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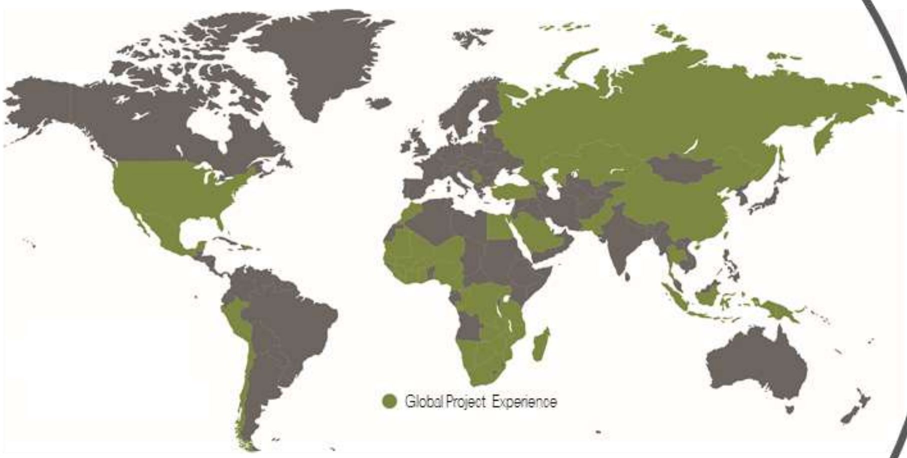

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Dalyshope Coal Environmental Impact Assessment

Hydrogeological Report

Prepared for:
Anglo Operations (Pty) Ltd

Project Number:
UCD6170

September 2020

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DETAILS AND DECLARATION OF THE SPECIALIST

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I, Robel Gebrekristos, declare that: –

- I act as the independent specialist in this application;
- I will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant;
  - I declare that there are no circumstances that may compromise my objectivity in performing such work;
  - I have expertise in conducting the specialist report relevant to this application, including knowledge of the Act, Regulations and any guidelines that have relevance to the proposed activity;
- I will comply with the Act, Regulations and all other applicable legislation;
- I have no, and will not engage in, conflicting interests in the undertaking of the activity;
- I undertake to disclose to the applicant and the competent authority all material information in my possession that reasonably has or may have the potential of influencing - any decision to be taken with respect to the application by the competent authority; and - the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority;
- All the particulars furnished by me in this form are true and correct; and

- I realise that a false declaration is an offence in terms of regulation 48 and is punishable in terms of section 24F of the Act.

13.09.2020

Signature of the Specialist *Date*

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EXECUTIVE SUMMARY

Anglo Operations Pty) Ltd (Anglo) has partnered with Universal Coal Development IV (Pty) Ltd (Universal) to participate in the proposed Dalyshope Coal Mining Project (the Project) through funding and managing the project development, including the Mining Right application.

Universal has appointed Digby Wells Environmental (hereinafter Digby Wells) as the Environmental Assessment Practitioner (EAP) to undertake environmental authorisations required for the proposed project. As part of this authorisations, an Environmental Impact Assessment (EIA) will have to be compiled and will be submitted.

This specialist report is compiled to feed into the overall EIA and assesses the potential impacts and mitigation plans on the groundwater environment during the construction, operation and closure phases of the project.

Baseline Hydrogeological Conditions

The main source of drinking water supply in and around the project area is groundwater through a number of solar energy, windmill, and submersible pumps which are mainly used for domestic and livestock watering.

A total of 88 private boreholes were surveyed, of which 10 are within the mining right area while 42 are within a 3 km radius of the mining right area. Of the 42 boreholes:

- 8 (9%) boreholes are used for game watering only;
- 20 (23%) are used for livestock watering;
- 11 (13%) are used for human drinking, gardening and livestock watering;
- 13 (15%) are used for groundwater monitoring;
- 12 (14%) are exploration holes (not boreholes) used for monitoring;
- 3 (3%) are not used; and
- The remaining 21 (24%) boreholes are unused.

None of the boreholes are of good water quality as they are all above the Class I category of the South African Water Quality Guideline (SAWQG) for domestic use. At least one of the tested parameters exceed the recommended limit, although the main elements of concern are Chlorine (Cl), Calcium (Ca) and Manganese (Mn). The water is generally not recommended for human drinking without treatment. The elevated element concentrations are mainly due to the natural dissolution of the host rocks. The only external impacts are associated with the elevated nitrate concentrations identified in one borehole which is associated with fertiliser application and/or animal waste as cattle often live nearby.

Noteworthy is the sulphate levels in these boreholes. The recommended maximum sulphate limit for drinking is 400 mg/L, but the concentration is currently less than 200 mg/L. Sulphate is expected to be an element of concern at Dalyshope Coal Mine based on the experience learned from other coal mines, including at Grootegeluk where it has reached up to 2 700 mg/L in some monitoring boreholes (Grootegeluk is the closest operational open pit mine located approximately 25 km southeast of the project area). The low levels of sulphate in all the boreholes suggests that no mine-related contamination has taken place at the project site. Sulphate could be considered as an indicator to assess the Dalyshope Coal Mine impact and the values obtained currently should be used as a baseline for future comparisons.

The groundwater level varies between 8 and 20 m below surface, with an average of 15.1 m. Under natural conditions, groundwater flow mimics the topography and regional surface water flow direction is towards the Limpopo River. However, local depression of water table could occur due to abstractions by the local farmers.

The coal deposit at Dalyshope Coal Mine is hosted in Karoo sedimentary sequence, which is comprised of interbedded shale, coal, carbonaceous shale, mudstone, siltstone and sandstone. The upper 20 m is highly weathered, while fractured rocks extends to about 100 m after which the sequence becomes more competent. Water strikes have been intercepted at depths between 20 and 100 m below ground level. Although some boreholes were drilled up to 160 m, no water strike was recorded below 100 m, defining the bottom of the aquifer. Unless disturbed by local abstraction, and possibly a localised perched aquifer, there is no change in hydraulic head even between shallow (<30m) and deep boreholes (>30m). The aquifer was therefore simplified into one layer.

The permeability values are as follows:

- Overall, the aquifer permeability ranges from very low (0.002 m/d) to very high (6.6 m/d); and
- The aquifer is highly heterogeneous with permeability values being variable in a relatively short distance.

Potential Impacts and Mitigation Measures

The main activities during the construction phase that could potentially result in groundwater impacts are associated with the site clearing and construction of the infrastructure. During the construction phase, all activities are expected to take place above the water table (15.1 m) and as such no impact on the groundwater is envisaged.

Mine dewatering is crucial to keep the mined area dry for safe working conditions during the operational phase. This can potentially impact the groundwater environment negatively by lowering the water level and creating a cone of depression. Depending on pit depth and mining sequence, the groundwater ingress is predicted to range between 0 and 3.4 ML/d (with an average of 1.5 ML/d). An important consideration is the possible cumulative impact associated with other proposed mining developments in the area, including the proposed Boikarabelo and Temo Coal Pits, neighbouring the proposed Dalyshope site. If these operations are established and operational together with the Dalyshope Coal Mine, the groundwater ingress will be lowered. Lowering the ingress will depend on the number of the nearby mines operating, the size and depth of the pits as well as the life of each mine.

In many instances, plant discard and inter-burden material has been stacked on discard dumps in the past, a practice that has led to the spontaneous combustion of the carbonaceous material on these dumps. To reduce or avoid the risk for spontaneous combustion and other surface impacts, Dalyshope Coal Mine will backfill the pit with discard and carbonaceous materials. The backfilling also has other advantages since it reduces surface waste storage costs and supporting unstable pit walls. However, if not managed properly, backfilling could have a significant environmental disadvantage since the in-pit storage of discards can contaminate the groundwater around the void. As water seeps through the backfill material, sulphates and metals could potentially dissolve and infiltrate to the groundwater zone. The environmental impact of the backfill can be managed if:

- The pit is not completely backfilled and contains a final void. The water table in the pit area should be lowered as part of the contaminant management plan whereby evaporation from the pit lake will keep the water level below the regional groundwater depth. The water level in the final void should always be below the regional water level taking advantage of the evaporation where it is approximately 1,950 mm/a, which is more than four times higher than the mean annual precipitation (438 mm/a).
- The potentially acid generating waste materials are deposited below the water table to avoid oxidation reactions.
- The waste rocks with neutralising potential are placed on top of the potentially acid-forming materials. Higher pH water that will seep from the alkaline waste rocks will neutralise low pH water released from the potentially acid forming materials placed underneath.

Groundwater model simulations show that the mine is unlikely to decant after closure due to the hydraulic sink. No decant mitigation is required, since no decanting is expected to occur. However, time-series groundwater monitoring is required to predict the rate of groundwater recovery and more accurately determine decanting risks in unforeseen circumstances. If, in the unlikely event, decanting occurs passive or active treatment options should be applied before the contaminated water flows into the Limpopo River.

Recommendations

The following recommendations are made following the hydrogeological study:

- To enable safe and efficient mining conditions, the water inflowing to the pit will be managed through pumping from sumps. This water will be used in the mining operation and therefore is considered to being used efficiently. Mine dewatering can be conducted from a sump within the open pit, or dewatering boreholes on the outside of the open pit or a combination of both. Considering the relatively low aquifer yield, it is proposed to be conducted from a sump(s) in the lowest working area of the pit floor. This is also in line with the various coal mines in South Africa, including the Grootegeluk Mine. Dewatering from boreholes has the advantage of intercepting the groundwater before it is potentially contaminated at the pit. However, no high yielding fractures were intersected during this study and installation of dewatering wellfield is likely to be more expensive than seepage management using sumps. If dewatering is to be conducted from boreholes, new boreholes will have to be drilled as mining progresses since mining will be conducted progressively and this is likely to increase the cost. Water collected at the sump should be incorporated with the process water system considering the water shortage in the Waterberg area.

- The evaporation rate is approximately four times higher than the precipitation and most of the rainfall collected in the pit during the rainfall events could potentially evaporate during the dry periods, unless it is managed properly. This water is recommended to be incorporated into the water system and used to reduce borehole abstraction requirements during the rainy periods.
- The Limpopo River is not at risk from mining at Dalyshope Coal Mine as it is located approximately 5 km from the project area. However, water level and quality monitoring of the boreholes between the mine and the river are recommended to detect any potential impacts on the Limpopo River. If in the unlikely event that an impact on the Limpopo River is confirmed through monitoring, the mine should actively intervene to reduce or avoid the impact. This can be done through the following two mechanisms:
  - The interception of the contaminated water before reaching the Limpopo River through interception boreholes; or
  - The treatment of the contaminated water to an acceptable quality and discharge to the Limpopo River or use it at the mine.

A few private boreholes are expected to fall within the radius of the dewatering influence. The following is recommended as part of the management plan:

- The mine should supply equal or better-quality water to affected parties that rely on groundwater, if proven that there is an impact.
- Monitoring of the groundwater quality and water levels in the private boreholes is recommended.
- The numerical model should be refined every two years in the first four years of commencement of operation and thereafter every five years based on groundwater monitoring results.

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ACRONYMS, ABBREVIATIONS AND DEFINITION

EAP	Environmental Assessment Practitioner
EIA	Environmental Impact Assessment
LoM	Life of Mine
mamsl	Meters above mean sea level
MAP	Mean Annual Precipitation
MPRDA	Mineral and Petroleum Resources Development Act, 2002 (Act No. 28 of 2002)
MRA	Mining Rights Area
MTIS	Mineable tonnes in-situ
NEMA	National Environmental Management Act, 1998 (Act No. 107 of 1998)
PCD	Pollution Control Dam
SAWQG	South African Water Quality Guideline

Legal Requirement		**Section in Report**
(1)	A specialist report prepared in terms of these Regulations must contain-	
(a)	details of- (i) the specialist who prepared the report; and (ii) the expertise of that specialist to compile a specialist report including a curriculum vitae;	
(b)	a declaration that the specialist is independent in a form as may be specified by the competent authority;	
(c)	an indication of the scope of, and the purpose for which, the report was prepared;	
cA	And indication of the quality and age of the base data used for the specialist report;	
cB	A description of existing impacts on site, cumulative impacts of the proposed development and levels of acceptable change;	
(d)	The duration, date and season of the site investigation and the relevance of the season to the outcome of the assessment;	
(e)	a description of the methodology adopted in preparing the report or carrying out the specialised process inclusive of the equipment and modelling used;	

Legal Requirement		Section in Report
(f)	Details of an assessment of the specific identified sensitivity of the site related to the proposed activity or activities and its associated structures and infrastructure inclusive of a site plan identifying site alternatives;	
(g)	an identification of any areas to be avoided, including buffers;	
(h)	a map superimposing the activity including the associated structures and infrastructure on the environmental sensitivities of the site including areas to be avoided, including buffers;	
(i)	a description of any assumptions made and any uncertainties or gaps in knowledge;	
(j)	a description of the findings and potential implications of such findings on the impact of the proposed activity or activities;	
(k)	any mitigation measures for inclusion in the EMPr;	
(l)	any conditions/aspects for inclusion in the environmental authorisation;	
(m)	any monitoring requirements for inclusion in the EMPr or environmental authorisation;	
(n)	a reasoned opinion (Environmental Impact Statement) -	
	whether the proposed activity, activities or portions thereof should be authorised; and	
	if the opinion is that the proposed activity, activities or portions thereof should be authorised, any avoidance, management and mitigation measures that should be included in the EMPr, and where applicable, the closure plan;	
(o)	a description of any consultation process that was undertaken during the course of preparing the specialist report;	
(p)	a summary and copies of any comments received during any consultation process and where applicable all responses thereto; and	
(q)	any other information requested by the competent authority.	

1. Introduction

Anglo Operations Pty) Ltd (hereafter Anglo or the Applicant) has partnered with Universal Coal Development IV (Pty) Ltd (hereafter Universal) to participate in the proposed Dalyshope Coal Mining Project (the Project) through funding and managing the project development, including the Mining Right application.

Universal has appointed Digby Wells Environmental (hereinafter Digby Wells) as the Environmental Assessment Practitioner (EAP) to undertake environmental authorisations required for the proposed project. As part this, an Environmental Impact Assessment (EIA) will have to be compiled and will be submitted.

This specialist report is compiled to feed into the overall EIA and assesses the potential impacts and mitigation plans on the groundwater environment during the construction, operation and closure phases of the project.

2. Project Description

The project site is located within the Lephalale Local Municipality which forms part of the Waterberg District Municipality of Limpopo Province (Figure 2.1). It is found, approximately 15 km north from Steenbokpan and approximately 75 km northwest from Lephalale.

The Limpopo River, which is a shared watercourse between South Africa, Botswana, Zimbabwe and Mozambique, is located approximately 5 km northwest of the pit area. The closest operational mine is the Grootegeluk mine owned by Exxaro located approximately 25 km southeast of the project area.

Anglo proposes to develop a coal mine and the proposed mining activities will take place on the Farms Dalyshope 232 LQ and Klaarwater 231 LQ. The Environmental Authorisation (EA) application will therefore focus on these two properties only.

The application considers the establishment of a contractor operated truck and shovel opencast mine, producing approximately 2.4 million tonnes per annum (Mtpa) of thermal coal product for approximately five years. After five years, the mine will ramp up production to approximately 12 Mtpa of product for approximately 25 years from a single open pit, giving a total Life of Mine (LoM) of approximately 30 years. The life of mine is given in Figure 2.2. This is incorporated into the groundwater model for impact assessment and groundwater inflow estimations.

The mine infrastructure that are relevant to the groundwater study are listed below and displayed in Figure 2.1:

- Open pit;
- Discard facility;
- Temporary topsoil stockpiles for construction;
- ROM stockpiles;
- Topsoil and subsoil stockpiles;

- Overburden (Hards/Softs) stockpiles
- Two Pollution Control Dams (PCDs);
- Washing plant;
- Sewage Treatment Plant (STP); and
- Water Treatment Plant (WTP).

2.1. Study Objectives

The objectives of the hydrogeological study are:

- To assess the current groundwater depth, quality and flow directions;
- To identify the groundwater sources, pathways and receptors in the project area. The receptors include: aquifers, private boreholes, groundwater users, the Limpopo River and its tributaries and surrounding ecosystems;
- To define the current groundwater availability;
- Estimate the groundwater inflow rates into the proposed pit;
- To develop a numerical model for the proposed mine that will be used as a predictive tool for the mine's groundwater management plan;
- Estimate the likely impacts of the pit dewatering on the Limpopo River and other water users in the area;
- To estimate the radius of influence that will be created by possible mine dewatering from the proposed pit;
- Simulate the contaminant plumes that could potentially be released from the backfill as a result of, disposal of discard into the open pit; and
- Evaluate the post-closure groundwater recovery rates and assess the possibility of mine decanting.
- To predict where and when potential decanting will take place after mine closure (if relevant); and
- To recommend a groundwater monitoring network that will optimally monitor the groundwater quality and water level changes during the construction, operation and post-closure phases.

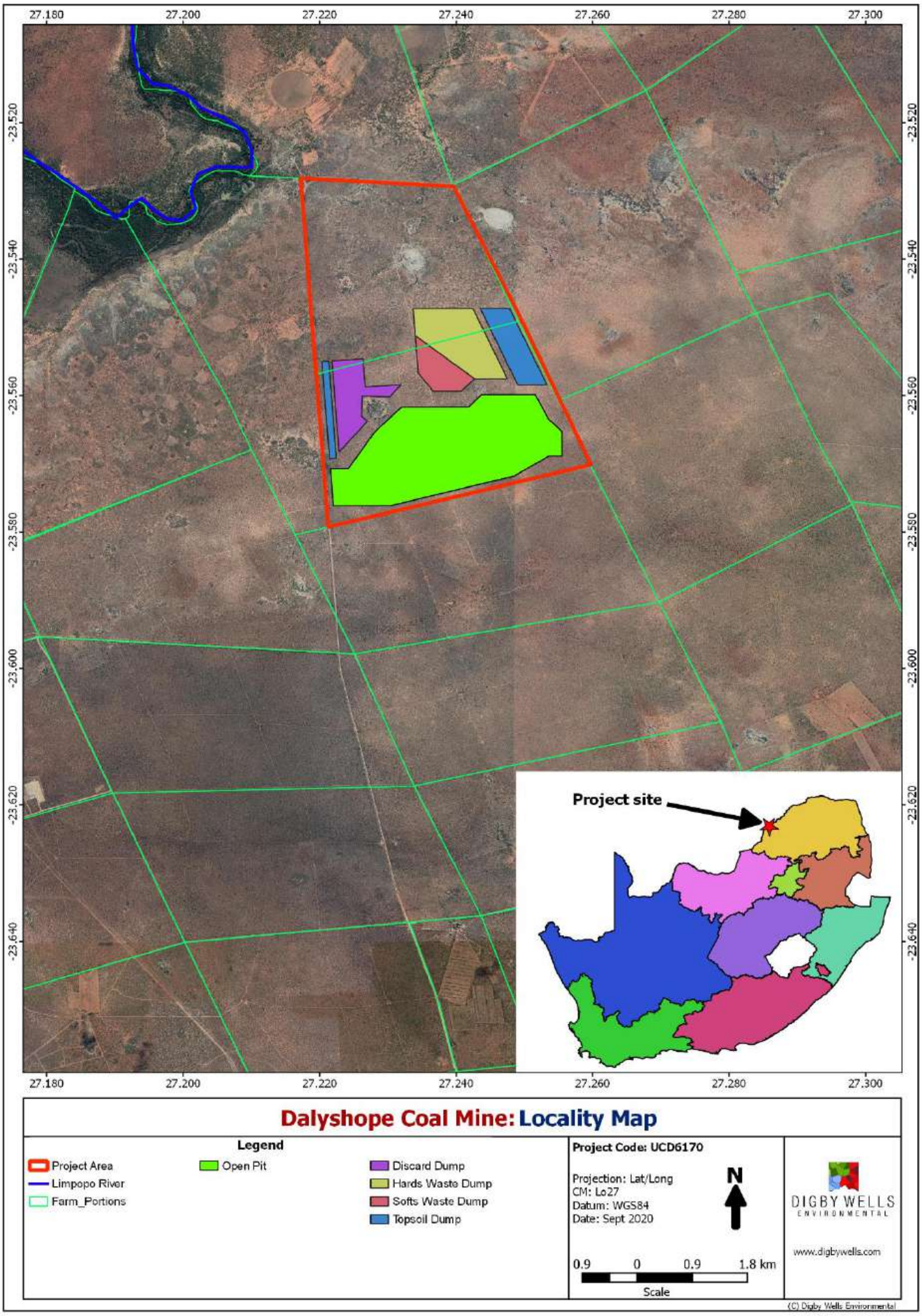

Figure 2.1: Site locality map

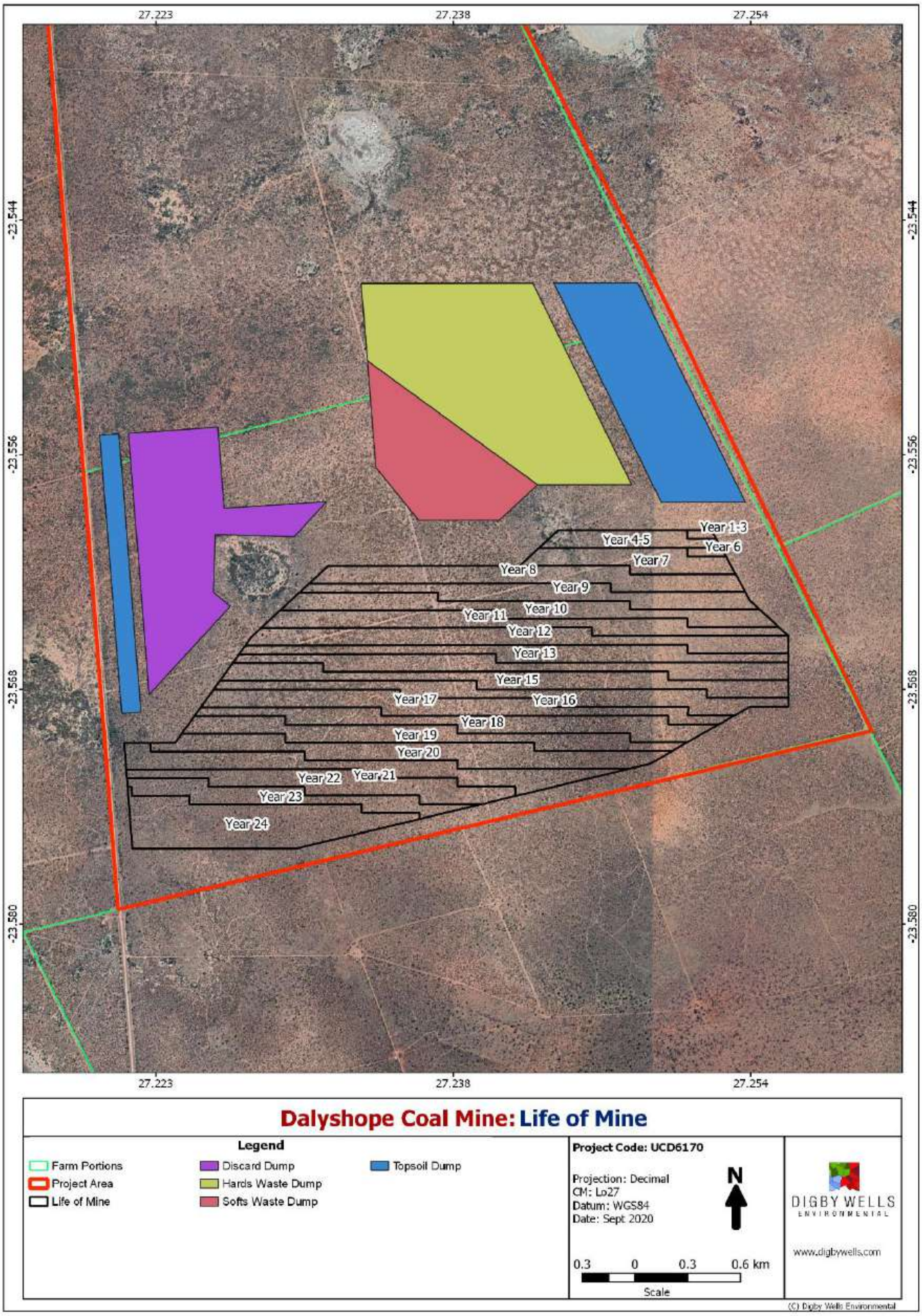

Figure 2.2: Life of mine

2.2. Topography and Drainage

The project site falls within the catchment boundaries of the A41E quaternary catchment, forming part of the larger Limpopo Water Management Area. The A41E catchment has an aerial extent of 1,938.3 km^2. The Limpopo River forms the northern boundary of the catchment.

The site topography is flat with a gentle slope towards the Limpopo River. The topography is 846 metres above mean sea level (mamsl) in the south-eastern part of the mine boundary and a minimum elevation of 836 mamsl in the north-western part of the pit area. The average gradient of the area is 0.003 towards the Limpopo River.

Although non perennial watercourses may drain towards the Limpopo River during rain events, there are no major tributaries in the area contributing to the flow of the Limpopo River.

The A41E quaternary catchment hosts most of the current coal exploration and coal mining areas within the Waterberg Coalfield and includes the proposed Temo Coal Mine, Boikarabelo Coal Mine and Thabametsi Coal Mine. The eastern boundary of this catchment extends immediately to the Grootegeluk Coal Mine.

2.3. Rainfall

The monthly rainfall data for the site was obtained from the WR2005 manual (WR2005, 2009) and is displayed in Figure 2.3. The relatively wet months range between November and February while the dry months span between April and October, with Mean Annual Precipitation (MAP) of 438 mm.

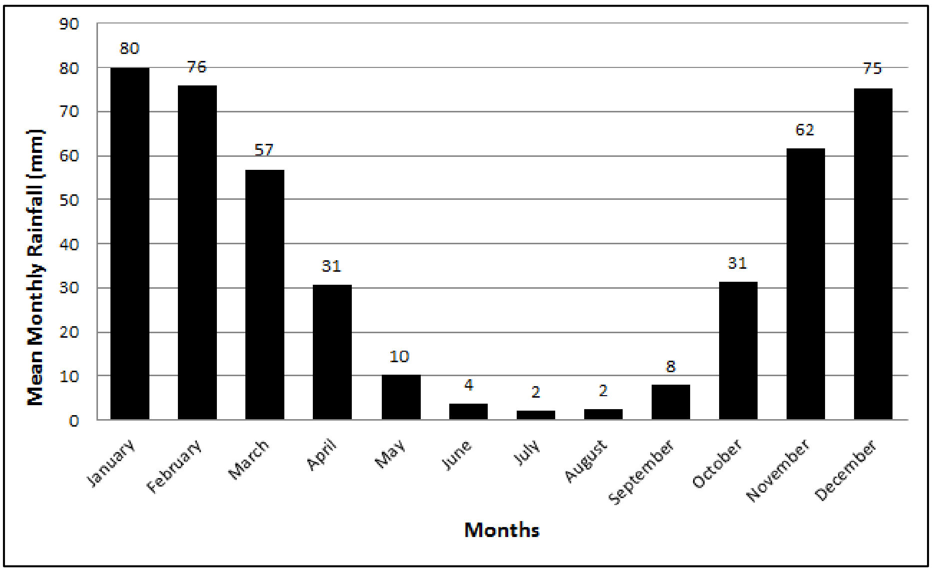

Figure 2.3: Mean Monthly Rainfall (WRC, 2009)

A number of studies have been conducted to predict the groundwater recharge rate in the Waterberg Coalfield. Some of the historical recharge estimations include (Digby Wells, June 2013):

- Vegter (1995) estimates the regional recharge in the range of 0.2 to 1.2% of MAP;
- Steenekamp (2001) between 0.1 to 0.4% of MAP;
- Golder Associates (2007) approximately 1% of MAP;
- WGC (2008) in the range of 2 to 6% of MAP;
- Bester and Vermeulen (2009) (using the chloride method) estimated the recharge to be 1.5%, but their final model was calibrated in the order of 0.005%; and
- ERM (2010) approximately 0.5%.

During this study, the recharge for the region has been calibrated at 0.75% of MAP.

2.4. Evaporation

Monthly evaporation data was obtained from the WR2005 manual. The A41E Quaternary Catchment where the project is located has a potential Mean Annual Evaporation (MAE) of 1,950 mm. Figure 2.4 is a summary of the mean monthly evaporation of the site and shows that the evaporation is maximum during the wet months and lowest during the dry months.

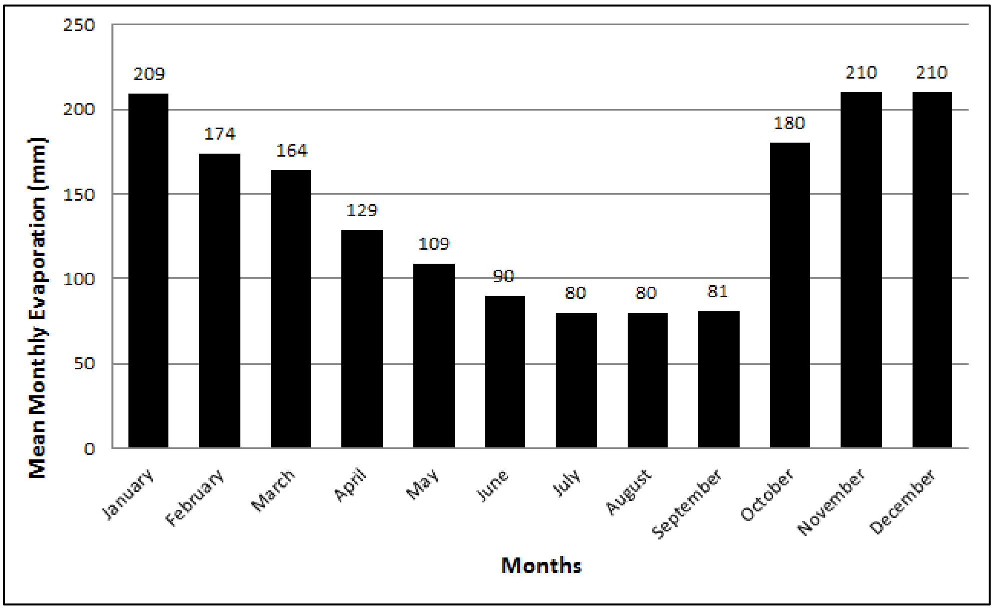

Figure 2.4: Mean Monthly Evaporation (WRC, 2009)

2.5. Temperature

The Project area falls within the Northern Arid Bushveld climatic region. This is a summer rainfall region with warm summers and moderate, dry winters. The period between November and February is the hottest with the average maximum temperatures reaching 33°C. The average minimum temperatures are reached during June and July with temperatures dropping to 5°C (Digby Wells, June 2011).

3. Relevant Legislation, Standards and Guidelines

Table 3-1 provides a summary of the relevant legal requirements and best practice guidelines applicable to the groundwater environment.

Table 3-1: Applicable Legislation, Regulations, Guidelines and By-Laws

Legislation, Regulation, Guideline or By-Law	Applicability
DWS[1] Best Practice Guideline – G1: Storm Water Management Plan (SWMP)	• Runoff of unmanaged stormed water could enhance groundwater recharge. • Clean storm water needs to be diverted before getting contaminated at the mine.
DWS Best Practice Guideline – G4: Impact Prediction	• Groundwater impacts should be predicted on risk-based. This entails characterisation of the source-pathway-receptor dynamics and interconnections. • When potential impacts are identified, mitigation measures should be put in place.
National Water Act, 1998 (Act No. 36 of 1998).	• Every citizen is entitled to clean water
National Environmental Management Act (Act 107 of 1998), as amended (NEMA), GNR 544 and GNR 545 (Section 24 (1)).	• Groundwater contamination should be managed
Water Services Act 108 of 1997.	• Water resource contamination should be managed
National Environmental Management: Waste Act (Act 59 of 2008) (NEMWA) and List of Waste Management Activities requiring a Waste Management Licence (WML) GN 718 of 2008.	• Groundwater environment should be minimised or avoided
Department of Water and Sanitation (DWS) (formerly DWAF). Government Gazette, No. 704 (GN 704). 1999. Regulations on the Use of Water for Mining and Related Activities Aimed at the Protection of Water Resources (Vol. 408, No. 20119). 4 June 1999.	• Groundwater contamination should be managed

[1] Previously the Department of Water Affairs (DWA)

Legislation, Regulation, Guideline or By-Law	Applicability
Department of Water and Sanitation (DWS) (formerly DWAF). 2006. Best Practice Guideline G3: Water Monitoring Systems.	• Groundwater quality and quantity should be monitored

4. Assumptions, Limitations and Exclusions

A numerical model was used to predict the potential impact of the proposed mine on the groundwater environment. Numerical models are commonly used to simulate and develop hydrogeological management solutions, i.e. the prediction of contaminant plume migration, groundwater inflow rate and groundwater level changes over time. However, groundwater systems are often complex and the data input requirements are beyond current capability to evaluate in detail. A model, no matter how sophisticated, will never describe the investigated groundwater system without deviation of model simulations from the actual physical process (Spitz, 1996). Therefore, it is necessary to make some assumptions to simplify the complex, real world hydrogeological conditions into a simplified, manageable model.

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

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

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

- Geological fractures change their openings and hydraulic properties by orders of magnitude within a short distance. The groundwater ingress and environmental impacts are dependent on the rock permeability. However, no drilling and aquifer testing had been conducted within the Dalyshope pit area. Aquifer permeability conducted outside the pit area has been interpolated to predict on the values within the pit zone.
- It may not be practical to drill a borehole at every fracture and investigate its permeability, calculate flow rates through each fracture, or assess how much rainfall infiltrates through individual rock openings. It is necessary to make some assumptions and interpolations to simplify the complex, real world hydrogeological conditions into a simplified, manageable model. Considering the hydrogeological heterogeneity and data gaps in the aquifer parameters, the Dalyshope model is expected to predict with accuracy of approximately 50%. The model is recommended to be updated as more hydrogeological information is obtained during mine operations; specifically once in every two years in the first four years of operation and then every five years thereafter.

- The groundwater ingress rate is dependent on the life of mine (Figure 2.2). This has been incorporated into the groundwater model for inflow rate as well as impact predictions. If the mine plan changes, the model needs updating to simulate the updated mine plans.
- There is currently only one water level monitoring borehole (DH2) that is located within the pit area with a water level depth of 8.0 m. The water level in the region ranges between 2 and 50 m, and only one borehole may not represent the entire pit footprint.
- Pit backfilling is assumed to start 8 years after closure and continue until closure.

5. Methodology

The details of the groundwater activities conducted are summarised below:

5.1. Desktop Study

All available hydrogeological, geotechnical, geochemical and geological data have been reviewed with references noted as relevant. Available data was selected and stored into a WISH (Windows Interpretation Software for Hydrogeologists) database system.

5.2. Hydrocensus

Numerous site visits and groundwater monitoring have been conducted since 2012 that included the hydrocensus of private boreholes. The data was saved in the WISH database and was used to define the baseline groundwater environment.

5.3. Borehole Drilling

Following the review of available aeromagnetic maps, mine plans, geological data and geophysical maps, 10 percussion boreholes were drilled for aquifer characterisation in July 2013. The boreholes were placed across the proposed pit and discard dump area to gain a representative understanding of Dalyshope Mine, considering the geological information and mine plan available then. The mine plan has since evolved and consequently none of the boreholes is within the pit area. The closest (borehole MBH1) is 3.5 km north of the proposed pit while the others are further to the north (Digby Wells, 2013). The positions of the boreholes are displayed in Figure 5.1. The drilling was performed using a rotary air percussion with an internal diameter of 165 mm. All boreholes were drilled until all the coal seam zones are intersected with approximate depth of 102 m.

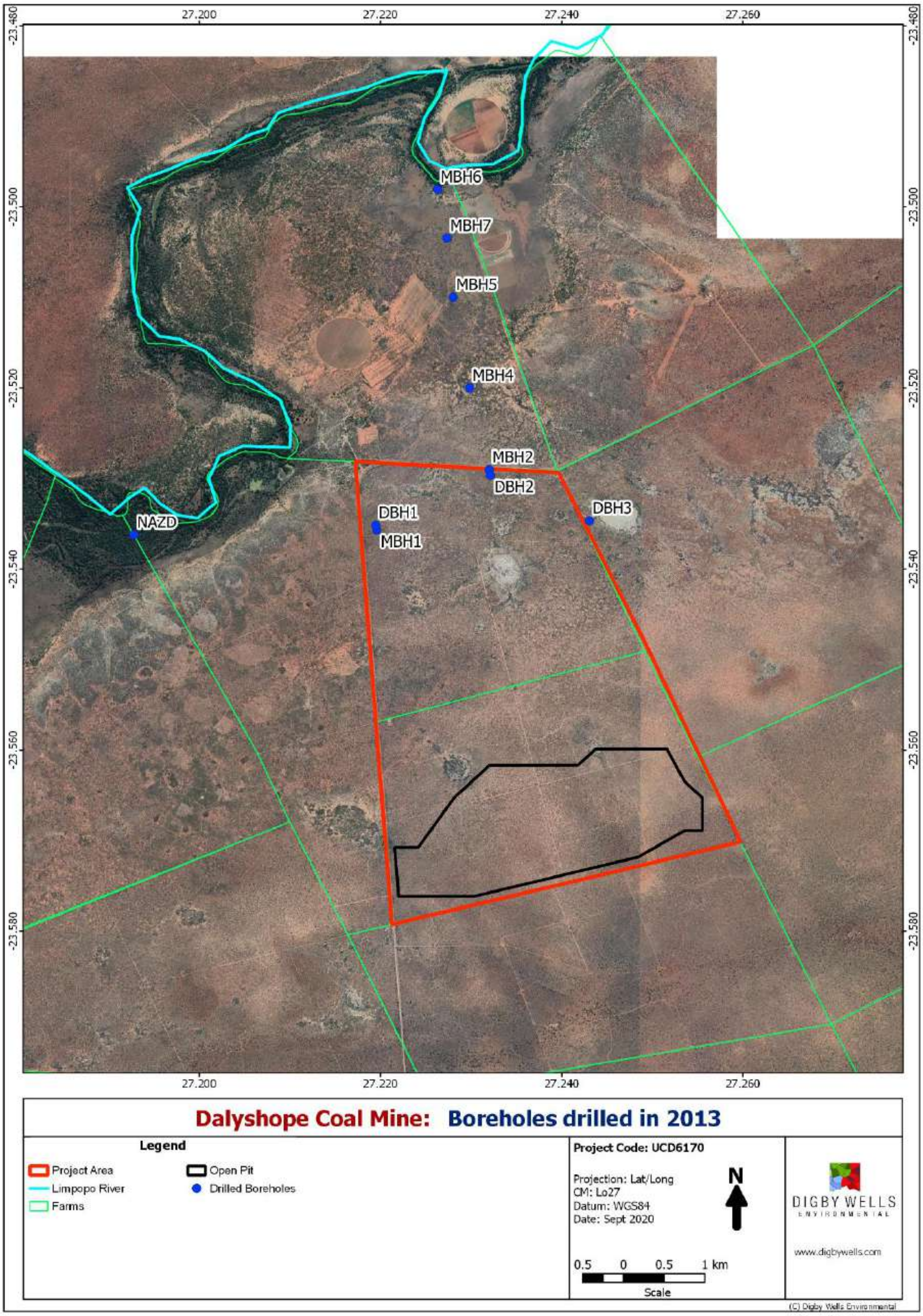

Figure 5.1: Positions of the percussion boreholes drilled historically

5.4. Aquifer Testing

Aquifer test results of 43 boreholes located in and around the project area were reviewed during this study. The test included pump testing, slug testing, airlift testing and packer testing. The permeability result is shown in Figure 6.8 and more discussion on the rock permeability is given in Section 1.2. Some of the tests were not conducted by Anglo or Universal Coal but are close to the project site and the hydraulic information is relevant.

5.5. Numerical Modelling

A numerical model was developed to evaluate the potential impact of the proposed mine on the groundwater environment as well as to predict the groundwater ingress rates as the mine progresses. The software code chosen was the modular 3D finite-difference groundwater flow model MODFLOW. MODFLOW is internationally recognised package published by the U.S. Geological Survey and is commonly used by groundwater specialists and environmental scientists. Processing MODFLOW Pro (v8.0) was used as a user interface. The solute transport was simulated using the transport module MT3DMS.

5.6. Impact Assessment and Mitigation Planning

The model was used to assess the potential impact of Dalyshope Coal Mine on the groundwater and nearby receptors. In this phase, the environmental impacts were rated based on their significance scoring before and after mitigation methods are implemented. Cumulative impact on the catchment was also predicted considering the many mines that are planned to operate in the Waterberg Coalfield.

Finally, the recommended mitigation and management options to minimise groundwater impacts are presented.

The impacts are assessed based on the impact's magnitude, as well as the receiver's sensitivity, culminating in an impact significance which identifies the most important impacts that require management.

Based on international guidelines and South African legislation, the following criteria are taken into account when examining potentially significant impacts:

- Nature of impacts (direct/indirect, positive/ negative);
- Duration (short/medium/long-term, permanent(irreversible) / temporary (reversible), frequent/seldom);
- Extent (geographical area, size of affected population/habitat/species);
- Intensity (minimal, severe, replaceable/irreplaceable);
- Probability (high/medium/low probability); and
- Possibility to mitigate, avoid or offset significant adverse impacts.

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 5-1. 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 5-2, which is extracted from Table 5-1. The description of the significance ratings is discussed in Table 5-3.

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

Table 5-1: Impact Assessment Parameter Ratings

RATING	INTENSITY/REPLACABILITY		EXTENT	DURATION/REVERSIBILITY	PROBABILITY
	Negative impacts	**Positive impacts**			
7	Irreplaceable damage to highly valued items of great natural or social significance or complete breakdown of natural and / or social order.	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 damage to highly valued items of natural or social significance or breakdown of natural and / or social order.	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.
5	Very serious widespread natural and / or social baseline changes. 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.

RATING	INTENSITY/REPLACABILITY		EXTENT	DURATION/REVERSIBILITY	PROBABILITY
	Negative impacts	**Positive impacts**			
4	On-going serious natural and / or social issues. Significant changes to structures / items of natural or social 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.
3	On-going natural and / or social issues. Discernible changes to natural or social baseline.	Average, on-going positive benefits, not widespread but felt by some elements of the baseline.	Local Local extending only as far as the development site area.	Medium term: 1-5 years and impact can be reversed with minimal management.	Unlikely: Has not happened yet but could happen once in the lifetime of the project, therefore there is a possibility that the impact will occur. <25% probability.
2	Minor natural and / or social impacts which are mostly replaceable. Very little change to the baseline.	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 natural and / or social impacts, low-level replaceable damage with no change to the baseline.	Some low-level natural and / or social benefits felt by a very small percentage of the baseline.	Very limited 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 5-2: Probability/Consequence Matrix

Significance

-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
-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
-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
-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
-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
-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
-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 5-3: Significance Rating Description

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

6. Baseline Hydrogeological Conditions

6.1. Geology

The coal deposit at Dalyshope Coal Mine is hosted in Karoo Supergroup formations which rest unconformably on the Waterberg Group and pre-Waterberg rocks (Figure 7.2).

The coal seams form part of the Upper (Volksrust formation) and Middle Ecca (Vryheid formation) with an average coal thickness of 115 m. The Upper Ecca is on average 60 m thick and comprises interblended shale and bright coal successions whilst the Middle Ecca, on average 50 m thick, forms the lower part of the coal deposit and contain dull coal, carbonaceous shale, as well as grit and sandstone.

The Waterberg coal field is fault-bounded along its northern and southern limits (Figure 7.2). The Eenzaamheid fault, with a displacement of at least 250 m, forms the southern boundary, whilst the northern boundary is formed by the Zoetfontein fault. The Daarby fault, with a displacement of 250 m, divides the Waterberg coal field into two areas: a shallow western area where it is possible to obtain the coal through open pit mining methods and a deep north-eastern area where the coal occurs at a depth of 250 m below surface. Although this coal field covers a relatively small surface area, it is one of South Africa`s most important coal fields in terms of in-situ reserves. The coalfield extends west across the Limpopo River into Botswana, where it is known as the Mmamabula Coalfield.

6.1.1. Stratigraphy

Only a few dolerite dykes are present in the south-eastern portion of the coalfield and no sill features have to date been encountered in any exploration borehole. A typical stratigraphic column of the coal deposit is presented in Figure 6.1.

The classical units of the Karoo sedimentary sequence are present in the coalfield and hence, the same nomenclature is applied. The geological formations of interest to the project include the Grootegeluk and Vryheid Formations of the Ecca Group which contain 11 coal-bearing zones representing a stratigraphic thickness of approximately 120 m. The Grootegeluk Formation consists of seven zones of finely intercalated bright coal and mudstone bands and lamina. The Vryheid Formation consists of carbonaceous mudstones at the top and medium-coarse sandstones toward the base, with four inter-bedded and prominent coal seams.

6.1.2. Coal deposit

The coal deposit forms part of the Waterberg Coalfield and consists of 11 coal-bearing zones numbered from No. 1 at the base to No. 11 at the top, containing various seams of coal of varying quality interspersed with waste rock.

The upper seven coal zones (Zone 5 to 11) occur up to a depth of 80 m and the individual seams vary in thickness from 7 m to 14 m. The highest quality coals are found in Zone 8 to Zone 11, which have a semi-soft coking coal yield. The remainder of the zones yield a low-grade thermal coal suitable for local power generation.

The lower four coal zones occur up to a depth of 125 m and are predominantly dull coal with minor carbonaceous mudstone intercalations which are mined as thermal coals.

The total coal resource is estimated at 1,500 Mt of in situ coal. All the coal found in Zone 2 to Zone 11 are indicated to be economically viable, but the initial focus of mining is on Zone 6 to Zone 11 (Digby Wells, 2013).

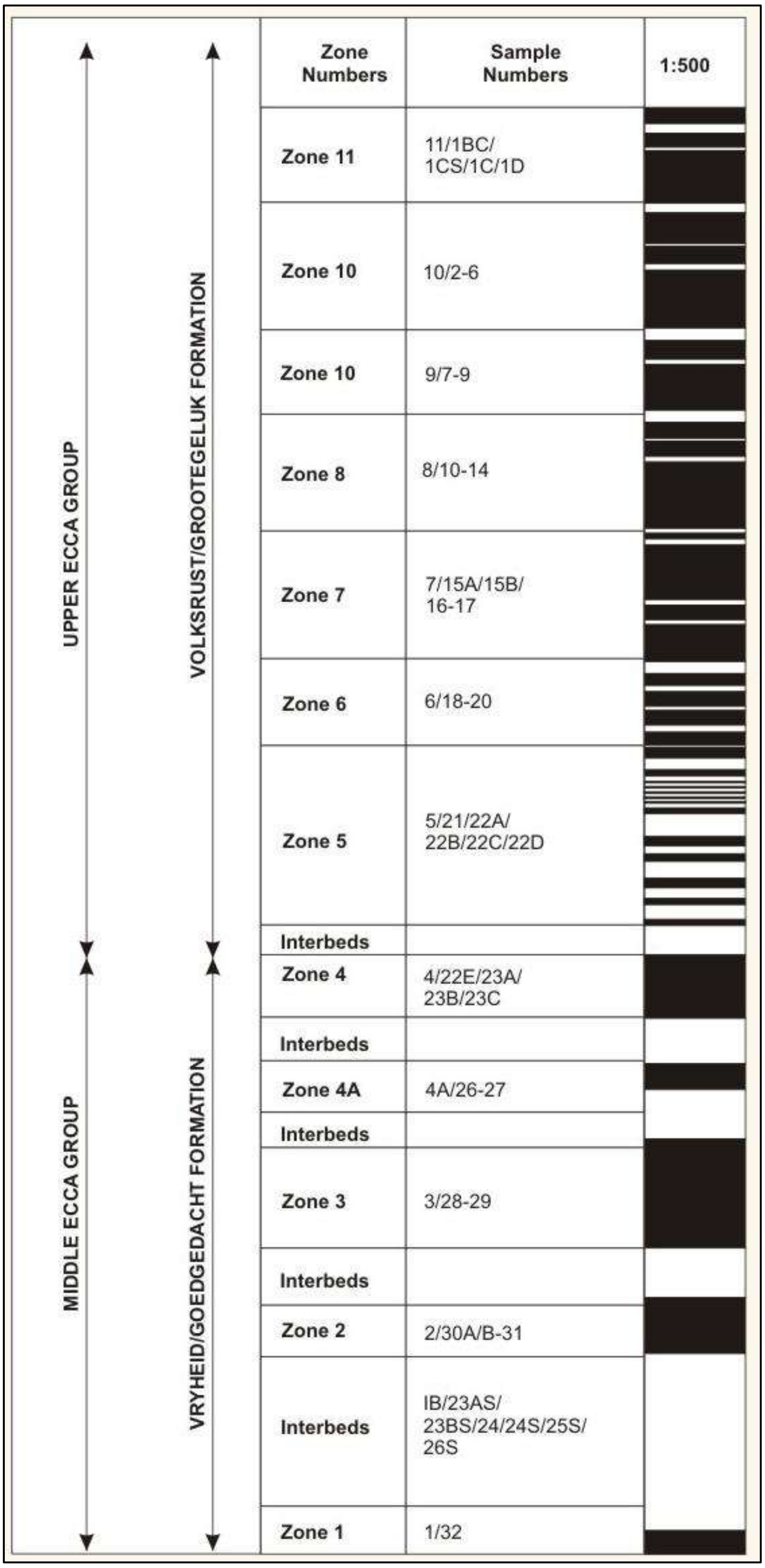

Figure 6.1: Stratigraphy of the Waterberg coal zones (Digby Wells, 2013)

6.2. Groundwater Usage

The main source of drinking water supply in and around the project area is groundwater through a number of solar energy, windmill pumps and submersible pumps which are mainly used for domestic and livestock watering.

As can be seen in Figure 6.2, a total of 88 private boreholes were surveyed, of which 10 are within the mining right area while 42 are within a 3 km radius of the mining right area. Of the 42 boreholes:

- 8 (9%) boreholes are used for game watering only;
- 20 (23%) are used for livestock watering;
- 11 (13%) are used for human drinking, gardening and livestock watering;
- 13 (15%) are used for groundwater monitoring;
- 12 (14%) are exploration holes (not boreholes) used for monitoring;
- 3 (3%) are not used; and
- The remaining 21 (24%) boreholes are unused.

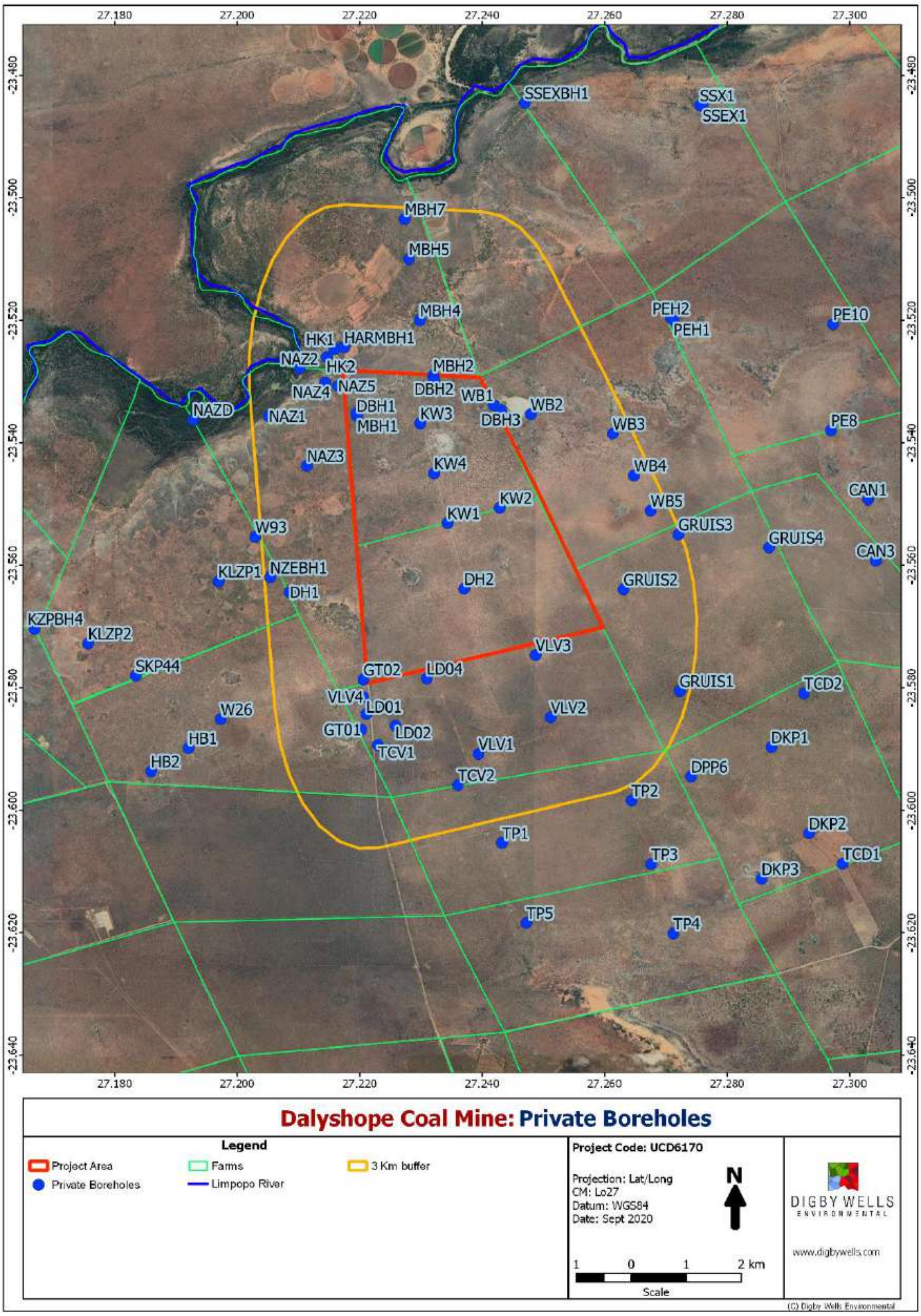

Figure 6.2: Distribution of the private boreholes

6.3. Baseline Groundwater Quality

A geochemical assessment is still being carried out separately by Digby Wells and is not included in this report.

A total of 48 samples were collected for baseline water quality assessment between 2012 and 2019. The samples were sent for analysis to Aquatico Laboratory (Pty) Ltd and Water Lab; both SANAS accredited laboratories in Pretoria. The boreholes sampled were chosen based on their geographical distribution to best represent the project site.

The groundwater quality results were compared against the South African Water Quality Guidelines (SAWQG) for domestic use as shown in Table 6-1. According to the SAWQG guideline, water quality has two benchmarks: Ideal, Acceptable and Unacceptable:

- Concentrations below the “Ideal” is considered of good quality;
- Concentrations between the “Ideal” and “Unacceptable” is considered as marginal. This is the maximum acceptable concentration if consumed for less than 7 years (depending on the sensitivity of the receptors); and
- Concentrations above the “Unacceptable” limits are unacceptable for human consumption.

As shown in Table 6-1, none of the boreholes are considered of good water quality as they are all above the Class I category. At least one of the tested parameters exceed the recommended limit. The water is generally not recommended for human consumption without treatment due to high Cl, TDS, Ca and other parameters. This is with the exception TCD1 which is in good quality and boreholes DH2, Gruis1, KW1, KW2, KW4, NAZ2A, SSEX1, SSX1, VLV2, W26 and WB5 which are within the acceptable limit and can be used for domestic use.

The elevated element concentrations can be attributed to the natural dissolution of the host rocks. The only external impacts are associated with the elevated nitrate concentrations identified in boreholes CAN1 and KW4 which is associated with fertiliser application and/or animal waste as cattle often live nearby.

The water chemistry is also displayed in the form of a Stiff Diagram in Figure 6.3. The water facies of the region range between Sodium Chloride (Na-Cl) and Calcium/ Magnesium bicarbonate (Ca/Mg-HCO_3) water types. Cl is the dominant anion, although bicarbonate (HCO_3) is also present. The dominant cation is Na, although Ca and Mg are also present.

High Na and Cl values are typical of Karoo aquifers with old stagnant water, with high salt loads. This is indicative of low recharge and long residency time (slow moving groundwater). The Ca/Mg-HCO_3 signature is often associated with recently recharged water. This is an indication of the aquifer heterogeneity whereby although the recharge in the area is low, there are high permeable zones, often associated with fractures, along which recharge takes place. Such chemical signature is unique to the Waterberg Coalfield, as the signature in the Ermelo, Highveld or Witbank Coalfields are characterised with Ca/Hg-HCO_3 type water with no or insignificant Cl in the baseline quality.

Noteworthy is the sulphate levels in these boreholes. The recommended maximum sulphate limit for drinking is 400 mg/L, but the concentration is currently less than 200 mg/L. Sulphate is expected to be an element of concern at Dalyshope Coal Mine based on the experience learned from other coal mines, including at Grootegeluk where it has reached up to 2 700 mg/L in some monitoring boreholes. The low levels of sulphate in all the boreholes suggests that no mine-related contamination has taken place at the project site. Sulphate should be used as an indicator to assess the Dalyshope Coal Mine impact and the values obtained currently should be used as a baseline for future comparisons. The baseline sulphate concentration is also displayed graphically in Figure 6.4.

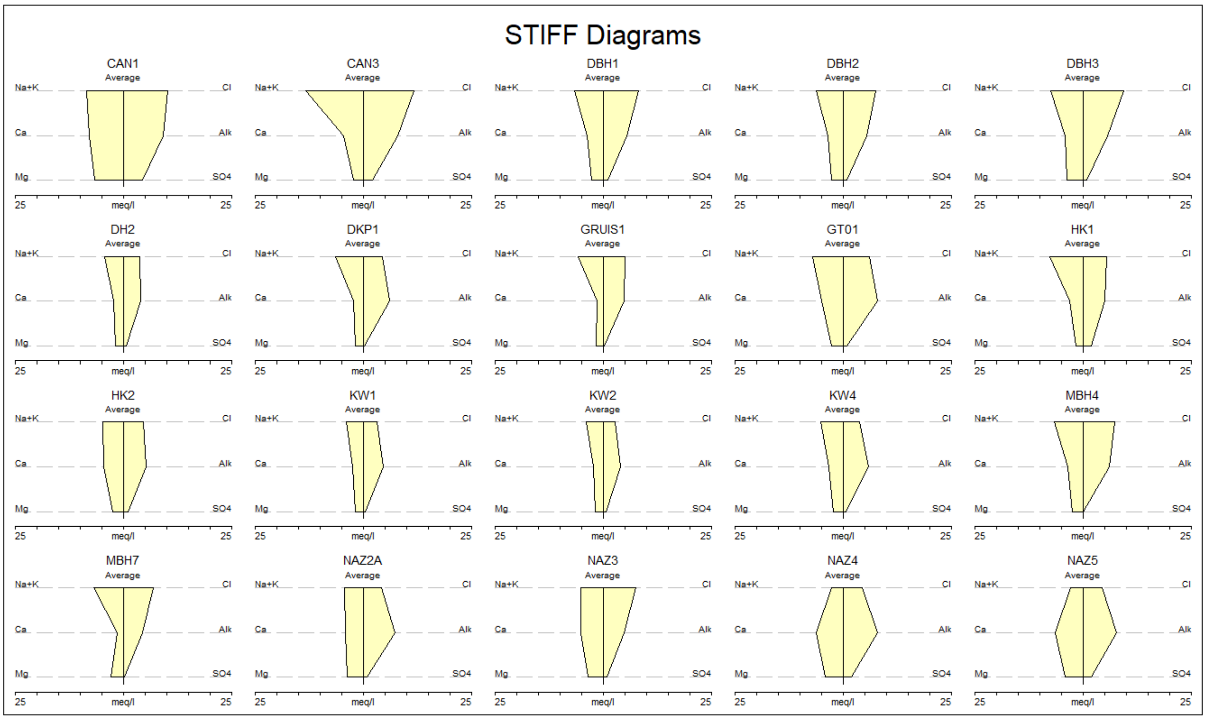

Figure 6.3: Stiff diagram of the groundwater chemistry

Table 6-1: Baseline groundwater quality as classified based on the SAWQG for domestic use

SAWQG for domestic use	pH	TDS mg/L	TALK mg/L	NO3_N mg/L	SO4 mg/L	Ca mg/L	Cl mg/L	F mg/L	Mg mg/L	Na mg/L	K mg/L	Al mg/L	As mg/L	Cd mg/L	Cu mg/L	Cr mg/L	Fe mg/L	Pb mg/L	Mn mg/L	Ni mg/L	Zn mg/L
Ideal	**6**	**450**		**6**	**200**	**32**	**100**	**1**	**30**	**100**	**50**	**0.15**	**0.01**	**0.005**	**1**	**0.05**	**0.1**	**0.01**	**0.05**	**0.15**	**3**
Acceptable	**6 - 9**	**450 - 1000**	**-**	**6 - 10**	**200 - 400**	**32 - 80**	**100 - 200**	**1 - 1.5**	**30 - 50**	**100 - 200**	**50 - 100**	**0.15 - 0.5**	**0.01 - 0.2**	**0.005 - 0.01**	**1 - 3**	**0.05 - 0.06**	**0.1 - 0.3**	**0.01 - 0.02**	**0.05 - 0.1**	**0.15 - 0.35**	**3 - 5**
Unacceptable	**9**	**1000**		**10**	**400**	**80**	**200**	**1.5**	**50**	**200**	**100**	**0.5**	**0.2**	**0.01**	**3**	**0.06**	**0.3**	**0.02**	**0.1**	**0.35**	**5**
CAN1	7.14	1316	459	12.2	214	158	367	2.12	81.2	182	24.6	<0.003	-	-	-	-	<0.003	-	<0.001	-	-
CAN3	8.71	1202	398	0.264	105	93.1	416	0.839	28.8	295	23.9	<0.003	-	-	-	-	<0.003	-	<0.001	-	-
DBH1	7.77	773	277	0.017	46.1	73.7	288	0.993	34.1	146	15.9	<0.003	-	-	-	-	<0.003	-	<0.001	-	-
DBH2	7.68	721	269	0.017	38.9	69.7	264	1.23	34.1	133	16.2	<0.003	-	-	-	-	<0.003	-	<0.001	-	-
DBH3	8.03	863	284	0.017	39.4	85.3	333	1.28	45.9	163	18.7	<0.003	-	-	-	-	<0.003	-	<0.001	-	-
DH2	6.9	684	204	9.6	<0.2	47.376	136	0.8	23.159	97.847	6.452	< 0.100	< 0.010	< 0.010	< 0.010	< 0.010	< 0.025	< 0.010	< 0.025	< 0.010	0.01
DKP1	7	562	322	0.303	4.97	39.6	158	1.18	22.9	137	3.78	<0.003	-	-	-	-	1.93	-	<0.001	-	-
GRUIS1	6.8	706	240	0.2	<0.2	30.514	176	0.8	19.723	128.813	6.106	< 0.100	< 0.010	< 0.010	< 0.010	< 0.010	0.082	< 0.010	0.081	< 0.010	0.016
GT01	7.3	912	328	0.3	<0.2	96.256	227	0.5	32.005	156.848	20.321	< 0.100	< 0.010	< 0.010	< 0.010	< 0.010	< 0.025	< 0.010	0.097	< 0.010	< 0.010
HK1	7.7	760	240	0.9	<0.2	34.565	129	3.4	10.996	164.603	6.841	< 0.100	< 0.010	< 0.010	< 0.010	< 0.010	< 0.025	< 0.010	< 0.025	< 0.010	0.1
HK1	7.75	726	258	0.979	80.5	72.2	216	2.44	23.4	169	6.89	<0.003	-	-	-	-	<0.003	-	<0.001	-	-
HK1	8.02	795	265	1.89	98.7	78.7	236	2.86	25.6	185	7.71	<0.003	-	-	-	-	<0.003	-	<0.001	-	-
HK2	7.66	584	256	0.017	55.4	88.7	152	0.894	28.3	98.4	7.27	<0.003	-	-	-	-	<0.003	-	0.025	-	-
HK2	7.31	641	272	0.298	52.4	99.2	175	1.15	31.5	110	8.21	<0.003	-	-	-	-	<0.003	-	0.044	-	-
KW1	7	606	240	1.7	0.3	47.017	123	0.7	20.607	86.988	6.903	0.278	< 0.010	< 0.010	< 0.010	< 0.010	0.062	< 0.010	0.075	< 0.010	0.036
KW1	7.3	405	213	7.22	23.7	47.9	88.9	0.558	21.5	83.4	4.17	<0.003	-	-	-	-	<0.003	-	<0.001	-	-

SAWQG for domestic use	pH	TDS mg/L	TALK mg/L	NO3_N mg/L	SO4 mg/L	Ca mg/L	Cl mg/L	F mg/L	Mg mg/L	Na mg/L	K mg/L	Al mg/L	As mg/L	Cd mg/L	Cu mg/L	Cr mg/L	Fe mg/L	Pb mg/L	Mn mg/L	Ni mg/L	Zn mg/L
Ideal	**6**	**450**		**6**	**200**	**32**	**100**	**1**	**30**	**100**	**50**	**0.15**	**0.01**	**0.005**	**1**	**0.05**	**0.1**	**0.01**	**0.05**	**0.15**	**3**
Acceptable	**6 - 9**	**450 - 1000**	**-**	**6 - 10**	**200 - 400**	**32 - 80**	**100 - 200**	**1 - 1.5**	**30 - 50**	**100 - 200**	**50 - 100**	**0.15 - 0.5**	**0.01 - 0.2**	**0.005 - 0.01**	**1 - 3**	**0.05 - 0.06**	**0.1 - 0.3**	**0.01 - 0.02**	**0.05 - 0.1**	**0.15 - 0.35**	**3 - 5**
Unacceptable	**9**	**1000**		**10**	**400**	**80**	**200**	**1.5**	**50**	**200**	**100**	**0.5**	**0.2**	**0.01**	**3**	**0.06**	**0.3**	**0.02**	**0.1**	**0.35**	**5**
KW1	7.68	458	240	5.73	21	48.8	114	0.713	23.2	94.3	5.45	<0.003	-	-	-	-	<0.003	-	<0.001	-	-
KW1	7.72	447	223	8.84	<0.04	58.9	119	0.765	24.2	95.8	6.61	<0.003	-	-	-	-	<0.003	-	<0.001	-	-
KW2	7.76	409	204	7.12	27.9	45.5	93.2	0.619	21.8	86.3	4.37	<0.003	-	-	-	-	<0.003	-	<0.001	-	-
KW4	7.16	549	290	9.26	36.5	63	116	0.989	26.8	108	14.3	<0.003	-	-	-	-	<0.003	-	<0.001	-	-
KW4	7.77	562	300	10.8	16.5	73.4	118	0.905	27.2	120	14.9	<0.003	-	-	-	-	<0.003	-	<0.001	-	-
KW4	8.12	598	279	6.12	40.5	69.1	162	1	29.6	107	15	<0.003	-	-	-	-	<0.003	-	<0.001	-	-
MBH4	8.03	713	299	0.017	1.43	72.4	258	2.48	30.9	139	23.9	<0.003	-	-	-	-	<0.003	-	<0.001	-	-
MBH7	8.36	624	215	0.024	15	28.2	245	1.44	35.5	147	15.2	<0.003	-	-	-	-	<0.003	-	<0.001	-	-
NAZ2A	7.67	643	330	0.561	60.1	119	146	0.601	49.3	60.5	8.28	<0.003	-	-	-	-	<0.003	-	0.007	-	-
NAZ2A	7.88	655	411	2.15	22.2	47.5	150	0.458	44	126	10.9	<0.003	-	-	-	-	<0.003	-	<0.001	-	-
NAZ3	7	1108	252	3.2	0.2	140.053	288	0.8	39.495	121.673	15.892	< 0.100	< 0.010	< 0.010	< 0.010	< 0.010	< 0.025	< 0.010	< 0.025	< 0.010	0.013
NAZ3	8.12	664	231	2.18	36.4	71.8	253	0.579	45.5	103	12.5	<0.003	-	-	-	-	<0.003	-	<0.001	-	-
NAZ4	7.64	730	396	0.017	93.2	126	156	0.581	50.3	59.9	5.71	<0.003	-	-	-	-	<0.003	-	0.169	-	-
NAZ4/5	7.77	652	330	0.631	61.4	128	146	0.661	49.9	59.2	8.23	<0.003	-	-	-	-	<0.003	-	0.043	-	-
NAZ5	7.73	732	387	0.017	95.5	129	155	0.617	51.8	61.4	5.55	<0.003	-	-	-	-	<0.003	-	<0.001	-	-
PEH1	8.46	1184	239	1.47	68.7	115	547	1.03	49.3	238	20.2	<0.003	-	-	-	-	<0.003	-	<0.001	-	-
PEH1	7.43	1183	246	0.961	94.4	114	532	0.966	57.3	215	22	<0.003	-	-	-	-	<0.003	-	<0.001	-	-
PEH2	7.35	1161	255	0.017	60.3	107	541	0.95	49.6	221	25.8	<0.003	-	-	-	-	<0.003	-	0.014	-	-
SSEX1	7.4	726	248	0.4	<0.2	63.462	108	0.6	33.164	68.27	4.921	< 0.100	< 0.010	< 0.010	< 0.010	< 0.010	< 0.025	< 0.010	< 0.025	< 0.010	< 0.010

SAWQG for domestic use	pH	TDS mg/L	TALK mg/L	NO3_N mg/L	SO4 mg/L	Ca mg/L	Cl mg/L	F mg/L	Mg mg/L	Na mg/L	K mg/L	Al mg/L	As mg/L	Cd mg/L	Cu mg/L	Cr mg/L	Fe mg/L	Pb mg/L	Mn mg/L	Ni mg/L	Zn mg/L
Ideal	**6**	**450**		**6**	**200**	**32**	**100**	**1**	**30**	**100**	**50**	**0.15**	**0.01**	**0.005**	**1**	**0.05**	**0.1**	**0.01**	**0.05**	**0.15**	**3**
Acceptable	**6 - 9**	**450 - 1000**	**-**	**6 - 10**	**200 - 400**	**32 - 80**	**100 - 200**	**1 - 1.5**	**30 - 50**	**100 - 200**	**50 - 100**	**0.15 - 0.5**	**0.01 - 0.2**	**0.005 - 0.01**	**1 - 3**	**0.05 - 0.06**	**0.1 - 0.3**	**0.01 - 0.02**	**0.05 - 0.1**	**0.15 - 0.35**	**3 - 5**
Unacceptable	**9**	**1000**		**10**	**400**	**80**	**200**	**1.5**	**50**	**200**	**100**	**0.5**	**0.2**	**0.01**	**3**	**0.06**	**0.3**	**0.02**	**0.1**	**0.35**	**5**
SSX1	7.51	469	263	0.042	62.3	64	89.1	0.42	36.4	55.3	2.84	<0.003	-	-	-	-	<0.003	-	0.481	-	-
SSX1	8.02	492	292	0.343	60	70.5	75.1	0.66	41.3	64.8	3.91	<0.003	-	-	-	-	<0.003	-	<0.001	-	-
TCD1	6.2	544	80	0.1	0.2	22.778	181	0.2	20.739	78.153	10.074	< 0.100	< 0.010	< 0.010	< 0.010	< 0.010	10.218	< 0.010	0.263	< 0.010	0.012
VLV1	7.15	779	271	0.017	63.1	75.8	282	0.622	37.6	142	15	<0.003	-	-	-	-	<0.003	-	0.161	-	-
VLV1	7.82	725	262	0.571	56.6	60.3	258	0.688	35.2	144	13.2	<0.003	-	-	-	-	<0.003	-	<0.001	-	-
VLV2	6.8	702	252	2.5	0.2	34.976	158	0.7	22.66	126.286	4.499	< 0.100	< 0.010	< 0.010	< 0.010	< 0.010	0.16	< 0.010	0.047	< 0.010	0.057
VLV3	8.43	587	198	0.017	<0.04	16.3	263	1.59	44.8	134	8.31	<0.003	-	-	-	-	<0.003	-	<0.001	-	-
VLV3	8	678	263	0.305	0.997	34.5	279	2.5	49.9	142	10.2	<0.003	-	-	-	-	<0.003	-	<0.001	-	-
W26	7.2	688	336	0.2	<0.2	76.942	72	1.2	33.22	78.414	15.126	< 0.100	< 0.010	< 0.010	< 0.010	< 0.010	< 0.025	< 0.010	0.045	< 0.010	< 0.010
WB 1	7.86	1497	264	1.53	73.6	92.9	707	0.941	40.8	380	41.8	<0.003	-	-	-	-	<0.003	-	<0.001	-	-
WB 1	7.74	1500	277	1.14	19.9	87.8	745	0.841	41.4	379	59	<0.003	-	-	-	-	<0.003	-	<0.001	-	-
WB 5	7.81	460	251	7.97	35.5	51.6	81.9	0.835	18.3	108	5.3	<0.003	-	-	-	-	<0.003	-	<0.001	-	-
WB 5	7.56	438	257	6.25	37	45.7	74	0.68	17.6	96.7	6.22	<0.003	-	-	-	-	<0.003	-	<0.001	-	-

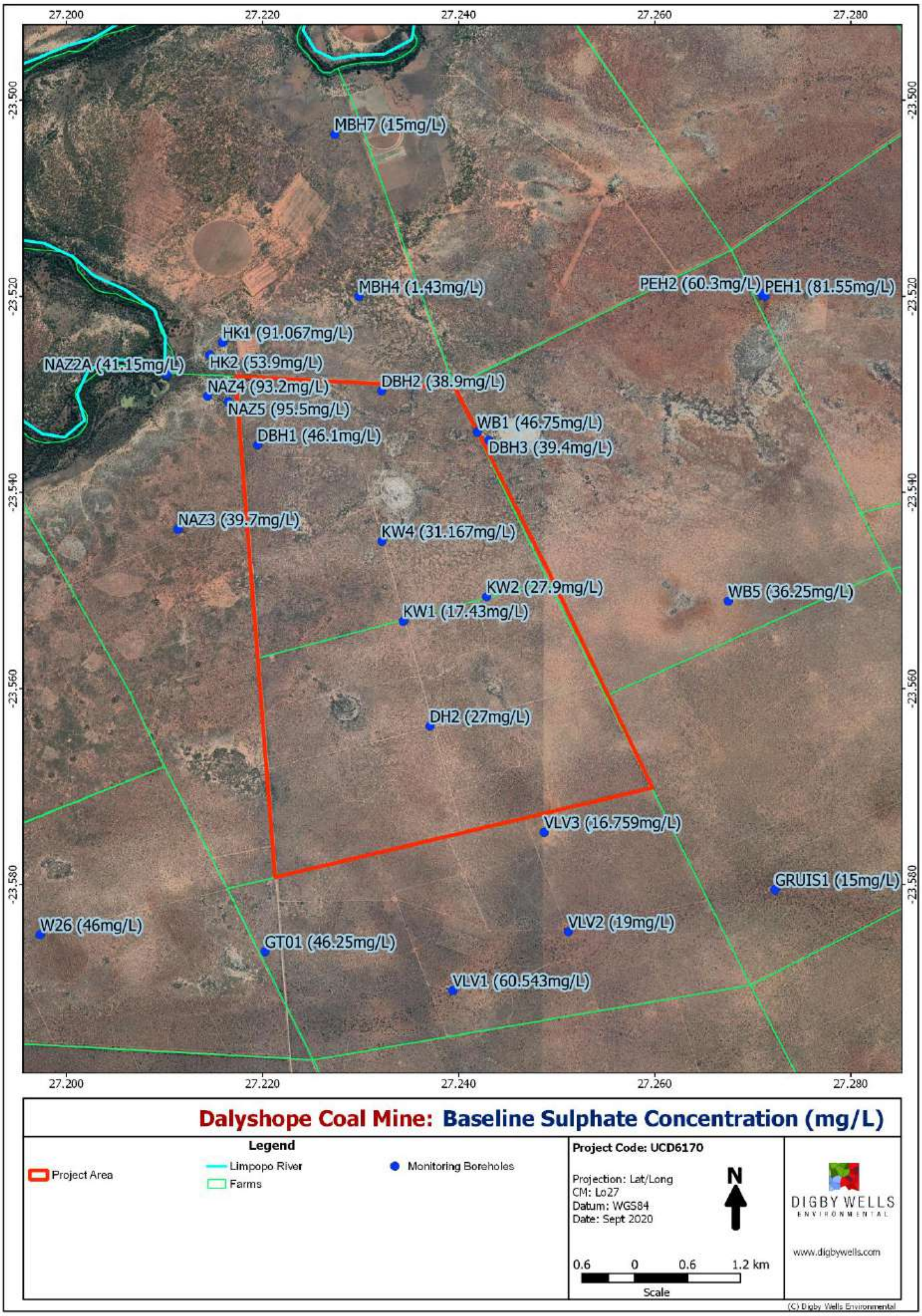

Figure 6.4: Baseline sulphate concentration

6.4. Groundwater Level and Flow Direction

The groundwater levels within the open pit area varies between 8 m and 20 m below surface, with an average of 15.1 m. There is currently only one water level monitoring borehole (DH2) that is located within the pit area. This is a limitation as the borehole may not be representative of the entire pit footprint. The water depth at the pit area is shown in Figure 6.5.

Under natural condition groundwater flow mimics the topography and regional surface water flow direction is towards the Limpopo River as shown in Figure 6.6. However, local depression of water table could occur due to abstractions by the local farmers.

The maximum hydraulic head is found in the eastern part of the project site, at an elevation of 829 metres above mean sea level (mamsl). The lowest hydraulic head is found in north-western part of the project site at an elevation of 824 mamsl. This would mean that the hydraulic gradient along the groundwater flow direction is approximately 0.0025.

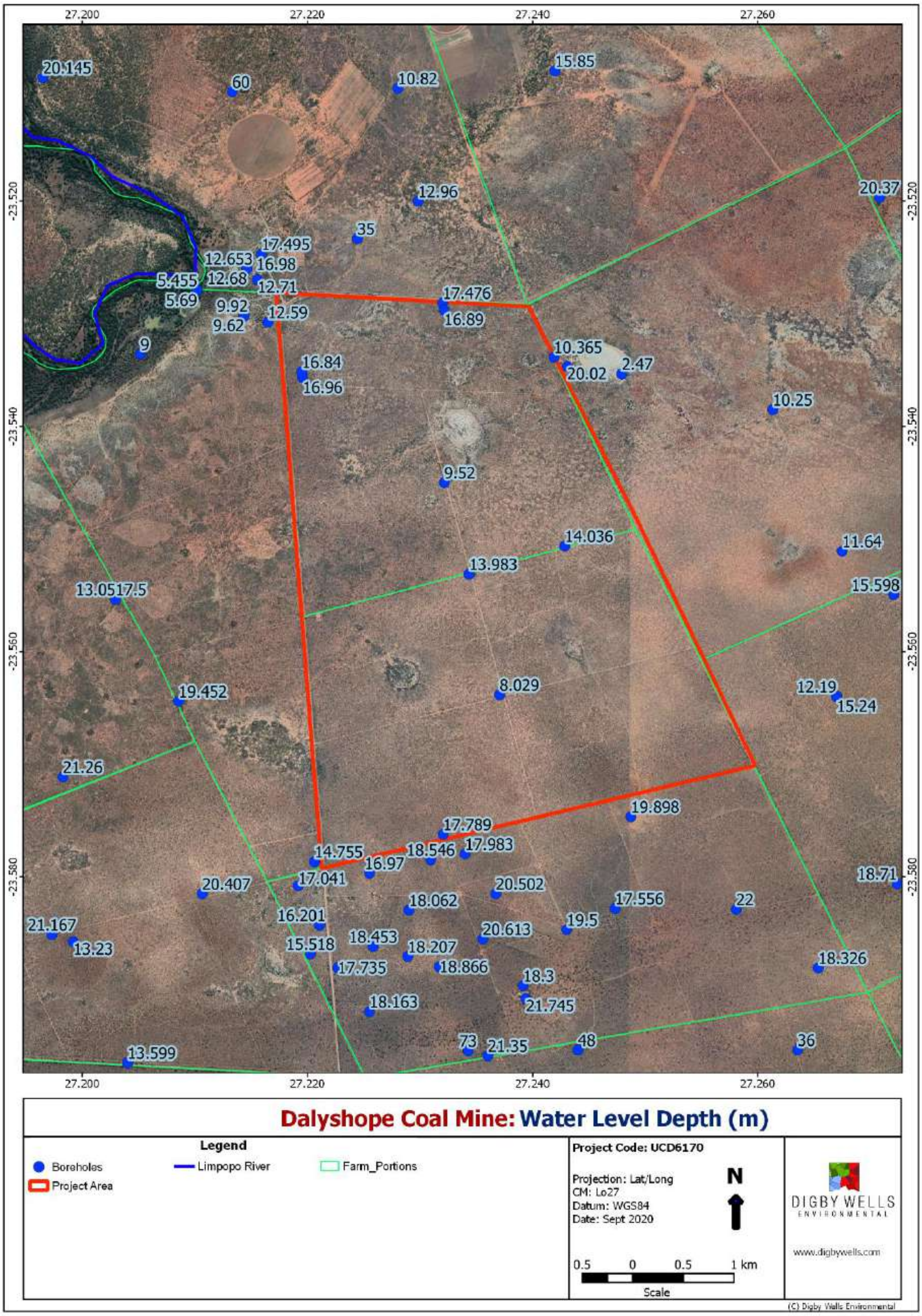

Figure 6.5: Groundwater depth at the project site

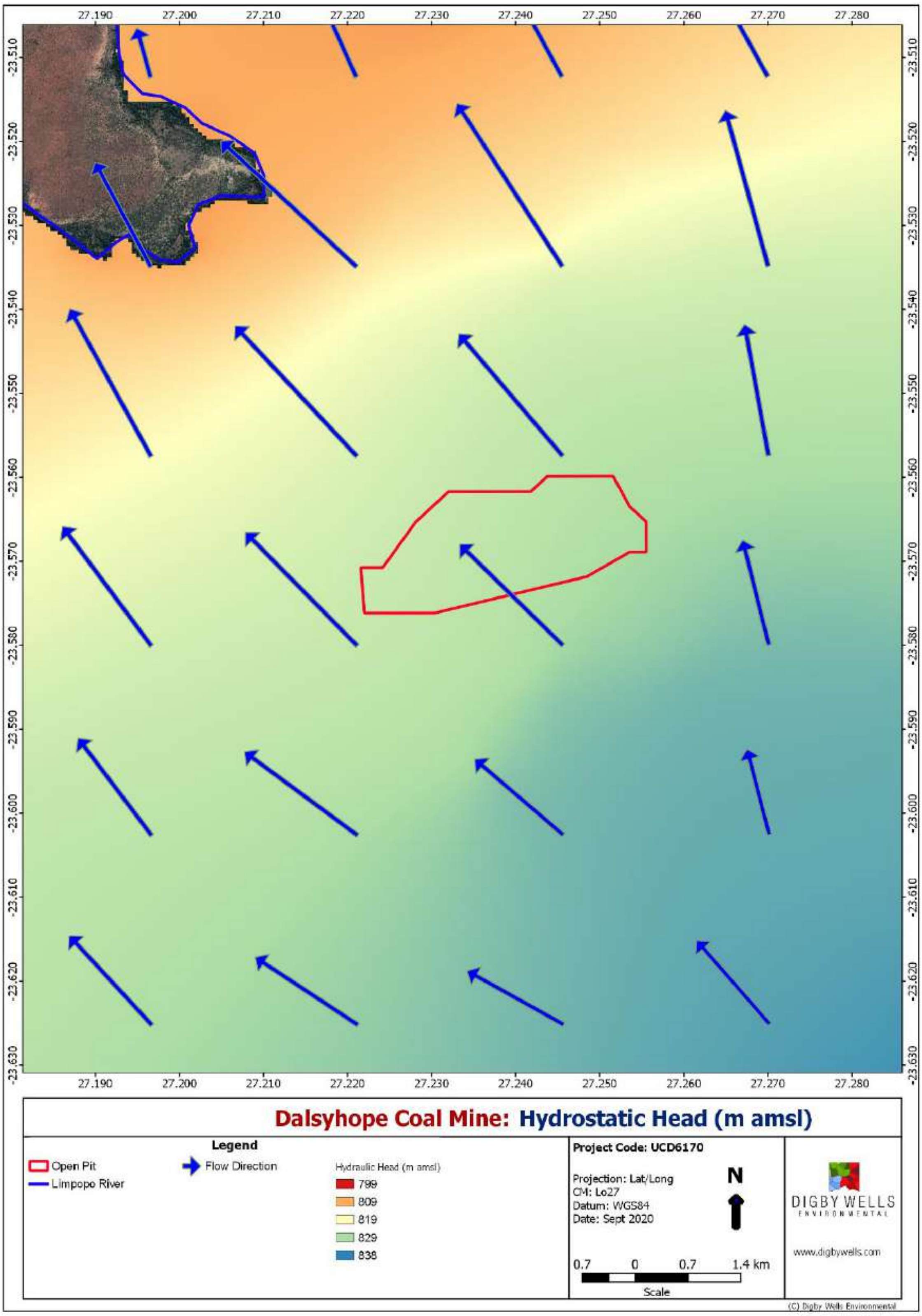

Figure 6.6: Hydraulic head and flow direction

1.1 Aquifer Layers

The frequency of the water strikes (fracture positions through which groundwater flows) observed from all the recorded boreholes in and around the project area is illustrated in Figure 6.7. Water strikes have been intercepted at depths between 20 and 100 m below ground level (bgl). Although some boreholes were drilled up to 160 m, no water strike was recorded below 100 m, defining the bottom of the aquifer.

The water strikes are distributed between the 20 and 100 m interval. The upper section of the interval is dominated by weathered zone, which gradually changes to fractured zone. Unless disturbed by local abstraction, and possibly a localised perched aquifer, there is no abrupt change in hydraulic head even between shallow (<30m) and deep boreholes (>30m). The aquifer was therefore simplified into one layer ranging in depth between 20 and 100 m.

A comparison of groundwater levels with water strikes in the boreholes indicates that the depth of water strikes is in most cases below the measured groundwater levels, which is indicative of confined groundwater flow conditions. The difference varies from a few centimetres to 46 m. However, a continuous confining layer appears to be absent and the aquifer underlying the site has been classified as being semi-confined.

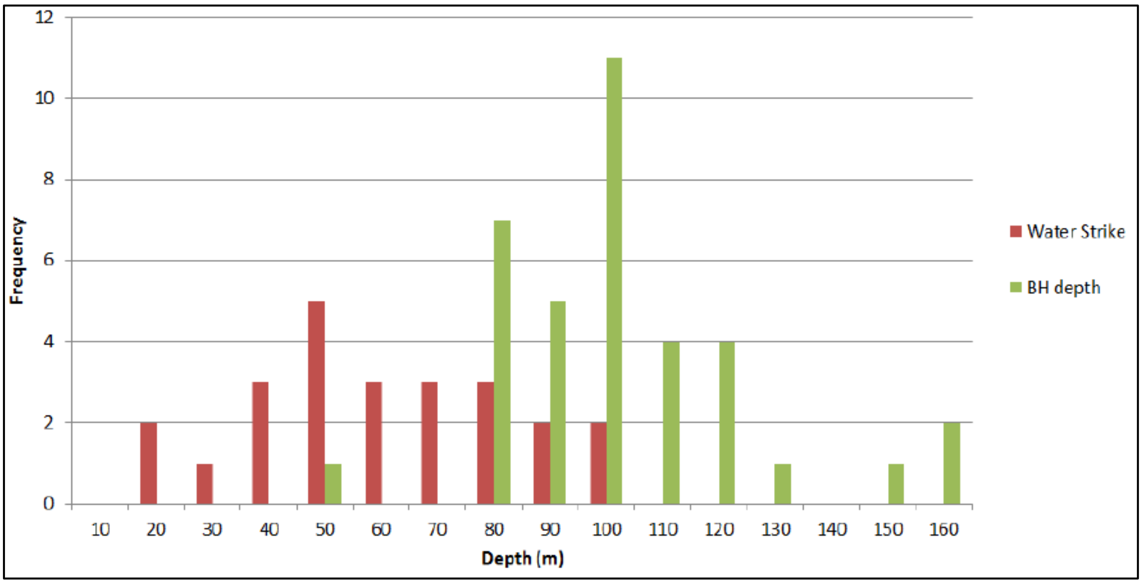

Figure 6.7: Water strike frequency

1.2 Aquifer Permeability

Permeabilities are classified from Very Low to Very High according to Bliss et al, (1984). These classifications are listed in Table 6-2 and have been applied to categorise the aquifer permeability at the project site.

The permeability values obtained from the aquifer testing are summarised in Table 6-2 and displayed in Figure 6.8.

The permeability values are as follows:

- Overall, the aquifer permeability ranges from very low (0.002 m/d) to very high (6.6 m/d); and
- The aquifer is highly heterogeneous with permeability values being variable in a relatively short distance.

Table 6-2: Aquifer classification based on permeability values (Bliss et al, 1984)

Permeability (m/d)	Classification	Condition of Rock Mass Discontinuities	Aquifer Test Results	Boreholes within the Pit Footprint area
< 0.009	Very Low	Very tight	9% (4 Bhs)	0
0.009 - 0.052	Low	Tight	38% (18 Bhs)	69% (9 Bhs)
0.052 - 0.173	Moderate	Few partly open	23% (11 Bhs)	31% (4 Bhs)
0.173 - 0.518	Medium	Some open	9% (4 Bhs)	0
0.518 - 0.864	High	Many open	4% (2 Bhs)	0
> 0.864	Very High	Open closely spaced or voids	17% (8 Bhs)	0

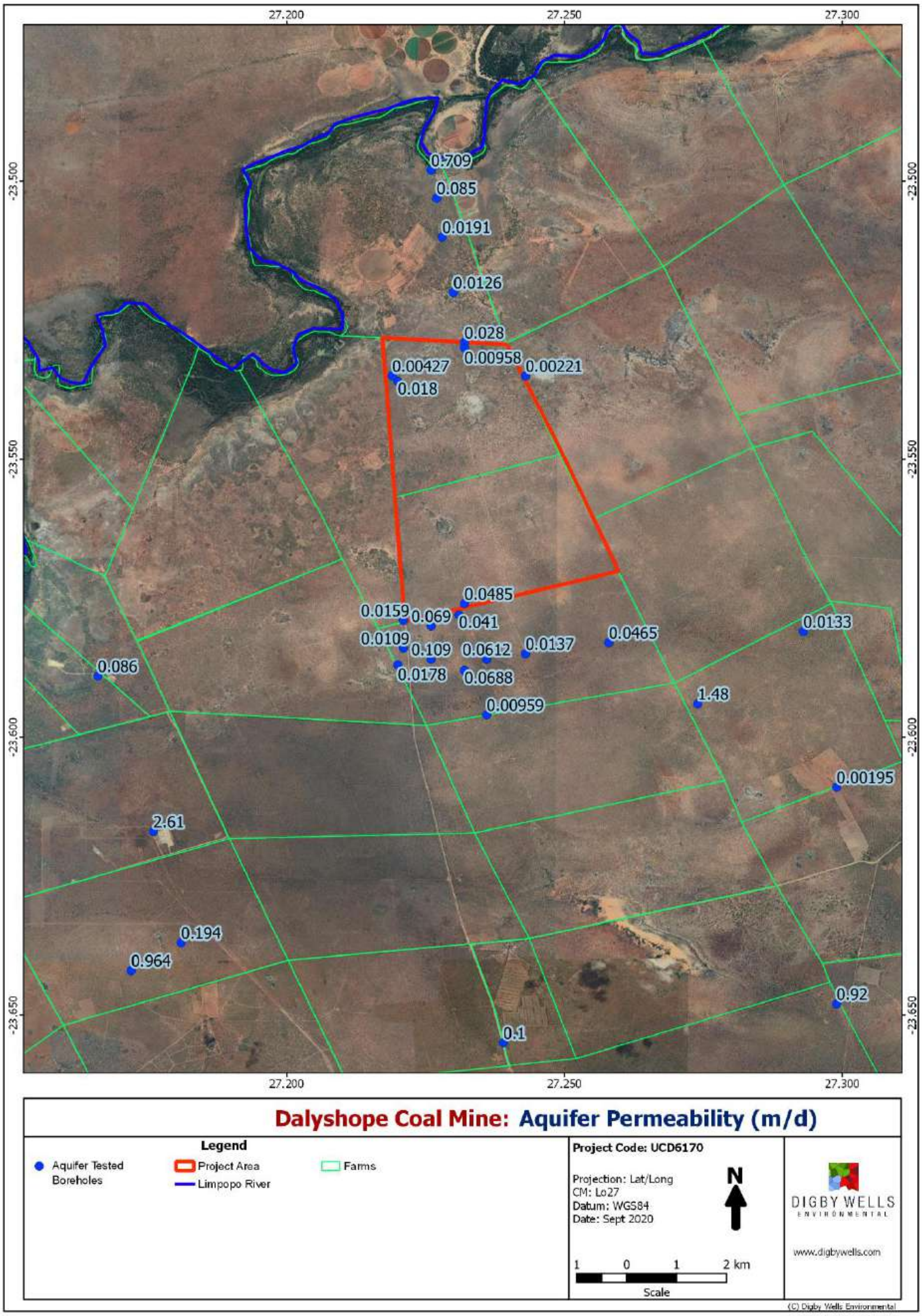

Figure 6.8: Distribution of the aquifer permeability

7. Numerical Modelling

The site conceptual model discussed in Chapter 4 has been used as an input into the numerical model. A conceptual model is a simplified, but representative description of the groundwater system that illustrates the interaction of the sources, pathways and receptors at the site.

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

As illustrated in Figure 7.1, an environmental risk exists only if the three components of a conceptual model (source, pathway and receptor) are linked.

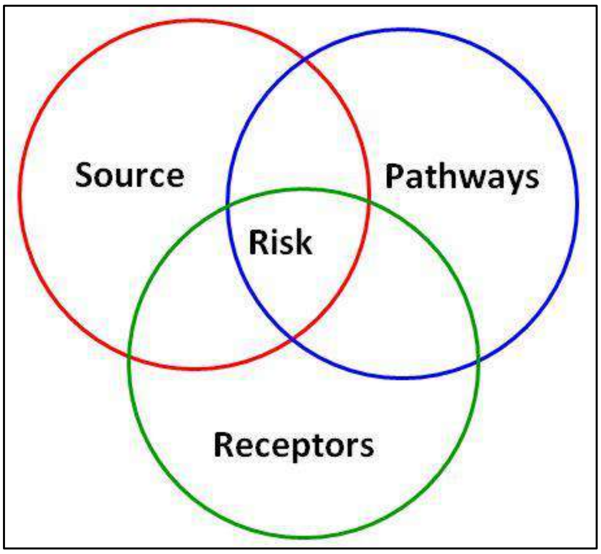

Figure 7.1: A conceptual model based environmental risk

7.1. Model Setup

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

7.2. Model Domain

The model domain (Figure 7.2 and Figure 7.3) is irregularly shaped with dimensions of 35 km by 32 km. A rectangular mesh was generated over the model domain, consisting of 660 rows and 748 columns. The mesh was refined in the entire of the model domain to cell sizes of 50 by 50 m. Although a smaller grid size may result in prolonged running time, it was important to refine the model so that the groundwater gradient and solute transport can be calculated with accuracy.

7.3. Boundary Conditions

The model domain is defined by the following boundaries:

- Limpopo River on the west and north, as a fixed head boundary;
- Eenzaamheid Fault to the south, as a general head boundary;
- Daarby Fault to the northeast, as a general head boundary; and
- An unnamed fault on the east (Figure 7.2), as a general head boundary. The fault connects the Daarby Fault with the Eenzaamheid Fault.

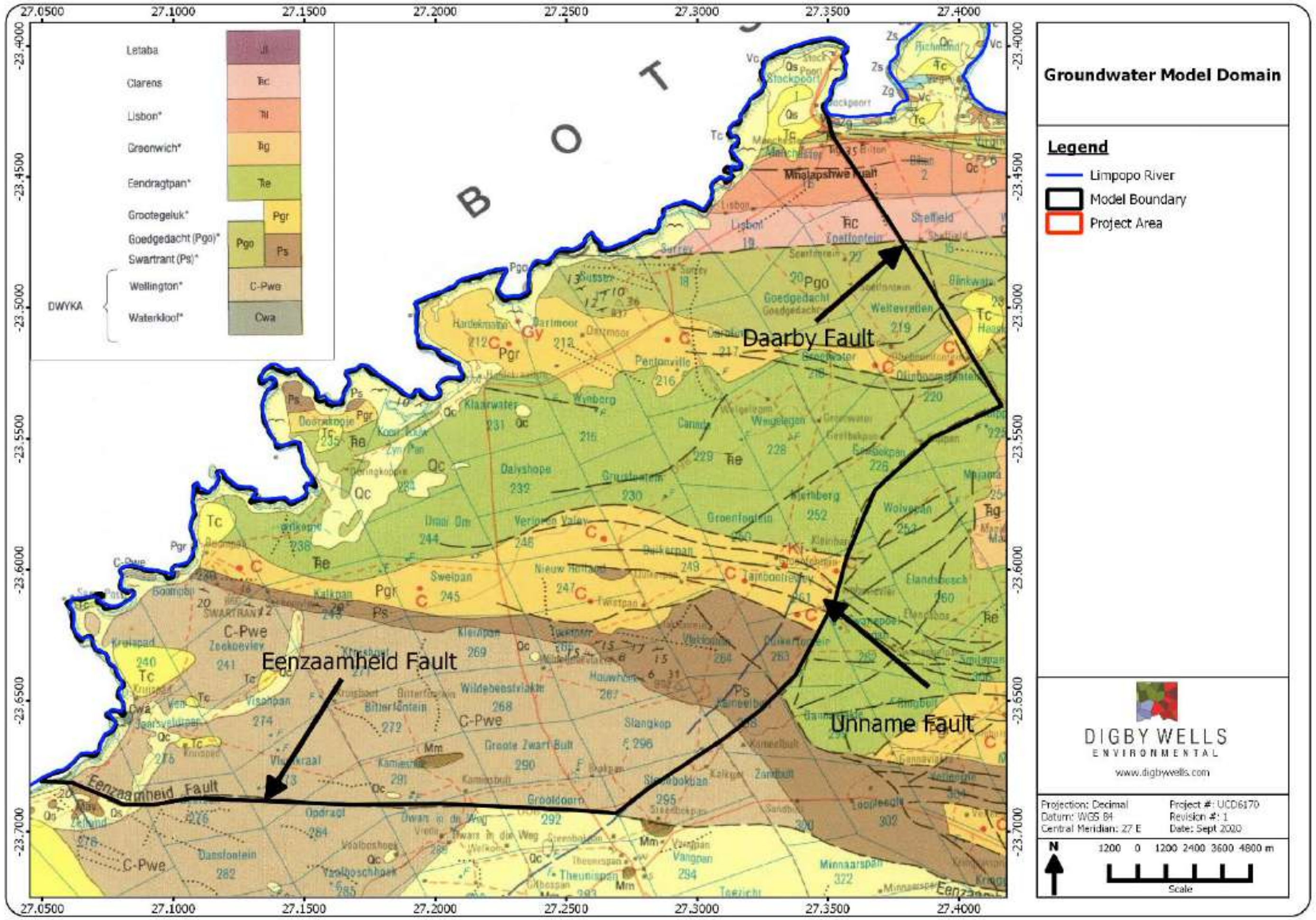

Figure 7.2: The numerical model domain

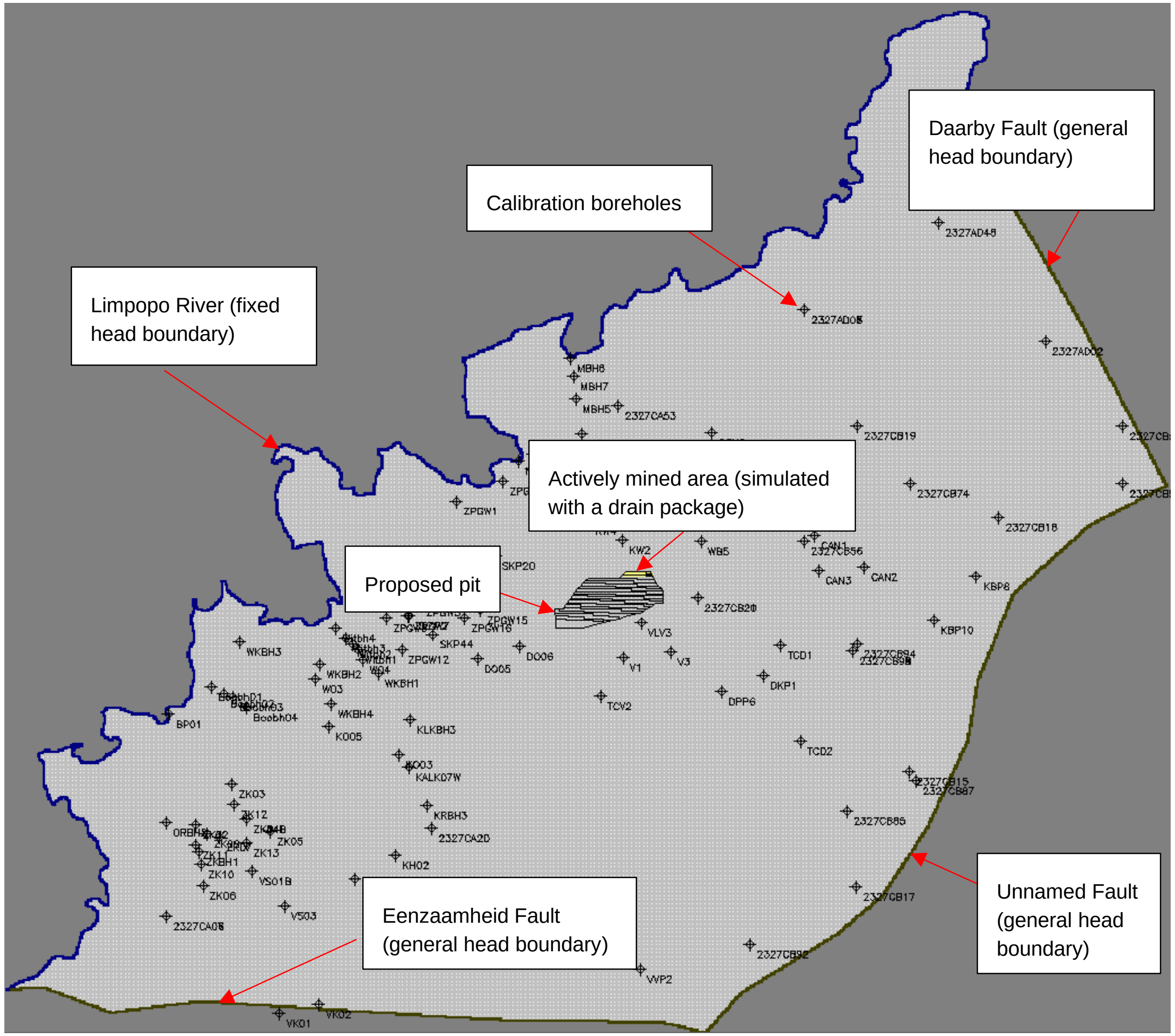

Figure 7.3: The numerical model mesh and boundary condition

7.4. Steady State Calibration

Prior to the simulation of the mining and dewatering activities, a baseline (pre-mining) steady state groundwater flow model was set up and calibrated. The objective of the steady state model was to simulate the undisturbed groundwater system in the region prior to mining and well field production. The impacts of mining activities on the groundwater environment can then be determined by comparing the transient state results with the steady state results.

A total of 82 observation boreholes were used for the steady state model calibration. After model calibration, an acceptable correlation of 96.36% was obtained between the simulated and observed groundwater elevation (Figure 7.4). An absolute mean error of 4.9 m for the model calibration was considered to be sufficiently small, given that the observed maximum head difference over the model domain area was 45.4 m and that the number of unknown input parameters was kept small. It should also be noted that water levels of some of the private boreholes were slightly lower (up to 5 m) from the steady state value due to abstraction.

Based on the steady state model calibration, the recharge in the project area is estimated at approximately 0.75% of the mean annual precipitation of 438 mm (but could range between 0.25 to 1.5% depending on the local hydraulic properties).

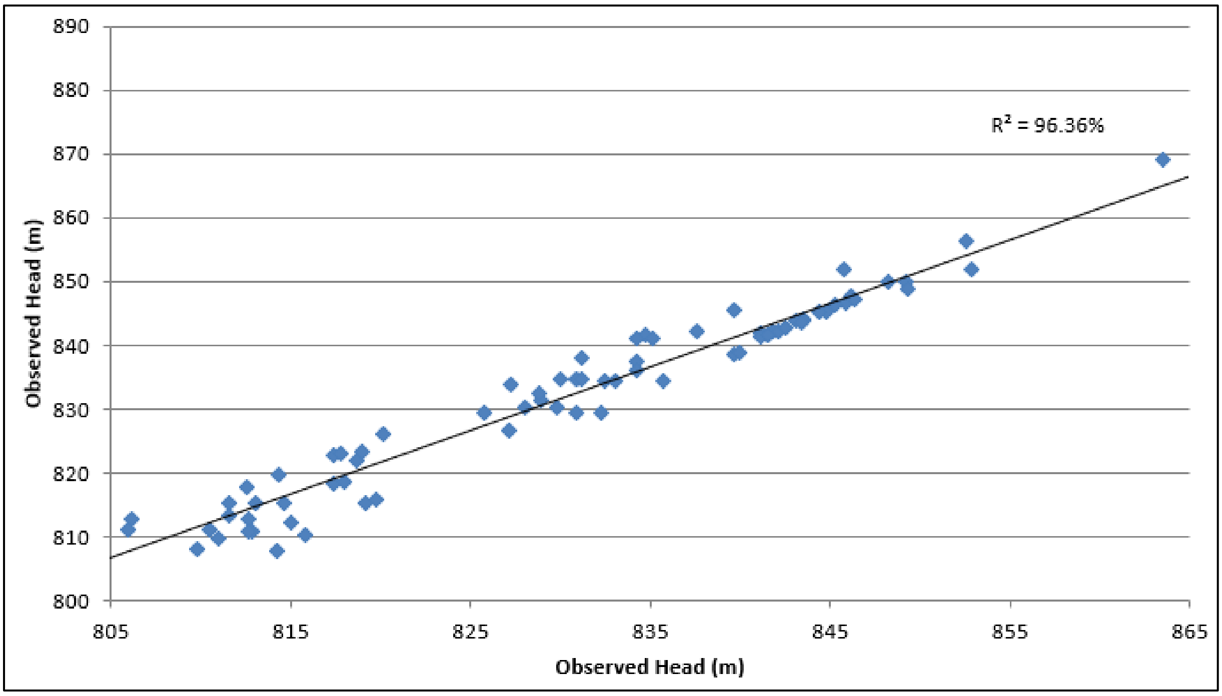

Figure 7.4: Correlation between observed and simulated head

7.5. Transient State Calibration

The pump test data of some of the boreholes near the pit area were used for the transient state calibration. Two examples are given in Figure 7.5 (borehole LD05) and Figure 7.6

(borehole LD01). An average specific storage of $1x10^{-4}m^{-1}$ and specific yield of 0.05 were found from these calibrations.

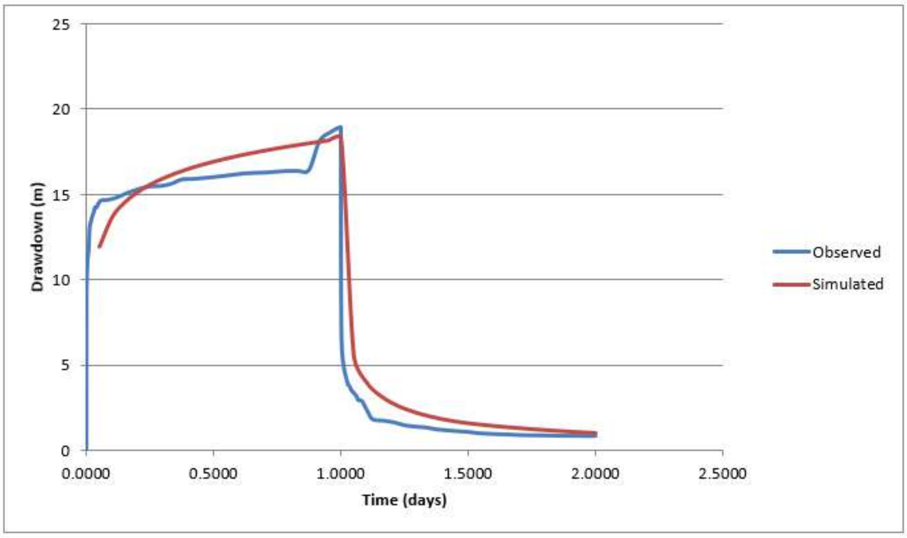

Figure 7.5: Pump test calibration of boreholes LD05

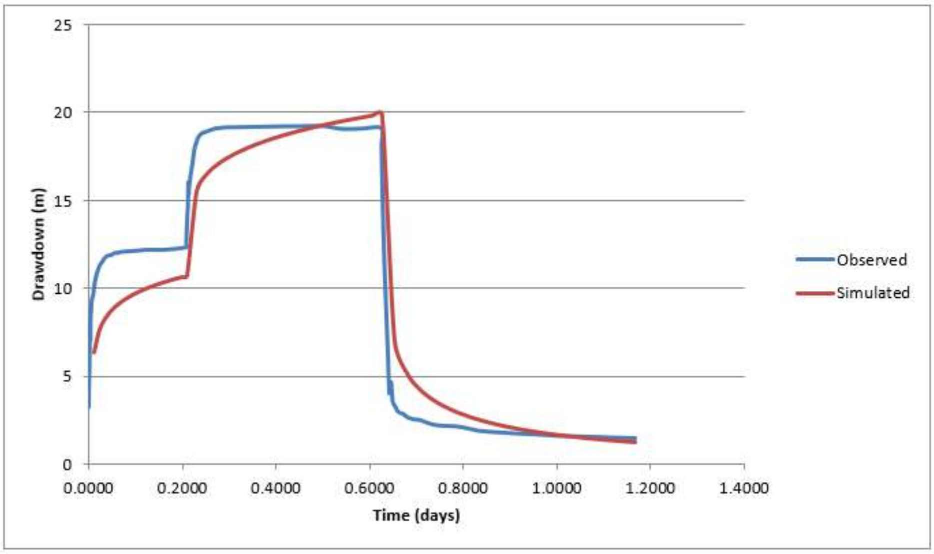

Figure 7.6: Pump test calibration of boreholes LD01

There are a number of companies planning to mine in the Waterberg Coalfield (Figure 8.5). Currently there is no information on when these mines will start. Two of the closest mines planned are the Temo Coal pit that belongs to Namane Resources and Boikarabelo Pit that belongs to Resources Generation. The pits are expected to be connected hydraulically and affect each other in terms of cone of dewatering. Groundwater ingress at the Dalyshope Pit will be affected by the distance, pit size, pit depth and excavation rate of the nearby pits. The proposed Temo Coal is only 130 m away from Dalyshope and is expected to significantly influence the groundwater ingress at Dalyshope. The proposed Boikarabelo pit is, however, 5 km away and will have barely any influence on Dalyshope as observed using the numerical model.

The following three scenarios have been simulated to predict the influence of the nearby Temo Coal Pit on the Dalyshope ingress rate:

- **Scenario 1**: if Dalyshope Coal pit is mined alone;
- **Scenario 2**: If both the Temo Coal Mine and Dalyshope pits are mined simultaneously. In this scenario, the groundwater will be shared by both pits depending on the mine size and aquifer properties; and
- **Scenario 3**: the same as Scenario 2 but the Temo pit is assumed to start 5 years before the Dalyshope pit. In this scenario, the groundwater storage is expected to be depleted by Temo Coal. By the time the Dalyshope mine starts, the groundwater ingress and hydraulic pressure is expected to be less.

7.6. Dewatering Simulation

The open pit was simulated with the drain package. The drain elevation was set at the pit floor elevation and the drain conductance as the product of the aquifer permeability and grid cell length.

Considering the proposed life of mine, 24 separate models were used to simulate the 24 years of operation. The hydraulic head result of the previous year was used as an initial head for the next. The recharge in the backfill area was set at 15% of the mean annual precipitation, in line with Hodgson *et al*. (1995). The backfill permeability and specific yield were set at 10 m/d and 0.25 respectively. The drains were applied to the open portion of the pit where mining is actively taking place, but not the backfilled section.

7.7. Mass Transport Modelling

The backfill discard material is a potential source of contamination as it could leach to the groundwater. A number of elements can seep from the backfill, including: calcium, sulphate, aluminium and sodium ions. These elements have different chemical and physical properties and will travel at different rates and concentrations based on site specific conditions, such as the pH, redox conditions and retardation factors.

The concentration of sodium will be affected by ion exchange while that of aluminium by the pH levels. A conservative element such as chloride can be used as an indicator to simulate the footprint of the groundwater contamination associated with the sources, representing worst case solute transport over time. Although chloride is more conservative than sulphate, it is often not a contaminant of concern at coal mines and is not as good indicator of groundwater contamination as sulphate, hence sulphate was chosen over chloride. The non-conservative contaminants are expected to slow down, and their contamination front will move slower than the conservative transport. This is due to the fact that the conservative elements will mainly migrate by advection and dispersion while the non-conservative will be affected by other processes such as adsorption to the aquifer matrix.

The average sulphate value in the natural groundwater is less than 60 mg/L, which is considerably less than the recommended drinking limit of 400 mg/L (South Africa Water

Quality Guideline and SANS 241: 2006). Any increase in sulphate in the vicinity of the Dalyshope Coal Mine is therefore likely to be a contamination from mine-related activities.

Sulphate is expected to be an element of concern at Dalyshope Coal Mine based on the experience learned from other coal mines, including at Grootegeluk where it has reached up to 2700 mg/L in some monitoring boreholes. A source-term concentration of 2700 mg/L has been used during this study as similar geochemical characteristics is assumed to exist in the Waterberg area.

Depending on the compaction of the backfilling material, the backfill recharge is expected to increase between 5 and 20%, a 15% recharge has been assumed in this study. This is in line with the study of Hodgson et. al. (1998) in various coal mines.

In the first 8 years of operation, a discard dump is expected to be placed on ground surface until sufficient space is available in the open pit for disposal. The seepage rate through the discard dumps to the groundwater is dependent on the hydraulic properties (permeability and compaction) of the foundation underlying the dumps, as well as the compaction of the dumps themselves. The dumps are expected to be constructed on a solid foundation, with a network of drains underneath to intercept seepage before infiltrating to the subsurface. The above together with the low permeability of the underlying aquifer and nearly flat groundwater gradient at the project area, is expected to limit the migration of contaminants down-gradient from the site.

To simulate the solute transport from these sources, seepage rates through the coal stockpile and discard dumps are estimated to be approximately 1% and 5% of the mean annual rainfall, respectively.

7.8. Dispersion and Diffusion

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

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

A longitudinal dispersivity of 500 m and a horizontal and vertical transversal dispersivity of 50 m are selected for the mass transport model. The selected longitudinal dispersivity represents 10% of the distance between the proposed Dalyshope Coal Mine pit and the Limpopo River (receptor) which is approximately 5 km at its nearest point.

A diffusion coefficient of 1x10^{-5} m^2/day was selected; acceptable for Karoo rocks. No site-specific field measurement of porosity is available, but assumed to be 10%; acceptable for Karoo rocks (Van der Voort, 2001).

7.9. Sensitivity Analysis

A model sensitivity analysis was carried out to give an indication of which assumptions in model input parameters were most likely to affect the model output. Input parameters (permeability, recharge, specific storage and specific yield) were varied within a factor of 0.5 and 2 of the calibrated value and the corresponding change of the groundwater inflow rate was measured.

Figure 7.7 presents the result of the sensitivity analyses for the various hydraulic parameters. The model is more sensitive to the aquifer permeability followed by the specific yield than the rest of the parameters (the recharge and specific storage). This means that changes in rock permeability and specific yield will have a greater impact on the model output than the other less sensitive parameters.

Since the model is most sensitive to the permeability and specific yield, any future groundwater study is recommended to focus on and refine these parameters of the aquifer mainly.

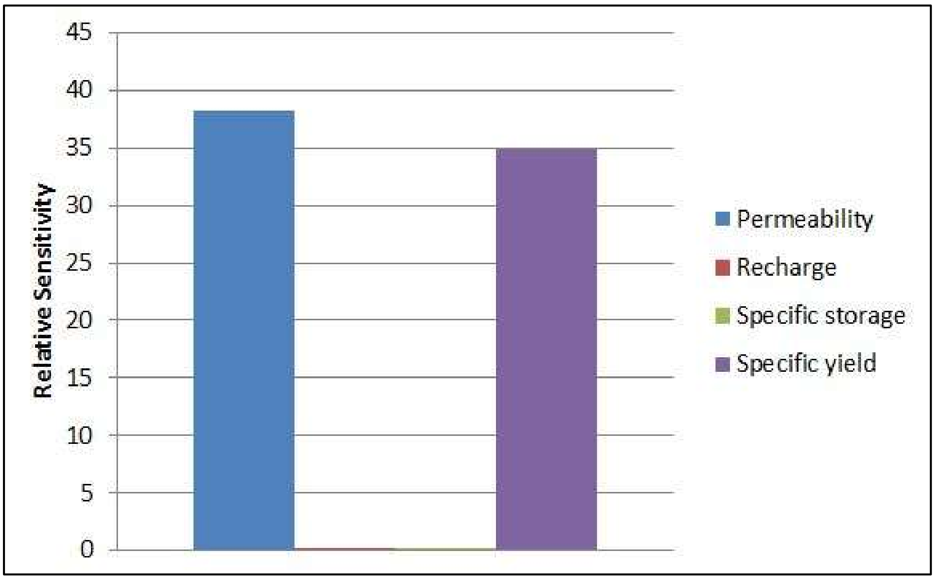

Figure 7.7: Model sensitivity to the hydraulic parameters

8. Impact Assessment

8.1. Construction Phase

The activities during the construction phase that could potentially impact the groundwater include:

- Site clearance and topsoil removal across the project area.

- The construction of overburden stockpile areas.
- The construction of pollution control dams (PCDs).

Table 8-1: Interactions and Impacts of Activity

Interaction	Impact
Site clearance	Lowering of the water table, if the site clearing will take place below the water table
Diesel storage and explosives magazine (Construction Phase)	Groundwater contamination due to spillages
PCD and stockpile construction	Lowering of the water table, if the construction activities are going to take place below the water table

8.1.1. Impact Description

The groundwater levels within the open pit area varies between 8 m and 20 m below surface, with an average of 15.1 m. All construction activities are expected to take place above this, and therefore, no impact on the groundwater is envisaged as a result.

8.1.1.1. Management Objectives

The objective of the management measures is to ensure that groundwater contamination during the construction phase is avoided or minimised.

8.1.1.2. Management Actions

Although no impact is foreseen during the construction phase, the following are management measures that can be implemented:

- Site clearance should be kept to a minimum;
- Areas cleared of vegetation for construction activities should be limited to those of absolute necessity;
- Ensure that all construction activities take place above the water table. The water table is deep and there is sufficient space for the construction activities to take place without reaching the aquifer;
- Conduct groundwater monitoring to determine the baseline which will allow the monitoring of potential impacts during the operations.

8.1.1.3. Impact Ratings

The significance rating of the potential impacts before and after mitigation is provided in Table 8-2.

Table 8-2: Potential impacts during the construction phase

Activity & Interaction: Site clearing for the development of surface infrastructure through the removal of the topsoil and weathered rocks			
Dimension	**Rating**	**Motivation**	**Significance**
Impact Description: Lowering of the water table			
Prior to mitigation/ management			
Duration	Short term (2)	Soil clearing, and development of infrastructure should take place in a relatively short duration.	Negligible (negative) – 4
Extent	Very limited (1)	Site clearing will only occur within and immediately around the project site	
Intensity	Minor - negative (-1)	No dewatering is anticipated during the construction phase.	
Probability	Probable (1)	It is highly unlikely that any construction activities will take place below the water table (21.4 m)	
Mitigation/ Management actions			
▪ Avoid constructing below the water table as far as possible. ▪ In the unlikely scenario where the foundation of structures is to be installed below the water level, dewatering of the aquifer to locally lower the water table can be considered. The abstracted water can be utilised for dust suppression, vegetation or discharged to the pollution control dams. ▪ Install long term monitoring boreholes.			
Post- mitigation			
Duration	Immediate (1)	Any impact on the groundwater (if any) is expected to recover due to natural processes in a short-time	Negligible (negative) – 3
Extent	Very limited (1)	Only the area in the site clearing area will be affected (if at all)	
Intensity	Minimal - negative (-1)	Considering that the construction phase will be for a short period, the intensity will be minimal	

Activity & Interaction: Site clearing for the development of surface infrastructure through the removal of the topsoil and weathered rocks			
Dimension	**Rating**	**Motivation**	**Significance**
Probability	Probable (1)	It is highly unlikely that any construction activities will take place below the water table (25 m)	

8.2. Operational Phase

The mine activities during the operation phase that could result in the groundwater impact are listed in Table 8-3:

- Mining of the open pit,
- Pit dewatering;
- Concurrent backfilling of the pit with waste rock material
- Backfilling of the open pit with discard material;
- Pollution control dams; and
- Overburden and topsoil stockpiling.

Table 8-3: Interactions and Impacts during the Operation Phase

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

8.2.1. Mine Dewatering

Mine dewatering is crucial to keep the mining area dry for safe working conditions. This can potentially impact the groundwater environment negatively by lowering the water level and creating a cone of depression.

The mine dewatering can be conducted from a sump located within the pit at the lowest point where the water will accumulate, or dewatering boreholes or a combination of both. Considering the relatively low aquifer yield, it is proposed to be conducted from a sump in the lowest working area of the pit floor.

Dewatering from a sump(s) within the open pit is also in line with the various coal mines in South Africa, including the Grootegeluk Mine. Dewatering from boreholes has the advantage of intercepting the groundwater before it is potentially contaminated at the pit. However, no high yielding fractures were intersected during this study and installation of dewatering wellfield is likely to be more expensive than seepage management using sumps.

If dewatering is to be conducted from boreholes, new boreholes will have to be drilled as mining progresses since mining will be conducted progressively and this is likely to increase the cost. A sump and drainage system within the open pit will be required in any event to collect surface runoff during rainy seasons even if dewatering boreholes are to be used. Water collected at the sump should be incorporated with the process water system considering the water shortage in the Waterberg area.

Due to the aquifer heterogeneity in the project area, the inflow rates and radius of influence at Dalyshope are not expected to be uniform. The design of the mine plan and implementation of backfill will also contribute to the fluctuation of the inflow rates. The estimated groundwater ingress at Dalyshope at various stages of the life of mine is given in Figure 8.1 and listed in Table 8-4.

- Ingress is highest (maximum of 3.4 ML/d) if only Dalyshope pit operates;
- If Dalyshope and Temo Coal pits operate simultaneously, a maximum of 3.0 ML/d is expected to report to the Dalyshope pit;
- If Dalyshope pit starts operating 5 years after Temo Coal, the inflow is expected to be lowered even further as shown in Figure 8.1.

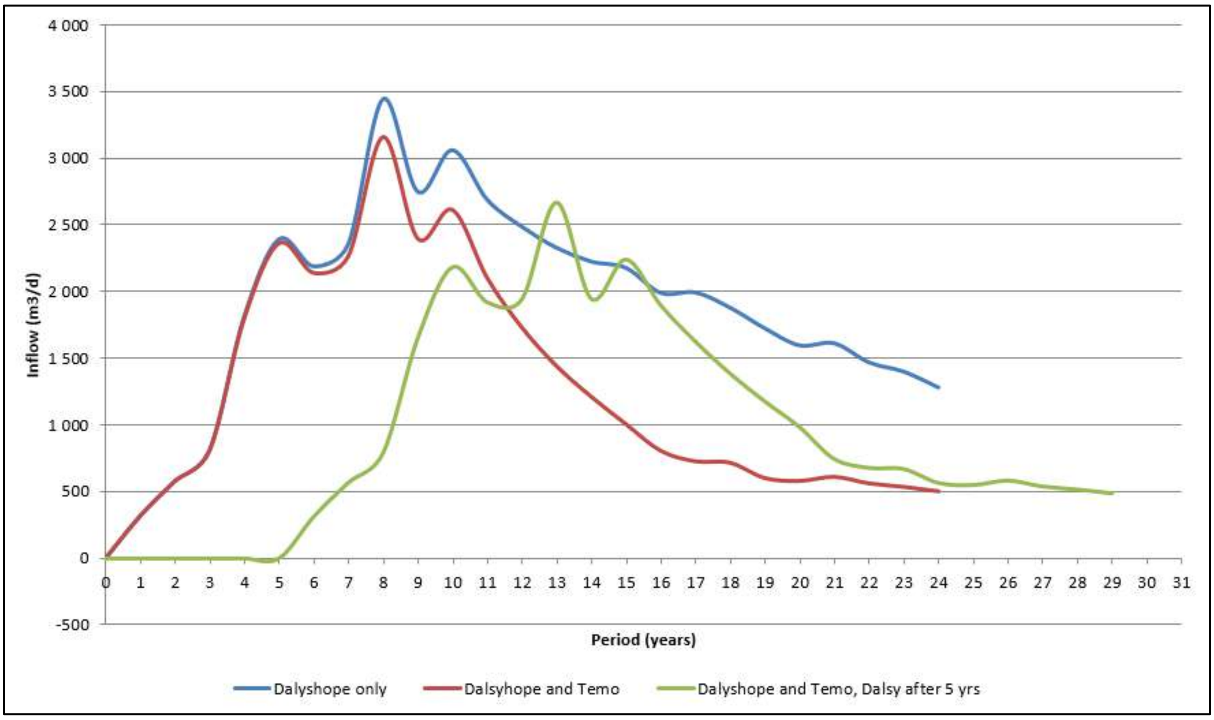

Figure 8.1: Estimated groundwater ingress

Table 8-4: Estimated groundwater ingress

Year	Dalyshope only (m3/d)	Dalyshope and Temo Coal (m3/d)	Dalyshope and Temo Coal with Dalyshope after 5 years (m3/d))
0	-	-	-
1	318	318	-
2	580	579	-
3	810	810	-
4	1 813	1 800	-
5	2 391	2 364	-
6	2 188	2 142	311
7	2 356	2 267	567
8	3 440	3 161	788
9	2 747	2 400	1 647
10	3 058	2 615	2 179
11	2 687	2 105	1 918
12	2 485	1 733	1 938
13	2 327	1 443	2 664
14	2 224	1 213	1 943
15	2 177	1 008	2 237
16	1 989	808	1 895
17	1 992	729	1 623
18	1 879	718	1 383
19	1 724	604	1 175
20	1 596	582	983
21	1 612	613	745
22	1 469	564	678
23	1 400	538	669
24	1 281	505	565
25			549
26			583
27			539
28			516
29			488

8.2.1.1. Impact on the Limpopo River

Model simulation showed that the Limpopo River is not at risk from mine contamination during the life of mine (Figure 8.3). It is also not expected to be impacted by the dewatering activities at the Dalyshope Coal Mine (Figure 8.2) and there is no need for active mitigation during this period.

However, monthly water level and quality monitoring of the boreholes between the mine and the river are recommended to detect any potential impacts on the Limpopo River. If in the unlikely event that an impact on the Limpopo River is confirmed through monitoring, the mine should actively intervene to reduce or avoid the impact. This can be done through the following two mechanisms:

- The interception of the contaminated water before reaching the Limpopo River through interception boreholes; or
- The treatment of the contaminated water to an acceptable quality and discharge to the Limpopo River or use it at the mine.

8.2.1.2. Impact on Private Boreholes

Some farms in the immediate vicinity of the project area fall within the radius of influence as shown in Figure 8.2. The following is recommended as part of the management plan:

- It is recommended that the mine should supply equal or better-quality water to affected parties that rely on groundwater, if proven that there is an impact. The baseline water quality of the private boreholes has already been analysed as discussed previously. These results should be used for future comparisons to evaluate if the solute transport has impacted the borehole water quantity or quality.
- Monitoring of the groundwater quality and water levels in the private boreholes is recommended (particularly those that are west of the pit), with continuous refining and updating of the monitoring network based on the results obtained. Since the operation phase will take place over a prolonged period compared to the construction phase, more monitoring boreholes will be required.
- Refine the conceptual and numerical models every 2 years in the first 4 years and thereafter every five years based on groundwater monitoring results.
- Harvesting of rainwater should be implemented as soon as possible which should be used in lieu of external water resource to ensure it is not wasted.

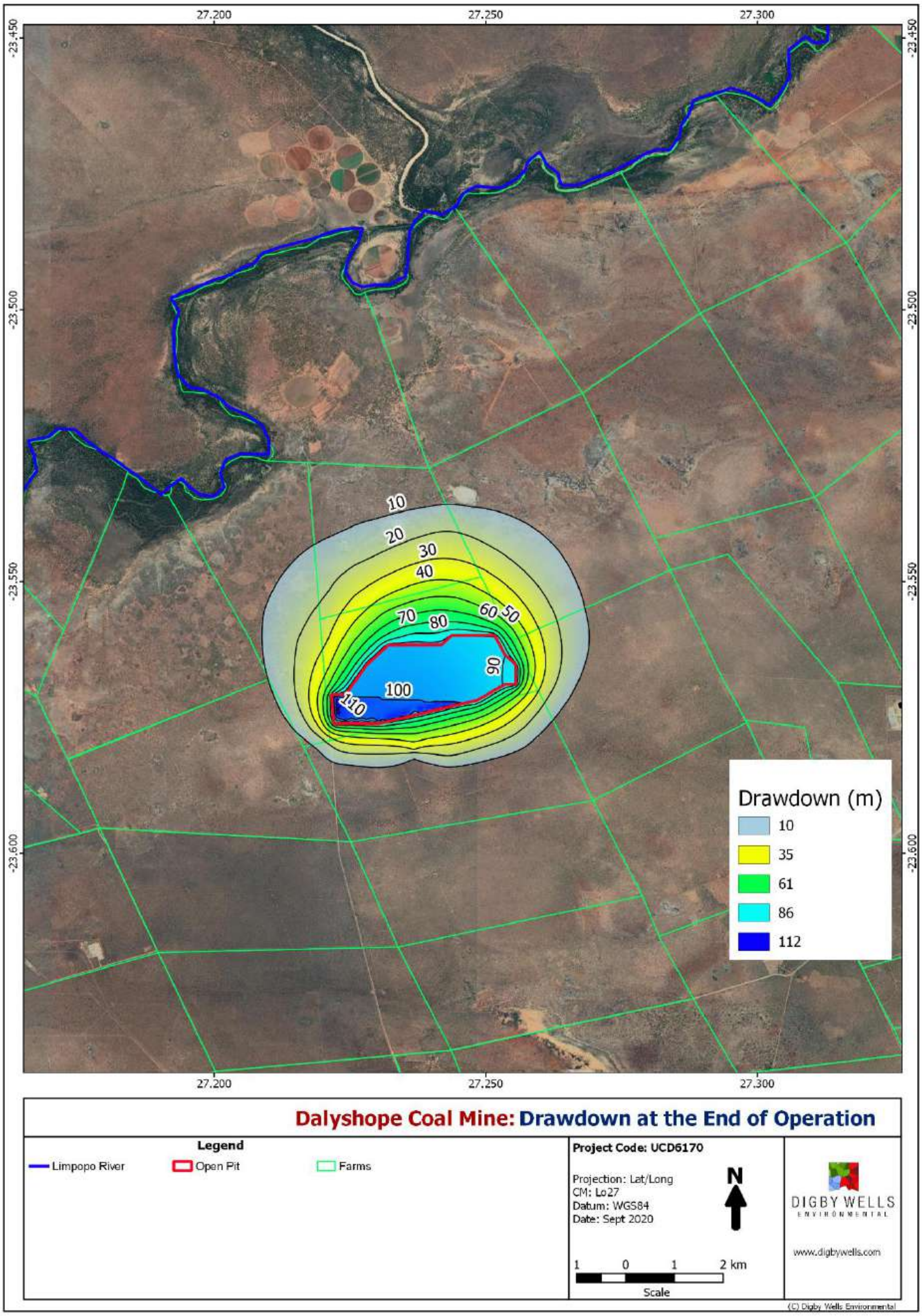

Figure 8.2: Cone of dewatering and impact zone at the end of operation

8.2.1.3. Impact Ratings

Dalyshope Coal Mine is expected to impact the groundwater quality and quantity. The impact rating for the groundwater quantity is given in Table 8-5, while for the groundwater quality is given in Table 8-6.

Table 8-5: Impact assessment on the groundwater quality during operation phase

Activity & Interaction: Mine dewatering and creation of cone of dewatering			
Dimension	**Rating**	**Motivation**	**Significance**
Impact Description: Lowering of the water table			
Prior to mitigation/ management			
Duration	Beyond Project Life (6)	The water level will remain below its natural level for some time after the life of a Project	Minor (negative) – 48
Extent	Limited (2)	The radius of influence will be limited to the site and its immediate surroundings	
Intensity	Serious - negative (-4)	The mine dewatering will result in lowering of the water table. This impact is unlikely to reverse in less than a year	
Probability	Almost likely (4)	It is almost certain that there will be a cone of drawdown formed due to the mine dewatering	
Mitigation/ Management actions			
• Store the dewatered water in pollution control dams and ensure that the dams will have sufficient storage volume. • Compensation of farmers with impacted groundwater levels, if impact is confirmed through monitoring. • Monitoring of groundwater water levels and pit inflow rates. • Minimise the impact associated with the lowering of the water table. Always keep the dewatering level close to the pit floor and not too far (more than 2 m) below. • Update numerical model as aquifer information becomes available.			
Post- mitigation			
Duration	Beyond project life (6)	The water level will remain below its natural level for some time after the life of a Project.	Minor (negative) – 44
Extent	Limited (2)	With the supply of treated water to the affected parties, the extent of impact will be limited.	

Activity & Interaction: Mine dewatering and creation of cone of dewatering			
Dimension	**Rating**	**Motivation**	**Significance**
Intensity	Moderate - negative (-3)	Once the abstracted water is treated and supplied to affected parties, or re-introduced to the streams, the environmental significance is rated as moderate.	
Probability	Probable (4)	The lowering of the water table will almost certainly occur.	

8.2.2. Groundwater Contamination

The footprint area of the solute transport is expected to be smaller than that of the cone of dewatering during the mine operation. Fewer private boreholes could be impacted by contamination as compared to that of dewatering and are located within the mine boundaries during the operational phae. The solute transport at the end of mine operation in relation to the farms is shown in Figure 8.3.

- Saline water with an acidic or alkaline pH can be released from the mine workings once coal zones and nearby rocks are exposed to oxygen and moisture. Contaminants can also be generated as a result of drilling and blasting during the operation.
- Rock dumps and stockpiles can release contaminants as rainfall percolates through them and ultimately reach the groundwater with unacceptable quality.
- During operation however, any contaminants that will originate from the mine workings will be pumped out as part of the mine dewatering process. No contaminants are expected to migrate away from the mine area to the river or private boreholes and therefore the impact has been rated as Minor (Table 8-6).

Table 8-6: Impact rating during operation phase due to contamination plume

Activity & Interaction: Groundwater contamination as a result of pit mining, pit backfilling, seepage from the PCD and waste stockpiling			
Impact Description: Solute transport in the groundwater			
Prior to mitigation/ management			
Duration	Beyond project life (6)	Groundwater contamination due to mine disturbance will occur during the operation and expected to persist even after closure	Minor (negative) – 42
Extent	Local (3)	The contaminated groundwater can impact the private boreholes that are close to the pit	

<table>
<tr><th colspan="4">Activity & Interaction: Groundwater contamination as a result of pit mining, pit backfilling, seepage from the PCD and waste stockpiling</th></tr>
<tr><th colspan="4">Impact Description: Solute transport in the groundwater</th></tr>
<tr><td>Intensity</td><td>Moderate – negative (-3)</td><td>The pit dewatering is expected to maintain the hydraulic head of the pit area to be below the regional groundwater level, thus containing the solute transport to within the mine property.</td><td rowspan="2"></td></tr>
<tr><td>Probability</td><td>Probable (4)</td><td>The impact is likely to occur, but the solute transport may not migrate beyond the mine area during the operational phase</td></tr>
<tr><td colspan="4">Mitigation/ Management actions</td></tr>
<tr><td colspan="4">

- Compensation of farmers with impacted groundwater or mine purchase land.
- Nitrate-based explosives should be avoided to minimise groundwater contamination.
- Contain the contamination plume to within the pit area, by dewatering the pit.
- Overburden stockpiles should be managed to minimise infiltration of contaminants to the groundwater. The stockpiling of carbonaceous contaminated with the topsoil stockpiles should be prevented and managed accordingly. Mitigation methods that should be considered include:
  - Management of the stockpile shape to control the ease with which water can run off.
  - The vegetation of the stockpile and covering them with soil to minimise rainfall infiltration and mobilisation of dissolved metals.
  - Implementation of a lime cover on overburden stockpiles to neutralise acidity.
- The following management activities can be implemented to minimise contamination that originates from the pollution control dam:
  - Implementation of adequate storm water management to contain all waste water and/or volatile organic compounds, for treatment and recycling.
  - Pollution control dams should be lined to pro-actively prevent infiltration of contaminated seepage water.

</td></tr>
<tr><td colspan="4">Post management</td></tr>
<tr><td>Duration</td><td>Beyond project life (6)</td><td>Groundwater contamination due to mine disturbance will occur during the operation and expected to persist even after closure</td><td>Minor (negative) – 40</td></tr>
</table>

Activity & Interaction: Groundwater contamination as a result of pit mining, pit backfilling, seepage from the PCD and waste stockpiling			
Impact Description: Solute transport in the groundwater			
Extent	Limited (2)	With the implementation of the above stated mitigation methods, the impact extent can be minimised to the site and its immediate surroundings	
Intensity	Minimal – negative (2)	The dewatering of the pit will contain the solute transport during the operational phase, with minor effects on the groundwater environment. The only possibility that the solute will move away from the pit is through diffusion, but since the force of advection is much higher than that of diffusion, the contaminants will always be concentrated around the pit area.	
Probability	Probable (4)	The impact is likely to occur even with the implementation of the above stated mitigation methods	

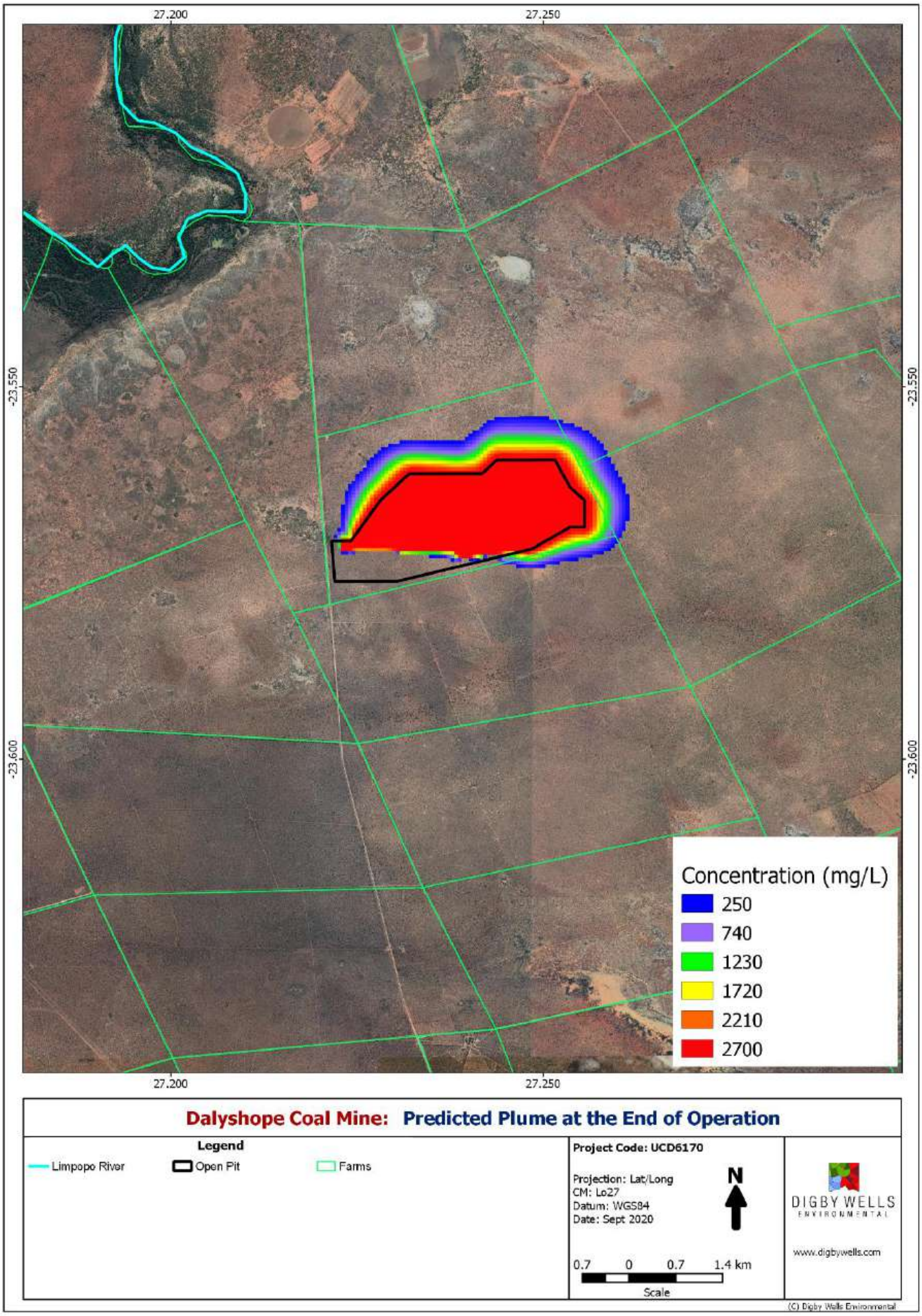

Figure 8.3: Simulated sulphate transport at the end of operation

8.3. Decommissioning Phase

The closure phase is characterised by the cessation of all mining activities and dewatering programmes and decommissioning of the mining infrastructure. Once mining and dewatering is ceased, groundwater will start to recover to its pre-mining level.

In many instances, plant discard and inter-burden material has been stacked on discards dumps, a practice that has led to the spontaneous combustion of the carbonaceous material on these dumps. To reduce or avoid the spontaneous combustion and other surface impacts, Dalyshope Coal Mine will backfill the pit with discard and carbonaceous materials. The backfilling also has other advantages since it reduces surface waste storage costs and supporting unstable pit walls.

However, if not managed properly, backfilling could have a significant environmental disadvantage since the in-pit storage of discards can contaminate the groundwater around the void. As water seeps through the backfill material, sulphates and metals could potentially dissolve and infiltrate to the groundwater zone. Sulphate concentrations as high as 2,700 mg/L have been recorded in boreholes located in the vicinity of the discard dumps at Grootegeluk Mine.

The concentration of contaminants is also dependent on the acid generation potential of the backfill material. Acid could potentially be generated in some interburden strata where the neutralisation potential is limited. Backfilling the pit with potentially acid generating material can lower the pH and mobilise heavy metals, with serious environmental degradation.

Historical works conducted at the Grootegeluk Mine (Golder Associates, 2007) showed that the average sulphate concentration in the leachate of the proposed backfilling material could be up to 7,300 mg/L. Although not all pits are the same, similar sulphate concentration could be expected at Dalyshope Coal Mine (note that the recommended sulphate concentration is only 400 mg/L).

The post-closure environmental impacts can be managed if:

- The pit is not completely backfilled and contains a final void. The water table in the pit area should be lowered as part of the contaminant management plan whereby evaporation from the pit lake will keep the water level below the regional groundwater depth. The water level should always be below the regional water level taking advantage of the evaporation where it is approximately 1,950 mm/a, which is more than 4 times higher than the mean annual precipitation (438 mm/a).
- The potentially acid generating waste materials should be deposited below the water table to avoid oxidation reactions.
- The waste rocks with neutralising potential should be placed on top of the potentially acid-forming materials. Water with a higher pH that will seep from the alkaline waste rocks and will neutralise low pH water released from the potentially acid forming materials placed underneath.

The model was run to simulate a final void pit lake after mine closure that will be left as a hydraulic sink. A simplified conceptual diagram of the final backfill is shown in Figure 8.4 respectively.

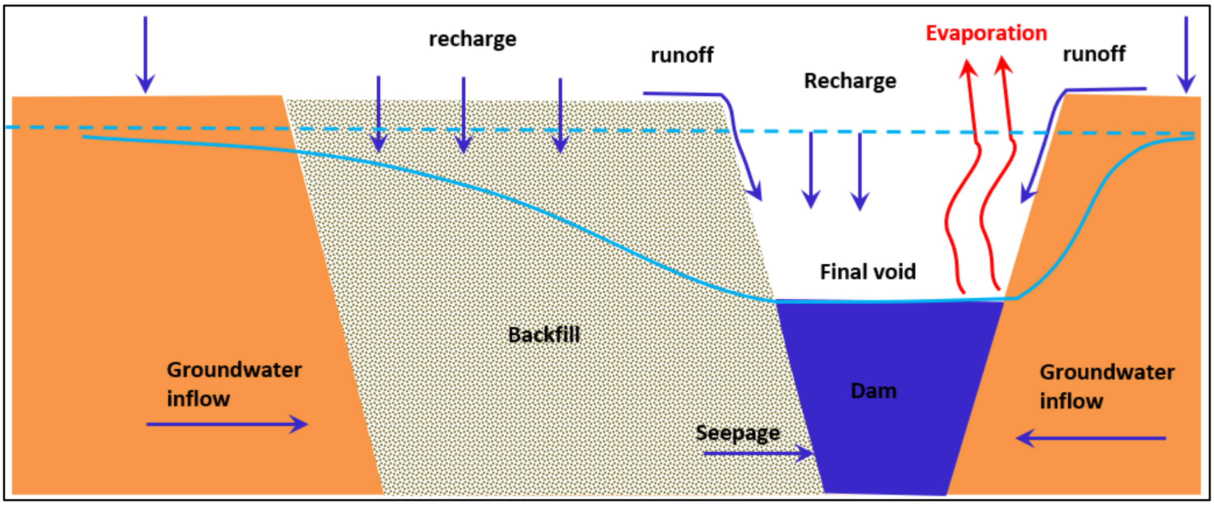

Figure 8.4: Conceptual diagram of the backfill and final void

This final void has been incorporated into the post-closure model and show that:

- Groundwater flow direction will always remain towards the final pit void since the water table in the void will be lower than the regional level.
- The only possibility that the solute will move away from the pit is through diffusion, but since the force of advection is much higher than that of diffusion, the contaminants will always be concentrated around the pit area.
- No solute transport will expand outside the pit area and the impact has been rated as Negligible (Table 8-7).

The groundwater is expected to continue flowing towards the pit (even after mine closure) until it has fully recovered. Precipitation and regional groundwater inflow would be the recharge mechanisms for water level recovery. Model simulations show that the mine is unlikely to decant after closure due to the hydraulic sink, although seasonal high-water levels could potentially exist in the pit lake that could result in changes in hydraulic gradients and pulses of solute released to environment.

No decant mitigation is required, since no decanting is expected to occur. However, time-series groundwater monitoring is required to predict the rate of groundwater recovery and decanting risks in unforeseen circumstances. If decanting occurs, passive or active treatment options should be applied before the contaminated water joins the river.

Table 8-7: Impact assessment after closure due to solute transport from the mine

<table>
<tr><td colspan="4">Activity & Interaction: Groundwater contamination as a result of pit backfilling and groundwater recovering</td></tr>
<tr><td colspan="4">Impact Description: Solute transport in the groundwater</td></tr>
<tr><td colspan="4">Prior to mitigation/ management</td></tr>
<tr><td>Duration</td><td>Beyond project life (6)</td><td>Groundwater contamination due to potential acid mine drainage or dissolution of heavy metals will occur even after the mine closure</td><td rowspan="4">Minor (negative) – 52</td></tr>
<tr><td>Extent</td><td>Local (3)</td><td>The contaminated groundwater can feed local private boreholes</td></tr>
<tr><td>Intensity</td><td>Serious – negative (-4)</td><td>There will be a risk of contaminants migrating from the backfilled pit to the private boreholes, which could eventually flow to the river</td></tr>
<tr><td>Probability</td><td>Likely (4)</td><td>The impact is likely to occur since the groundwater will recover after closure and start to flow towards the streams</td></tr>
<tr><td colspan="4">Mitigation/ Management actions</td></tr>
<tr><td colspan="4">The water table in the pit area should be lowered as part of the contaminant management plan whereby evaporation from the pit lake will keep the water level below the regional groundwater depth.
The hydraulic head in the pit should be less than the regional head to make it a hydraulic sink so that no water (and solute transport) flows away from the project site
Compensation of farmers with impacted groundwater or mine purchase land.
Monitoring of groundwater water levels and pit inflow rates.
Update numerical model and decant rates as aquifer information becomes available.</td></tr>
<tr><td colspan="4">Post management</td></tr>
<tr><td>Duration</td><td>Beyond project life (6)</td><td>Groundwater contamination due to mine disturbance will continue even after mine closure</td><td rowspan="3">Negligible (negative) – 30</td></tr>
<tr><td>Extent</td><td>Limited (2)</td><td>With the implementation of the above stated mitigation methods, the impact extent can be minimised to the site only</td></tr>
<tr><td>Intensity</td><td>Minor – negative (2)</td><td>If the pit is a permanent hydraulic sink, the solute transport can be contained, with minor effects on the groundwater environment</td></tr>
</table>

Activity & Interaction: Groundwater contamination as a result of pit backfilling and groundwater recovering			
Impact Description: Solute transport in the groundwater			
Probability	Unlikely (3)	The impact is unlikely to occur if the above stated mitigation plans are implemented	

8.3.1. Mine decant

The groundwater is expected to continue flowing towards the pit (even after mine closure) until it has fully recovered. Precipitation and regional groundwater inflow would be the recharge mechanisms for water level recovery. Model simulations show that the mine is unlikely to decant after closure due to the hydraulic sink, although seasonal high-water levels could potentially exist in the pit lake that could result in changes in hydraulic gradients and pulses of solute released to environment.

No decant mitigation is required, since no decanting is expected to occur. However, time-series groundwater monitoring is required to predict the rate of groundwater recovery and decanting risks in unforeseen circumstances. If decanting occurs, passive or active treatment options should be applied before the contaminated water joins the river.

8.4. Cumulative Impacts

The only active mine in the proximity of the Dalyshope Coal Mine is Exxaro's Grootegeluk mine. Grootegeluk is, however, at about 25 km from Dalyshope Coal Mine and no direct hydraulic interaction is expected between them, therefore no cumulative impact is foreseen.

There are several mines that are planned to be operational in the Waterberg Coalfield as shown in Figure 8.5. Those that are currently known in the vicinity of the Dalyshope Coal Project include:

- Temo Coal Mine which is approximately 130 m to the south;
- Boikarabelo Mine which is approximately 5 km to the west; and
- Mafutha Mine which his approximately 4.4 km to the southeast.

The close proximity of these mines means that the impact of the dewatering activities at Dalyshope Coal Mine may potentially affect them. It is also likely that the cones of dewatering and solute transport from the nearby mines may affect Dalsyhope Coal Mine and have a cumulative impact on the water level.

During this study, a preliminary large-scale model has been run to simulate the cumulative impact on the water level. Since there is no comprehensive information on the sizes, depths, life of mines, waste disposal areas and mining methods of the nearby mines, a number of assumptions have been made such as:

- All of the mines will be approximately 81 m deep; and
- All of the mines will be operational for 24 years and will operate at the same time.

The cumulative impact on the water table is illustrated in Figure 8.6 and shows that the radius of influence could be significant with a potential impact on the Limpopo River. Integrated inter-mine hydrogeological studies of the entire Waterberg Coalfield are required to quantify the cumulative impacts and to strategize a large-scale management plan during operation and after closure.

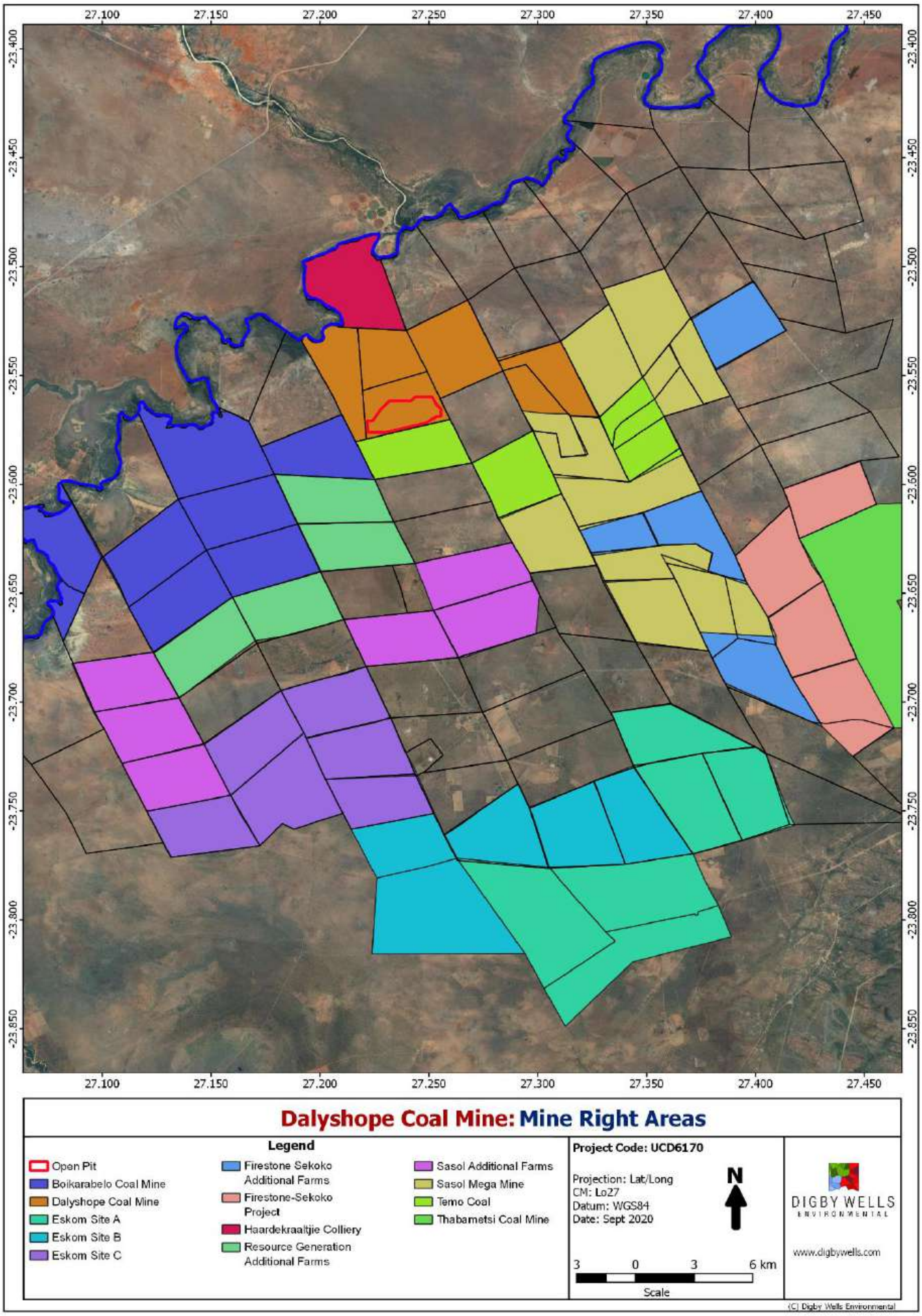

Figure 8.5: Proposed mine plans in the Waterberg Coalfield

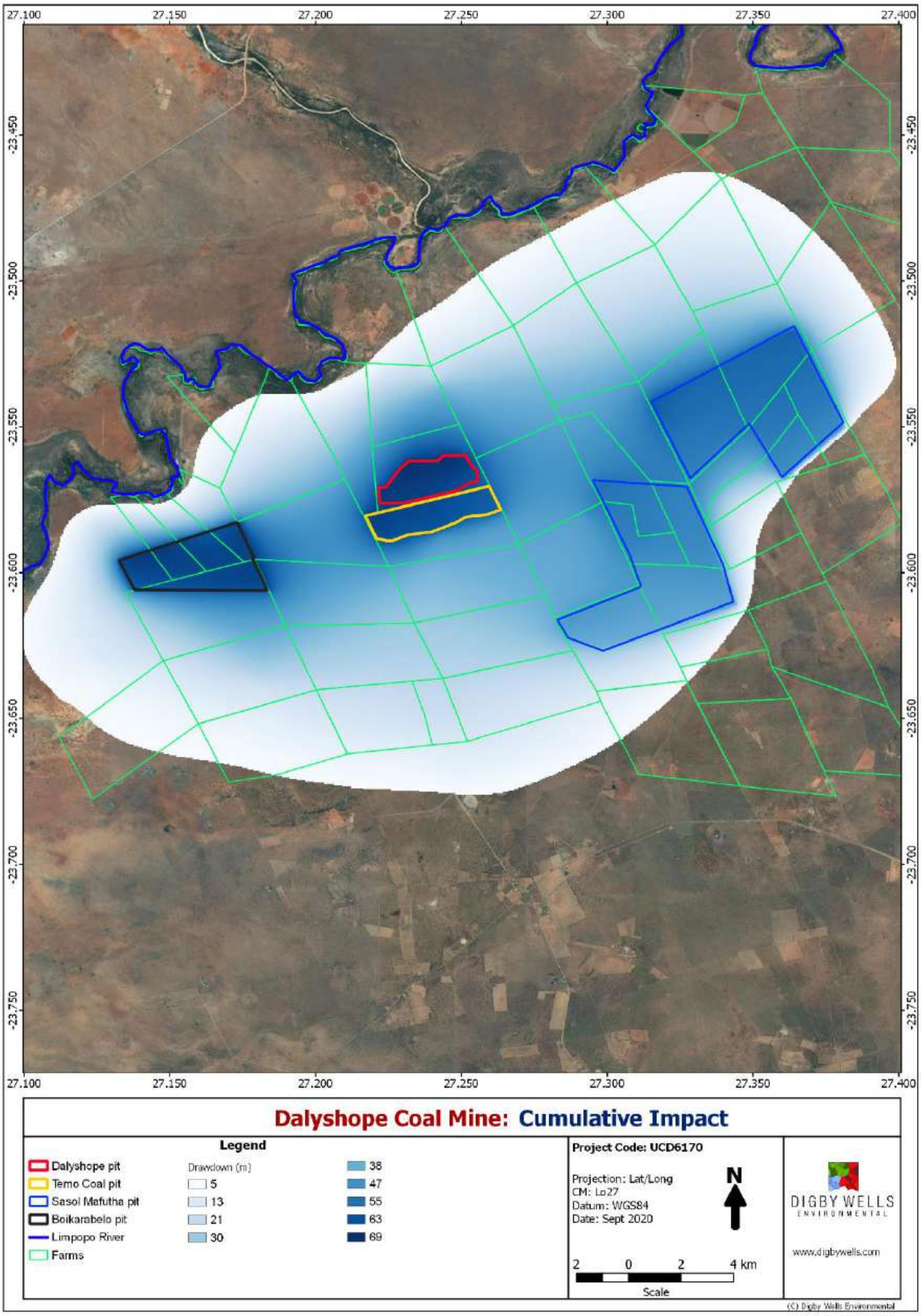

Figure 8.6: Cumulative impact considering the mines nearby Dalyshope

8.5. Unplanned and Low Risk Events

The unplanned events that may happen at the project site and the proposed mitigation plan are listed in Table 8-8.

Table 8-8: Unplanned events and associated mitigation measures

Unplanned Risk	Mitigation Measures
• Hydrocarbon spills from storage tanks, vehicles and heavy machinery or hazardous materials or waste storage facilities.	• Hydrocarbons and hazardous materials must be stored in bunded areas and refuelling should take place in contained areas; • Ensure that oil and silt traps are well maintained; • Vehicles and heavy machinery should be serviced and checked in a demarcated area on a regularly basis to prevent leakages and spills; • Hydrocarbon spill kits must be available on site at all locations where hydrocarbon spills could take place; • Monitoring boreholes, particularly those located within the construction area, have to be monitored for both water level and quality to detect any changes in quality; and • If a considerable amount of fluid is accidentally spilled, the contaminated soil should be scraped off and disposed of at an acceptable dumping facility. The excavation should be backfilled with soil of good quality.
• Spills / leaks from the dirty water pipeline.	• Regular inspections of the pipeline for any leaks. Seeping pipeline should be sealed; and • Ensure that storm water management structures are put in place to separate clean and dirty water and ensure that contaminated runoff water is captured and conveyed to the PCD.
• Contamination from the temporary topsoil stockpiles	• Management of the stockpile shape to control the ease with which water can run off; and • Ensure that storm water management structures are put in place to capture all runoff from the ash dump and spoils and to convey to the PCD.

9. Environmental Management Plan

Table 9-1: Environmental Management Plan

Activity/ies	Potential Impacts	Aspects Affected	Phase	Mitigation Measure	Mitigation Type	Time period for implementation
• Site clearing	Lowering of the water table if excavation during the site clearing process is going to take place below the water table.	Groundwater quantity	Construction	• Fill the area with soil if it is low-laying and is below the water table. This will ensure that the construction takes place above the water table. • If trenches are going to be excavated below the water level, dewatering of the aquifer to locally lower the water table can be considered to ensure that the construction takes place above the groundwater level and the water quality remains acceptable. The abstracted water can be utilised for dust suppression, vegetation or discharged to pollution control dams for evaporation. Since the groundwater is not expected to be polluted at this stage, the utilisation of the water for activities such as dust suppression or irrigation is not expected to cause environmental impacts. • Groundwater monitoring.	Minimise impact on the groundwater by operating in the unsaturated zone above the water table	• Groundwater monitoring must commence from the start of the construction phase • Protection of the water table and groundwater quality should commence with the start of the construction phase
• Hydrocarbon spills from storage tanks, vehicles and heavy machinery or hazardous materials or waste storage facilities.	Deterioration of groundwater quality	Groundwater quality	Construction and operation	• Hydrocarbons and hazardous materials must be stored in bunded areas and refuelling should take place in contained areas; • Ensure that oil and silt traps are well maintained; • Vehicles and heavy machinery should be serviced and checked in a demarcated area on a regularly basis to prevent leakages and spills; • Hydrocarbon spill kits must be available on site at all locations where hydrocarbon spills could take place; • Monitoring boreholes, particularly those located within the construction area, have to be monitored for both water level and quality to detect any changes in quality; and • If a considerable amount of fluid is accidentally spilled, the contaminated soil should be scraped off and disposed of at an acceptable dumping facility. The excavation should be backfilled with soil of good quality.	Control the release of hydrocarbons by the use of barriers or property hydrocarbon management	• During the construction phase

Activity/ies	Potential Impacts	Aspects Affected	Phase	Mitigation Measure	Mitigation Type	Time period for implementation
Overburden rock and topsoil stockpile	Infiltration to the subsurface and groundwater quality deterioration	Groundwater	Operation	• Overburden stockpiles should be managed to minimise infiltration of contaminants to the groundwater. • Management of the stockpile shape to control the ease with which water can run off.. • The vegetation of the stockpile and covering them with soil to minimise rainfall infiltration and mobilisation of dissolved metals. • Groundwater monitoring.	Avoid groundwater seepage	• Stockpile design should be completed before the construction starts. • Groundwater monitoring must commence from the start of the construction phase.
Seepage from the PCD	Groundwater contamination.	Groundwater	Operation	• All contaminant, storm water, waste and hazardous waste storage facilities and other contaminated water storage areas (pollution control dams) should be lined to prevent infiltration of contaminated seepage water proactively. • Monitoring of groundwater quality and water levels is recommended with continuous refining and updating of the monitoring network based on the results obtained.	Avoid groundwater seepage	• PCD design should be completed before the construction starts. • Groundwater monitoring must commence from the start of the construction phase.
Pit dewatering	Depletion of the groundwater; Lowering of water tables in private boreholes.	Groundwater	Operation and closure	• Mine should supply equal/better amount of water to affected parties. • Monitoring of water levels. • Updating of the numerical model as aquifer properties become available.	Avoid or minimise impact on the groundwater quantity	• Before the mine depth reaches the water table

Activity/ies	Potential Impacts	Aspects Affected	Phase	Mitigation Measure	Mitigation Type	Time period for implementation
Pit backfilling	Groundwater contamination	Acid mine drainage and dissolution of heavy metals.	Operation and post closure	• Mine should supply equal/better amount of water to affected parties. • Nitrate-based explosives should be avoided to minimise groundwater contamination. • Pit dewatering to intercept the contamination plume to within the pit area. • Monitoring of groundwater quality and water levels. • Update the numerical model as more groundwater information is collected.	Avoid or minimise impact on the groundwater quality	During the operation phase

10. Monitoring Programme

Groundwater monitoring has to commence as soon as possible when construction commence and continue during all phases of the mine operation to identify impacts over time, and effective measures can be undertaken at an early stage before serious damage to the environment takes place. There are several pieces of legislations that deal with the water management and water contamination prevention and a monitoring programme has to be conducted to ensure compliance with the legislations.

10.1. Proposed Monitoring Boreholes

The main objectives in positioning the monitoring boreholes are to:

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

Based on the numerical modelling results, Digby Wells proposes that the monitoring network be updated. There are sufficient monitoring boreholes that already exist at the project area that can be used for the long-term groundwater monitoring and there is no need of drilling.

A total of 21 boreholes, which are all existing, are proposed for the Dalyshope Coal Mine Project and their positions are displayed in Figure 10.1.

10.2. Monitoring Frequency

Groundwater levels is recommended to be recorded using an electrical contact tape or pressure transducer, to detect any changes or trends in groundwater elevation and flow direction. Groundwater levels should be taken from the proposed monitoring points on a monthly basis. In-pit samples are also recommended when operation starts. This will assist with an assessment of recharge and refinement of conceptual and numerical models.

Groundwater is a slow-moving medium and drastic changes in the groundwater composition are not normally encountered within days. Considering the proximity of Limpopo River and private boreholes to the proposed mine, water quality monitoring should be conducted monthly to reflect influences of wet and dry seasons. Samples should be collected, using best practice guidelines and should be analysed by a SANAS accredited laboratory.

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

10.2.1. Parameters to be monitored

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

- Macro Analysis i.e. Ca, Mg, Na, K, SO_4, NO_3, F, Cl;
- Al, Fe, Mn and other trace metals using ICP scanning;

- pH and Alkalinity; and
- TDS and EC.

10.3. Monitoring Database Management

In any project, good water management decisions require good information developed from raw data. The production of good, relevant and timely information is the key to achieve qualified long-term and short-term plans. For the prevention of water contamination, the development of mine dewatering schemes and the siting of water supply or dewatering boreholes, it is necessary to utilize all relevant water data.

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

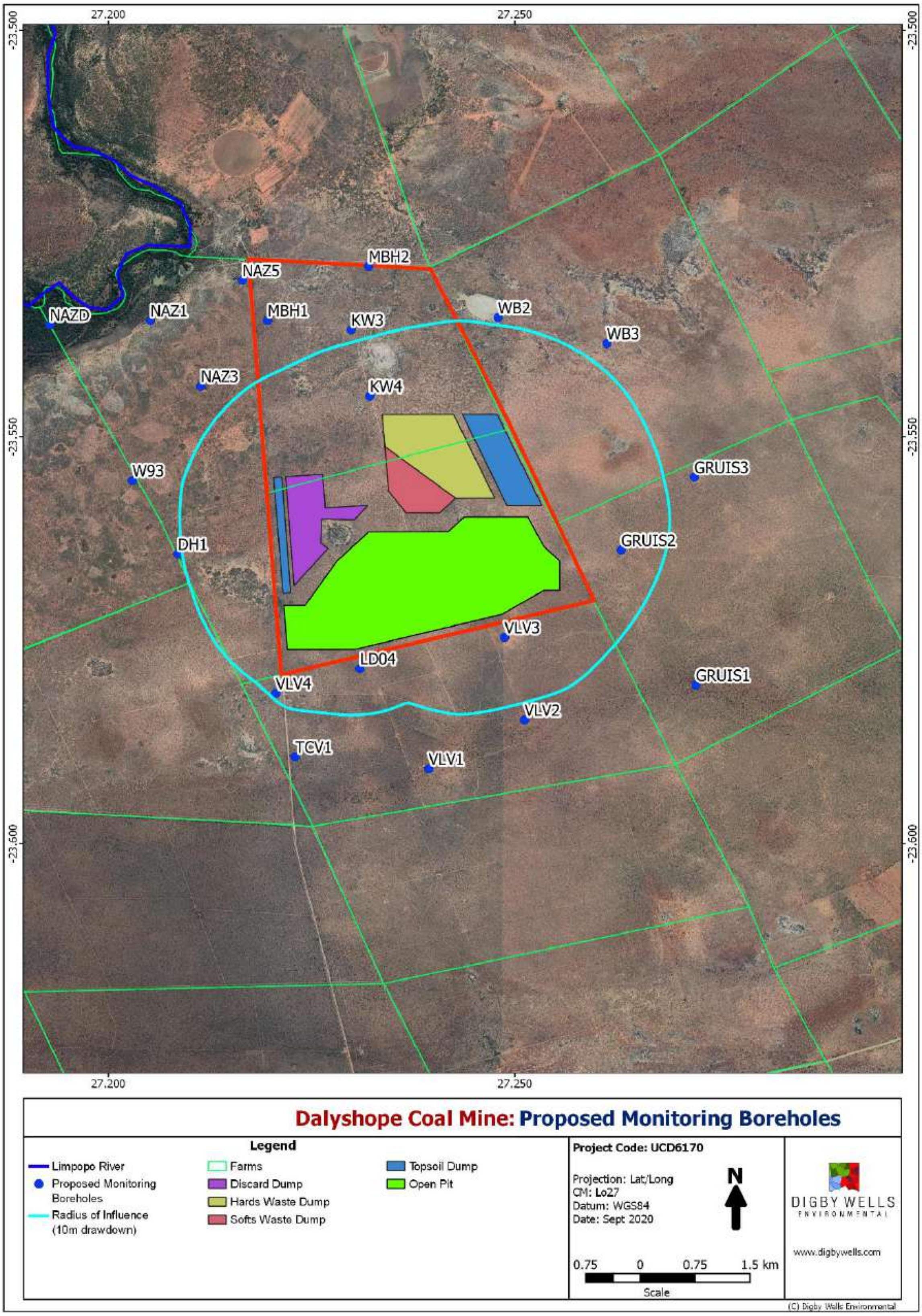

Figure 10.1: Proposed monitoring boreholes

Table 10-1: Proposed monitoring programme

Monitoring Element	Comment	Frequency	Responsibility
• Macro Analysis i.e. Ca, Mg, Na, K, SO^4, NO^3, F, Cl; • Al, Fe, Mn and other trace metals using ICP scanning; • pH and Alkalinity; and • TDS and EC.	Ensure water quality monitoring as per sampled and proposed monitoring locations (See Figure 10.1).	Monthly monitoring during construction, operation, decommissioning and for at least three (3) years after closure, or until rehabilitation has reached a sustainable state with no further changes.	Environmental Officer

11. Stakeholder Engagement Comments Received

Before any of the hydrocensus was carried out, the farmers were informed in advance of the proposed activities. Detailed information on what will be done, where and for how long it will be carried out was passed from the hydrogeology team to the Public Participation Practitioners (PPP) team within Digby Wells. The PPP Team contacted the relevant stakeholders and secured the access permit. The farmers then met with the hydrogeology team to guide them to the private boreholes.

A number of progress meetings were held during the course of the project between the hydrogeology team and the client. This was carried out to consolidate the investigation results and align project progress with the project schedule.

12. Recommendations

The following recommendations are made following the hydrogeological study:

- The evaporation rate is approximately four times higher than precipitation and most of the rainfall collected in the pit during the rainfall events could potentially evaporate during the dry periods, unless it is managed properly. This water is recommended to be contained immediately and used to reduce borehole water usage during the rainy periods.
- The Limpopo River is not at risk from mining at the Dalyshope Coal Mine. However, water level and quality monitoring of the boreholes between the mine and the river are recommended to detect any potential impacts on the Limpopo River. If in the unlikely event that an impact on the Limpopo River is confirmed through monitoring, the mine should actively intervene to reduce or avoid the impact. This can be done through the following two mechanisms:
  - The interception of the contaminated water before reaching the Limpopo River through interception boreholes; or

- The treatment of the contaminated water to an acceptable quality and discharge to the Limpopo River or use it at the mine.

A few private boreholes are expected to fall within the radius of the dewatering influence. The following is recommended as part of the management plan:

- The mine should supply equal or better-quality water to affected parties that rely on groundwater, if proven that there is an impact.
- Monitoring of the groundwater quality and water levels in the private boreholes is recommended.
- The numerical model should be refined every 2 years in the first 4 years and thereafter every five years based on groundwater monitoring results.

To enable safe and efficient mining conditions, the water inflowing to the pit should be managed through pumping from sumps. This water should be used in the mining operation and therefore is considered to be being used efficiently. Mine dewatering can be conducted from a sump, or dewatering boreholes or a combination of both. Considering the relatively low aquifer yield, it is proposed to be conducted from a sump(s) in the lowest working area of the pit floor. This is also in line with the various coal mines in South Africa, including the Grootegeluk Mine. Dewatering from boreholes has the advantage of intercepting the groundwater before it is potentially contaminated at the pit. However, no high yielding fractures were intersected during this study and installation of dewatering wellfield is likely to be more expensive than seepage management using sumps. If dewatering is to be conducted from boreholes, new boreholes will have to be drilled as mining progresses since mining will be conducted progressively and this is likely to increase the cost. Water collected at the sump should be incorporated with the process water system considering the water shortage in the Waterberg area.

13. Reasoned Opinion Whether Project Should Proceed

A number of potential impacts on the groundwater quantity and quality have been identified during this study. For each identified impact, a mitigation measure has been provided which will minimise the environmental significance.

It is the professional opinion of Digby Wells that the project should proceed with the condition that the recommended mitigation measures are put in place.

14. Conclusion

14.1. Baseline Hydrogeological Conditions

The main source of drinking water supply in and around the project area is groundwater through a number of solar energy, windmill pumps and submersible pumps which are mainly used for domestic and livestock watering.

However, no major groundwater abstraction takes place within the study area. A total of 88 private boreholes were surveyed, of which 10 were within the mining right area while 42 were within a 3 km radius of the mining right area. Of the 42 boreholes:

- 8 (9%) boreholes are used for game watering only;
- 20 (23%) are used for livestock watering;
- 11 (13%) are used for human drinking, gardening and livestock watering;
- 13 (15%) are used for groundwater monitoring;
- 12 (14%) are exploration holes (not boreholes) used for monitoring;
- 3 (3%) are not used; and
- The remaining 21 (24%) boreholes are unused.

None of the boreholes are of good water quality as they are all above the Class I category. At least one of the tested parameters exceed the recommended limit. The water is generally not recommended for human drinking without treatment. This is with the exception TCD1 which is in good quality and boreholes DH2, Gruis1, KW1, KW2, KW4, NAZ2A, SSEX1, SSX1, VLV2, W26 and WB5 which are within the acceptable limit and can be used for domestic use.

The elevated element concentrations are mainly due to the natural dissolution of the host rocks. The only external impacts are associated with the elevated nitrate concentrations identified in boreholes CAN1 and KW4 which is associated with fertiliser application and/or animal waste as cattle often live nearby.

Noteworthy is the sulphate levels in these boreholes. The recommended maximum sulphate limit for drinking is 400 mg/L, but the concentration is currently less than 200 mg/L. Sulphate is expected to be an element of concern at Dalyshope Coal Mine based on the experience learned from other coal mines, including at Grootegeluk where it has reached up to 2700 mg/L in some monitoring boreholes. The low levels of sulphate in all the boreholes suggests that no mine-related contamination has taken place at the project site. Sulphate should be used as an indicator to assess the Dalyshope Coal Mine impact and the values obtained currently should be used as a baseline for future comparisons.

The groundwater levels within the study area vary between 8 m and 20 m below surface, with an average of 15.1 m. Under natural condition groundwater flow mimics the topography and regional surface water flow direction is towards the Limpopo River. However, local depression of water table could occur due to abstractions by the local farmers.

Water strikes have been intercepted at depths between 20 and 100 m below ground level. Although some boreholes were drilled up to 160 m, no water strike was recorded below 100 m, defining the bottom of the aquifer. The water strikes are distributed almost uniformly between this interval. There is no zone in this interval without distinct absence of water strike. Unless disturbed by local abstraction, and possibly a localised perched aquifer, there is no abrupt change in hydraulic head even between shallow (<30m) and deep boreholes (>30m). The aquifer was therefore simplified into one layer.

The permeability values are as follows:

- Overall, the aquifer permeability ranges from very low (0.002 m/d) to very high (6.6 m/d); and
- The aquifer is highly heterogeneous with permeability values being variable in a relatively short distance.

14.2. Potential Impacts and Mitigation Measures

The main activities during the construction phase that could potentially result in groundwater impacts are associated with the site clearing and construction of the infrastructure. The water table in the project area is approximately 15.1 m below the ground surface. During the construction phase, all activities are expected to take place above this and no impact on the groundwater is envisaged as a result.

Mine dewatering is crucial to keep the mined area dry for safe working conditions. This can potentially impact the groundwater environment negatively by lowering the water level and creating a cone of depression. Since the pit will be backfilled concurrent to mining, the groundwater ingress is predicted to range between 0 and 3.4 ML/d (with an average of 1.5 ML/d) if only Dalyshope Coal Mine pit operates. If any of the nearby mines, such as the Boikarabelo and Temo Coal Pits, operate together with the Dalyshope Coal Mine, the groundwater ingress will be lowered depending on the number of the nearby mines operating, the size of the pits, depth of excavation and life of mining. This will lower the amount of groundwater that could be used in the process water.

In many instances, plant discard and inter-burden material has been stacked on discards dumps, a practice that has led to the spontaneous combustion of the carbonaceous material on these dumps. To reduce or avoid the spontaneous combustion and other surface impacts, Dalyshope Coal Mine will backfill the pit with discard and carbonaceous materials. The backfilling also has other advantages since it reduces surface waste storage costs and supporting unstable pit walls. However, if not managed properly, backfilling could have a significant environmental disadvantage since the in-pit storage of discards can contaminate the groundwater around the void. As water seeps through the backfill material, sulphates and metals could potentially dissolve and infiltrate to the groundwater zone. Sulphate concentrations as high as 2,700 mg/L have been recorded in boreholes located in the vicinity of the discard dumps at Grootegeluk Mine.

The environmental impact of the backfill can be managed if the pit is not completely backfilled after mine closure.

- Lowering of the topography around the pit using a final void that is left could assist in the contaminant management plan whereby evaporation from the pit lake will keep the water level below the regional groundwater depth. The water level will always be below the regional water level since the mean annual evaporation at the site is approximately 1,950 mm/a, which is more than 4 times higher than the mean annual precipitation (438 mm/a).

- The use of the pit-lake as a sustainable water reservoir for community projects or emergency use during droughts.

Model simulations show that the mine is unlikely to decant after closure due to the hydraulic sink. No decant mitigation is required, since no decanting is expected to occur. However, time-series groundwater monitoring is required to predict the rate of groundwater recovery and decanting risks in unforeseen circumstances. If decanting occurs, passive or active treatment options should be applied before the contaminated water joins the river.

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