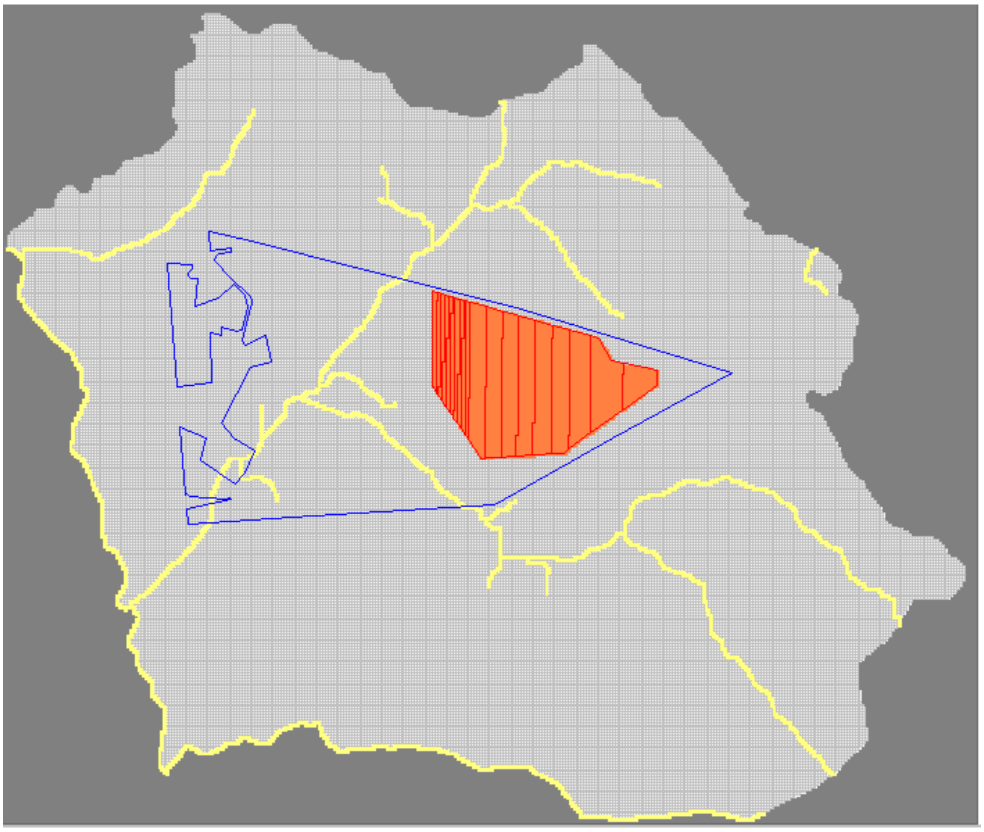

Figure 7-2: Model domain and boundary conditions

7.2 Model Calibration

The model was calibrated by manually adjusting recharge, aquifer properties and drain conductance (used to simulate rivers) within an acceptable range, according to the available data and field investigation results. This is done to establish a good correlation between the groundwater levels calculated by the model and those observed on site.

The calibrated model yielded a 99% correlation between the observed groundwater levels and calculated groundwater levels (Figure 7-3 and Figure 7-4).

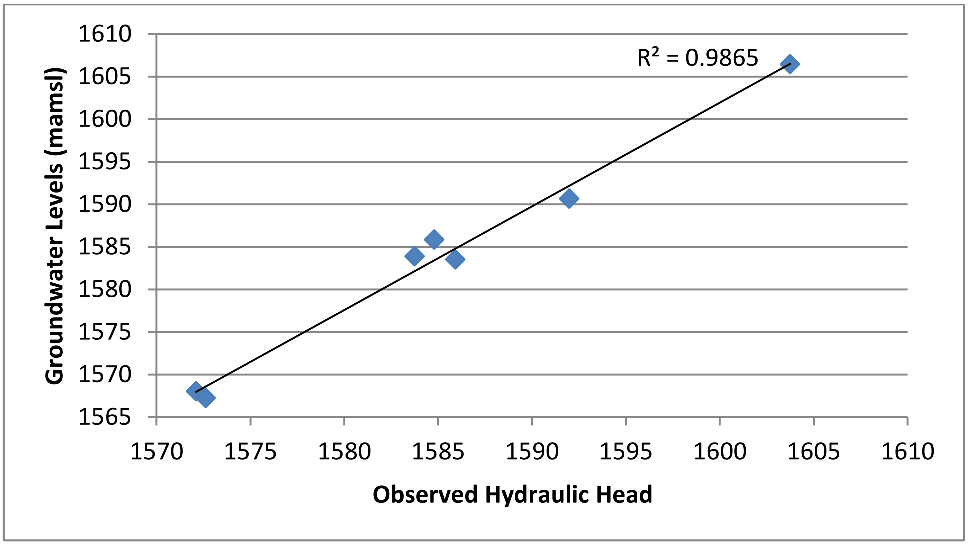

Figure 7-3: Groundwater level correlation

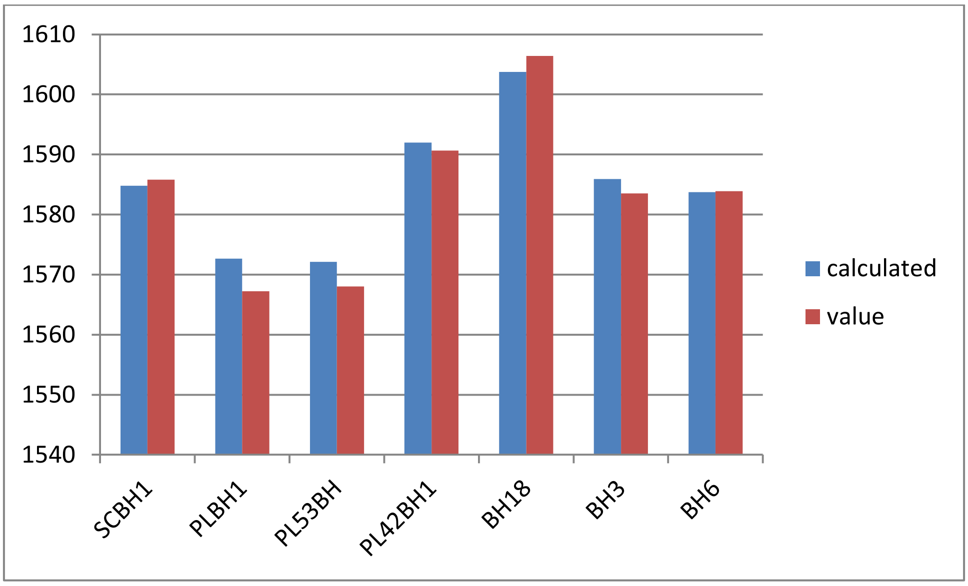

Figure 7-4: Groundwater level comparison

8 Sensitivity Analysis and No-Go Areas

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

8.1 Impact on Groundwater Quantity

Mine dewatering will result in the lowering of the water table, reducing the water quantity and creating a cone of depression. Groundwater users identified in Section 6.8 could potentially be impacted by this activity if they are located within the radius of influence.

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 mining operation.

The cone of dewatering at the end of operation is given in Figure 8-1. In this study, the size of the impacted 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. Streams and wetlands in the area are generally fed by groundwater as baseflow. The lowering of the groundwater level could therefore potentially lower the amount of water fed by the groundwater.

The impacted area is predominantly within the mine boundary area. No private boreholes have been identified that are outside the mine area but within the impacted area. The impacted area in relation to the identified private boreholes is illustrated in Figure 8-1.

8.2 Impact on Water Quality

Mining is likely to alter the natural geochemistry by exposing the sulfides for oxygenation and weathering. This could result in sulfate contamination and acid generation as observed in the coal mines in the region and from experience the concentration could reach up to 2,500 mg/L.

Contamination plumes predominantly migrate as a result of advection (i.e. with the flow of the groundwater). No or limited contamination is expected to reach the identified potential receptors during operation, due to the hydraulic gradient being towards the mining and abstraction areas.

After mine closure, however, dewatering will cease and groundwater will recover and start to flow towards the rivers and streams if no mitigation measures are put in place. The contamination plume will be transported with the groundwater flow.

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.

A source-term concentration of 100% has been simulated and the impacted concentration area has been defined from 1%. If, for example, the concentration of sulfate at the pit is 100 mg/L, a contour value of 50% indicates a concentration value of 50 mg/L. The plume extends into the vicinity of Verdrietlaagte wetland/stream and Dwars-in-die-Wegvlei' wetland/stream and could potentially have a negatively effect on the wetland/stream water quality.

Decant is predicted after mine closure at a maximum of approximately 5 L/s and could have a negatively effect on the Dwars-in-die-Wegvlei' wetland/stream quality if not properly managed.

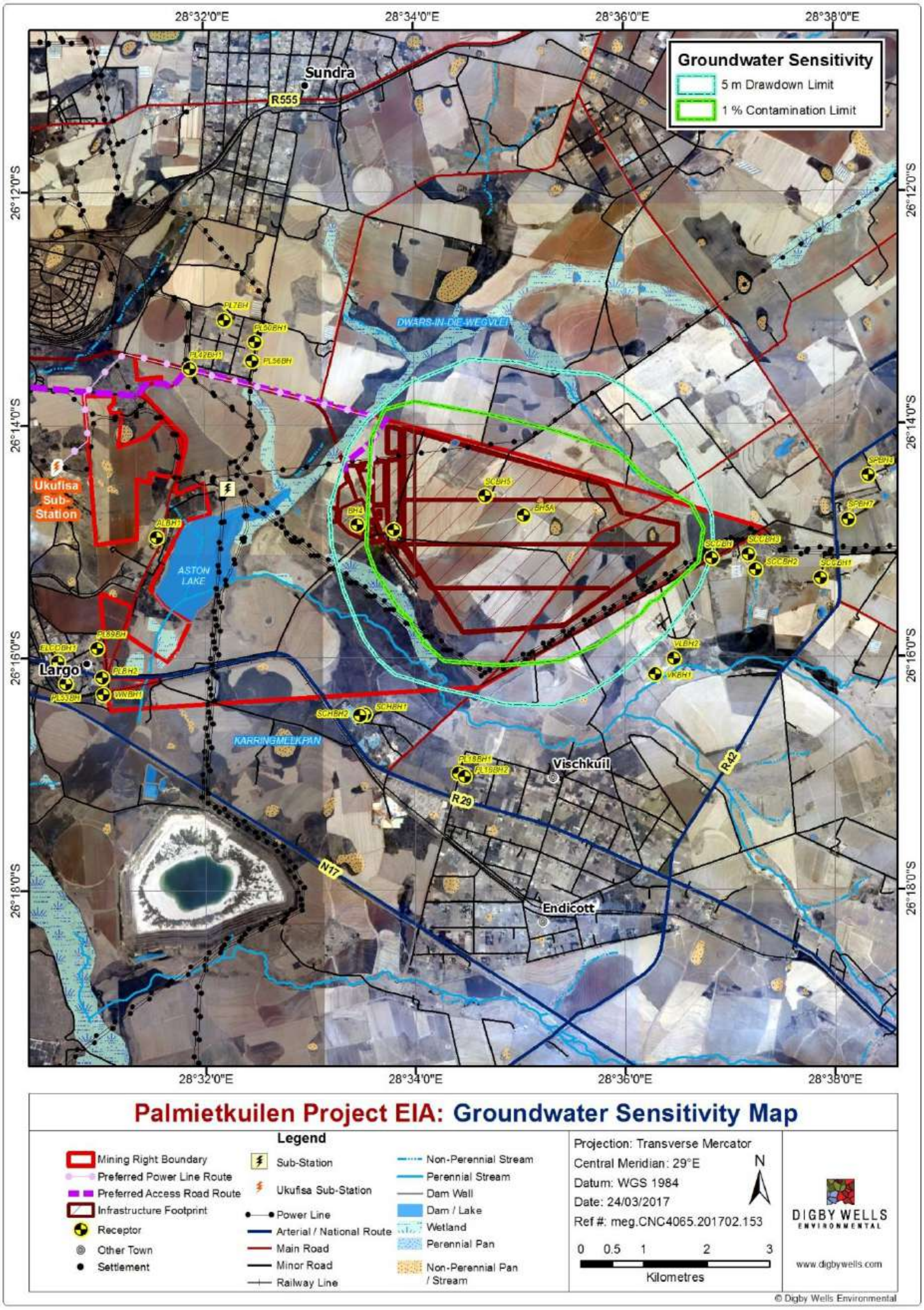

Figure 8-1: Groundwater sensitivity map

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 (recharge, hydraulic conductivity, drain conductance of the pit, 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 input aquifer parameters relative to one another. In descending order, the groundwater model is sensitive to hydraulic conductivity, specific yield, recharge, drain conductance of the pit and specific storage. This means that changes in hydraulic conductivity will have a greater impact on the model output than the other less sensitive parameters (i.e. recharge, specific yield, recharge, drain conductance of the pit and specific storage).

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

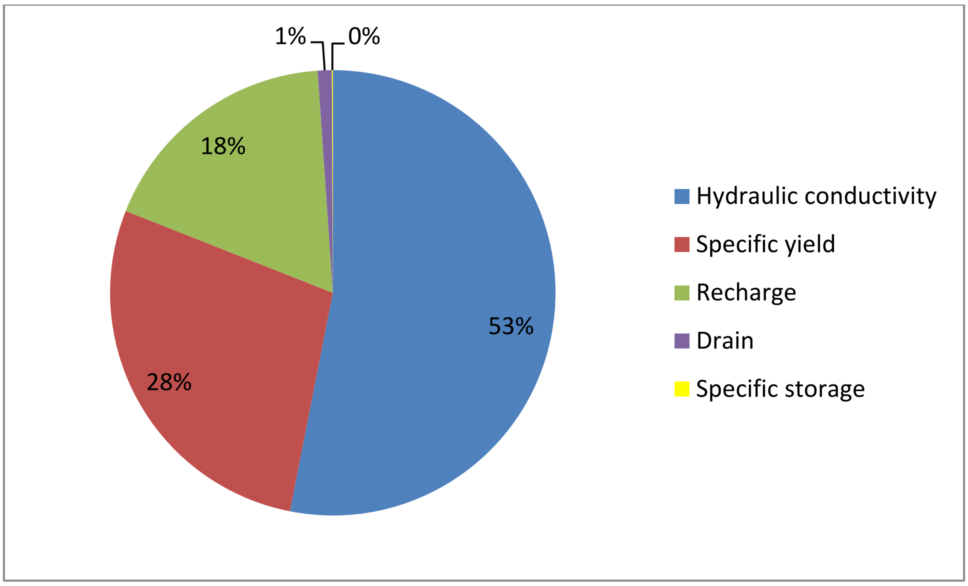

Figure 8-2: Sensitivity analysis

9 Impact Assessment and Management Planning

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.	<u>Province/ Region</u> 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.	<u>Municipal Area</u> 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

Probability	Significance																																					
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
Consequence	-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

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 Assessed

The list of project activity that is relevant to the groundwater impact assessment is 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
	Water Abstraction and Use	Water Tanks and Pipes
	Waste Generation and Disposal Stockpiling (box –cut material)	Waste Stockpile Pollution Control Dam
Operations	Stockpiling	Overburden Stockpile Product Stockpile Slurry Dam
	Plant and Equipment Operations	Workshop and Diesel Storage Tanks
	Waste Generation and Storage	Sewage Treatment Plant Waste Stockpile
	Mine Dewatering	Pumps and Pipes
Decommissioning and Closure	Waste Generation and Disposal	Waste Stockpiles

9.3 Impact Assessment

The proposed opencast 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 groundwater quality at most of the coal mines in the country is characterised by sulfate concentrations in the order of 2,500 mg/L. Similar impacts could also occur at the project site and management plans should be put in place to deal with these potential impacts.

Potential impacts are assessed in this section considering the construction, operation 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 the PCD.

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

9.3.1.2 Impact Description

The water table at the proposed infrastructure area is between 1.0 m and 16.2 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.

9.3.1.2.1 Management/ Mitigation Measures

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;
- Site clearance should be kept to a minimum area and short duration, if 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;

- The PCD should not be placed on areas with the potential for increased infiltration to groundwater, such as over fault zones; and
- The PCD should be lined to pro-actively prevent infiltration of contaminated seepage water.

9.3.1.2.2 Management Actions and Targets

The following actions and targets are required:

- Restrict areas that must be cleared of vegetation for construction activities to those absolutely necessary;
- Avoid constructing below the water table as far as possible;
- Apply a liner underneath the PCD to minimise or avoid infiltration;
- Implementation of adequate storm water management to contain all waste water and/or volatile organic compounds, for treatment and recycling; and
- Install long term monitoring boreholes. The positions of the monitoring boreholes are provided in Section 12.3.

9.3.1.2.3 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 mine infrastructure (box- cut, stockpiles, PCD) through the removal of the top soil and weathered rocks			
Dimension	**Rating**	**Motivation**	**Significance**
Impact Description: Lowering of the water table			
Pre-Mitigation			
Duration	Short term: Less than 1 year (2)	Construction activities are expected to be short-lived (i.e. during the construction phase)	Negligible (-15)
Extent	Limited (1)	Site clearing will only occur within and immediately around the project site	
Intensity x type of impact	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			

▪ Restrict areas that must be cleared of vegetation for construction activities to those absolutely necessary. ▪ Avoid or minimise construction activities to a depth of below the water table. ▪ Apply a liner underneath the PCD to minimise or avoid infiltration. ▪ Avoid placement of the pollution control dams on areas with the potential for increased infiltration to groundwater, such as over fault zones. ▪ Pollution control dams should be lined to pro-actively prevent infiltration of contaminated seepage water. ▪ If that is not possible, 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 (if applicable) is not expected to cause environmental impacts. ▪ Adequate storm water management should be implemented to contain all waste water and/or volatile organic compounds, for treatment and recycling. ▪ Install groundwater monitoring boreholes to assess the time series water level and quality impacts and trends.			
Post-Mitigation			
Duration	Short term: Less than 1 year (2)	Any lowering of the water table during the construction phase is expected to be shallow and recover relatively quickly	Negligible (-8)
Extent	Limited (1)	No impacts are expected however if they occur they will be reduced to isolated parts of the mine where site clearing is going to take place	
Intensity x type of impact	Negative (-1)	Considering that the construction phase will be for a short period, the intensity will be minimal	
Probability	Rare (2)	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;
- PCD;
- Slurry deposition; and
- Overburden and topsoil stockpiling.

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

Interaction	Impact
Groundwater dewatering	Water level lowering
Pollution control dam	Groundwater contamination due to seepage from the dam
Slurry and discard deposition and temporary stockpiles	Groundwater contamination due to seepage
Overburden stockpiles	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 and geotechnical stability. Dewatering is recommended to start with the starting of the excavations. This can potentially impact the groundwater environment negatively by lowering the water level and creating a cone of depression in the top weathered aquifer where the majority of private boreholes are often located. It has however been found that the dewatering cone will not affect any private boreholes that are outside the mine property.

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 1,790 m^3/d. It should be noted that this estimate is based on permeability studies conducted on 5 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. A maximum drawdown of 63 m expected to occur. The maximum radius of influence is predicted to be 3 km, with 1.3 km going beyond the project area boundary and the remaining contained within the project area.

Table 9-8: Estimated groundwater inflow rates

Year	Inflows (m^3/d)		Year	Inflows (m^3/d)
Y0	0		Y10	580
Y1	375		Y11-15	701
Y2	385		Y16-20	815
Y3	397		Y21-25	984
Y4	404		Y26-30	1120
Y5	419		Y31-35	1260

Y6	453		Y36-40	1410
Y7	460		Y41-45	1560
Y8	517		Y46-50	1690
Y9	572		Y51-53	1790

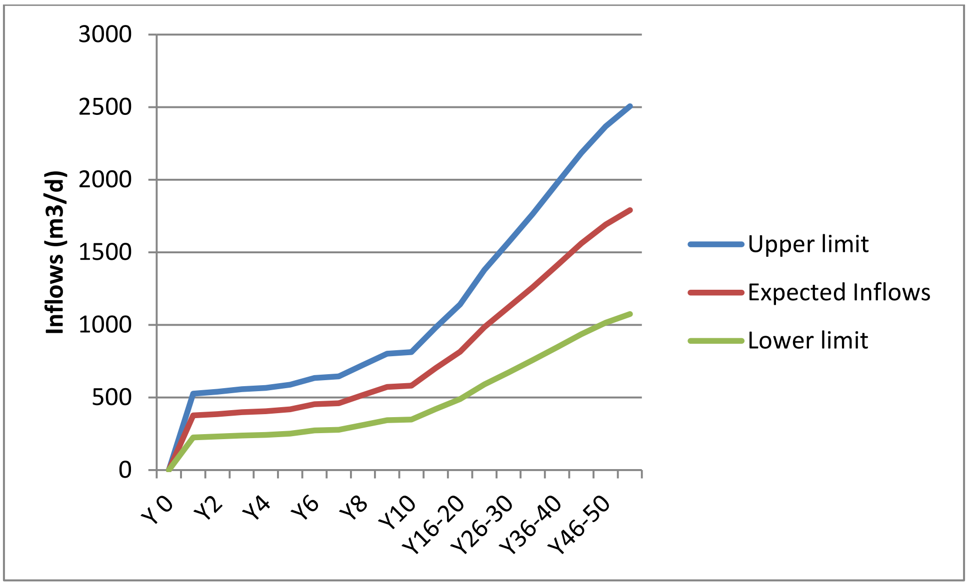

Figure 9-1: Estimated groundwater inflow rates

A study of various coal mines shows 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 the coalfields 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 water pumped out is assumed to be kept in closed circuit and utilised on the mine.

9.3.2.1.2 Management Actions and Targets

The following actions and targets are required:

- Contain the contaminated water in the mine water systems;
- Monitor the effects of dewatering; 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 if dewatering boreholes are used.

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

<table>
<tr><th colspan="4">Activity & Interaction: Mine dewatering and creation of cone of dewatering</th></tr>
<tr><th>Dimension</th><th>Rating</th><th>Motivation</th><th>Significance</th></tr>
<tr><th colspan="4">Impact Description: Lowering of the water table</th></tr>
<tr><th colspan="4">Pre-Mitigation</th></tr>
<tr><td>Duration</td><td>Beyond project life (6)</td><td>The water level will remain below its natural level for some time after the life of a project</td><td rowspan="4">Moderate (-91)</td></tr>
<tr><td>Extent</td><td>Local (3)</td><td>The cone of depression extends beyond the development area.</td></tr>
<tr><td>Intensity x type of impact</td><td>Serious (-4)</td><td>Mine dewatering will result in lowering of the water table within the site, with a potential impact on the local wetlands and streams</td></tr>
<tr><td>Probability</td><td>Definitely (7)</td><td>Definite: There are sound scientific reasons to expect that the impact will definitely occur with a >80% probability</td></tr>
<tr><td colspan="4">Mitigation/ Management actions</td></tr>
<tr><td colspan="4">Store the dewatered water in pollution control dam and ensure that the dam will have sufficient storage volume and utilise this water in the process. If that is not possible, re-introduce treated water into the streams after ensuring that it meets the required river quality objectives.
If impact is confirmed through monitoring, management solutions should be implemented acceptable to the authorities such as the purchase of impacted land or the provision of alternate sources of water.
Groundwater monitoring should be conducted.</td></tr>
<tr><td colspan="4">Post-Mitigation</td></tr>
<tr><td>Duration</td><td>Beyond project life (6)</td><td>The water level will remain below its natural level for some time after the life of a Project</td><td rowspan="4">Minor (-27)</td></tr>
<tr><td>Extent</td><td>Limited (2)</td><td>With the above stated mitigation methods, the extent is expected to be limited</td></tr>
<tr><td>Intensity x type of impact</td><td>Minor - negative (-1)</td><td>If the abstracted water is stored in the PCD or treated and re-introduced to the streams, the environmental significance is rated as minor</td></tr>
<tr><td>Probability</td><td>Unlikely (3)</td><td>With the application of the proposed mitigation plans, the probability of the impact will be unlikely</td></tr>
</table>

<table>
<tr><th>Activity & Interaction: Groundwater contamination as a result of opencast mining</th></tr>
<tr><th>Impact Description: Contamination plume in the groundwater</th></tr>
</table>

<table>
<tr><td colspan="4">Activity & Interaction: Groundwater contamination as a result of opencast mining</td></tr>
<tr><td colspan="4">Impact Description: Contamination plume in the groundwater</td></tr>
<tr><td colspan="4">Prior to mitigation/ management</td></tr>
<tr><td>Duration</td><td>Beyond project life (6)</td><td>Groundwater contamination due to mine disturbance will occur during the operational phase and is expected to persist even after closure</td><td rowspan="4">Minor (negative) – 40</td></tr>
<tr><td>Extent</td><td>Limited (2)</td><td>The contaminated groundwater is unlikely to feed the rivers and will not contaminate an area larger than the mine footprint. This is due to the groundwater dewatering that will intercept the contamination plume during the operation phase. The net inflow will be toward the pit</td></tr>
<tr><td>Intensity x type of impact</td><td>Minor – negative (-2)</td><td>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</td></tr>
<tr><td>Probability</td><td>Probable (4)</td><td>The impact is likely to occur, although the plume is unlikely to migrate beyond the mine area during the operational phase</td></tr>
<tr><td colspan="4">Mitigation/ Management actions</td></tr>
<tr><td colspan="4">Concurrent rehabilitation should be conducted to minimise water and oxygen inflow from the atmosphere.
The pit should be enclosed with berms to contain surface water runoffs from entering.
If impact is confirmed through monitoring, management solutions should be sought for upon agreement with the farmers or communities with impacted groundwater or mine purchase land.
Contaminated water should be utilised by the mine, instead of using freshwater (if practical).</td></tr>
<tr><td colspan="4">Post management</td></tr>
<tr><td>Duration</td><td>Beyond project life (6)</td><td>Groundwater contamination due to mine disturbance will occur during the operational phase and is expected to persist even after closure</td><td rowspan="4">Negligible (negative) – 30</td></tr>
<tr><td>Extent</td><td>Limited (2)</td><td>With the implementation of the above stated mitigation methods, the impact extent can be minimised to the site only</td></tr>
<tr><td>Intensity x type of impact</td><td>Minimal – negative (2)</td><td>The dewatering of the opencast mine will contain the pollution plume during the operational phase, with minor effects on the groundwater environment</td></tr>
<tr><td>Probability</td><td>Unlikely (3)</td><td>The impact is unlikely to be significant with the implementation of the above stated mitigation methods</td></tr>
</table>

<table>
<tr><td colspan="4">Activity & Interaction: Groundwater contamination as a result of seepage from the waste stockpiles and slurry dam</td></tr>
<tr><td colspan="4">Impact Description: Contamination plume in the groundwater</td></tr>
<tr><td colspan="4">Prior to mitigation/ management</td></tr>
<tr><td>Duration</td><td>Permanent (7)</td><td>The stockpiles and slurry dam are likely to seep and contaminate the groundwater, even after mine closure</td><td>Minor (negative) – 77</td></tr>
</table>

Activity & Interaction: Groundwater contamination as a result of seepage from the waste stockpiles and slurry dam			
Impact Description: Contamination plume in the groundwater			
Extent	Limited (2)	The contaminated groundwater is unlikely to feed the rivers and will not contaminate an area larger than the mine footprint. This is due to the groundwater dewatering that will intercept the contamination plume during the operation phase	
Intensity x type of impact	Minor (-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	Definite (7)	Seepage from unlined dams will definitely impact the groundwater	
Mitigation/ Management actions			
▪ Slurry dam, overburden and topsoil stockpiles should be managed to minimise infiltration of contaminants to the groundwater. Mitigation methods that should be considered include the correct placement of the stockpile and covering them with soil to minimise rainfall infiltration and mobilisation of dissolved metals and vegetate them. The shape of the stockpile should be managed to control the ease with which water can run off from the facility. ▪ Implement the required prevention mechanisms at the discard and slurry stockpiles to prevent pollution migration. ▪ Discard being placed back into the pit should be put on the coal seam floor or as low as possible and definitely below the water table in areas where there will be no oxygenation and water throughflow.			
Post management			
Duration	Permanent (7)	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 opencast 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	

Activity & Interaction: Dirty mine water storage in the PCD			
Dimension	**Rating**	**Motivation**	**Significance**
Impact Description: Groundwater contamination due to seepage from PCD			
Prior to mitigation/ management			
Duration	Project life (5)	Seepage of contaminated water will occur during the operation of the dam	Minor (negative) – 70
Extent	Limited (2)	The impact from the pollution control dam is expected to be local and limited to within 150 m of	

		the PCD footprint area	
Intensity x type of impact	Minor (3)	Once contamination starts, it take time to rehabilitate naturally	
Probability	Definite (-7)	Seepage from unlined PCD will definitely impact the groundwater	
Mitigation/ Management actions			
▪ Apply a liner underneath the PCD to minimise or avoid infiltration; and ▪ Monitor the groundwater quality for impact detection.			
Post management			
Duration	Project life (5)	The seepage from the pollution control dam will take place throughout the project life	Negligible (negative) – 21
Extent	Very limited (1)	With the application of a liner, the plume will be very limited	
Intensity x type of impact	Minimal (-1)	The intensity is minimal with the application of liners	
Probability	unlikely (3)	The impact is unlikely to occur	

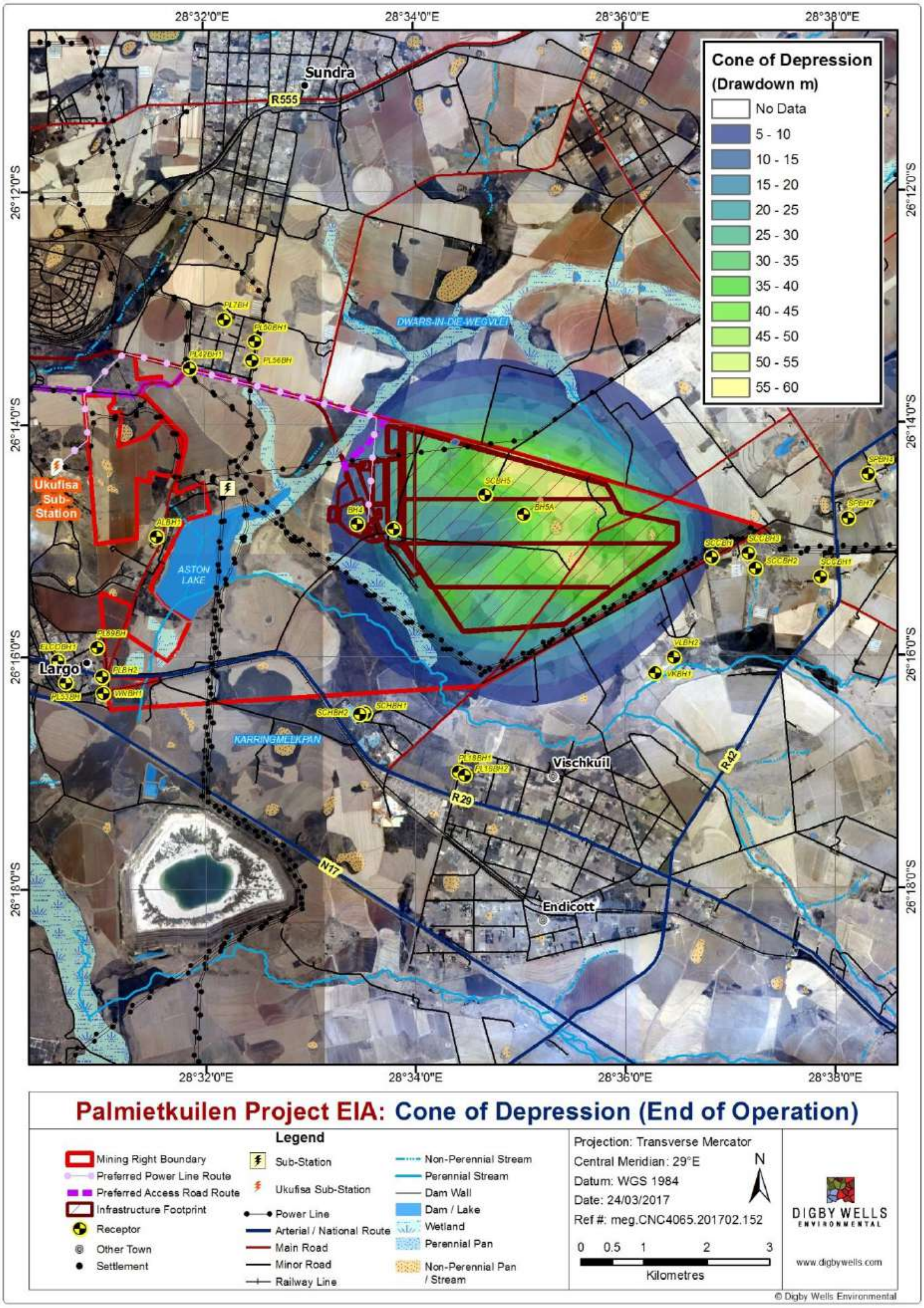

Figure 9-2: Estimated cone of depression at the end of operation

9.3.3 Decommissioning and Post-Closure Impacts

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 water contamination	Groundwater and possibly 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 35 years after closure) the contaminants will start to migrate away from the mine site.

A geochemical assessment was conducted by Geostratum Groundwater and Geochemistry Consult (2016) which reported that 5% of the rocks (consisting of carbonaceous rocks and sandstone adjacent to coal seams) have a significant potential to generate AMD. It is also expected that the discard and slurry will have the potential to generate leachates.

The simulated contamination plumes 100 years after closure are displayed in Figure 9-3. The plume is simulated in terms of percentage; a sulphate concentration of 100% is assumed at the source of contamination. The plume is expected to extend approximately 500 m beyond the project area boundary.

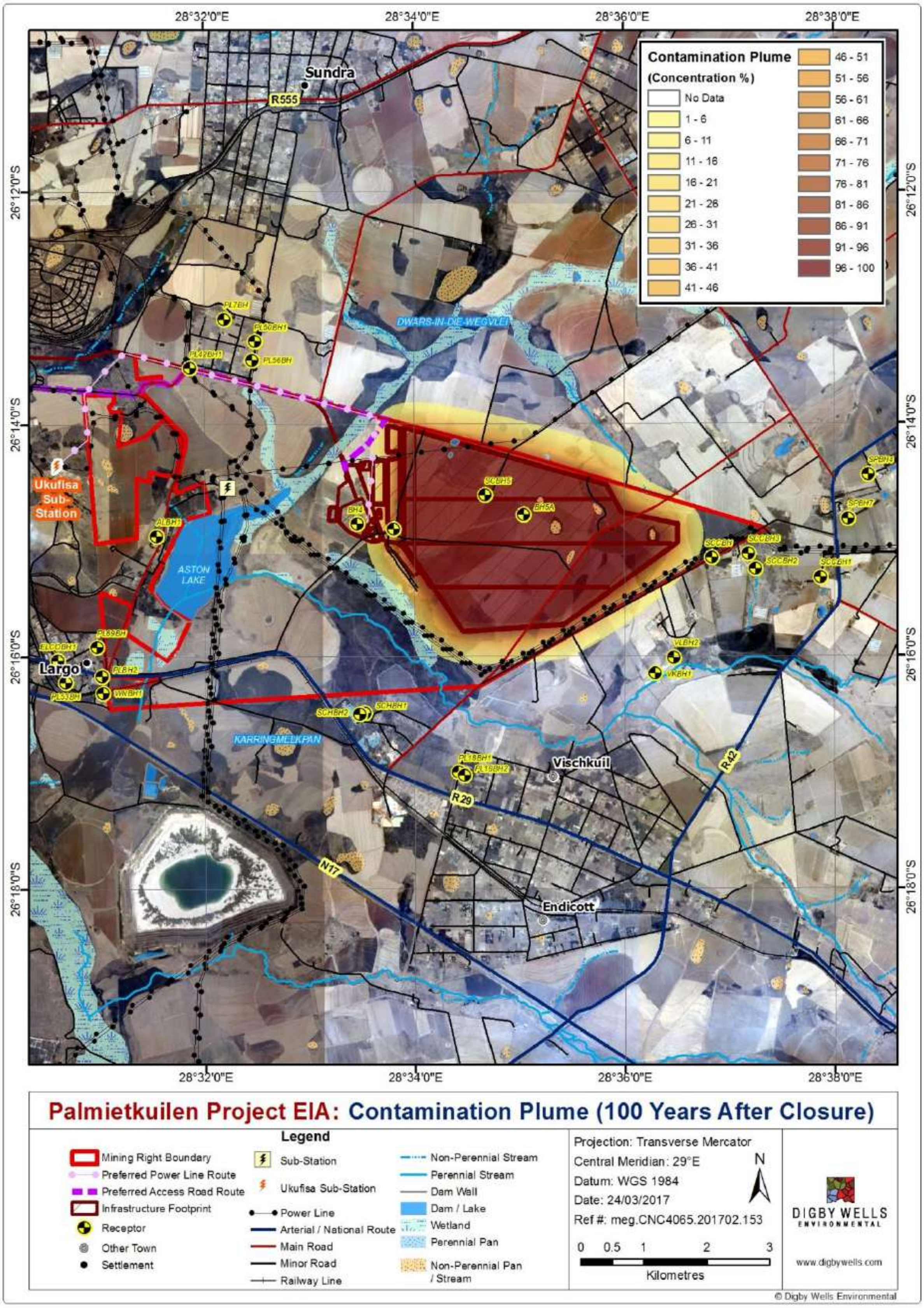

Figure 9-3: Contamination plume migration 100 years after mine closure

Model simulations and hydrostatic calculations show that the mine is likely to decant after closure. The decanting is expected to occur at a locality shown in Figure 9-5. A summary of the decant includes:

- The decanting will start 35 years after mine closure and is expected to decant at a rate ranging between 3 and 7 L/s, with the average being 5 L/s (Figure 9-4); and
- Once the decant (which is expected to be poor in quality) 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 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 seepage and decant followed by rehabilitation will be required.

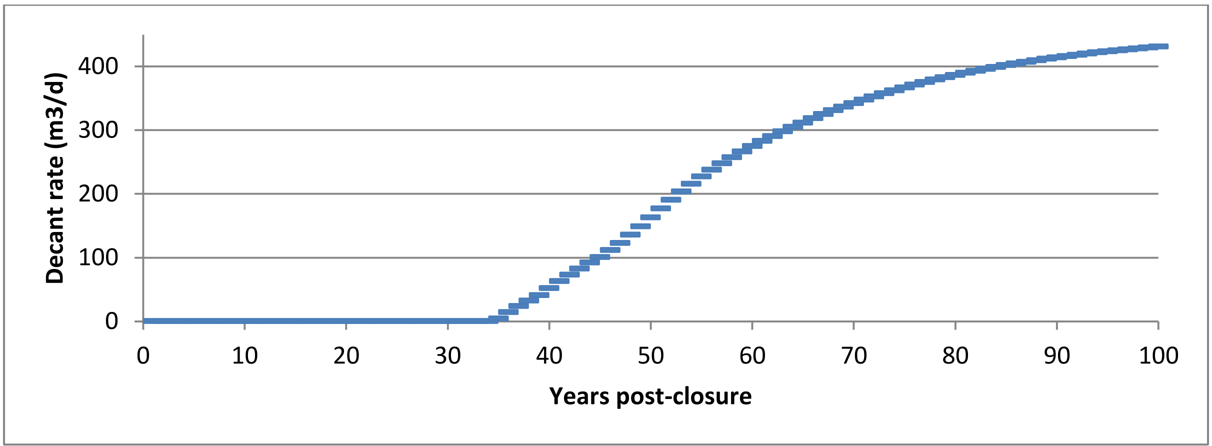

Figure 9-4: Predicted decanting period and rate

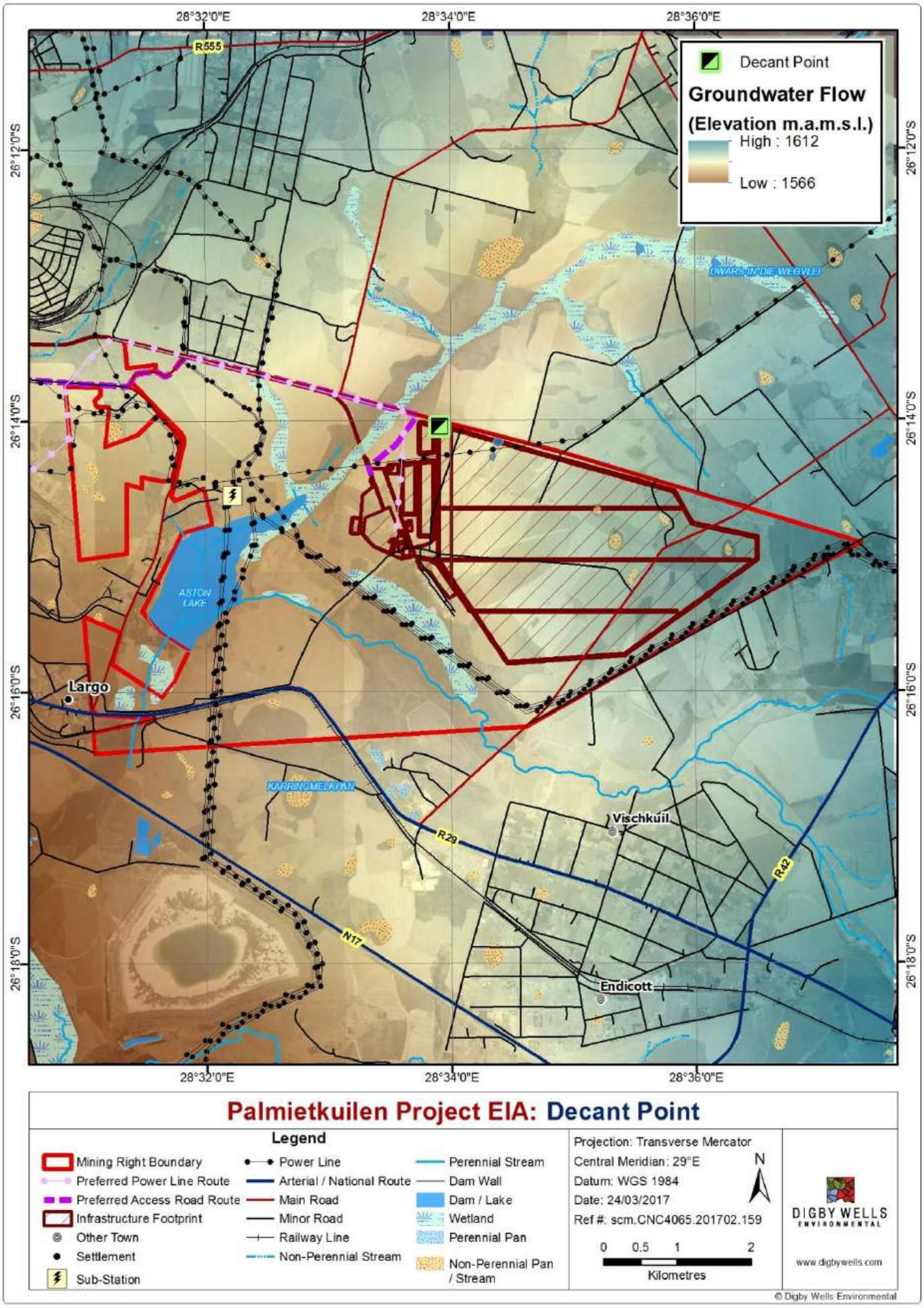

Figure 9-5: Potential decant location

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;
- Minimise the generation of poor quality water; 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 Management Actions and Targets

The following actions and targets are required:

- Place potentially leachate generating materials as low as possible in the the mining pit to prevent leachate generation and movement;
- Contain the contamination plume to within the mine area, by active or passive mitigation ways; and
- Minimise the impact associated with the decant by intercepting and treating it before joining the streams.

9.3.3.1.4 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 can flow to the streams 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	
Probability	Certain (7)	Based on analytical and numerical modelling, it is certain that there will be a decant after mine closure	
Mitigation/ Management actions			

Activity & Interaction: Mine decanting and contamination of surface water bodies			
Dimension	**Rating**	**Motivation**	**Significance**
▪ The decant should be captured before joining the streams. It should be treated, passively if possible using wetlands, and re-introduced into the streams. As experienced from other coal mines, the decant quality could be up to 2500 mg/L of sulfate. ▪ If an impact is confirmed through monitoring, management solutions should be implemented to an acceptable level to the authorities such as the purchase of impacted land or the provision of alternate sources of water. ▪ The pit should be backfilled and rehabilitated after closure to minimise water and oxygen inflow from the atmosphere. ▪ The potentially leachate generating material should be placed at the bottom of the mining pits; ▪ Decant rate and quality should be monitored as part of the regular groundwater monitoring. ▪ The numerical model should be updated annually for the first 2 years with the monitoring data. There after the model can be updated once in 5 years.			
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	
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 mining operations			
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 boreholes that would be drilled at or close to the rehabilitated pit. The maximum extent from the pit sides is 550 m	
Intensity x type of impact	Moderate – negative (-3)	Overall the streams are gaining from the groundwater baseflow. There will be a risk of contaminants migrating from the pit area to the wetlands and streams which modelling shows not to be extensive but this needs to be monitored and appropriate action taken if necessary.	
Probability	Likely (4)	The impact is likely to occur since the groundwater will recover after closure and start to decant	
Mitigation/ Management actions			

Activity & Interaction: Groundwater contamination as a result of mining operations			
Impact Description: Contamination plume in the groundwater			
▪ Groundwater will flow away from the mine footprint if the hydraulic head within the mine is higher than the surrounding elevation. Ensure that water quality is not poor by placement of leachate generating materials in a position where they will not adversely affect water quality. ▪ If impact is confirmed through monitoring, 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 should be conducted.			
Post management			
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 Impact

There are a number of mining related operations located within a 10 km radius of the project area. Located directly west of the project area is the Grootvlei Gold Mine Shaft, northeast of the project area is Kangala Coal Mine, Manungu Colliery and Eloff Coal Mine Project and east of the Blesbokspruit is an area of old coal mine workings and current sand and clay mining operations called New Largo. Additionally, located upstream and downstream of the Blesbokspruit in relation to the project area, there are vast amounts of unknown mining related infrastructure that contribute to the cumulative impacts within this area (shown in Figure 10-1).

As discussed previously, the maximum water level drawdown at the project site will occur in at the end of the operational phase as illustrated in Figure 9-2. The figure shows that the impact of the dewatering activities is predominantly contained within the project area. The potential contamination plume 100 years after mine closure (Figure 9-3) also shows the same result with plumes not migrating far away from the workings.

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

As discussed in Section 9.3.3, decanting is expected to occur in the north-west area of the mine after mine closure. Decanting is also possible from other mines in the catchment. The Grootvlei mine is pumping out and treating mine water at the rate of 80-120 Ml/day. This water is discharged to the Blesbokspruit and is a much larger impact than the proposed mine would have. There are plans to treat this water to a potable standard and thus a large flow could be removed from the catchment. Potentially the Palmietkuilen water could also be added to this treated water. All the mines within this catchment could potentially have a cumulative impact on the streams and surface water bodies. Surface water bodies are essential for water supply and the ecological well-being of the environment. Cumulative impacts that could occur include:

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

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

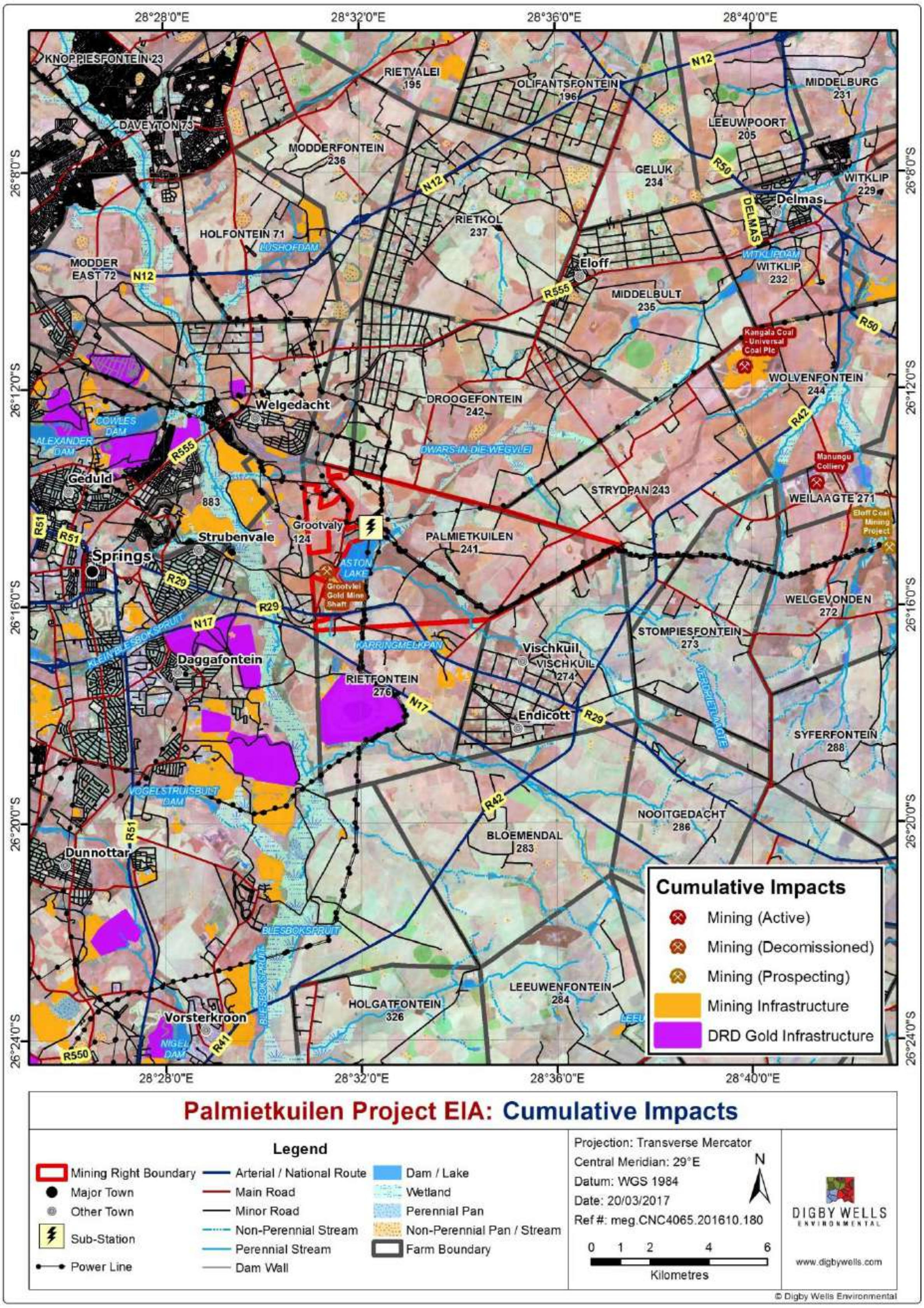

Figure 10-1: Mines and infrastructure within 10 km of the project site

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 bounded 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; 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 should be conducted 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; ▪ The stockpile shape should be managed 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 discard stockpile	Groundwater	▪ Groundwater contamination.
Pollution control dam	Groundwater	▪ Groundwater contamination.
Opencast development	Dewatering	▪ Depletion of the groundwater; ▪ Reduction of the flow rate of the streams; ▪ Reduction of water in wetland; and ▪ Lowering of water tables in private boreholes.
	Groundwater contamination	▪ AMD and dissolution of heavy metals.
Contamination plume and decant	Groundwater and surface water	▪ Deterioration of groundwater and surface water quality. Deterioration of water quality in wetland 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 is also provided 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

Activities	Phase	Size and scale of disturbance	Mitigation Measures	Compliance with standards	Time period for implementation
Site clearing	Construction	<0.5 km^2	▪ 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; ▪ Site clearance should be kept to a minimum area and short duration, if 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; ▪ The PCD should not be placed on areas with the potential for increased infiltration to groundwater, such as over fault zones; and ▪ PCD should be lined to pro-actively prevent infiltration of contaminated seepage water.	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

Activities	Phase	Size and scale of disturbance	Mitigation Measures	Compliance with standards	Time period for implementation
Overburden and topsoil stockpile	Operation	<1km^2	▪ Overburden and discard 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.

Activities	Phase	Size and scale of disturbance	Mitigation Measures	Compliance with standards	Time period for implementation
Pollution control dam	Operation	<0.5 km^2	▪ Avoid placement of the pollution control dam 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 dam) 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 dam 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 Dam	▪ PCD design should be completed before the construction starts. ▪ Groundwater monitoring must commence from the start of the construction phase.

Activities	Phase	Size and scale of disturbance	Mitigation Measures	Compliance with standards	Time period for implementation
Opencast development - Dewatering	Operation and post-closure	8.5 km^2	▪ Store the dewatered water in pollution control dam and ensure that the dam will has sufficient storage volume. If that is not possible, re-introduce treated water into the streams after ensuring that they meet the required river quality objectives. ▪ Affected receptors (if proven through monitoring) should be compensated. ▪ Groundwater monitoring should be conducted.	▪ 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. ▪ Conceptual and numerical models should be refined every two years in the first four years and thereafter every five years based on groundwater monitoring results.

Activities	Phase	Size and scale of disturbance	Mitigation Measures	Compliance with standards	Time period for implementation
Opencast development - Groundwater contamination	Operation and post-closure	8.5 km^2	▪ Ensure that backfilled areas are rehabilitated and revegetated; ▪ Place all material which could generate leachates at the base of the pits so that groundwater contamination is minimised. ▪ Affected receptors should be compensated; ▪ Groundwater monitoring, to assess the time series water level and quality impacts and trends; and ▪ 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. ▪ Conceptual and numerical models should be refined every two years in the first four years and thereafter every five years based on groundwater monitoring results.
Mine decant	Post-closure	5 L/s	▪ 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 35 years after closure).

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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	▪ 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; ▪ Site clearance should be kept to a minimum area and short duration, if 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; ▪ The PCD should not be placed on areas with the potential for increased infiltration to groundwater, such as over fault zones; and ▪ The PCD should be lined to pro-actively prevent infiltration of contaminated seepage water.	▪ N/A

Activities	Potential impacts	Aspects affected	Phase	Mitigation	Standard to be achieved/objective
Hard rock and discard stockpile	Groundwater contamination	Groundwater quality	Operation	▪ Overburden and discard 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. ▪ The discard stockpile should be appropriately designed and managed to prevent groundwater impacts. ▪ Groundwater monitoring.	▪ DWS Best Practice Guideline G4: Impact prediction
Pollution control dam	Groundwater contamination	Groundwater quality	Operation	▪ Avoid placement of the pollution control dam 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 dam) 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 Dam.

Activities	Potential impacts	Aspects affected	Phase	Mitigation	Standard to be achieved/objective
Opencast development - Dewatering	Groundwater, wetland and surface water depletion	Surface and groundwater quantity	Operation	▪ Store the dewatered water in pollution control dam and ensure that the dam will has sufficient storage volume. If that is not possible, re-introduce treated water into the streams after ensuring that they meet the required river quality objectives. ▪ Affected receptors (if proven through monitoring) should be compensated. ▪ Groundwater monitoring should be conducted.	▪ N/A.
Opencastdevelopment - Groundwater contamination	Groundwater, wetland and surface water contamination	Surface and groundwater quality	Operation and post-closure	▪ Dewatering should be conducted efficiently ▪ Dewatering level should be kept close to the coal seam floor, not deeper. ▪ Affected receptors should be compensated ▪ Ensure that the waste rock material that shows a significant potential to generate acid is deposited at the base of the pit in such a way that it will be completely flooded with groundwater. ▪ Groundwater monitoring should be conducted monthly.	▪ 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	▪ Ensure that backfilled areas are rehabilitated and revegetated; ▪ Affected receptors should be compensated; ▪ Groundwater monitoring, to assess the time series water level and quality impacts and trends; and ▪ 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.

Table 12-4: Mitigation

Activities	Potential impacts	Aspects affected	Mitigation type	Time period for implementation	Compliance with standards
Site clearing	Groundwater depletion	Groundwater quantity	▪ 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; ▪ Site clearance should be kept to a minimum area and short duration, if 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; ▪ The PCD should not be placed on areas with the potential for increased infiltration to groundwater, such as over fault zones; and ▪ The PCD should be lined to pro-actively prevent infiltration of contaminated seepage water.	▪ 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

Activities	Potential impacts	Aspects affected	Mitigation type	Time period for implementation	Compliance with standards
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
Pollution control dam	Groundwater contamination	Groundwater quality	▪ Avoid placement of the pollution control dam 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 dam) 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

Activities	Potential impacts	Aspects affected	Mitigation type	Time period for implementation	Compliance with standards
Opencast development - Dewatering	Groundwater, wetland and surface water depletion	Surface and groundwater quantity	▪ Store the dewatered water in pollution control dam and ensure that the dam will has sufficient storage volume. If that is not possible, re-introduce treated water into the streams after ensuring that they meet the required river quality objectives. ▪ Affected receptors (if proven through monitoring) should be compensated. ▪ Groundwater monitoring should be conducted.	▪ If impact is confirmed through monitoring, management solutions should be sought for upon agreement with the farmers or communities with impacted groundwater or mine purchase land. ▪ Groundwater monitoring must commence from the start of the construction phase. ▪ Conceptual and numerical models should be refined every two years in the first four years and thereafter every five years based on groundwater monitoring results.	▪ N/A

Activities	Potential impacts	Aspects affected	Mitigation type	Time period for implementation	Compliance with standards
Opencast-Groundwater contamination	Groundwater, wetland and surface water contamination	Surface and groundwater quality	▪ Affected receptors should be compensated. ▪ Mine dewatering to intercept the contamination plume to within the mine area. ▪ Ensure that the waste rock material that shows a significant potential to generate acid is deposited at the base of the pit, during backfilling, in such a way that it will be completely flooded with groundwater. ▪ Monitoring of groundwater quality and water levels. ▪ Update the numerical model as more groundwater information is collected.	▪ If impact is confirmed through monitoring, management solutions should be sought for upon agreement with the farmers or communities with impacted groundwater or mine purchase land; ▪ Groundwater monitoring must commence from the start of the construction phase. ▪ Backfilling should take pace concurrently with the opencast development. ▪ Conceptual and numerical models should be refined every two years 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.

Activities	Potential impacts	Aspects affected	Mitigation type	Time period for implementation	Compliance with standards
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 35 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 will be undertaken to establish the following:

- The impact of mine dewatering on the local aquifers. This will be achieved through monitoring of groundwater levels; and
- Groundwater quality trends. This will be achieved through sampling and laboratory analysis of the groundwater.

It is proposed that groundwater monitoring be undertaken according to the schedule contained in this chapter (refer to Table 12-6 and Figure 12-1). The proposed monitoring boreholes are strategically located up gradient and down gradient of the predicted contamination plume and cone of depression proposed Palmietkuilen project area.

Table 12-6: Proposed groundwater monitoring boreholes

No.	Borehole	Existing/ Proposed	Latitude	Longitude
1	BH6	Existing	-43419.9	-2902810
2	BH3	Existing	-43019.6	-2906022
3	BH4	Existing	-44204	-2904353
4	SCBH1	Existing	-43624.3	-2904428
5	SCCBH3	Existing	-37992.3	-2904809
6	SCHBH1	Existing	-44071.9	-2907355
7	SPBH1	Existing	-36488	-2904007
8	PROBH1	Proposed	-41895.9	-2902784
9	PROBH10	Proposed	-43219.2	-2905456
10	PROBH2	Proposed	-42133	-2901599
11	PROBH3	Proposed	-38277.2	-2902215
12	PROBH4	Proposed	-39462.4	-2906719
13	PROBH5	Proposed	-41658.9	-2907525
14	PROBH6	Proposed	-45198.6	-2904886
15	PROBH7	Proposed	-44534.9	-2903385
16	PROBH8	Proposed	-40078.7	-2905802
17	PROBH9	Proposed	-40047.1	-2903337

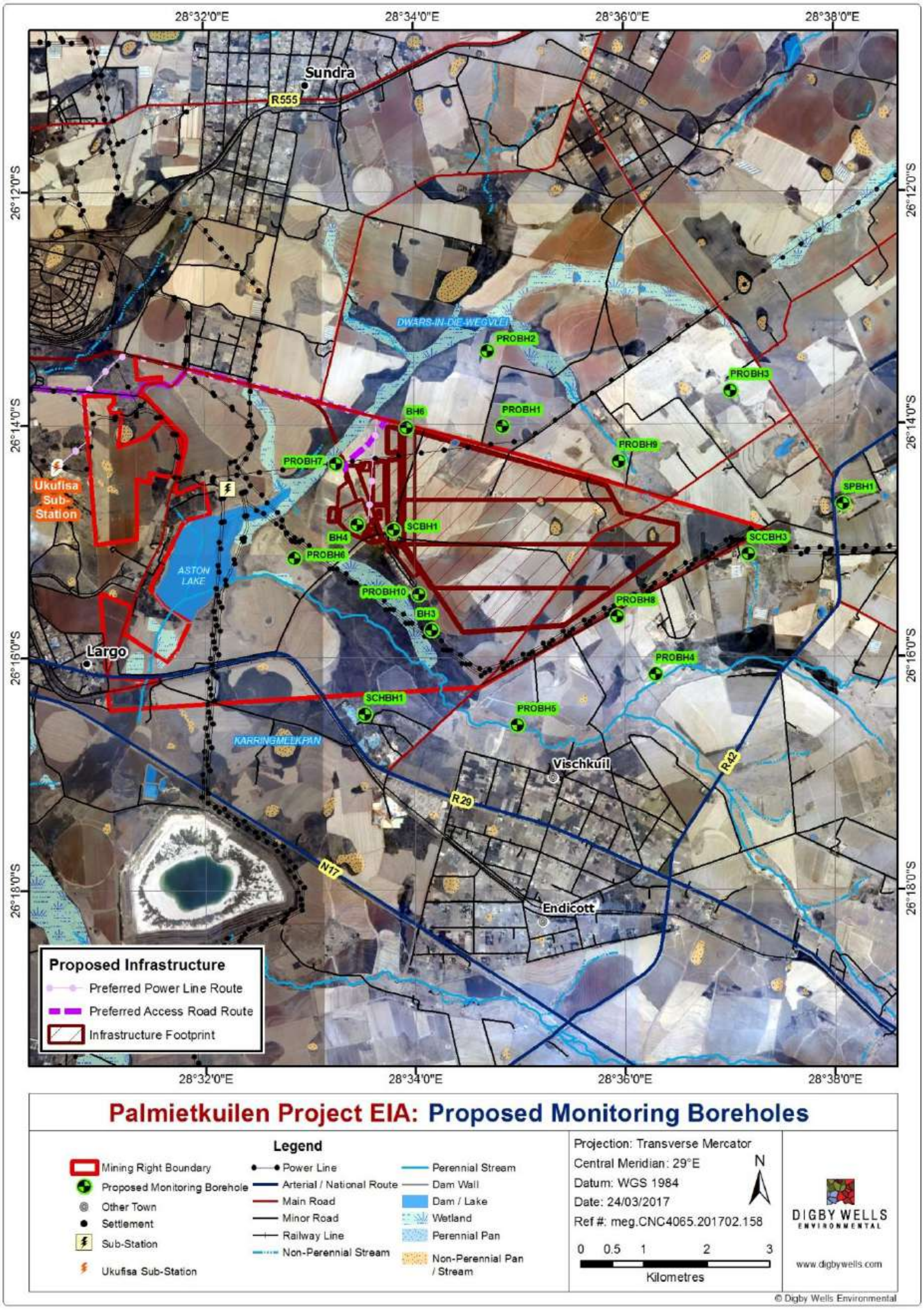

Figure 12-1: Proposed groundwater monitoring boreholes

12.3.1 Water Level

Groundwater levels must be recorded on a quarterly basis using a dip meter to detect any changes or trends in groundwater elevation and flow direction.

12.3.2 Water Sampling and Preservation

When sampling the following procedures are proposed:

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

12.3.3 Sampling Frequency

Groundwater is a slow-moving medium and drastic changes in the groundwater composition are rarely 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.

Post closure monitoring should continue on monthly basis until a sustainable situation is reached and after it has been signed off by the authorities.

12.3.4 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, As, Ba, Cu, Se, Pb, Fe, Mn and other metals identified according to results of the initial analyses;
- pH and Alkalinity; and
- TDS and EC.

12.3.5 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

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.

14 Conclusions and recommendations

14.1 Conclusion

The following conclusions are evident from the hydrogeological evaluation of the proposed Palmietkuilen project area:

14.1.1 Baseline study

- Groundwater use in the immediate vicinity of the Palmietkuilen project area include domestic and drinking water supply;
- Water levels are generally shallow ranging between 1 m bgl and 16.27 m bgl. The groundwater flow direction follows the surface topography. Therefore, groundwater will flow from highest to lowest elevation, in the direction of surface water drainage;
- Groundwater generally flows towards the nearby wetland and Aston lake;
- Only three boreholes intersected fractures yielding above 0.5 l/s and the rest were below 0.5 l/s;
- Hydraulic conductivity in the aquifers intersected during the drilling is low ranging between 0.007 m/d and 0.154 m/d and could act as retarding factor when contaminant flow arises; and
- Water quality is generally good and suitable for drinking and well within the South African National Standards for drinking water with the exception of borehole WNBH1, SCBH01 and SCCBH1 with elevated nitres

Geostratum Groundwater and Geochemistry Consult (2016) acid-base testing yielded the following results:

- Majority of clastic waste rocks (approximately 85% of all waste rock) have very low sulphide content and will not generate acid mine drainage (AMD);
- 10% of the clastic waste rocks have a moderate amount of sulphides and have a moderate potential to generate AMD; and
- 5% of the clastic rocks (some carbonaceous rocks and especially high sulphide containing sandstone adjacent to coal seams) have a significant potential to generate localised AMD and will form localised hot-spots within the backfill.

The backfill will therefore be a heterogeneous mixture of acid generation and non-acid generation rocks. The acid generating rocks should be placed at the bottom of the mining sequence and the moderate potential ones low down in the rehabilitation sequence.

14.1.2 Impact Assessment

- The most extensive cone of depression is experienced at the end of the life of mine (year 53); with a maximum drawdown of 63 m and a maximum radius of influence extending a total of 3 km from the pit with 1.3 km going beyond the project area boundary;
- The local water resources; Verdrietlaagte stream and Dwars-in-die-Wegvlei' wetland/stream are within the radius of influence of the cone of depression. Wetlands/streams that are gaining in that area may receive less water. The impact significance of the cone of depression on the wetlands/streams could be minimised by discharging the dewatered water to the streams, after the water is treated to the water quality objectives of the catchment or other applicable standards;
- The expected inflows over the life of mine are presented in the table below:

Year	Inflows (m^3/d)		Year	Inflows (m^3/d)
Y 0	0		Y10	580
Y1	375		Y11-15	701
Y2	385		Y16-20	815
Y3	397		Y21-25	984
Y4	404		Y26-30	1120
Y5	419		Y31-35	1260
Y6	453		Y36-40	1410
Y7	460		Y41-45	1560
Y8	517		Y46-50	1690
Y9	572		Y51-53	1790

- The Verdrietlaagte wetland/stream and Dwars-in-die-Wegvlei' wetland/stream are within the radius of influence of the plume. Wetlands/streams that are gaining in that area may receive water of poor quality (emanating from the contamination plume) resulting in the water quality deterioration at the Wetlands/streams. The impacts of the contamination plume is expect to occur post-closure and could be reduced by inhibiting acid generating reactions at the source by ensuring that the waste rock material (carbonaceous rocks and sandstone adjacent to coal seams) that is high in pyrite content and prone to acid generation is deposited at the base of the rehabilitated pit in such a way that it will be completely flooded with groundwater.
- The contamination plume and cone of depression are not expected to affect any private boreholes (identified during the hydrocensus) during the operational phase and 100 years post closure;

- Decant is expected to start 35 years post closure, reaching a decant rate of 5 L/s.

14.2 Recommendations

The following recommendation is made after the field investigation:

- No boreholes were found during the hydrocensus in the northern section of the project area. As a result, there is information gap in terms of the current groundwater usage, baseline water quality and water level. More investigation is recommended to be conducted in the north of the project area for baseline hydrogeological understanding;
- Quarterly monitoring of water quality and levels is recommended with continuous refining and updating of the monitoring network based on the results obtained;
- It is recommended that the mine should supply equal/better amount of water to interested and affected parties that rely on groundwater in the receiving environment, if proven that there is impact on specific users;
- Organic solvents, diesel or other organic fluids may be spilled on the ground surface or leak from storage tanks during mine operation. Proper or good handling methodology should be applied to minimax the contamination;
- Refine the conceptual and numerical models every two years in the first four years and thereafter every five years based on groundwater monitoring results; and
- Annual audits of monitoring and management systems should be conducted by environmental consultants.

The following recommendation is made after the impact assessment:

- Dewatering efficiently, according to the expected inflows, enough to provide for dry conditions at required locations;
- Geostratum Groundwater and Geochemistry Consult (2016) identified that the waste rock material has a significant potential to generate acid. These materials should be deposited at the base of the rehabilitated pit in such a way that it will be completely flooded with groundwater;
- ;
- Capture of decant if the quality is below the standards before joining the tributaries, treating it and re-introducing it into the tributaries;
- If impact is confirmed through monitoring, management solutions should be sought for upon agreement with the farmers or communities with impacted groundwater or mine purchase land;
- Groundwater monitoring, to assess the time series water level and quality impacts and trends; and

- The decant predictions, conceptual and numerical models should be refined every two years in the first four years and thereafter every five years based on groundwater monitoring results.

15 References

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Appendix A: Lab Results

DIGBY WELLS ENVIRONMENTAL

aquatico Laboratories (Pty). Ltd.

ilac-MRA sanas Testing Laboratory T0685

Test Report Page 1 of 2

Client:	Digby Wells & Associates	**Date of certificate:**	09 September 2016
Address:	359 Pretoria Ave, Fern Isle, Section 5, Ferndale, Randburg	**Date accepted:**	01 September 2016
Report no:	33216	**Date completed:**	09 September 2016
Project:	Digby Wells & Associates	**Revision:**	0

	Lab no:			13639	13640	13641	13642	13643	13644	13645
	Date sampled:			26-Aug-2016	23-Aug-2016	25-Aug-2016	23-Aug-2016	23-Aug-2016	24-Aug-2016	26-Aug-2016
	Sample type:			Water	Water	Water	Water	Water	Water	Water
	Locality description:			SCHBH1	SCBH05	SCCBH1	ALBH01	VLBH2	WNBH1	PL18BH2
	Analyses	**Unit**	**Method**							
A	pH @ 25°C	pH	ALM 20	8.67	8.37	8.73	8.73	8.67	8.46	8.46
A	Electrical conductivity (EC) @ 25°C	mS/m	ALM 20	33.7	27.2	46.2	39.2	51.9	213	15.7
A	Total dissolved solids (TDS)	mg/l	ALM 26	245	207	345	282	380	1446	104
A	Total alkalinity	mg CaCO3/l	ALM 01	180	138	196	171	225	227	73.8
A	Chloride (Cl)	mg/l	ALM 02	10.8	18.8	23.1	22.2	40.5	327	9.49
A	Sulphate (SO_4)	mg/l	ALM 03	9.37	13.4	28.5	40.3	38.9	425	4.25
A	Nitrate (NO_3) as N	mg/l	ALM 06	5.68	2.09	11.8	2.41	4.82	21.8	1.07
A	Ammonium (NH_4) as N	mg/l	ALM 05	0.149	0.069	0.115	0.190	0.259	0.190	0.287
N	Ammonia (NH_3) as N	mg/l	ALM 26	0.025	0.007	0.022	0.037	0.045	0.024	0.036
A	Orthophosphate (PO_4) as P	mg/l	ALM 04	0.061	0.068	0.047	0.041	0.050	0.055	0.048
A	Fluoride (F)	mg/l	ALM 08	<0.263	0.271	<0.263	<0.263	0.330	0.520	<0.263
A	Calcium (Ca)	mg/l	ALM 30	46.1	31.4	64.3	47.6	59.8	195	21.7
A	Magnesium (Mg)	mg/l	ALM 30	21.7	14.7	24.7	22.4	25.0	102	6.75
A	Sodium (Na)	mg/l	ALM 30	15.7	22.6	24.7	25.6	54.9	153	9.15
A	Potassium (K)	mg/l	ALM 30	5.83	12.5	7.63	8.03	1.99	9.50	2.47
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	0.015	<0.004	<0.004	<0.004	<0.004	<0.004
A	Manganese (Mn)	mg/l	ALM 31	<0.001	<0.001	<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	<0.002	<0.002	<0.002	<0.002	3.89	0.161
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	Turbidity	NTU	ALM 21	1.58	0.514	0.344	59.7	0.179	0.631	0.481
A	Total hardness	mg CaCO3/l	ALM 26	204	139	262	211	252	905	82
A	Dissolved Uranium (U)	mg/l	ALM 37	<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.

M. Swanepoel
Technical Signatory

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aquatico Laboratories (Pty). Ltd.

ilac-MRA sanas Testing Laboratory T0685

Test Report

Client: Digby Wells & Associates
Address: 359 Pretoria Ave, Fern Isle, Section 5, Ferndale, Randburg
Report no: 33216
Project: Digby Wells & Associates

Date of certificate: 09 September 2016
Date accepted: 01 September 2016
Date completed: 09 September 2016
Revision: 0

	Analyses	Unit	Method			
	Lab no:			13646	13647	13648
	Date sampled:			26-Aug-2016	26-Aug-2016	23-Aug-2016
	Sample type:			Water	Water	Water
	Locality description:			PL42BH	PL50BH	SCBH01
A	pH @ 25°C	pH	ALM 20	8.69	8.78	8.12
A	Electrical conductivity (EC) @ 25°C	mS/m	ALM 20	38.8	47.2	29.6
A	Total dissolved solids (TDS)	mg/l	ALM 26	273	338	236
A	Total alkalinity	mg CaCO3/l	ALM 01	185	228	29.7
A	Chloride (Cl)	mg/l	ALM 02	12.2	30.4	22.3
A	Sulphate (SO_4)	mg/l	ALM 03	3.30	32.0	21.3
A	Nitrate (NO_3) as N	mg/l	ALM 06	10.4	1.06	24.3
A	Ammonium (NH_4) as N	mg/l	ALM 05	0.099	0.214	0.131
N	Ammonia (NH_3) as N	mg/l	ALM 26	0.018	0.046	0.007
A	Orthophosphate (PO_4) as P	mg/l	ALM 04	0.050	0.048	0.049
A	Fluoride (F)	mg/l	ALM 08	<0.263	0.349	<0.263
A	Calcium (Ca)	mg/l	ALM 30	52.1	31.7	24.9
A	Magnesium (Mg)	mg/l	ALM 30	24.5	19.2	16.9
A	Sodium (Na)	mg/l	ALM 30	11.4	75.8	18.5
A	Potassium (K)	mg/l	ALM 30	9.81	4.24	6.53
A	Aluminium (Al)	mg/l	ALM 31	<0.002	<0.002	<0.002
A	Iron (Fe)	mg/l	ALM 31	<0.004	<0.004	<0.004
A	Manganese (Mn)	mg/l	ALM 31	<0.001	<0.001	<0.001
A	Chromium (Cr)	mg/l	ALM 31	<0.003	<0.003	<0.003
A	Copper (Cu)	mg/l	ALM 31	<0.002	<0.002	<0.002
A	Nickel (Ni)	mg/l	ALM 31	<0.002	<0.002	<0.002
A	Zinc (Zn)	mg/l	ALM 31	0.464	<0.002	<0.002
A	Cobalt (Co)	mg/l	ALM 31	<0.003	<0.003	<0.003
A	Cadmium (Cd)	mg/l	ALM 31	<0.002	<0.002	<0.002
A	Lead (Pb)	mg/l	ALM 31	<0.004	<0.004	<0.004
A	Turbidity	NTU	ALM 21	9.41	4.33	2.52
A	Total hardness	mg CaCO3/l	ALM 26	231	158	132
A	Dissolved Uranium (U)	mg/l	ALM 37	<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.

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Appendix B: Geophysics Figures

Figure 15-1: Geophysics Line 1

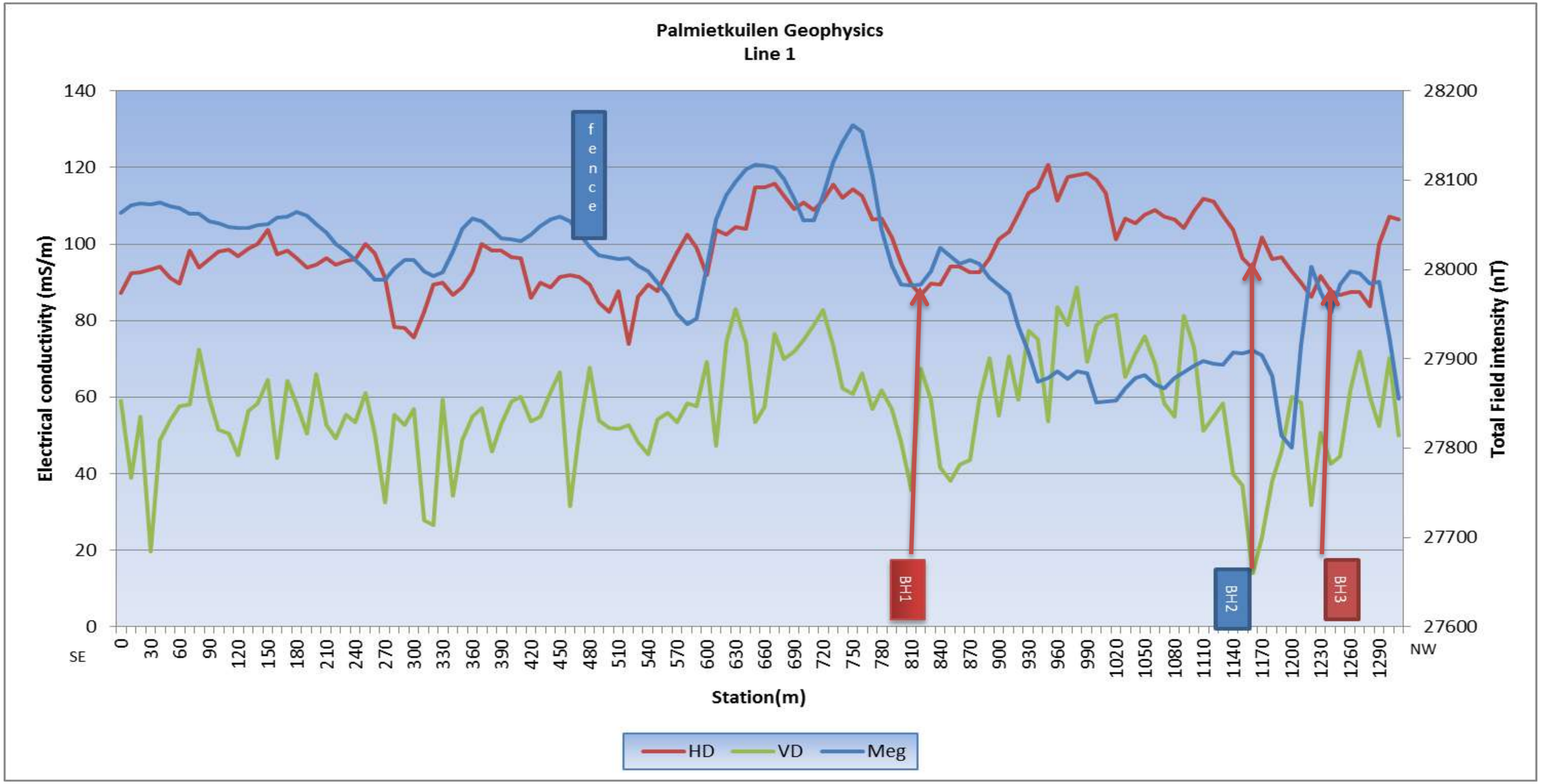


Figure 15-2: Geophysics Line 2

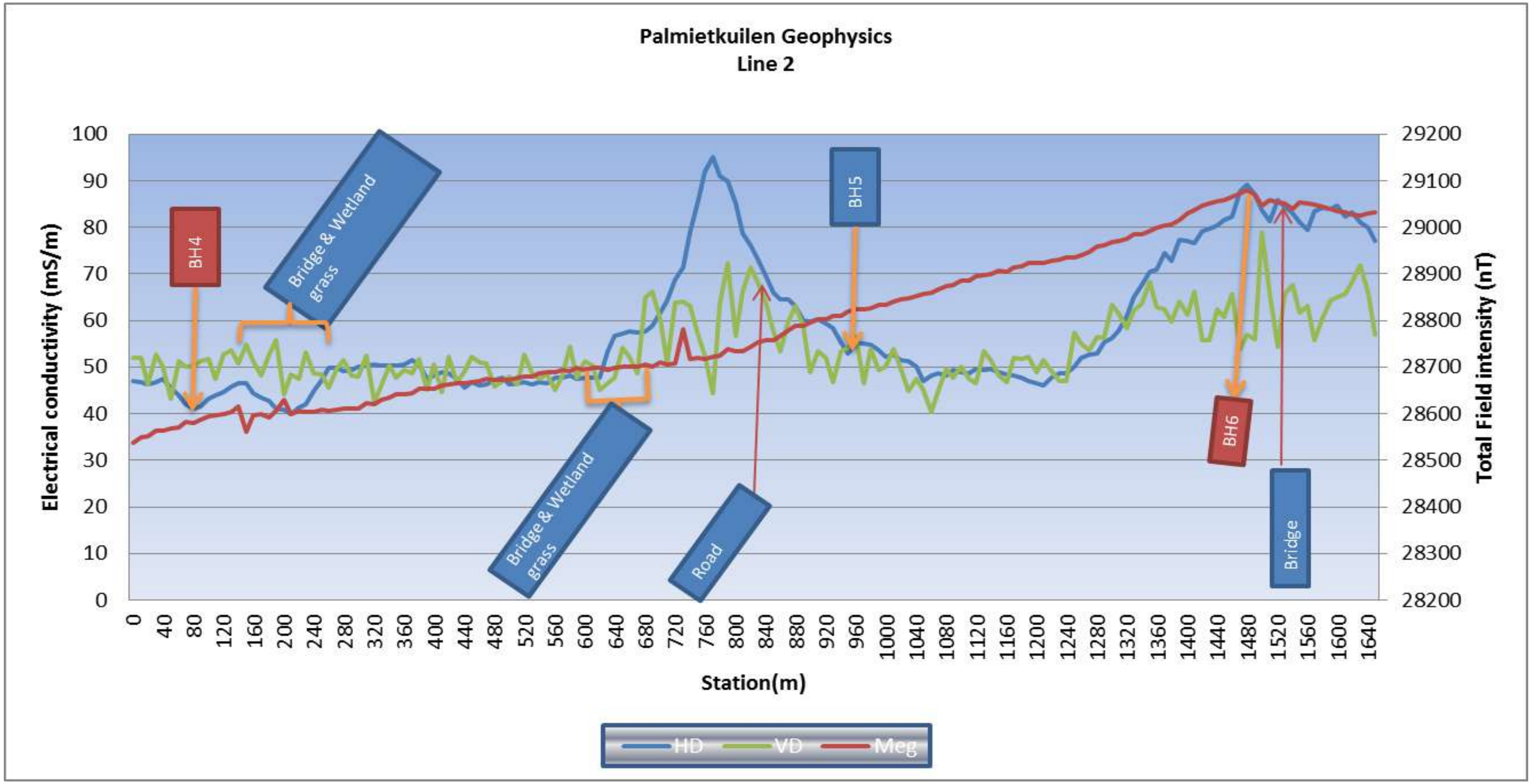


Figure 15-3: Geophysics Line 3

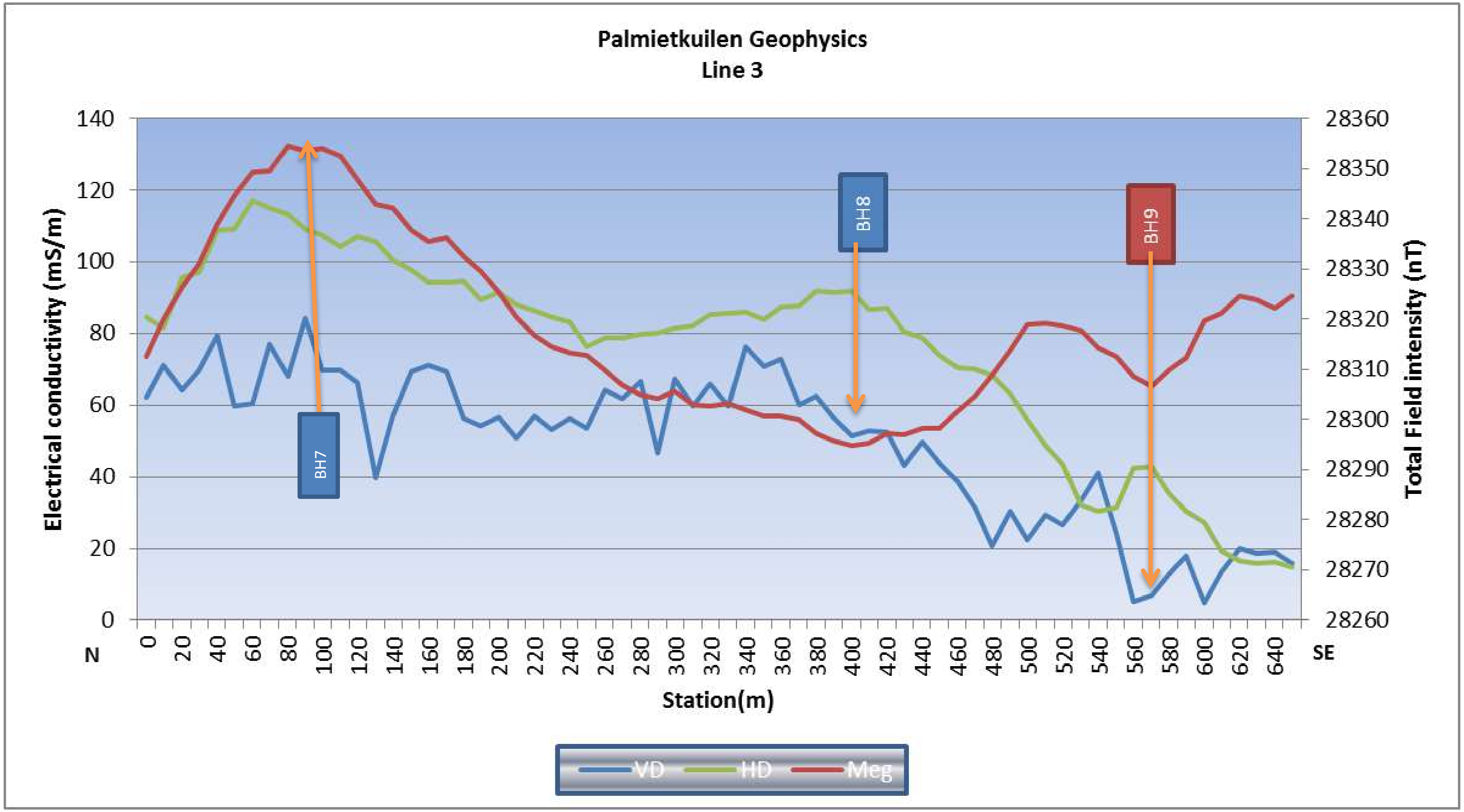
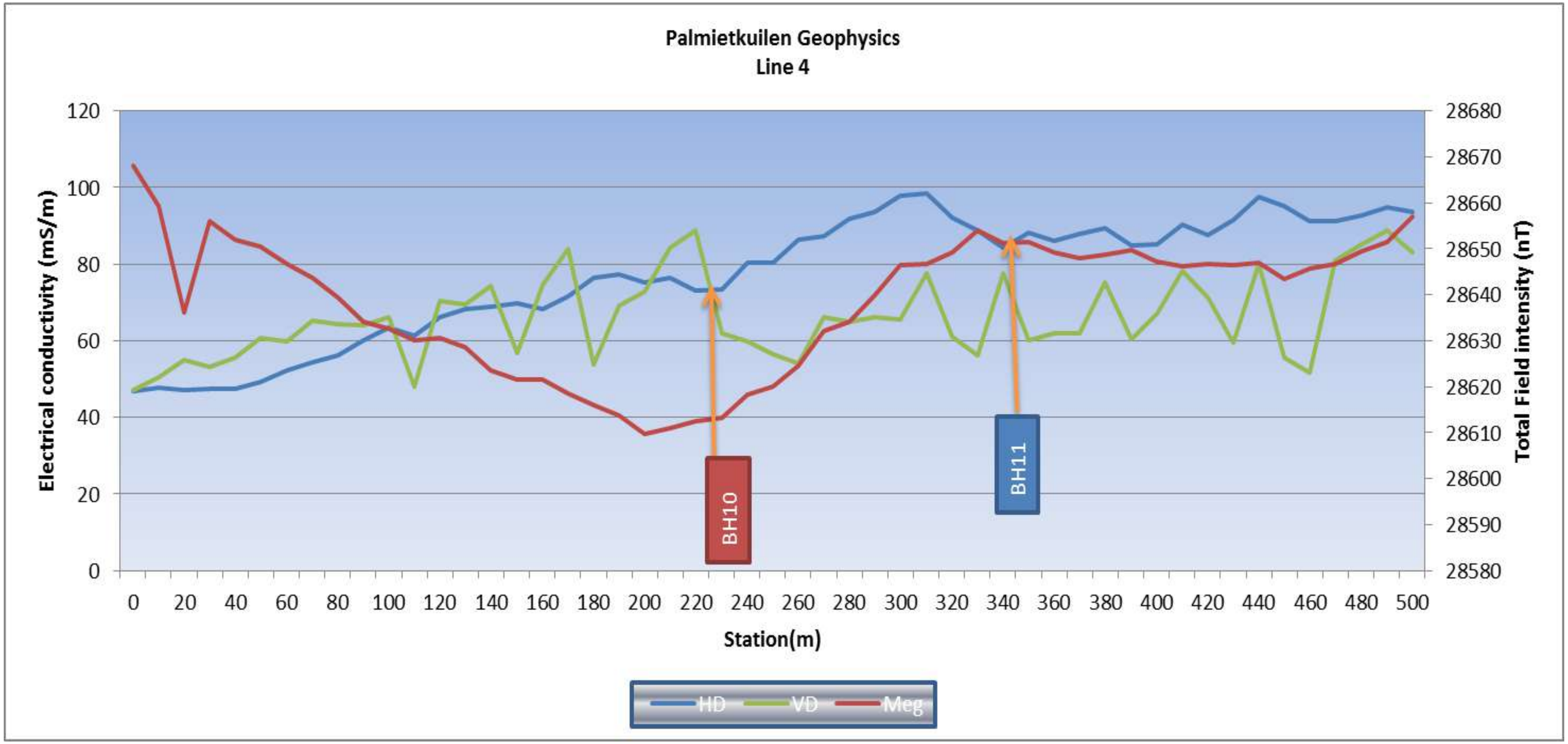
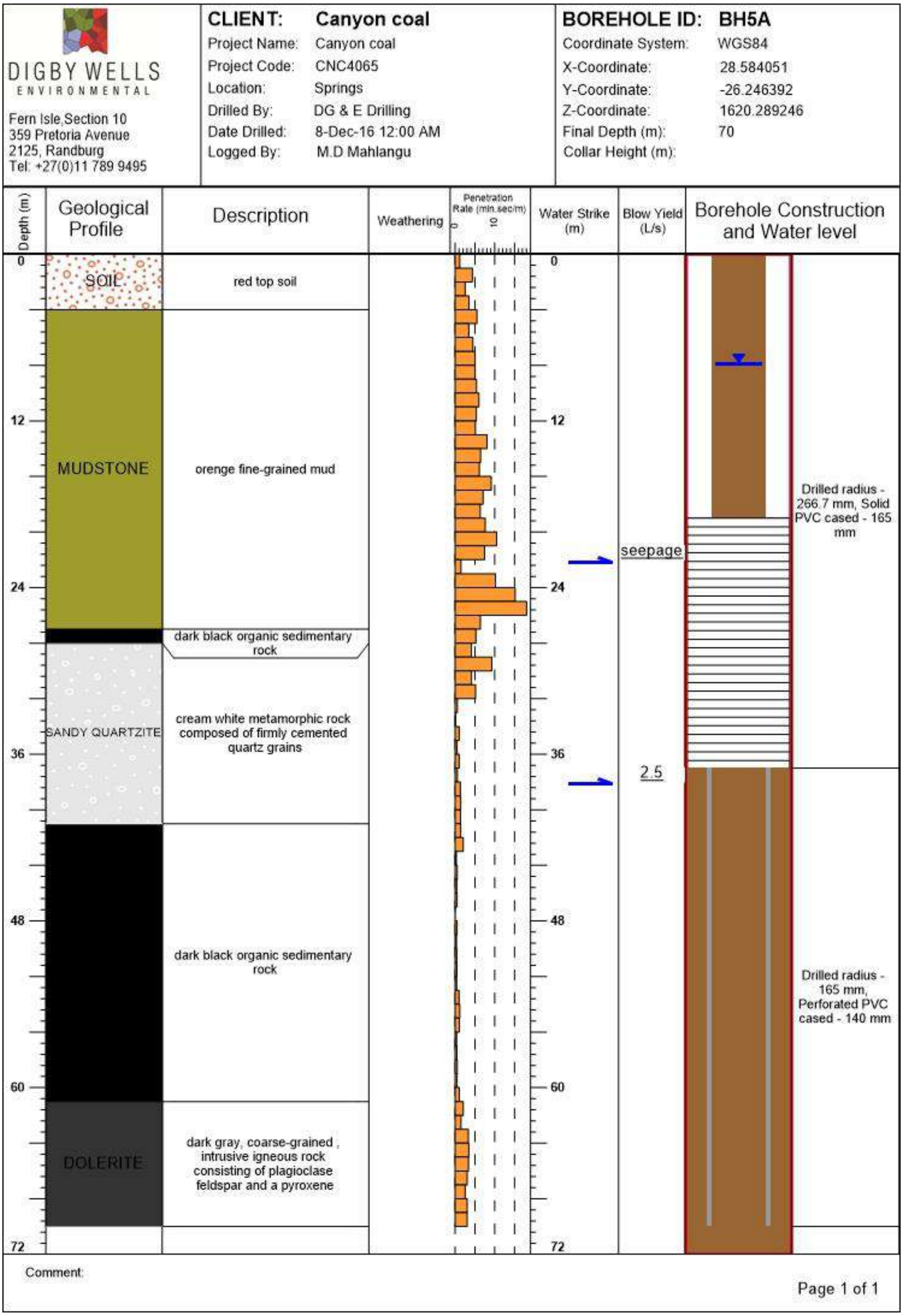
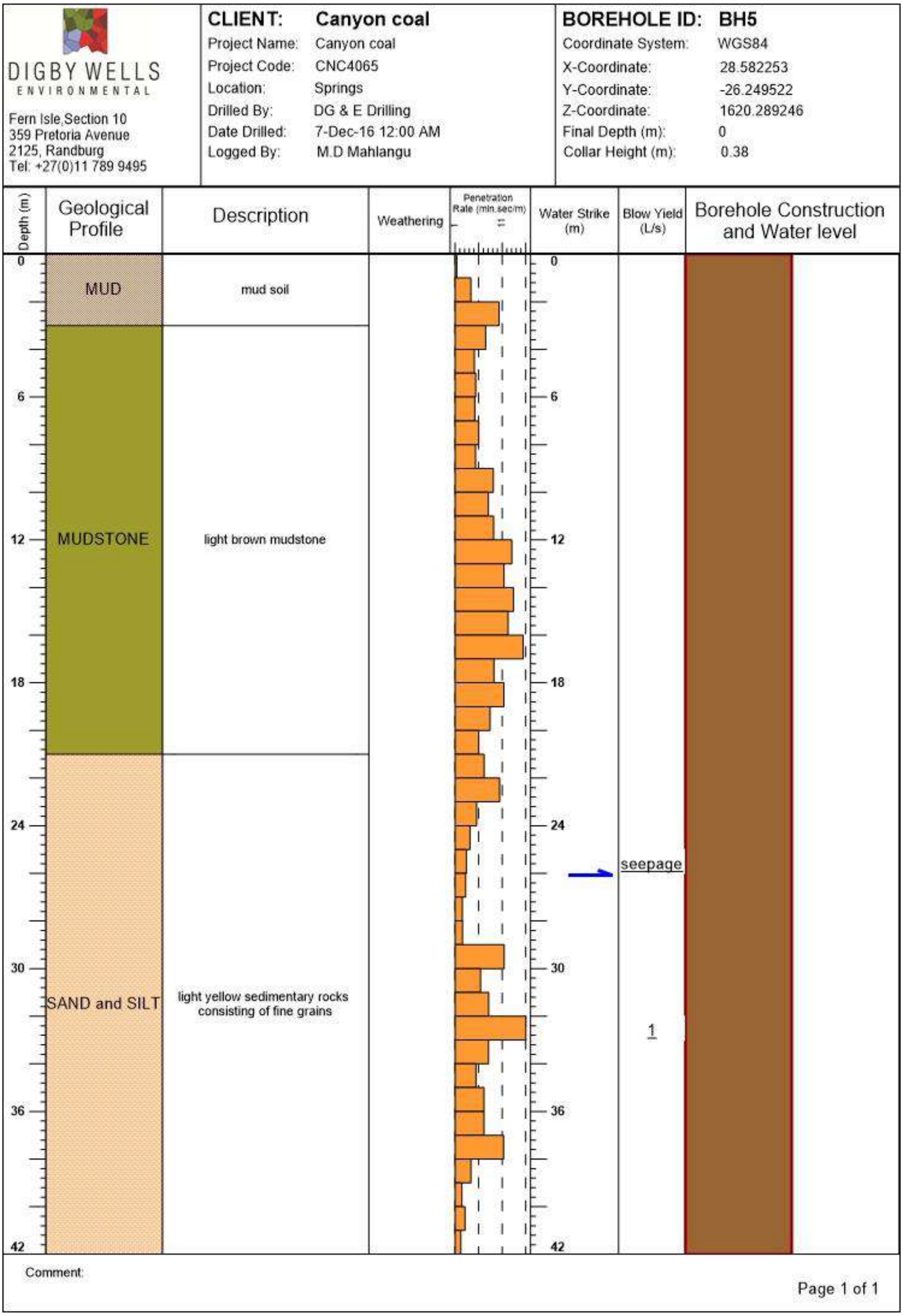


Figure 15-4: Geophysics Line 4



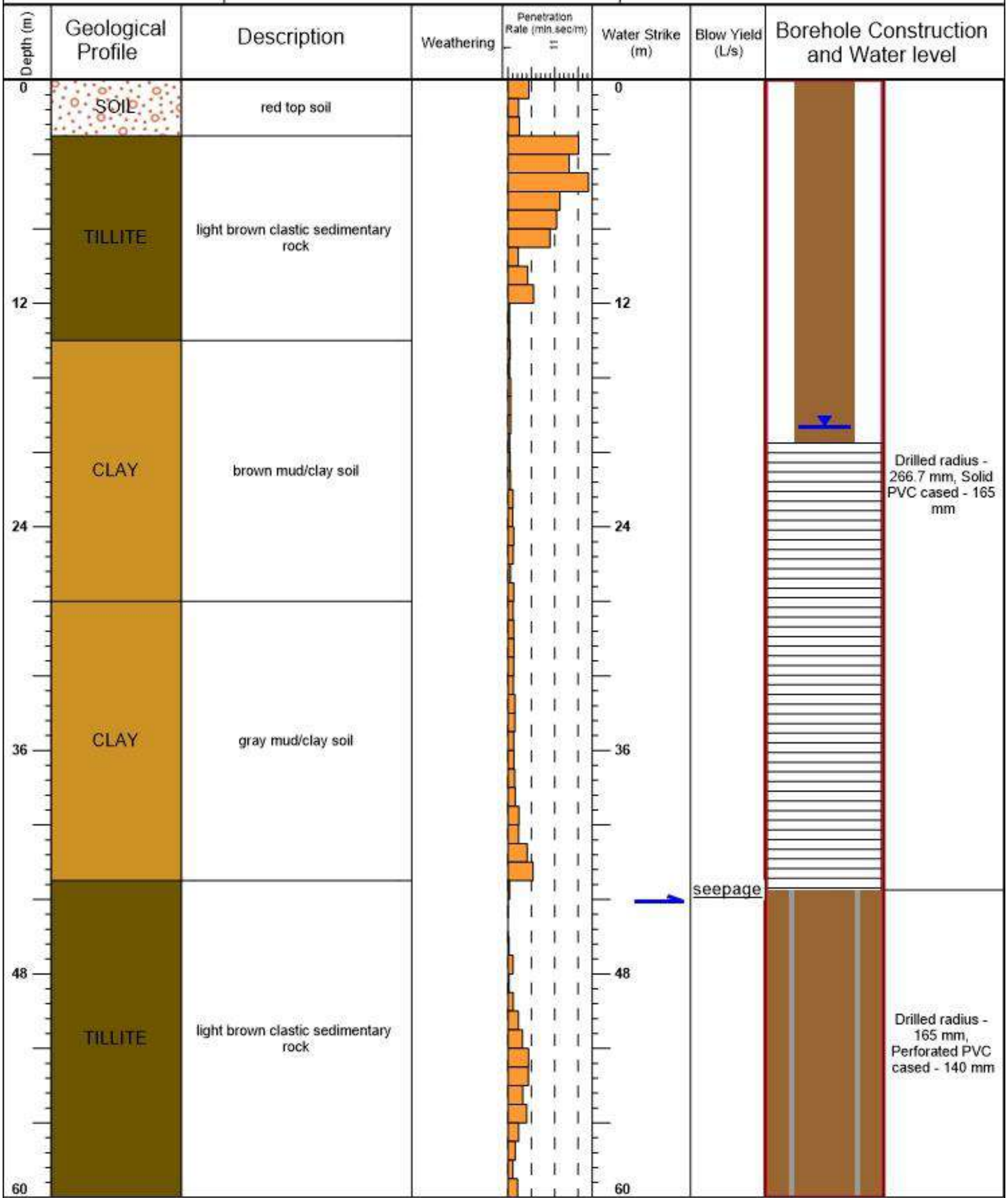
Appendix C: Boreholes Logs


DIGBY WELLS ENVIRONMENTAL
Fern Isle,Section 10
359 Pretoria Avenue
2125, Randburg
Tel: +27(0)11 789 9495
CLIENT: Canyon coal
Project Name: Canyon coal
Project Code: CNC4065
Location: Springs
Drilled By: DG & E Drilling
Date Drilled: 8-Dec-16 12:00 AM
Logged By: M.D Mahlangu
BOREHOLE ID: BH5A
Coordinate System: WGS84
X-Coordinate: 28.584051
Y-Coordinate: -26.246392
Z-Coordinate: 1620.289246
Final Depth (m): 70
Collar Height (m):
Depth (m)
Geological Profile
Description
Weathering
Penetration Rate (min.sec/m)
0
10
Water Strike (m)
Blow Yield (L/s)
Borehole Construction and Water level
0
12
24
36
48
60
72
SOIL
red top soil
MUDSTONE
orenge fine-grained mud
dark black organic sedimentary rock
SANDY QUARTZITE
cream white metamorphic rock composed of firmly cemented quartz grains
dark black organic sedimentary rock
DOLERITE
dark gray, coarse-grained , intrusive igneous rock consisting of plagioclase feldspar and a pyroxene
seepage
2.5
Drilled radius - 266.7 mm, Solid PVC cased - 165 mm
Drilled radius - 165 mm, Perforated PVC cased - 140 mm
Comment:
Page 1 of 1


DIGBY WELLS ENVIRONMENTAL
Fern Isle,Section 10
359 Pretoria Avenue
2125, Randburg
Tel: +27(0)11 789 9495
CLIENT: Canyon coal
Project Name: Canyon coal
Project Code: CNC4065
Location: Springs
Drilled By: DG & E Drilling
Date Drilled: 7-Dec-16 12:00 AM
Logged By: M.D Mahlangu
BOREHOLE ID: BH5
Coordinate System: WGS84
X-Coordinate: 28.582253
Y-Coordinate: -26.249522
Z-Coordinate: 1620.289246
Final Depth (m): 0
Collar Height (m): 0.38
Depth (m)
Geological Profile
Description
Weathering
Penetration Rate (min.sec/m)
Water Strike (m)
Blow Yield (L/s)
Borehole Construction and Water level
0
6
12
18
24
30
36
42
MUD
mud soil
MUDSTONE
light brown mudstone
SAND and SILT
light yellow sedimentary rocks consisting of fine grains
seepage
1
Comment:
Page 1 of 1

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

CLIENT:	**Canyon coal**	**BOREHOLE ID:**	**BH4**
Project Name:	Canyon coal	Coordinate System:	WGS84
Project Code:	CNC4065	X-Coordinate:	28.55755
Location:	Springs	Y-Coordinate:	-26.247744
Drilled By:	DG & E Drilling	Z-Coordinate:	1584.533807
Date Drilled:	9-Dec-16 12:00 AM	Final Depth (m):	60
Logged By:	M.D Mahlangu	Collar Height (m):	0.35



Comment:

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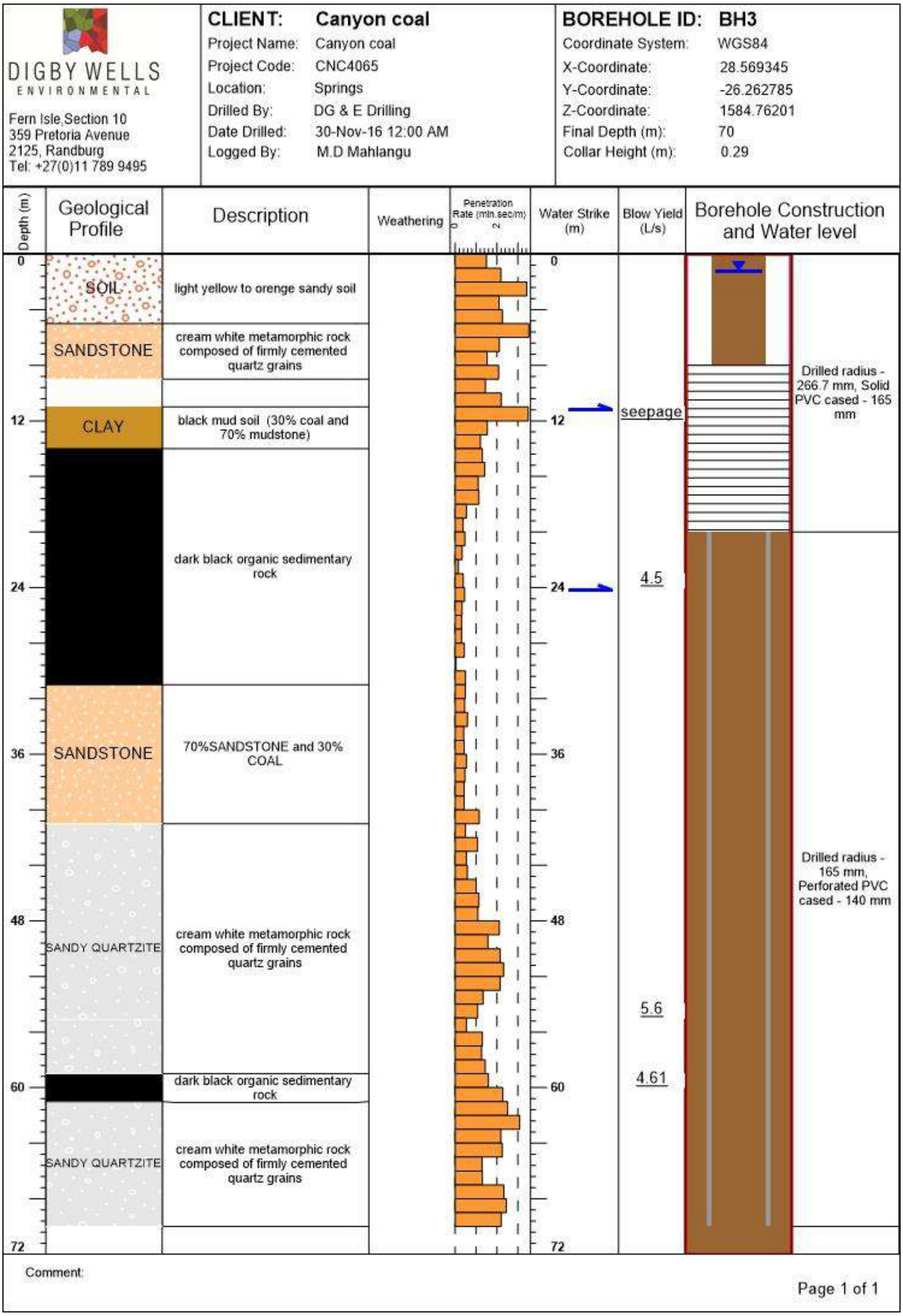
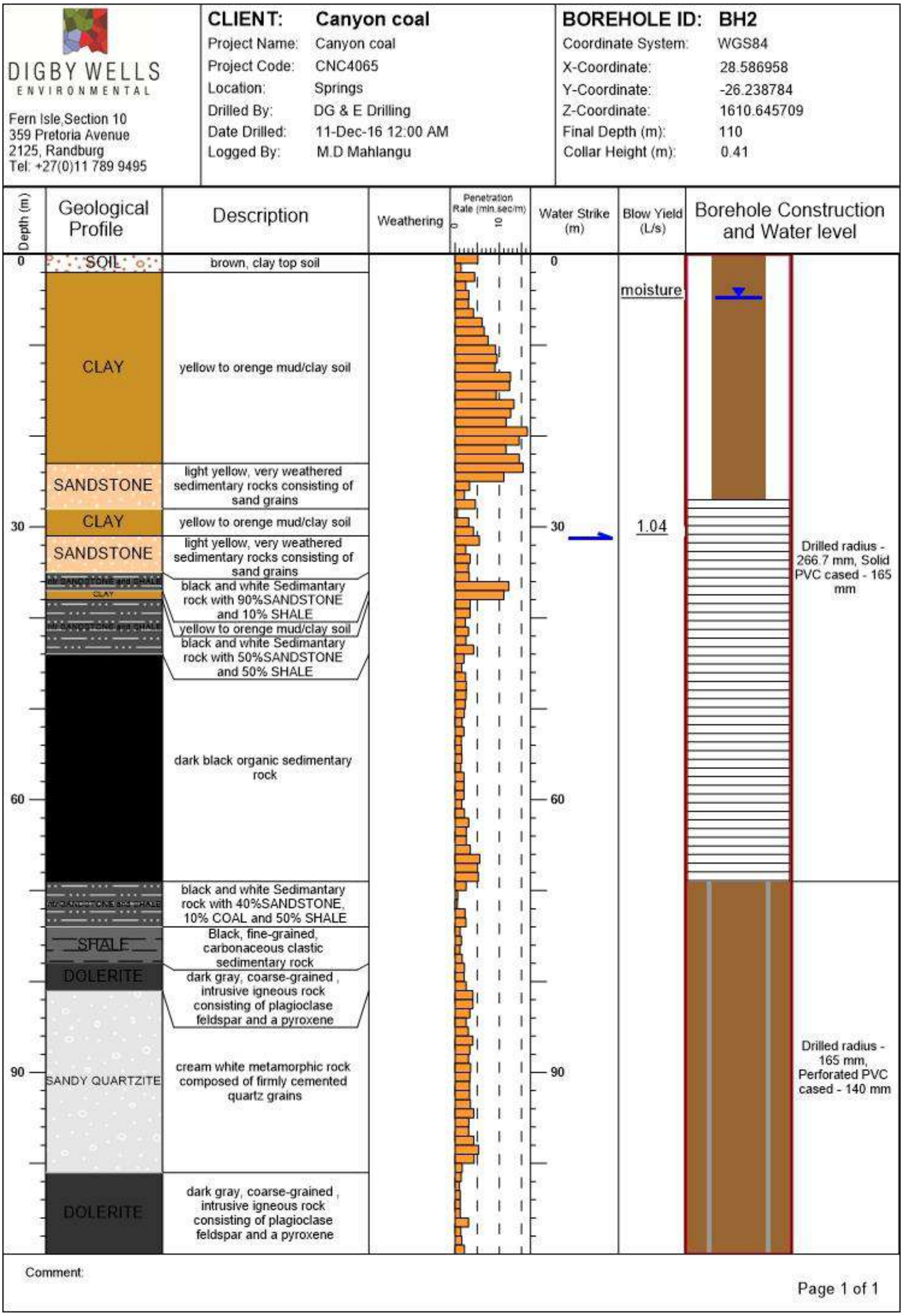
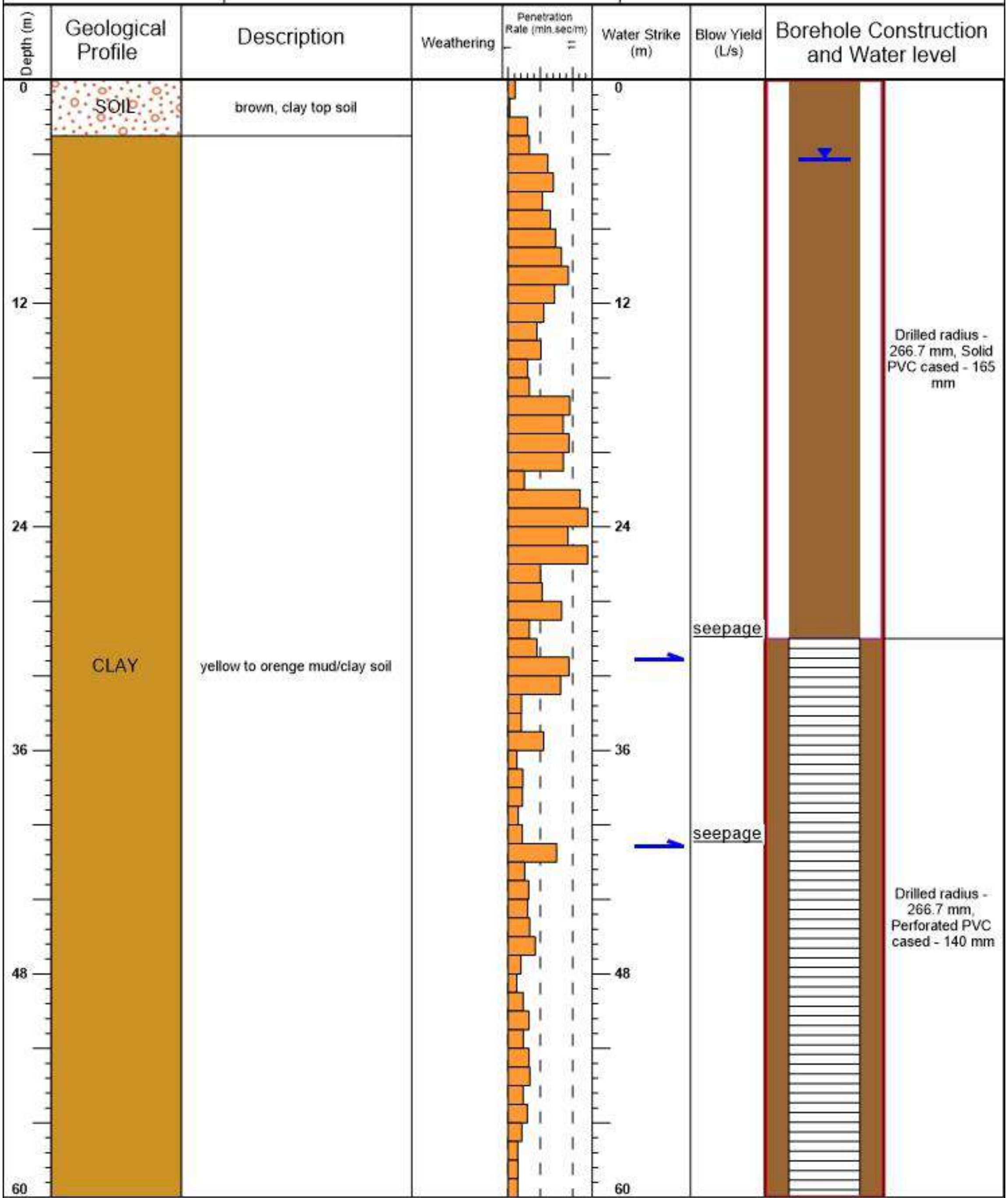

DIGBY WELLS ENVIRONMENTAL
Fern Isle,Section 10
359 Pretoria Avenue
2125, Randburg
Tel: +27(0)11 789 9495
CLIENT: Canyon coal
Project Name: Canyon coal
Project Code: CNC4065
Location: Springs
Drilled By: DG & E Drilling
Date Drilled: 30-Nov-16 12:00 AM
Logged By: M.D Mahlangu
BOREHOLE ID: BH3
Coordinate System: WGS84
X-Coordinate: 28.569345
Y-Coordinate: -26.262785
Z-Coordinate: 1584.76201
Final Depth (m): 70
Collar Height (m): 0.29
Depth (m)
Geological Profile
Description
Weathering
Penetration Rate (min.sec/m)
Water Strike (m)
Blow Yield (L/s)
Borehole Construction and Water level
0
12
24
36
48
60
72
SOIL
light yellow to orenge sandy soil
SANDSTONE
cream white metamorphic rock composed of firmly cemented quartz grains
CLAY
black mud soil (30% coal and 70% mudstone)
dark black organic sedimentary rock
SANDSTONE
70%SANDSTONE and 30% COAL
SANDY QUARTZITE
cream white metamorphic rock composed of firmly cemented quartz grains
dark black organic sedimentary rock
SANDY QUARTZITE
cream white metamorphic rock composed of firmly cemented quartz grains
seepage
4.5
5.6
4.61
Drilled radius - 266.7 mm, Solid PVC cased - 165 mm
Drilled radius - 165 mm, Perforated PVC cased - 140 mm
Comment:
Page 1 of 1


DIGBY WELLS ENVIRONMENTAL
Fern Isle,Section 10
359 Pretoria Avenue
2125, Randburg
Tel: +27(0)11 789 9495
CLIENT: Canyon coal
Project Name: Canyon coal
Project Code: CNC4065
Location: Springs
Drilled By: DG & E Drilling
Date Drilled: 11-Dec-16 12:00 AM
Logged By: M.D Mahlangu
BOREHOLE ID: BH2
Coordinate System: WGS84
X-Coordinate: 28.586958
Y-Coordinate: -26.238784
Z-Coordinate: 1610.645709
Final Depth (m): 110
Collar Height (m): 0.41
Depth (m)
Geological Profile
Description
Weathering
Penetration Rate (min.sec/m)
Water Strike (m)
Blow Yield (L/s)
Borehole Construction and Water level
0
30
60
90
SOIL
brown, clay top soil
moisture
CLAY
yellow to orenge mud/clay soil
SANDSTONE
light yellow, very weathered sedimentary rocks consisting of sand grains
CLAY
yellow to orenge mud/clay soil
1.04
SANDSTONE
light yellow, very weathered sedimentary rocks consisting of sand grains
Drilled radius - 266.7 mm, Solid PVC cased - 165 mm
black and white Sedimantary rock with 90%SANDSTONE and 10% SHALE
yellow to orenge mud/clay soil
black and white Sedimantary rock with 50%SANDSTONE and 50% SHALE
dark black organic sedimentary rock
black and white Sedimantary rock with 40%SANDSTONE, 10% COAL and 50% SHALE
SHALE
Black, fine-grained, carbonaceous clastic sedimentary rock
DOLERITE
dark gray, coarse-grained , intrusive igneous rock consisting of plagioclase feldspar and a pyroxene
SANDY QUARTZITE
cream white metamorphic rock composed of firmly cemented quartz grains
Drilled radius - 165 mm, Perforated PVC cased - 140 mm
DOLERITE
dark gray, coarse-grained , intrusive igneous rock consisting of plagioclase feldspar and a pyroxene
Comment:
Page 1 of 1

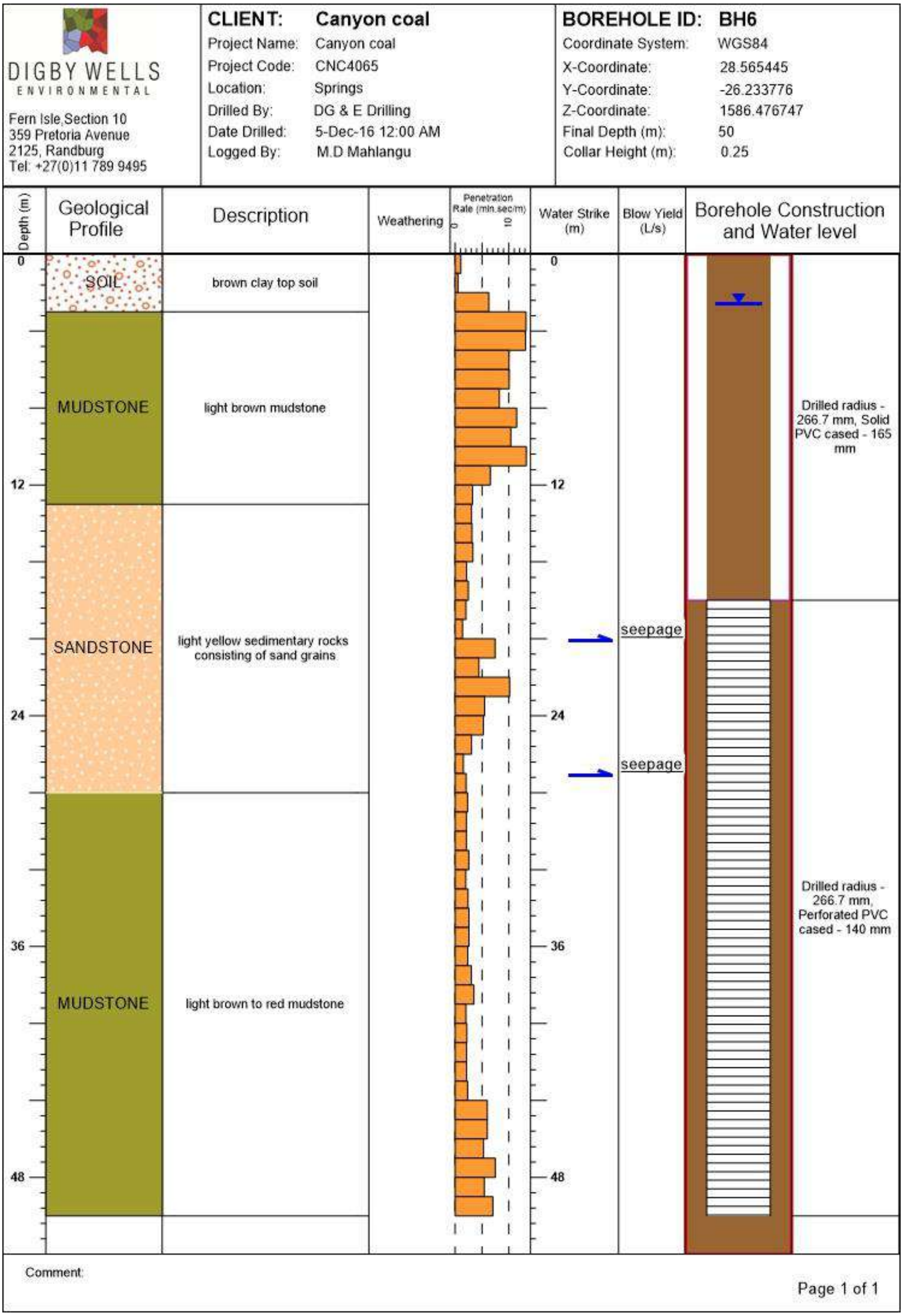
DIGBY WELLS ENVIRONMENTAL
Fern Isle,Section 10
359 Pretoria Avenue
2125, Randburg
Tel: +27(0)11 789 9495

CLIENT:	**Canyon coal**	**BOREHOLE ID:**	**BH1**
Project Name:	Canyon coal	Coordinate System:	WGS84
Project Code:	CNC4065	X-Coordinate:	28.609097
Location:	Springs	Y-Coordinate:	-26.247584
Drilled By:	DG & E Drilling	Z-Coordinate:	1622.365053
Date Drilled:	01-Dec-16 12:00 AM	Final Depth (m):	60
Logged By:	M.D Mahlangu	Collar Height (m):	0.35



Comment:

Page 1 of 1


DIGBY WELLS ENVIRONMENTAL
Fern Isle,Section 10
359 Pretoria Avenue
2125, Randburg
Tel: +27(0)11 789 9495
CLIENT: Canyon coal
Project Name: Canyon coal
Project Code: CNC4065
Location: Springs
Drilled By: DG & E Drilling
Date Drilled: 5-Dec-16 12:00 AM
Logged By: M.D Mahlangu
BOREHOLE ID: BH6
Coordinate System: WGS84
X-Coordinate: 28.565445
Y-Coordinate: -26.233776
Z-Coordinate: 1586.476747
Final Depth (m): 50
Collar Height (m): 0.25
Depth (m)
Geological Profile
Description
Weathering
Penetration Rate (min.sec/m)
0
10
Water Strike (m)
Blow Yield (L/s)
Borehole Construction and Water level
0
12
24
36
48
SOIL
brown clay top soil
MUDSTONE
light brown mudstone
SANDSTONE
light yellow sedimentary rocks consisting of sand grains
MUDSTONE
light brown to red mudstone
seepage
seepage
Drilled radius - 266.7 mm, Solid PVC cased - 165 mm
Drilled radius - 266.7 mm, Perforated PVC cased - 140 mm
Comment:
Page 1 of 1

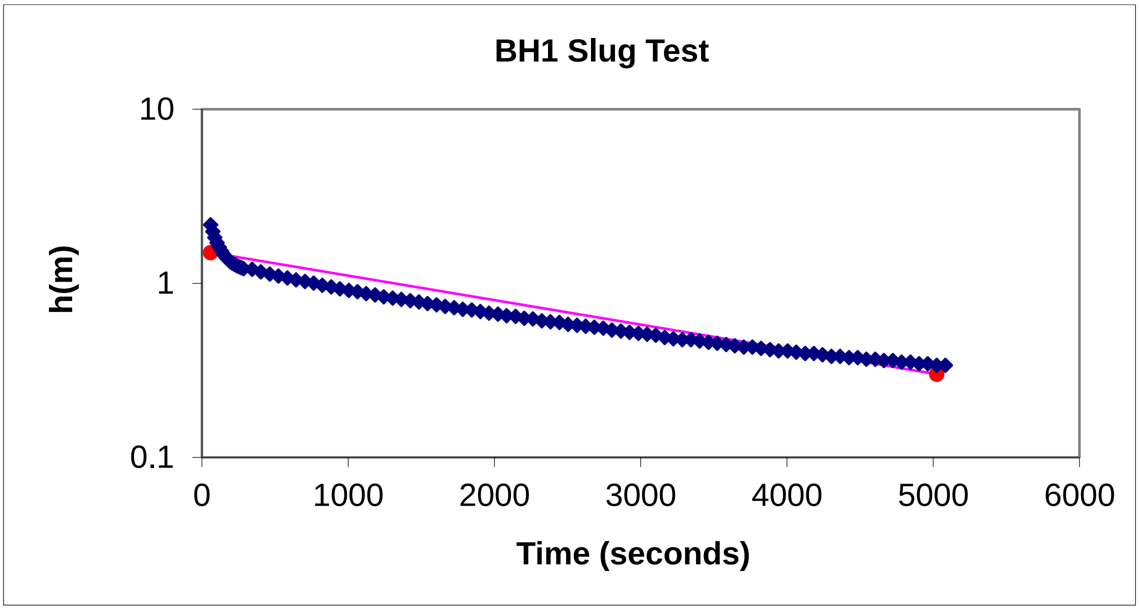
Appendix D: Hydrocensus Summary Table

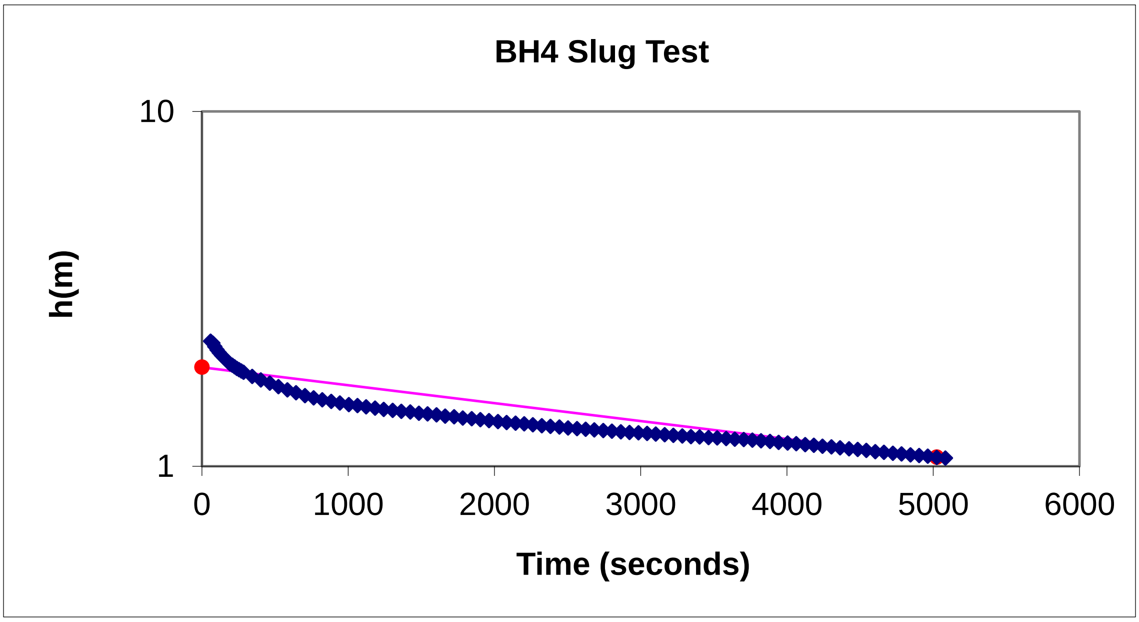
BH ident	Latitude	Longitude	altitude	Dates	Farm Name	Water level	BH Usage	Casing height	comments
ALBH1	-26.2494	28.5258	1588.69	23/08/2016	Witpoort Estate AH	Equipped	Domestic used		sample taken from jojo tank
ELCOBH1	-26.2672	28.5100	1577.16	24/08/2016		Equipped	Domestic used		
JbBH1	-26.2292	28.5057	1592.06	26/08/2016	Grootvaly	dry	not used		destroyed
PL18BH1	-26.2833	28.5736	1594.22	26/08/2016	Witpoort Estate AH	Equipped	Domestic used		locked
PL18BH2	-26.2838	28.5745	1598.31	26/08/2016	Witpoort Estate AH	Equipped	Domestic used		locked
PL42BH1	-26.2253	28.5311	1622.1	26/08/2016		20.45	Domestic used	0	
PL47BH	-26.2648	28.5138	1583.16	24/08/2016	Grootvaly SH	13.04	not used	0	no sample taken due to broken pump
PL50BH1	-26.2215	28.5414	1621.38	26/08/2016	Prosperity AH	73.51	drinking water	0.25	sample taken from the house tap
PL50BH2	-26.2223	28.5406	0	26/08/2016	Prosperity AH	dry			
PL53BH	-26.2703	28.5112	1583.41	24/08/2016	Grootvaly SH	12.33	Domestic used		
PL55BH	-26.2243	28.5380	1616.81	26/08/2016	Prosperity AH	blocked			borehole blocked at 24 meters
PL56BH	-26.2242	28.5410	1611.52	26/08/2016	Prosperity AH	Equipped	drinking water		no sample taken
PL57BH1	-26.2257	28.5376	1619.21	26/08/2016	Prosperity AH	51.86	not used	0	not used borehole & not sampled due to equipment in the borehole
PL69BH	-26.2653	28.5163	1594.7	25/08/2016	Grootvaly SH	Equipped	Domestic used		
PL74BH	-26.2660	28.5136	1582.92	25/08/2016	Grootvaly SH	blocked	not used	-	
PL74BH2	-26.2658	28.5158	1577.4	25/08/2016	Grootvaly SH	15.25	not used	0.26	currently not used borehole
PL7BH	-26.2183	28.5365	1612.48	26/08/2016	Prosperity AH	Equipped	Domestic used		no measurements due to borehole being locked

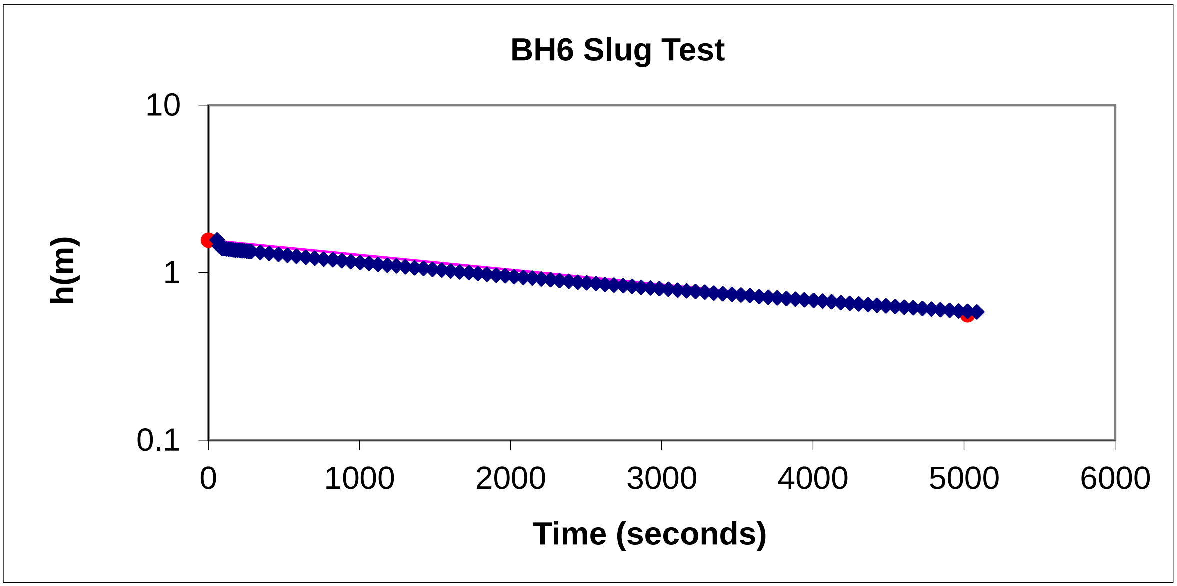
BH ident	Latitude	Longitude	altitude	Dates	Farm Name	Water level	BH Usage	Casing height	comments
PLBH1	-26.2687	28.5128	1589.41	24/08/2016	Grootvaly SH	13.7	not used	0	currently not use
PLBH2	-26.2695	28.5170	1586.77	24/08/2016	Grootvaly SH	Equipped	Domestic used		no water samples taken
Scbh1	-26.2484	28.5633	1597.58	23/08/2016	Palmietkuilen	5.12	Domestic used	0	Bh currently not being used
SCBH2	-26.2515	28.5625	1591.58	23/08/2016	Palmietkuilen	blocked	not used	-	blocked at 3 meter
SCBH3	-26.2506	28.5626	1586.77	23/08/2016	Palmietkuilen	blocked	not used	-	blocked at 5 meter & was used for household
SCBH4	-26.2559	28.5638	1583.41	23/08/2016	Palmietkuilen	blocked	not used	-	blocked at 5 meter
SCBH5	-26.2436	28.5779	1613.45	23/08/2016	Palmietkuilen	Equipped	Domestic used	0	bh currently used for drinking purposes
SCCBH	-26.2526	28.6139	1622.82	25/08/2016	Vischkuil	14.43	Domestic used	0	water used for drinking, Stock watering & Gardening
SCCBH1	-26.2554	28.6312	1626.9	25/08/2016	Strydpan	9.73	stock watering	0.33	currently not use due to broken pump
SCCBH2	-26.2542	28.6208	1617.53	25/08/2016	Vischkuil	8.63	stock watering	0.12	currently not use due to broken pump
SCCBH3	-26.2520	28.6197	1621.14	25/08/2016	Vischkuil	15.8	drinking water	0	pumping to the dam mixing with SCCBH1
SCHBH1	-26.2748	28.5588	1588.93	26/08/2016	Rietfontein	8.15	drinking water	0	school bh currently being used
SCHBH2	-26.2750	28.5579	1596.38	26/08/2016	Rietfontein	9.14	drinking water	0.24	school bh currently being used
SPBH1	-26.2448	28.6348	1622.34	25/08/2016	Strydpan	-	not used		dry up to 60 meters
Spbh2	-26.2436	28.6355	1615.61	25/08/2016	Strydpan	blocked	not used		
SPBH3	-26.2419	28.6344	1609.36	25/08/2016	Strydpan	15.73	not used	0	
SPBH4	-26.2407	28.6388	1613.21	25/08/2016	Strydpan	-	used		no water level due to mud in the BH
SPBH5	-26.2459	28.6355	1626.66	25/08/2016	Strydpan	8.37	not used	0.17	no pump in the bh

BH ident	Latitude	Longitude	altitude	Dates	Farm Name	Water level	BH Usage	Casing height	comments
SPBH6	-26.2462	28.6354	1624.5	25/08/2016	Strydpan	dry	not used	0	bh dry at 50 meters
SPBH7	-26.2470	28.6356	1626.42	25/08/2016	Strydpan	morethan 60 m	drinking water		water level deeper than 60 meter
VKBH1	-26.2692	28.6048	1593.98	25/08/2016	Vischkuil	4.02	stock watering	0.74	bh located in the wetland area
VLBH2	-26.2669	28.6078	1595.66	25/08/2016	Vischkuil	22.66	drinking water		pumping when water level measured
WNBH1	-26.2719	28.5172	637.23	24/08/2016	Grootvaly	Equipped	drinking water	-	owner indicated that water level is at 18 meter

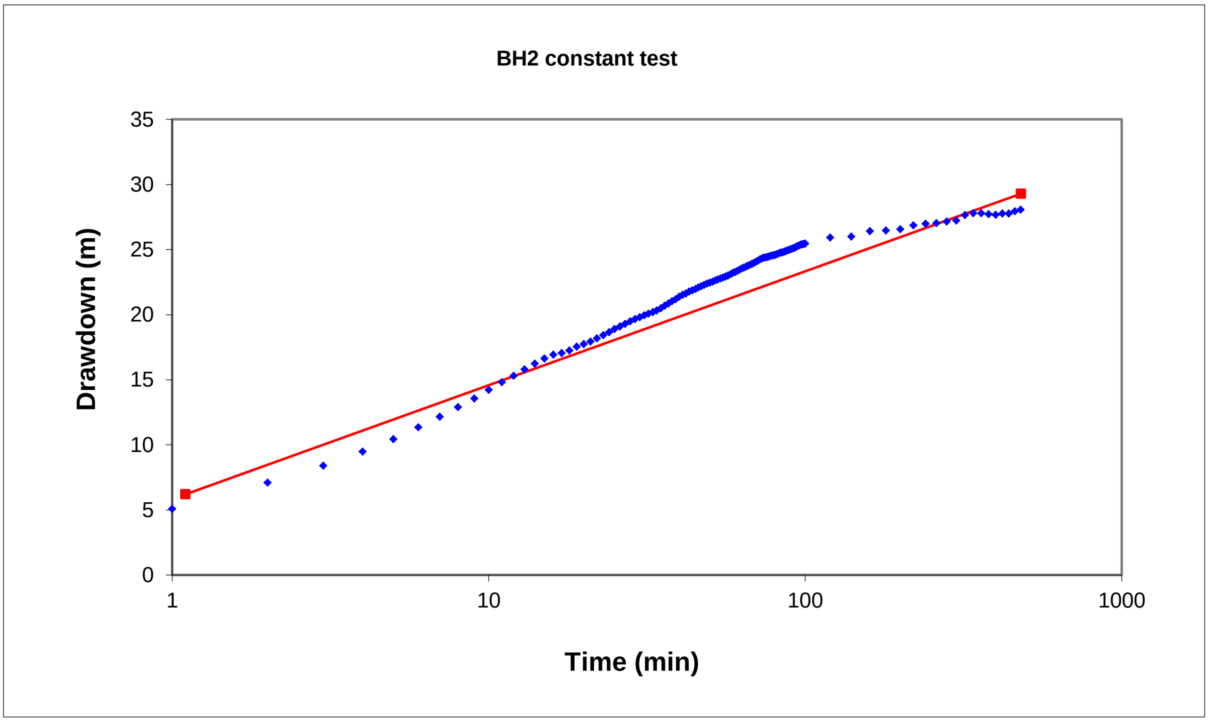
Appendix E: Aquifer test results

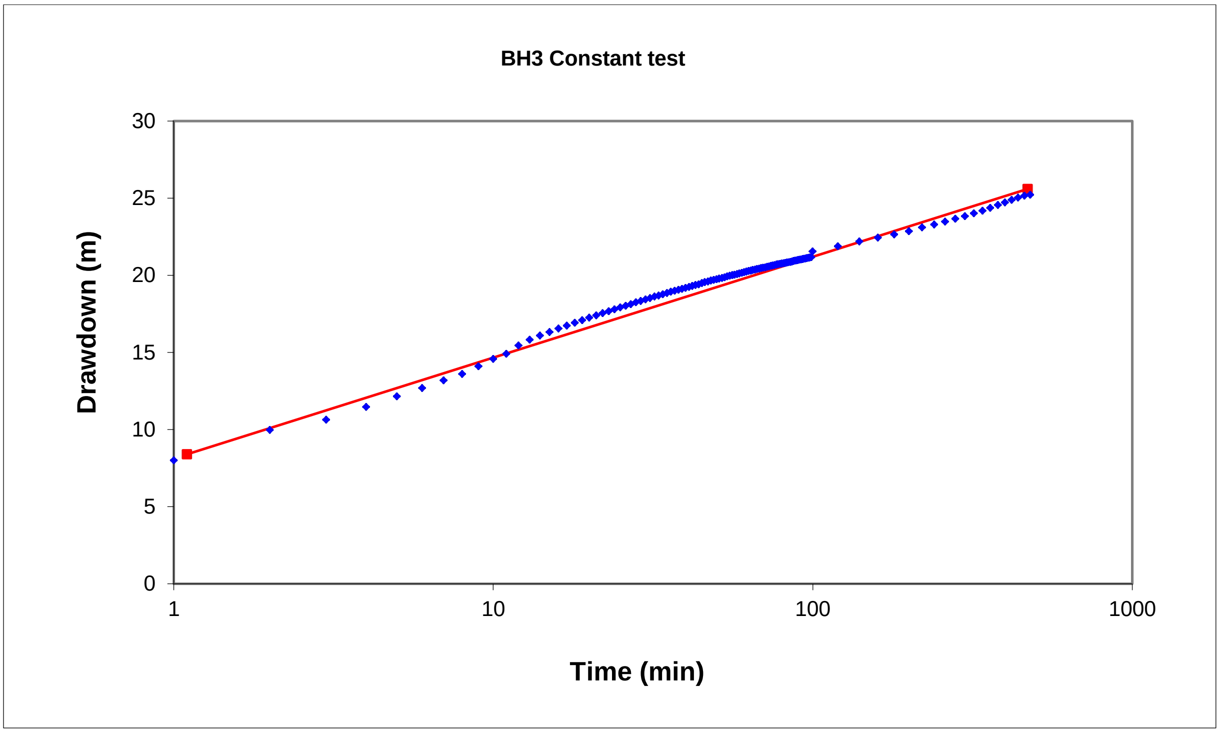

BH1 Slug Test
h(m)
10
1
0.1
0
1000
2000
3000
4000
5000
6000
Time (seconds)


BH4 Slug Test
h(m)
10
1
0
1000
2000
3000
4000
5000
6000
Time (seconds)



Graphs for hydraulic head recovery following slug tests





Drawdown data vs. time for the constant rate pumping test