Dagsoom Twyfelaar Coal Mining Project near Ermelo, Mpumalanga

Groundwater Impact Assessment

Project Number:

DAG5603

Prepared for:

Dagsoom Coal Mining

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This document has been prepared by Digby Wells Environmental.

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Project Name:	**Dagsoom Twyfelaar Coal Mining Project near Ermelo, Mpumalanga**
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I, Arjan van 't Zelfde, as duly authorised representative of Digby Wells and Associates (South Africa) (Pty) Ltd., hereby confirm my independence (as well as that of Digby Wells and Associates (South Africa) (Pty) Ltd.) and declare that neither I nor Digby Wells and Associates (South Africa) (Pty) Ltd. have any interest, be it business, financial, personal or other, in any proposed activity, application or appeal in respect of Dagsoom Coal Mining (Pty) Ltd other than fair remuneration for work performed, specifically in connection with the Social Impact Assessment for the Twyfelaar Coal Mining Project.

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EXECUTIVE SUMMARY

Digby Wells Environmental (hereafter Digby Wells) was appointed by Dagsoom Coal Mining (Pty) Ltd to undertake a Groundwater Impact Assessment study for the proposed Twyfelaar Coal Mine Project (the Project), currently a greenfield site located 6 km from Sheepmoor in Mpumalanga Province, South Africa.

The mining method will be underground mining with all associated infrastructure around the mine access area on the eastern side of the Project Area on the farm Twyfelaar 298IT. The area where mining will take place within the Mining Right boundary is referred to as Block A.

Baseline Assessment

The Mean Annual Precipitation (MAP) of region surrounding the project Area is ~825 mm and the main drainage at and around the Project Area flows in a general west to south-easterly direction. Small streams originate from a horizontal dolerite sill forming the flat top of a hill under which the Block A is situated and flow down the slopes in an approximate radial pattern.

The Project Area is underlain by coal-bearing sandstone, mudstone, siltstone, shale and coal seams of the Vryheid Formation. The coal reserve intersected at the Project Area is confined to the topographical setting of a hill with a dolerite sill at the top that has protected the coal seams below from erosion. No faults or dykes were discovered during the exploration phase. Monitoring borehole testing at and near two linear structures did not indicate high yielding characteristics for these regional structures.

The Karoo rocks are not known for large scale development of aquifers but can occasionally produce high-yielding boreholes. The aquifers that occur in the area can therefore be classified as minor aquifers (low yielding), but of high importance. Two distinct superimposed groundwater systems are present at the Project Area: an upper weathered aquifer and a deeper, fractured aquifer.

The weathered zone within the Project Area is expected to be between 5-10 mbgl based on logs for seven monitoring/ aquifer test boreholes which were drilled at locations derived from a geophysical survey. All boreholes intersected lithologies part of the Vryheid Formation with two boreholes intersecting dolerite sills. Six of the seven boreholes yielded water with one borehole remaining dry.

Groundwater levels ranged between 2.6 mbgl and 28.6 mbgl, indicating groundwater levels are relatively shallow and mainly located within the weathered aquifer. Groundwater flow directions mainly follow topographical gradients.

Aquifer testing of six boreholes indicated hydraulic conductivity values of between 0.01 and 0.05 m/d, typical for weathered Karoo aquifers. DAGBH07 showed a relatively high sustainable yield (1.7 l/s) likely associated with the alluvial aquifer in close proximity to the borehole.

The groundwater at the Project Area is of good quality, with only aluminium exceeding the WHO drinking water guidelines and SANS drinking water standards. Aluminium forms part of

clay minerals and the elevated concentrations could be derived from interaction of water with shale lithologies.

Geochemical Assessment and Waste Classification

The geochemical assessment indicated that all waste rock samples are Potentially Acid Forming (PAF). The results for the coal samples results indicate a significant variability for the coal materials, with one sample (DSC1) being PAG while DSC2 is Non-Acid Forming (NAF). The waste classification indicated that the coal and waste rock materials are classified as a Type 3 waste and need to be disposed at a Class C landfill site or a facility with a similarly performing liner system.

Hydrogeological Model

The weathered zone hydraulic conductivity is in the range of 10^{-2} m/d with exception of the conductivity for the alluvium, which will likely be in the range of 10^{-1} m/d. Hydraulic conductivities for the highly fractured zone are in the range of 10^{-2}-10^{-3} m/d, with hydraulic conductivities for the low fractured units likely in the range of 10^{-4} m/d.

Groundwater recharge from rainfall for Karoo lithologies are generally low, between 1-5% of MAP, with recharge to dolerite sills expected to be less than 1% of MAP due to the higher resistance to weathering of dolerite sills.

The following sources, pathways and receptors were discerned:

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

A numerical groundwater model was setup for groundwater flow and contaminant transport scenario modelling. Steady-state model calibration was deemed acceptable with a Mean

Residual Head of -0.9, a Mean Residual Absolute Head of 6.4 and a Root Mean Square Error (RMSE) of 7.8. Pre-mining groundwater levels were simulated and show the general south-south-eastern flow direction of groundwater as previously discussed.

Transient flow simulation was carried out to estimate groundwater drawdown for the Operational Phase and groundwater recovery in the Post-Closure Phase. In addition, increased seepage was modelled for the proposed discard dump. As the main source of contamination with coal mining is the weathering of pyrite, the contaminant of choice is sulphate that is released, together with acidity, due to the solution of pyrite. Model input concentrations for the underground mine and discard dump were based on the results of the geochemical assessment.

Impact Assessment

Construction

The Construction Phase will consist of building surface infrastructure and the construction of an adit to access the Block A mining area, and potential groundwater impacts are contamination of groundwater due to hydrocarbon spillages and leaks from construction vehicles and groundwater drawdown due to small-scale dewatering for the construction of the adit. However, these activities are of small magnitude and will only pose Project Area-specific groundwater risks. Therefore, the impact of these activities is expected to be low.

Proposed mitigation measures are the regular service of vehicles in designated repair bays, refuelling of vehicles on hardstanding areas and to keep the adit construction time as short as possible.

Operational

The potential cone of drawdown in the Karoo sediments due to dewatering of Block A is largest at the end of LoM and extends to a maximum radius of ~200 m around the mine, and groundwater inflows will likely be in the range of ~50 to ~80 m^3/d. Based on the simulations, no third-party sources, wellfields or other groundwater abstractions are present within the zone of influence. As the wetlands surrounding the hill are fed by a perched aquifer in the dolerite sill cap, and impact from the dewatering is not expected to impact on this perched aquifer.

During the Operational Phase groundwater flow directions will be directed towards the mining areas due to the mine dewatering and therefore contamination will be contained within the mining area.

Based on the NEM:WA classification, the discard material does show a potential for the generation of AMD and is therefore classed as a Type 3 waste. This type of waste would require a Class C liner or similar effective mitigation.

Any discard dumps, pollution control dams and/or coal stockpile areas should be lined, thereby minimising seepage of contaminated water into the underlying aquifers.

Monitoring of groundwater quality down-gradient of infrastructures should be carried out for the LoM.

Post-Closure

After the end of life of mine pumping of groundwater from the underground void will seize and groundwater levels will be allowed to recover. However, due to the low recharge influx it will take Approximately 30 years before groundwater levels will return to pre-mining conditions.

Once the mining has ceased, AMD is likely to form and sulphate could migrate from the discard dump and from the mining area once water levels have recovered. The maximum extent of the contaminant plume was calculated to be ~275 m from the void. Based on the contaminant transport simulations it is very unlikely that privately owned boreholes located in the vicinity of the proposed mining will be impacted upon.

Contamination of groundwater via seepage from the discard dump showed a potential sulphate plume to a maximum distance of ~520 m southeast of the discard dump. This plume reaches a non-perennial stream located east of the discard dump 50 years post-closure. This impact can be mitigated by installing a recommended Class C liner or similar mitigation measure for the discard dump and to carry out proper rehabilitation of the dump post-closure to significantly reduce infiltration of rainwater into the dump.

The adit is situated at a topographical elevation of 1 619 mamsl. As this is above the modelled pre-mining groundwater levels at the adit it is very unlikely that decant will occur. It is recommended to close all access routes into the underground mine, such as the adit or any vent shafts.

The following conclusions were made for the site:

- The potential cone of drawdown is largest at the end of life of mine and water levels are expected to be lowered over a relatively small area (a maximum radius of ~200 m is expected) around the underground void;
- During steady state production the groundwater inflows will likely be in the range of ~50 to ~80 m^3/d which are regarded as relatively low. This is due to the fact that Block A mining is taking place in low fractured rock. The anticipated groundwater abstraction volumes are not expected to significantly impact on the local groundwater availability;
- Based on the simulations no third-party sources, wellfields or other groundwater abstractions are present within the zone of influence. Therefore, it is unlikely there will be an impact on third party abstraction sources by lowering of water levels as a result of the projected mining activities;
- Groundwater flow directions for the operational phase will be directed towards the mining areas due to the mine dewatering. Therefore, contamination during the operational phase will be contained within the mining area, and little contamination will be able to migrate away from the mining area;
- However, due to the low recharge influx it will take a long time before groundwater levels will return to pre-mining conditions. The numerical model was used to simulate groundwater rebound and indicates the rebound will indeed be slow and groundwater levels in the vicinity of the site will take approximately 30 years to recover.

- The maximum extent of the contaminant plume was calculated to be ~275 m from the void moving in a general east to southeast direction. Based on the contaminant transport simulations for the underground mine it is very unlikely that privately owned boreholes located in the vicinity of the proposed development will be impacted upon; and
- The potential sulphate plume from the discard dump will mainly flow towards the southeast and extend to a maximum distance of ~520 m from the discard dump, reaching a non-perennial stream east of the discard dump. This impact can be mitigated by dump rehabilitation post-closure and application of a Class C liner or mitigations with a similar effectiveness.

The following recommendations are made:

- A closure water management plan should be developed. This should assess the management of a critical water level to minimise contamination of the shallow weathered aquifer. The discard dump should also be assessed in terms of a remediation action plan. This should all be analysed in a financial model to further inform the most effective closure water management options. The groundwater model should be used as a management tool to inform this process;
- All mining areas should be flooded as soon as possible to restrict oxygen ingress into the backfill and lower sulphate levels in seepage;
- The rate of water level recovery in the underground void should be monitored. Stage curves should be developed which would aid in the management of closure phase;
- A groundwater monitoring network should be put in place;
- The numerical model should be updated once every two-three years or after significant changes in mine schedules or plans by using the measured water ingress and water levels to re-calibrate and refine the impact predictive scenario. Updates to the model should be carried out more frequently if significant changes are made to the mine schedule or plan;
- Based on the NEM:WA classification the discard material does show a potential for the generation of AMD and is therefore classed as a Type 3 waste. This type of waste would require a Class C liner. However, alternative mitigations or liner options can be implemented if it can be shown to the authorities (liner exemption motivation), by following a risk-based approach, that these alternatives will perform in a similar manner to a standard Class C liner; and
- Additional geochemical assessment giving more insight in the variability of the NAG of the coal material should be performed, and if applicable, the liner requirement re-assessed.
- If further expansion of the mining activities is proposed, it is recommended to update the hydrocensus and to drill additional monitoring boreholes, if more third-party boreholes cannot be located.

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ROM	Run-Of-Mine
ktpm	Kilotonees per month
LoM	Life of Mine
ABA	Acid Base Accounting
NAG	Net Acid Generation
XRD	X-Ray Diffraction
XRF	X-Ray Fluorescence
DW test	Reagent (Distilled) Water test
ICP-OES	Inductively coupled plasma atomic emission spectroscopy
WMA	Water Management Area
UTM	Universal Transverse Mercator
mbgl	Meters below ground level
k	Hydraulic conductivity
k_h	Horizontal hydraulic conductivity
k_v	Vertical hydraulic conductivity
T	Transmissivity

mamsl	Meters above mean sea level
SANS	South African National Standards
WHO	World Health Organisation
wt. %	Weight percentage
AMD	Acid Mine Drainage
AP	Acid Potential
NP	Neutralising Potential
NNP	Net Neutralising Potential
NPR	Neutralising Potential Ratio
SS	Sulphide-Sulphur
NAG	Net Acid Generating
PAN	Potential Acid Neutralising
PAG	Potential Acid Generating
TC	Total Concentration
LC	Leachable Concentration
TCT	Total Concentration Threshold
LCT	Leachable Concentration Threshold
EIA	Environmental Impact Assessment
RMSE	Root Mean Square Error
MAP	Mean Annual Precipitation

1 Introduction

Digby Wells Environmental (hereafter Digby Wells) was appointed by Dagsoom Coal Mining (Pty) Ltd to undertake a Groundwater Impact Assessment study for the proposed Twyfelaar Coal Mine Project (the Project), currently a greenfield site. The Project is located off the N2 National Road, approximately 6 km from Sheepmoor in Mpumalanga Province, South Africa.

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

2 Project Description

The mining activities for the proposed Project will be located on the farm Twyfelaar 298 IT, within the Msukaligwa local municipality (MP302), situated in the Gert Sibande District Municipality in the Highveld sub-region of Mpumalanga. The closest towns are Sheepmoor which is approximately 4 km from the proposed Project Area as defined by the mining right area shown on Figure 2-1, and Ermelo which is approximately 30 km from the Project Area (Figure 2-1).

The mining method will be underground mining with all associated infrastructure around the mine access area on the eastern side of the Project Area on the farm Twyfelaar 298IT. The area where mining will take place within the Mining Right boundary is referred to as Block A with associated infrastructure located in the Northern Underground Access area (Figure 2-2).

The resource access is proposed through a box-cut on the side of the mountain and the C-lower seam will be accessed directly without any declines (see Figure 2-2). The resource is proposed to be accessed with at least three roads from the box-cut high wall; one road for men and material, one for the Run of Mine (ROM) conveyor and one the return airway which will be connected to the ventilation fans on the side “high wall” of the box-cut (ECMA, 2014).

The coal reserves are proposed to be mined at a rate of up to and over 500 ktpa, slightly in excess of 40 ktpm. Stooping production rates may increase up to 30 kilotonnes per month (ktpm) due to less support requirements. The Life of Mine (LoM) schedule allows a current LoM of five years. Please refer to Figure 2-3 for the proposed Northern Underground Access mine schedule.

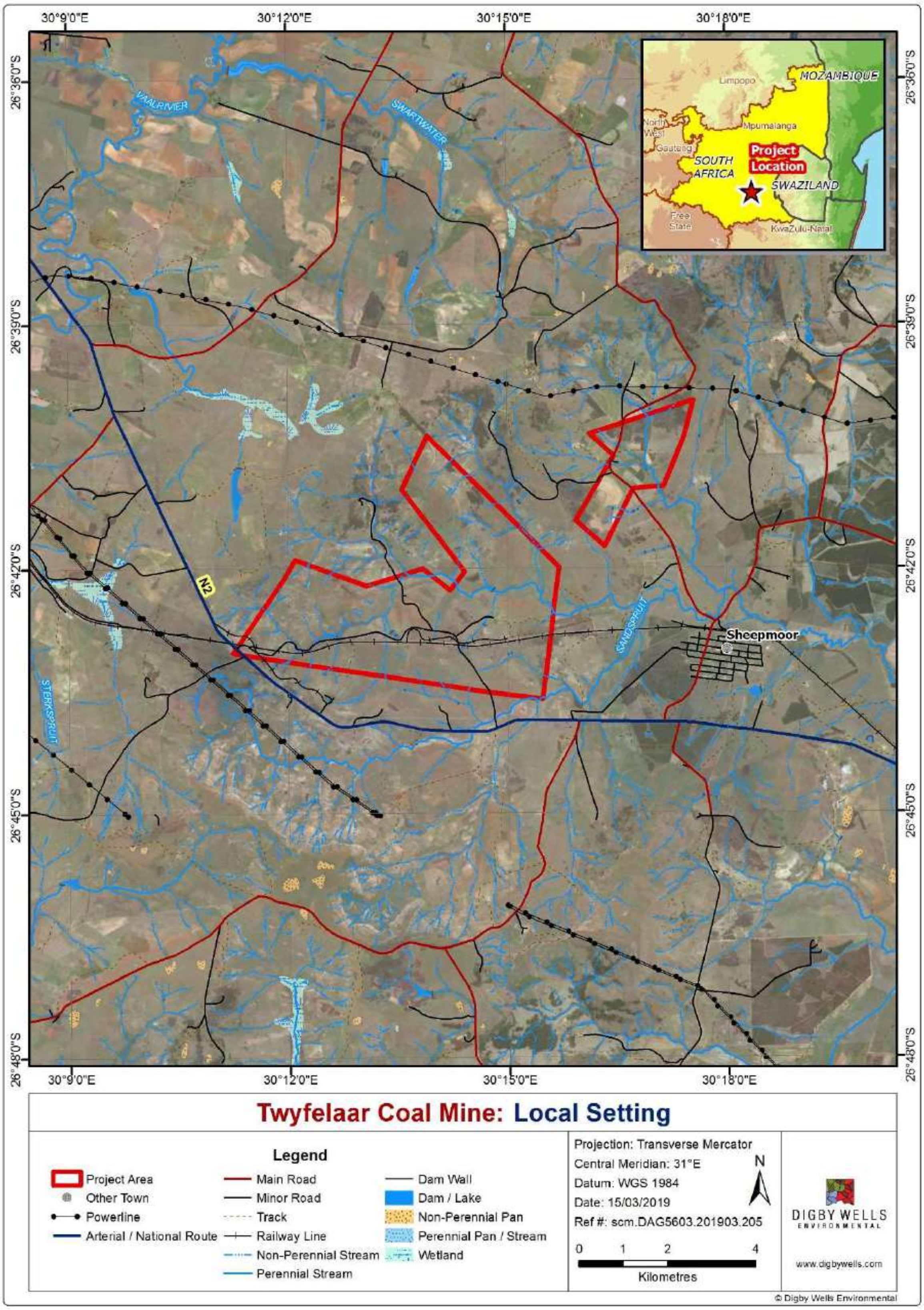


Figure 2-1: Project Location

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

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

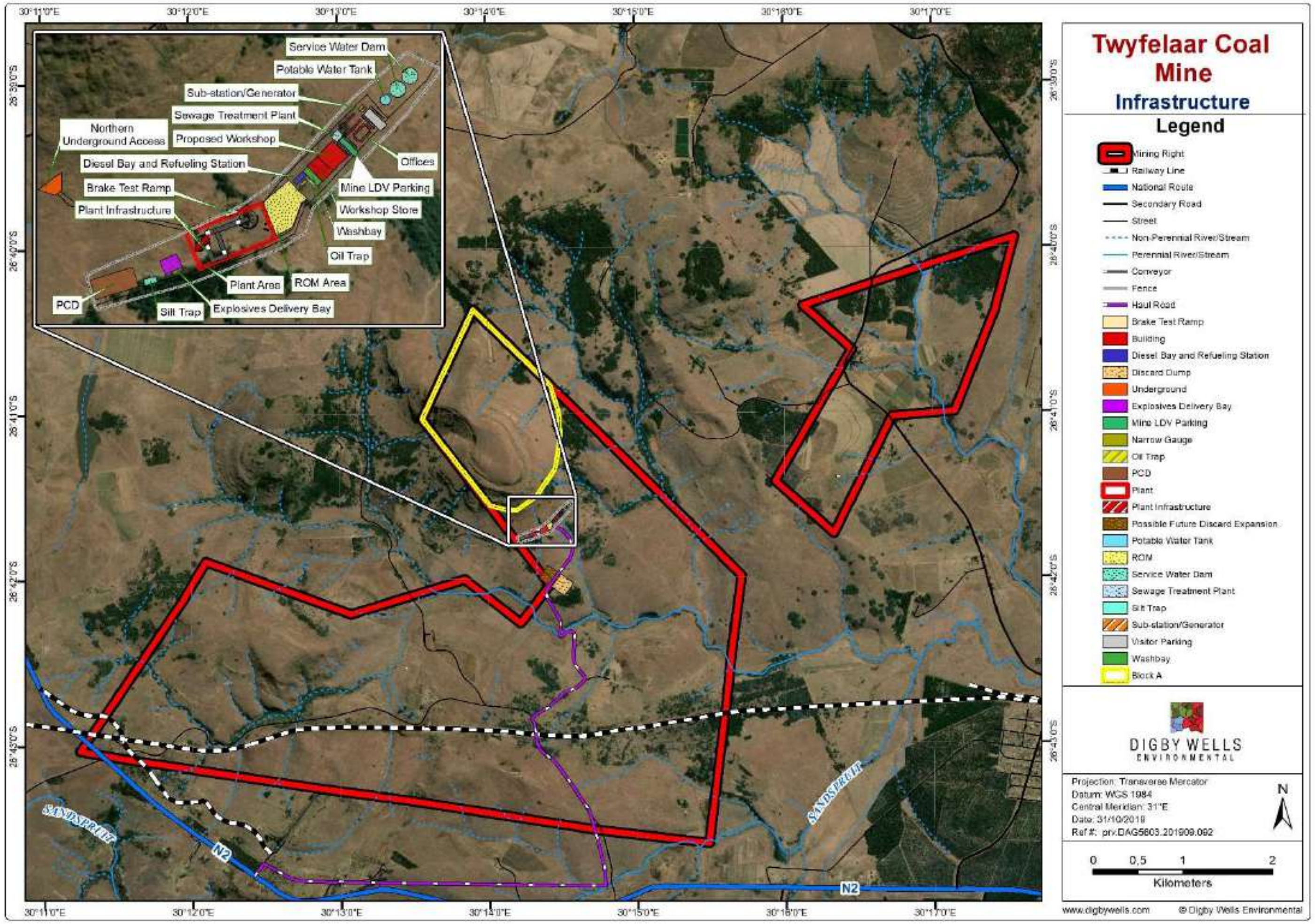


Figure 2-2: Site Layout showing the proposed Block A mining area and infrastructure at the Northern Underground Access.

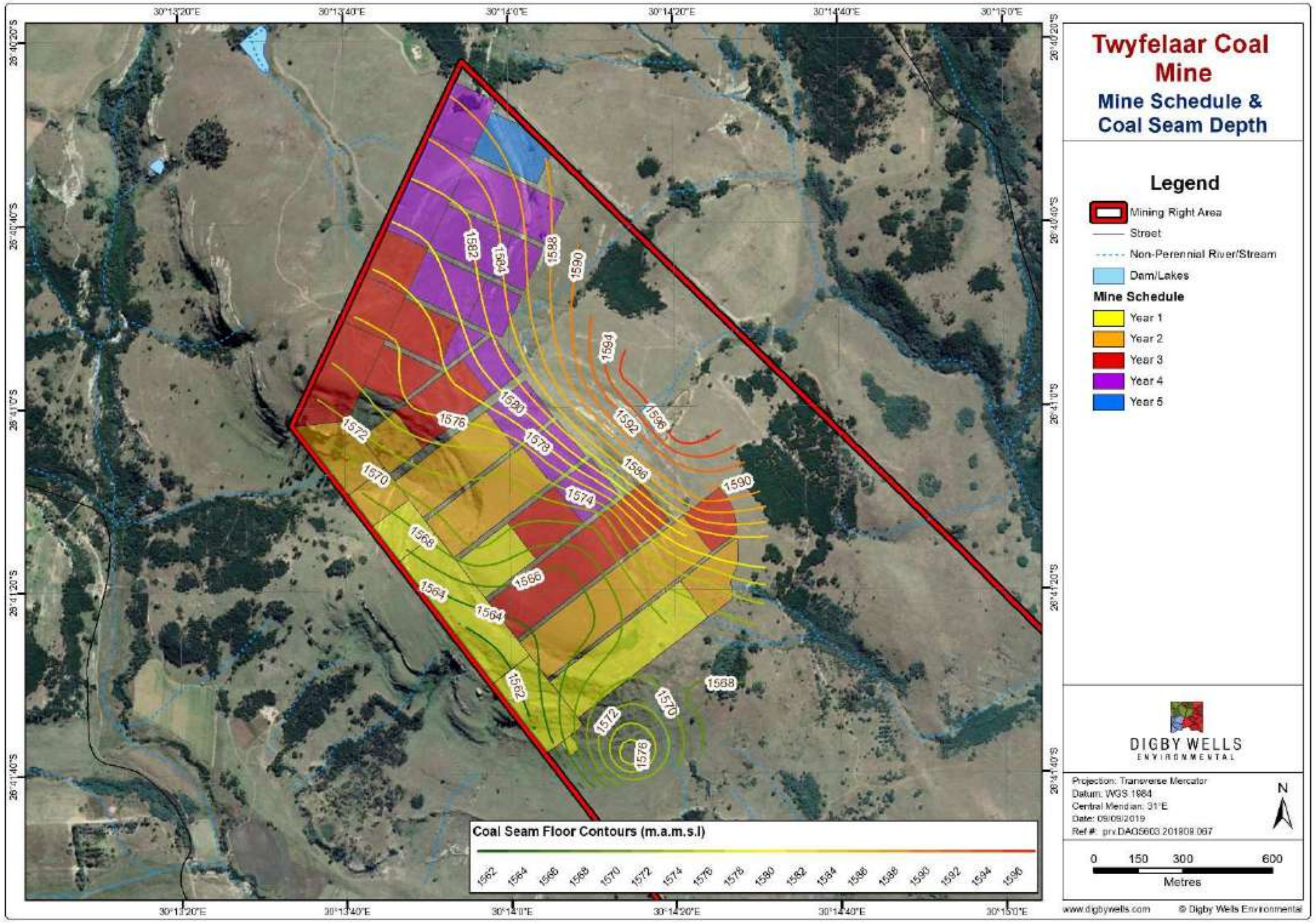


Figure 2-3. Proposed Block A Mine Schedule and Coal Floor Elevations

3 Methodology

For this project a baseline assessment was done for the Project Area as defined by the entire mining right area (Figure 2-1). The impact assessment was only carried out for part of the mining right area which includes the Block A underground mining area and the Northern Underground Access Infrastructure as shown in Figure 2-2.

3.1 Baseline Assessment

In depth analyses of all relevant and available secondary data such as reports, data sheets, proposals and maps were utilised to compile a base of data that feeds into the Groundwater Impact Assessment report.

3.1.1 Hydrocensus

A hydrocensus survey was conducted from the 25th to the 26th of March 2019. The survey was undertaken to provide insights on the understanding of the baseline hydrogeological conditions in and around the proposed Twyfelaar Mining Right boundary. The survey included visits to communal water supply borehole(s), exploration borehole(s), and springs.

A total of five water supply boreholes, two exploration boreholes, four springs and a river entering the Project Area were identified. The following information was collected at each of the field sites (where possible):

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

A total of four samples were collected for water quality analysis (Section 4.5.4). Samples were collected at two springs and from two exploration boreholes. Samples were couriered and submitted to Waterlab laboratories (a SANAS accredited lab) for analysis. The information listed above was used to define the groundwater baseline condition and will be used as a reference for future water monitoring and impact assessments. The analysis was performed for inorganic constituents such as major cations, anions and metals as shown in Table 3-1.

3.1.1.1 Water Level Measurements

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

Table 3-1: Analysed parameters

<table>
<tr><th>Physical parameters</th><th>Nutrients</th><th>Dissolved anions</th><th>Dissolved metals</th><th>Others</th></tr>
<tr><td>pH</td><td>Ammonia-N</td><td>M Alkalinity</td><td rowspan="7">ICP-OES (i.e. major, minor and trace metals)</td><td>Total cations</td></tr>
<tr><td>EC in mS/m</td><td>Nitrate-N</td><td>P Alkalinity</td><td>Total anions</td></tr>
<tr><td>Total Suspended Solids</td><td>Nitrite-N</td><td>Bromide (Br)</td><td>% error</td></tr>
<tr><td>Total Dissolved Solids</td><td>Total Phosphate (P)</td><td>Chloride (Cl)</td><td>Total Balance</td></tr>
<tr><td></td><td></td><td>Fluoride (F)</td><td>Total hardness</td></tr>
<tr><td></td><td></td><td>Sulphate (SO_4)</td><td>Ca hardness</td></tr>
<tr><td></td><td></td><td></td><td>Mg hardness</td></tr>
</table>

3.2 Environmental Sensitivity

Based on the groundwater characteristics, the environmental sensitivity was qualitatively described for the Project Area and guides recommendations made on the placement of infrastructure and activities. The sensitivity analysis includes interactions with ecology and hydrology as these are linked to the groundwater environment.

3.3 Fieldwork

Further intrusive fieldwork was carried out for the characterisation of the underlying aquifers and to obtain parameters to enable the construction of a conceptual model and to carry out numerical modelling of potential impacts. The fieldwork included a geophysical survey, borehole drilling, and aquifer testing as described in the subsections below.

3.3.1 Geophysical Survey

A geophysical survey was carried out to identify any anomalies or structures within the Project Area the Project Area that could indicate aquifers and/or preferential groundwater flow paths. Based in the geophysics results, drill targets were generated to drill aquifer test boreholes. The two geophysical methods used were the electromagnetic (carried out by EM34) and magnetic (carried out by Geotron G5) surveys. A total of eight survey lines of between 1 and 1.6 km in length were carried out on site based on the preliminary site layout to site aquifer test boreholes. Seven drill targets were derived based on the geophysical survey results.

3.3.2 Borehole Drilling

Seven aquifer test/ monitoring boreholes were drilled across the Project Area to allow for aquifer parameter estimations. The boreholes were drilled into the Karoo lithologies to allow for testing of these hydrostratigraphic units, from which most of the groundwater inflow is expected. The boreholes were drilled at 165 mm (6.5”) and installed with plain/slotted casing at 114 mm (4.5”). The drilling was carried out by Hallcore Drilling. under supervision by Digby Wells. Six boreholes yielded water, where one remained dry.

3.3.3 Aquifer Testing

The six boreholes in which groundwater collected were aquifer tested using submersible pumps. The testing was carried out by Hallcore Water/VBS Leboa Consulting (Pty) Ltd. Digby Wells carried out aquifer test supervision and interpreted the test data to derive aquifer parameters.

3.4 Geochemical Assessment and Waste Classification

Footwall and hangingwall rock, as well as coal samples were collected during drilling of the aquifer test boreholes to undertake geochemical testing. In total, eight samples were collected and submitted for geochemical characterisation. The following characterisation tests were conducted:

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

The discard and coal samples are described in Table 3-2.

Table 3-2 : Sample description

No.	Laboratory ID	Reporting ID	Origin/Description	Exploration Boreholes
1	L5001	DSD1	Roof Sample of TW009	TW009
2	L5002	DSD2	Floor sample of TW009	TW009
3	L5003	DSD3	Roof Sample of TW002	TW002
4	L5004	DSD4	Floor sample of TW002	TW002
5	L5005	DSD5	Roof Sample of TW006	TW006
6	L5006	DSD6	Floor sample of TW006	TW006
7	1256419/ 1256936	DSC1	Coal Sample	
8	T7	DSC2	Coal Sample	DAGBH07

3.5 Site Conceptual Hydrogeological Model

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

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

3.6 Numerical Modelling

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

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

3.7 Impact Assessment

A Groundwater Impact Assessment was carried out based on the outcome of the numerical model, and recommended mitigation measures were given that may be necessary to address groundwater impacts associated with the Project.

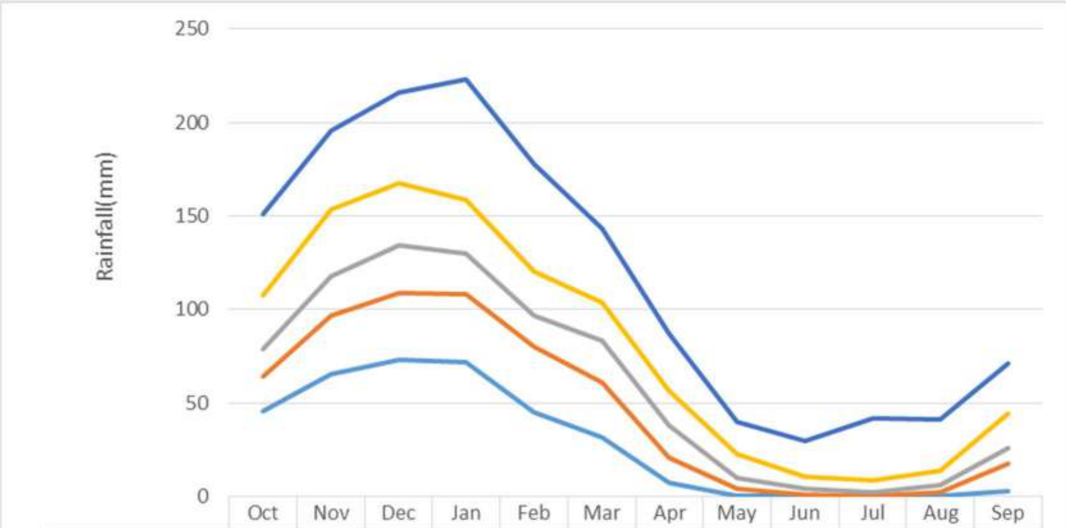
A network of observation points and a monitoring programme that would satisfactorily monitor groundwater conditions (levels and quality) before and after commencement of operations were proposed. Existing boreholes drilled during the investigations were identified and additional monitoring sites were proposed.

4 Baseline Groundwater Environment

4.1 Climate

The Köppen-Geiger system classification was used to classify the climate for the Project Area. The classification scheme divides climates into five main climate groups: *A* (tropical), *B* (dry), *C* (temperate), *D* (continental), and *E* (polar), that are further subdivided into thirty climate classes. The Project Area and surroundings are situated in an area with climate class Cwb that stretches over much of the South African highveld and escarpment and typically indicates warm summer temperatures, whilst winters are generally cold with a high incidence of frost (Mucina and Rutherford, 2012). The average daily maximum temperature in January (the hottest month) is 25.2°C and in July (the coldest month) is 16.7°C.

The Project Area falls within the summer rainfall area of South Africa, and as such rainfall is highly seasonal with rainfall predominantly occurring in the summer months. The Mean Annual Precipitation (MAP) of region surrounding the project Area is ~825 mm which is likely to be distributed as indicated in Figure 4-1 (WRC, 2015).



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
90 Percentile	45	65	73	72	45	31	8	0	0	0	0	3
70 Percentile	64	97	109	108	80	61	20	4	1	0	2	17
50 Percentile	79	118	135	130	97	83	38	10	4	2	6	26
30 Percentile	107	153	168	158	120	104	57	23	10	8	13	44
10 Percentile	151	196	216	223	178	143	87	40	30	42	41	71

Figure 4-1: Monthly Rainfall distribution for quaternary W53A

4.2 Topography and drainage

The topography is dominated by the Eastern escarpment which has a general southwest to northeast orientation, with a higher plain to the west and a lower, slight to moderately undulating plain to the east (Figure 4-2).

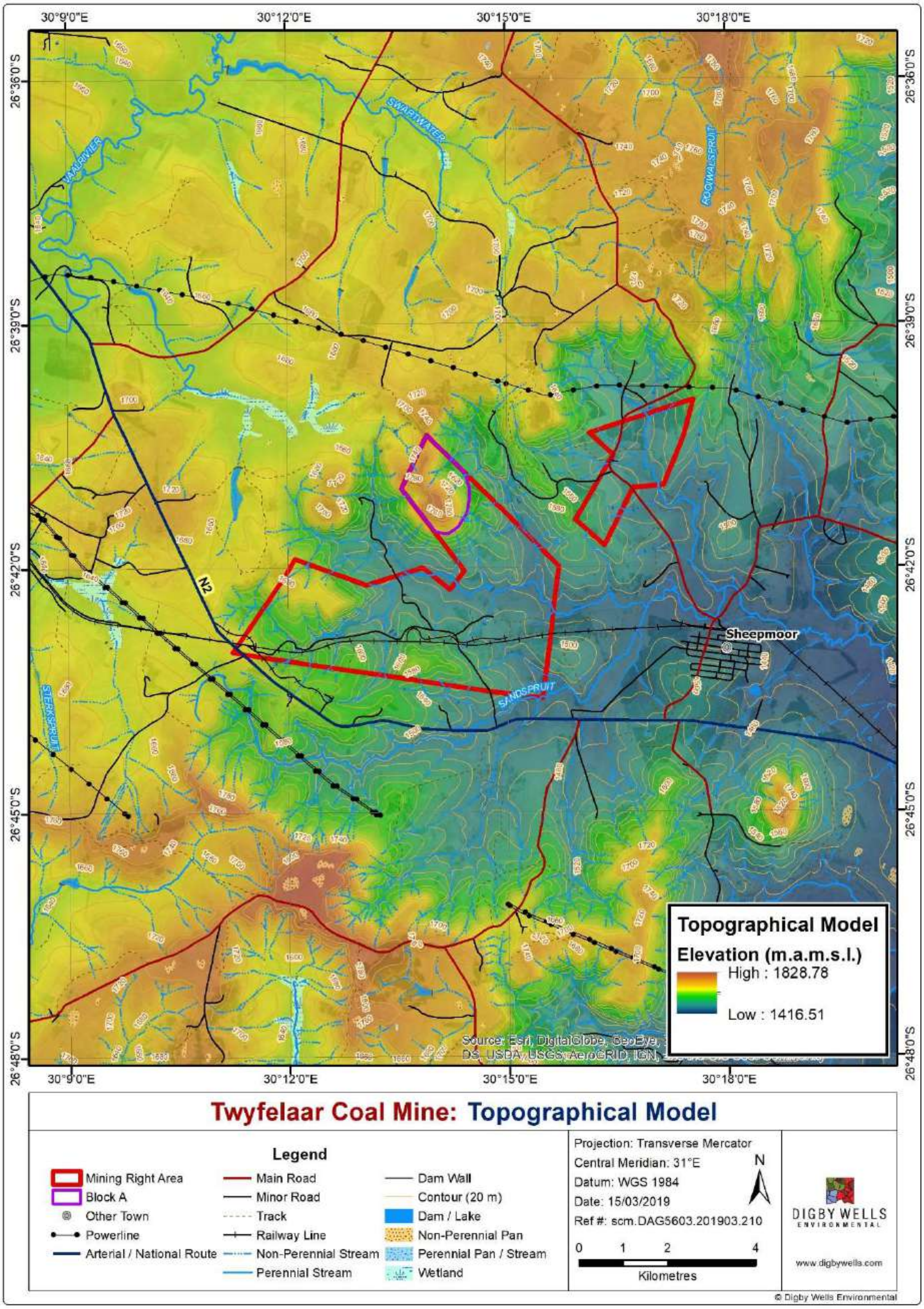


Figure 4-2: Topographical Map

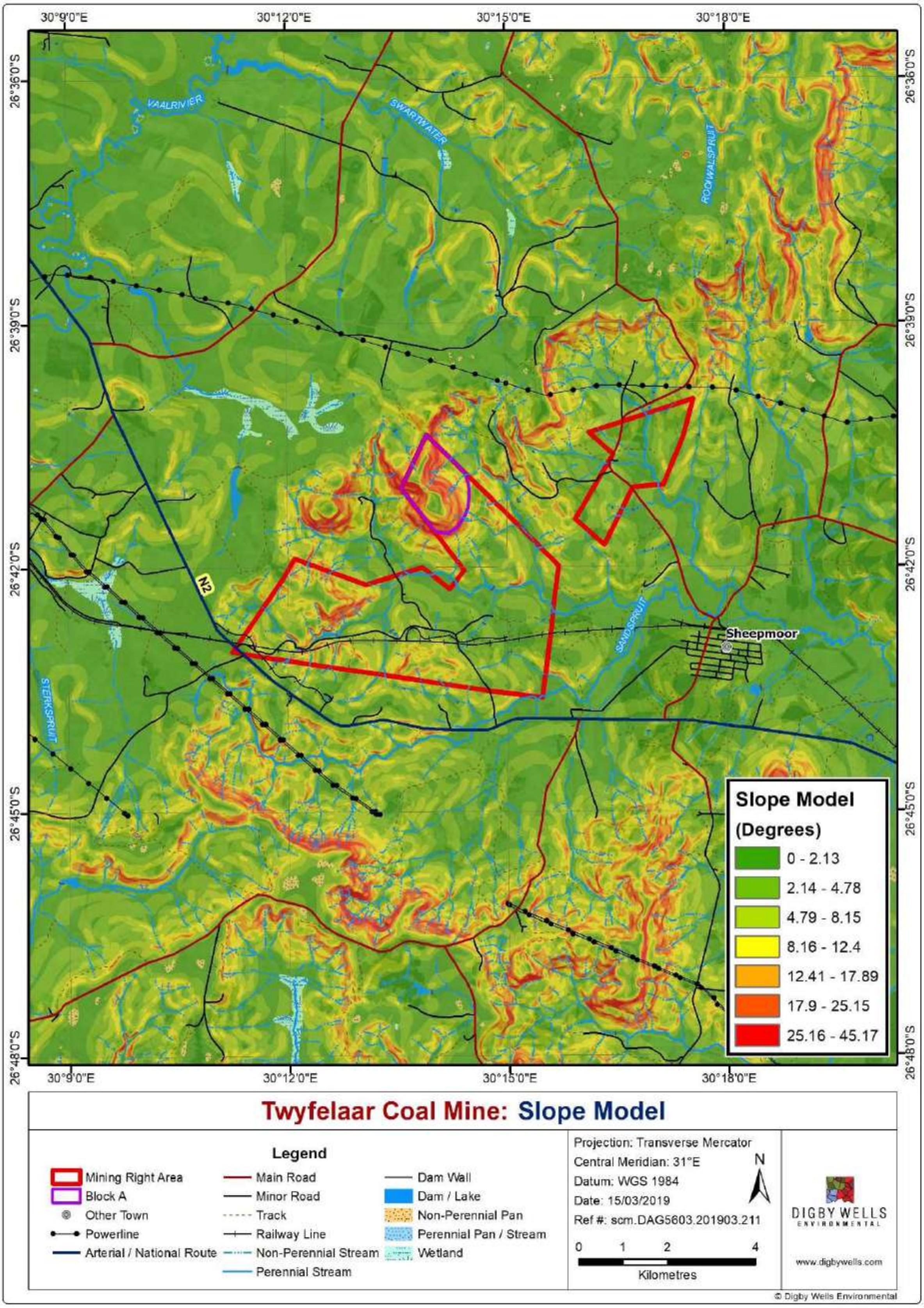


Figure 4-3: Slope Aspect Map

Low hills and pans are scattered throughout the landscape. Altitude typically varies from ~1 800 mamsl on the highveld west of the escarpment to ~1 500 mamsl east of the escarpment. The majority of the Project Area has steep slopes with steeper slopes between 10° and 45° for the higher lying areas and more gentle slopes between 0° and 10° for the lower lying areas (Figure 4-3).

The escarpment dominates the main drainage patterns. The Project Area is situated to the south-east of a major catchment divide between the Vaal and the Usuthu Rivers. The Project Area itself is located in the W53A quaternary catchment of the Inkomati-Usuthu Water Management Area (WMA). Drainage in the area surrounding the site flows in a general west to south-easterly direction with non-perennial drainage lines located to the north-east and south to south-west (Zandspruit) of the proposed Block A.

At the hill under which the Block A underground mine is proposed, small streams originate at the base of a horizontal dolerite sill forming the top of the hill and flow down the slopes in an approximate radial pattern. These streams are mostly associated with hillslope seep wetlands (following the valleys) and bench (mostly horizontal, following more resistant stratigraphical units) wetlands. Refer to the wetland report attached to the EIA Report for further wetlands details.

4.3 Geology

4.3.1 Regional geology

The regional area surrounding the Project Area is situated within the Ermelo Coalfield on the eastern escarpment of the Mpumalanga Highveld. The Ermelo Coalfield extends from Carolina in the north to Dirkiesdorp in the south encompassing a surface area of ~11,250,000 ha. The Project Area specifically lies within the eastern boundaries of the Ermelo Coalfield which is defined by the sub-outcrop of the coal-bearing strata against the pre-Karoo basement. The area is predominantly underlain by Formations of the Karoo Supergroup with a total thickness of sedimentary rocks ranging between 0 - 100 m. The dominant lithologies present in the region are coal-bearing sandstone, mudstone, siltstone, shale and coal seams of the Vryheid Formation with dolerite dyke and sill type intrusions of the Karoo dolerite Suite present throughout the area (Figure 4-4). The Vryheid Formation, part of the Ecca group, rests unconformably on diamictites and associated glaciogenic sediments of the Dwyka Group or in the absence of Dwyka on granitic basement rocks (Johnson et. al, 2006).

4.3.2 Local geology

The coal reserve of the Vryheid Formation intersected in the Project Area is confined to the topographical setting of a hill. The hill rises approximately 200 m above the surrounding valleys and is capped by a dolerite sill with a perceived thickness of ~35 m. The sill is situated at ~115 m above the upper coal seam and has protected the coal seams from erosion as it is more resistant to weathering than the underlying Karoo lithologies.

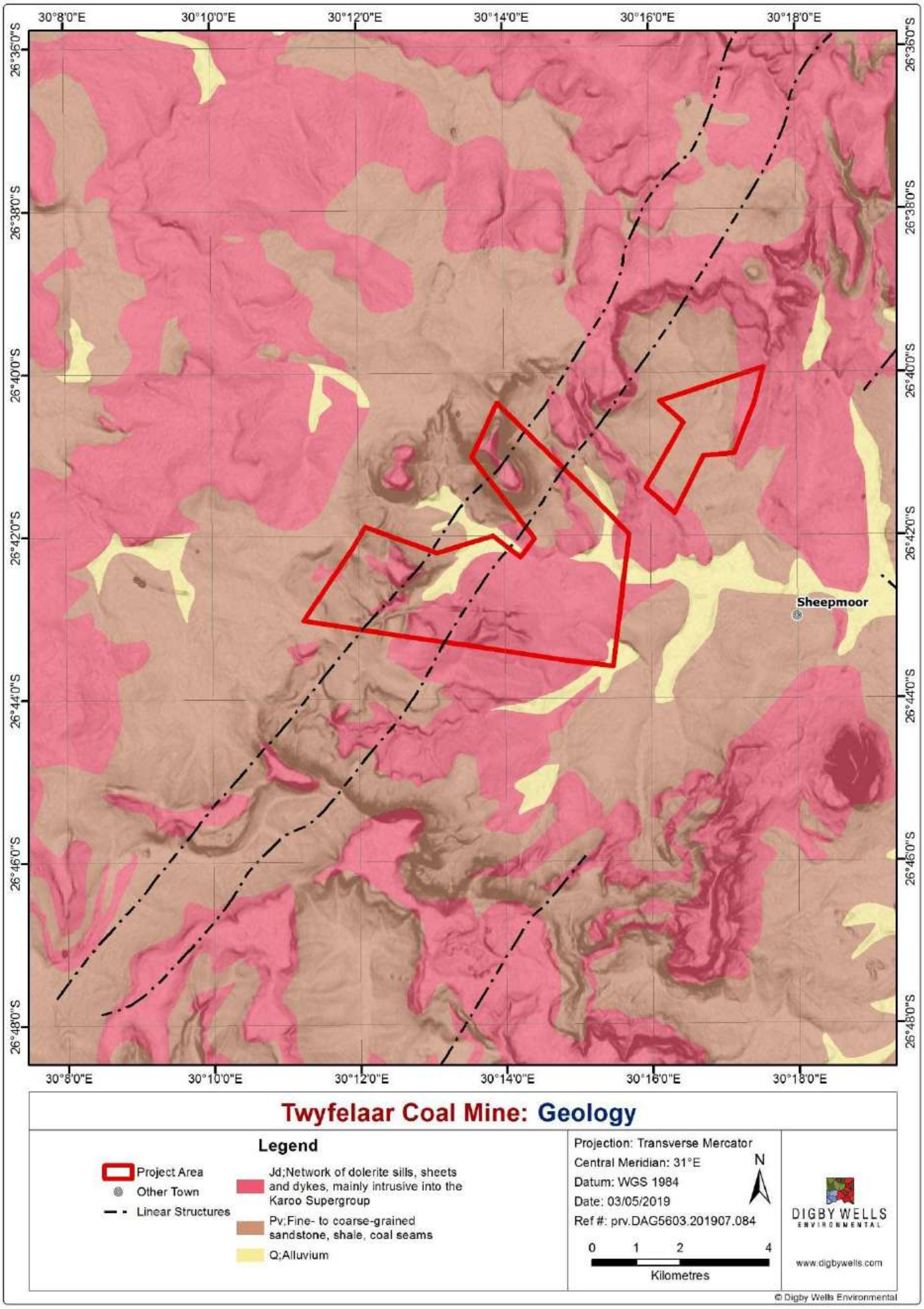


Figure 4-4: Regional Geology

Aside from the cap sill no other significant dolerite intrusions were recorded in the exploration boreholes (ECMA, 2014). Eight coal seams (A, BU, BL, CU, CL, DU, D and E) were logged below the sill cap and outcrop around the slopes of the ridge with the C-seam being the main target for the proposed development. No faults or dykes were discovered during the exploration phase. Monitoring borehole drilling and testing at and near the two linear structures (refer to section 3.3.2 above) did not indicate high yielding characteristics for these regional structures.

4.4 Hydrogeology

4.4.1 General Aquifer Description

The conceptual hydrogeological model of the Project Area is based on the generally accepted model for the Mpumalanga coal fields. In this model, three principal aquifers are identified: the weathered aquifer; the fractured Karoo aquifer; and the fractured pre-Karoo aquifer (Hodgson & Krantz, 1998).

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

Three distinct superimposed groundwater systems are present at the Project Area and surroundings and can be classified as (Hodgson and Krantz, 1998, Woodford and Chevallier, 2002):

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

These types of groundwater systems are common to the groundwater regime in the Karoo environment. The systems do not necessarily occur in isolation and often form a composite groundwater regime that is comprised of one, some, or all of the systems.

In the Project Area the main aquifer types are the upper weathered and the deeper, fractured aquifers formed in the sedimentary rocks of the Vryheid Formation. Furthermore, numerous dolerite sills have intruded into the sediments of the Vryheid Formation and are in some cases overlying this formation, as is the case in the area where Block A is situated. As these sills are more resistant to weathering, they form hills and ridges in the landscape.

In general, the shallow aquifer depth ranges between 5-20 m overlying the fractured rock formations throughout the region. In terms of pollution risk and/ or susceptibility to pollution, the shallow primary aquifer is understood to be highly susceptible to pollution due to coal mining in the area as the pollutants travel shorter distance to reach the aquifer system (Hodgson and Krantz, 1998).

4.4.2 Geophysical Survey

The geophysical survey carried out between 11th and 14th of July 2019 and eight (8) lines in total were surveyed across the site (Figure 4-5). The survey lines were interpreted based on anomalies in the EM and Mag data in conjunction with lithological units and geological structures as indicated on the regional geological map. The results are shown in Figure 4-6. Eight drill targets were identified (Table 4-1). Based on a field reconnaissance of the targets, seven targets were chosen. Line 2, target 2 and Line 7, target 1 were omitted due to access constraints on site.

Table 4-1. Identified drill targets with details

Drill target	Coordinates (UTM 36, WGS 84)		Targeting
	X	Y	
Line 1, target 1	-75689.3	-2952407.1	Vryheid Formation - anomaly in Mag data
Line 2 target 1	-75682.5	-2952775.1	Possible linear structure - anomaly in EM and Mag data
Line 2 target 2	-76079.6	-2952409.5	Vryheid Formation - anomaly in EM data
Line 4 target 1	-75837.3	-2954282.5	Possible linear structure - anomaly in EM and Mag data
Line 5 target 1	-72792.5	-2953716.5	Possible dolerite sill - anomaly in EM data
Line 6 target 1	-72484.6	-2952982.1	Vryheid Formation - anomaly in EM data
Line 7 target 1	-76588.6	-2955043.0	Possible geological contact - anomaly in EM and Mag data
Line 8 target 1	-77500.4	-2955960.9	Possible geological contact - anomaly in EM data

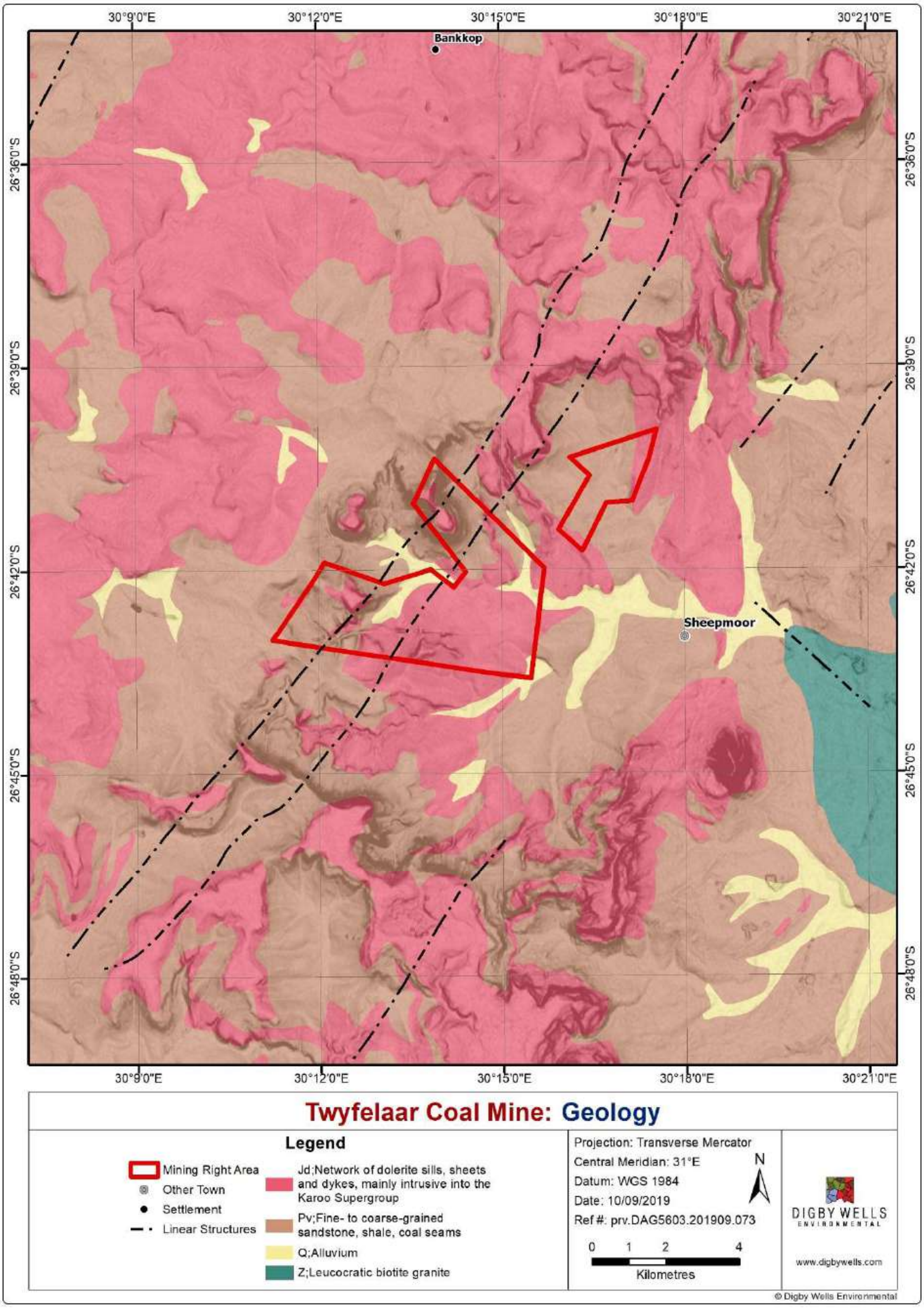
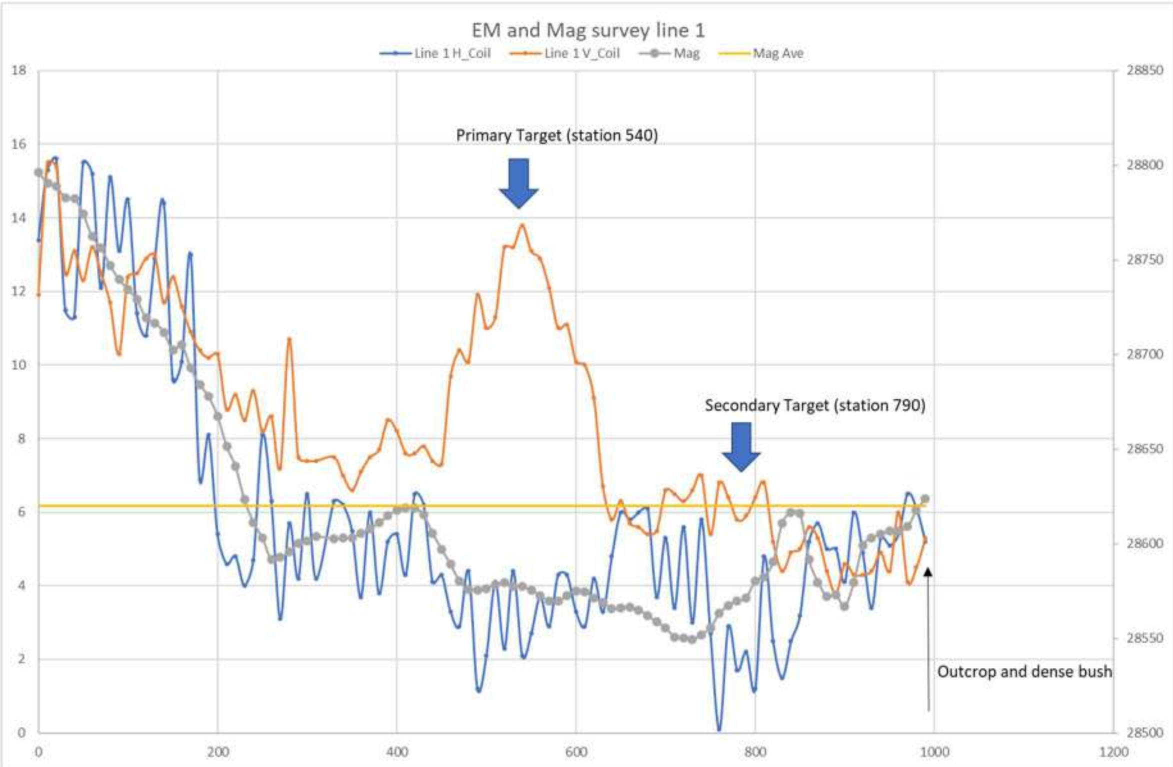
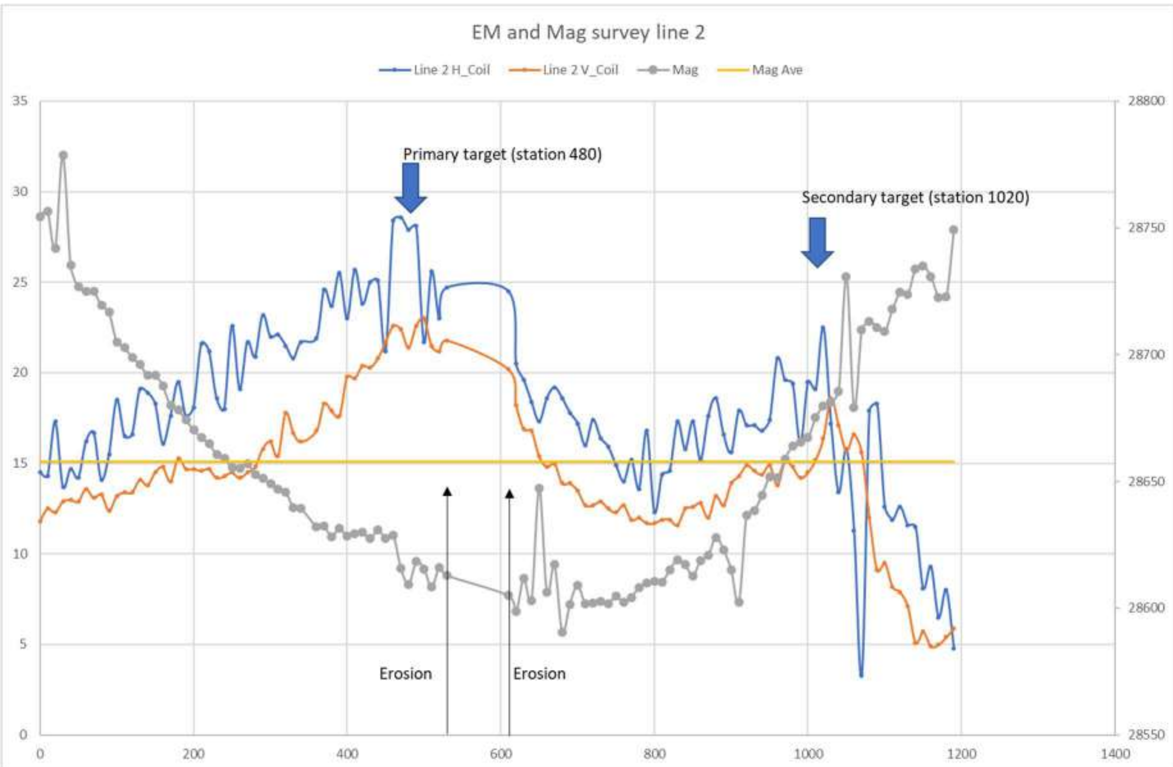


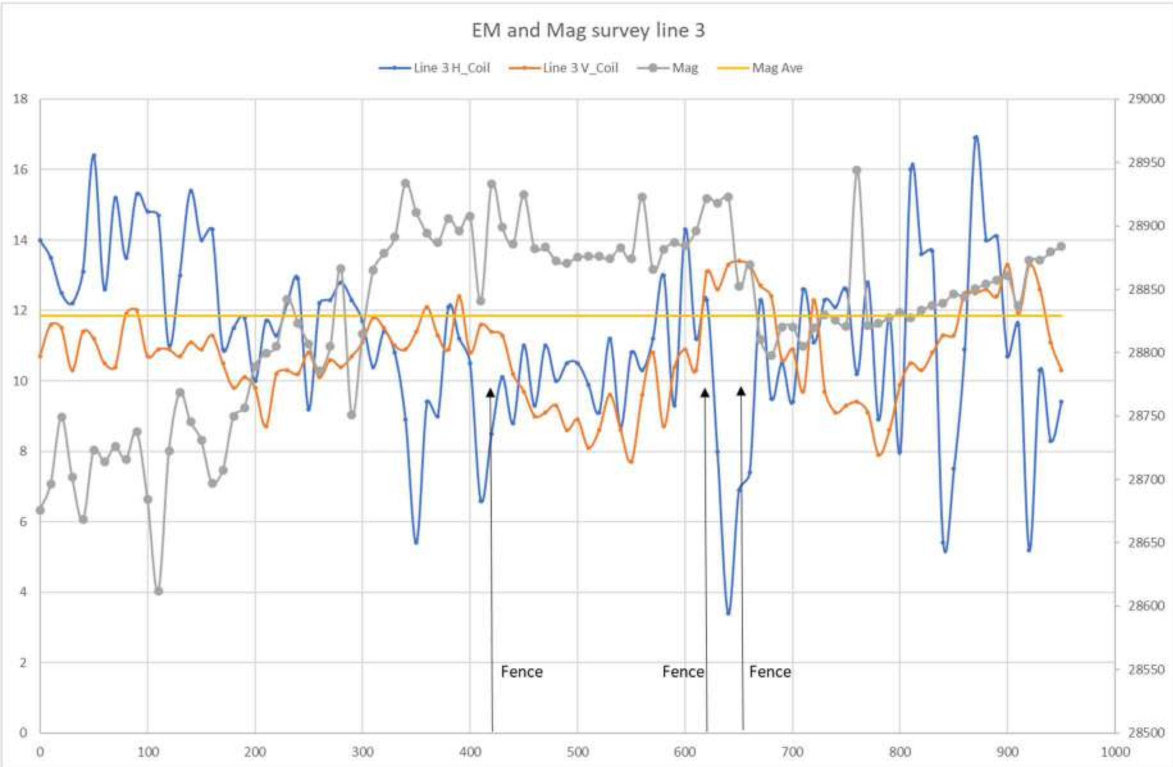
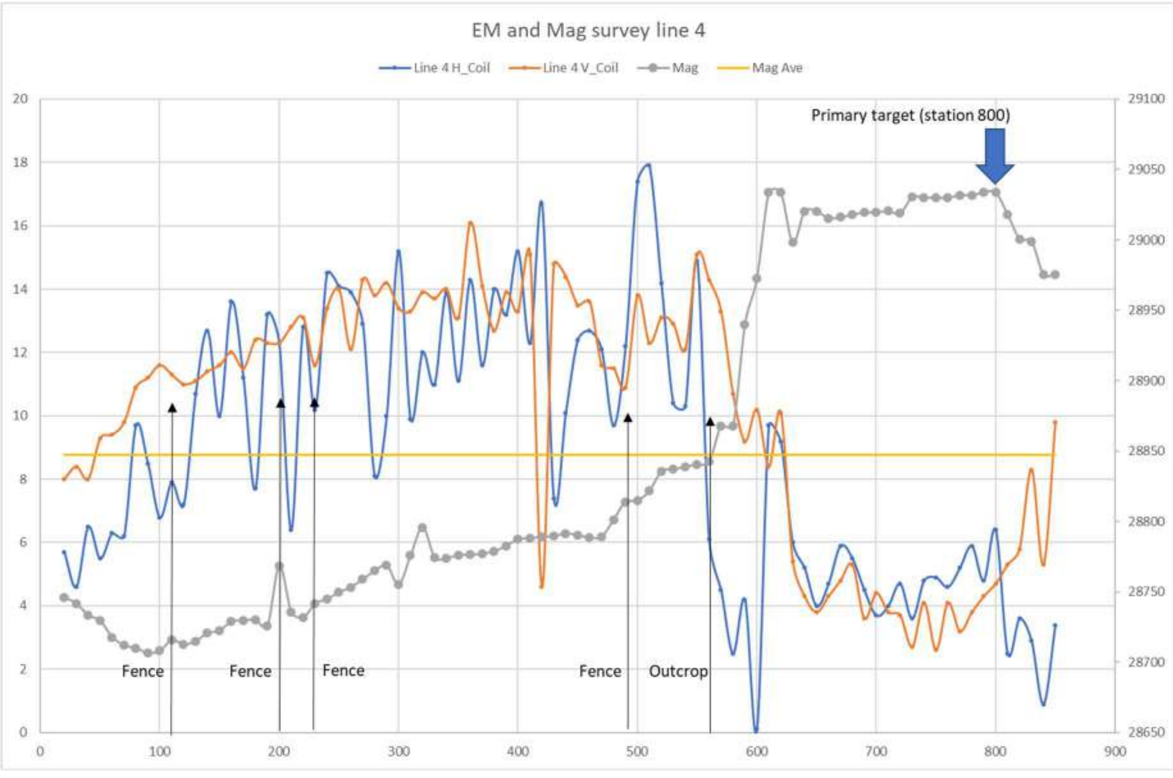
Figure 4-5: Geophysical survey lines and derived drill targets

Line 1

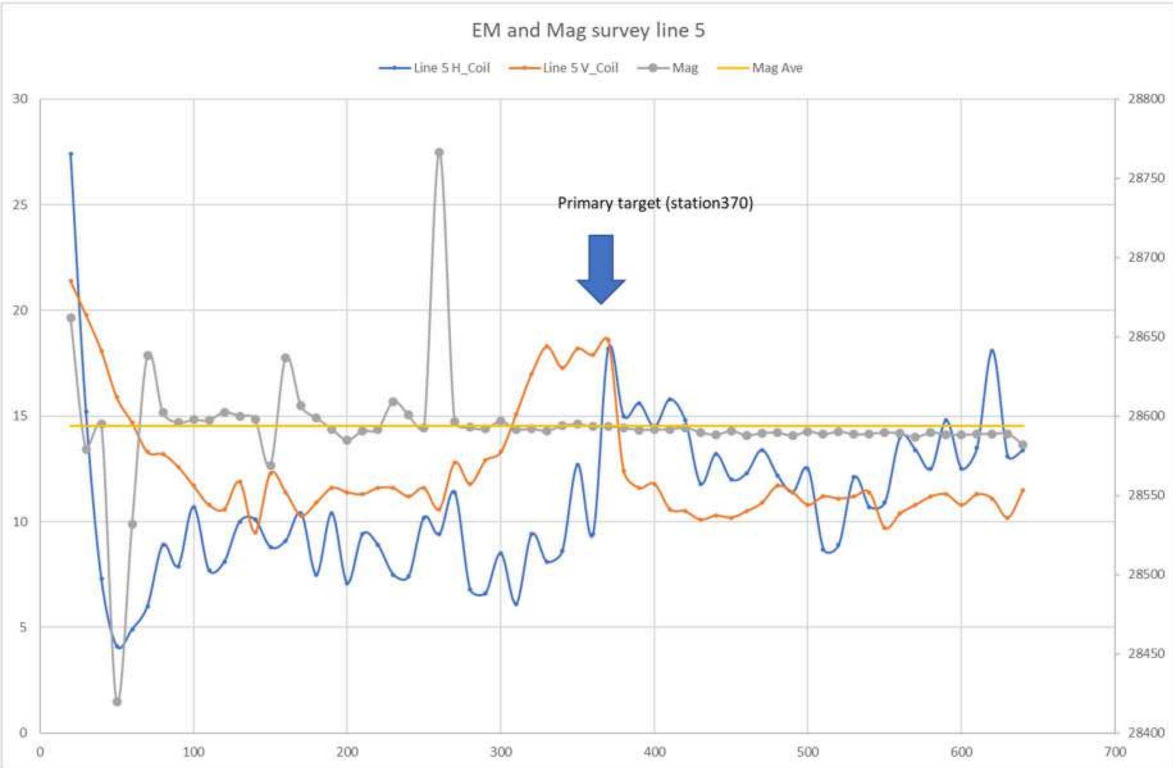

EM and Mag survey line 1
Line 1 H_Coil
Line 1 V_Coil
Mag
Mag Ave
Primary Target (station 540)
Secondary Target (station 790)
Outcrop and dense bush

Line 2

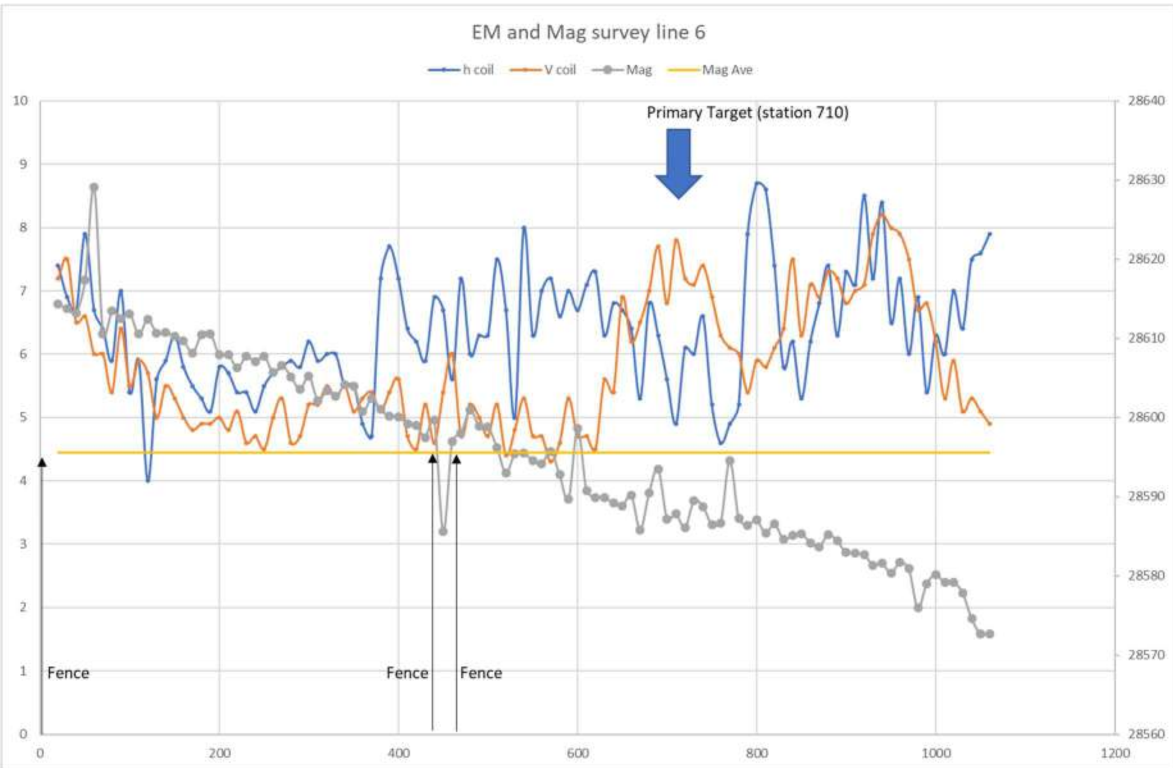

EM and Mag survey line 2
Line 2 H_Coil
Line 2 V_Coil
Mag
Mag Ave
Primary target (station 480)
Secondary target (station 1020)
Erosion
Erosion

Line 3
EM and Mag survey line 3 Line 3 H_Coil Line 3 V_Coil Mag Mag Ave Fence Fence Fence
Line 4
EM and Mag survey line 4 Line 4 H_Coil Line 4 V_Coil Mag Mag Ave Primary target (station 800) Fence Fence Fence Fence Outcrop

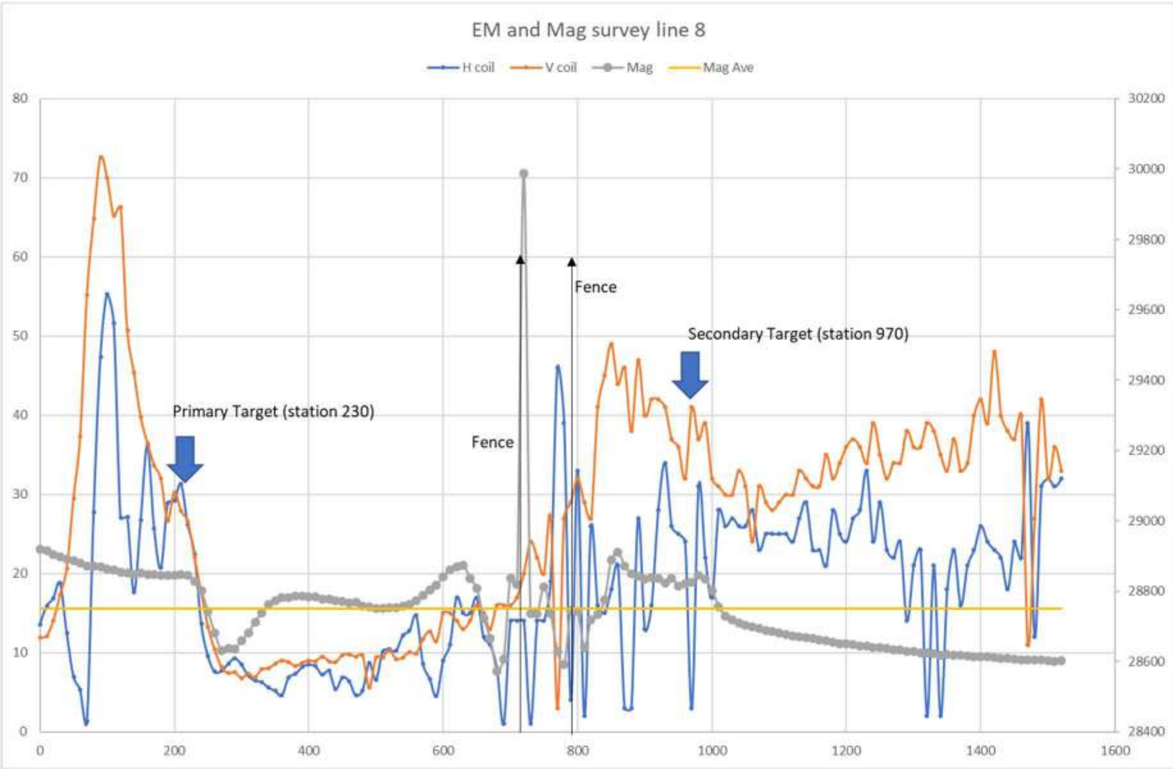
Line 5


EM and Mag survey line 5
Line 5 H_Coil
Line 5 V_Coil
Mag
Mag Ave
Primary target (station370)
30
25
20
15
10
5
0
28800
28750
28700
28650
28600
28550
28500
28450
28400
0
100
200
300
400
500
600
700

Line 6


EM and Mag survey line 6
h coil
V coil
Mag
Mag Ave
Primary Target (station 710)
Fence
Fence
Fence
10
9
8
7
6
5
4
3
2
1
0
28640
28630
28620
28610
28600
28590
28580
28570
28560
0
200
400
600
800
1000
1200

Line 7



Line 8

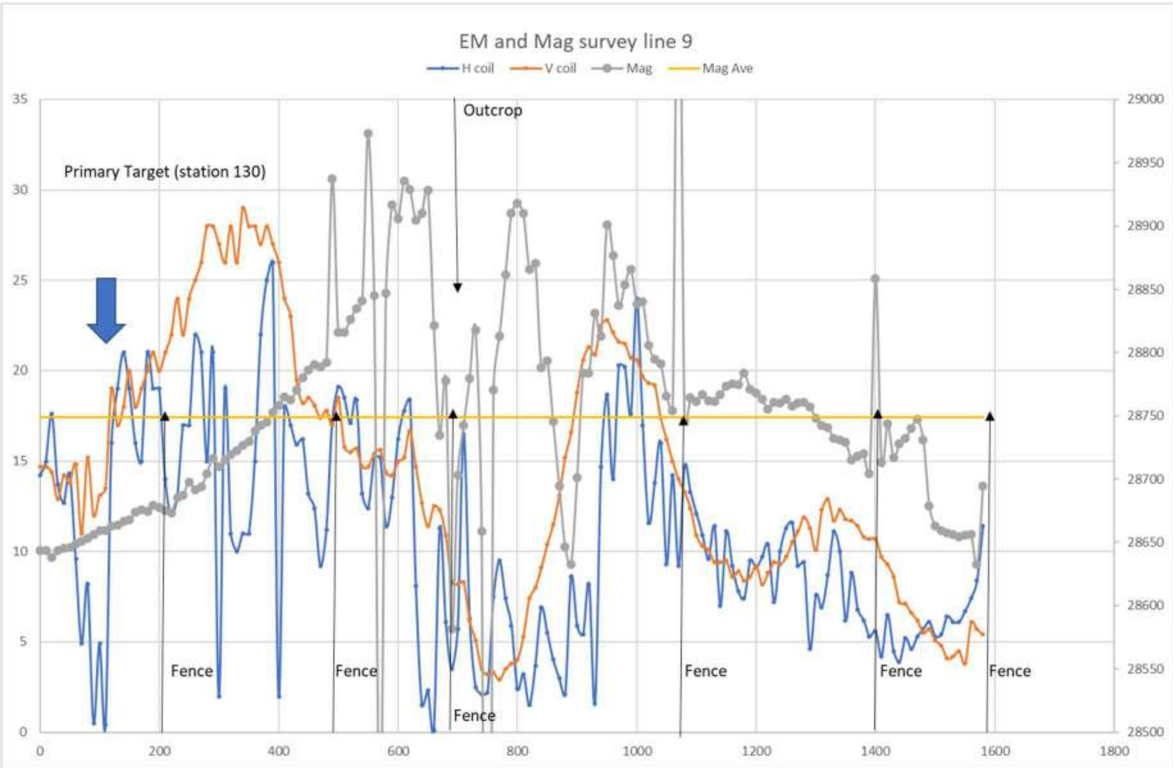


Figure 4-6. Geophysical survey line results

4.4.3 Borehole Drilling

The drilling of seven aquifer test boreholes was carried out between the 9th and 17th of August 2019. The boreholes were drilled to depths between 36 and 49 mbgl. The boreholes construction for all seven holes was as follows:

- Percussion drilling at 165 mm (6.5 inch) open hole diameter;
- Installation of temporary mild steel casing to prevent hole collapse;
- Installation of uPVC casing (60% slotted / 40% plain casing);
- Backfill of the annulus with a gravel pack at the height of the slotted casing, bentonite seal on top of the gravel pack and backfill with arisings; and
- Installation of lockable standpipe with concrete plinth.

The boreholes were drilled for the following purposes:

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

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

- Geological information:
  - Lithology – 1 m intervals;
  - Interpreted structure; and
  - Depth and degree of weathering.
- Hydrogeological information:
  - Depth of groundwater strikes and/or seepage; and
  - Air-lift yield.
- Other information:
  - Penetration rate (indication of weathered/competent rock).

The drill locations are shown on Figure 4-5 and the borehole logs are shown in Appendix A. The main findings of the logging are summarised below, with a summary of the intersected lithology and hydrogeological characteristics summarised in Table 4-2. The monitoring boreholes were given a code related to the Project Name (Dagsoom) and a number corresponding to the target number (i.e. “Target 1” was renamed “DAGBH1”).

4.4.3.1 DAGBH1

Drilled on the 15th of August 2019 at a topographical elevation of 1 568 mamsl. A reddish brown, dry and fine-grained topsoil was encountered between 0-1 meters below ground level (mbgl). This was followed by yellowish brown, coarse-grained, dry, slightly weathered sandstone between 1-4 mbgl with the top layers being more competent, but the lower part of the layer including sub-rounded chips of sandstone. Subsequently light-grey, damp, fresh sandstone was encountered between 4-19 mbgl with a reducing percentage of sub-rounded sandstone chips with depth. Between 19-40 m (end of hole) dark-grey, dry, angular chips of dolerite (~2 cm) were encountered. As the borehole was advanced further down, the penetration rate increased with a highest penetration rate of three minutes towards the end of hole indicating the interception of a competent dolerite sill.

4.4.3.2 DAGBH2

Drilled on the 16th of August 2019 with a final depth of 49 mbgl. A reddish-brown fine-grained topsoil was encountered between 0-1 mbgl followed by a yellowish brown, damp and coarse to medium grained weathered sandstone encountered between 1-4 mbgl. The weathered sandstone comprises of sub-rounded chips of the sandstone with some quartz grains. Greyish brown, dry mudstone with small coal chips of 0.5 cm followed between 4-5 mbgl. A coal seam 1 m in thickness was encountered between 5-6 mbgl which is black, dry with chips of coal.

Fresh sandstone, light-grey, dry and medium grained with the presence of small amount of coal chips of less than half a centimetre but predominantly powder was encountered between 8-14 mbgl. Dark-grey, dry with sub-rounded chips of carbonaceous shale of ~1 cm was encountered between 14-18 mbgl. A fine-grained light-grey siltstone was also encountered between 18-19 mbgl, followed by light-grey, dry and coarse-grained fresh sandstone between 20-27 mbgl with some sub-rounded shale chips observed at the bottom of the sandstone layer. Dark-grey, damp, sub-rounded chips of carbonaceous shale encountered between 27-32 mbgl. Light grey, dry and fine-grained siltstone was encountered between 32-37 mbgl. The lithology encountered from 37 mbgl to the end of hole (49 mbgl) was mudstone with colour changing from medium grey to reddish-brown with depth. A water strike was intercepted at 46 mbgl.

4.4.3.3 DAGBH3

Drilled on the 16th August 2019 at a depth of 43 mbgl. Brown, dry and fine-grained topsoil as encountered between 0-1mbgl. This was followed by a yellowish brown, dry, medium-grained, weathered sandstone layer between 1-4 mbgl with some intercalations of coal and mudstone toward the bottom of this layer. Mudstone was also encountered between 4-6 mbgl. Light-grey, dry, fresh, coarse to medium grained sandstone was encountered between 6-13 mbgl with coarser sandstone encountered at the top of this layer and more medium grained sandstone observed towards the bottom of this layer. As drilling continued a light brown, dry and fine-grained mudstone was encountered between 13-19 mbgl becoming more light-grey in colour with depth. A light-grey, dry, medium grained sandstone was encountered between 19-24 mbgl. Dark-grey to black carbonaceous shale was encountered between 24 -29 mbgl with a coal seam of less than 0.5 m thick. Fresh, light-grey, dry, medium-grained sandstone was then intercepted between 29-43 mbgl.

4.4.3.4 DAGBH4

DAGBH4 was drilled on the 9th of August 2019 with a final depth of 35 mbgl. Brown, dry, fine grained mudstone was the first lithology encountered between 0-3 mbgl. Yellowish brown, dry, coarse- to medium-grained weathered sandstone with some sub-rounded quartz grains <0.25 cm was encountered between 3-4 mbgl. Dark brown, dry mudstone was encountered between 4-6 mbgl. Medium-grained, dry, weathered sandstone was encountered between 6-8 mbgl followed by light-grey, dry, medium grained, fresh, sandstone between 8-25 mbgl. Dark-grey to black, dry, fine grained dolerite was encountered between 25-35 mbgl, with angular chips of ~0.5 cm increasing in size with depth. The penetration rate increased with drilling depth up to two minutes at 35 mbgl. The hole was not cased as no coal layers or water strikes were intersected.

4.4.3.5 DAGBH5

Drilled on the 10th of August 2019, with an elevation of 1517 mamsl with a depth of 45 m. From 0-1mbgl, a reddish brown, dry and fine-grained top soil was encountered. This was followed by a highly weathered coarse sandstone that was yellowish brown with sub-rounded chips of plagioclase and quartz and wet at 1-10mbgl. There is a decrease in the number and size of the chips and the depth increases. The sandstone was coarse between 1-5 mbgl and between 5-10 mbgl the sandstone became more medium-grained with the weathering factor still the same. Water strike was encountered at 5 mbgl. A dark grey, wet, fine-grained with sub-rounded chips of carbonaceous shale was observed at 10-13 mbgl. Between 13-16 mbgl, fine grained light-grey and wet powdered siltstone was encountered. A thick sandstone was encountered between from 16-46 mbgl it was light grey, medium to fine grained and wet.

4.4.3.6 DAGBH6

DAGBH6 was drilled on the 10th of August 2019 to a final depth of 45 mbgl. between 0-1 mbgl a brown, dry, fine-grained topsoil was encountered. Yellowish brown, dry, coarse to medium grained, weathered sandstone with sub-rounded chips of sandstone and quartz followed between 1-3 mbgl. Brown, dry and fine-grained mudstone was encountered between 4-6 mbgl with some sub-rounded chips of weathered sandstone. Between 4-6 mbgl a yellowish brown, medium grained, slightly weathered sandstone with some intercalations of mudstone was encountered. Dark-grey, dry, medium-grained carbonaceous shale with sub-rounded chips was encountered between 6-8 mbgl. Light-grey, dry and medium-grained fresh sandstone was encountered between 8-10 mbgl. Dark grey, dry, fine grained carbonaceous shale was again encountered between 10-15 mbgl with drill chips about 0.5 cm in size. Light-grey, dry, medium-grained sandstone with some intercalates shale was encountered between 15-19 mbgl with chips <0.5 cm. A coal seam was intercepted between 19-20 mbgl with a thickness of up to 0.5 m and interlayered with a light-grey, medium grained, fresh sandstone with some shale. Dark-grey, dry, fine grained carbonaceous shale was encountered between 23-29 mbgl which was with chips <1 cm in size. Between 29-45 mbgl light-grey, dry and medium grained sandstone was encountered.

4.4.3.7 DAGBH7

The first borehole drilled on the 8th of August 2019 to a final depth of 42 mbgl. The first lithology encountered between 0-4 mbgl was a brown, damp mudstone. Between 4-6 mbgl fresh, grey, dry sandstone was encountered. A dark-grey, dry, carbonaceous shale was encountered between 9-12 mbgl, with sub-rounded chips <1 cm in size. Black, dry coal was encountered between 9-12 mbgl. Light-grey, dry sandstone was encountered between 17-21 mbgl. A second seam of black, dry coal was encountered between 17-21 mbgl. Light-grey, wet, medium grained sandstone was encountered between 21-42 mbgl. A water strike was intercepted at 23 mbgl with a blow yield of ~2.2 l/s. A static groundwater level was measured at 2.37 mbgl.

Table 4-2. Monitoring / Aquifer Test Borehole Drilling Summary

Borehole ID	Borehole Depth (m)	Water Strike (mbgl)	Static Water Level (mbgl)	Final Blow Yield (L/s)	Lithology summary
DAGBH1	40	-	20.1	n/a	Topsoil, Sandstone, Dolerite
DAGBH2	49	46	13.1	n/a	Topsoil, Sandstone, Mudstone, Coal, Sandstone, Shale, Siltstone, Sandstone, Shale, Siltstone, Mudstone
DAGBH3	43	-	21.0	n/a	Topsoil, Sandstone, Coal, Mudstone, Sandstone, Mudstone, Shale, Sandstone
DAGBH4	35	-	Dry	n/a	Topsoil, Mudstone, Sandstone, Mudstone, Sandstone, Siltstone and Dolerite
DAGBH5	46	5	3.5	<0.5	Topsoil, Sandstone, Shale, Siltstone, Sandstone
DAGBH6	45	-	19.4	<0.5	Topsoil, Sandstone, Mudstone, Sandstone, Shale, Siltstone, Shale, Sandstone, Coal, Sandstone, Shale, Sandstone
DAGBH7	42	23	2.6	2.2	Topsoil, Mudstone, Sandstone, Carbonaceous shale, Sandstone, Coal, Sandstone

4.5 Aquifer Testing

Six boreholes were subjected to pumping tests between the 20th and 26th of August 2019. The aquifer tests consisted of step tests (where possible); constant discharge tests followed by recovery tests. The objectives of the aquifer testing programme included the determination of the response of the aquifer to an imposed stress (pumping), and estimation of the hydraulic parameters, i.e. the transmissivity (T in m^2/d), hydraulic conductivity (k in m/d) and storativity (S) of the aquifer system. The hydrogeological parameters represent an integral component of the impact assessment concerning potential groundwater inflows and sulphate plume migration.

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

- Step testing in four steps with a duration of approximately one hour each (where possible);
- A constant-rate discharge test (where possible); and
- Recovery tests.

Blow yields were generally low and indicated that most boreholes would be low yielding with estimated yield of <0.5 l/s. As such a constant discharge test of 12 hours was only carried out on DAGBH7, which showed an estimate blow yield of 2.2 l/s.

During step testing, one step was achieved for DAGBH03, DAGBH05 and DAGBH06 and two steps were achieved for DAGBH01 and DAGBH02 with pumping yields between 0.1 and 0.34 l/s. This shows an overall low yield of the aquifer based on the general low yields for these boreholes. Four steps were achieved for DAGBH07 with a maximum pumping rate of 3.7 l/s. However, the borehole was over pumped at this rate, and a yield of 1.74 l/s was set for the constant discharge test.

Recovery tests were performed with recovery durations ranging between 90 minutes and 12 hours. The final recovery water level as a percentage of the pre-pumping water level varied between 24 % (very slow recovery) and 100 %. A summary of the test programme is presented in Table 4-3.

4.5.1 Data Interpretation

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

Although the applied methodology for calculating analytical parameters is based on assumptions which may differ from actual site conditions (e.g. infinite areal extent, homogenous and isotropic aquifer conditions, no delayed gravity response of aquifer), the resulting hydraulic parameter from these calculations are representative of the aquifer system in the vicinity of the tested boreholes. A summary of the hydraulic parameters estimated from the aquifer test analysis is provided in Table 4-3.

The aquifer testing yielded similar results for most boreholes, indicating hydraulic conductivity values of between 0.01 and 0.05 m/d, typical for weathered Karoo aquifers. DAGBH07 showed a relatively high sustainable yield (1.7 l/s) and transmissivity between ~3 - 6 m^2/d, likely associated with the alluvial aquifer that is in close proximity to the borehole, allowing for higher groundwater flow rates.

4.5.2 Groundwater Use

Refer to a summary of locations identified during the hydrocensus in Table 4-4 and Figure 4-7. The following conclusions were drawn from the hydrocensus:

- The main source of drinking water supply in and around the proposed mining area is community hand pumps supplemented by a number of springs which are mainly used for domestic use and livestock watering (Table 4-4);
- The pH values (Field parameters) measured during the survey varied from 5.9 at Zwartwater spring (ZW-Spring) to 9.8 at BABH1 with an average pH of 7.2. A pH between 5.9 and 9.8 is indicative of a slightly acidic to alkaline waters. Conductivity values varied from 44.1 µS/m at ZW-Spring to 1 219 µS/m at BABH1 and thus, indicative of moderate low to slightly high conductivity (saline water) values (Table 4-5);
- Groundwater level elevations were measured at three boreholes only (Table 4-6) as most of the boreholes were equipped with hand pumps. Based on the three measurements depth-to-groundwater ranges between 11 and 19 mbgl (average of 14 mbgl), with groundwater level elevations ranging between 1 662.6 mamsl at WBH1 and 1 591.2 mamsl at EBH1;
- The groundwater level elevations indicate a general west-northwest to southeast groundwater gradient for the site. This seems to suggest that groundwater flow directions follow general topography and drainage directions; and
- The areas that have no sampling points show no evidence of any residents and/or have no boreholes that are in use.

Table 4-3. Aquifer Test Results

BH ID	Depth (mbgl)*	Pump Depth (mbgl)	SWL (mbgl)	Available Draw-down (m)	Pump yield (L/s)	Total Draw-down (m)	Test duration (min)	Recovery time	Recovery %	Transmissivity (m^2/day)					Hydraulic Conduc-tivity (m/day)
								(min)		Cooper-Jacob - early T	Cooper-Jacob - late T	Theis	Theis Recovery	Average	
DAGBH01	39	37.4	20.14	17.26	0.12-0.28	17.26	110	110	100%	2.84	0.25	0.39	0.16	0.91	0.05
DAGBH02	49	28.4	13.31	15.09	0.18-0.26	14.94	180	185	96%	3.37	0.23	0.47	0.30	1.09	0.03
DAGBH03	39.2	37.4	21	16.4	0.01-0.16	16.4	30	445	24%	1.57	0.18	0.17	-	0.64	0.04
DAGBH05	49	40.5	3.51	36.99	0.17-0.36	22.98	90	210	100%	1.38	0.10	0.13	0.14	0.44	0.01
DAGBH06	36.3	35.4	19.4	16	0.06-0.17	15.87	20	200	66%	1.12	0.26	0.14	0.13	0.41	0.02
DAGBH07	42.7	37.5	3.4	34.1	1.7	20.6	720	1440	76%	6.17	5.26	4.29	3.37	4.77	0.12
Average														**1.38**	**0.04**
Geometric														**0.90**	**0.03**
Harmonic														**0.71**	**0.03**

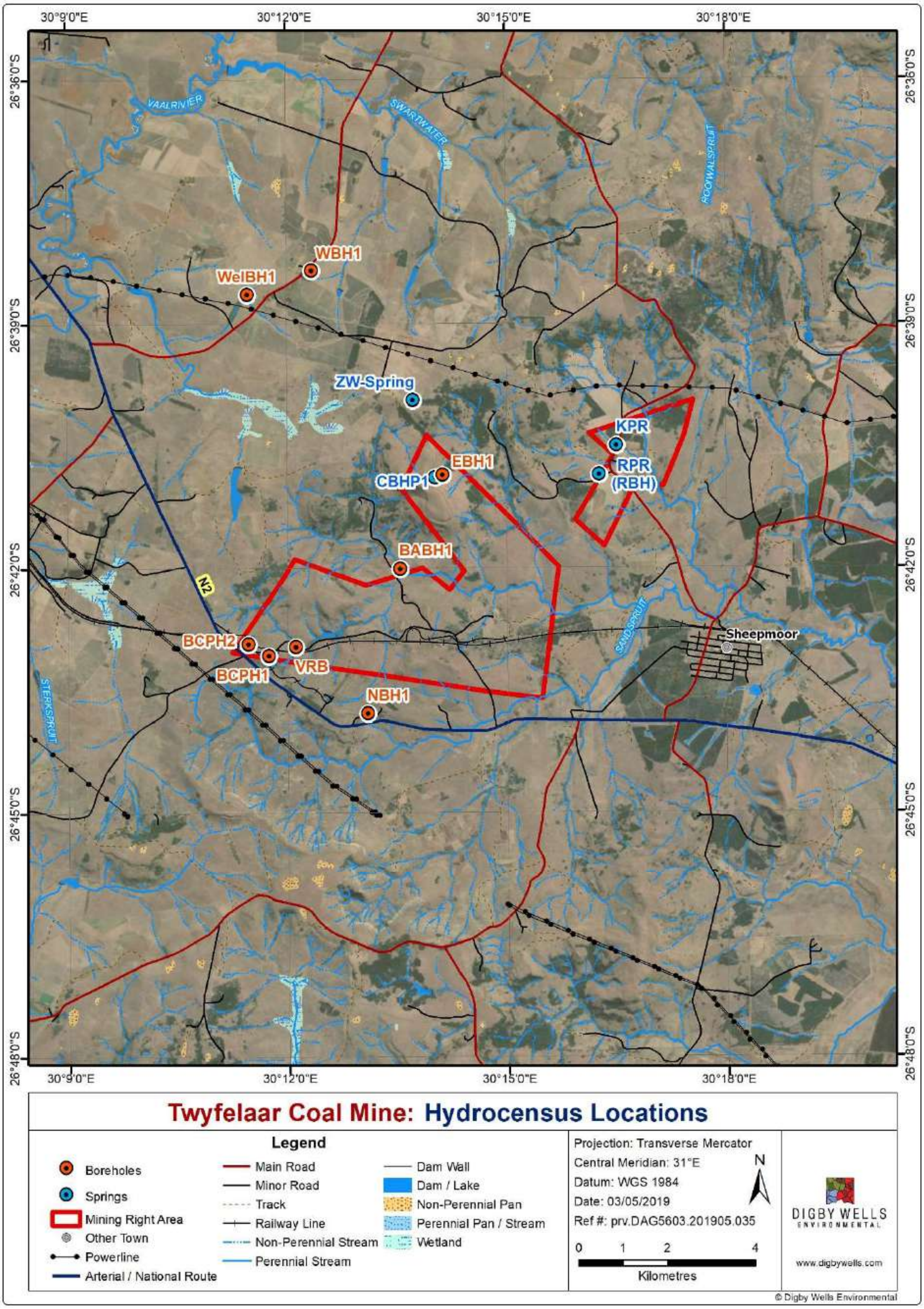


Figure 4-7: Hydrocensus Map

Table 4-4: Identified boreholes, spring and dug wells during the hydrocensus

Name	X	Y	Status	Comment
BABH1	30.225787	-26.70028	Sampled	Artesian well at Bambanani II in Masina farm. The borehole was drilled as part of exploration. According to the residents the water has a salty taste, however it’s still being used for domestic purposes.
BCPH1	30.195737	-26.718042	Sampled	Water supply borehole at Bambanani CPA (communal farm). The borehole has a hand pump installed. According to the residents is that the water level is deep as they have pump for longer periods before water comes out of the borehole
BCPH2	30.191087	-26.715635	Sampled	Not functioning water supply borehole. The windmill is broken and prior being broken the borehole ran dry after Transnet drilled their water supply borehole a couple of meters from the borehole
CBP1	30.233784	-26.681652	Sampled	Spring from the proposed mining area (Phakamani, Twyfelaar)
EBH1	30.235469	-26.681075	Sampled	Exploration borehole at Twyfelaar. The water is slightly brown
KPR	30.275106	-26.675079	Sampled	A drinking water supply spring at Nick Vorster and Seuns farm
NBH1	30.218195	-26.729878	Sampled	Water supply borehole at Nhlapho`s farm. The borehole has a hand pump installed
RPR (RBH)	30.271108	-26.681063	Sampled	A Spring used for domestic uses.
VRB	30.201895	-26.716252	Sampled	River entering the Project Area.
WelBH1	30.191154	-26.644074	Sampled	A wind pump at Weltevreden farm. The pump water into the nearby dam
WBH1	30.205812	-26.639166	Sampled	Livestock and possible irrigation (gardening) borehole at Weltevreden farm. The borehole has a pump installed
ZW-Spring	30.228773	-26.665794	Sampled	A Spring used for domestic and livestock watering purposes at Manzimnyama (Thandukhanya CPA, previously Zwartwater))

Table 4-5: Field parameters

Sample ID	pH	EC µS/m	TDS mg/l	Temperature ◦C
BABH1	9.81	1219	851	21
BCBH1	6.89	176.5	121.3	21.2
BCBH2	6.34	164.2	111.9	24.3
CBP1	9.5	176.4	122.7	27
EBH1	7.05	268	184	25
KPR	6.21	841	585	21.4
NBH1	6.84	283	189	21.9
RBH (RPR))	6.6	871	608	20.3
WelBH1	6.84	254	175	19.6
WBH1	7.26	169.3	116.9	20.5
ZW-Spring	5.93	44.1	32.9	20.8

4.5.3 Groundwater Levels

Groundwater level measurements were taken at three Hydrocensus boreholes, six monitoring boreholes and one spring. The groundwater level ranged between 2.6 mbgl at BH7 and 28.6 mbgl at BH1 (Table 4-6).

This indicates that in general groundwater levels are relatively shallow, mostly less than ~20 mbgl near the site and mainly located within the shallow weathered aquifer. Groundwater levels were compared to surface elevations and a good correlation between surface elevation and groundwater level was found with a correlation coefficient of 0.98, indicating groundwater flow directions will mainly follow topography and the main surface water drainage directions (Figure 4-8). For the Project Area, this indicates the main groundwater flow direction will be to the southeast towards the Nkomati River.

Due to the elevated nature of the area surrounding Block A and relatively deeper groundwater levels (~10 mbgl) on the slopes of the hill, it appears that limited connection exists between the streams originating at the base of the sill cap and groundwater levels in the Karoo lithologies. It is therefore assumed that streams with associated wetlands present on the hillslopes are fed from a perched aquifer in the dolerite sill.

Table 4-6: Groundwater level elevation

Name	Elevation (mamsl)	Water level depth (mbgl)	Water level elevation (mamsl)
BCPH2	1661.8	10.6	1651.2
EBH1	1611.0	11.7	1599.2
WBH1	1691.3	19.4	1671.9
DAGBH01	1568.7	20.1	1548.5
DAGBH02	1595.2	13.1	1582.0
DAGBH03	1559.6	21	1538.6
DAGBH05	1506.9	3.5	1503.4
DAGBH06	1524.5	19.4	1505.1
DAGBH07	1501.5	2.6	1498.9
ZW-Spring	1721.6	-	1721.6

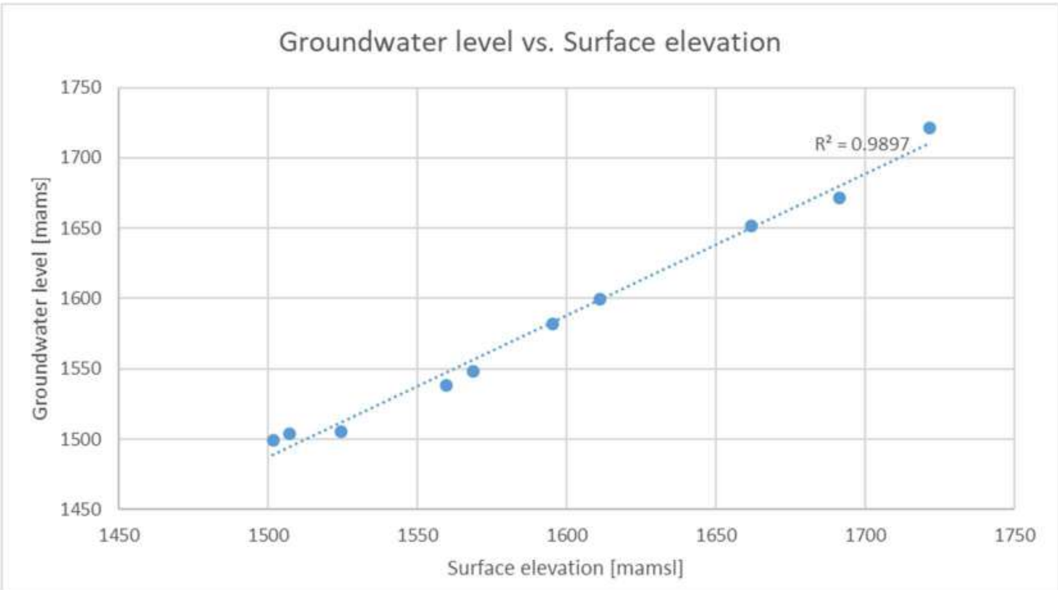


Figure 4-8: Bayesian correlation between surface elevation and groundwater level.

4.5.4 Groundwater Quality

The water quality results for the tested Hydrocensus sites and the monitoring boreholes are shown in Table 4-7. These results form the baseline water quality data for the groundwater assessment. A total of four Hydrocensus samples (BABH1, CBP1, EBH1, and ZW-Spring) were sent for lab analysis in March 2019 and another six monitoring borehole samples were sent in August 2019. Based on the water quality results, the following summary can be made for the baseline water quality:

- The groundwater types found were a mixture of mainly calcium bicarbonate (Ca-HCO_3), magnesium bicarbonate (Mg-HCO_3), sodium bicarbonate (Na-HCO_3) with one sample showing a magnesium sulphate (Mg-SO_4) type groundwater. These water types are typical for the Vryheid Formation. Bicarbonate being the dominant cation could indicate general flowing as opposed to stagnant groundwater;
- The Ca-HCO_3 and Mg-HCO_3-type waters are indicative of recently recharged groundwater with low residence time, mostly representative for the shallow weathered aquifer. Spring CPB1 and exploration borehole EBH1 are near each other and show a similar, Ca-Mg-HCO3-type groundwater, as do monitoring boreholes DAGBH05, DAGBH06 and DAGBH07;
- The Na-HCO_3 type water is likely to be related to the deeper, fractured aquifer though which water flow is more restricted to fracture zones and flows at a slower rate though the rock matrix where ion exchange through water-rock interaction is allowed to take place. The sample taken from artesian borehole BABH1 showed a very strong Na-HCO_3 characteristic, of which residents noted the water was salty in taste. The sample from ZW-Spring also has a Na-HCO_3 signature, as do monitoring boreholes DAGBH01, DAGBH02 and DAGBH03;
- The dominant sulphate cation in DAGBH08 is likely related to the coal seams or carbonaceous shale layers that are present in the Vryheid Formation by solution of pyrite;
- The 10 water samples taken showed the groundwater in the area to be of good quality. Parameters exceeding the limits as per the South African National Standards (SANS) for drinking water and World Health Organisation (WHO) guidelines was mainly aluminium (Al) in three boreholes and a high pH in one borehole. Aluminium forms part of clay minerals and the elevated concentrations could be derived from interaction of water with shale lithologies; and
- Selected metals were also analysed for but were all found to be in concentrations below their respective detection limits.

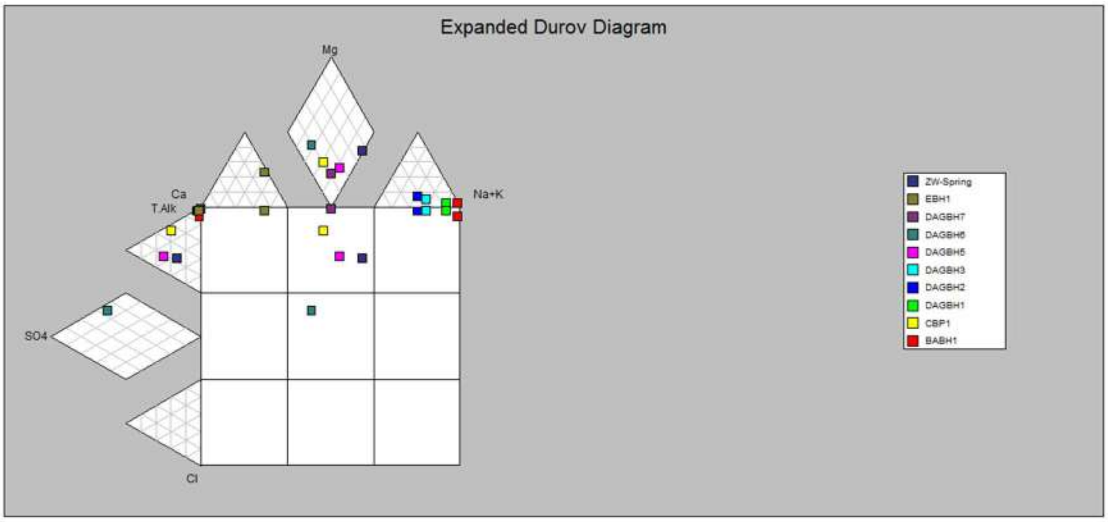


Figure 4-9: Expanded Durov Diagram

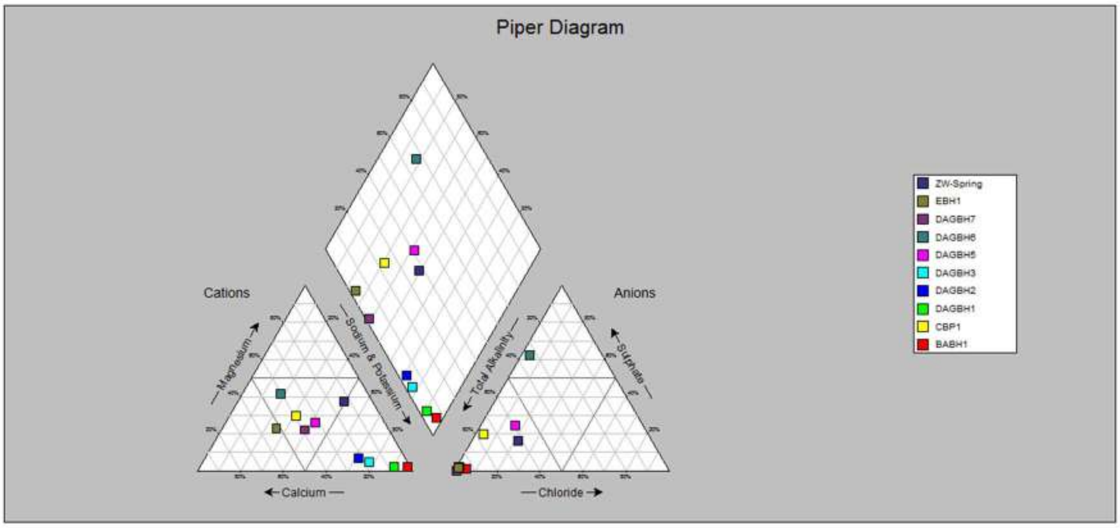


Figure 4-10: Piper Diagram

Table 4-7: Baseline groundwater quality analysis

Site Name	Date Measured	pH	TDS mg/l	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	Cl mg/l	SO_4 mg/l	F mg/l	Al mg/l	Fe mg/l	Mn mg/l
WHO Drinking Standards		6.5-9	600	300	NS	200	NS	250	250	1.5	0.1	2	0.4
SANS 241-1:2015		5-9.5	2400	NS	NS	200	NS	300	500	1.5	0.3	2	0.4
BABH1	2019/03/25	9.70	386	0.77	1.00	89.17	0.67	8.00	2.00			1.20	
CBP1	2019/03/25	8.80	108	10.80	4.89	9.37	0.91	<2.00	13.00			0.20	
EBH1	2019/03/25	7.10	208	31.15	8.38	15.96	2.92	<2.00	2.00			0.30	
ZW-Spring	2019/03/25	6.00	28	0.57	1.00	1.80	1.21	<2.00	2.00			<0.20	
DAGBH1	2019/08/29	7.70	224	4.40	0.81	62.00	2.77	<2.00	<4.00	0.20	0.43	0.54	0.02
DAGBH2	2019/08/29	6.80	240	13.30	2.54	50.00	2.40	<2.00	<4.00	0.50	1.03	0.57	0.15
DAGBH3	2019/08/29	7.60	284	11.70	1.96	57.00	4.44	2.03	<4.00	0.30	0.25	0.06	0.03
DAGBH5	2019/08/29	6.60	40	2.50	1.23	2.15	2.78	<2.00	<4.00	<0.10	0.29	0.05	0.03
DAGBH6	2019/08/29	6.90	348	33.90	21.00	14.34	5.62	6.50	119	0.20	<0.02	0.01	0.15
DAGBH7	2019/08/29	7.50	288	37.60	12.89	42.00	2.41	2.84	0.20	0.50	0.03	0.00	0.23

**NS – Not specified*

*

* Exceeding WHO drinking water guideline

* Exceeding SANS drinking water standard

* Exceeding SANS and WHO drinking water standards/guidelines

5 Geochemical Assessment and Waste Classification

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

5.1 Mineralogy and Acid Mine Drainage

Waste rock material samples were taken from floor and roof lithologies from exploration borehole cores, and coal material was collected from the main coal seam to be mined (C-lower) to determine minerology and potential for Acid Mine Drainage (AMD) as a result of the Project proceeding. The results are summarised in Table 5-1.

The mineralogy of the waste rock samples (based in the XRD results) indicate these are dominated mainly by kaolinite (between ~34.5 and 48.2 weight percentage %) and quartz (between 25 and 34 wt. %) with minor microcline, chlorite, diopside and muscovite minerals. Presence of neutralising potential mineral calcite was detected in sample DSD5-DSD6 while diopside was detected in in sample DSD1-DSD3. Based on the XRD results, there is no indication of sulphide minerals, however, soils and sediments may contain high levels of reduced inorganic sulphur. This may accumulate and lead to saline and sulphate rich water. The elemental composition (XRF) data corelates with the XRD data with the first example that both methods detect the presence of clay minerals such as kaolinite which contains aluminium, and subsequently the results indicate a high Aluminium Oxide (Al_2O_3) content. A minor Iron Oxide (Fe_2O_3) content was also detected in support of the presence of biotite and chlorite minerals. A high Silicon Oxide (SiO_2) content was detected as expected, as this forms part of all the minerals except calcite. The mentioned mineralogy is typical of the geology of the Vryheid Formation with sedimentary sequences of siltstone, sandstone, carbonaceous shale and mudstone dominating the area.

The XRD results for the two coal samples show the samples comprise predominantly of amorphous minerals which in the case of these samples will be the coal or carbon material that was lost on ignition during the test work. The presence of pyrite in sample DCS1 was detected at 1.8 %. This is above 0.3% indicating this sample could be potentially acid generating. There is also some neutralising potential in both samples in the form of mineral calcite, but sample DSC2 has the highest neutralising potential with a calcite content of 13.8%.

Table 5-1: XRD results for waste rock and coal materials

Mineral composition per sample (%)								
Mineral	**DSD1**	**DSD2**	**DSD3**	**DSD4**	**DSD5**	**DSD6**	**DSC1**	**DSC2**
Biotite	-	-	-	3.9	4.64	1.43		
Calcite	-	-	-	0.97	1.72	0.79	2.00	13.98
Chlorite	3.41	5.01	4.12	7.61	7.26	6.86		
Diopside	2.94	3.48	3.36	-	-	-		
Kaolinite	46.68	48.21	41.91	37.4	34.53	40.41	6.89	12.68
Microcline	10.74	9.29	11.4	9.56	10.32	7.09		
Muscovite	8.07	8.92	9.14	10.7	7.49	10.2	3.61	8.79
Quartz	28.16	25.09	30.07	29.86	34.04	30.09	2.82	22.61
Amorphous	-	-	-	-	-	-	80.05	34.9
Anatase	-	-	-	-	-	-	1.18	1.44
Plagioclase	-	-	-	-	-	-	1.65	5.6
Pyrite	-	-	-	-	-	-	1.8	-

The AMD potential of materials is determined by assessing the Acid Potential (AP), Neutralising Potential (NP) and the relationship between these two reactions by calculating the net neutralising potential (NNP = NP - AP) and Neutralising Potential Ratio (NPR = NP/AP). The above reactions and potentials are driven by the mineralogy of the materials. Certain minerals are acid buffering/neutralising and others such as pyrite are acid producing. Sulphide content is the main driver of acid production and AMD under aerobic conditions and that is why the Sulphide-Sulphur (SS) content of material is also assessed. The test work with the main parameters and results are shown in Table 5-2.

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

The XRD and XRF results indicate relatively neutral mineralogy. However, the ABA, NAG and sulphur speciation results indicate all waste rock samples to be Potentially Acid Generating (PAF). However, the coal samples results indicate a significant variability for the coal materials, with one sample (DSC1) being PAG while DSC2 is more Non-Acid Forming (NAF).

Based on this, coal sample DSC2 has no AMD potential while the waste rock materials and coal sample DSC1 are all potentially acid generating with a negative NP (Figure 5-1).

Table 5-2: ABA and Sulphur Speciation Results

Sample ID	NAG pH	Net Neutralization Potential (NNP) = NP – AP (kg CaCO3/t)	Neutralising Potential Ratio (NPR) (NP: AP)	Total Sulphur (%) (LECO)	Sulphate (SO_4^{2-}) Sulphur (%)	Sulphide-(S^{2-}) Sulphur (%)	Acid Generating Potential
DSD1	3.80	-12.20	0.53	0.83	0.02	0.81	PAF
DSD2	3.20	-16.13	0.23	0.68	0.01	0.68	PAF
DSD3	7.20	-11.40	0.58	0.86	0.04	0.82	PAF
DSD4	3.90	-7.10	0.74	0.87	0.03	0.83	PAF
DSD5	6.00	-6.40	0.72	0.75	0.01	0.75	PAF
DSD6	6.20	-6.40	0.72	0.73	0.01	0.72	PAF
DSC1	2.2	-33.4	0.42	1.84	0.08	1.82	PAF
DSC2	6.9	189	8.99	0.76	<0.01	0.76	NAF

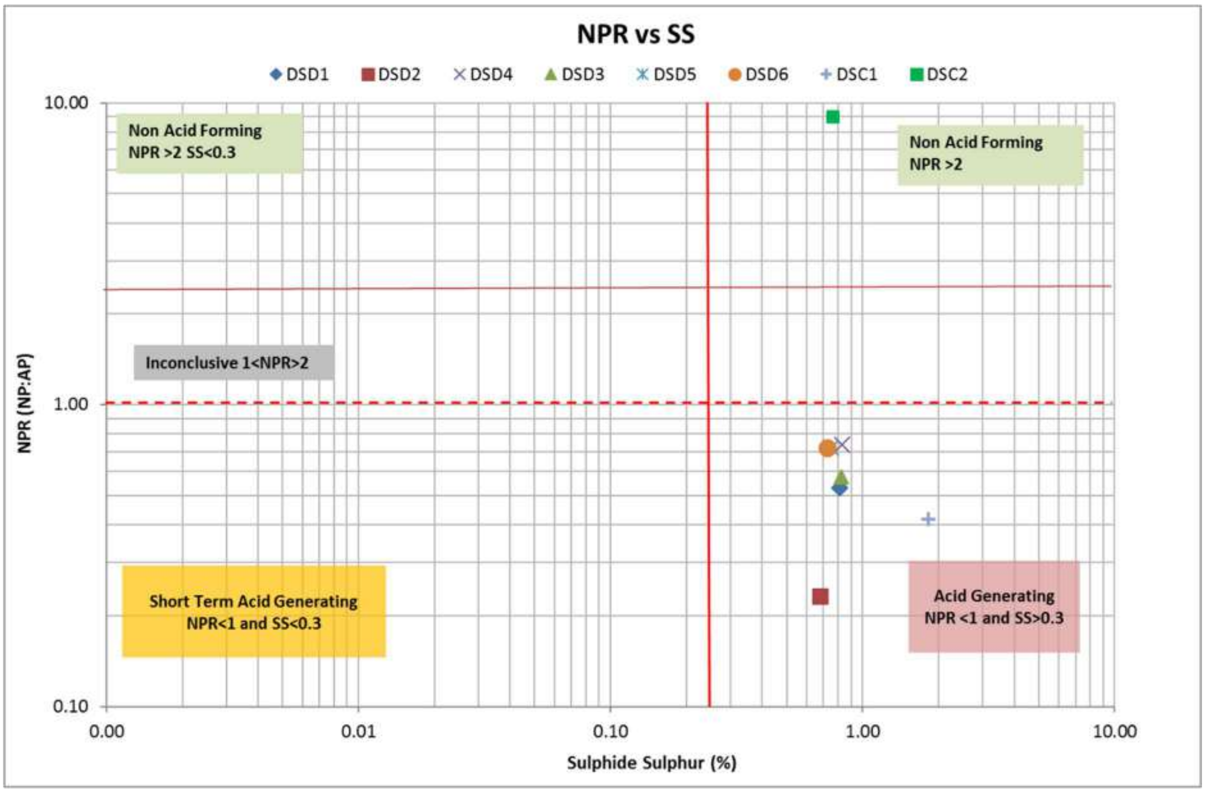


Figure 5-1: Waste rock and coal material AMD – NPR vs SS%

5.2 Waste Classification

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

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

The coal and waste rock materials that were tested are classified as a Type 3 waste and need to be disposed at a Class C landfill site or a facility with a similarly performing liner system. Figure 5-2 shows a conceptual design for a Class C liner as an example. The Type 3 waste classification is only due to the leachate concentration results being above the LCT0 guideline values. LCT0 values are derived from human health effect values for drinking water, as published by the Department of Water and Sanitation (DWS), South African National Standards (SANS), World Health Organization (WHO) or the United States Environmental Protection Agency (USEPA). According to the test methodologies followed and the results of the leachable concentrations, the risk of elements leaching into the receiving environment from the Class C waste facility is low.

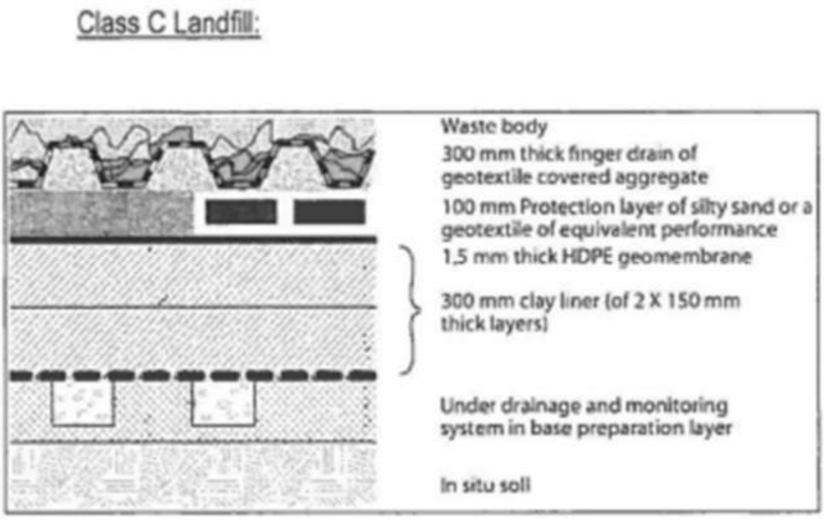


Figure 5-2: Class C liner conceptual design

6 Site Conceptual Hydrogeological Model

The conceptual model describes the hydrogeological environment and is used to design and construct the numerical model to represent simplified, but relevant conditions of the groundwater system. The conditions were chosen in view of the specific objective of the modelling for the Project, including underground mining of Block A and the placement of a coal discard dump. The conceptual model is based on the source-pathway-receptor principle. From the baseline assessment and available data (Section 4), the following conceptual model was derived.

6.1 Aquifers

The following aquifer units were discerned in the conceptual model: shallow weathered and fractured rock aquifer units in the Karoo sedimentary lithologies, and a perched aquifer in the dolerite sill cap on the hill above Block A.

The weathered aquifer units are mainly the sandstone, siltstone and shale of the Vryheid Formation and weathered dolerite sills. At the site the weathered rocks are overlain by a thin layer of in-situ formed soil, with the Mispah and Glenrosa soil forms dominant due to the shallow depth.

In some areas dolerite sills act as caps, preventing weathering of the underlying Vryheid Formation, such as at the site where the proposed Block A is situated. Where these caps are present, perched aquifers can form in the dolerite sills with limited connection to the aquifers in the Vryheid formation.

The weathered zone is expected to be between 5-10 mbgl overlying the fractured rock formations based on the logs for the monitoring boreholes drilling localities. The weathered zone hydraulic conductivity is in the range of 10^{-2} m/d with exception of the conductivity for the alluvium, which will likely be in the range of 10^{-1} m/d.

The fractured rock unit mainly consists of the fractured Vryheid Formation with basement granite present in the easternmost part of the model. As it is expected that fracture frequency decreases with depth, the fractured unit is subdivided in an upper, highly fractured zone and a lower, low fractured zone. The highly fractured zone depth is in line with the water strike depths as observed in the monitoring/aquifer test boreholes and was assumed to have a depth of 30 mbgl based on the water strike information.

Hydraulic conductivities for the highly fractured zone are in the range of 10^{-2}-10^{-3} m/d, with hydraulic conductivities the low fractured units likely in the range of 10^{-4} m/d. Linear structures were indicated on the regional geological map with a south-southwest to north-northeast orientation, however, DAGBH03, targeting one of the lineaments did not show an increase in hydraulic conductivity.

6.2 Groundwater Recharge

Recharge values for Karoo lithologies are generally low, between 1-5% of MAP. Due to the higher resistance to weathering of dolerite sills when compared to the sandstone, mud/siltstone and shale of the Vryheid Formation it is expected that the recharge to dolerite sills is less than 1% of MAP.

6.3 Groundwater Levels

Groundwater levels are shallow and mainly located within the shallow weathered aquifer. Groundwater levels mainly follow topography and the main surface water drainage directions which are towards the Nkomati River southwest of the site.

6.4 Sources, Pathways and Receptors

The following sources, pathways and receptors were discerned:

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

7 Numerical Modelling

7.1 Model Setup

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

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

7.2 Model Domain

The model domain (Figure 7-1) is irregularly shaped with dimensions of 12 km by 16 km. A rectangular mesh was generated for the model domain, consisting of 476 rows and 695 columns. The mesh was refined in the model domain to cell sizes of 25 m by 25 m in the area surrounding the Project Area, with cells gradually coarser further away from the mining area (resulting in a total of 2,550,493 active cells for eleven model layers). Although a smaller grid size may result in a prolonged model render, it was important to refine the model close to the Project Area to properly delineate geological units and to calculate the groundwater gradient and pollution plumes more accurately in the direct vicinity of the proposed activities.

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

7.3 Boundary Conditions

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

a. specified head or Dirichlet; or

b. specified flux or Neumann; or

c. mixed or Cauchy boundary conditions.

Local hydraulic boundaries were identified for model boundaries. They were represented by local perennial and non-perennial water courses and topographical highs and delineated the entire model domain. These hydraulic boundaries were selected far enough from the area of investigation to not influence the numerical model behaviour in an artificial manner. The model boundaries and model grid are shown in Figure 7-1. Table 7-1 provides a summary of the boundaries, boundary descriptions and boundary conditions specified in the hydrogeological model.

Table 7-1: Identification of real-world boundaries and adopted model boundary conditions.

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

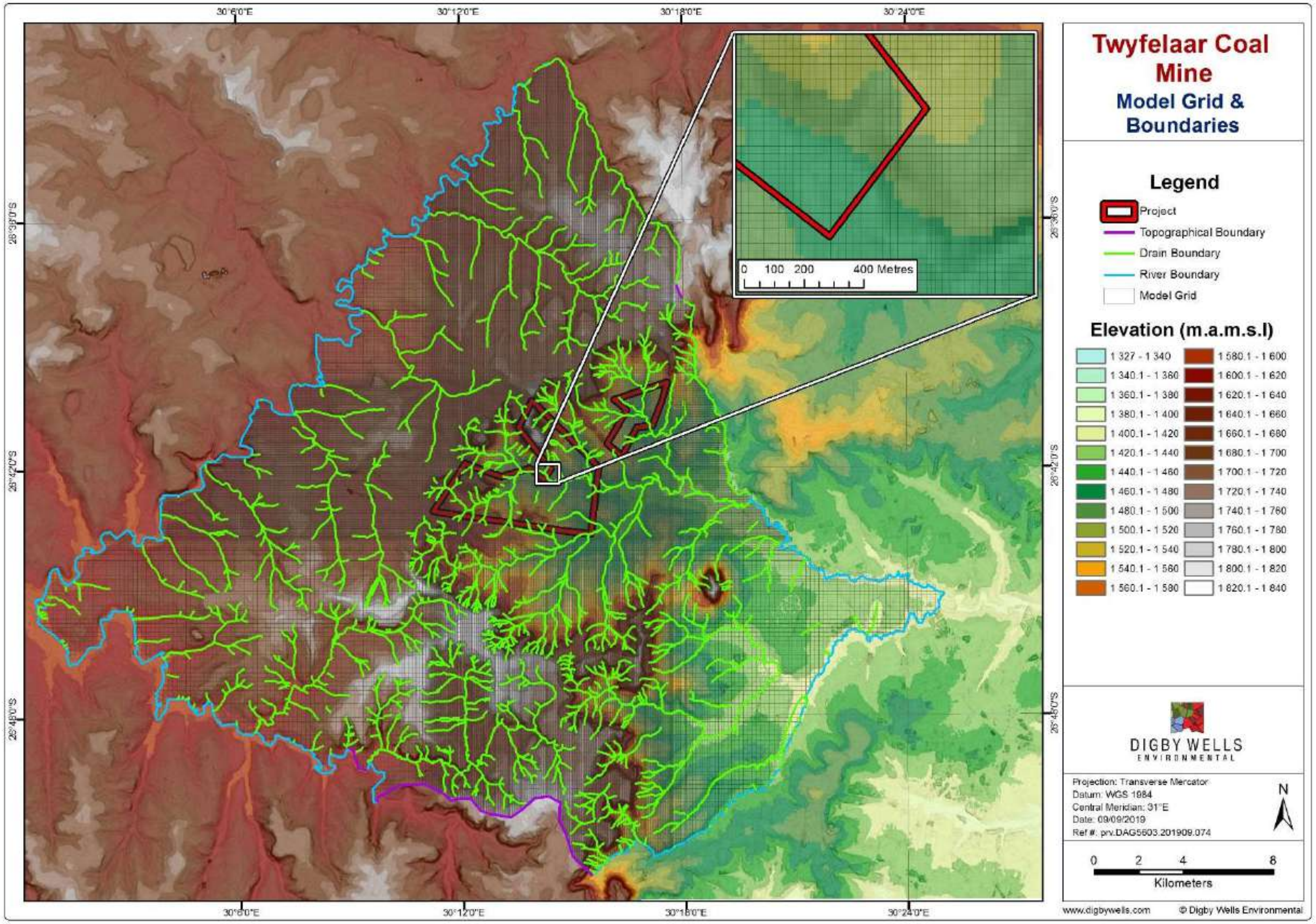


Figure 7-1: Numerical Model Domain, Grid and Boundaries

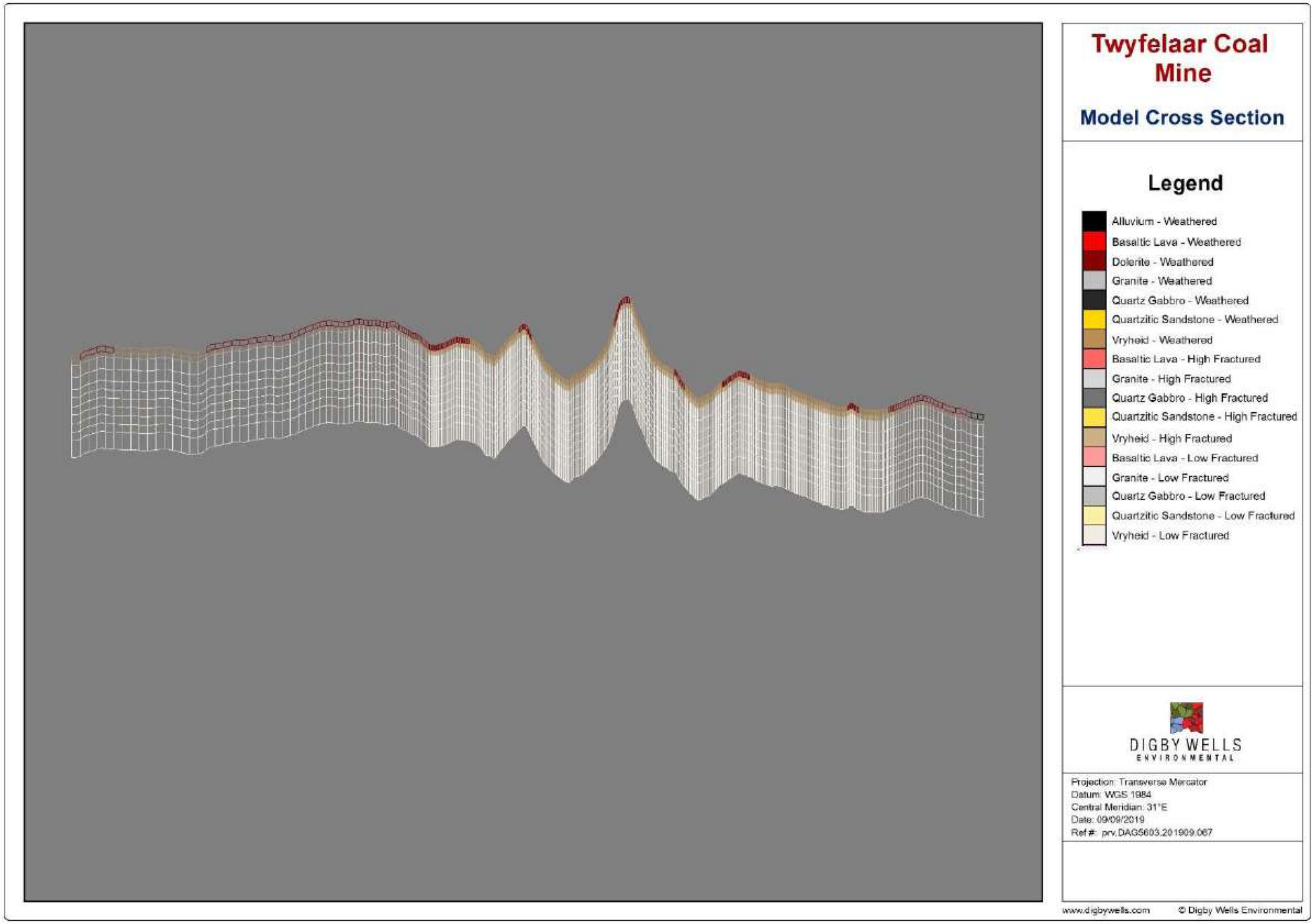


Figure 7-2: Numerical Model Cross Sections

7.4 Steady State Simulation

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

7.4.1 Steady State Calibration

Digby Wells collated the most recent borehole data and hydrocensus information available for the Project. The steady state model was calibrated with this data to produce a model simulating the baseline groundwater conditions. A total of 10 observation points (six monitoring boreholes, three third-party boreholes and one spring) were used for the steady-state calibration, based on the most recent groundwater level data. Based on the good correlation between topography and groundwater levels and between observed and modelled groundwater levels, this was deemed sufficient for the model for dewatering at Block A. However, if further expansion of the mining activities is proposed, it is recommended to update the hydrocensus and to drill additional monitoring boreholes, if more third-party boreholes cannot be located.

The model was calibrated by varying model input data over realistic ranges of values until a satisfactory match between simulated and observed water level data was achieved. In addition, the following data was used as input:

- Results from the aquifer testing for aquifer unit parameters;
- Recharge rates were estimated based on the prevailing hydrostratigrahic units present around the site;

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

The MODFLOW-NWT package was used to solve the partial differential equations. Convergence criteria of a head change of 10^{-3} m were selected. After model calibration, a correlation of 99% was obtained between the simulated and observed groundwater elevation (Figure 7-3). The calibration was deemed acceptable with a Mean Residual Head of -0.9, a Mean Residual Absolute Head of 6.4 and a Root Mean Square Error (RMSE) of 7.8.

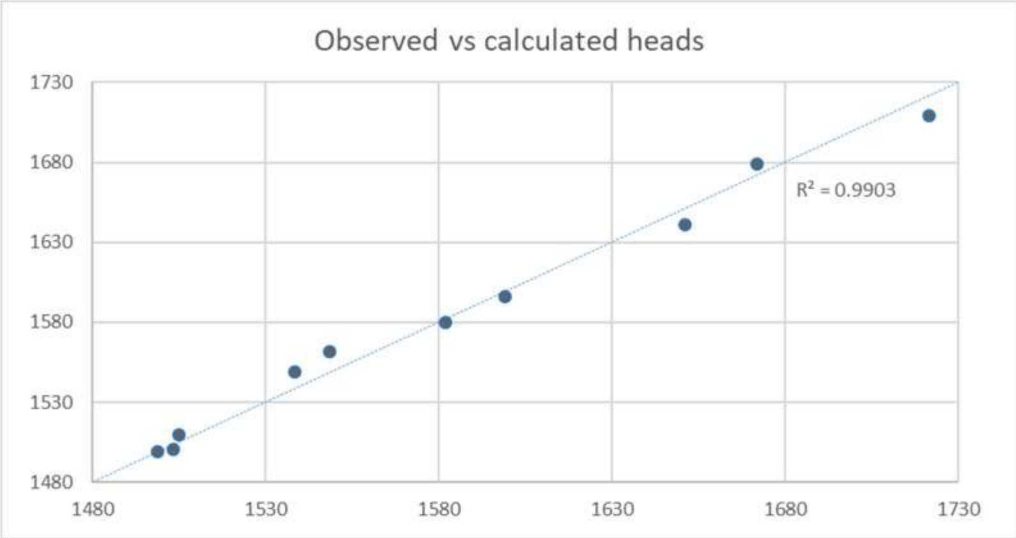


Figure 7-3: Correlation between observed and calculated heads.

A water balance error (all flows into the model minus all flows out of the model) of less than 0.5% is regarded as an accurate balance calculation. The steady state mass balance for entire model domain presented in Figure 7-1 achieved a water balance error of 0.0001% (Table 7-2).

Table 7-2: Mass balance of steady state model.

	Flow In (m^3/day)	Flow Out (m^3/day)
Rivers	3102.5	-7126.3
Drains	0	-8428.7
Recharge	12452.4	0
TOTAL FLOW	**15554.9**	**-15554.9**
Summary	In – Out	% difference
Total	**-1.7578E-02**	**-0.0001**

7.4.2 Aquifer Hydraulic Conductivity

Initial estimates of the hydraulic conductivity for the different geological units were obtained from the aquifer test data collected as part of this investigation and based on expert knowledge from other nearby model sites. These hydraulic conductivity values were assigned to hydrogeological layers within the model area. The initial estimates were used for a combination of automatic PEST (Parameter ESTimation) and manual calibration. The resulting calibrated horizontal and vertical hydraulic conductivities (k_h and k_v) and transmissivity (T) values for each layer as summarised in Table 7-3.

Table 7-3: Calibrated values of horizontal and vertical hydraulic conductivities

Aquifer unit	Parameter code	Model Layer	kh (m/d)	kv (m/d)	T (m^2/d)
Alluvium - weathered	HK_100	1	0.49	0.049	2.5
Dolerite - weathered	HK_300	1	0.024	0.0024	2.3
Granite - weathered	HK_400	1	0.03	0.0030	2.9
Vryheid - weathered	HK_700	1	0.034	0.0034	3.2
Granite - high fractured	HK_900	2	0.01	0.0010	0.1
Vryheid - high fractured	HK_1200	2	0.004	0.0004	0.4
Granite - low fractured	HK_1400	3-11	0.0001	0.00001	0.0
Vryheid - low fractured	HK_1700	3-11	0.00008	0.000008	0.0

7.4.3 Other model parameters

Recharge values were re-estimated as part of the steady state flow model calibration. An effective large-scale annual recharge value of between 0.2 (dolerite) and 3.6% (alluvium) of MAP (amounting to $3.6x10^{-6}$ – $8.1x10^{-5}$ m/d) was estimated for the model which is deemed acceptable for the hydrogeological units present within the Project Area. Other model parameters used in the calibrated model were as follows:

- Non-perennial streams:
  - Drain level at surface level;
  - Drain conductance of 0.1 $m^2/d/m^2$.

7.4.4 Sensitivity Analysis

A sensitivity analysis was carried out on the calibrated model. The purpose of the sensitivity analysis was to quantify the uncertainty in the calibrated model caused by the uncertainty in the estimates of aquifer parameters. During the sensitivity analysis horizontal conductivity and recharge were assessed. The sensitivities for the parameters the model results are most sensitive as can be seen in Figure 7-4. Results of the sensitivity analysis indicate that the water levels in the model are mainly sensitive to changes in recharge for the Vryheid Formation, followed by conductivities of the weathered Vryheid and fractured Vryheid units.

Based on these results it is recommended that groundwater monitoring should focus on all parameters for the Vryheid Formation within the Project Area and its surroundings to provide improved data regarding the parameters for these aquifer units. Continued time series groundwater level data from selected shallow groundwater monitoring boreholes will benefit future model updates the most.

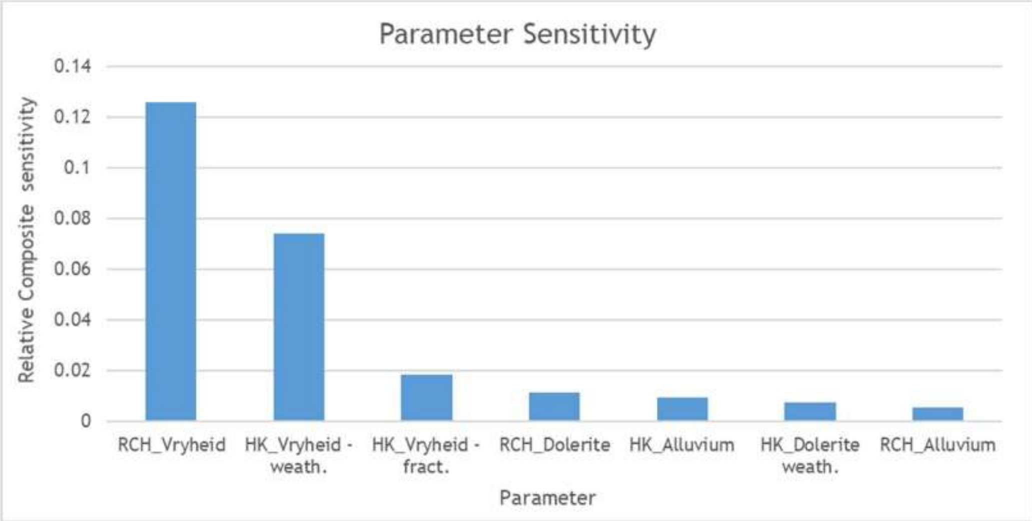


Figure 7-4: Model Parameter Relative Composite Sensitivity

7.4.5 Simulated Water Levels and Flow Direction

The simulated groundwater levels for the current situation are shown in Figure 7-5. The groundwater levels show the general south-south-eastern flow direction of groundwater as previously discussed, with highest groundwater levels along the northern model boundary at the topographical divide, and lowest groundwater levels at the south-eastern end of the model, where the hydrological outflow point for the model is situated.

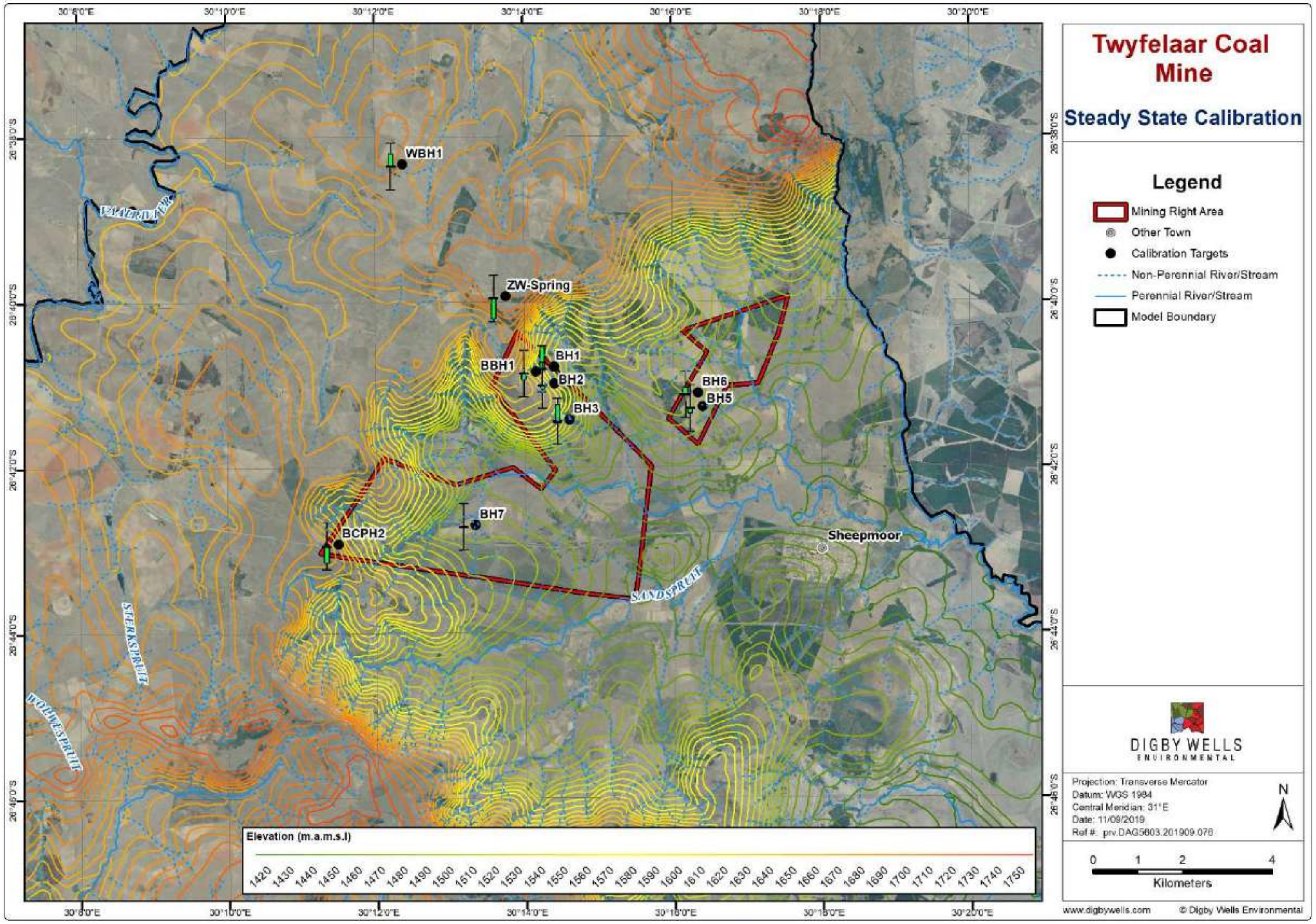


Figure 7-5: Steady-state groundwater levels and calibration results

7.5 Transient State Flow Simulation

Transient flow simulation was carried out to estimate groundwater drawdown for the Operational Phase and groundwater recovery in the Post-Closure Phase. The transient flow model was based on coal seam floor depths and the latest mine schedule as provided by Dagsoom. The current LoM is five years in total.

In addition, increased seepage was modelled for the proposed discard dump. Seepage from the discard was estimated based on experience with coal mine discard dumps at other similar mines, and a recharge rate of approximately 8% of MAP was assigned, linearly increasing from the natural recharge rate over the Operational Phase and remaining constant for the Post-Closure Phase.

7.6 Mass Transport Simulation

Mass transport calculations were carried out for the underground mine void and the coal discard dump. Contamination from the mine void can occur when contaminated water from the void infiltrates into the surrounding aquifer. This will most likely only occur post-closure when water levels return to pre-mining conditions. A modelling scenario with and without a Class C liner was carried out to calculate the unmitigated and mitigated plume extent.

Contamination from the discard dump can occur through s eepage from the discard dump infiltrating into the underlying aquifers due to infiltration of rainfall through the discard. This can occur during the LoM, but more importantly, can continue into the Post-Closure Phase.

7.6.1 Dispersion and Diffusion

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

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

7.6.2 Effective Porosity and Specific Yield

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

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

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

7.6.3 Selection of the Contamination

As the main source of contamination with coal mining is the weathering of pyrite, the contaminant of choice is sulphate that is released, together with acidity, due to the solution of pyrite. The input concentrations were based on the results of the geochemical assessment, which indicated sulphate levels can increase to over 1 200 mg/l. Conservatively a value of 1 500 mg/l was used as input, linearly increasing during the Operational Phase, and lowered to 1 000 mg/l 50 years post-closure. These are assumed reasonable concentrations based on the geochemical composition of the coal material.

8 Impact Assessment

The aim of an impact assessment is to strive to avoid damage or loss of ecosystems and services that they provide, and where they cannot be avoided, to reduce, and mitigate these impacts (DEA, 2014). Offsets to compensate for the loss of habitat are regarded as a last resort, after all efforts have been made to avoid, reduce, and mitigate. The potential impacts of the proposed activities on groundwater resources are shown below per phase of the mine; the impacts were derived based on previous experience and literature review.

1.1 Construction Phase

The Construction Phase will consist of building surface infrastructure and the construction of an adit to access the Block A mining area. The following potential impacts could result from these on-site activities (Table 8-1 and Table 8-2):

- Project Area contamination of groundwater due to hydrocarbon spillages and leaks from construction vehicles; and
- Small-scale dewatering during the construction of the adit.

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

8.1.1 Mitigations and Management Actions

Mitigation measures for the construction phase are as follows:

- Regular service of vehicles in designated repair bays;
- Refuelling of vehicles only in designated areas;
- Keep the adit construction time as short as possible; and
- If the groundwater level is intercepted the extent and depth of the box-cut should be as minimal as possible while still allowing access into the underground mine.

Table 8-1. Construction Phase Impacts –Groundwater Contamination

Dimension	Rating	Motivation	Significance
Activity and Interaction: Fuel storage, construction vehicles causing potential groundwater contamination			
Impact Description: Storage of fuel and the usage of construction vehicles on-site could cause spillages of hydrocarbons. These spillages may seep into the underlying aquifers, causing contamination of groundwater with hydrocarbons.			
Prior to Mitigation/Management			
Duration	1	Any occurrence could be reversed within a months' time	Negligible (negative) -10
Extent	1	Impacts will be limited to specific isolated parts of the site.	
Intensity	2	Expected minor impacts on the biological or physical environment; damage can be rehabilitated internally.	
Probability	3	There is a possibility of this impact to occur	
Nature	Negative		
Mitigation/Management Actions			
▪ Regular service of vehicles in designated repair bays			
▪ Refuelling of vehicles only in designated areas with correct liners and surfaces			
Post-Mitigation			
Duration	1	Any occurrence could be reversed within a months' time	Negligible (negative) -6
Extent	1	Impacts will be limited to specific isolated parts of the site.	
Intensity	2	Expected minor impacts on the biological or physical environment; damage can be rehabilitated internally.	
Probability	1	With mitigation measures in place it is not expected to happen	
Nature	Negative		

Table 8-2: Construction Phase Impacts – Mine Access Dewatering

Dimension	Rating	Motivation	Significance
Mine access dewatering causing groundwater level drawdown			
Impact Description: During construction of the adit into the underground mine, small scale dewatering associated with the construction could lead to local drawdown of groundwater levels in the vicinity of the adit.			
Prior to Mitigation/Management			
Duration	1	Any occurrence could be reversed within a months' time	Negligible (negative) -8
Extent	1	Impacts will be limited to specific isolated parts of the site.	
Intensity	2	Expected minor impacts on the biological or physical environment; damage can be rehabilitated internally.	
Probability	2	There is a possibility of this impact to occur if the adit goes below the groundwater table	
Nature	Negative		
Mitigation/Management Actions			
▪ Keep the box cut construction time as short as possible.			
▪ Keep the extents and depth of the box cuts as small as possible			
Post-Mitigation			
Duration	1	Any occurrence could be reversed within a months' time	Negligible (negative) -6
Extent	1	Impacts will be limited to specific isolated parts of the site.	
Intensity	2	Expected minor impacts on the biological or physical environment; damage can be rehabilitated internally.	
Probability	1	Expected not to happen if adit depth can be limited to above the groundwater table	
Nature	Negative		

1.2 Operational Phase

During the Operational Phase dewatering of the Block A mining area and the placement of coal discard will be the main activities of concern. Mine dewatering can cause a decrease in groundwater availability and groundwater level drawdown in the area surrounding the proposed mining. Potential contamination from the coal discard dump can already occur during the Operational Phase.

8.1.2 Groundwater level drawdown

The lowest coal floor elevations for Block A are partially below the regional groundwater levels thus causing groundwater inflows into the underground mine from the surrounding aquifer during operation. The mining area will have to be actively dewatered to ensure dry working conditions. Pumping of water that seeps into the underground mine will cause dewatering of the surrounding aquifer and an associated decrease in groundwater levels within the zone of influence of the dewatering cone.

The zone of influence of the dewatering cone depends on several factors including the depth of mining below the regional groundwater level, recharge from rainfall to the aquifer, the size of the mining area and the aquifer transmissivity, amongst others.

During the Operational Phase it is expected that the main impact on the groundwater environment will be dewatering of the surrounding Karoo fractured and weathered aquifer. A numerical groundwater flow model was used to simulate the development of the drawdown cone over time in the Project Area. The mine plan includes mining for a period of five years in total. The potential cone of drawdown in the Karoo sediments is largest at the end of the LoM and extends to a maximum radius of ~200 m around the mine (Figure 8-2).

8.1.3 Impact on aquifer yield (groundwater abstraction volumes)

The numerical model was used to predict groundwater inflows into the proposed mine. The computed inflow into the underground workings was calculated based on the provided mine schedules and assumptions of the numerical model (refer to Section 0).

For the first three years of the Operational Phase, the groundwater inflow increases due to the increase in annual production. During steady state production, the groundwater inflows will likely be in the range of ~50 to ~80 m^3/d which are regarded as relatively low. This is due to the fact that mining at Block A is taking place at great depth below ground level, as the mine void is present below a significant hill capped by a dolerite sill. Therefore, the aquifer unit in which the mining will take place is expected to be low fractured rock.

The anticipated groundwater abstraction volumes are not expected to significantly impact on the local groundwater availability. The following deductions can be made:

- The water levels are expected to be lowered over a small area (a maximum radius of ~200 m is expected) around the underground void; and

- Based on the simulations, no third-party sources, wellfields or other groundwater abstractions are present within the zone of influence. Therefore, it is unlikely there will be an impact on third party abstraction sources by lowering of water levels as a result of the projected Dagsoom mining activities.

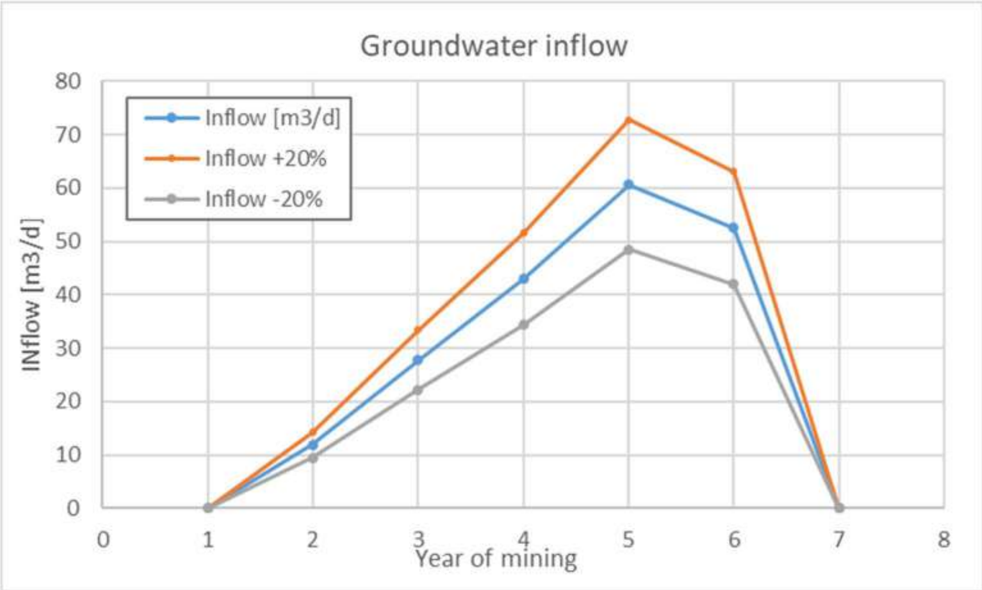


Figure 8-1. Simulated groundwater inflows into the Dagsoom Mine

8.1.4 Groundwater Quality (Potential contamination of groundwater)

The current mining schedule for includes a five-year LoM. This allows sufficient time for chemical reactions to take place in the mined-out areas, discard dump and other potential pollution sources to produce AMD conditions. Groundwater flow directions will be directed towards the mining areas due to the mine dewatering. Therefore, contamination during the Operational Phase will be contained within the mining area, and little contamination will be able to migrate away from the mining area.

8.1.5 Mitigations and Management Actions

Based on the NEM:WA classification, the discard material does show a potential for the generation of AMD and is therefore classed as a Type 3 waste. This type of waste would require a Class C liner. However, alternative mitigations or liner options can be implemented if it can be shown to the authorities, by following a risk-based approach, that these alternative barriers will perform in a similar manner to a standard Class C liner. Due to the relatively high costs associated with lining of the discard area of 30 000 m^2 (excluding the potential expansion) it will be of benefit to follow this approach and provide a liner exemption motivation to the authorities for relaxation of the Class C liner and to allow alternatives to be used.

Any discard dumps, pollution control dams and/or coal stockpile areas should be lined, thereby minimising seepage of contaminated water into the underlying aquifers. During the

Operational Phase, clean water and rainwater needs to be diverted away from these surface infrastructures as much as possible to reduce seepage to groundwater.

Contamination from workshops, sewage treatment plant, wash bay or waste collection areas, if any, should be contained as much as possible by proper construction of hardstanding and bunded areas. The extents of these areas should be minimised, and proper management should be in place in case of any spills/leakages observed.

Monitoring of groundwater quality down-gradient of infrastructures should be carried out for the LoM.

Table 8-3: Operational Phase Groundwater Impact – Groundwater Volume Abstraction

Dimension	Rating	Motivation	Significance
Activity and Interaction: Mine dewatering causing a decrease in groundwater reserves			
Impact Description: Due to active mine dewatering required to ensure dry working conditions in the underground mine, certain groundwater volumes will be extracted from the underground void, limiting the groundwater resource.			
Prior to Mitigation/Management			
Duration	6	Expected for LoM and a short period post-closure	Negligible (negative) -30
Extent	2	Limited to Block A and surroundings.	
Intensity	3	Moderate, short-term effects but not affecting ecosystem function.	
Probability	2	Low probability of the impact	
Nature	Negative		
Mitigation/Management Actions			
▪ Mining should progress as swiftly as possible to reduce the period of active dewatering ▪ The mining area extent should be kept to a minimum ▪ Dewatering of the underground mine should stop should as soon as the mining activities cease ▪ Dewatering volumes should be monitored frequently throughout the LoM to note deviations from the predicted inflows as soon as possible			
Post-Mitigation			
Duration	5	Expected for LoM	Negligible (negative) -27
Extent	2	Limited to Block A and surroundings.	
Intensity	3	Moderate, short-term effects but not affecting ecosystem function.	
Probability	2	Low probability of the impact	
Nature	Negative		

Table 8-4: Operational Phase Groundwater Impact – Groundwater Level Drawdown

<table>
<tr><th>Dimension</th><th>Rating</th><th>Motivation</th><th>Significance</th></tr>
<tr><td colspan="4">Activity and Interaction: Mine dewatering causing lowering of groundwater levels</td></tr>
<tr><td colspan="4">Impact Description: Active mine dewatering will be required to ensure dry working conditions in the underground void. The dewatering will cause ground levels to be drawn down in the vicinity of the mining area.</td></tr>
<tr><td colspan="4">Prior to Mitigation/Management</td></tr>
<tr><td>Duration</td><td>6</td><td>Expected for LoM</td><td rowspan="5">Minor (negative) -42</td></tr>
<tr><td>Extent</td><td>2</td><td>Limited to Block A and surroundings.</td></tr>
<tr><td>Intensity</td><td>3</td><td>Moderate, short-term effects but not affecting ecosystem function.</td></tr>
<tr><td>Probability</td><td>6</td><td>It is likely that this impact will occur</td></tr>
<tr><td>Nature</td><td>Negative</td><td></td></tr>
<tr><td colspan="4">Mitigation/Management Actions</td></tr>
<tr><td colspan="4">Mining should progress as swiftly as possible to reduce the period of active dewatering
The mining area extent should be kept to a minimum
Dewatering of the underground mine should stop should as soon as the mining activities cease
Groundwater levels surrounding the mine void should be monitored on a regular basis throughout the LoM to verify the extent of the cone of drawdown</td></tr>
<tr><td colspan="4">Post-Mitigation</td></tr>
<tr><td>Duration</td><td>5</td><td>Expected for LoM</td><td rowspan="5">Minor (negative) -39</td></tr>
<tr><td>Extent</td><td>2</td><td>Limited to Block A and surroundings.</td></tr>
<tr><td>Intensity</td><td>3</td><td>Moderate, short-term effects but not affecting ecosystem function.</td></tr>
<tr><td>Probability</td><td>6</td><td>It is likely that this impact will occur</td></tr>
<tr><td>Nature</td><td>Negative</td><td></td></tr>
</table>

Table 8-5: Operational Phase Groundwater Impact – Groundwater Contamination

Dimension	Rating	Motivation	Significance
Activity and Interaction: AMD formation in the underground void and discard dump causing groundwater contamination			
Impact Description: Due to AMD taking place within the underground void and in the discard dump, potential groundwater contamination with sulphate and a lower pH could occur, which would have an impact on the groundwater quality.			
Prior to Mitigation/Management			
Duration	6	Expected for LoM and post-closure	Negligible (negative) -22
Extent	2	Limited to Block A and surroundings.	
Intensity	2	Negligible effects due to drawdown cone preventing contaminants from spreading	
Probability	3	With current limited data available and based on previous experience this impact is probable	
Nature	Negative		
Mitigation/Management Actions			
▪ Groundwater asbstraction should continue for the LoM to maintain a cone of drawdown ▪ Monitoring of groundwater quality in the area surrounding the mine void should continue throughout the LoM ▪ Groundwater levels surrounding the mine void should be monitored on a regular basis throughout the LoM to verify the extent of the cone of drawdown			
Post-Mitigation			
Duration	5	Expected for LoM	Negligible (negative) -18
Extent	2	Limited to Block A and surroundings.	
Intensity	2	Negligible effects due to drawdown cone preventing contaminants from spreading	
Probability	2	With current limited data available and based on previous experience this impact is likely to occur but reduced with mitigations in place	
Nature	Negative		

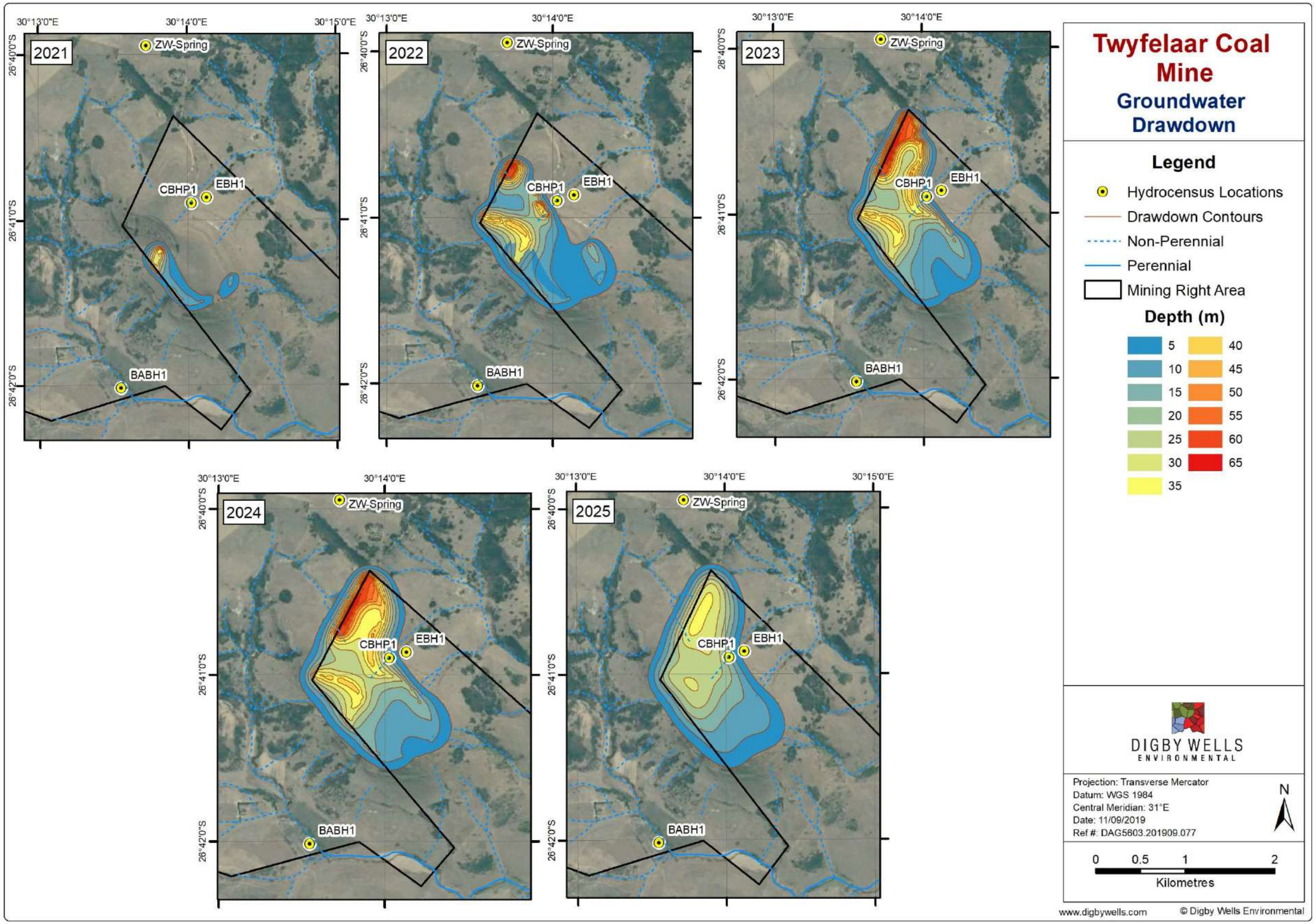


Figure 8-2: Groundwater cone of drawdown during the operational phase

1.3 Post-Closure Phase

In the Post Closure Phase contamination from mining areas, discard dumps and other surface infrastructure (such as waste rock dumps or TSFs) that may cause groundwater contamination, and subdued groundwater levels due to the prolonged mine dewatering in the Operational Phase are the main concerns.

8.1.6 Groundwater level recovery

After the end of life of mine pumping of groundwater from the underground mine will seize and groundwater levels will be allowed to recover. Groundwater levels in the surrounding area which were drawn down due to the dewatering will subsequently return to close to the natural, pre-mining state.

However, due to the low recharge influx it will take a long time before groundwater levels will return to pre-mining conditions. The numerical model was used to simulate groundwater rebound and indicates the rebound will indeed be slow and groundwater levels in the vicinity of the site will take approximately 30 years to recover (Figure 8-3). This was also indicated by the slow recovery in some of the tested monitoring boreholes.

8.1.7 Groundwater contamination

Once the mining has ceased, AMD is likely to form given the unsaturated conditions in the facility and contact of water and oxygen. Groundwater contaminants could migrate from the mining areas once groundwater levels in the underground voids have recovered.

The migration of contaminated water from the underground mine has been simulated for end of LoM, 50 and 100 years post-closure (Figure 8-4) and the maximum extent of the contaminant plume was calculated to be ~275 m from the void moving in a general east to southeast direction. Based on the contaminant transport simulations for the underground mine it is very unlikely that privately owned boreholes located in the vicinity of the proposed development will be impacted upon.

Contamination of groundwater via seepage from the discard dump was also simulated. The potential sulphate plume from the discard dump will mainly flow towards the south and extend to a maximum distance of ~520 m southeast of the discard dump. This plume reaches a non-perennial stream located east of the discard dump 50 years post-closure. This impact can be mitigated by installing a recommended Class C liner or similar mitigation measure for the discard dump and to carry out proper rehabilitation of the dump post-closure to significantly reduce infiltration of rainwater into the dump.

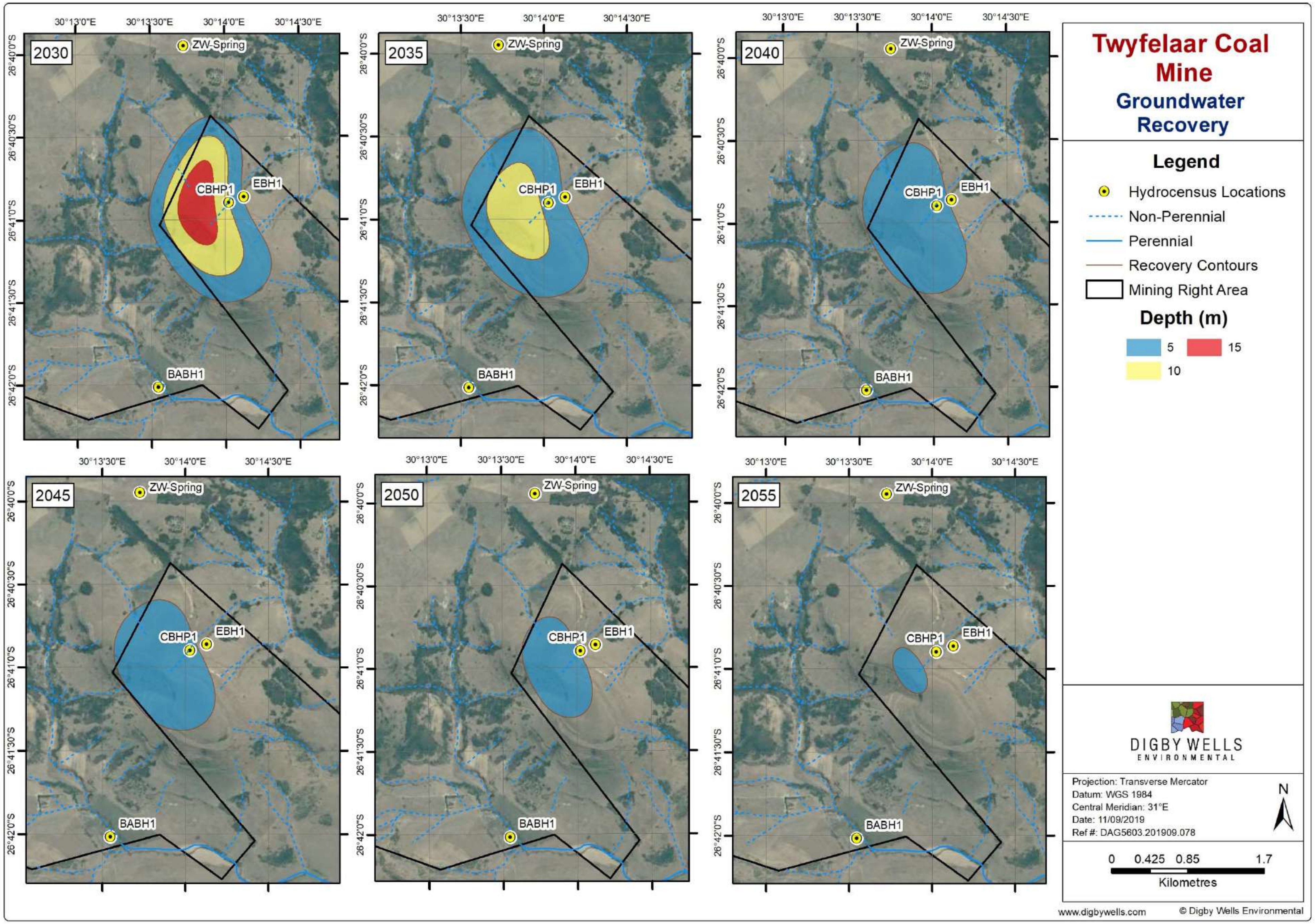


Figure 8-3: Groundwater level recovery post-closure

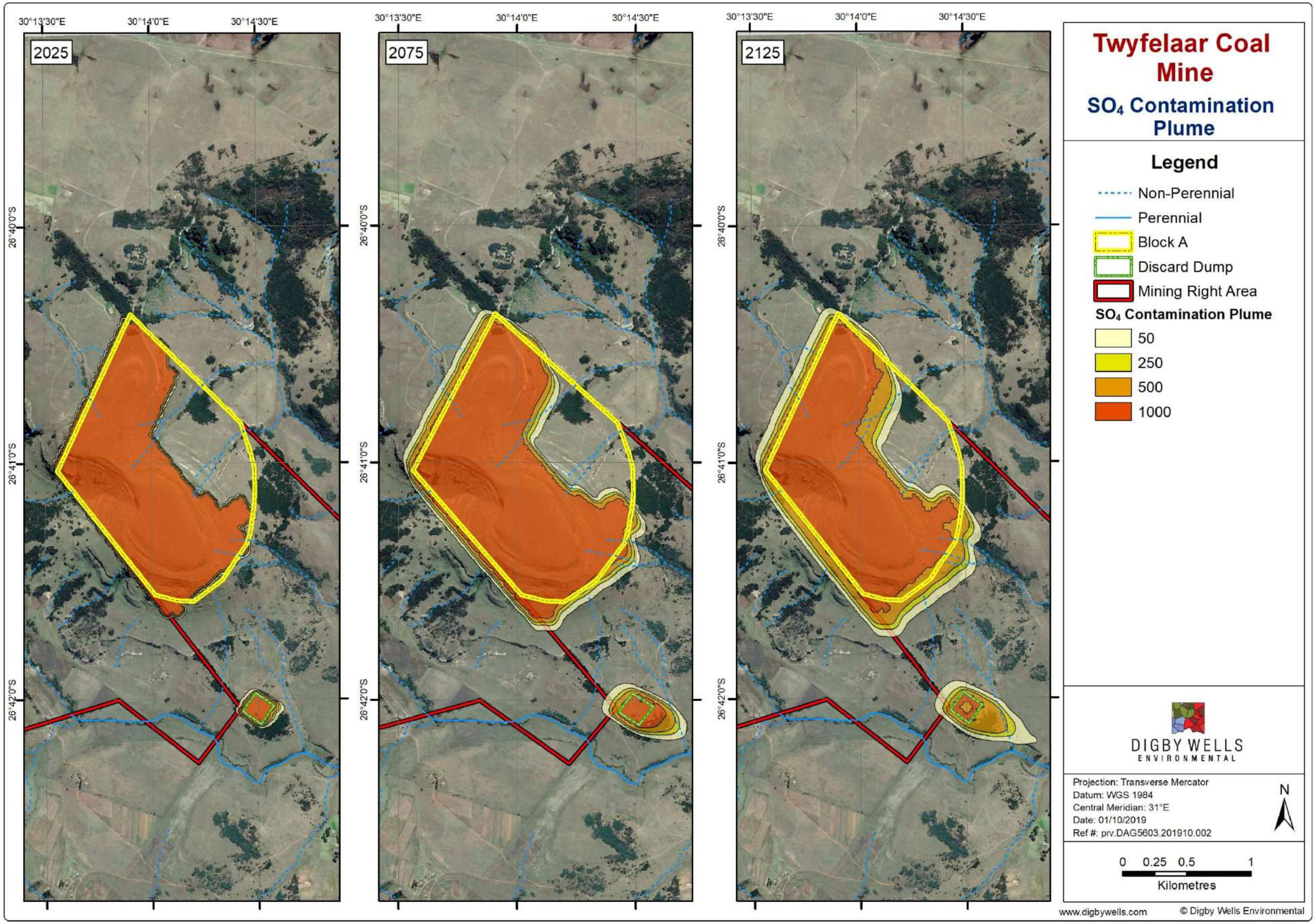


Figure 8-4: Groundwater contaminant plumes post-closure (no liner scenario)

8.1.8 Mine Decant

For underground mining the decant point can be established as paths, that create a connection between the underground mine and topography i.e. a shaft, decline, adit, vent shaft etc. When the active dewatering of the underground voids has ceased groundwater levels will rebound. As the underground voids flood, decant can occur when the groundwater level recovers to above the surface elevation of any of the access paths. This can occur long after the end of life of mine and is referred to as the time-to-decant.

At the Project Area underground mining is planned for Block A. Based on the proposed mine layout and site topography the potential decant point have been determined to be the adit into the underground mine at the southern end of the mine (Figure 2-2Figure 2-2).

However, the adit is situated at a topographical elevation of 1 619 mamsl. Based on the groundwater levels measured in third-party and monitoring boreholes, the modelled steady-state water levels indicate a groundwater level of ~1 571 mamsl in the vicinity of the adit at approximately 48 mbgl. Therefore, it is very unlikely that decant will occur from the proposed underground mine.

8.1.9 Mitigations and Management Actions

The discard dump should be properly rehabilitated to reduced infiltration of rainwater, and a Class C liner was recommended based on the NEM:WA regulations. A modelling scenario was run for a discard dump with a liner and this showed to prevent contamination going to the mon-perennial stream, showing this approach would be effective. Therefore, a liner or alternative with similar effectiveness (in case the liner requirement can be relaxed) must be considered.

Any pollution control dams, coal stockpile areas, coal washing bays and coal slurry/sludge dams should also be lined, thereby minimising seepage of contaminated water into the underlying aquifers.

Infrastructure such as workshops, sewage treatment plants, wash bay or waste collection areas should be completely removed during closure. Monitoring of groundwater quality down-gradient of infrastructures should be carried out in the post-closure phase for a period of between 2-5 years, after which the monitoring results should be used to indicate monitoring requirements going forward.

It is recommended to close all access routes into the underground mine, such as the adit or any vent shafts that may be included by grouting these openings to prevent the spread of any ground contamination that could emanate from the underground void to the surrounding aquifer though these openings.

Table 8-6: Post-closure Groundwater Impact – Groundwater Level Recovery

Dimension	Rating	Motivation	Significance
Activity and Interaction: Mine Dewatering and residual effect on rebounding groundwater levels			
Impact Description: Due to the dewatering activities during the Operational Phase, groundwater levels surrounding Block A will be subdued at the start of the Post Closure Phase, after it will gradually recover towards pre-mining levels.			
Prior to Mitigation/Management			
Duration	6	Reduced groundwater levels will be fully recovered within 30 years, but will be sufficiently recovered approximately 10 years post-closure to not affect any areas surrounding the mine void	Minor (negative) -42
Extent	2	Limited to Block A and surroundings.	
Intensity	3	Moderate, short-term effects are expected	
Probability	6	This impact could occur	
Nature	Negative		
Mitigation/Management Actions			
▪ Dewatering of the underground voids should cease as soon as possible after mining activities are completed to allow for groundwater level recovery ▪ Groundwater level recovery should be frequently monitored to identify deviations from the predicted recovery rate ▪ Groundwater quality should be frequently sampled to establish if a contaminant plume will migrate ▪ Clean water and runoff should be diverted where possible towards the underground mining voids to flood areas as fast as possible after mining has stopped.			
Post-Mitigation			
Duration	5	Reduced groundwater levels will be fully recovered within 30 years, but will be sufficiently recovered approximately 10 years post-closure to not affect any areas surrounding the mine void	Minor (negative) -39
Extent	2	Limited to Block A and surroundings.	
Intensity	3	Moderate, short term effects are expected	
Probability	6	This impact could occur	
Nature	Negative		

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Table 8-7: Post Closure groundwater Impact – Groundwater Contamination

<table>
<tr><th>Dimension</th><th>Rating</th><th>Motivation</th><th>Significance</th></tr>
<tr><td colspan="4">Activity and Interaction: AMD in underground void and discard dump causing groundwater contamination</td></tr>
<tr><td colspan="4">Impact Description: Due to AMD taking place within the underground void and in the discard dump, potential groundwater contamination with sulphate and a lower pH could occur, which would have an impact on the groundwater quality.</td></tr>
<tr><td colspan="4">Prior to Mitigation/Management</td></tr>
<tr><td>Duration</td><td>7</td><td>The impact will remain long after the life of the Project. The impacts are irreversible.</td><td rowspan="5">Minor (negative) -70</td></tr>
<tr><td>Extent</td><td>2</td><td>Limited to Block A and surroundings.</td></tr>
<tr><td>Intensity</td><td>5</td><td>Serious impact on ecosystems within the contaminant plume.</td></tr>
<tr><td>Probability</td><td>5</td><td>This impact will likely occur</td></tr>
<tr><td>Nature</td><td>Negative</td><td></td></tr>
<tr><td colspan="4">Mitigation/Management Actions</td></tr>
<tr><td colspan="4">
Dewatering of the underground voids should cease as soon as possible after mining activities are completed to allow for groundwater level recovery
Rehabilitation of the discard dump to reduce infiltration of rainwater into the dump to reduce seepage generation
Lining of the discard dump will reduce seepage into the underlying aquifer.
Clean water and runoff should be diverted where possible towards the underground mining voids to flood areas as fast as possible after mining has stopped.
Groundwater quality should be frequently sampled to establish if a contaminant plume will migrate
</td></tr>
<tr><td colspan="4">Post-Mitigation</td></tr>
<tr><td>Duration</td><td>5</td><td>The impact will remain long after the life of the Project. The impacts are however mitigated in duration if proposed mitigation of faster flooding is implemented</td><td rowspan="5">Minor (negative) -36</td></tr>
<tr><td>Extent</td><td>2</td><td>Limited to Block A and surroundings.</td></tr>
<tr><td>Intensity</td><td>3</td><td>Moderate, short-term impact on ecosystems within the contaminant plume.</td></tr>
<tr><td>Probability</td><td>5</td><td>This impact will likely occur</td></tr>
<tr><td>Nature</td><td>Negative</td><td></td></tr>
</table>

Table 8-8: Post Closure Groundwater Impact – Mine Decant

Dimension	Rating	Motivation	Significance
Activity and Interaction: Mine decant causing contamination of groundwater			
Impact Description: If groundwater levels within the mine void recover to elevations higher than surface elevations of any underground mine access paths, this water may then flow from the mine void and cause groundwater contamination down gradient of the mine.			
Prior to Mitigation/Management			
Duration	7	The impact will remain long after the life of the Project. The impacts are irreversible.	Minor (negative) -50
Extent	1	Limited to the site only	
Intensity	5	Serious impact on ecosystems within the contaminant plume.	
Probability	2	Unlikely to happen	
Nature	Negative		
Mitigation/Management Actions			
▪ Underground voids should be allowed to flood as soon as possible after mining activities are completed ▪ Groundwater level recovery in the mine void should be frequently monitored to create stage curves and predict the final water recovery level. ▪ All access paths into the underground void should be closed, i.e. grouting of the adit and ventilation shafts, if any.			
Post-Mitigation			
Duration	6	The impact will remain long after the life of the Project. The impacts are irreversible.	Minor (negative) -40
Extent	1	Limited to the site only	
Intensity	5	Serious impact on ecosystems within the contaminant plume.	
Probability	1	Highly unlikely to happen	
Nature	Negative		

9 Groundwater Monitoring Network

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

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

Groundwater Monitoring should be undertaken according to the schedule presented in Table 9-1. The proposed Dagsoom monitoring network can be seen in Figure 9-1. It is envisaged that the frequency of monitoring remains on a quarterly basis.

Table 9-1 Groundwater Monitoring Programme

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

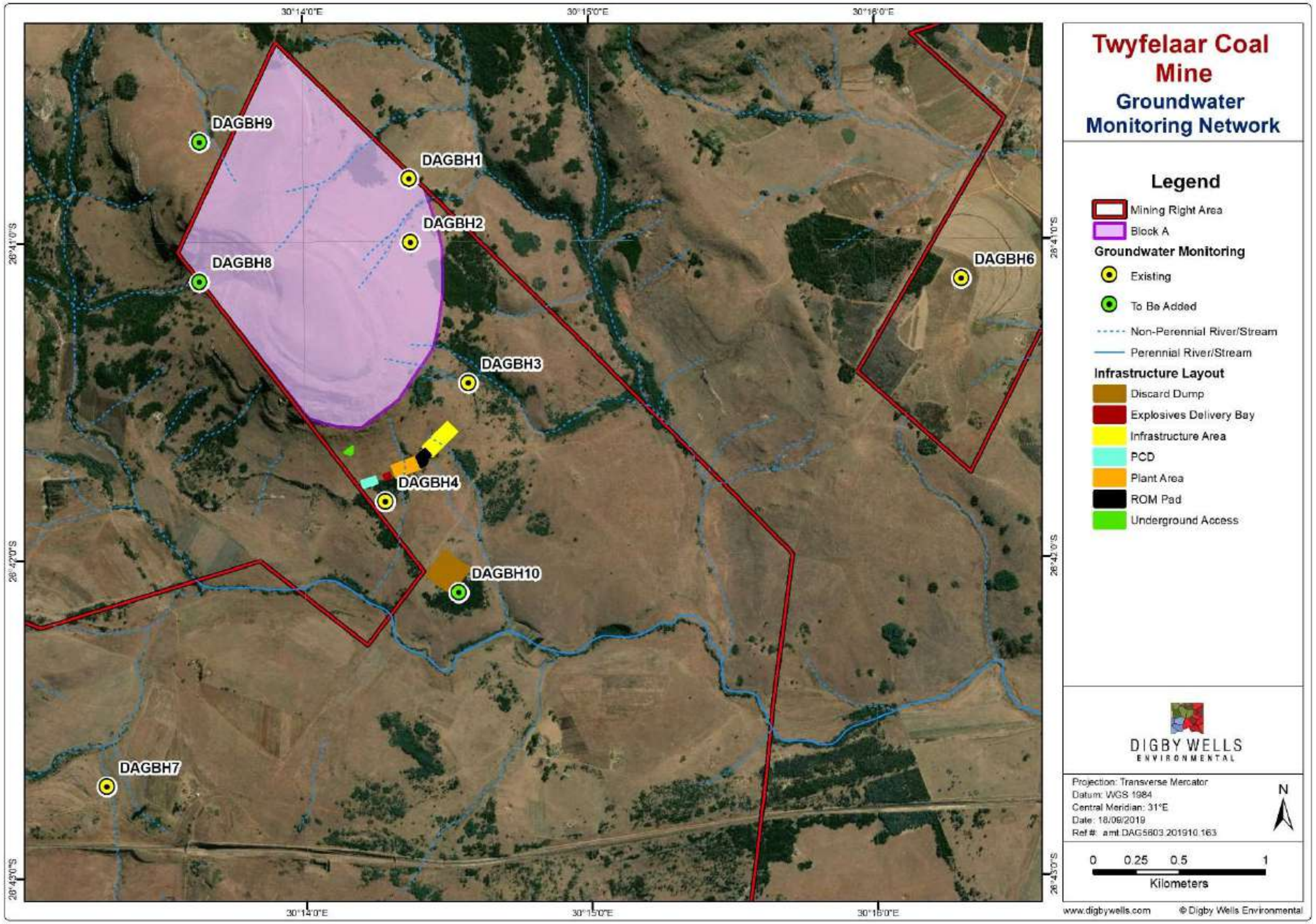

Figure 9-1: Proposed groundwater monitoring network

10 Gaps in Knowledge and Limitations

The following limitations and gaps were identified:

- A model is a simplified representation of reality. This is also the case for numerical groundwater models. Numerical models assume uniform flow within the different aquifer units assigned to the model. In real-life there may be fractured or faulted zones within those units that could enhance groundwater flows;
- Porosity values for the aquifers were not available but were chosen based on experience in similar geological settings and values are deemed representative for Karoo strata;
- No in-field verification of dispersion was available for this study. However, representative, generic values for dispersion and parameters have been used as input into the numerical model.
- The model calibration was based on available groundwater levels taken in on-site monitoring and aquifer test holes and accessible third-party boreholes;
- Contaminant plume calculations were based on results from the geochemical assessment on 6 waste rock and 2 coal samples retrieved from exploration and aquifer test boreholes. Additional coal samples would be recommended to verify the current results and increase the accuracy of the potential seepage concentrations from coal materials.

11 Conclusions and recommendations

11.1 Conclusions

The following conclusions were made for the site:

- The MAP of region surrounding the site is ~825 mm;
- The topography is dominated by the Eastern escarpment which has a general south-west to north-east orientation, with a higher plain to the west and a lower, slight to moderately undulating plain to the east;
- Drainage in the area surrounding the site flows in a general west to south-easterly direction with non-perennial drainage lines located to the north-east and south to south-west (Zandspruit) of the proposed mining area;
- The dominant lithologies present in the area are coal-bearing sandstone, mudstone, siltstone, shale and coal seams of the Vryheid Formation with dolerite sill type intrusions of the Karoo dolerite Suite. Eight (8) coal seams (A, BU, BL, CU, CL, DU, D and E) were logged below the sill cap and outcrop around the slopes of the ridge with the C-seam being the main target for the proposed development;

- Three principal aquifers were identified for the site: the weathered and fractured Karoo aquifers (Vryheid Formation) and dolerite sills. The aquifers that occur in the area are classified as minor aquifers (low yielding), but of high importance and are understood to have a low to medium development potential, mostly used for small scale domestic purposes or occasionally for large scale irrigation;
- The shallow weathered aquifer depth at the site ranges varies between 3 and 10 mbgl with an average of ~8 mbgl. In terms of pollution risk and/ or susceptibility to pollution, the shallow primary aquifer is understood to be highly susceptible to pollution;
- The main source of water supply in and around the proposed mining area is groundwater which is abstracted by use of community hand pumps supplemented by a number of springs. Water is mainly used for domestic use and livestock watering;
- Groundwater depth mostly ranges between ~2-20 mbgl, indicating that in general groundwater levels are relatively shallow and mainly located within the weathered aquifer Groundwater flow directions generally follow topography and drainage directions, indicating the main groundwater flow direction will be to the southeast towards the Nkomati River;
- The groundwater types found were a mixture of mainly Ca-HCO_3, Mg-HCO_3, Na-HCO_3 with one sample showing a Mg- SO_4-type groundwater. These water types are typical for the Vryheid Formation. The groundwater is generally of good quality and only iron, manganese and aluminium exceedances over the SANS drinking water guideline values were observed, likely related to natural background concentrations within the Karoo aquifers;
- The potential cone of drawdown is largest at the end of life of mine and water levels are expected to be lowered over a relatively small area (a maximum radius of ~200 m is expected) around the underground void;
- During steady state production the groundwater inflows will likely be in the range of ~50 to ~80 m^3/d which are regarded as relatively low. This is due to the fact that Block A mining is taking place in low fractured rock. The anticipated groundwater abstraction volumes are not expected to significantly impact on the local groundwater availability;
- Based on the simulations no third-party sources, wellfields or other groundwater abstractions are present within the zone of influence. Therefore, it is unlikely there will be an impact on third party abstraction sources by lowering of water levels as a result of the projected Twyfelaar mining activities;
- Groundwater flow directions for the operational phase will be directed towards the mining areas due to the mine dewatering. Therefore, contamination during the operational phase will be contained within the mining area, and little contamination will be able to migrate away from the mining area;
- However, due to the low recharge influx it will take a long time before groundwater levels will return to pre-mining conditions. The numerical model was used to simulate

groundwater rebound and indicates the rebound will indeed be slow and groundwater levels in the vicinity of the site will take approximately 30 years to recover.

- The maximum extent of the contaminant plume was calculated to be ~275 m from the void moving in a general east to southeast direction. Based on the contaminant transport simulations for the underground mine it is very unlikely that privately owned boreholes located in the vicinity of the proposed development will be impacted upon; and
- The potential sulphate plume from the discard dump will mainly flow towards the southeast and extend to a maximum distance of ~520 m from the discard dump, reaching a non-perennial stream east of the discard dump. This impact can be mitigated by dump rehabilitation post-closure and application of a Class C liner or mitigations with a similar effectiveness.

11.2 Recommendations

The following recommendations are made:

- A closure water management plan should be developed. This should assess the management of a critical water level to minimise contamination of the shallow weathered aquifer. The discard dump should also be assessed in terms of a remediation action plan. This should all be analysed in a financial model to further inform the most effective closure water management options. The groundwater model should be used as a management tool to inform this process;
- All mining areas should be flooded as soon as possible to restrict oxygen ingress into the backfill and lower sulphate levels in seepage;
- The rate of water level recovery in the underground void should be monitored. Stage curves should be developed which would aid in the management of closure phase;
- A groundwater monitoring network should be put in place;
- The numerical model should be updated once every two-three years or after significant changes in mine schedules or plans by using the measured water ingress and water levels to re-calibrate and refine the impact predictive scenario. Updates to the model should be carried out more frequently if significant changes are made to the mine schedule or plan;
- Based on the NEM:WA classification the discard material does show a potential for the generation of AMD and is therefore classed as a Type 3 waste. This type of waste would require a Class C liner. However, alternative mitigations or liner options can be implemented if it can be shown to the authorities (liner exemption motivation), by following a risk-based approach, that these alternatives will perform in a similar manner to a standard Class C liner; and

- Additional geochemical assessment giving more insight in the variability of the NAG of the coal material should be performed, and if applicable, the liner requirement re-assessed.
- If further expansion of the mining activities is proposed, it is recommended to update the hydrocensus and to drill additional monitoring boreholes, if more third-party boreholes cannot be located.

12 References

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Hodgson, F.D.I., Krantz, R.M., (1995). Investigation into groundwater quality deterioration in the Olifants River catchment above the Loskop Dam with specialized investigation in the Witbank Dam sub-catchment. Institute for Groundwater Studies, University of the Orange Free State. WRC Report No. 291/1/95

Johnson, M.R., Anhaeusser, C.R. and Thomas, R.J., 2006. The Geology of South Africa.

Woodford, A.C., and Chevallier, L., 2002. Hydrogeology of the Main Karoo Basin: Current Knowledge and Future Research Needs, WRC Report No. TT 179/02.

Appendix A: Borehole logs

DIGBY WELLS ENVIRONMENTAL

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

CLIENT	**Dagsoom Coal Mine**	**BOREHOLE ID**	**DAGBH01**
Province	Mpumalanga	X-coordinate	030° 40' 48.30"
Location	Ermelo	Y-coordinate	26° 14' 22.50"
Site		Z-coordinate (mams	1568
Project Name	**Twyfelaar ESIA**	Coordinate System	
Project No.	DAG5601	Final Depth (m)	40
Drilled By	Hall Core Drilling	Water Level (mbgl)	
Date Drilled		Colar Height (m)	
		Logged By	Kgaugelo Thobejane

PERCUSSION DRILL LOG

Columns: LITHOLOGICAL DESCRIPTION | GEOLOGICAL PROFILE | DEPTH mbgl | Weathering (Slight, Moderate, Very, Complete) | Penetration rate (mm.sec/m) | WATER STRIKE mbgl | BLOW YIELD L/s (measure at every water strike and rod change) | DEPTH mbgl | BOREHOLE DESCRIPTION | BOREHOLE CONSTRUCTIO

Lithological description	Depth (mbgl)
Alluvium	0 – 1
Weathered Sandstone	1 – 4
Sandstone	4 – 19
Dolerite	19 – 40

Borehole description	
Solid PVC	0 - 6 m
Perforated PVC	6 - 40 m

Depth (m)	Penetration rate (mm.sec/m)
1	49.70
2	48.13
3	46.30
4	46.82
5	55.60
6	62.80
7	65.87
8	58.76
9	55.20
10	49.88
11	47.16
12	51.85
13	47.26
14	45.89
15	33.85
16	53.71
17	60.48
18	51.06
19	53.32
20	58.12
21	65.80
22	76.80
23	72.43
24	72.60
25	72.90
26	75.60
27	77.69
28	86.07
29	88.60
30	92.69
31	95.90
32	100.83
33	105.76
34	110.69
35	115.62
36	120.55
37	125.48
38	130.41
39	135.34
40	140.27

Depth scale: 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65

Comment:

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CLIENT	**Dagsoom Coal Mine**	**BOREHOLE ID**	**DAGBH02**
Province	Mpumalanga	X-coordinate	030° 40' 53.51" S
Location	Ermelo	Y-coordinate	26° 40' 53.51"
Site		Z-coordinate (mams	1568
Project Name	**Twyfelaar ESIA**	Coordinate System	
Project No.	DAG5601	Final Depth (m)	49
Drilled By	Hall Core Drilling	Water Level (mbgl)	
Date Drilled	16th August 2019	Colar Height (m)	
		Logged By	Kgaugelo Thobejane

PERCUSSION DRILL LOG

Columns: LITHOLOGICAL DESCRIPTION | GEOLOGICAL PROFILE | DEPTH mbgl | Weathering (Slight, Moderate, Very, Complete) | Penetration rate (mm.sec/m) | WATER STRIKE mbgl | BLOW YIELD L/s (measure at every water strike and rod change) | DEPTH mbgl | BOREHOLE DESCRIPTION | BOREHOLE CONSTRUCTIO

Lithological description:

LITHOLOGICAL DESCRIPTION
Alluvium
Weathered Sandstone
Mudstone
Coal
Sandstone
Carbonaceous shale
Mudstone
Sandstone
Carbonaceous shale
Sandstone
Mudstone
Sandstone

Penetration rate (mm.sec/m):

Penetration rate
25.95
25.69
34.62
30.58
75.59
75.38
57.30
51.47
44.80
55.63
60.59
51.45
49.42
66.46
55.85
42.79
41.93
66.23
62.69
60.28
87.72
83.43
72.85
80.82
77.47
78.53
67.05
69.99
94.34
94.62
61.55
90.41
63.15
73.66
53.96
62.64
63.40
52.42
49.87
72.10
67.18
60.29
58.22
61.65
55.55
96.79
109.65
104.37
81.23

Depth scale (mbgl): 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65

Borehole description:
Solid PVC 0 - 6 m
Perforated PVC 6 - 49 m

Comment:

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

CLIENT	**Dagsoom Coal Mine**	**BOREHOLE ID**	**DAGBH03**
Province	Mpumalanga	X-coordinate	030° 14' 22.5"
Location	Ermelo	Y-coordinate	26° 40' 48.3"
Site		Z-coordinate (mams	1568
Project Name	**Twyfelaar ESIA**	Coordinate System	
Project No.	DAG5601	Final Depth (m)	43
Drilled By	Hall Core Drilling	Water Level (mbgl)	
Date Drilled	16th August 2019	Colar Height (m)	
		Logged By	Kgaugelo Thobejane

PERCUSSION DRILL LOG

LITHOLOGICAL DESCRIPTION
Alluvium
Weathered Sandstone
Sandstone/Coal/
Mudstone
Sandstone
Mudstone
Sandstone
Carbonaceous shale
Sandstone

Columns: GEOLOGICAL PROFILE; DEPTH mbgl (0–65); Weathering (Slight, Moderate, Very, Complete); Penetration rate (mm.sec/m); WATER STRIKE mbgl; BLOW YIELD L/s (measure at every water strike and rod change); DEPTH mbgl; BOREHOLE DESCRIPTION; BOREHOLE CONSTRUCTION

Depth (m)	Penetration rate (mm.sec/m)
1	49.70
2	102.58
3	100.91
4	46.82
5	74.36
6	96.24
7	65.87
8	58.76
9	49.16
10	49.88
11	47.16
12	51.85
13	47.26
14	45.89
15	33.85
16	53.71
17	60.48
18	51.06
19	53.32
20	58.12
21	65.80
22	76.80
23	72.43
24	56.13
25	58.69
26	65.82
27	54.74
28	56.14
29	58.81
30	59.81
31	51.65
32	100.83
33	62.35
34	68.84
35	130.54
36	74.07
37	96.60
38	79.35
39	74.92
40	72.06
41	78.57
42	78.13
43	82.24

BOREHOLE DESCRIPTION:
- Solid PVC 0 - 6 m
- Perforated PVC 6 - 43 m

Comment:

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CLIENT	**Dagsoom Coal Mine**	**BOREHOLE ID**	**DAGBH04**
Province	Mpumalanga	X-coordinate	030° 14' 17.10"
Location	Ermelo	Y-coordinate	26° 41' 9.10"
Site		Z-coordinate (mams	1517
Project Name	**Twyfelaar ESIA**	Coordinate System	
Project No.	DAG5601	Final Depth (m)	35
Drilled By	Hall Core Drilling	Water Level (mbgl)	Dry
Date Drilled	9th August 2019	Colar Height (m)	
		Logged By	Kgaugelo Thobejane

PERCUSSION DRILL LOG

Columns: LITHOLOGICAL DESCRIPTION | GEOLOGICAL PROFILE | DEPTH mbgl | Weathering (Slight, Moderate, Very, Complete) | Penetration rate (mm.sec/m) | WATER STRIKE mbgl | BLOW YIELD L/s (measure at every water strike and roc change) | DEPTH mbgl | BOREHOLE DESCRIPTION | BOREHOLE CONSTRUCTIO

Lithological description (top to bottom): Mudstone; Highly Weathered; Mudstone; Weathered Sandstone; Sandstone; Dolerite

Weathering: Very

Depth (mbgl)	Penetration rate (mm.sec/m)
1	66.00
2	42.18
3	40.41
4	43.41
5	69.38
6	70.91
7	72.63
8	75.62
9	64.40
10	56.88
11	37.81
12	64.78
13	102.22
14	67.82
15	79.51
16	63.37
17	82.70
18	69.28
19	86.20
20	86.25
21	83.77
22	81.03
23	90.01
24	81.46
25	101.96
26	111.92
27	110.74
28	109.16
29	82.57
30	105.23
31	198.86
32	122.02
33	120.78
34	206.01
35	232.11

Depth scale: 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65

Comment:

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Fern Isle, Section 10,
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CLIENT	**Dagsoom Coal Mine**	**BOREHOLE ID**	**DAGBH05**
Province	Mpumalanga	X-coordinate	030° 16' 18.3"
Location	Ermelo	Y-coordinate	26° 41' 07.5"
Site		Z-coordinate (mams	1524
Project Name	**Twyfelaar ESIA**	Coordinate System	
Project No.	DAG5601	Final Depth (m)	49
Drilled By	Hall Core Drilling	Water Level (mbgl)	2.5
Date Drilled	10th August 2019	Colar Height (m)	
		Logged By	Kgaugelo Thobejane

PERCUSSION DRILL LOG

Columns: LITHOLOGICAL DESCRIPTION | GEOLOGICAL PROFILE | DEPTH mbgl | Weathering (Slight, Moderate, Very, Complete) | Penetration rate (mm.sec/m) | WATER STRIKE mbgl | BLOW YIELD L/s (measure at every water strike and rod change) | DEPTH mbgl | BOREHOLE DESCRIPTION | BOREHOLE CONSTRUCTIO

Lithological description (top to bottom): Alluvium; Weathered Sandstone; Carbonaceous Shale; Siltstone; Sandstone

Borehole description: Solid PVC 0 - 6 m; Perforated PVC 6 - 46 m

Blow yield: 0.5 (at 30 mbgl)

Depth scale (mbgl): 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65

Penetration rate (mm.sec/m), top to bottom:

28.55	62.46	46.83	50.59	50.57	54.36	51.80	54.99	34.12	95.27
80.37	46.77	54.23	109.11	76.90	65.41	64.08	57.38	55.47	54.69
52.79	54.64	71.30	73.36	71.62	86.38	76.46	64.43	78.22	78.38
64.09	74.83	64.07	82.31	74.03	74.28	75.01	85.90	80.68	61.14
82.45	82.11	92.54	85.21	77.72	74.12				

Comment:

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CLIENT	**Dagsoom Coal Mine**	**BOREHOLE ID**	**DAGBH06**
Province	Mpumalanga	X-coordinate	030° 14' 17.1"
Location	Ermelo	Y-coordinate	26° 41' 49.15"
Site		Z-coordinate (mams	1526
Project Name	**Twyfelaar ESIA**	Coordinate System	
Project No.	DAG5601	Final Depth (m)	45
Drilled By	Hall Core Drilling	Water Level (mbgl)	24.5
Date Drilled	10th August 2019	Colar Height (m)	
		Logged By	Kgaugelo Thobejane

PERCUSSION DRILL LOG

Columns: LITHOLOGICAL DESCRIPTION | GEOLOGICAL PROFILE | DEPTH mbgl | Weathering (Slight, Moderate, Very, Complete) | Penetration rate (mm.sec/m) | WATER STRIKE mbgl | BLOW YIELD L/s (measure at every water strike and rod change) | DEPTH mbgl | BOREHOLE DESCRIPTION | BOREHOLE CONSTRUCTIO

Lithological description (top to bottom):

LITHOLOGICAL DESCRIPTION
Alluvium
Highly weathered sandstone
Mudstone
Weathered Sandstone
Carbonaceous shale
Siltstone
Carbonaceous shale
Sandstone
Coal (half a meter)
Sandstone
Carbonaceous shale
Sandstone
Carbonaceous shale
Siltstone

Penetration rate (mm.sec/m), per metre from surface:

1	42.96
2	45.69
3	48.64
4	50.60
5	47.30
6	48.35
7	52.80
8	54.01
9	62.89
10	63.08
11	50.07
12	56.72
13	73.25
14	61.12
15	68.27
16	60.95
17	82.03
18	59.38
19	45.44
20	55.39
21	63.78
22	74.76
23	77.92
24	53.01
25	60.24
26	48.19
27	42.19
28	65.31
29	85.67
30	95.73
31	83.17
32	106.34
33	96.03
34	102.61
35	81.15
36	75.15
37	59.96
38	75.59
39	59.96
40	75.59
41	94.09
42	75.01
43	81.02
44	104.15
45	96.15

Depth scale (mbgl): 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65

Borehole description:
- Solid PVC 0 - 6 m
- Perforated PVC 6 - 45 m

Comment:

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48 Grosvenor Road
Bryanston, 2191
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CLIENT	**Dagsoom Coal Mine**	**BOREHOLE ID**	**DAGBH07**
Province	Mpumalanga	X-coordinate	030° 13' 18.2"
Location	Ermelo	Y-coordinate	26° 42' 42.7"
Site		Z-coordinate (mams	1510
Project Name	**Twyfelaar ESIA**	Coordinate System	
Project No.	DAG5601	Final Depth (m)	43
Drilled By	Hall Core Drilling	Water Level (mbgl)	2.37
Date Drilled	08/08/2019	Colar Height (m)	
		Logged By	Kgaugelo Thobejane

PERCUSSION DRILL LOG

Column headings: LITHOLOGICAL DESCRIPTION | GEOLOGICAL PROFILE | DEPTH mbgl | Weathering (Slight, Moderate, Very, Complete) | Penetration rate (mm.sec/m) | WATER STRIKE mbgl | BLOW YIELD L/s (measure at every water strike and rod change) | DEPTH mbgl | BOREHOLE DESCRIPTION | BOREHOLE CONSTRUCTIO

Lithological description (top to bottom): Mudstone; Weathered Sandstone; Carbonaceous shale; Coal; Sandstone; Carbonaceous shale; Sandstone

Penetration rate (mm.sec/m), per metre from 0 m:

47.81, 50.05, 51.59, 53.00, 52.70, 49.93, 51.18, 62.62, 63.59, 61.15, 122.22, 63.23, 77.21, 65.87, 70.22, 71.80, 164.13, 58.29, 86.59, 61.07, 130.86, 75.54, 116.64, 160.07, 78.69, 63.71, 69.94, 75.50, 62.72, 158.02, 82.83, 75.50, 78.59, 148.78, 62.19, 60.24, 74.00, 68.36, 74.26, 148.66, 71.79, 137.97

Blow yield L/s: 2.2

Borehole description: Solid PVC 0 - 6 m; Perforated PVC 6 - 42 m

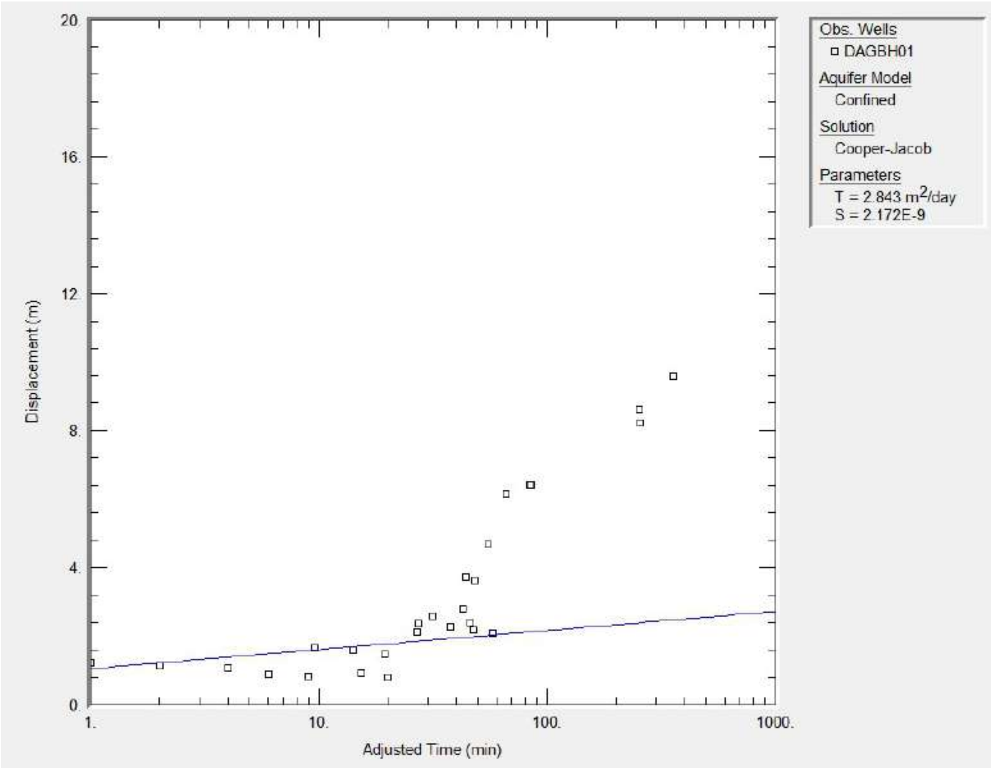
Depth scale: 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65

Comment:

Appendix B: Aquifer test results

Appendix X Aquifer Test Analyses

DAGBH01



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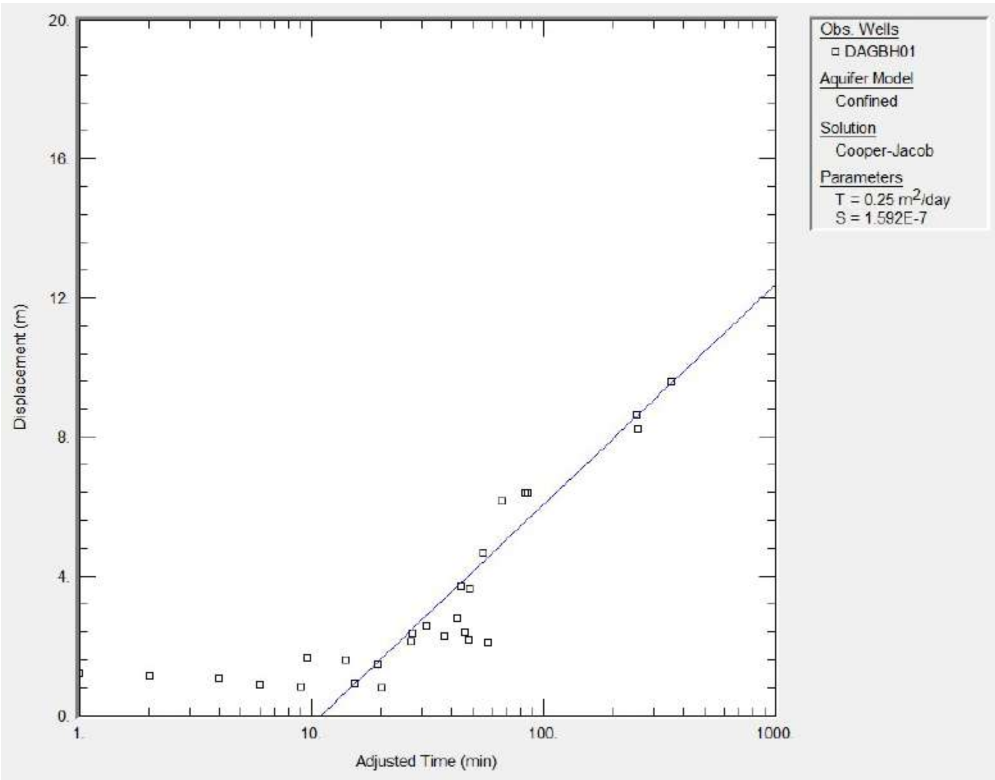

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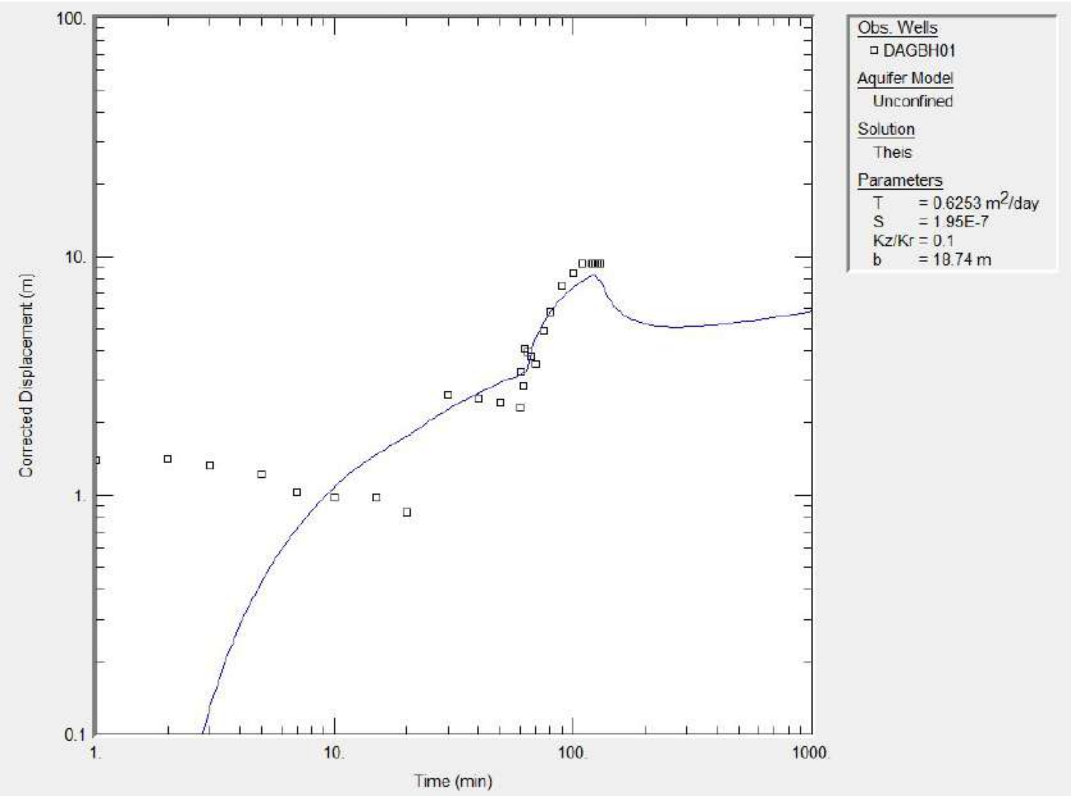

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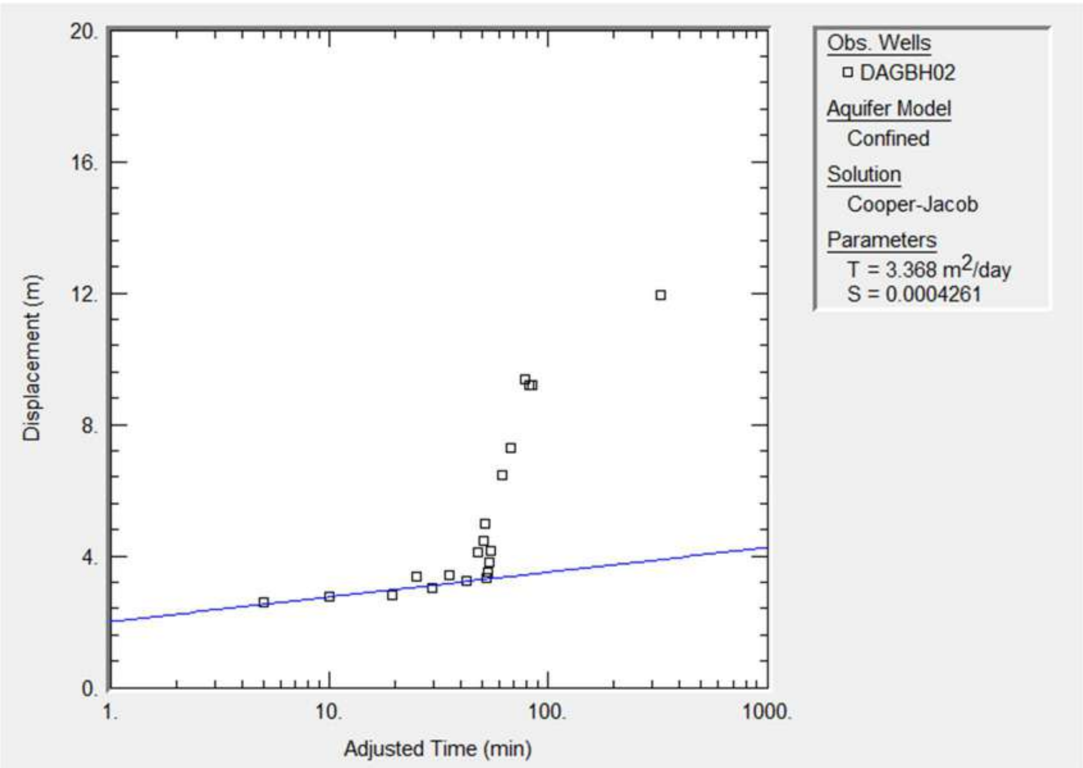

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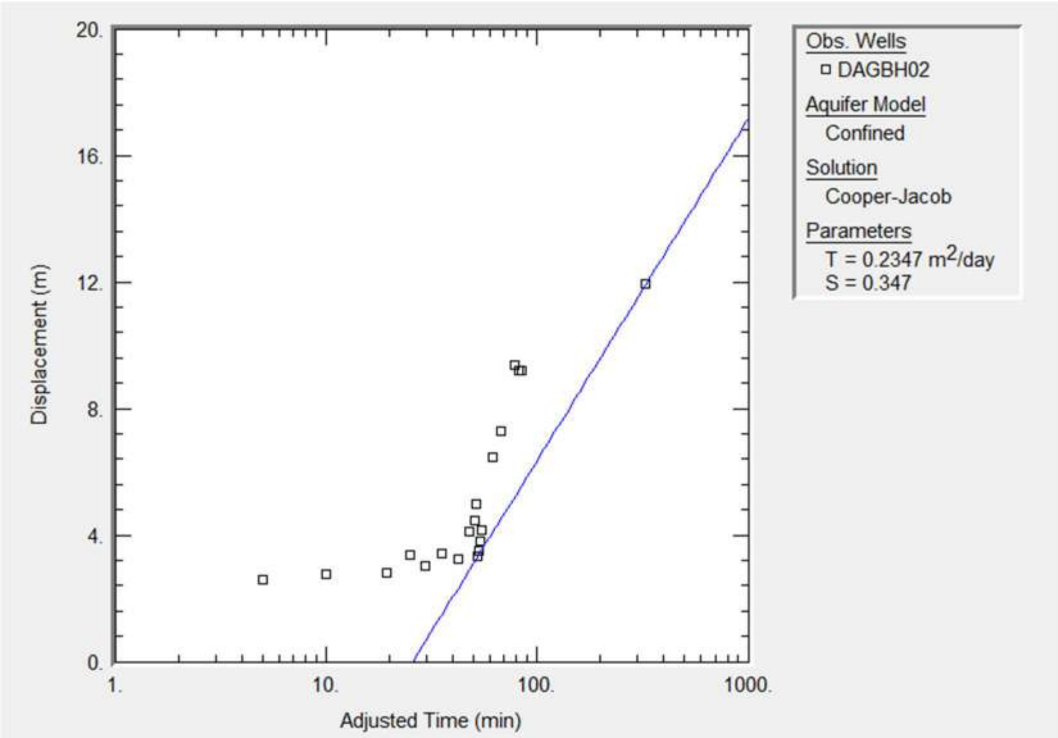

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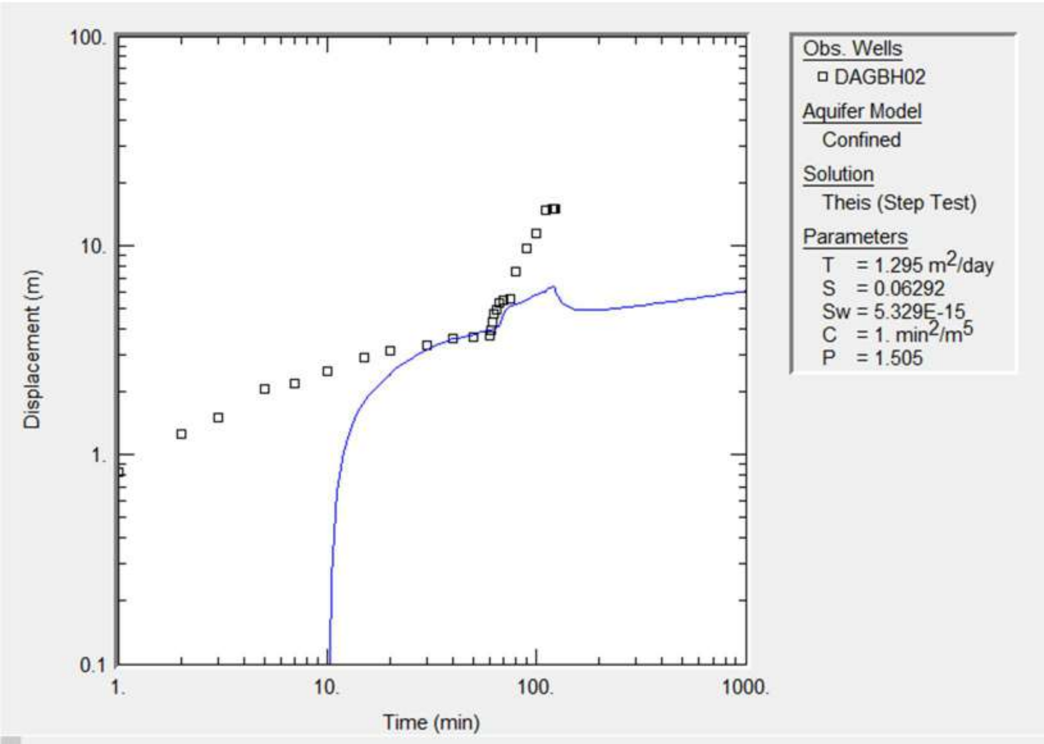

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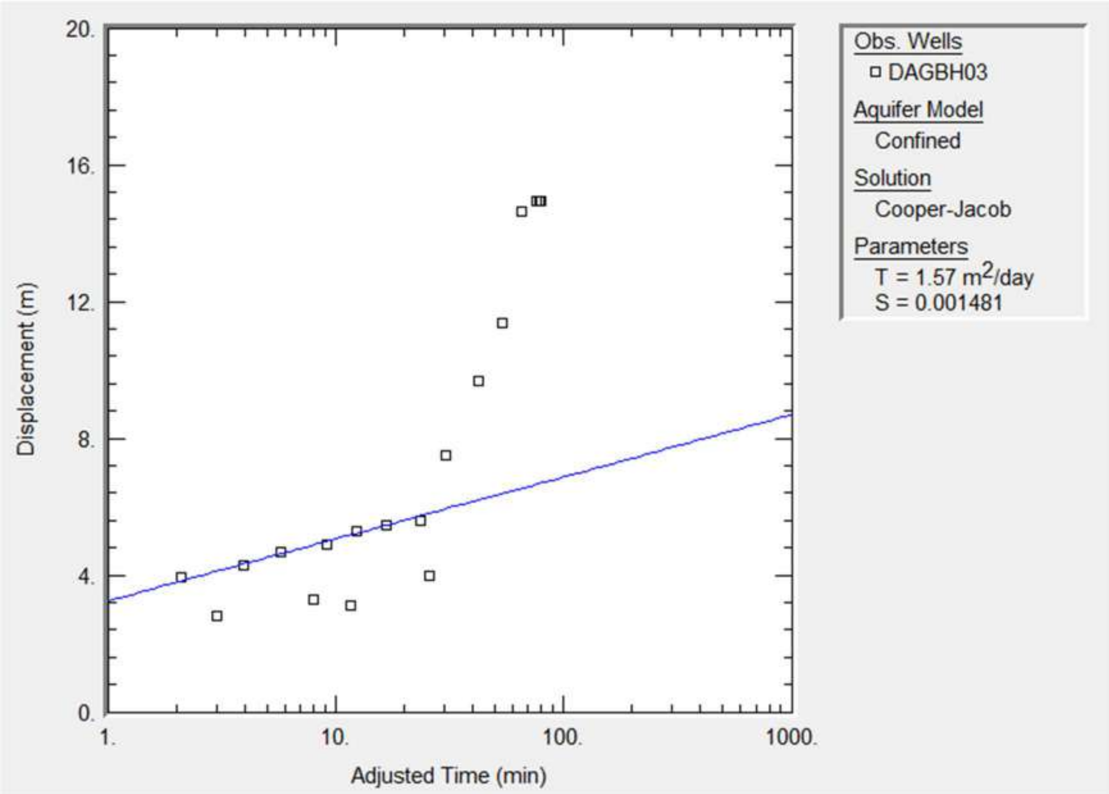

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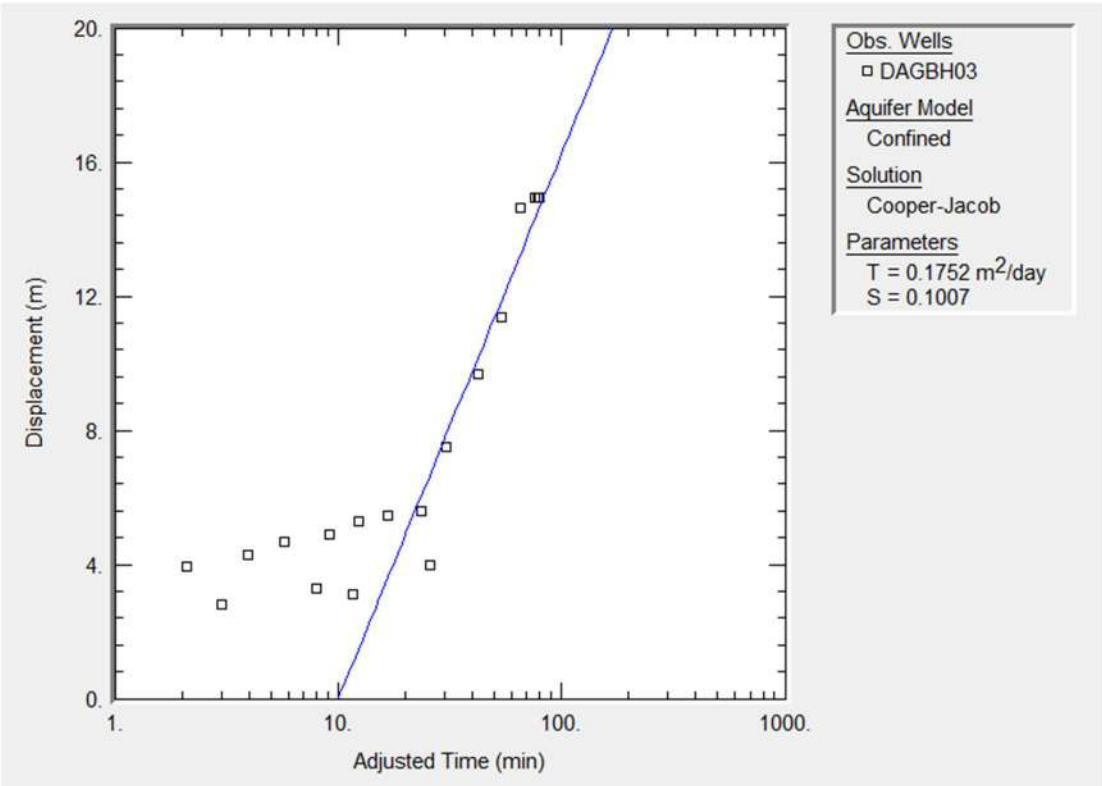

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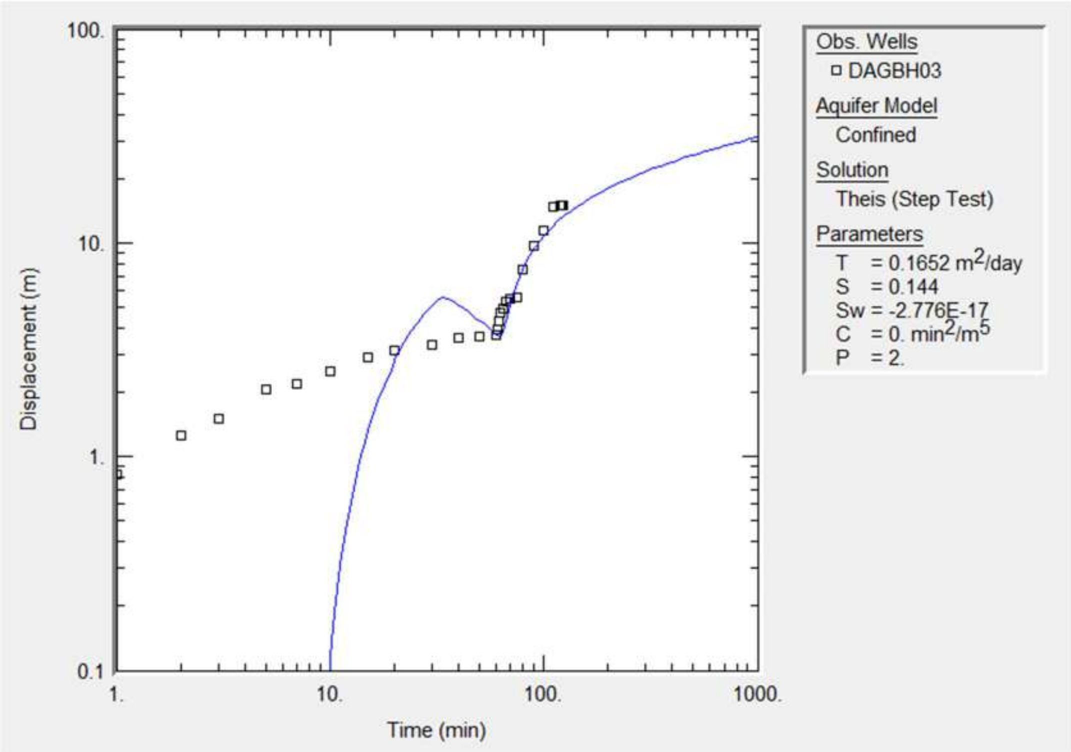

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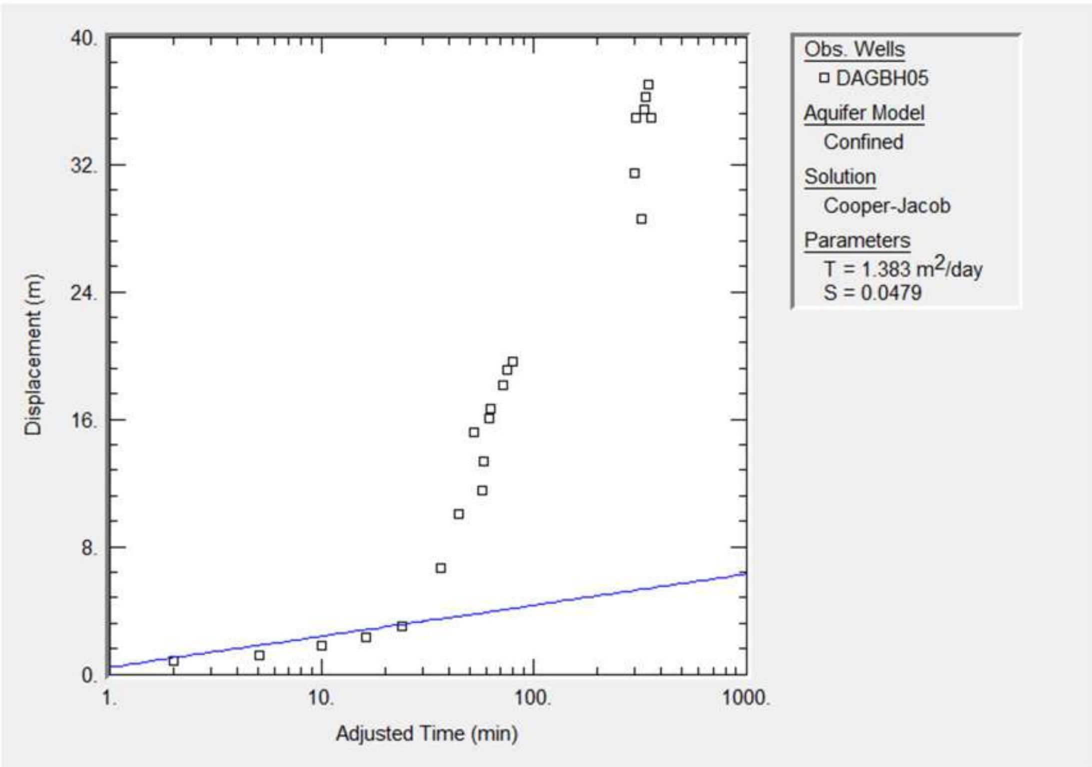

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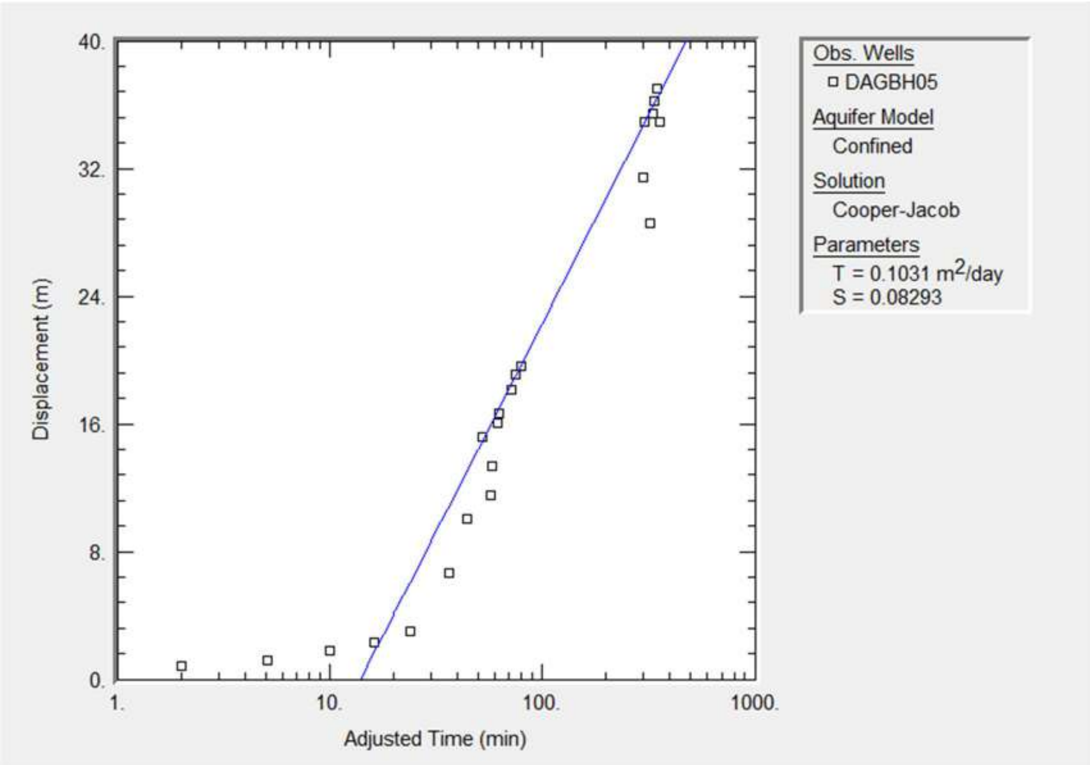

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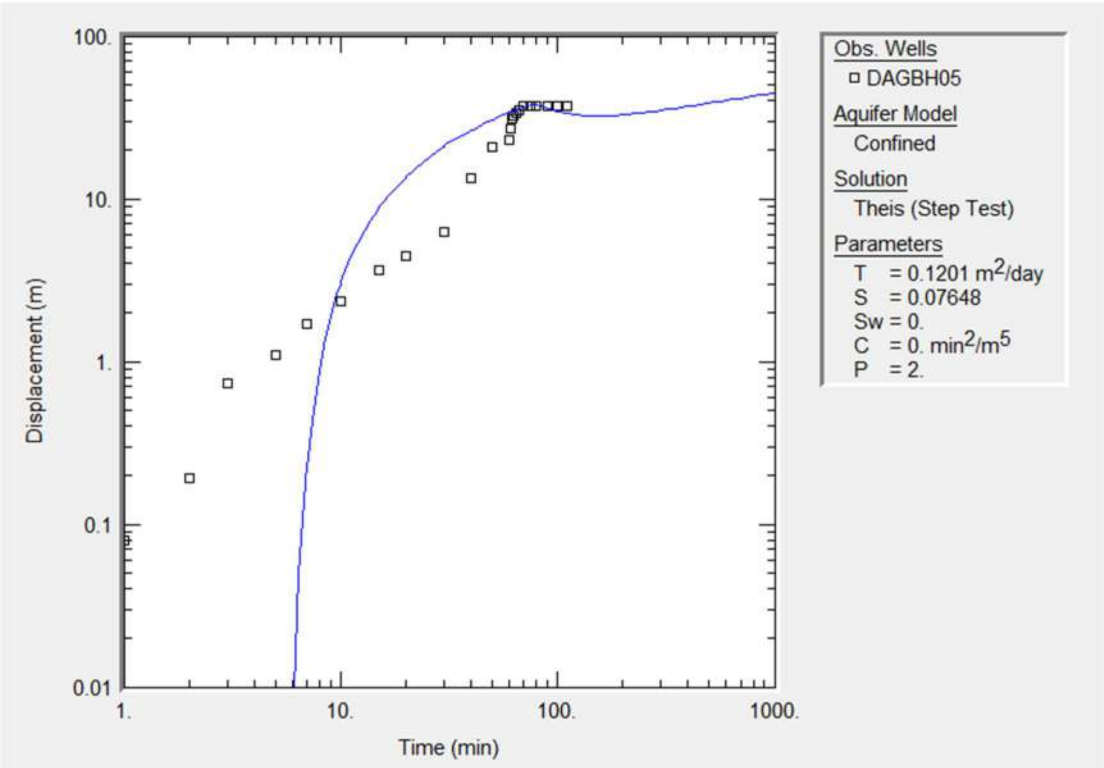

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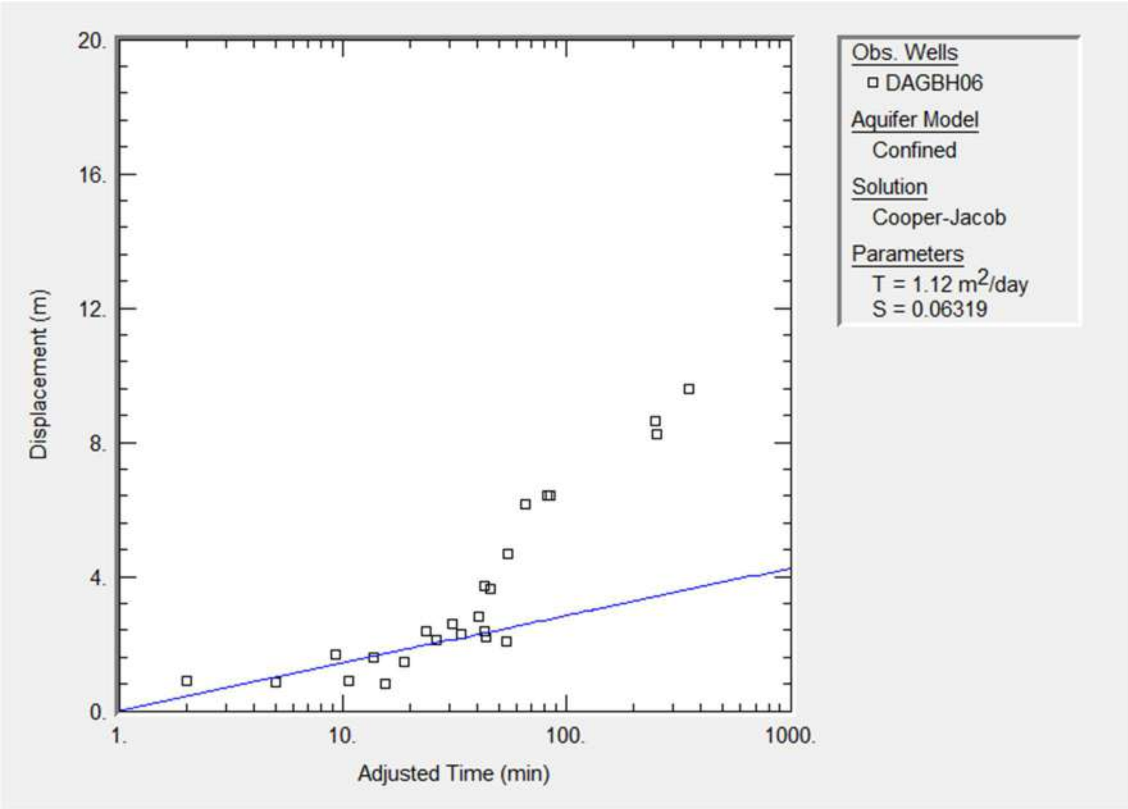

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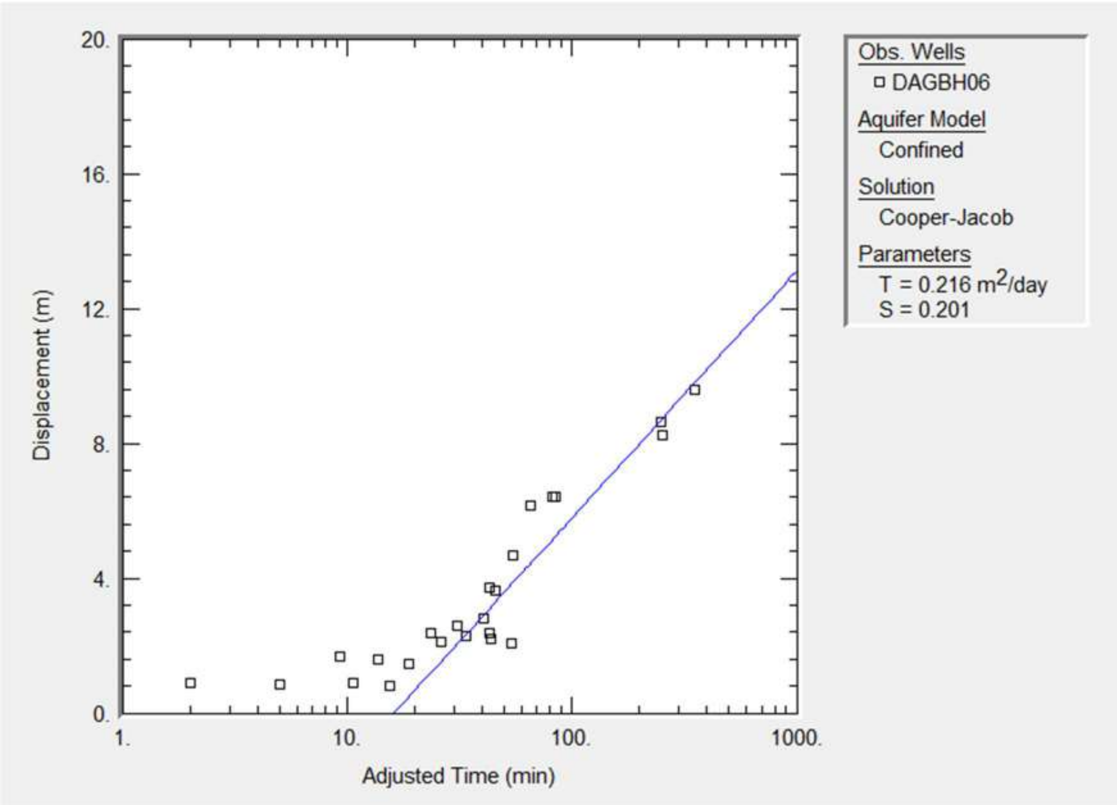

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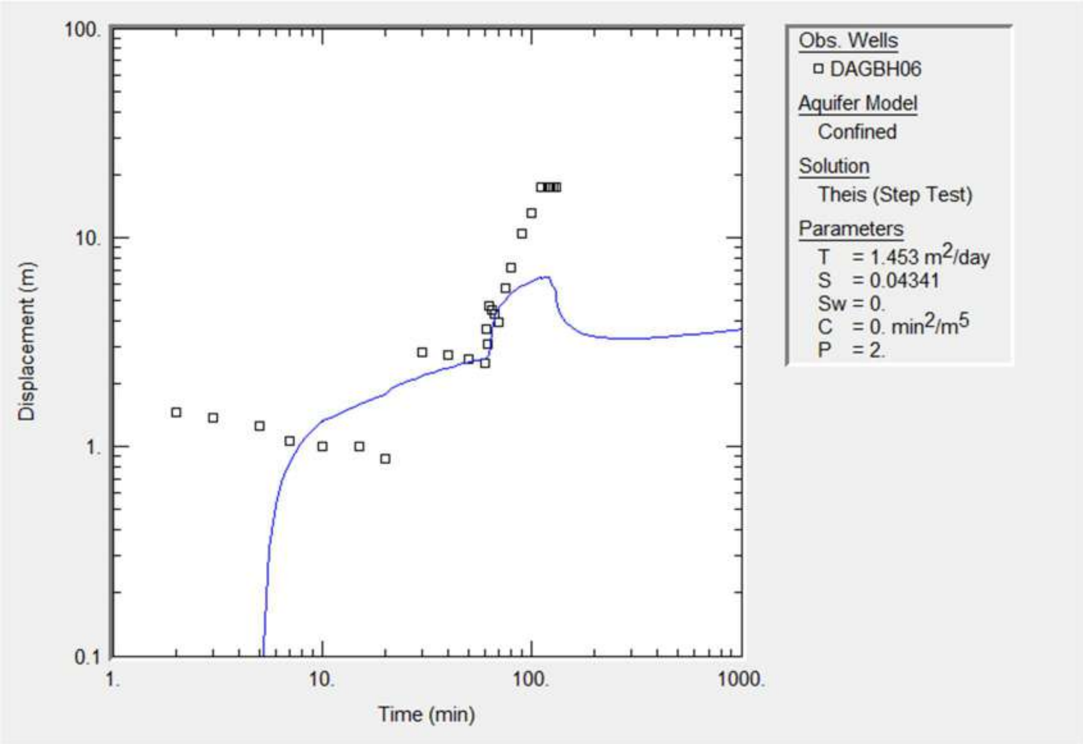

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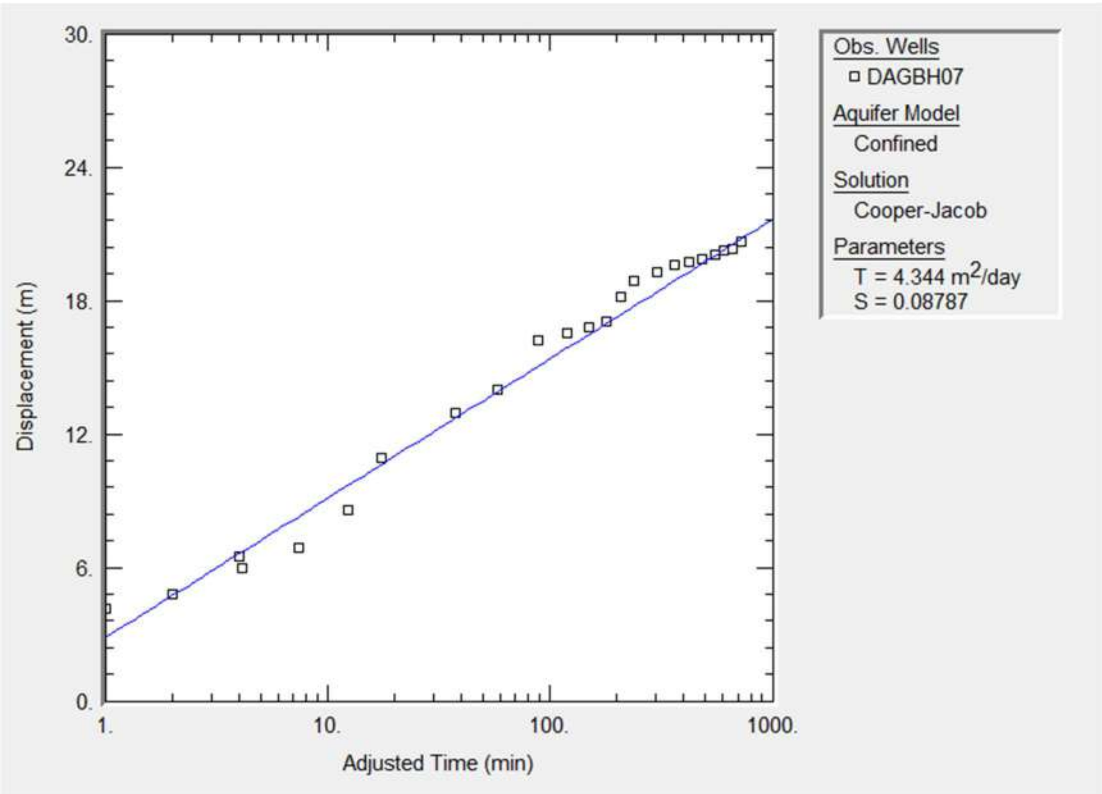

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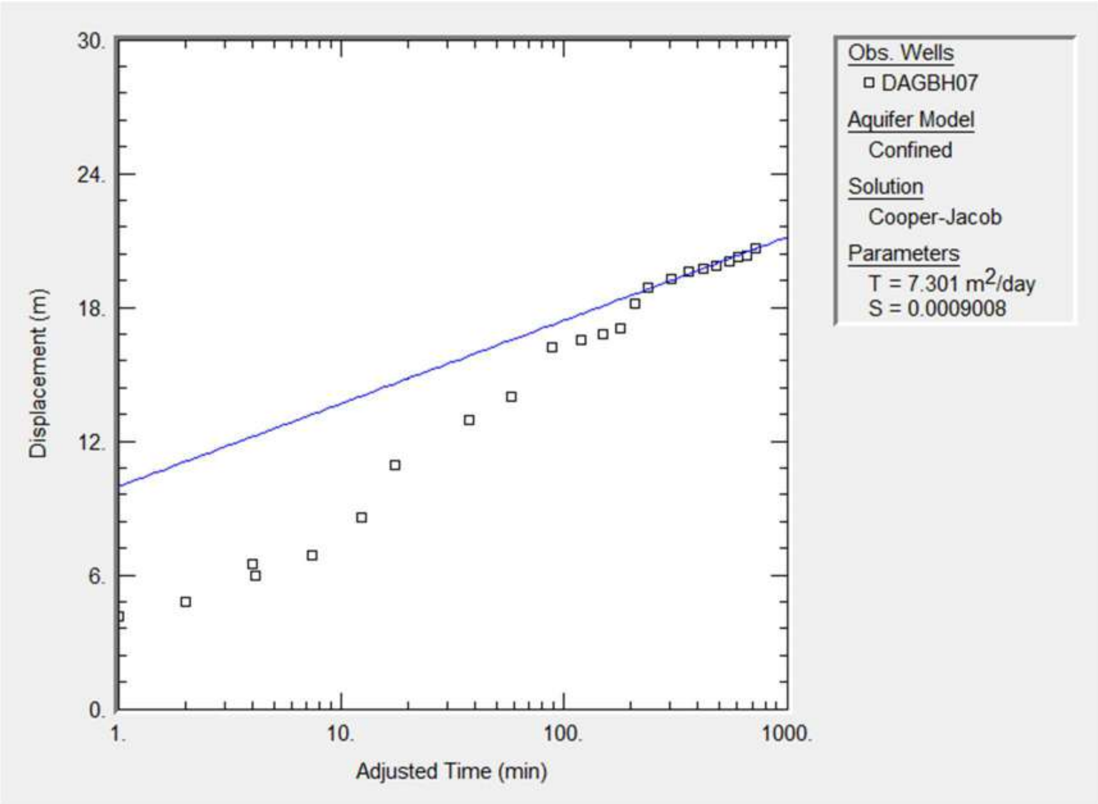

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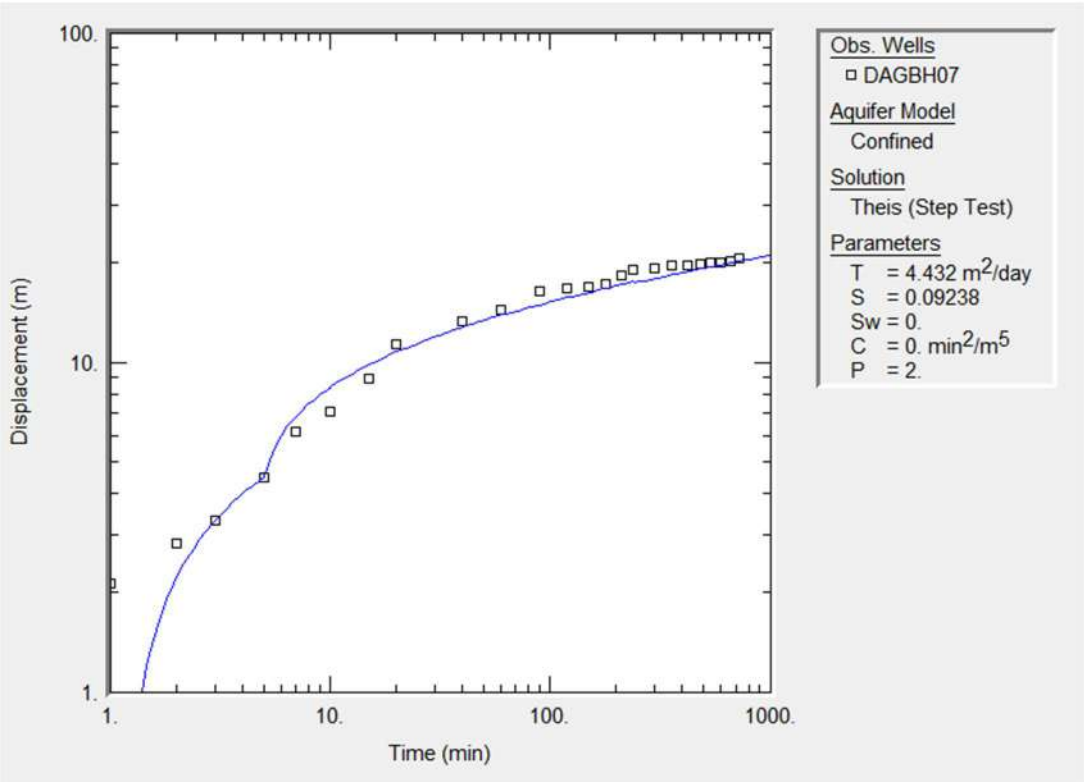

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Appendix C: Geochemical Assessment and Waste Classification

DIGBY WELLS
ENVIRONMENTAL

Geochemical Assessment and Waste Classification

Dagsoom Twyfelaar Coal Mining Project near Ermelo, Mpumalanga

Project Number:

DAG5601

Prepared for:

Dagsoom Coal Mining

October 2019

Digby Wells and Associates (South Africa) (Pty) Ltd
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This document has been prepared by Digby Wells Environmental.

Report Type:	**Dagsoom Twyfelaar Coal Mining Project near Ermelo, Mpumalanga**
Project Name:	**Geochemical Assessment and Waste Classification**
Project Code:	**DAG5601**

Name	**Responsibility**	**Signature**	**Date**
Kgaugelo Thobejane	Reporting		20 September 2019
Andre van Coller	Reviewer		29 September 2019
Xanthe Taylor	Project Manager		15 October 2019

DECLARATION OF INDEPENDENCE

Digby Wells and Associates (South Africa) (Pty) Ltd

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

Kgaugelo Thobejane

Full Name:	Kgaugelo Thobejane
Title/ Position:	Assistant Geochemist
Qualification(s):	BSc Hons. (mining and Geology)
Experience (Years):	<1 year
Registration(s):	*SACNASP Cand.Nat.Sci (120881)*

EXECUTIVE SUMMARY

Digby Wells Environmental (hereafter Digby Wells) was appointed by Dagsoom Coal Mining (Pty) Ltd (hereafter Dagsoom) to conduct a geochemical assessment and waste classification on the coal material at the proposed Twyfelaar Mine (the Project) with the aim of quantifying the acid generation potential and waste classification of coal and waste material.

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

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

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

The project situated within the Ermelo coalfield on the eastern escarpment of the Mpumalanga Highveld. The Ermelo Coalfields extends from Carolina in the north to Dirkiesdorp in the south encompassing a surface area of ~11,250,000 ha. Within and around the project area is predominantly underlain by Formations of the Karoo Supergroup with dominant lithologies present in the area being coal-bearing sandstone, mudstone, siltstone, carbonaceous shale and coal seams of the Vryheid Formation with dolerite dyke and sill type intrusions of the Karoo Dolerite Suite. The mineralogy of samples collected indicated there were coal materials demonstrated by amorphous minerals and there was also presence of sedimentary rocks from the waste rock material indicated by clay minerals. There are no acid generating minerals detected in all samples apart from coal sample DSC1.

The Acid Potential (AP) and Neutralising Potential (NP) of a sample is linked to the mineralogy and the reactions formed under aerobic conditions. When these parameters are used to calculate the Net Neutralising Potential (NNP = NP – AP) and Neutralising Potential Ration (NPR = NP/AP) an indication of the non-acid mine drainage potential can be reached. All waste rock material and coal sample DSC1 are potentially acid generating with negative while DSC2 is non-acid forming.

The coal and waste materials situated in the boreholes are classified as a Type 3 waste and needs to be disposed at a Class C landfill site or a facility with a similarly performing liner system. The Type 3 waste classification is only due to the leachate concentration results being above the LCT0 guideline values. LCT0 limits derived from human health effect values for drinking water, as published by the Department of Water and Sanitation (DWS), South African

National Standards (SANS), World Health Organization (WHO) or the United States Environmental Protection Agency (USEPA). According to the test methodologies followed and the results of the leachable concentrations the risk of elements leaching into the receiving environment from the waste facility is low.

From the laboratory analysis and waste classification results the following recommendations are made:

- The waste and coal materials are classified as a Type 3 waste and disposal of the material should be done to a Class C landfill facility or a facility with a similar performing liner system;
- Due to the variation of the coal samples one being potential acid generating while the other is not, additional sampling and test work is required to determine the average AMD potential of the coal seam that will be mined. This will need to be done on a larger sample population distributed across all coal seams and waste rock lithologies to statistically back any conclusions;
- Implementation of the stormwater management plan as recommended in the surface water assessment; and
- The leachate factor of 1:20 used for waste classification is conservative and diluted approach. The leachate results of these tests can lead to a diluted result not always presenting the true concentrations to be expected on site once mining has started. For this reason, the expected sulphate concentration in the seepage water will be more than what has been observed in the results and a conservative approach of SO4 of more than 1200 mg/L should be used for the contaminant transport modelling in the groundwater assessment.

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1 Introduction

Digby Wells Environmental (hereafter Digby Wells) was appointed by Dagsoom Coal Mining (Pty) Ltd (hereafter Dagsoom) to conduct a geochemical assessment and waste classification to evaluate if the coal and waste materials that will be generated as a result of mining will be acid generating or not and to classify the waste materials in terms of the National Environmental: Waste Management Act, 2008 (Act No. 59 of 2008), as amended (NEM:WA). The following terms of refence were provided:

- Assess the acid generating potential of the coal material that will remain underground as well as stockpiled;
- Assess the leachate potential of the stockpiled material as well as the release of heavy metals from the remaining mine voids; and
- Advise on the required liner to be installed for the stockpiles.

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

1.1 Scope of Work and Methodology

1.1.1 Site visit and Sampling

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

1.1.2 Laboratory Tests

The following sample preparation and tests were done on the samples submitted as discussed in section 1.1.1:

Coal and Discard Material

Two coal samples and six waste rock samples were taken for laboratory analyses. The samples were submitted for the following test work:

- XRD and XRF to determine the mineralogy of each sample;
- ABA, NAG and Sulphur Speciation to determine the acid generating and/or acid neutralising potential of each sample. This allows an evaluation of the potential for AMD;
- *Aqua Regia* Digestion with full Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) Quant to evaluate the total chemical makeup of the material and to determine the Total Concentrations (TC) for evaluation against the waste classification Total Concentration Threshold (TCT) guideline values; and
- Distilled water leachate tests at a ratio of 1:20 (solid: liquid) with pH, Electrical Conductivity (EC), Alkalinity, P-Alkalinity (for carbonate and bicarbonate calculations), Total Dissolved Solids (TDS), Fluorine (F), Chlorine (Cl), Nitrate (NO_3), Cyanide (CN), Sulphate (SO_4), Nickel (Ni), Arsenic (As) and Manganese (Mn)to determine the leachable concentrations of the material to compare it to the waste classification Leachable Concentration Threshold (LCT) National Environmental Management: Waste Amendment Act 2014 (Act No. 26 of 2014) guideline values.

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

1.2 Deliverables

The following deliverables are provided in this report:

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

1.3 Study Limitations and Assumptions

The following limitations and assumptions apply:

- XRD Results:
  - Mineral names may not reflect the actual compositions of minerals identified, but rather the mineral group;

- Due to preferred orientation and crystallite size effects, a small percentage error may occur in the mineral distribution, but the general proportion of minerals and their presence is accurate; and
- Sample contained organic carbon and the results presented were checked by the lab against the amount of material losses on ignition during other static tests.

- Sulphur Speciation:
  - Samples were analysed with Pyrolysis at 550°C, as per Prediction Manual for Drainage Chemistry from Sulphidic Geological Materials MEND Report 1.20.1; and
  - Organic Sulphur was not tested for but may be present in the test results.
- Leachate Tests and Characterisation
  - The distilled water leachate tests are a static method applied to identify potential elements of concern;
  - Distilled water tests were done at a neutral pH (7) at a solid:liquid ratio of 1:20; and
  - NEM: WA classification thresholds were used as a reference point in characterising the leachate quality. This report is intended to serve as a waste classification and guideline on liner requirements.

2 Geology

2.1.1 Regional geology

The Project area (now Mining Right boundary) is situated within the Ermelo coalfield on the eastern escarpment of the Mpumalanga Highveld. The Ermelo Coalfields extends from Carolina in the north to Dirkiesdorp in the south encompassing a surface area of ~11,250,000 ha. The project area specifically lies within the eastern boundaries of the Ermelo Coalfield which is defined by the sub-outcrop of the coal-bearing strata against the pre-Karoo basement.

The regional geology in and surrounding the project area is predominantly underlain by Formations of the Karoo Supergroup with a total thickness of sedimentary rocks ranging between 0 - 100 m. The dominant lithologies present in the project area are coal-bearing sandstone, mudstone, siltstone, carbonaceous shale and coal seams of the Vryheid Formation with dolerite dyke and sill type intrusions of the Karoo Dolerite Suite present in and around the project area (Figure 3-1). The Vryheid Formation, part of the Ecca Group, rests unconformably on diamictites and associated glaciogenic sediments of the Dwyka Group or, in the absence of Dwyka, on granitic basement rocks (Johnson et. al, 2006).

The coal reserve of the Vryheid Formation intersected in the project area is confined to the topographical setting of a ridge. The ridge rises approximately 200 m above the surrounding valleys and is capped by a dolerite sill with a perceived thickness of ~35 m. The sill is situated at ~115 m above the upper coal seam and has protected the coal seams from erosion.

Aside from the cap sill, no other significant dolerite intrusions were recorded in the exploration boreholes (ECMA, 2014). Eight coal seams (A, BU, BL, CU, CL, DU, D and E) were logged below the sill cap and outcrop around the slopes of the ridge with the C-seam being the main target for the proposed development. No faults or dykes were discovered during the exploration phase but could still be present at the site.

3 Sample Description

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

Table 3-1: Sample Description

No.	Laboratory ID	Reporting ID	Origin/Description	Exploration Boreholes
1	L5001	DSD1	Roof Sample of TW009	TW009
2	L5002	DSD2	Floor sample of TW009	TW009
3	L5003	DSD3	Roof Sample of TW002	TW002
4	L5004	DSD4	Floor sample of TW002	TW002
5	L5005	DSD5	Roof Sample of TW006	TW006
6	L5006	DSD6	Floor sample of TW006	TW006
7	1256419/ 1256936	DSC1	Coal Sample	
8	T7	DSC2	Coal Sample	DAGBH07

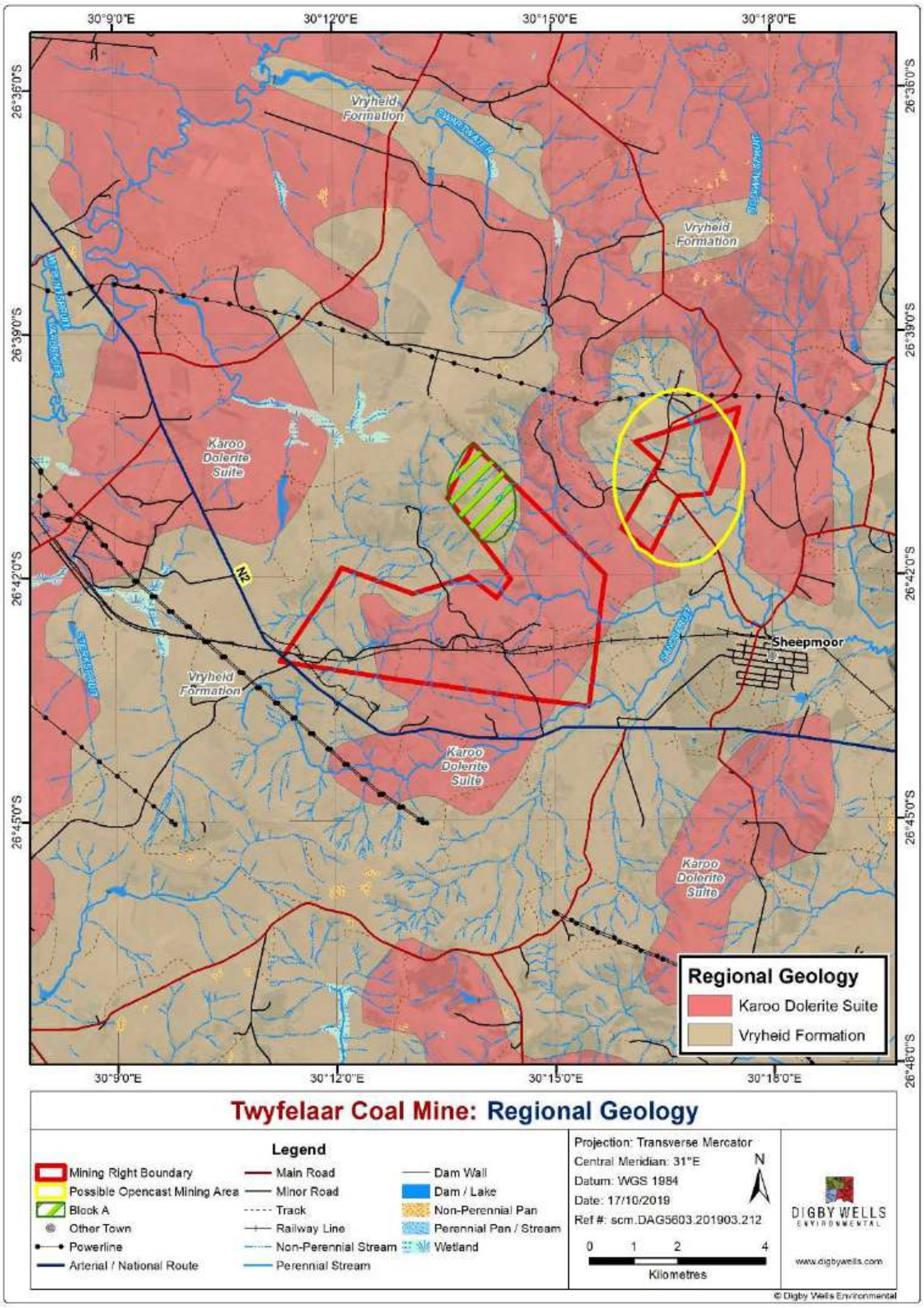

Figure 3-1: Regional geology of the mining right boundary

4 Mineralogy

All laboratory certificates are provided in Appendix A.

4.1 Waste Rock Material

Waste rock material samples were taken from floor and roof lithologies from exploration borehole cores, and coal material was collected from the main coal seam to be mined (C lower). The results are summarised in Table 4-1.

The XRD results show that the roof waste rock samples, namely DSD1, DSD3 and DSD5 are dominated mainly by kaolinite between ~35 and 47 Weight (wt.). %, and quartz between 28 and 34 wt. %, with minor microcline, chlorite, diopside, and muscovite; while sample DSD5 also includes calcite. No biotite was detected in DSD3, but diopside was detected In DSD1. The XRF data corelates with the XRD data with the first example that both methods detect the presence of clay minerals such as kaolinite which contains aluminium, and subsequently the results indicate a high Aluminium Oxide (Al_2O_3) content. A minor Iron (III) oxide (Fe_2O_3) content was also detected in support of the presence of biotite and chlorite minerals. A high Silicon Dioxide (SiO_2) content was detected as expected, as this forms part of all the minerals except calcite.

Similarly, the floor samples (DSD2, DSD4 and DSD6) indicate that kaolinite (between 37 and 48 wt. %) and quartz are the most dominant minerals (25 and 30 wt. %) with minor minerals such as microcline, muscovite and chlorite. In some cases, diopside is detected most notably in DSD2 which is the only floor sample that does not have calcite detected. Based on the XRD results there is no indication of sulphide minerals, however, soils and sediments may contain high levels of reduced inorganic sulphur. This may accumulate and lead to saline and sulphate rich water. The presence of chlorite indicates an alteration/change in the rock composition during a metamorphic event. Chlorite also acts as a cementing agent for sedimentary rocks such as sandstone and siltstone. Neutralizing potential mineral calcite was detected in DSD4 and DSD6 from the floor samples and from the roof samples it was only detected in DSD5.

The above-mentioned mineralogy is typical of the geology of the Vryheid Formation with sedimentary sequences of siltstone, sandstone, carbonaceous shale and mudstone dominating the area.

Table 4-1: XRD results for waste material

Mineral composition per sample (%)						
Mineral	**DSD1**	**DSD2**	**DSD3**	**DSD4**	**DSD5**	**DSD6**
Biotite	-	-	-	3.9	4.64	1.43
Calcite	-	-	-	0.97	1.72	0.79
Chlorite	3.41	5.01	4.12	7.61	7.26	6.86
Diopside	2.94	3.48	3.36	-	-	-
Kaolinite	46.68	48.21	41.91	37.4	34.53	40.41
Microcline	10.74	9.29	11.4	9.56	10.32	7.09
Muscovite	8.07	8.92	9.14	10.7	7.49	10.2
Quartz	28.16	25.09	30.07	29.86	34.04	30.09

4.2 Coal Material

Coal materials were sampled during the exploration programme with the XRD results demonstrated in Table 4-2.

The XRD results for the two coal samples show that these samples comprise predominantly of amorphous minerals which will be the coal or carbon material that was lost on ignition during the test work. Sample DSC1 comprises 80.05 % while DSC2 is at 34.9 %. The presence of pyrite in sample DCS1 was detected at 1.8 %. This is above 0.3%, indicating this sample could potentially be acid generating. There is also some neutralising potential in both coal samples in the form of mineral calcite, but sample DSC2 has the highest neutralising potential with a calcite content of 13.8%.

Table 4-2: XRD results for coal materials

Mineral composition per sample (%)		
Mineral	**DSC1**	**DSC2**
Amorphous	80.05	34.90
Anatase	1.18	1.44
Calcite	2.00	13.98
Kaolinite	6.89	12.68
Muscovite	3.61	8.79

Mineral composition per sample (%)		
Mineral	**DSC1**	**DSC2**
Plagioclase	1.65	5.60
Pyrite	1.80	
Quartz	2.82	22.61

5 Acid-Base Accounting Result

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

The main values used to classify materials as Non-Acid Forming (NAF), Potentially Acid Generating (PAG) are the NPR and sulphide sulphur content. If the NPR is below 1 there is a PAG (red cells), if the NPR is above 3 the sample is NAF (green cells). When the NPR is between 1 and 2, a balance exists between the buffering and acid producing reactions and a clear conclusion cannot be based on the NPR only. When focussing on the Sulphide Sulphur (SS) %, if the SS% is above 0.3 (red cells) it is generally accepted that this material will be PAG.

5.1 Waste Rock Material

The XRD and XRF results indicate relatively neutral mineralogy. However, the ABA, NAG and Sulphur speciation results indicate the potential for acid generation. The following conclusions were reached from the AMD test work with the main parameters and results shown in Figure 5-1:

- If the NAG pH is less than 4.5 which indicates a low acid generation potential. Where it approaches 0 it indicates a high acid generating potential and if the pH is higher than 4.5 it indicates no acid generation potential. Based on the NAG pH, samples DSD2 and DSD4 have a high acid generating potential, DSD1 has low capacity acid generating potential while DSD4, DSD5 AND DSD6 are potentially non-acid generating;
- A negative NNP indicates an acid generating potential. Based on this, all samples have acid forming potential;

- The NPR is less than 1 for all samples and this means that the samples are potentially acid generating, unless sulphide minerals are non-reactive;
- The SS% is above 0.3% and this also confirms the acid generating potential for all samples depending on the reactivity of the sulphide; and
- All samples can be classified as PAG and therefore have the potential to form AMD.

5.2 Coal Material

The XRD and XRF results indicate relatively neutral mineralogy for one sample (DSC2) while the sample, DSC1, is potentially acid generating. The following conclusions were reached from the AMD test work with the main parameters and results shown in Figure 5-1:

- NAG pH for DSC1 is 2.2, indicating a high acid generating potential, while DSC2 has a NAG pH of 6.9 which indicates this sample is non-acid generating;
- A negative NNP was indicated for sample DSC1 while a positive NNP was indicated for sample DSC2;
- The sulphide-sulphur contents for samples DSC1 and DSC2 were 1.82 and 0.76, respectively; and
- Sample DSC1 is classified as PAG with a risk of AMD formation where sample DSC2 is classified as non-acid forming (NAF).

5.3 AMD Conclusion

Based on the AMD results, the following was concluded:

- All waste rock samples and coal sample DSC1 are potentially acid generating with a risk of AMD formation; and
- Sample DSC2 coal material is the only sample that is non-acid forming.

Table 5-1: ABA and SS% Results

Sample ID	NAG pH	Net Neutralization Potential (NNP) = NP – AP (kg CaCO3/t)	Neutralising Potential Ratio (NPR) (NP: AP)	Total Sulphur (%) (LECO)	Sulphate (SO_4^{2-}) Sulphur (%)	Sulphide (S^{2-}) Sulphur (%)
DSD1	3.80	-12.20	0.53	0.83	0.02	0.81
DSD2	3.20	-16.13	0.23	0.68	0.01	0.68

Sample ID	NAG pH	Net Neutralization Potential (NNP) = NP – AP (kg CaCO3/t)	Neutralising Potential Ratio (NPR) (NP: AP)	Total Sulphur (%) (LECO)	Sulphate (SO_4^{2-}) Sulphur (%)	Sulphide (S^{2-}) Sulphur (%)
DSD3	7.20	-11.40	0.58	0.86	0.04	0.82
DSD4	3.90	-7.10	0.74	0.87	0.03	0.83
DSD5	6.00	-6.40	0.72	0.75	0.01	0.75
DSD6	6.20	-6.40	0.72	0.73	0.01	0.72
DSC1	2.2	-33.4	0.42	1.84	0.08	1.82
DSC2	6.9	189	8.99	0.76	<0.01	0.76

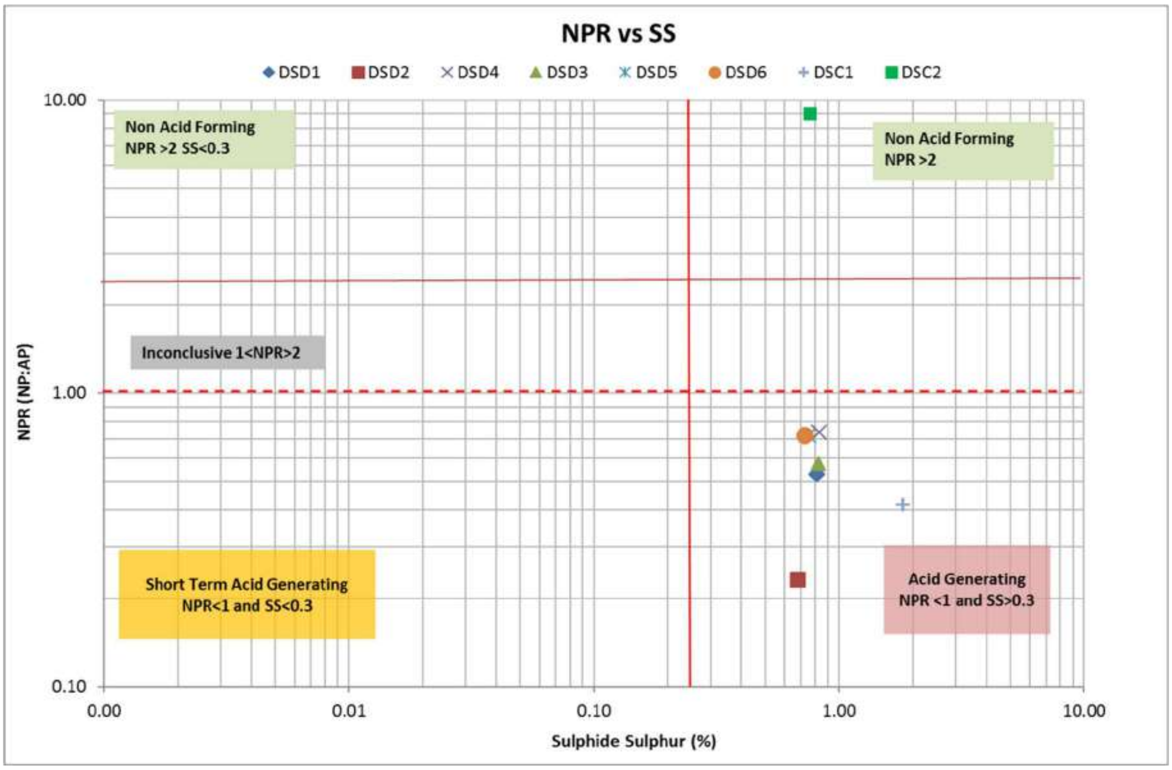

Figure 5-1: Waste rock and coal material AMD – NPR vs Sulphide Sulphur

6 Waste Classification

6.1 Legislative Guidelines

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

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

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

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

The Department of Environmental Affairs (DEA) has published

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

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

In addition, the quality of seepage from residue facilities needs to be predicted:

- Notice 1006 of 2014 (14 November 2014): Proposed Regulations to Exclude a Waste Stream or a Portion of a Waste Stream from the Definition of Waste.

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

6.2 Waste Classification Methodology

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

TCT limits are subdivided into three categories:

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

LCT limits are subdivided into four categories:

- LCT0 limits derived from human health effect values for drinking water, as published by the DWS, SANS, World Health Organization (WHO) or the United States Environmental Protection Agency (USEPA);

- LCT1 limits derived by multiplying LCT0 values by a Dilution Attenuation Factor (DAF) of 50, as proposed by the Australian State of Victoria;
- LCT2 limits derived by multiplying LCT1 values by a factor of 2; and
- LCT3 limits derived by multiplying the LCT2 values by a factor of 4.

GN R 634 identifies waste classes (Waste Types 0 to 4) ranging from high risk to low risk, based on comparison of the TCT and LCT of individual constituents in the waste against the following threshold limits. Waste is assessed by comparison of the total and leachable concentration of elements and chemical substances in the waste material to TCT and LCT limits as specified in the National Norms and Standards for Waste Classification and the National Norms and Standards for Disposal to Landfill as per Table 6-1 and .

Table 6-1: Waste Classification Criteria

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

6.3 Results and Classification

Results of the analysis of LC and TC are shown in Table 6-2 and Table 6-3 respectively and compared to threshold concentrations published in the NEM: WA Waste Classification and Management Regulations.

Waste Samples:

- DSD1
  - LCT0<Arsenic (As)<LCT1, and LCT0<cyanide (CN) < LCT1 values; and
  - Based on total concentrations, all parameters are below the TCT0 values.
- DSD1, DSD3 and DSD5

- LCT0< CN< LCT1 values; and
- Based on total concentrations, all parameters are below the TCT0 values.

- DSD4 and DSD6L5004 and L5006
  - All parameters for these samples are below LCT0; and
  - Based on total concentrations, all parameters are below the TCT0 values.

Coal Samples:

- DSC1
  - LCT0<As<LCT1, LCT0<Manganese (Mn), Nickel (Ni) and sulphate (SO_4) < LCT1 values; and
  - Based on total concentrations, all parameters are below the TCT0 values.
- DSC2
  - LCT0 <As <LCT1 values; and
  - Based on total concentrations, all parameters are below the TCT0 values.

Based on the outcome of leachate concentration at least one parameter such As, Mn, Ni, SO_4 and CN failed to be below the LCT0 in all samples with an exception of DSD1 and DSD6. On these bases, the waste and coal material are classified as Type 3. If disposed of at a landfill disposal site or alternative site on surface requires a Class C liner or similar demonstrated in

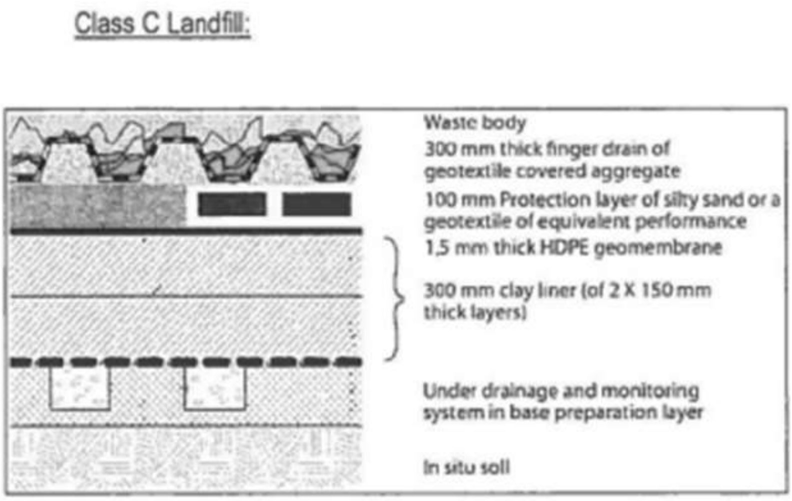

Figure 6-1 .

Class C Landfill:

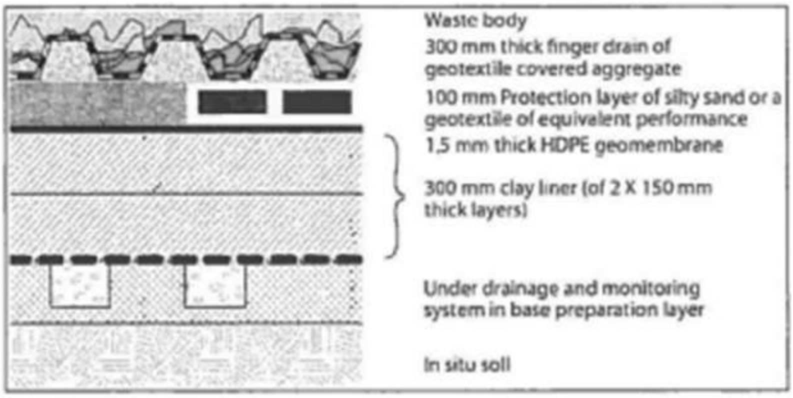

Figure 6-1: Class C Liner Design

Table 6-2: LCT Classification (mg/L) Results

Parameter	Unit	SANS241-2015 Drinking Water	DSD1	DSD2	DSD3	DSD4	DSD5	DSD6	DSC1	DSC2	LCT0	LCT1	LCT2	LCT3
As, Arsenic	mg/L	0.01	0.022	<0.02	<0.02	<0.02	<0.02	<0.02	0.022	0.028	**0,01**	**0.5**	**1**	**4**
B, Boron	mg/L	2.4	0.063	0.066	0.12	0.093	0.049	0.037	0.23	0.23	**0,5**	**25**	**50**	**200**
Cd, Cadmium	mg/L	0.003	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	0.001	**0,003**	**0,15**	**0,3**	**1,2**
Co, Cobalt	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.27	<0.001	**0,5**	**25**	**50**	**200**
Cr total	mg/L	0.05	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	**0,1**	**5**	**10**	**40**
Cu, Copper	mg/L	2	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	**2**	**100**	**200**	**800**
Mn, Manganese	mg/L	0.4	0.017	0.1	<0.001	<0.001	<0.001	<0.001	0.57	<0.001	**0,5**	**25**	**50**	**200**
Mo, Molybdenum	mg/L		0.004	0.001	0.012	0.011	0.011	0.006	0.003	0.031	**0.07**	**3.5**	**7**	**28**
Ni, Nickel	mg/L	0.07	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.8	<0.003	**0.07**	**3.5**	**7**	**28**
Pb, Lead	mg/L		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	**0.01**	**0.5**	**1**	**4**
Chloride as Cl	mg/L	300	1.5	1.24	1.83	1.65	1.43	0.98	3.3	2.8	**300**	**15000**	**30000**	**120000**
Sulphate as SO4	mg/L	500	58	62	28	31	19.7	20	364.2	7.33	**250**	**12500**	**25000**	**100000**
Nitrate as N	mg/L	11	0.1	0.1	0.2	0.1	<0.1	<0.1	0.35	0.37	**11**	**550**	**1100**	**4400**
F, Fluoride	mg/L	1.5	0.26	0.16	1.18	1.31	0.44	0.18	0.5	0.38	**1,5**	**75**	**150**	**600**
CN total, Cyanide total	mg/L		0.27	0.44	0.41	0.05	0.07	0.031			**0,07**	**3,5**	**7**	**28**
pH		5 to 9.7	7	6.5	7.3	7.4	7.5	7.5	6.94	7.11				

Table 6-3: TCT Classification (mg/kg) Results

Parameter	Unit	DSD1	DSD2	DSD3	DSD4	DSD5	DSD6	DSC1	DSC2	TCT0	TCT1	TCT2
As, Arsenic	mg/kg	<2.0	3.44	4.23	4.79	<2.0	2.01	5.3	3.89	5,8	500	2000
B, Boron	mg/kg	54	22	121	105	55	55	23	111	150	15000	60000
Cd, Cadmium	mg/kg	<0.10	0.15	0.47	0.19	<0.10	<0.10	<0.05	<0.14	7,5	260	1040
Co, Cobalt	mg/kg	14.32	3.52	14.21	8.24	8.82	11.79	13.68	11.49	50	5000	20000
Cr (IV), Chromium (IV)	mg/kg	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	6,5	500	2000
Hg, Mercury	mg/kg	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0,93	160	640
Mo, Molybdenum	mg/kg	<0.10	<0.10	<0.10	<0.10	0.59	<0.10	<0.10	<0.10	40	1000	4000
Ni, Nickel	mg/kg	26	9.88	45	26	15.23	27	29	27	91	10600	42400
Sb, Antimony	mg/kg	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	10	75	300
Se, Selenium	mg/kg	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	10	50	200
Chloride as Cl	mg/kg	<1	<1	<1	<1	3	<1	11	21	n/a	n/a	n/a
Sulphate as SO_4	mg/kg	0.07	<0.01	0.13	0.08	<0.01	0.04	0.23	<0.0	n/a	n/a	n/a
Nitrate as N	mg/kg	1.15	1.1	1.25	0.45	<0.5	<0.5			n/a	n/a	n/a
F, Fluoride	mg/kg	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.1	0.6	100	10000	40000
CN total, Cyanide total	mg/kg	0.65	0.81	0.63	0.81	0.42	0.67			14	10500	42000
pH		8.3	7.5	9.2	9.2	8.5	8.1	6.3	9.3			

7 Recommendations

- The waste and coal materials are classified as a Type 3 waste and disposal of the material should be done to a Class C landfill facility or a facility with a similar performing liner system;
- Due to the variation of the coal samples one being potential acid generating while the other is not, additional sampling and test work is required to determine the average AMD potential of the coal seam that will be mined. This will need to be done on a larger sample population distributed across all coal seams and waste rock lithologies to statistically back any conclusions;
- Implementation of the stormwater management plan as recommended in the surface water assessments; and
- The leachate factor of 1:20 used for waste classification is conservative and diluted approach. The leachate results of these tests can lead to a diluted result not always presenting the true concentrations to be expected on site once mining has started. For this reason, the expected sulphate concentration in the seepage water will be more than what has been observed in the results and a conservative approach of SO_4 of more than 1200 mg/L should be used for the contaminant transport modelling in the groundwater assessment.

Appendix A: Laboratory Certificates

Appendix D: Impact Assessment Methodology

Impact Assessment Methodology

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. 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 measure proposed in this report. The significance of an impact is then determined and categorised into one of eight categories, as indicated in Table, which is extracted from Table. The description of the significance ratings is discussed in Table.

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 1: Impact Assessment Parameter Ratings

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

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

Rating	Intensity/Replacability		Extent	Duration/Reversibility	Probability
	Negative Impacts (Nature = -1)	**Positive Impacts (Nature = +1)**			
	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.

Rating	Intensity/Replacability		Extent	Duration/Reversibility	Probability
	Negative Impacts (Nature = -1)	Positive Impacts (Nature = +1)			
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.
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 2: Probability/Consequence Matrix

Significance

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

Consequence

Table 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) (-)

Score	Description	Rating
-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) (-)