ENVIRONMENTAL & ENGINEERING

REPORT

# CANYON RESOURCES (PTY) – PROPOSED KOPPIE MINING PROJECT

## GEOHYDROLOGICAL REPORT FOR INPUT INTO THE MRA & WUL- DRAFT

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## DECLARATION OF INDEPENDENCE

I, Elida Naude, 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 71 and is punishable in terms of section 24F of the Act.

Naude

2020/11/16

**Signature** **Date**

**Mrs. Elida Naude**
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# EXECUTIVE SUMMARY

## BACKGROUND

Eco Elementum Geohydrology (Pty) Ltd was contracted by Canyon Resources (Pty) Ltd to conduct a Geohydrological Investigation as part of the Mining Right Application and Water Use License for the proposed Koppie project. The Koppie project is located approximately 13km north of Bethal and 25 km south-west of the town of Hendrina in the Mpumalanga Province. Access to the project

The mine will be located on portion 4 of the farm Koppie 228 IS, and portions 2, 3, 6, 9, 10, 11, 21, 27, 30, 31, and 32 of the farm Uitgedacht 229 IS. The mining area covers an area of 1955.45 ha while the proposed infrastructure for the mine is expected to cover 80ha.

The underground mining operation will target the No. 2 and 4 coal seams with the bord-&-pillar method. The seam depths of the 4 Seam vary between 58.96 to 118.8 mbs and the 2 Seam between 89.35 and 132.72 mbs.

The following infrastructure will form part proposed for the Koppie mining operation:

- Access / haul roads
- Washing plant
- Workshops
- Offices
- Weighbridge
- Pollution Control Dams
- Slurry Dam
- Stormwater management facilities
- Boreholes
- Powerlines
- Substation
- Sewage management systems
- Conveyor belt systems
- Explosive magazine
- Shaft complex
- Lamp room
- Ventilation Shafts
- Discard Dump

The proposed project area is within the Smithfield Ridge and thus on the boundary between the Highveld and Witbank Coalfields and the site falls within the B11A quaternary catchment in the Olifants Water Management Area (WMA).

## CONCLUSION / RECOMMENDATION

The geohydrological environment at proposed mining area can be summarised as follows:

- The Proposed Koppie Mining Project is located in the Highveld region of Mpumalanga and in a summer rainfall region.
- The mean annual precipitation is ± 700 mm/annum, while the evaporation is estimated at 1 680 mm/annum.
- Drainage over the regional area and locally is towards the north.
- The Proposed Koppie Mining Project is underlain by sedimentary rocks from the Karoo Super group's Vryheid Formation.
- Geological structures such as dykes and faults are known to exist in the region of the proposed mine. These structures and the weathered zone are possible pathways of elevated groundwater flow and contamination migration.
- On the basis of seam thickness and coal quality the S4L is the prime exploitation target within the No. 4 Seam Group.
- The 2 seam is often split into No. 2 Lower and No. 2 Upper Seam. The No. 2 Lower Seam ("S2L") generally is the thicker seam of the two sub-seams; it has better quality coal, and therefore will be the "theoretical" mining target.
- Two main aquifer systems are found in the proposed mine's region. Firstly, the shallow weathered aquifer and secondly, the deeper, secondary aquifer.

- Groundwater level information is available for the model area as they were recorded during the 2020 hydrocensus as well as from NGA boreholes (DWS). Only 4 water levels could be measured during the hydrocensus as the majority of the boreholes were equipped with pumps and no access to measure the water levels could be obtained. Groundwater levels varied between 5 and 17mbs in the boreholes recorded.
- The overall quality of the groundwater in the area is good to marginal.
- The nitrate concentration in six of the thirteen boreholes exceeded the permissible limits for drinking water. The nitrate concentrations in these six boreholes varied between 20 and 40 mg/l.
- The fluoride concentration in PU11 and the manganese concentration in PU13a also exceeded the permissible limits for drinking water.
- The ABA from the proposed mining area concluded that the analysed samples can be classified as intermediate to potentially acid generating.
- The waste classification indicated a Type 3 waste and therefore Class C liners are required in all areas where waste is placed.
- Groundwater Sources:
  - Recharge:
    - Natural recharge: in the region of the proposed project the natural recharge is estimated between 1 and 2% of the MAP. Rivers and drainage systems can also be seen as potential recharge sources. Gaining or losing streams play a role here. Losing streams "lose" their water to the aquifer, making it a natural recharge source. The streams in the immediate vicinity of the proposed project have not been identified as losing or gaining streams or even disconnected streams if they are not connected in any way to the groundwater regime.
    - Artificial recharge: Artificial recharge from the PCD may occur if the lining leaks.
  - Contamination Sources: At the proposed mining operation the potential contamination sources can include:
    - Wet sources: PCD's and other unlined facilities or where the linings have failed. Water level mounding can be expected at these sources which may influence the groundwater flow gradients.
    - Dry sources: Overburden stockpiles, Discard dumps and ROM stockpiles. Dry sources are only active should water be introduced to the system by means of recharge or some other form where poor quality water seeps into the underlying aquifer. Water level mounding will not occur under dry source areas.
- Groundwater pathways:
  - Fault zones and dykes surrounding the proposed project area may be potential pathways for groundwater contamination migration. Geological structure information is available for the site and these structures are expected to play a role in the impact zone of the proposed mining operation.
- Groundwater receptors:
  - River Systems: any contamination from potential sources may be discharged in terms of baseflow into the receiving river systems in the area.
  - Potential groundwater users: In the area of the proposed mining operation's impact zone groundwater users exist. The impact zone may increase as pathways such as geological structures are present.
  - Underground void: once dewatering of the void commence, water will flow towards the void and therefore act as a groundwater receptor, even though an artificial receptor.

The following impacts may be expected from the proposed Koppie Mining project:

- Construction phase:
  - The development of the decline shaft is expected to cause a decrease in the water level due to dewatering as the shaft will be developed to an elevation lower than the steady state water level elevations.
  - Fuel spillages from construction vehicles may occur during this phase.
- Operational phase:
  - Impacts in terms of groundwater levels are expected during this phase. The dewatering of the underground voids will cause a drawdown in the water levels within the immediate vicinity of the underground activities in the secondary aquifer.
  - No adverse impacts on the groundwater qualities surrounding the underground voids in the secondary aquifer are expected during this phase.

- A pollution plume may start to migrate downgradient of the potential surface contamination sources such as the discard dump and PCDs.
- The simulated results of the operational phase in term of the water levels are indicated in the table below:

| Area | Drawdown Depth (mbs) | Drawdown Extent (m) |
|---|---|---|
| Shaft Area | 90 | 600 |
| Underground mining voids | 112 | In aquifer = 570m<br>On Dykes = 900m |

- Post Closure:
  - The water level post-closure will start to rise as the underground void starts to fill.
  - Decant may occur once the water level in the underground void has recovered and there is a connection between the underground void and the surface.
  - Once the water levels have recovered, a groundwater pollution plume may start to migrate down gradient away from the underground void.
  - The simulated results of the end of operational and post-closure phase in term of the water quality are indicated in the table below:

| Area | Maximum simulated Sulphate Concentration (mg/l) | Maximum simulated plume extent from boundary (m) | Potential plume migration direction from the source area |
|---|---|---|---|
| Preferred Option – Surface infrastructure | 900 mg/l (at end of mining) | 210m at mine closure,<br>550m at 50 years post-closure. | East from discard dump and plant area, south from overburden stockpile. |
| Alternative Option – Surface infrastructure | 900 mg/l (at end of mining) | 250 m at mine closure,<br>430m at50 years post-closure. | West and east from discard dump, East from plant, south from Overburden Stockpile. |
| Underground voids | 1 500 mg/l (100 years post-closure) | 300m at 100 years post closure | Only along the dykes. The plume at 100 years post-closure are not expected to exceed beyond the mine boundary since the water level in the voids has not yet recovered at this time. In the region where the water level has recovered, plume migration will be towards the north-east. |

The proposed mitigation measures for the proposed mining operation are summarised below:

| Phase | Mitigation Measures |
|---|---|
| **Construction Phase** | • Should fuel spillages occur during the construction phase immediate action is required to minimise the impact on the groundwater regime.<br>• No management can be incorporated to limit the impacts of dewatering in the immediate vicinity of the shaft area. |
| **Operational Phase** | • Groundwater levels in the monitoring boreholes should be measured on at least a quarterly interval.<br>• Should the water levels of surrounding users be influenced in terms of groundwater level or quality decline, any potential users should be compensated. |

| | |
|---|---|
| | • Monitor groundwater inflow rates on a monthly basis throughout the mining operation.<br>• The groundwater quality in the monitoring boreholes should be analysed on a quarterly basis.<br>• Annual reporting on the groundwater qualities and levels should be conducted and submitted to the DWS.<br>• The numerical model should be updated once a year when time-series monitoring data (water levels and qualities) are available.<br>• Conduct frequent surface inspection to detect any surface subsidence as soon as possible.<br>• Any subsidence areas should be mitigated to obtain free surface run-off. |
| **Post-Closure Phase** | • Conduct frequent surface inspection to detect any surface subsidence as soon as possible.<br>• Any subsidence areas should be mitigated to obtain free surface run-off.<br>• The groundwater quality in the monitoring boreholes should continue to be analysed on a quarterly interval basis.<br>• Should any evidence of potential decant emerge, methods of handling potential decant should be investigated and may include treatment of polluted water. |

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## List of Abbreviations

| | |
|---|---|
| ARD- | Acid Rock Drainage |
| EC- | Electrical Conductivity |
| EIA- | Environmental Impact Assessment |
| EMP- | Environmental Management Plan |
| GQM- | Groundwater Quality Management |
| Ha- | Hectares |
| $Km^{2}$- | Square Kilometre |
| L/s- | Litres per second |
| Meq/l – | Milliequivalent per litre |
| Mamsl- | Metres above mean sea level |
| MAP- | Mean Annual Precipitation |
| MAE- | Mean Annual Evaporation |
| Ml/d- | Mega litres per day |
| m/d- | meter per day |
| m- | Meter |
| mbs- | meter below surface |
| mm- | Millimetre |
| mm/a- | Millimetres per annum |
| mS/m- | Millisiemens per metre |
| $m^{3}$- | Cubic metre |
| NGA- | National Groundwater Archive |
| PCD- | Pollution Control Dam |

# 1. INTRODUCTION

Eco Elementum Geohydrology (Pty) Ltd was contracted by Canyon Resources (Pty) Ltd to conduct a Geohydrological Investigation s part of the Mining Right Application and Water Use License for the proposed Koppie Mining Project (Koppie). The Koppie project is located approximately 13km north of Bethal and 25 km south-west of the town of Hendrina in the Mpumalanga Province. Access to the project

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The proposed project area is within the Smithfield Ridge and thus on the boundary between the Highveld and Witbank Coalfields and the site falls within the B11A quaternary catchment in the Olifants Water Management Area (WMA). The location of the Koppie is indicated in **Figure 1**.

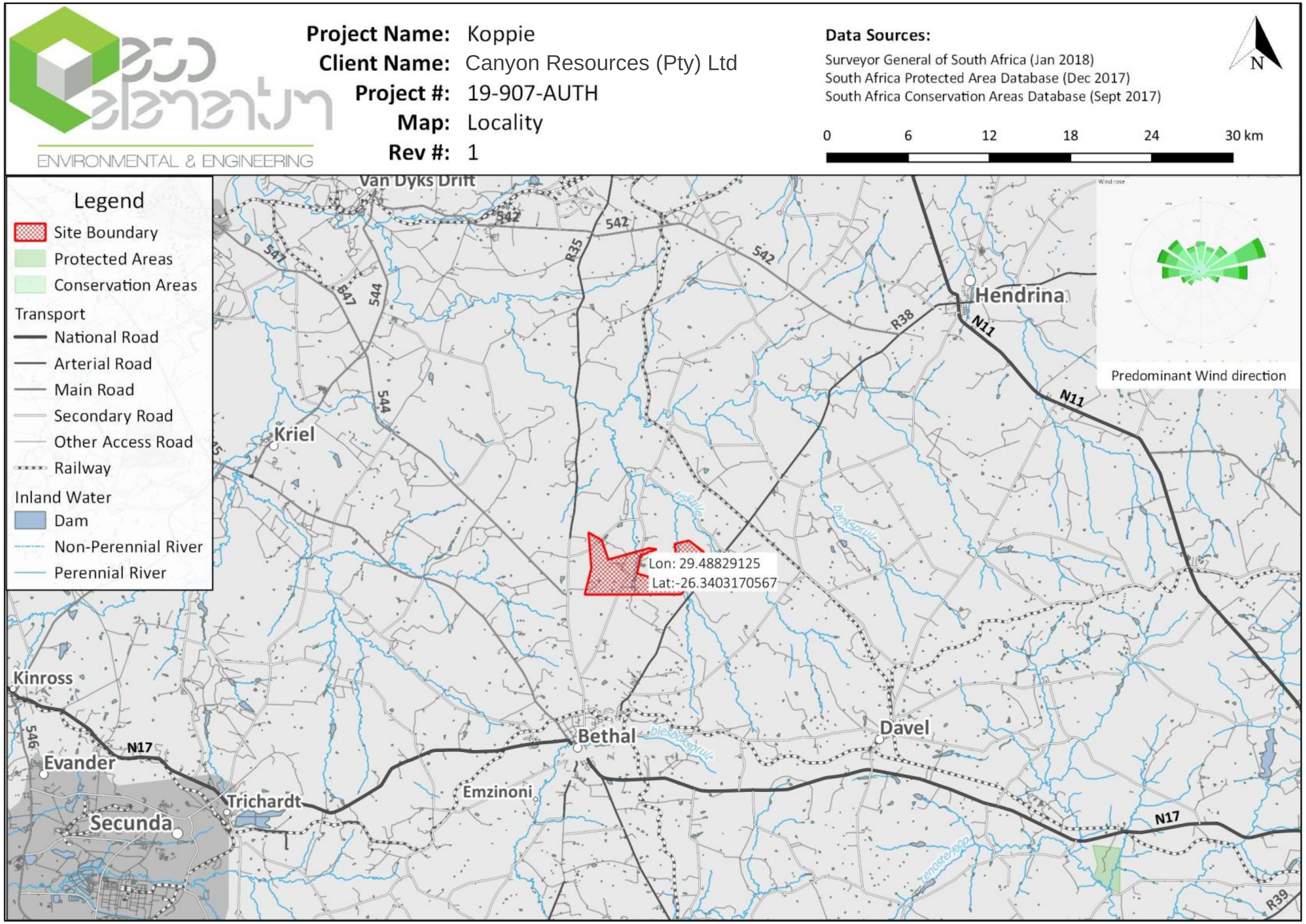


Figure 1: Koppie Locality Map, Bethal, Mpumalanga, South Africa

## 2. GEOGRAPHICAL SETTING

### 2.1 Topography and Drainage

The Koppie area is intersected by the Joubertsvlei and Diepsloot streams which in turn is tributaries of the Viskuil River. The surface water features drains in a northernly direction where it flows into the Olifants River. The Koppie project area falls within the B11A quaternary catchment.

The topography comprises of flat rolling hills and valleys. The topography within the groundwater model domain ranges between 1 700 metres above mean sea level (mamsl) in the south to 1 580 m in the north.

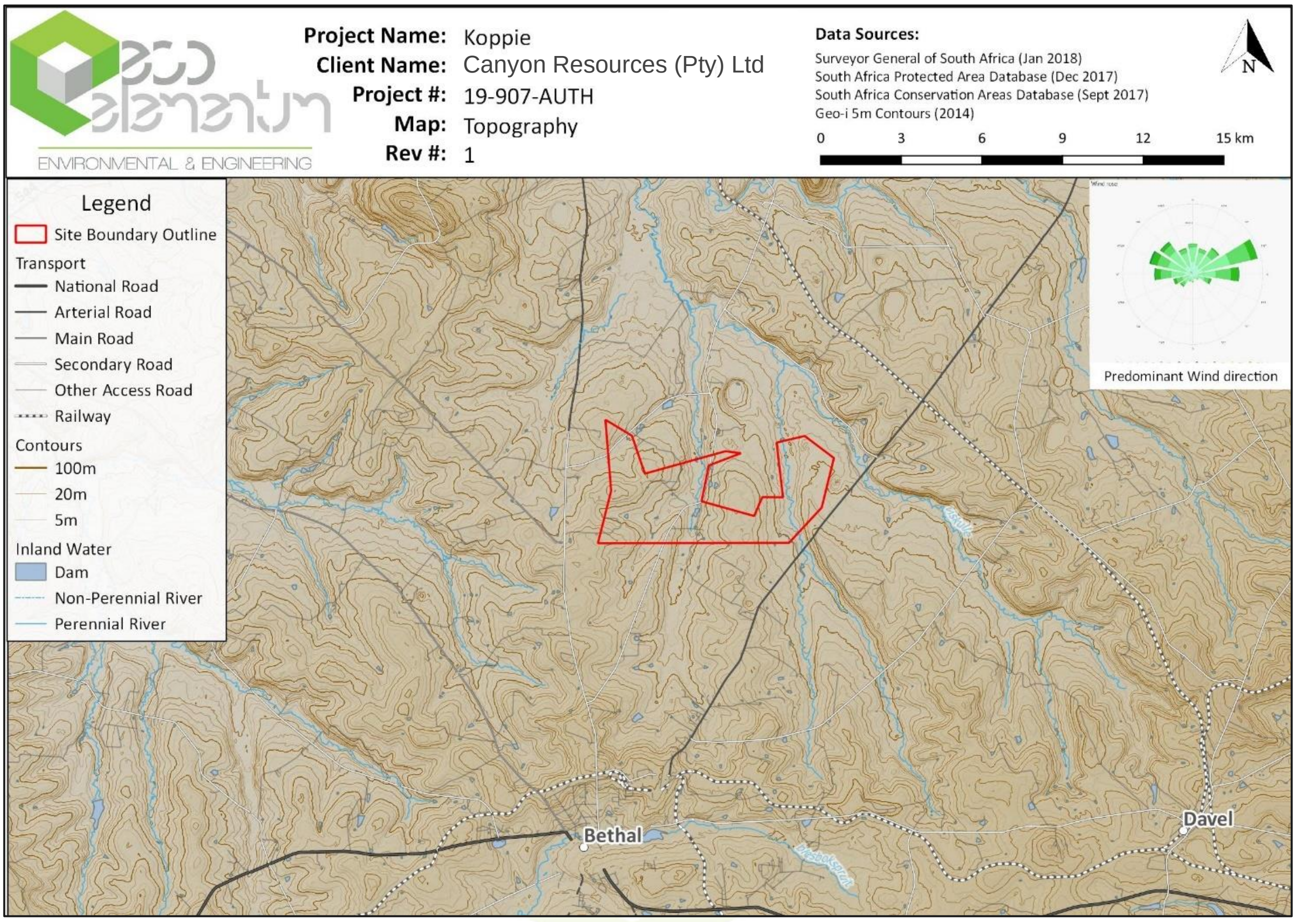


**Figure 2: Topographical map for the Koppie area.**

## 2.2 CLIMATE

The following discussion on climate has mainly been extracted from the Eco Elementum Koppie Scoping Report. The climate sources include:

- DWA weather station Witbank at Witbank dam.
- Tala Bethal Coal Air Quality Assessment Report (Eco Elementum, 2018).

Wind: The predominant wind direction is predicted to occur mainly from the east-north-east direction more than 1 300 hours per year, secondary winds can be expected from the west to the north-west 2 400 hours per year. Winds from the east is predicted to occur 930 hours per year. At the site, calm conditions with wind speeds of 12 km/h or less, are predicted 2-7 days per month throughout the year. 12-19 km/h winds are predicted 10-16 days per month through the year. Wind speeds of more than 19 km/h are predicted to occur 8-17 days per year on average.

Temperature: Falling in a summer rainfall area, the location is predicted to receive the most precipitation in the summer months of October to March overall. November to January is predicted the highest rainfall months with between 85 mm to 107 mm predicted per month during these months. February, March and October is predicted to receive 54 mm to 76 mm precipitation. All other months are predicted to receive less than 26 mm precipitation on average during the month.

Precipitation: The highest precipitation days are predicted during the months of October to March. During these months' precipitation is predicted to only occur 13 to 22 days on average. The rest of the year precipitation is predicted to occur less than 6 days per month.

According to climatedata.eu the average precipitation in the Bethal region is approximately 700 mm/a.

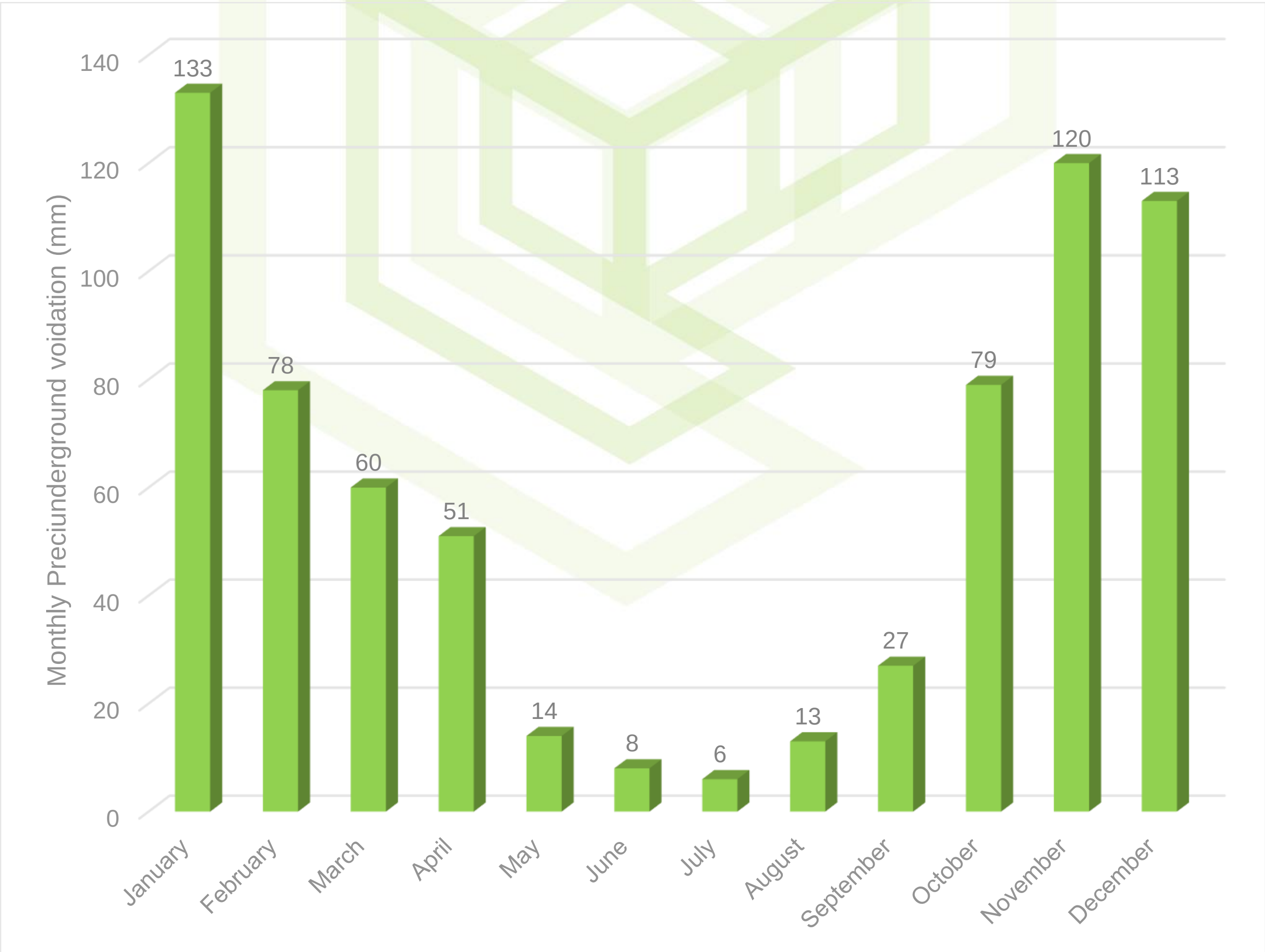


**Figure 3: Monthly preciunderground voidation in the proposed Koppie area (climatedata.eu)**

Evaporation information from the DWS weather station Witbank at Witbank dam for the Emalahleni area indicated an average annual evaporation of approximately 1 680 mamsl. Maximum evaporation is observed in the summer months with averages varying between 157 and 194 mm/month (September to February).

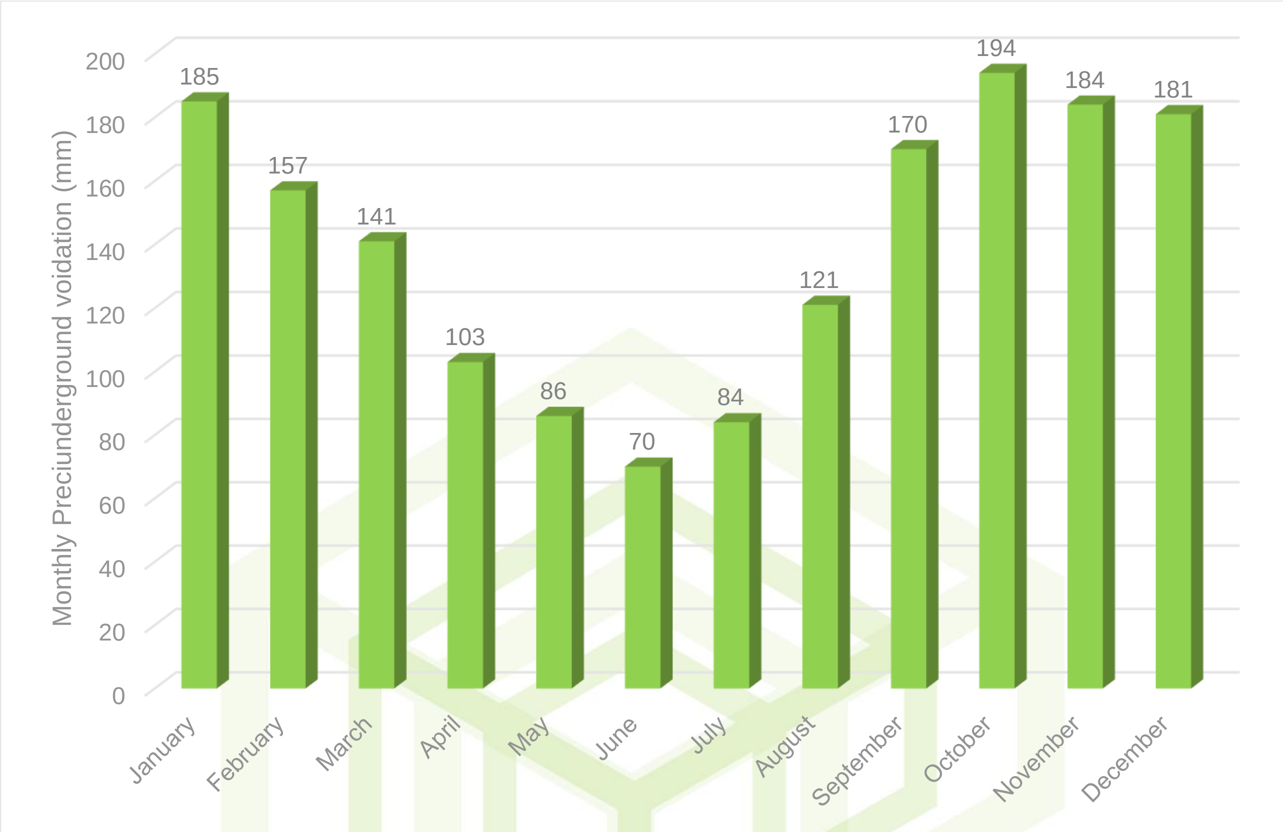


**Figure 4: Monthly evaporation in the proposed Koppie area (DWS)**

## 3. SCOPE OF WORK

The main aim of this report is to determine and discuss the main impacts of the proposed mining at Koppie area. This report will include discussions on:

- Topography,
- Climate,
- Geology,
- Hydrogeology:
- Unsaturated zone,
- Saturated zone,
- Groundwater recharge,
- Hydraulic conductivity,
- Groundwater levels,
- Potential impacts on groundwater quality and quantity,
- Aquifer characteristics.
- Numerical Groundwater modelling,
- The groundwater monitoring system,
- Groundwater Environmental Management Programme,
- Post-closure management plan.

The information sources for the Koppie geohydrological study include:

- Mine layouts and schedules obtained from the mine;
- Topographical and geological maps as well as satellite imagery for describing the physical site properties;
- Geohydrological and EIA reports:
  - GPT, 2018. Groundwater Impact Study for the Proposed Tala Bethal Coal Mining Right (7.4km north-east of the proposed Koppie mining project).
- WA series of maps that include:
  - Groundwater Quality of South Africa;
  - Aquifer Classification of South Africa;
  - Aquifer Vulnerability of South Africa; and
  - Aquifer Susceptibility of South Africa.

## 4. METHODOLOGY

### 4.1 Desk Study

This geohydrological investigation is based both on a desk-top study with some of the information gathered from previous geohydrological investigations conducted for the area. Site specific studies and associated information have been assessed and used for the investigation as part of the EIA Amendment. The following studies have been used as references:

- GPT, 2018. Groundwater Impact Study for the Proposed Tala Bethal Coal Mining Right.

Site specific information include:

- Hydrocensus survey- water levels and geochemistry,
- Geophysical Survey,
- Waste Classification.

### 4.2 Results Of Hydrocensus/User Survey

A hydrocensus survey was conducted to locate boreholes and springs within a specified area. The uses of the groundwater from the boreholes and springs are recorded together with abstraction rates, borehole depths and all possible properties of the boreholes are noted. Where possible water levels and water samples are taken for analysis.

A hydrocensus survey was conducted by Eco Elementum in October 2020 for the proposed Koppie mining area. The locations of the boreholes recorded during the survey is presented in Figure 6. A total of 16 boreholes were located within a ± 1 km radius around and within the proposed Koppie mining area. The majority of the groundwater is used for domestic and livestock watering purposes (**Figure 5**). Only 4 water levels could be measured as the majority of the boreholes are equipped with pumps. A total of 13 boreholes were sampled for quality analysis.

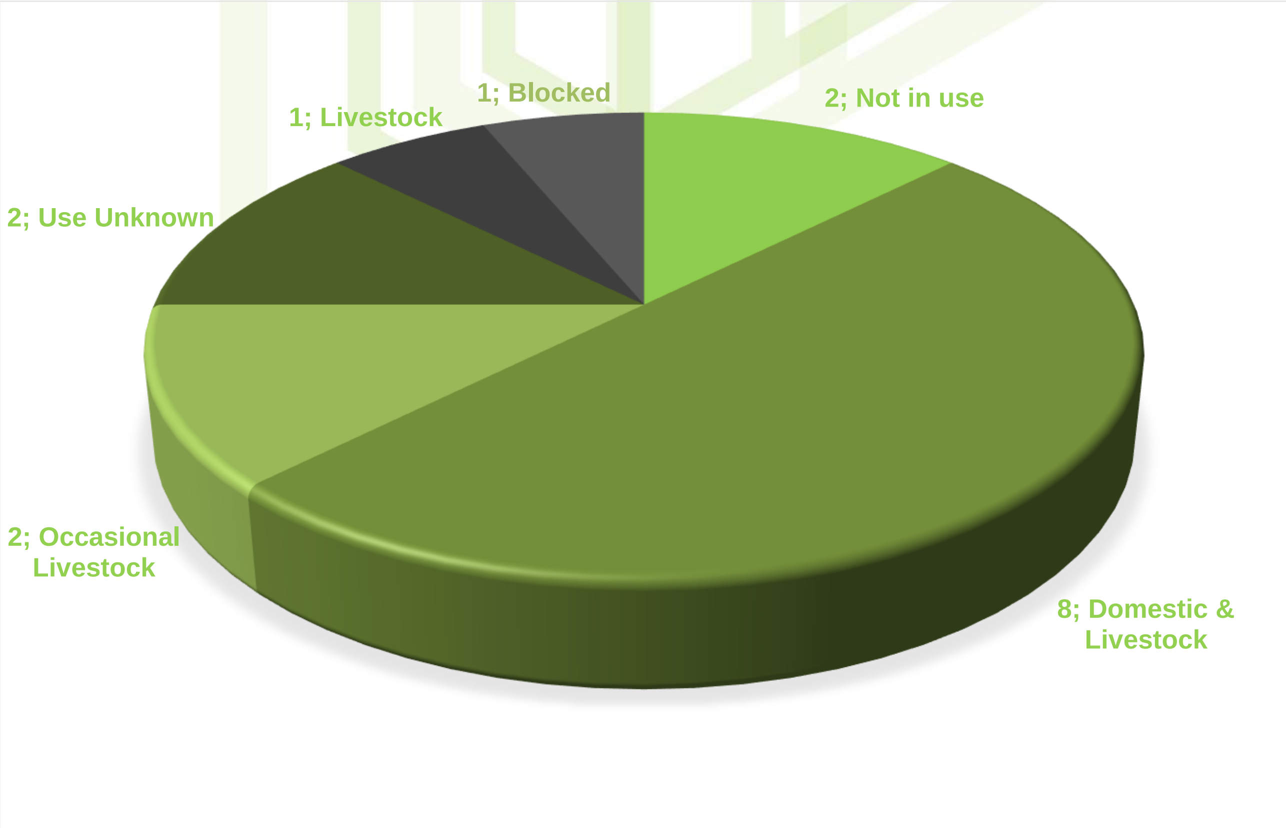


**Figure 5: Groundwater use for 16 boreholes within the proposed Koppie mining area.**

**Table 1: Hydrocensus borehole information.**

| Borehole ID | X-coord | Y-coord | Status | Use | SWL | Depth | Sampled |
|---|---|---|---|---|---|---|---|
| PU15a | 47974 | -2911705 | Submersible Pump | Domestic, Livestock | - | - | ✓ |
| PU19a | 46152 | -2913355 | Submersible Pump | Domestic, Livestock | - | - | ✓ |
| PU19b | 46015 | -2913426 | Not equipped | Occasional Livestock | 7,5 | 27 | ✓ |
| PU6 | 49715 | -2912811 | Submersible Pump | Domestic, Livestock | - | - | ✓ |
| PU7 | 48906 | -2913670 | Submersible Pump | Livestock | - | - | ✓ |
| PU17 | 50370 | -2913862 | Submersible Pump | Domestic, Livestock | - | - | ✓ |
| PU11 | 50523 | -2913948 | Submersible Pump | Domestic, Livestock | 15,9 | - | ✓ |
| PU10a | 50305 | -2915582 | Not equipped | Occasional Livestock | 5,7 | 17 | ✓ |
| PU10b | 50255 | -2915581 | Submersible Pump | Domestic, Livestock | - | - | ✓ |
| PU10c | 50274 | -2915608 | Submersible Pump | No Use | - | - | ✓ |
| PU2 | 50127 | -2915898 | Submersible Pump | Domestic, Livestock | 6,1 | 28 | ✓ |
| PU14 | 53611 | -2912271 | Submersible Pump | Domestic, Livestock | - | - | ✓ |
| PU13 | 52887 | -2915596 | Submersible Pump | No Use | - | - | ✓ |
| PU8 | 47550 | -2915066 | Windmill | Unknown | - | - | X |
| PU1 | 46204 | -2911950 | Windmill | Unknown | - | - | X |
| PU16 | 49564 | -2913301 | Blocked | Blocked | - | - | X |

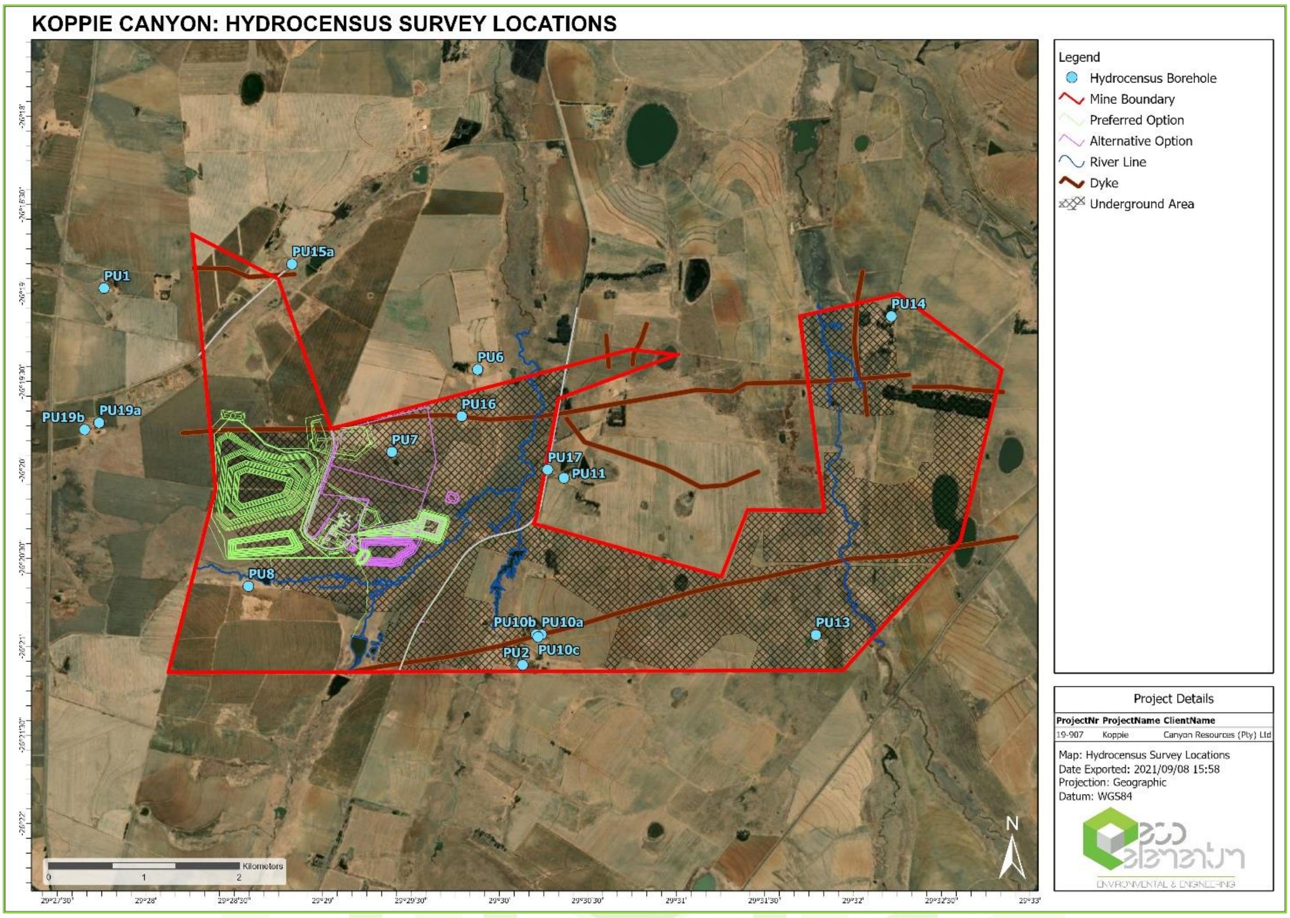


**Figure 6: Hydrocensus boreholes for the proposed Koppie mining area.**

## 4.3 Geophysical Survey And Results

A geophysical survey was conducted for the proposed Koppie area to determine the best positions for mine monitoring boreholes. The PQWT KD 50 instrument was used for the geophysical survey. The PQWT is a series geophysical prospecting instrument. It utilises the natural electric field source that detects resistivity contrasts of underground rocks and minerals or groundwater.

Five geophysical traverses were included in the geophysical survey. The geophysical traverses are indicated in Figure 7. Only T5 and T2 targeted the underground monitoring boreholes. Access to the other sites pre-located for the geophysical survey for underground monitoring boreholes were not granted on the day of the survey. It should also be noted that T6, T7 and T8 targeted the surface infrastructure for Alternative Option.

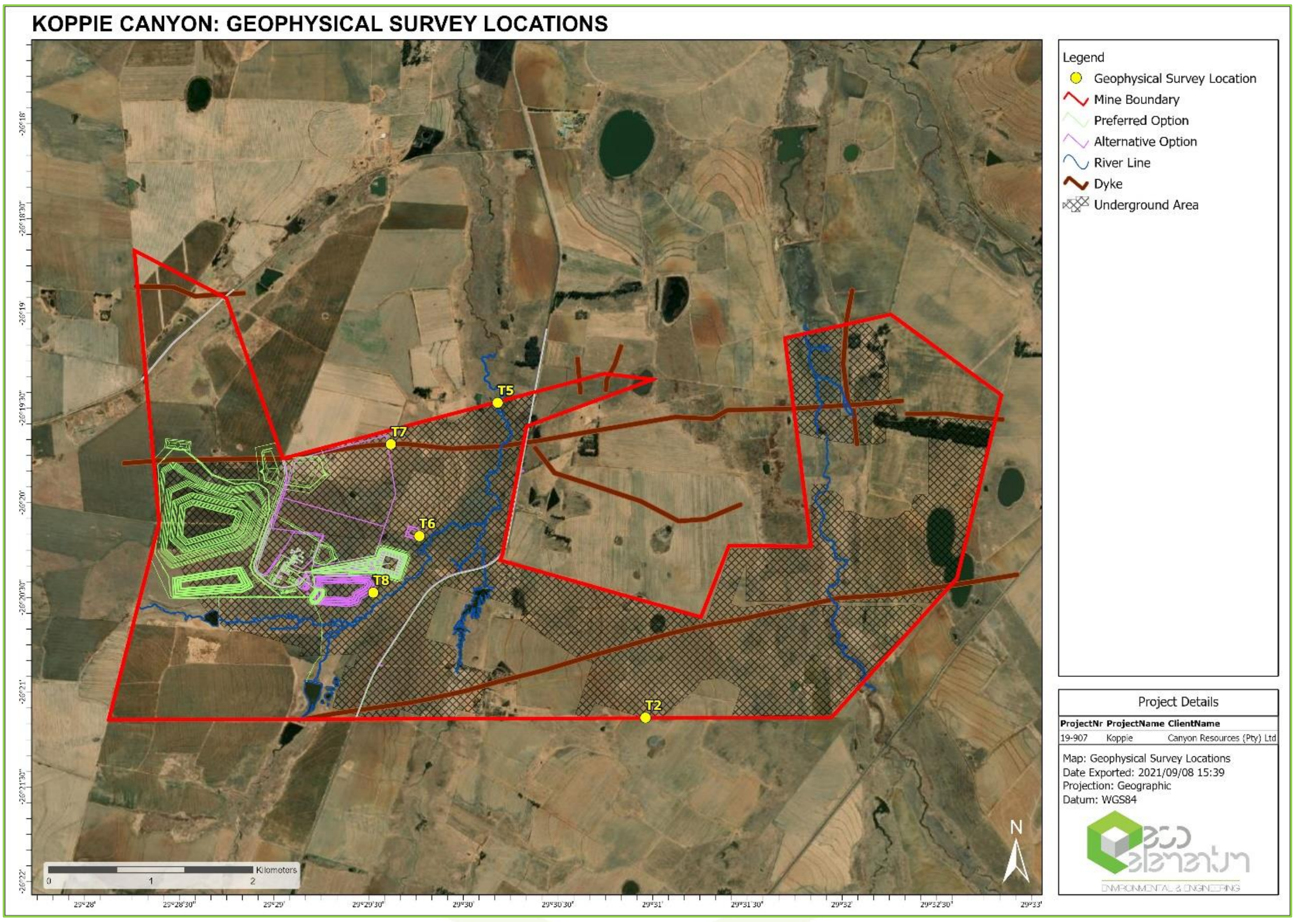


**Figure 7: Geophysical Traverse Locations for the placement of mine monitoring boreholes.**

## 4.4 Drilling And Siting Of Boreholes

Monitoring borehole positions have been determined by means of geophysics as well as topographical information. The positions of the proposed monitoring boreholes are presented in Table 2. Proposed monitoring boreholes include both the underground mine monitoring as well as the surface potential source monitoring boreholes. Two alternatives for the surface infrastructure were investigated for this study- Preferred Option and Alternative Option. The two alternatives differ in terms of layout and location. Depending on which alternative is approved, the relevant monitoring boreholes as indicated in Table 2 should be drilled.

**Table 2: Monitoring boreholes to form part of the quarterly monitoring program.**

| | Borehole | Coordinates (WGS84- TM29) | | Drill Depth (mbs) |
|---|---|---|---|---|
| | Unit | X-coordinate | Y-coordinate | |
| Underground Monitoring Boreholes | KC-BH01UG | 50221 | -2912888 | 75 |

| | Borehole | Coordinates (WGS84- TM29) | | Drill Depth (mbs) |
|---|---|---|---|---|
| | Unit | X-coordinate | Y-coordinate | |
| | KC-BH02UG | 51498 | -2915962 | 135 |
| | KC-BH03UG | 47867 | -2913428 | 80 |
| | KC-BH04UG | 52939 | -2912214 | 55 |
| | KC-BH05UG | 54583 | -2913062 | 105 |
| Preferred Option Surface Infrastructure Monitoring boreholes | KC-BH06S | 47199 | -2914292 | 30 |
| | KC-BH07S | 47701 | -2914759 | 30 |
| | KC-BH08S | 48623 | -2914411 | 30 |
| | KC-BH09S | 48676 | -2914827 | 30 |
| | KC-BH10S | 47801 | -2913633 | 30 |
| | KC-BH11S | 47506 | -2913241 | 30 |
| Alternative Option Surface Infrastructure Monitoring boreholes | KC-BH12S | 49282 | -2913289 | 30 |
| | KC-BH13S | 49529 | -2914183 | 30 |
| | KC-BH14S | 49121 | -2914733 | 30 |

## 4.5 Aquifer Testing

Aquifer testing are conducted to determine the hydraulic aquifer characteristics which include the transmissivity or hydraulic conductivity. Aquifer testing is the abstraction of measured quantities of water over a period of time. Aquifer testing also involves the recovery of the water levels after the abstraction of groundwater has stopped. The results of the aquifer tests are important to form a conceptual model for the study area. This in turn form an integral part of the numerical groundwater modelling.

Transmissivity is the rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient. It is expressed as the product of the average hydraulic conductivity and thickness of the saturated portion of an aquifer.

$$T = KhD$$

*Where:* *T is the transmissivity,*
*Kh is the average horizontal conductivity (measured in length per unit time),*
*D is the aquifer thickness.*

## 4.6 Sampling And Chemical Analysis

The hydrocensus boreholes have been sampled by Eco Elementum in September 2020. The samples from the hydrocensus boreholes that has been sampled by Eco Elementum were analysed by Yanka Laboratory in Witbank. Yanka is a SANAS accredited laboratory (Testing Laboratory T0391).

Yanka Laboratories is a SANAS ISO 17025 Accredited Testing Laboratory:

Yanka is an ISO 17025 SANAS accredited Testing Laboratory. Certificate available directly from SANAS or from the Yanka website.

Note that this includes compliance with ISO 9001 - for the pertinent communiqué and explanatory letter refer International Organisation for Standardization (ISO) or National Institute for Standards and Technology (NIST) or International Laboratory Accreditation Cooperation (ILAC).

The following parameters have been analysed for: pH, Electrical Conductivity, Total Dissolved Solids, Calcium, Magnesium, Sodium, Potassium, Total Alkalinity, Chloride, Sulphate, Nitrate, Fluoride, Aluminium, Iron and Manganese. It is highly recommended that quality analysis of these parameters continues in the monitoring boreholes and is conducted by a SANAS approved laboratory.

## 4.7 Groundwater Recharge Calculations

Groundwater recharge is mainly identified as the percentage of mean annual precipitation (MAP) that seeps through the unsaturated zone and reaches the saturated zone. Therefore, the percentage that contributes to the aquifer water make after run-off and evaporation. Recharge to the region of the Koppie mining area has been estimated by the following methods (van Tonder & Xu, 2000):

- Soil cover;
- Geology;
- Vegter Acru;
- Harvest Potential; and
- Expert's Guesses.

These estimations represent the general region of the study site and the characters on site may differ by small fractions of percentages.

**Table 3: Recharge estimations for the proposed Koppie region.**

| Method | % of MAP | Certainty level (High = 5, Low = 1) |
|---|---|---|
| **Soil** | 4.5 | 3 |
| **Geology** | 4.5 | 3 |
| **Vegter** | 4.5 | 3 |
| **Acru** | 2.8 | 3 |
| **Harvest Potential** | 3.5 | 3 |
| **Expert's Guesses** | 3.0 | 3 |
| **Average** | 3.8 | 3 |

Recharge to the Koppie area is estimated to be as much as 3.8%. Depending on the soil coverage, geology and other relevant factors the recharge may be higher and lower in some areas. Based on work by Kirchner et al. (1991) and Bredenkamp (1995) the recharge can range between 1% to 3% of the mean annual precipitation (MAP).

Recharge to Karoo sediments and to various types of mining has been studied extensively over the past in the Mpumalanga Mines. Factors relevant for recharge in mines are identified in **Table 4**. The recharge to deep underground bord-&-pillar mining such as at Koppie (58 to 133 mbs) can range between 1 and 2% depending on the rehabilitation plan. For the sake of this groundwater investigation, the recharge to the underground mining areas at Koppie will be taken as 1.5%.

**Table 4: Factors relevant for recharge in mines (Hodgson, 1999).**

| Description | Recharge % of Annual Rainfall |
|---|---|
| Recharge to undisturbed Karoo sediments | 3 |
| Recharge to underground areas | 10 – 20 |
| Influx into bord-and-pillar mining > 100 m in depth | 1 |
| Influx into bord-and-pillar mining 60 – 100 m in depth | 1.5 |
| Influx into bord-and-pillar mining 30 – 60 m in depth | 2 |
| Influx into bord-and-pillar mining 15 – 30 m in depth | 2.5 |
| Influx into bord-and-pillar mining < 15 m in depth | 4 – 6 |
| Recharge to stooped areas | 6 - 11 |

## 4.8 Groundwater Modelling

Groundwater modelling is an effective tool used for groundwater management and remediation. It is a simplified representation of reality used to replicate current groundwater conditions as well as predicting future potential impacts or conditions of the groundwater regime.

Once a conceptual model has been formed, the fundamentals are used as the basis of the numerical groundwater model. Known characteristics such as the aquifer parameters including transmissivity and conductivity as well as measured water levels, qualities, recharge etc. are used to calibrate the model.

Both flow and mass transport models were constructed for the proposed Koppie area. The software, model set-up and boundaries used are discussed in more detail in Section 7 of this report.

## 4.9 Groundwater Availability Assessment

The proposed Koppie is situated within the Olifants River Catchment area in quaternary catchment B11A. A summary of the Groundwater Resource Directed Measures (GRDM) for the quaternary catchment B11A (in which Koppie is located) is presented in **Table 5.** According to the table a total of 2.98 $Mm^3$ of groundwater is allocable in the catchment area.

**Table 5: Groundwater Resource Directed Measures (GRDM) for quaternary catchment B11A (Government Gazette, 2017).**

| Preliminary Groundwater Reserve Quantity Component Parameter | | B11A |
|---|---|---|
| Recharge | Area ($km^2$) | 945.4 |
| | MAP (mm/a) | 702 |
| | Groundwater recharge (% MAP) | 1.8 |
| | Groundwater recharge ($Mm^3$/a) | 11.99 |
| Use | Groundwater Use ($Mm^3$/a) | 0.57 |
| Reserve | Groundwater Component of Baseflow ($Mm^3$/a) | 10.29 |
| | Population at minimum living level | - |
| | Basic Human Needs Reserve ($Mm^3$/a) | 0.10 |
| | Total Reserve ($Mm^3$/a) | 12.30 |
| Allocation | Allocable Groundwater ($Mm^3$/a) | 2.98 |
| | Allocable Groundwater (% of reserve) | 24 |
| | Allocable Groundwater (% of recharge) | 24.8 |

# 5. PREVAILING GROUNDWATER CONDITIONS

## 5.1 GEOLOGY

### 5.1.1 Regional Geology

The Koppie project is situated south of the Smithfield Ridge and thus on the boundary between the Highveld and Witbank Coalfields. The pre-Karoo basement rocks forming the ridge outcrop to the north west of the Koppie area. The basement rocks consist of Rooiberg felsite and granite of late Bushveld age. These are overlain unconformably by diamictite and associated glaciogenic sediments of the Dwyka Group of the Karoo Supergroup. The Dwyka rocks are in turn overlain by sediments of the Vryheid Formation of the Ecca Group.

During Permo-Carboniferous times erosion by continental ice-sheets sculpted the pre-Karoo palaeo-topography. The resultant glaciated relief consists of elongated low ridges and shallow valleys. This topography has influenced the depositional patterns until at least No. 5 Seam times.

Sediments of glacial origin like tillites, diamictites and varvites, characterize the Dwyka Group. The Vryheid Formation comprises a predominately arenaceous sequence of sandstones and conglomerates with subordinate siltstones, shale and the coal seams. The Vryheid Formation comprises a series of five upward-coarsening depositional sequences of siltstone and sandstone, each capped by a coal seam or seam package. The thickness of the coal seams is generally larger in the trough of the glaciated valleys, whilst towards the banks of said valleys there is a tendency for seams to wedge out against the palaeo-topography. The major coal seams present in the area are named from the base upwards the No. 1, No. 2 Lower, No. 2 Upper, No. 4 Lower, No. 4 Upper and No. 5 Seam respectively. Refer to figure 2 below for the general stratigraphy of the coal seams.

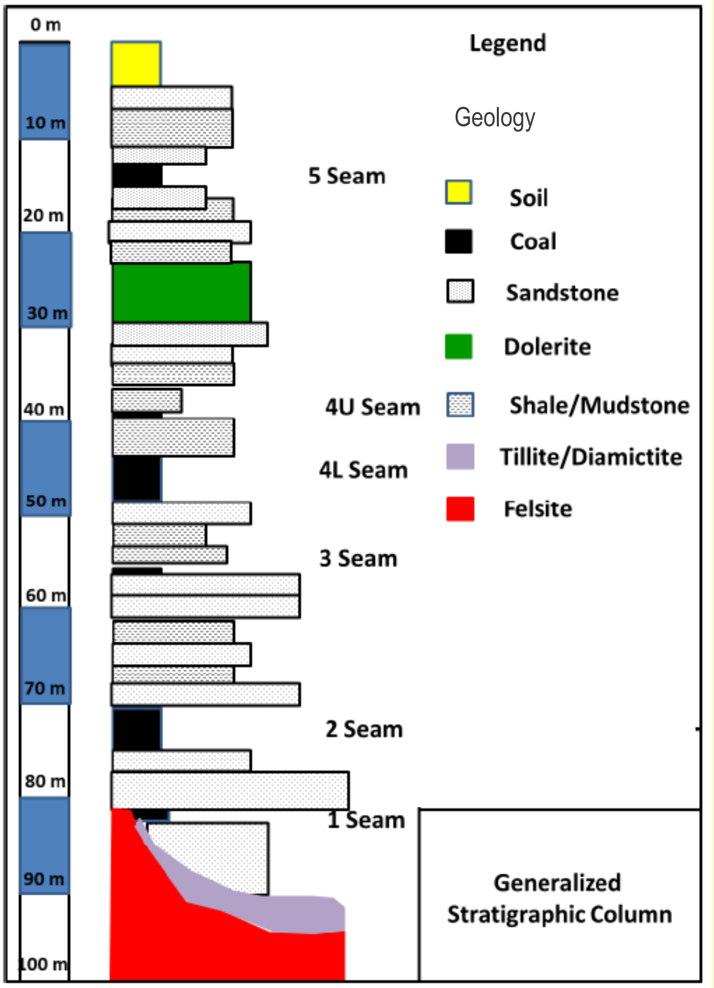


**Figure 8: Generalised stratigraphy collumn for the Koppie area (Koppie MWP).**

### 5.1.2 Local Geology

The following section has been extracted from the Koppie Mine Works Program. Exploration drilling was conducted on this project, the exploration included the drilling of 15 boreholes, the logging and sampling of the coal intersections. These boreholes were numbered K001 to K015.The coal samples were submitted for analyses at a SANAS accredited coal laboratory namely SGS South Africa (Pty) Ltd (SGS). Based on this information the coal deposited is characterised as bituminous coal with burnt coal closed to dolerite sills and dykes.

On the basis of seam thickness and coal quality the S4L is the prime exploitation target within the No. 4 Seam Group. It is the result of a relatively long period of basin stability, which resulted in limited clastic input. The coal is characteristically banded with alternating dull and bright coal. Pyrite is present in the form of nodules or in disseminated form. Fluvial activity during peat formation resulted in the deposition of shale like partings. The S4L contains one in seam parting of significant thickness and lateral extent.

The 2 Seam is often split into No. 2 Lower and No. 2 Upper Seam. The No. 2 Lower Seam ("S2L") generally is the thicker seam of the two sub-seams; it has better quality coal, and therefore will be the "theoretical" mining target. The S2L has been split into 6 resource blocks with varying qualities and based on the structures present the S2L contains a significant sill in the western and eastern blocks

## 5.2 HYDROGEOLOGY

### 5.2.1 Unsaturated Zone

The unsaturated zone is the zone between the ground surface and the static water table. In the unsaturated zone the pores between the ground particles are filled with air and water- thus below saturation. Static water levels in the region of the Koppie mining area as obtained from the hydrocensus as well as the NGA boreholes, range between 5 and 17 mbs, therefore also the thickness of the unsaturated zone. The unsaturated zone may consist of soil, weathered bedrock and even solid bedrock from the sandstone and shale of the Ecca Group.

### 5.2.2 Saturated Zone

The saturated zone is that part of the aquifer below the regional static water level where all pores and fractures are filled with water at a pressure greater than atmospheric pressure. The depth of the saturated zone in the Koppie mining area, is therefore more than 5 to 17 mbs. From studies compiled in the larger region of Koppie area, the saturated zone mainly consists of two aquifer systems.

- Firstly, the weathered, unconfined aquifer that typically occurs on the transition between soil and weathered bedrock (typically sandstone and shale). The groundwater flow closely mimics the surface topography. Groundwater levels are usually shallow in the low lying topographical regions and may even daylight on surface which is referred to as springs. The weathered aquifer is more prominent in the wet season because it is located on top of solid bedrock or clayey layers. This aquifer normally has a low yield.
- The second aquifer is known as the deeper, confined aquifer. Flow in this aquifer mainly occurs along fractures, bedding planes and other groundwater flow paths. The presence of fractures generally decreases with depth in this aquifer. The secondary aquifer, due to its heterogeneous nature, may be higher yielding than the weathered aquifer. Due to longer residence time of the groundwater in this aquifer, the salt load may be higher than that of the weather aquifer.

A third aquifer at great depth may occur within the pre-Karoo geology (Transvaal Group), underlying the Dwyka-tillites. Very little information of this aquifer in the area is available since very few boreholes have been drilled to this great depth. The water quality in quantity in this aquifer may be inferior to that of the overlying Karoo aquifers. Where dolomite underlay the Karoo geology, the yields of this aquifer may be significantly higher.

### 5.2.3 Hydraulic Conductivity

Hydraulic conductivity refers to the ease with which water passes through a porous medium in a certain time under a hydraulic gradient (m/d). Hydraulic Conductivity (K) can be determined as:

$$K = \frac{\text{Transmissivity (T)}}{\text{Aquifer thickness (d)}}$$

Aquifer tests were not conducted for the proposed Koppie mining area. The aquifer characteristics in the area is expected to correspond with other similar Karoo Aquifers. The hydraulic conductivity range can vary anywhere between $10^{-4}$ to $10^{-2}$. It is expected that:

- The hydraulic conductivity will decrease with depth.
- That the fracture zones, also along the dykes, will have a higher hydraulic conductivity than the surrounding rock matrix. These zones will act as preferred groundwater flow paths along which potential contamination will migrate at a higher rate than in the surrounding rock matrix.
- The dykes are expected to have a significantly lower hydraulic conductivity and will therefore in most cases act as groundwater flow barriers.
- The coal seams can also have a higher hydraulic conductivity than the surrounding rock matrix.

## 5.3 GROUNDWATER LEVELS

Groundwater level information is available for the model area as they were recorded during the 2020 hydrocensus as well as NGA boreholes (DWS). Only 4 water levels could be measured during the hydrocensus as the majority of the boreholes were equipped with pumps and no access to measure the water levels could be obtained. Groundwater levels varied between 5 and 17mbs in the boreholes recorded.

**Table 6: Summary of water levels in the boreholes used as calibration points in the numerical model.**

| Borehole ID | X-coord | Y-coord | Status | SWL |
|---|---|---|---|---|
| PU19b | 46015 | -2913426 | Hydrocensus Borehole | 7,5 |
| PU11 | 50523 | -2913948 | Hydrocensus Borehole | 15,9 |
| PU10a | 50305 | -2915582 | Hydrocensus Borehole | 5,7 |
| PU2 | 50127 | -2915898 | Hydrocensus Borehole | 6,1 |
| 2629AD00221 | 44049 | -2911103 | NGA Borehole | 16,8 |
| 2629AD0043 | 48208 | -2918533 | NGA Borehole | 4,9 |
| 2629AD0187 | 48499 | -2908132 | NGA Borehole | 7,0 |
| 2629BC0085 | 57588 | -2923249 | NGA Borehole | 7,3 |
| 2629BC0088 | 54557 | -2918927 | NGA Borehole | 5,5 |
| 2629BC0153 | 52419 | -2905745 | NGA Borehole | 15,0 |

The groundwater level elevations correlate very well with the topography – 95% (**Figure 9**), which is typical of the Karoo aquifers. No impacts in terms of mining or water abstraction is observed in the water levels.

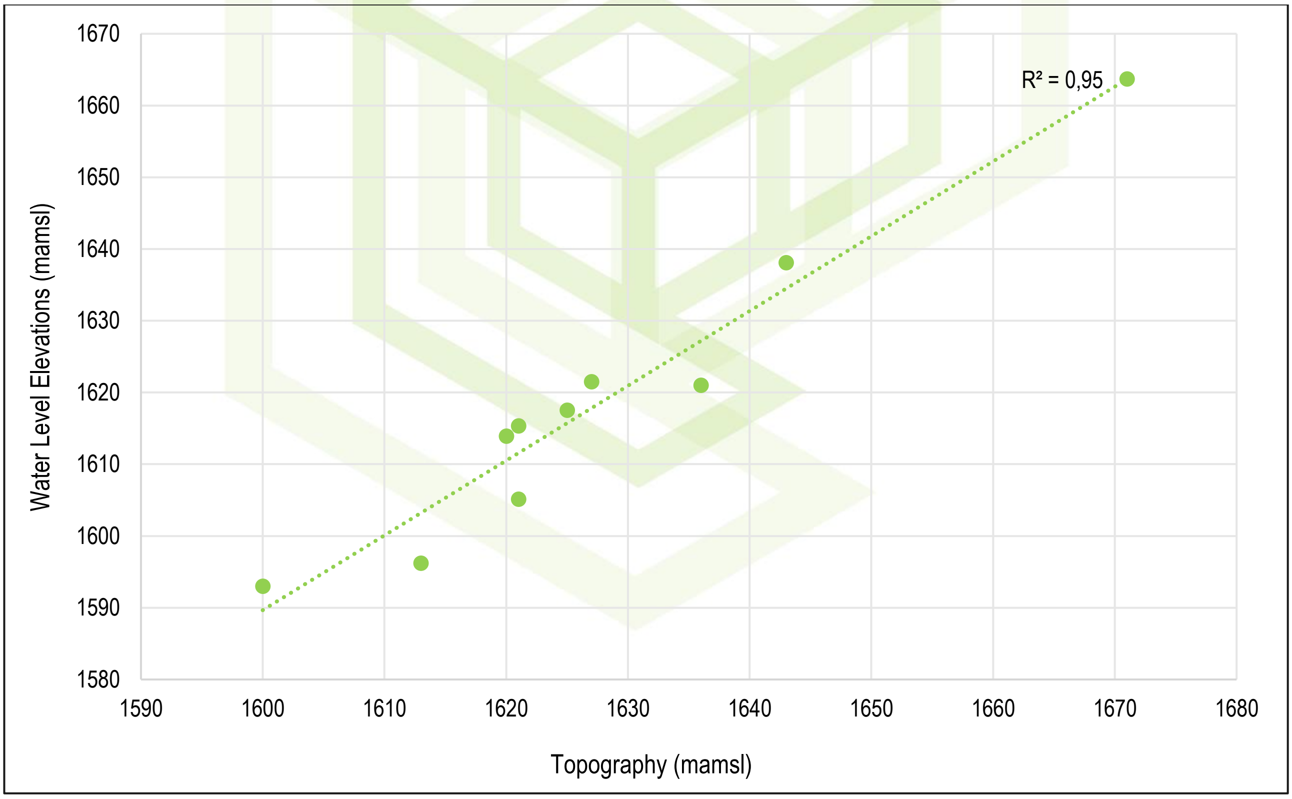


**Figure 9: Correlation between groundwater level elevations and topography.**

## 5.4 Groundwater Potential Contaminants

Acid generation is a common response to the coal mining environment. Coal and carbonaceous material contain a mineral known as pyrite, an iron-sulphide mineral, which is the main contributor to acid rock drainage (ARD). After being exposed to oxygen and water the sulphide minerals react to form an acid. Bacteria, which increases with the exposure to water and oxygen often accelerates the acidification process. The reaction can however also occur abiotically.

The general equation of pyrite oxidation is as follows:

$$2FeS_2 + 7O_2 + 2H_2O \rightarrow 2Fe^{2+} + 4SO_4^{2-} + 4H^+$$

Ferrous iron is oxidised to ferric iron:

$$4Fe^{2+} + O_2 + 4H^+ \rightarrow 4Fe^{3+} + 2H_2O$$

As mentioned previously these two reactions can occur abiotically or with the catalisation by micro-organisms. These organisms arise from the oxidation reactions. The ferric cations reduce to ferrous ions:

$$FeS_2 + 14Fe^{3+} + 8H_2O \rightarrow 15Fe^{2+} + 2SO_4^{2-} + 16H^+$$

The release of H+ lowers the pH. At the lower pH the solubility of the ferric ion continuous which increases the acid generation.

### 5.4.1 Acid Generation Capacity

ABA tests were conducted for the proposed Koppie mining area. Three samples were subjected to ABA analyses. The analysis was conducted by UIS lab in Pretoria. UIS Analytical Services is an ISO/IEC 17025 accredited laboratory. The samples were taken as follow:

- Above Coal seam: 1m above the coal seam,
- Coal seam: The coal seam itself (also representing the remaining pillars underground)
- Below seam: 1m below the coal seam.

According to the results of the ABA tests, the coal and the 1m below the coal samples is Type II rock types and therefore have an intermediate acid generating potential. The sample from below the coal seam have a mild acid generating potential. The best approach is to treat all the material (ROM and discard) as acid forming to minimise the pollution.

**Table 7: Rock Type Classification (De Wet, 2012).**

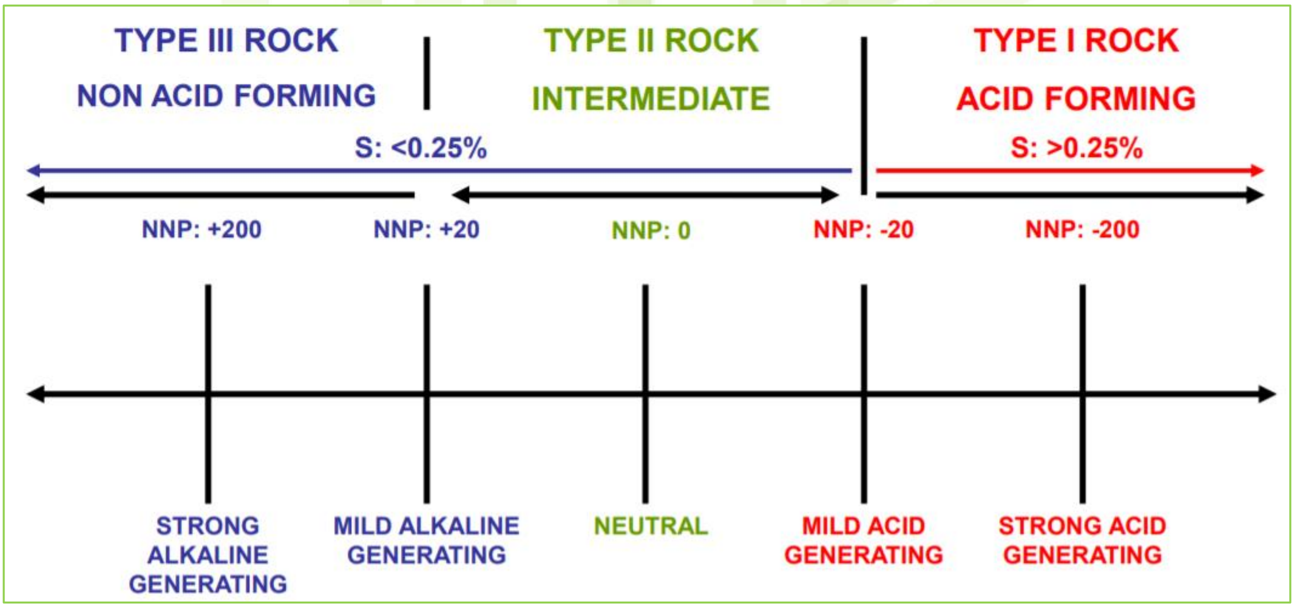


**Table 8: ABA results for Koppie.**

| Method : EPA 600 Modified Sobek | Unit | COAL | ABOVE/COAL | BELOW/COAL |
|---|---|---|---|---|
| Paste pH | | 7,33 | 6,10 | 5,39 |
| Total Sulphur | % | 0,30 | 0,093 | 0,71 |
| Acid Potential (AP) | kg CaCO3/t | 9,38 | 2,89 | 22,2 |

| Method : EPA 600 Modified Sobek | Unit | COAL | ABOVE/COAL | BELOW/COAL |
|---|---|---|---|---|
| Neutralization Potential (NP) | kg CaCO3/t | 3,52 | 0,00 | 1,00 |
| Nett Neutralization Potential (NNP) | kg CaCO3/t | -5,86 | -2,89 | -21,2 |
| Neutralising Potential Ratio (NPR) (NP: AP) | NP:AP | 0,38 | 0,00 | 0,05 |
| Total Carbon | % | 57,5 | 7,43 | 0,68 |
| Rock Type | | Type II | Type II | Type III |

### 5.4.2 Waste Classification

A waste classification was conducted for the Koppie study area. Three samples were analysed. A composite sample for 1m above the coal seam, the coal seam itself and 1 m below the coal seam.

A waste classification should be conducted in accordance with the National Environmental Management: Waste Act (NEM: WA) Regulations (2013). The assessment is undertaken by comparing the samples' leachate concentration (LC) to the leachable concentration threshold (LCT), and the total concentration (TC) to the total concentration thresholds (TCT). The results will indicate the type of waste and the type of liner, if any, required for the potential source.

**Table 9: Waste Classification Criteria**

| Waste Type | Disposal |
|---|---|
| 0 | Not allowed |
| 1 | Class A or Hh:HH landfill |
| 2 | Class B or GLB+ landfill |
| 3 | Class C or GLB- landfill |
| 4 | Class D or GLB- landfill |

From the waste classification the following can be concluded:

1. No tests were conducted for the overburden material from the box-cut construction of the shaft area. From investigations at other coal mining projects in the same region of the Witbank Coalfields, it may be assumed that the physical and geochemical properties of overburden materials will be similar. It is therefore concluded that the overburden materials to be stockpiled at Koppie Canyon will most likely classify as Type 3 waste. This statement should be confirmed once the overburden material from Koppie Canyon is available.
2. According to Regulation 7(6) of GNR635 the samples at Koppie Canyon mining area, are all classified as a Type 3 waste. Type 3 waste may only be disposed of at a Class C landfill designed in accordance with Section 3(1) and 3(2), or, subject to Section 3(4), may be disposed of at a landfill site designed and operated in accordance with the requirements for a GLB+ landfill as specified in the Minimum Requirements for Waste Disposal by Landfill (2nd Ed., DWAF, 1998). The stockpiling of coal and waste at Koppie Canyon should therefore be under these regulations.
3. It is highly recommended that the ROM and coal products be managed in a manner that prevents environmental pollution. A hard surface with appropriate surface water management structures feeding into a dirty water management infrastructure should be incorporated. The collected dirty water runoff and seepage should be lined pollution control dam. ROM material was included in this assessment in the case where ROM material is not stored as described above.

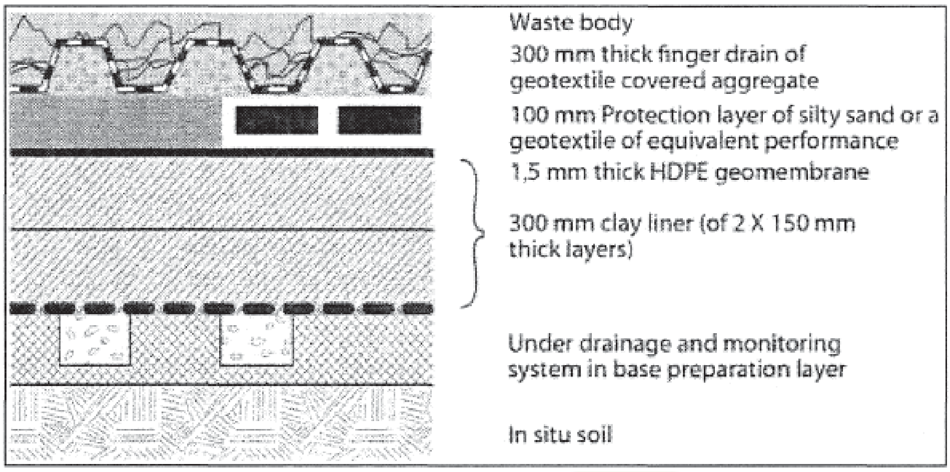


**Figure 10: Class C landfill site liner requirements.**

**Table 10: Waste Classification results of the proposed Koppie mining area.**

| Determinant | | Coal- Measured Concentrations | | Above Coal- Measured Concentrations | | Below Coal- Measured Concentrations | | Threshold Levels (GNR 635) | | | | | | | Waste Type |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Total Concentration (TC) | Leachate Concentration (LC) | Total Concentration (TC) | Leachate Concentration (LC) | Total Concentration (TC) | Leachate Concentration (LC) | TCT0 | TCT1 | TCT2 | LCT0 | LCT1 | LCT2 | LCT3 | |
| | | $mg.kg^{-1}$ | $mg.L^{-1}$ | $mg.kg^{-1}$ | $mg.L^{-1}$ | $mg.kg^{-1}$ | $mg.L^{-1}$ | $mg.kg^{-1}$ | | | $mg.L^{-1}$ | | | | |
| Metal Ions | As, Arsenic | 1,88 | 0,001 | 5,73 | 0,002 | 13,4 | <0.001 | 5.8 | 500 | 2 000 | 0.01 | 0.5 | 1 | 4 | Type 3 |
| | B, Boron | 24,9 | 0,027 | 22,6 | 0,026 | 8,98 | 0,029 | 150 | 15 000 | 60 000 | 0.5 | 25 | 50 | 200 | Type 4 |
| | Ba, Barium | 126 | 0,134 | 497 | 0,182 | 384 | 0,261 | 62.5 | 6 250 | 25 000 | 0.7 | 35 | 70 | 280 | Type 3 |
| | Cd, Cadmium | 0,44 | <0.0001 | 0,46 | <0.0001 | 0,30 | <0.0001 | 7.5 | 260 | 1 040 | 0.003 | 0.15 | 0.3 | 1.2 | Type 4 |
| | Co, Cobalt | 27,2 | 0,004 | 20,8 | 0,047 | 10,3 | 0,060 | 50 | 5 000 | 20 000 | 0.5 | 25 | 50 | 200 | Type 4 |
| | CrTotal, Chromium Total | 223 | <0.001 | 103 | <0.001 | 182 | <0.001 | 46 000 | 800 000 | N/A | 0.1 | 5 | 10 | 40 | Type 4 |
| | Cr(VI), Chromium (VI) | <5 | <0,5 | <5 | 0,500 | <5 | <0,5 | 6.5 | 500 | 2 000 | 0.05 | 2.5 | 5 | 20 | Type 4 |
| | Cu, Copper | 68,7 | 0,001 | 38,6 | 0,001 | 13,4 | <0.001 | 16 | 19 500 | 78 000 | 2 | 100 | 200 | 800 | Type 3 |
| | Hg, Mercury | 0,080 | <0.0001 | 0,127 | <0.0001 | 0,098 | <0.0001 | 0.93 | 160 | 640 | 0.006 | 0.3 | 0.6 | 2.4 | Type 4 |
| | Mn, Manganese | 49,1 | 0,005 | 56,8 | 0,063 | 109 | 0,261 | 1 000 | 25 000 | 100 000 | 0.5 | 25 | 50 | 200 | Type 4 |
| | Mo, Molybdenum | 7,77 | 0,008 | 1,45 | <0.001 | 2,20 | <0.001 | 40 | 1 000 | 4 000 | 0.07 | 3.5 | 7 | 28 | Type 4 |
| | Ni, Nickel | 37,1 | <0.001 | 51,0 | 0,039 | 15,4 | 0,055 | 91 | 10 600 | 42 400 | 0.07 | 3.5 | 7 | 28 | Type 4 |
| | Pb, Lead | 23,6 | <0.001 | 33,9 | <0.001 | 12,6 | <0.001 | 20 | 1 900 | 7 600 | 0.01 | 0.5 | 1 | 4 | Type 3 |
| | Sb, Antimony | 3,68 | 0,008 | 0,24 | 0,012 | 0,29 | 0,003 | 10 | 75 | 300 | 0.02 | 1 | 2 | 8 | Type 4 |
| | Se, Selenium | 0,30 | 0,002 | 0,05 | <0.001 | 0,05 | 0,004 | 10 | 50 | 200 | 0.01 | 0.5 | 1 | 4 | Type 4 |
| | V, Vanadium | 351 | 0,025 | 79,8 | 0,003 | 41,9 | 0,001 | 150 | 2 680 | 10 720 | 0.2 | 10 | 20 | 80 | Type 3 |

| Determinant | | Coal- Measured Concentrations | | Above Coal- Measured Concentrations | | Below Coal- Measured Concentrations | | Threshold Levels (GNR 635) | | | | | | | Waste Type |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Total Concentration (TC) | Leachate Concentration (LC) | Total Concentration (TC) | Leachate Concentration (LC) | Total Concentration (TC) | Leachate Concentration (LC) | TCT0 | TCT1 | TCT2 | LCT0 | LCT1 | LCT2 | LCT3 | |
| | | $mg.kg^{-1}$ | $mg.L^{-1}$ | $mg.kg^{-1}$ | $mg.L^{-1}$ | $mg.kg^{-1}$ | $mg.L^{-1}$ | $mg.kg^{-1}$ | | | $mg.L^{-1}$ | | | | |
| | Zn, Zinc | 139 | 0,004 | 112 | 0,042 | 37,3 | 0,039 | 240 | 160 000 | 640 000 | 5 | 250 | 500 | 2 000 | Type 4 |
| Inorganic Ions | Total Dissolved Solids* | NA | 32,0 | NA | 50,0 | NA | 44,0 | N/A | N/A | N/A | 1 000 | 12 500 | 25 000 | 100 000 | Type 4 |
| | Fluoride as F | NA | 0,16 | NA | 0,13 | NA | 0,10 | 100 | 10 000 | 40 000 | 1.5 | 75 | 150 | 600 | Type 4 |
| | Chloride as Cl | NA | 0,52 | NA | 0,68 | NA | 0,56 | N/A | N/A | N/A | 300 | 15 000 | 30 000 | 120 000 | Type 4 |
| | Nitrate as N | NA | 0,13 | NA | <0.1 | NA | 0,12 | N/A | N/A | N/A | 11 | 550 | 1 100 | 4 400 | Type 4 |
| | Sulphate as $SO_4$ | NA | 10,3 | NA | 17,8 | NA | 17,3 | N/A | N/A | N/A | 250 | 12 500 | 25 000 | 100 000 | Type 4 |

## 5.5 Groundwater Quality

Groundwater quality information is available from the hydrocensus boreholes from October 2020. All chemical parameters were compared to the standards as indicated in **Table 11**. Concentrations highlighted in red exceeded the specific guideline concentrations.

The overall quality of the groundwater in the area is good to marginal. The pH in the boreholes were more basic with values varying between 7.1 and 8.5. The most significant impacts on the groundwater are observed in terms of elevated nitrate concentrations. The nitrate concentration in six of the thirteen boreholes exceeded the permissible limits for drinking water. The nitrate concentrations in these six boreholes varied between 20 and 40 mg/l. In the agricultural environment the main source of elevated nitrate concentrations is the use of fertilisers. It is also believed to be the source in the case of these boreholes.

The fluoride concentration in PU11 and the manganese concentration in PU13a also exceeded the permissible limits for drinking water. Drinking of fluoride rich groundwater can cause dental fluorosis or crippling skeletal fluorosis, which is associated with osteosclerosis, calcification of tendons and ligaments, and bone deformities. Exposure to high concentrations of manganese over the course of years has been associated with nervous system diseases with symptoms like Parkinson's disease. The majority of the measured parameters in PU19a seems to be elevated above the baseline concentrations of the area. PU19a is situated at a residence and the causes for the elevated concentrations is unknown. Elevated fluoride concentration may be a result of natural water and rock interactions.

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**Table 11: Groundwater qualities for the proposed Koppie area (Hydrocensus boreholes).**

| Borehole ID | pH | EC mS/m | TDS mg/l | Ca mg/l | Mg mg/l | Na mg/l | K mg/l | Cl mg/l | SO4 mg/l | NO3-N mg/l | F mg/l | Al mg/l | Fe mg/l | Mn mg/l |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SANS241:2015 | ≥5 to ≤9,7 | 170 | 1200 | - | - | 200 | - | 300 | 500 | 11 | 1,5 | 0,3 | 2 | 0,4 |
| PU19a | 7,8 | 133 | 791 | 141 | 57 | 49 | 3,6 | 182 | 109 | **21** | <0.09 | <0.01 | <0.01 | <0.01 |
| PU19b | 7,4 | 87 | 505 | 100 | 33 | 19 | 3,4 | 87 | 58 | **20** | <0.09 | <0.01 | <0.01 | <0.01 |
| PU15a | 7,7 | 76 | 436 | 62 | 34 | 45 | 9,5 | 52 | 76 | 3 | <0.09 | <0.01 | 0,03 | <0.01 |
| PU6 | 7,4 | 39 | 215 | 34 | 14 | 14 | 6,2 | 27 | 15 | 10 | <0.09 | <0.01 | <0.01 | <0.01 |
| PU7 | 7,2 | 59 | 358 | 54 | 29 | 8 | 6,1 | 41 | 54 | **24** | <0.09 | <0.01 | <0.01 | <0.01 |
| PU17 | 7,7 | 56 | 298 | 51 | 22 | 35 | 3,7 | 31 | 13 | 1,3 | 1,3 | <0.01 | <0.01 | 0,09 |
| PU11 | 8,5 | 88 | 498 | 10 | 6,4 | 180 | 3,5 | 57 | 3,7 | 3,0 | **2,1** | <0.01 | <0.01 | <0.01 |
| PU10a | 7,5 | 43 | 255 | 36 | 14 | 14 | 7,3 | 22 | 39 | **20** | <0.09 | <0.01 | 0,02 | <0.01 |
| PU10b | 7,4 | 43 | 254 | 36 | 14 | 14 | 7,8 | 22 | 38 | **20** | <0.09 | <0.01 | <0.01 | <0.01 |
| PU10c | 7,7 | 44 | 230 | 29 | 15 | 25 | 10 | 36 | 53 | <0.35 | <0.09 | <0.01 | <0.01 | 0,19 |
| PU2 | 7,8 | 54 | 303 | 22 | 8,8 | 85 | 4,0 | 32 | 3,9 | 0,36 | 0,34 | <0.01 | <0.01 | <0.01 |
| PU13a | 7,8 | 47 | 240 | 48 | 11 | 24 | 8,1 | 7,2 | 4,5 | <0.35 | 0,21 | <0.01 | 0,23 | **0,41** |
| PU14 | 7,1 | 79 | 463 | 63 | 20 | 44 | 10 | 85 | 7,5 | **40** | <0.09 | <0.01 | <0.01 | <0.01 |

# 6. AQUIFER CHARACTERISTICS

## 6.1 GROUNDWATER VULNERABILITY

Groundwater vulnerability refers to the likelihood for contamination to reach a certain area/receptor after it has been introduced to the surface. For the Koppie area the vulnerability was estimated from the Aquifer Vulnerability map of South Africa (DWA, 2013) and by the Groundwater Vulnerability Classification System. According to the Aquifer Vulnerability map the Koppie area is located in a low to moderate vulnerability rating area. Therefore, an area that if continuously exposed to contamination may be vulnerable to some pollutants.

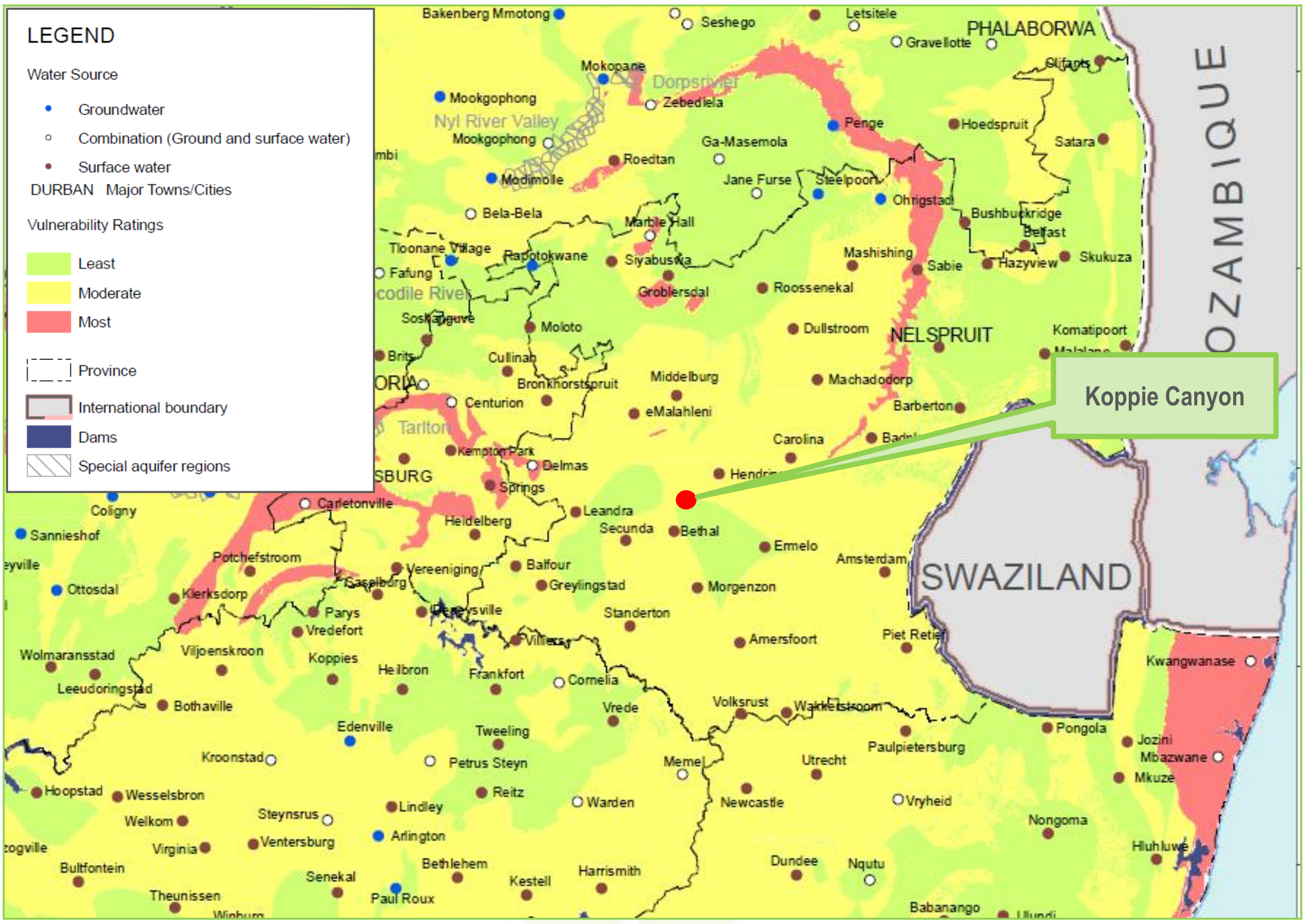


**Figure 11: Aquifer vulnerability rating of the proposed Koppie area (DWA, 2013)**

The Groundwater Vulnerability Classification System incorporates the Parsons Aquifer Classification System (Section 6.2) and the drinking water guidelines from the Department of Water and Sanitation.

**Table 12: Groundwater Vulnerability Classification System**

| Rating | Depth to Water Level | Groundwater Quality | Aquifer Type- Parsons |
|---|---|---|---|
| 1 | > 10 m | Poor (TDS > 2 400 mg/l) | Non-Aquifer System |
| 2 | 6 – 10 m | Marginal (TDS > 1 000 < 2 400 mg/l) | Minor Aquifer System |
| 3 | 3 – 6 m | Good (TDS > 450 < 1 000 mg/l) | Major Aquifer System |
| 4 | 0 – 3 m | Excellent (TDS < 450 mg/l) | Sole Aquifer System |

Table 13: Groundwater Vulnerability Rating

| Rating | Vulnerability |
|---|---|
| ≤ 4 | Low |
| > 4 ≤ 8 | Medium |
| ≥ 9 | High |

Table 14: Groundwater Vulnerability for Koppie area.

| Rating | |
|---|---|
| Depth to water level | 2 |
| Groundwater quality | 4 |
| Aquifer Type | 2 |
| **Total Score** | **8** |

According to the Groundwater Vulnerability Classification System, the Koppie aquifer scored a rating of 8 which is indicative of a medium vulnerability. Due to the groundwater qualities in terms of TDS concentrations being mostly < 450 mg/l, the aquifer in some areas may even be highly vulnerable.

## 6.2 Aquifer Classification

According to the Aquifer Classification map (DWA, 2012), the Koppie area is situated in a minor aquifer classification area. Aquifer classification is based on the Parsons System (1995). Qualities in these aquifers can vary and is typically moderately yielding aquifers.

Table 15: Aquifer System Management Classes.

| | |
|---|---|
| **Sole Aquifer System** | An aquifer that is used to supply 50% or more of domestic water for a given area, and for which there is no reasonably available alternative sources should the aquifer be impacted upon or depleted. Aquifer yields and natural water quality are immaterial. |
| **Major Aquifer System** | Highly permeable formation, usually with a known or probable presence of significant fracturing. They may be highly productive and able to support large abstractions for public supply and other purposes. Water quality is generally very good (less than 150 mS/m). |
| **Minor Aquifer System** | These can be fractured or potentially fractured rocks that do not have a primary permeability, or other formations of variable permeability. Aquifer extent may be limited and water quality variable. Although these aquifers seldom produce large volumes of water, they are important both for local suppliers and in supplying base flow for rivers. |
| **Non-Aquifer System** | These are formations with negligible permeability that are generally regarded as not containing groundwater in exploitable quantities. Water quality may also be such that it renders the aquifer unusable. However, groundwater flow through such rocks, although impermeable, does take place, and needs to be considered when assessing the risk associated with persistent pollutants. |
| **Special Aquifer System** | An aquifer designated as such by the Minister of Water Affairs, after due process. |

Two main aquifer systems exist in the Koppie area. Firstly, is a shallow, weathered aquifer which is found in the transitional soil and weathered bedrock zone. Due to direct recharge and dynamic groundwater flow through the weathered sediments, the natural groundwater qualities are often good. The direct recharge and dynamic groundwater flow are also the reason why this aquifer is vulnerable to pollution. Water levels in this aquifer are often shallow (few meters below ground level) and follow the surface topography.

Secondly is a deeper semi-confined to confined fractured aquifer where groundwater flow is predominantly fracture flow. The fractured Karoo aquifer consists of sedimentary successions of siltstone, shale, sandstone and the coal seams. Groundwater flow is dominated by secondary porosities like faults, fractures, joints, bedding planes or other geological contacts. Yields can be higher in this aquifer along these geological structures. The rock matrix is characterised by a low permeability. Borehole yields in the in the Ecca aquifers are generally low and can be expected to be less than 2 l/s.

A third aquifer at great depth may occur within the pre-Karoo geology (Transvaal Group), underlying the Dwyka-tillites. Very little information of this aquifer in the area is available since very few boreholes have been drilled to this great depth. The water quality in quantity in this aquifer may be inferior to that of the overlying Karoo aquifers. Where dolomite underlay the Karoo geology, the yields of this aquifer may be significantly higher.

## 6.3 Aquifer Protection Classification

As part of policy and regulation development and implementation, the aquifer classification used in **Table 15** alone is not sufficient. To minimise misinterpretation, the decision support tool in **Table 16** also needs to be incorporated as part of aquifer classification (Parsons, 1995). The combination of the Aquifer System Management Classification and the Aquifer Vulnerability Classification rating is referred to as the Groundwater Quality Management (GQM) classification, which provide a level of aquifer protection.

**GQM = Aquifer System Management x Aquifer Vulnerability**

**Table 16: GQM Classification for the Koppie Area.**

| Aquifer System Management Classification | | Aquifer Vulnerability Classification | | GQM | | GQM |
|---|---|---|---|---|---|---|
| **Class** | **Points** | **Class** | **Points** | **Index** | **Level of protection** | **Koppie** |
| Sole Source Aquifer System | 6 | High | 3 | <1 | Limited | |
| Major Aquifer System | 4 | | | 1 - 3 | Low | |
| Minor Aquifer System | 2 | Medium | 2 | 3 - 6 | Medium | 4 |
| Non-aquifer System | 0 | | | 6 - 10 | High | |
| Special Aquifer System | 0-6 | Low | 1 | >10 | Strictly non-degradation | |

The level protection for the Koppie according to the GQM Index is 4. This indicates a medium level of protection. Based on the findings of the geohydrological study it is highly recommended that a proposed monitoring protocol should be in place for the proposed project area.

The DWS (previously DWA – Department of Water Affairs) has also compiled a susceptibility map for South Africa (2013). This map indicates the qualitative measure of the relative ease with which an aquifer can potentially be contaminated. According to the aquifer susceptibility map, the Koppie area is also classified as low to medium susceptible to contamination.

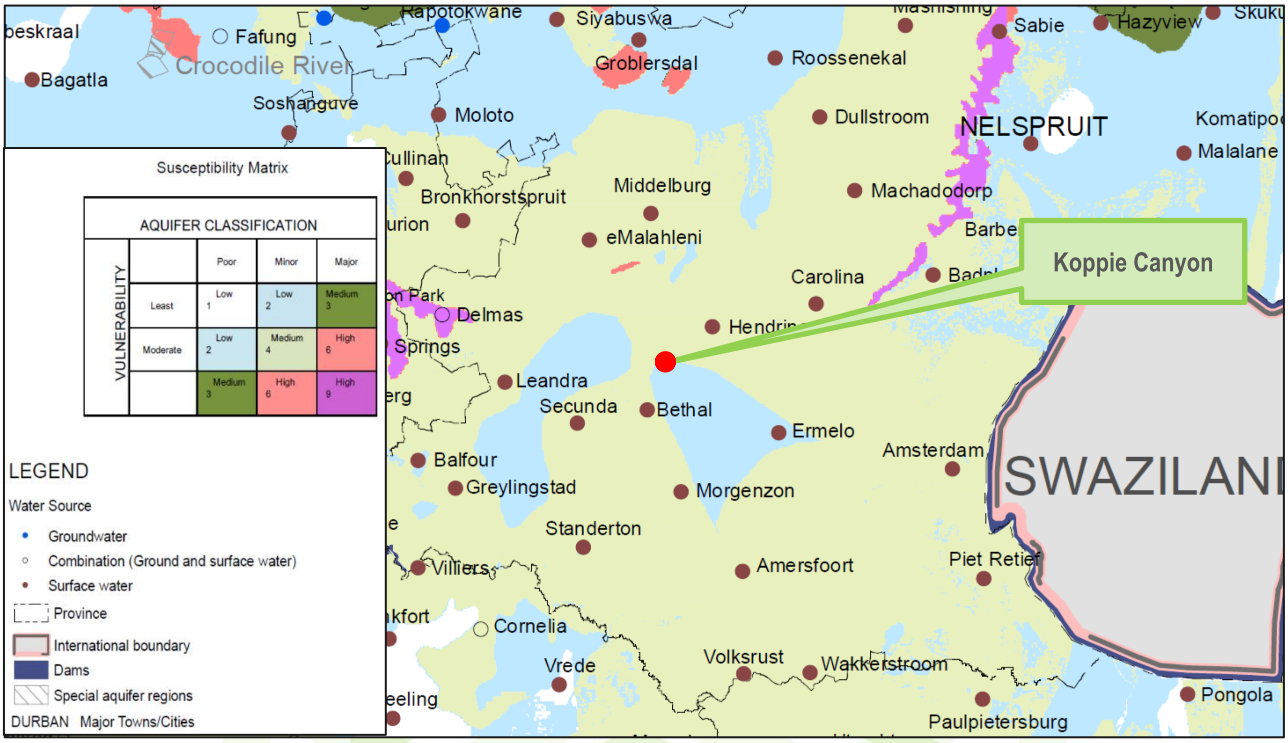


Figure 12: Susceptibility rating of the proposed Koppie mining area (DWA. 2013)

# 7. GROUNDWATER MODELLING

## 7.1 Software Model Choice

The Processing Modflow 8 (PMWIN) modelling package was used for the numerical flow and mass transport simulations. PMWIN is a finite difference modelling package where the domain is broken up into blocks or rectangular cells where the finite difference analogue of the partial differential equation for flow is applied to a node within a cell.

## 7.2 Model Set-up and Boundaries

After the conceptual model has been constructed, the numerical model is based on this model. The numerical model grid indicating the model boundaries are presented in **Figure 13**. The model dimensions used for the Koppie numerical groundwater model is summarised in **Table 17**.

The following model boundaries have been used in the Koppie numerical model:

- River nodes were used in the most northern and eastern regions of the model and act as constant head boundaries. The river node will add or remove water from the aquifer as the water level increases or decreases. The water level at the river nodes therefore remain relatively constant.
- General Head boundaries: groundwater flow over these boundaries is possible. The rate at which groundwater flow over these boundaries depend on the specified hydraulic conductivity of the boundary and therefore the aquifer on the opposite side of the boundary. These boundaries were used on the western, southern and portion of the north-eastern region of the model boundary area.

**Table 17: Model extent and aquifer parameters.**

| | |
|---|---|
| **Model Grid Size** | Easting = 21599.82<br>Northing = 25879.86 |
| **Rows** | 967 |
| **Columns** | 1012 |
| **Cell Size** | Varying from 13 x 13 m at the proposed mining site to 40 x 40 m on the model edges. |
| **Layer Thickness** | Layer 1 = 20 m<br>Layer 2 = 150 m |
| **Layers** | Layer 1 = Confined / Unconfined<br>Layer 2 = Confined |
| **Transmissivity** | Shallow weathered aquifer = 1.2 $m^2$/day<br>Deep, secondary aquifer = 0.5 $m^2$/day<br>Dykes = 0.05 $m^2$/day<br>Fractured zone adjacent to dykes = 30 $m^2$/day |
| **Recharge** | 1% |

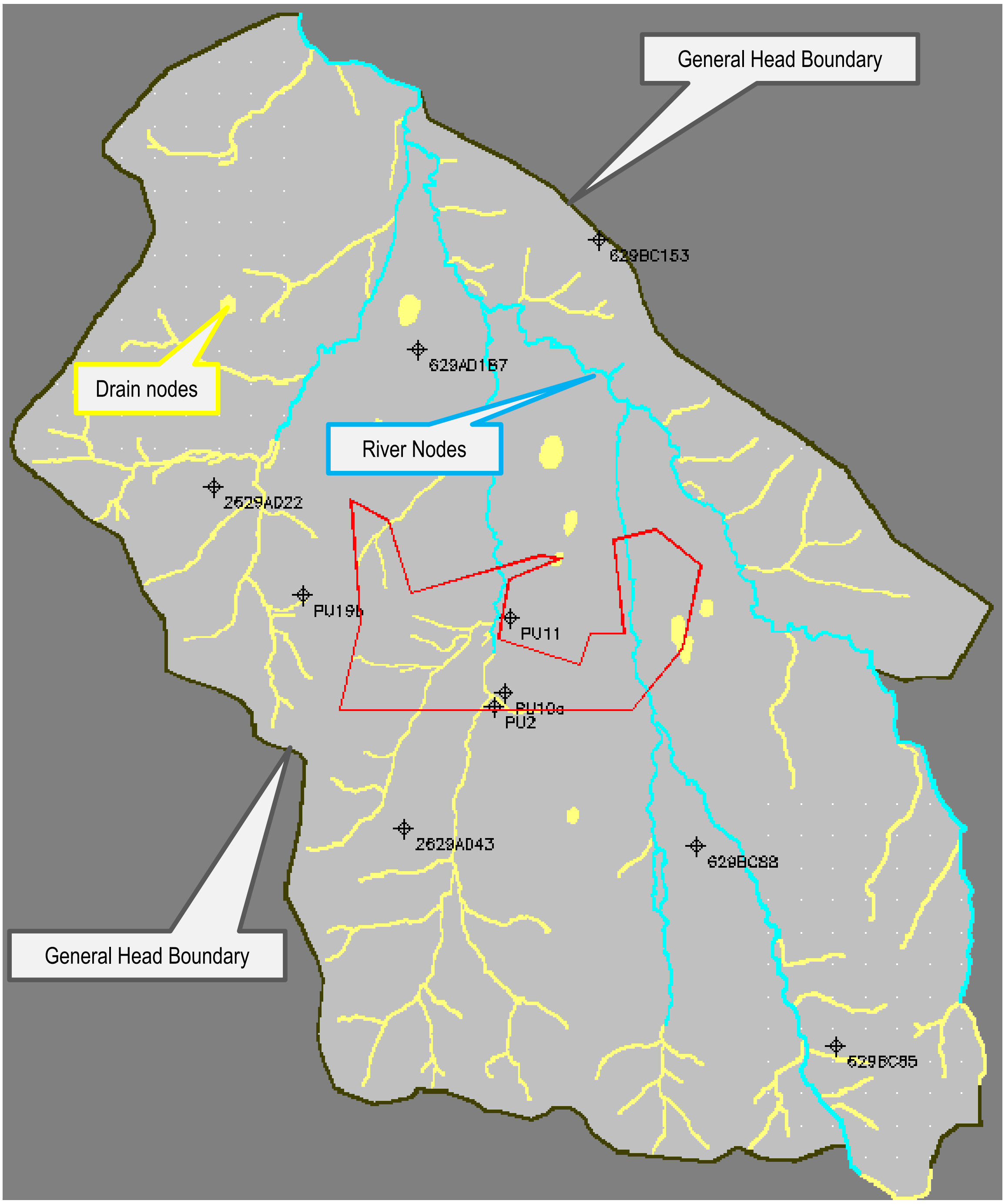


**Figure 13: Koppie model domain and boundaries.**

## 7.3 GROUNDWATER ELEVATION AND GRADIENT

Steady state flow model calibration involves the varying of aquifer parameters in the model until the observed water levels correlates well with the measured water levels. The measured water levels must represent the levels prior to any impacts from mining activities. Steady state water levels therefore represent "reality" prior to changes caused by mining activities.

Water level elevations used for steady state model calibration was obtained from the water levels recorded during the hydrocensus as well as NGA boreholes in the area (

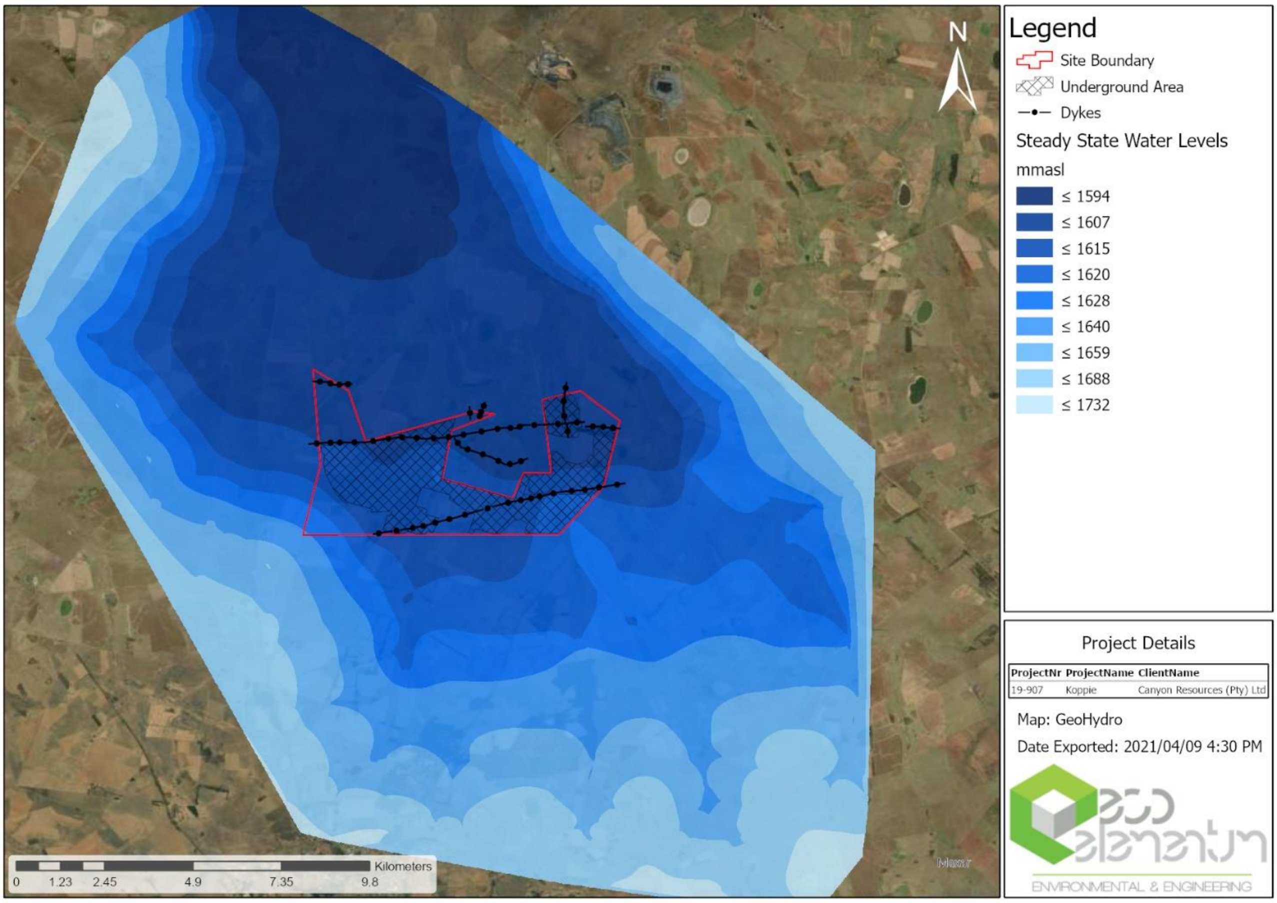


**Figure 16**).

By adjusting the aquifer parameters in the model to the values indicated in **Table 17**, a good correlation of 95% were obtained (**Figure 17**). It should be noted that although the correlation is very good in the boreholes used during calibration, very little / no information is available for a large portion of the model area. Due to the heterogeneous characteristics of the aquifer, over or under estimation of the water levels over these areas with little information can be possible.

Groundwater within the Koppie model area decrease from approximately 1 590 mamsl (North of the Koppie model area) to 1 730 mamsl south-east of the model area (

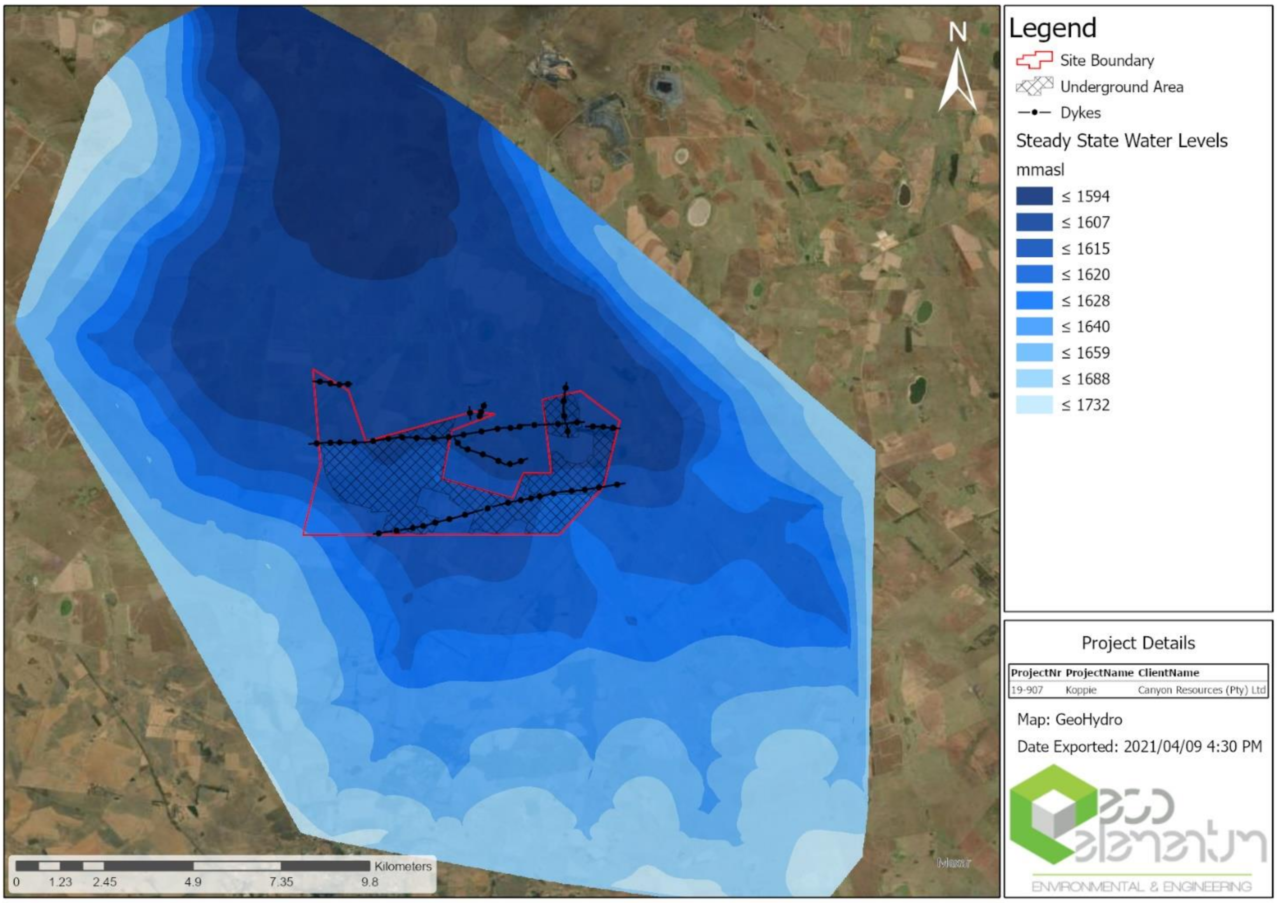


**Figure 16**). Groundwater gradients over the area is approximately 0.6%.

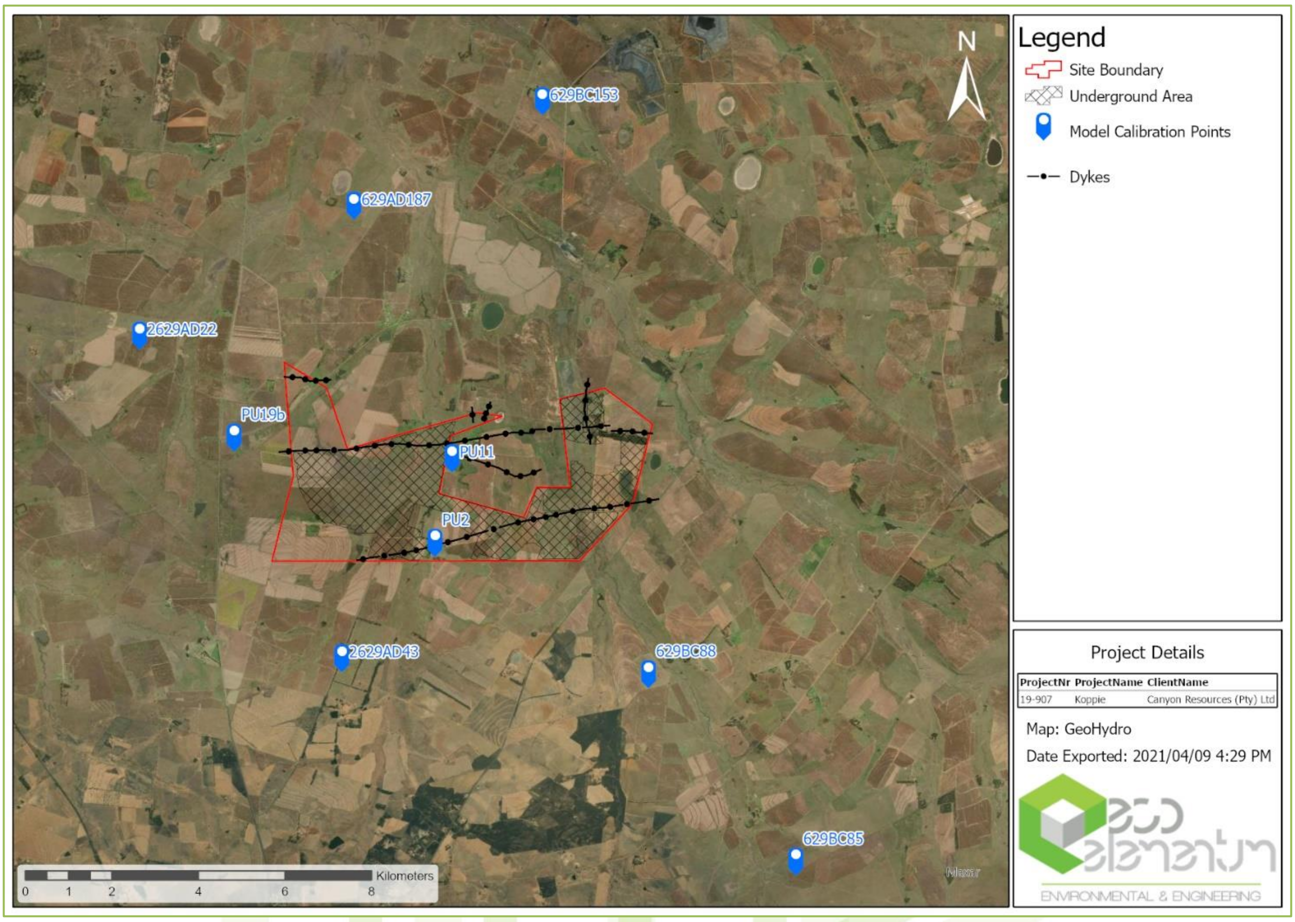


Figure 14: Position of calibration boreholes located in the proposed Koppie model area.

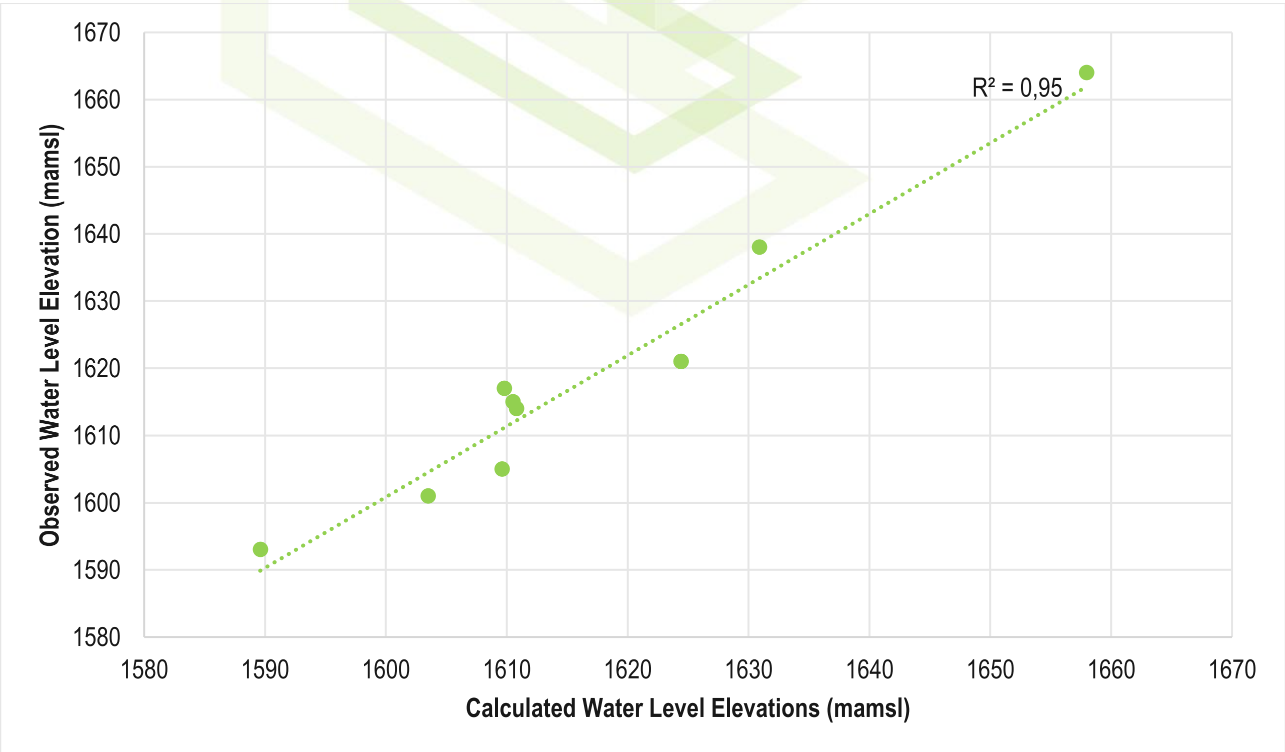


Figure 15: Model calculated water level elevations vs observed water level elevations correlation.

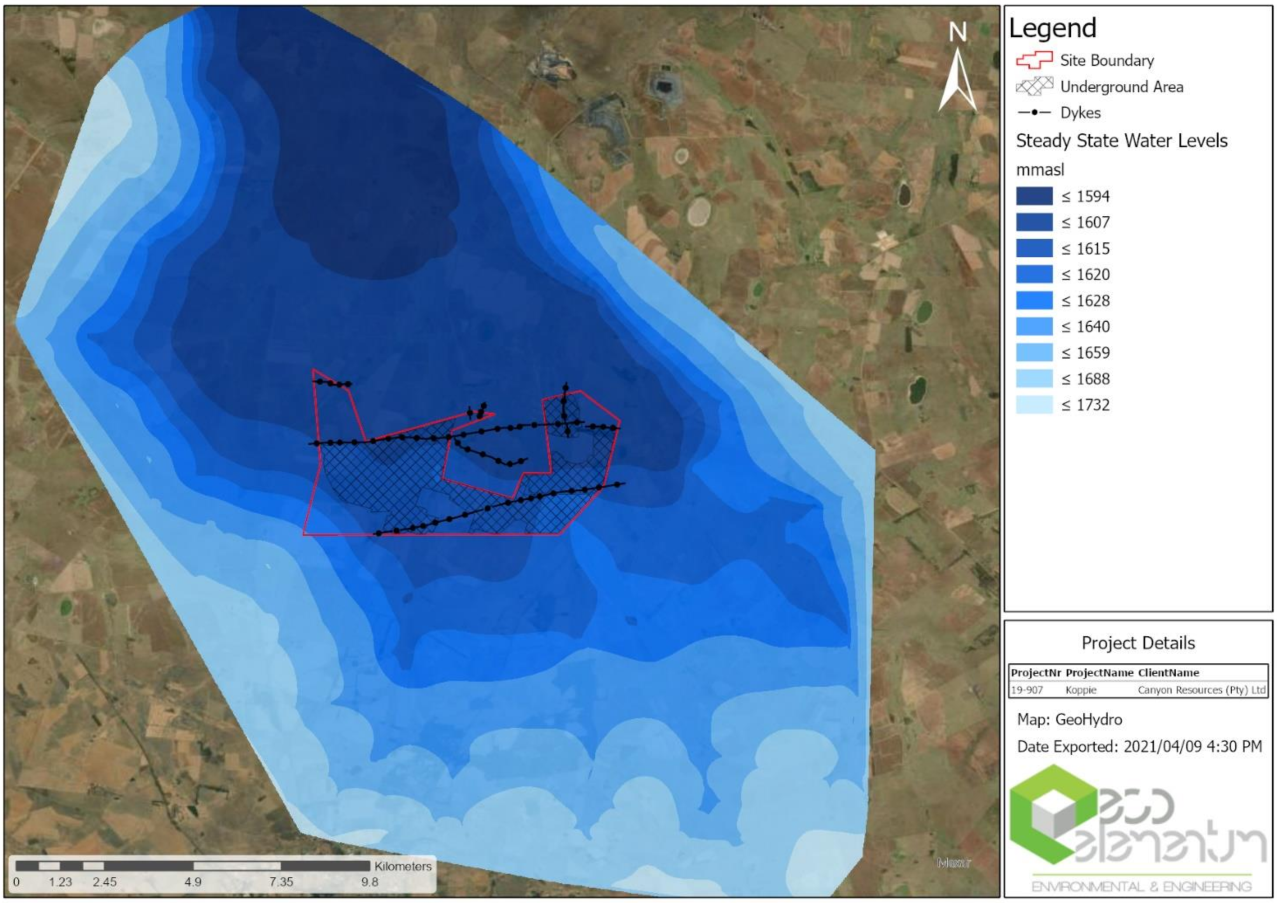


**Figure 16: Steady state water level elevation contours.**

## 7.4 Geometric Structure Of The Model

Table 17 in Section 7.2 summarises the geometric set-up of the model. The model grid simulates an area of just under 560 km² (21.6 km E and 25.8 km N). The grid cells are squares and rectangles that varies from 13 x 13 m in the proposed mining area to 40 x 40 m at the model boundaries.

Two layers were simulated in the model. Layer 1 represents the shallow, weather aquifer and was assigned a thickness of 20 m. The deep, secondary aquifer were simulated with Layer 2 with a thickness of 150 m.

## 7.5 Groundwater Sources And Sinks

Groundwater sources and sinks are features that either add (source) or remove (sink) water from the aquifer. During the steady state model calibration river nodes representing the streams can act as either a sink or a source. Drain nodes were used to represent less prominent streams, which are not perennial and therefore mostly act as a sink.

Recharge also acts as a source since it contributes to the water make in the model. A recharge of 1% were used for the Koppie model area.

During the transient model simulations, the underground mining operations will act as a groundwater sink, since groundwater flow will be towards the void due to dewatering and therefore remove water from the model.

## 7.6 Conceptual Model

A conceptual model involves the construction of a simplified version of the real world. All the geohydrological information gathered by different means, including during the hydrocensus, aquifer tests, chemical analysis etc., are used to construct this simplified model. The conceptual model forms the basis of the numerical model and aids in understanding the geohydrological characteristics of the model area.

The basis of the conceptual model can be summarised as follows:

- The Koppie is located in the Highveld region of Mpumalanga and in a summer rainfall region.
- The mean annual precipitation is ± 700 mm/annum, while the evaporation is estimated at 1 680 mm/annum.
- Drainage over the regional area and locally is towards the north.
- The Koppie area is underlain by sedimentary rocks from the Karoo Super group's Vryheid Formation.
- Geological structures such as dykes and faults are known to exist in the region of the Koppie. These structures and the weathered zone are possible pathways of elevated groundwater flow and contamination migration.
- On the basis of seam thickness and coal quality the S4L is the prime exploitation target within the No. 4 Seam Group.
- The 2 seam is often split into No. 2 Lower and No. 2 Upper Seam. The No. 2 Lower Seam ("S2L") generally is the thicker seam of the two sub-seams; it has better quality coal, and therefore will be the "theoretical" mining target.
- Two main aquifer systems are found in the Koppie region. Firstly, the shallow weathered aquifer and secondly, the deeper, secondary aquifer.
- Groundwater level information is available for the model area as they were recorded during the 2020 hydrocensus as well as from NGA boreholes (DWS). Only 4 water levels could be measured during the hydrocensus as the majority of the boreholes were equipped with pumps and no access to measure the water levels could be obtained. Groundwater levels varied between 5 and 17mbs in the boreholes recorded.
- The overall quality of the groundwater in the area is good to marginal.
- The nitrate concentration in six of the thirteen boreholes exceeded the permissible limits for drinking water. The nitrate concentrations in these six boreholes varied between 20 and 40 mg/l.
- The fluoride concentration in PU11 and the manganese concentration in PU13a also exceeded the permissible limits for drinking water.
- The ABA from the proposed Koppie mining area concluded that the analysed samples can be classified as intermediate to potentially acid generating.
- The waste classification indicated a Type 3 waste and therefore Class C liners are required in all areas where waste is placed.

- Groundwater Sources:
  - Recharge:
    - Natural recharge: in the region of the proposed project the natural recharge is estimated between 1 and 2% of the MAP. Rivers and drainage systems can also be seen as potential recharge sources. Gaining or losing streams play a role here. Losing streams "lose" their water to the aquifer, making it a natural recharge source. The streams in the immediate vicinity of the proposed project have not been identified as losing or gaining streams or even disconnected streams if they are not connected in any way to the groundwater regime.
    - Artificial recharge: Artificial recharge from the PCD may occur if the lining leaks.
  - Contamination Sources: At the proposed mining operation the potential contamination sources can include:
    - Wet sources: PCD's, Slurry dam and other unlined facilities or where the linings have failed. Water level mounding can be expected at these sources which may influence the groundwater flow gradients.
    - Dry sources: Overburden stockpiles, Discard dumps and ROM stockpiles. Dry sources are only active should water be introduced to the system by means of recharge or some other form where poor quality water seeps into the underlying aquifer. Water level mounding will not occur under dry source areas.
- Groundwater pathways:
  - Fault zones and dykes surrounding the proposed project area may be potential pathways for groundwater contamination migration. Geological structure information is available for the site and these structures are expected to play a role in the impact zone of the proposed mining operation.

- Groundwater receptors:
  - River Systems: any contamination from potential sources may be discharged in terms of baseflow into the receiving river systems in the area.
  - Potential groundwater users: In the area of the proposed mining operation's impact zone groundwater users exist. The impact zone may increase as pathways such as geological structures are present.
  - Underground void: once dewatering of the void commence, water will flow towards the void and therefore act as a groundwater receptor, even though an artificial receptor.

## 7.7 Numerical Model

The numerical groundwater model is used to represent both the flow and contamination/pollution migration of the groundwater regime. The numerical model consists of:

1. Groundwater Flow model; and
2. Mass Transport Model.

### 7.7.1 Groundwater Flow Model

After the steady state calibration have been obtained (Section 7.4), the model is set-up for transient state simulations. The boundaries, mesh size, layer type, top and bottom of the layers and aquifer transmissivity of the model remain as defined in the steady state model. The transient state model consists of several stress periods which represents different time frames of the mining activities. The groundwater flow and mass transport conditions remain the same during a stress period. Sources and sinks can change between stress periods but not within a stress period. The groundwater flow model for Koppie consist of 19 stress periods:

| Stress Period | Duration (Years) | Description |
|---|---|---|
| 1 - 19 | 1 Year | Simulates the proposed 2 seam and 4 seam underground bord-&-pillar mining over a period of 19 years. |

### 7.7.2 Mass Transport Model

The mass transport model is used to simulate contamination migration in the aquifer. The main contaminant and a major concern in the coal mining environment is sulphate. Sulphate contamination was simulated for the Koppie mass transport model. A worst-case source concentration of 3 000 mg/l was used for the underground areas. A general representative source concentration for coal mining activities were applied to the source areas. The following parameters were used for the mass transport model:

**Table 18: Parameters for the mass transport model.**

| Parameter | Value |
|---|---|
| Dispersion | 10 m |
| Diffusion | 0.00001 |
| Sulphate Source Concentration | 3 000 mg/l |
| Specific Yield | 0.08 |
| Storage Coefficient | 0.08 |
| Effective Porosity | 10% |

## 7.8 Results of the Model

### 7.8.1 Pre-facility

The pre-facility or steady state water level elevations were discussed in Section 7.3 of this document. These elevations represent the conditions prior to any impacts from the Koppie activities.

### 7.8.2 During Facility

The main purpose of this geohydrological investigation is to determine the impacts from the Koppie activities in terms of quality and quantity. The underground mining of the 2 and 4 seams are planned for the proposed mining project. The LOM is planned for a period of 19 years.

The following activities is planned to take place at the Koppie area and the activities that are expected to have an impact on the groundwater regime was also simulated in the model:

- Bord-&-pillar mining of the 4 and 2 seams.
- Access / haul roads
- Washing plant
- Workshops
- Offices
- Weighbridge
- Pollution Control Dams
- Slurry Dams
- Stormwater management facilities
- Boreholes
- Powerlines
- Substation
- Sewage management systems
- Conveyor belt systems
- Explosive magazine
- Shaft complex
- Lamp room
- Ventilation Shafts
- Discard Dump.

During the operational phase, dewatering of the secondary aquifer is required for the mining of the underground voids. The dewatering of the aquifer will also be the most significant impact on the groundwater levels in the vicinity of the mining void during the operational phase.

The estimated recharge to underground bord-&-pillar mining operations have been estimated by Hodgson in 1999 (Table 4). The mining depth for the proposed Koppie mining project varies between 59 and 133 mbs. The estimated recharge to the underground mining areas is expected to be in the region of 1.5% of the MAP. The bord-&-pillar mining method proposed for the Koppie mining area will not cause increases in the recharge to the mining voids unless cracking of rock strata above the mine or subsidence occur. This is however not expected with the proposed mining method, mining depth and extraction ratio. For this reason it is also not expected that the shallow aquifer above the proposed underground mining void areas will be greatly impacted on as a result of dewatering of the underground mining areas.

Due to the aquifer type and depth of mining the main contributor to mine water inflows during the operational phase will be recharge. The surface area of the mine blocks at the proposed Koppie mining area has been used as an estimate for recharge during the LOM (Table 19). The surface area was calculated by using the combined horizontal surface area of the 2 seam and 4 seam workings on a year-by-year basis as received in the LOM schedule and layout plan.

A sensitivity analysis for the expected recharge to the underground voids was conducted. Recharge rates of 1, 1.5 and 2% of the MAP were used to determine the mine water inflows during the operational phase. The recharge of 1.5% is expected to be the most probable rate for the specific underground mining areas.

**Table 19: Estimated daily and annual groundwater inflows for every year of mining.**

| Schedule | Area | Recharge / Groundwater Inflow (m³/day) | | | Recharge / Groundwater Inflow (m³/a) | | |
|---|---|---|---|---|---|---|---|
| | | Lowest 1% | Most Probable 1,5% | Highest 2% | Lowest 1 % | Most Probable 1,5% | Highest 2% |
| Development of Shaft | | 360 | | | [redacted] | | |
| Year 1 | 350 070 | 7 | 10 | 13 | 2 450 | 3 676 | 4 901 |
| Year 2 | 973 360 | 19 | 28 | 37 | 6 814 | 10 220 | 13 627 |
| Year 3 | 1 771 630 | 34 | 51 | 68 | 12 401 | 18 602 | 24 803 |
| Year 4 | 2 280 680 | 44 | 66 | 87 | 15 965 | 23 947 | 31 930 |
| Year 5 | 2 886 010 | 55 | 83 | 111 | 20 202 | 30 303 | 40 404 |
| Year 6 | 3 612 890 | 69 | 104 | 139 | 25 290 | 37 935 | 50 580 |
| Year 7 | 4 332 850 | 83 | 125 | 166 | 30 330 | 45 495 | 60 660 |
| Year 8 | 5 006 610 | 96 | 144 | 192 | 35 046 | 52 569 | 70 093 |
| Year 9 | 5 481 960 | 105 | 158 | 210 | 38 374 | 57 561 | 76 747 |
| Year 10 | 6 097 700 | 117 | 175 | 234 | 42 684 | 64 026 | 85 368 |
| Year 11 | 6 694 960 | 128 | 193 | 257 | 46 865 | 70 297 | 93 729 |
| Year 12 | 7 482 050 | 143 | 215 | 287 | 52 374 | 78 562 | 104 749 |
| Year 13 | 8 293 780 | 159 | 239 | 318 | 58 056 | 87 085 | 116 113 |
| Year 14 | 8 841 590 | 170 | 254 | 339 | 61 891 | 92 837 | 123 782 |
| Year 15 | 9 506 870 | 182 | 273 | 365 | 66 548 | 99 822 | 133 096 |
| Year 16 | 10 009 770 | 192 | 288 | 384 | 70 068 | 105 103 | 140 137 |
| Year 17 | 10 316 460 | 198 | 297 | 396 | 72 215 | 108 323 | 144 430 |
| Year 18 | 11 057 720 | 212 | 318 | 424 | 77 404 | 116 106 | 154 808 |
| Year 19 | 11 307 960 | 217 | 325 | 434 | 79 156 | 118 734 | 158 311 |

#### *7.8.2.1 Drawdown*

Drawdown during the operational phase will continue in the shallow aquifer at the decline shaft and in the secondary aquifer as mining progress.

The simulated drawdown cone as a result of the underground mining at the Koppie in the secondary aquifer is presented in

Figure **17**. Groundwater users that utilise the secondary aquifer as groundwater source and are located within the drawdown cone extent, may be impacted on in terms of water level decrease. The simulated drawdown cone as a result of the dewatering in the shaft area is presented in Figure 18. The extent and depth of impact on the water levels are presented in Table 20. It should be noted that the extent of drawdown impact may increase on the dykes and associated fracture zones running along these dykes. The drawdown on these dykes may increase the impact extent by up to 300m.

**Table 20: Drawdown impact on the shallow, weathered and secondary fractured aquifers.**

| Area | Drawdown Depth (mbs) | Drawdown Extent (m) |
|---|---|---|
| Shaft Area | 90 | 600 |
| Underground mining voids | 112 | In aquifer = 570m<br>On Dykes = 900m |

Potential users ( Figure 6) that may be affected by dewatering if abstracting from the:

1. Shallow aquifer: PU7, PU8, PU11, PU10a, PU10b, PU10c, PU13, PU16 and PU17,
2. Deep Aquifer: PU2, PU7, PU8, PU11, PU10a, PU10b, PU10c, PU13, PU14 and PU17.

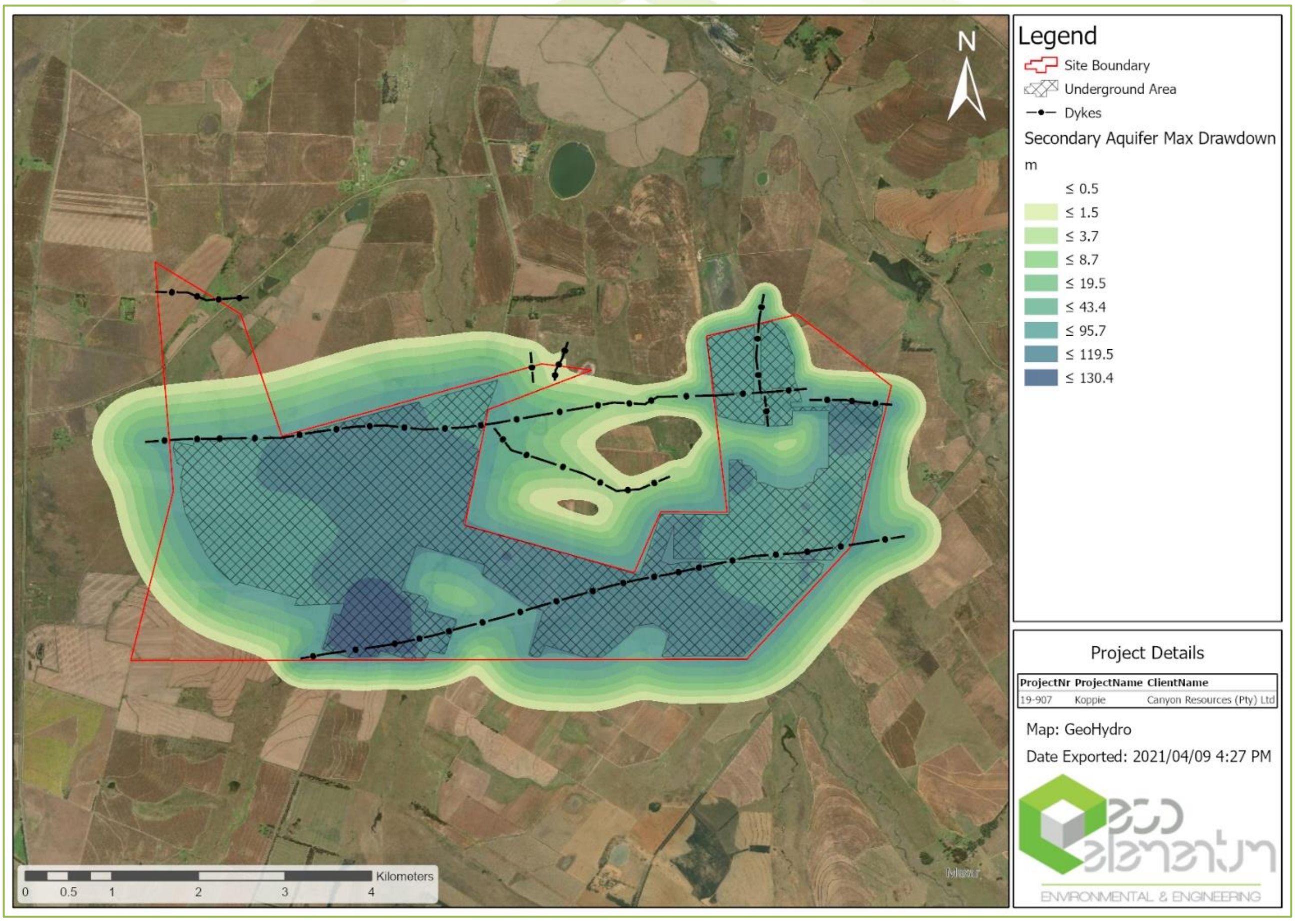


**Figure 17: Deep, secondary aquifer- Simulated maximum drawdown in the underground voids at the proposed Koppie mining area.**

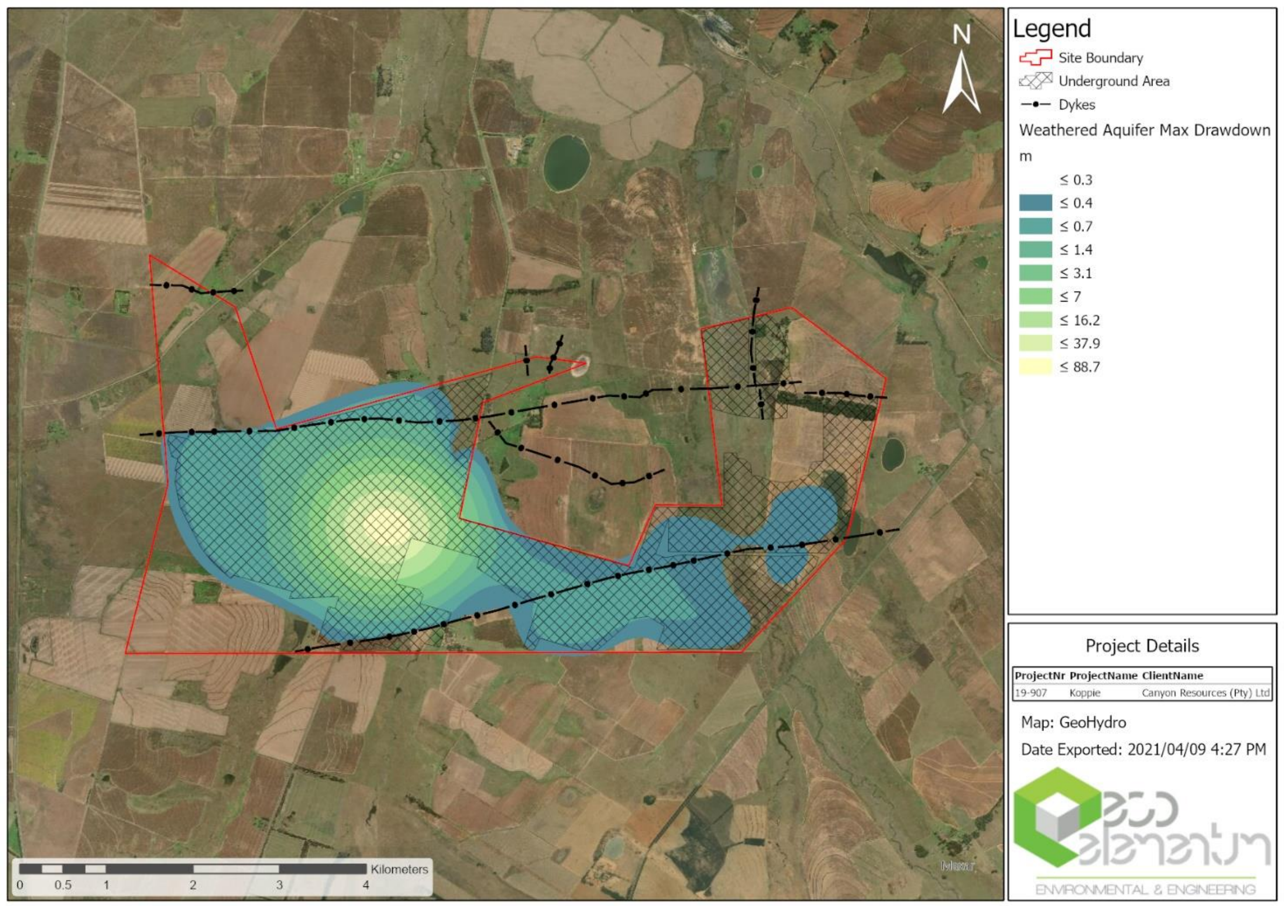


**Figure 18: Shallow, weathered aquifer- Simulated maximum drawdown in the shaft area of the proposed Koppie mining area.**

#### 7.8.2.2 Mass Transport during Facility

##### 7.8.2.2.1 Underground Mining Operation

During the operational phase and for a period after, until the water level has reached equilibrium, a contamination plume will not migrate away from the mining operation. This is due to the fact that the underground void act as a groundwater sink. Contaminated groundwater, as a result of acid mine drainage will be contained within the underground void area. The mass transport simulations at the end of the proposed mining operations for the proposed Koppie activities as are presented in Figure 19.

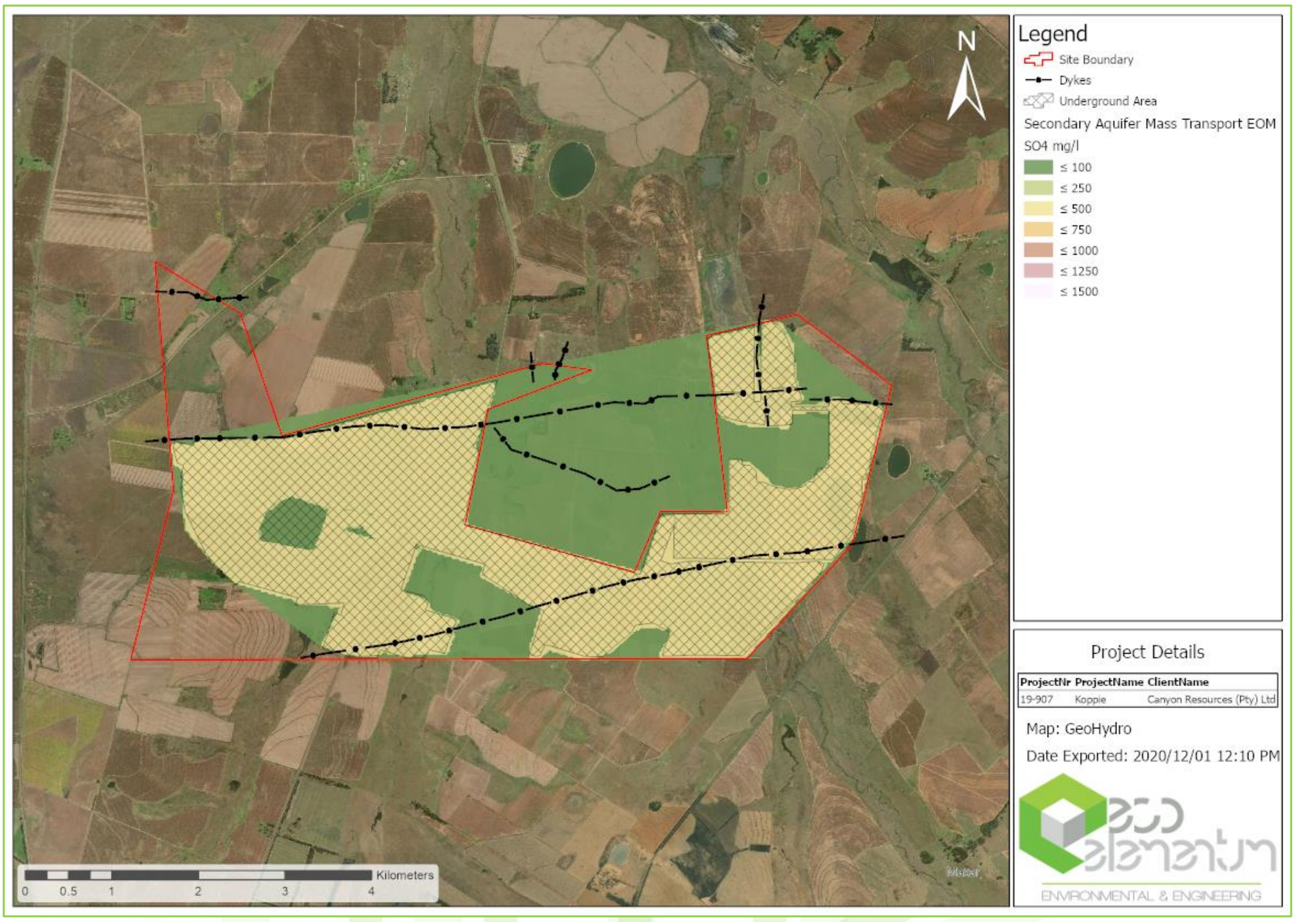


**Figure 19: Secondary Aquifer Mass Transport EOM.**

From the figure it is clear that the pollution plumes from the underground voids have not yet started to migrate away from the underground void areas. The concentrations in the underground voids may be up to 430 mg/l at the end of mining.

Potential users ( Figure 6) that may be affected by secondary aquifer contamination if abstracting from the secondary aquifer:

- PU2, PU7, PU10a, PU10b, PU10c, PU13, PU14 and PU16.

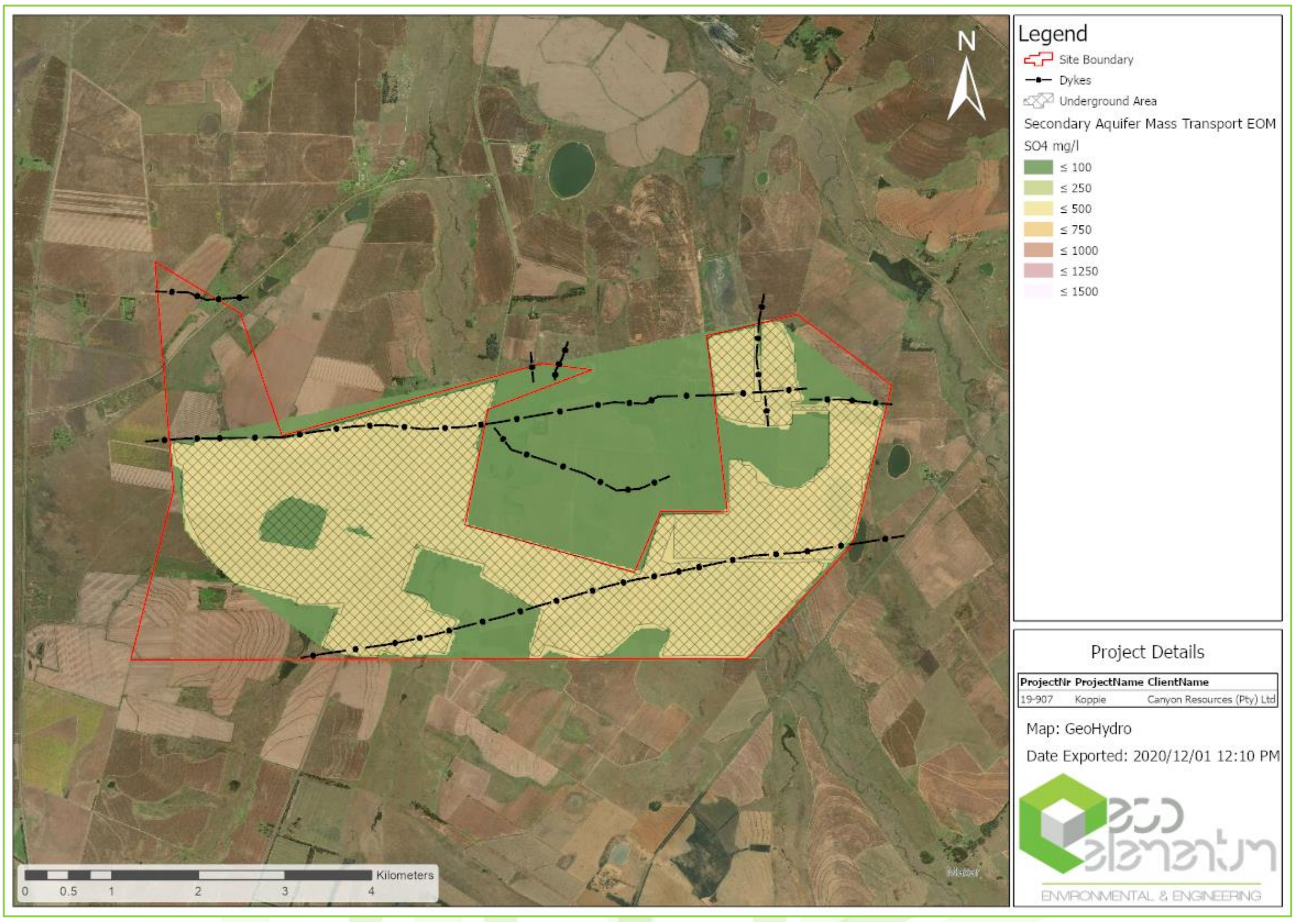


**Figure 20: The simulated mass transport at the end of the operational phase in the secondary aquifer at the Koppie area.**

#### *7.8.2.2.2 Preferred Option-Surface Infrastructure*

The mass transport at the end of mining for Preferred Option is presented in Figure 22. The maximum sulphate concentration from the surface infrastructure at the end of the operational phase is not expected to exceed 900 mg/l. The plume is expected to migrate further along the dyke to the east of the northern PCD as a result of the fracture zone adjacent to the dyke. The depression cone as a result of the dewatering at the shaft area is not expected to impact the plume migration of Preferred Option. The contamination plumes from the Preferred Option surface sources are expected to migrate in a north-easterly direction. The maximum extent of the pollution plume at the end of the operational phase is not expected to exceed 250 m.

No users are expected to be impacted on by the end of the mining in terms of quality.

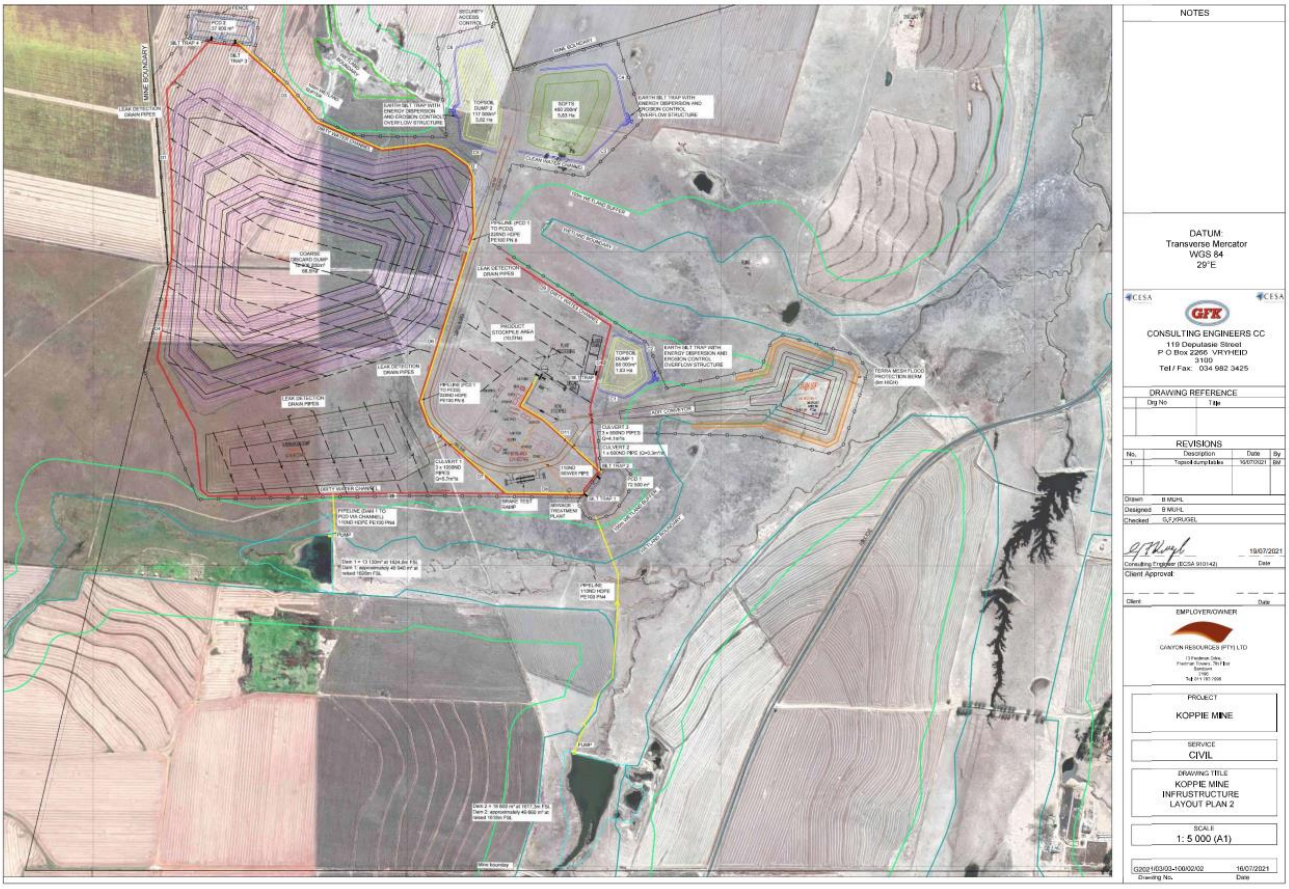


**Figure 21: Surface Infrastructure Layout for Preferred Option.**

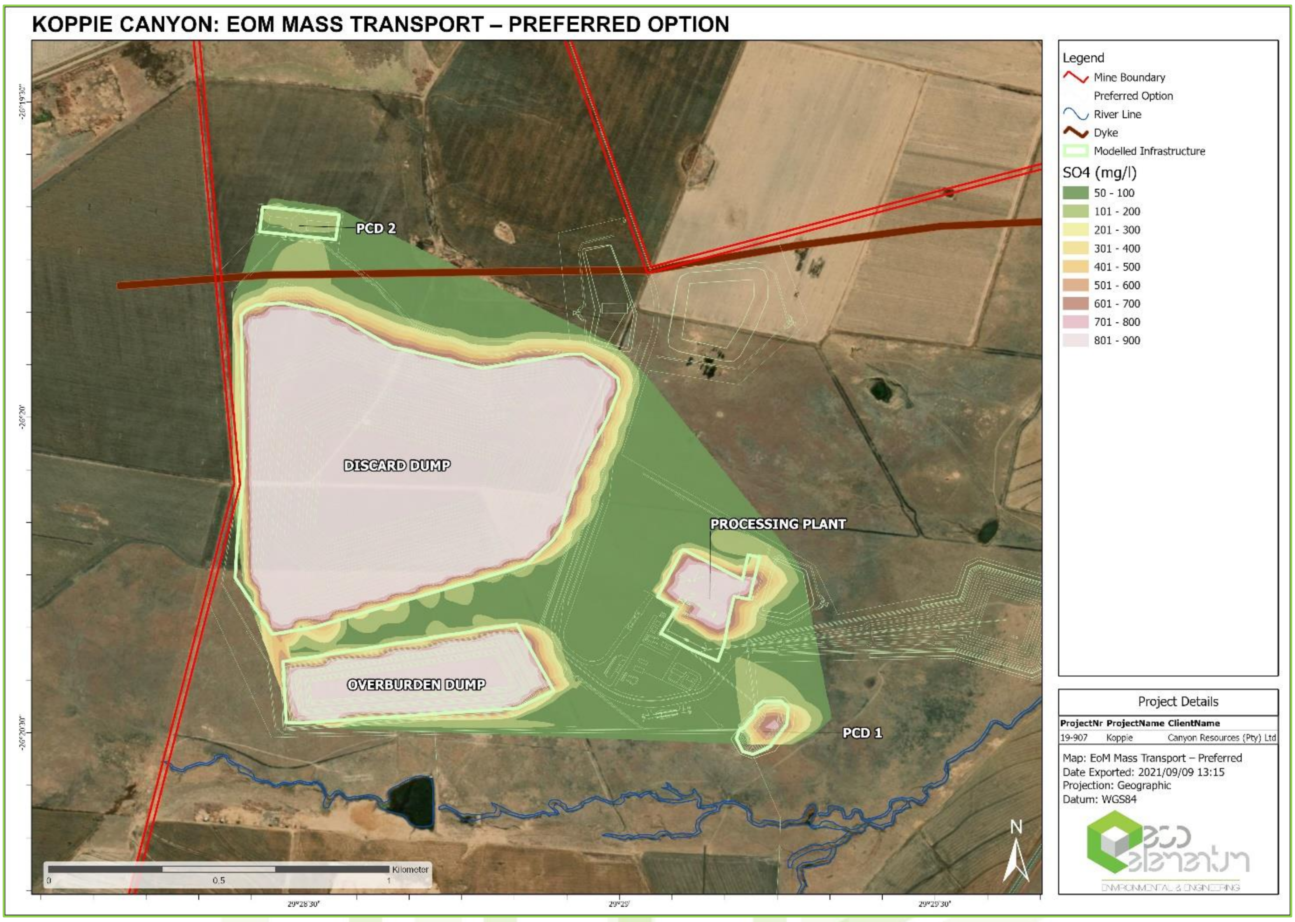


**Figure 22: Preferred Option- The Simulated mass transport at the end of the operational phase in the weathered aquifer.**

##### *7.8.2.2.3 Alternative Option-Surface Infrastructure*

Two alternatives are proposed for the surface infrastructure which include discard dump, PCD and a plant area. The mass transport at the end of mining for Alternative Option is presented in **Error! Reference source not found.**. The maximum sulphate c oncentration from the surface infrastructure at the end of the operational phase is not expected to exceed 900 mg/l. The shaft area acts as a groundwater sink and groundwater flow will be towards the shaft area in some areas. As is visible in **Error! Reference s ource not found.**, the plume migration is constrained by the shaft. The plume is however expected to migrate further along the dyke north of the discard dump area as a result of the fracture zone adjacent to the dyke. The maximum extent of the pollution plume at the end of the operational phase is not expected to exceed 210m.

Potential users (Figure 6) that may be affected by quality impacts:

- PU7.

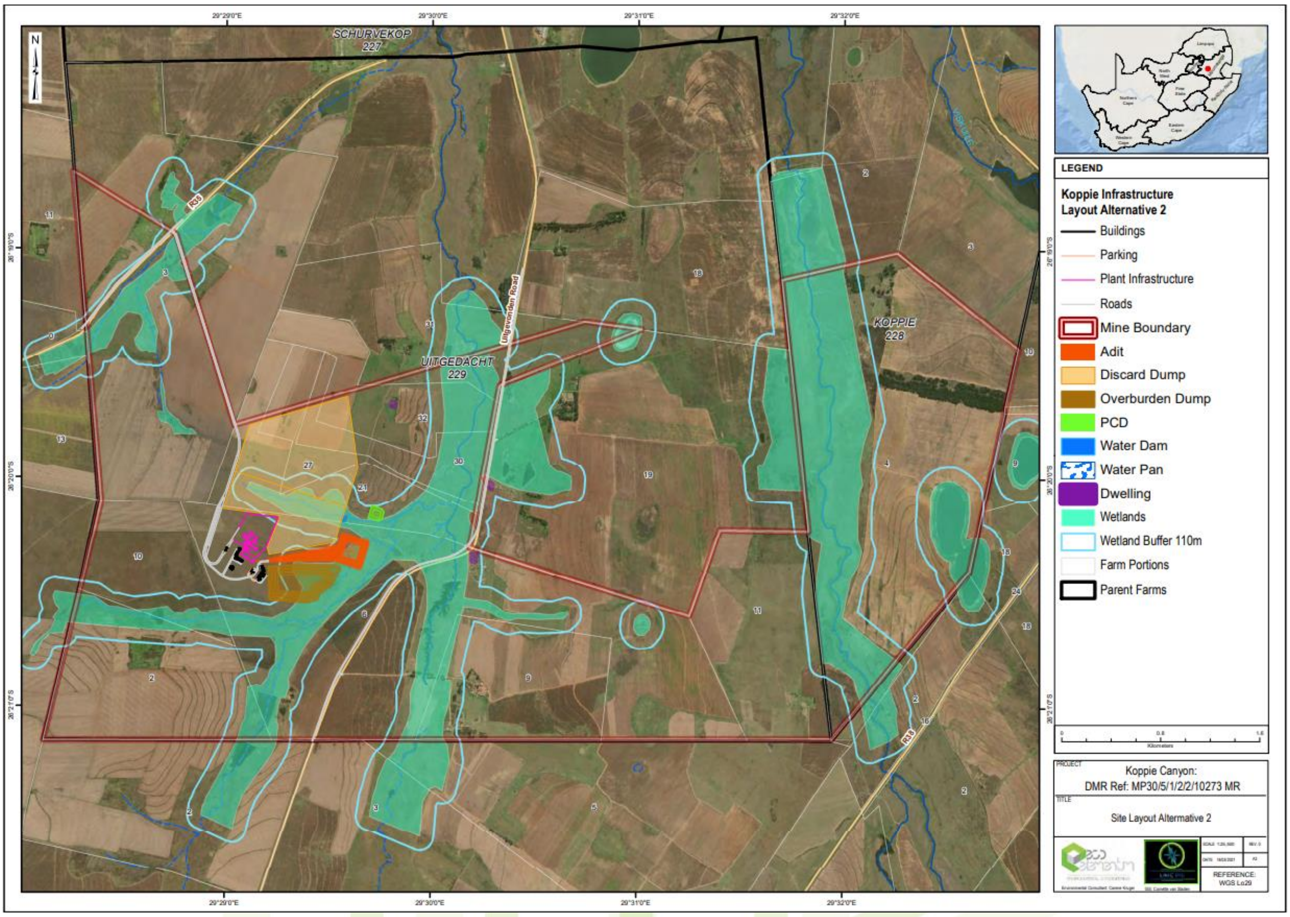


Figure 23: Alternative Option Infrastructure Layout.

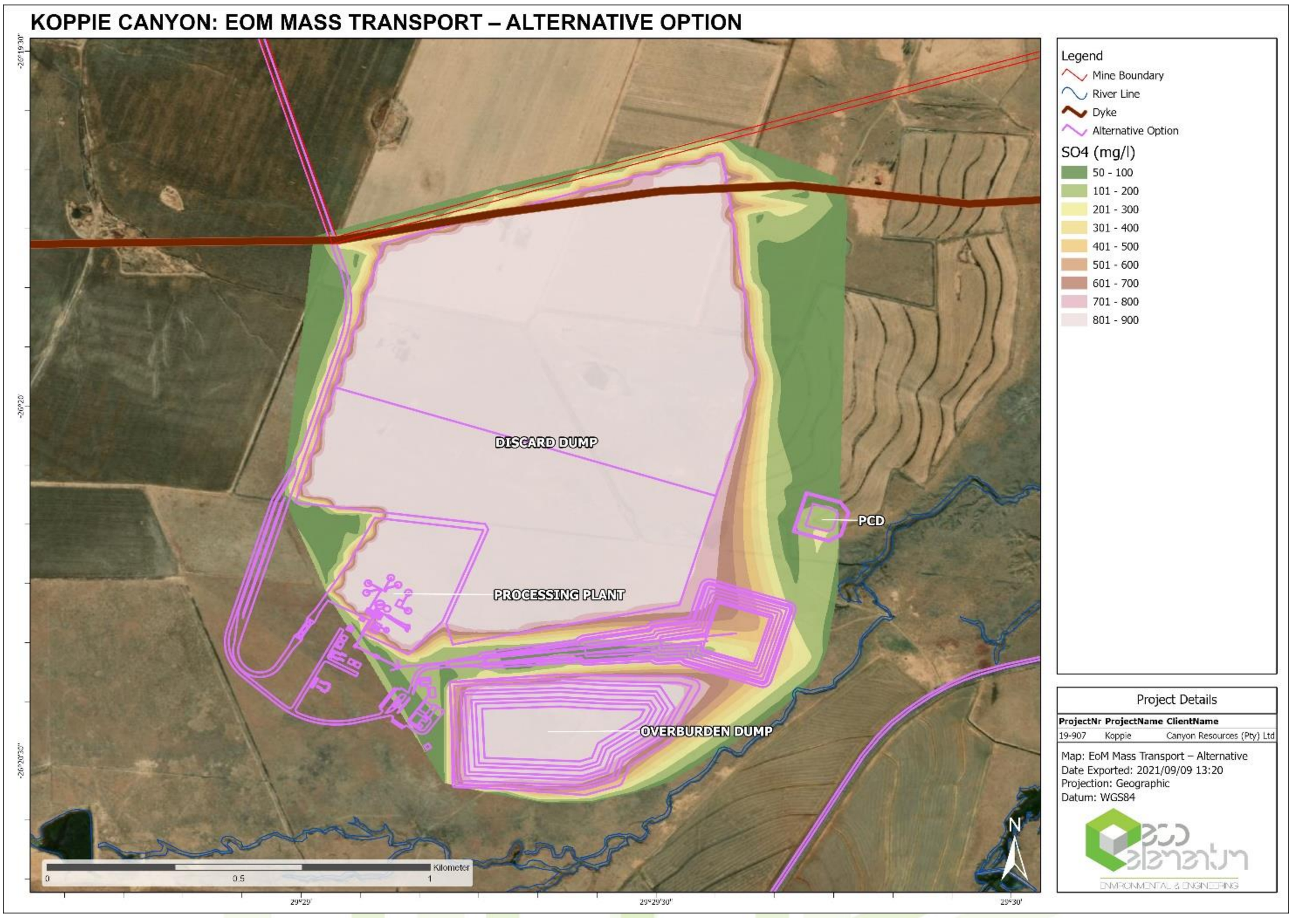


**Figure 24: Alternative Option- The Simulated mass transport at the end of the operational phase in the weathered aquifer.**

### 7.8.3 Post-Facility

For the post-facility model simulations, the model was run an additional 50 years for the two alternatives for surface infrastructure and 100 years for the underground voids for both the flow and mass transport models. The mass transport contours for the underground mining voids are represented in

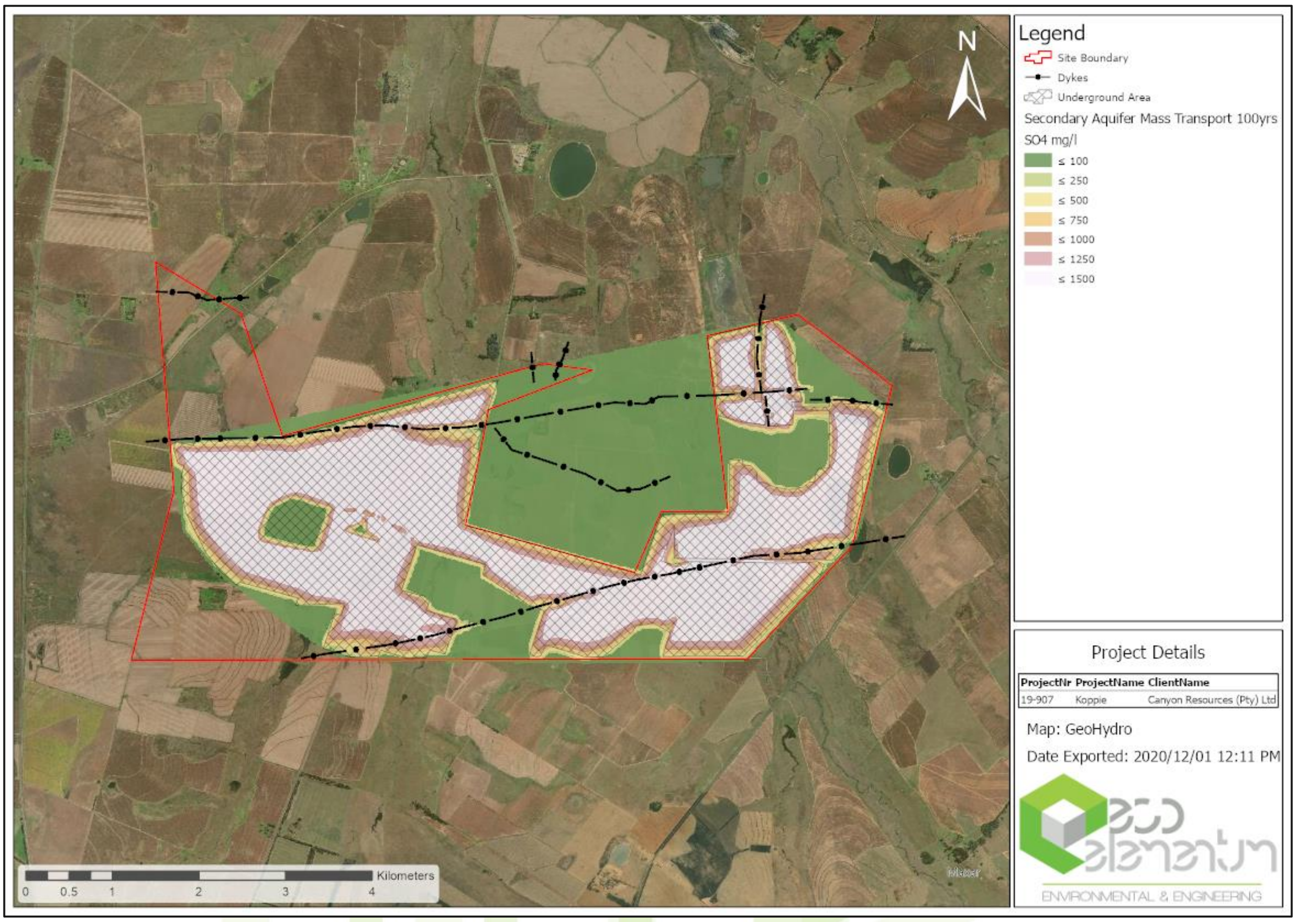


Figure 26 for the proposed Koppie voids. The mass transport contours for the potential surface sources are presented in Figure 27 (Preferred Option) and Figure 28 (Alternative Option).

The most common effects of a coal mining operation post-facility are:

- Decanting of the underground voids into the shallow aquifer and on surface.
- Acid generation and therefore decrease in groundwater qualities in the voids.
- Down gradient movement of a contamination plume in the secondary deep aquifer.

Decant at the proposed Koppie mining area may be expected in the case where subsidence of the roof strata above the underground mining area occur. In the case of subsidence, the recharge to the underground void will be significantly higher due to natural recharge as well as the shallow aquifer dewatering into the underground void. The downgradient aquifer will therefore not be able the accommodate the elevated recharge which finally results in decant on surface through crack and fractures caused by subsidence. It is highly recommended that mining is conducted in such a manner as to minimise or prevent subsidence.

The estimated decant of the mining has been estimated in the case where the mining is conducted in a manner that fracturing and cracking occur. Estimated filling times to decant elevation of the mining underground voids at Koppie are presented in Table 21. The estimated filling times of the underground void areas is 133 years. Decant, if any, is expected to be up to 434 m$^3$/day. The theoretical decant point is presented in Figure 25 but may be at any area where the underground void is connected to the surface. The connection may also be an unsealed borehole drilled into the underground or even a ventilation shaft.

**Table 21: Estimated decant rates and fill times of the proposed Koppie underground voids.**

| | Seam 4 | Seam 2 |
|---|---|---|
| Annual Rainfall (m) | 0,7 | |
| Average Seam Thickness | 1,86 | 2,84 |

| | | |
|---|---|---|
| Mined area for each seam (m2) | 7301250 | 8463770 |
| Total void Volume for each seam (m3) | 13580325 | 24037107 |
| Combined Mined Area (m2) | 11307960 | |
| Combined Mined Volume (m2) | 37617432 | |
| **Recharge rate to underground areas (m3/annum)** | | |
| Low recharge 1% | 118734 | |
| **Most Probable recharge 1,5%** | **158311** | |
| High recharge 2% | 237467 | |
| **Voids (m3):** | | |
| **54% Extraction Ratio** | 20313413 | |
| **56% Extraction Ratio** | 21065762 | |
| **58% Extraction Ratio** | 21818110 | |
| **Average Time to Fill (Years):** | **133** | |
| **Average Decant Rate (m3/day)** | **434** | |

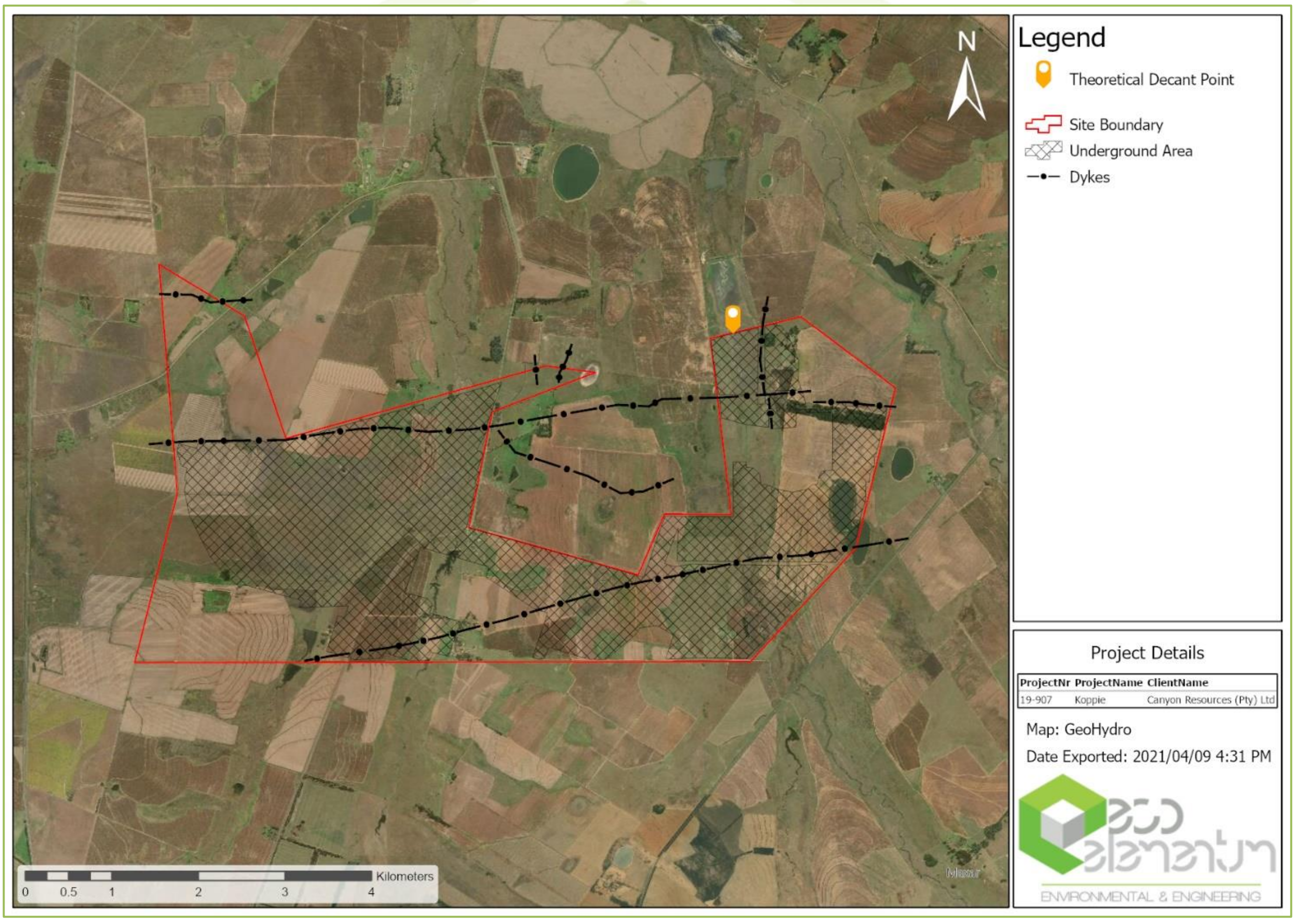


**Figure 25: The theoretical decant point position of the proposed Koppie mining area.**

### *7.8.3.1 Underground- 100 years post-closure*

The simulated groundwater contamination plumes at 100 years post-facility presented in

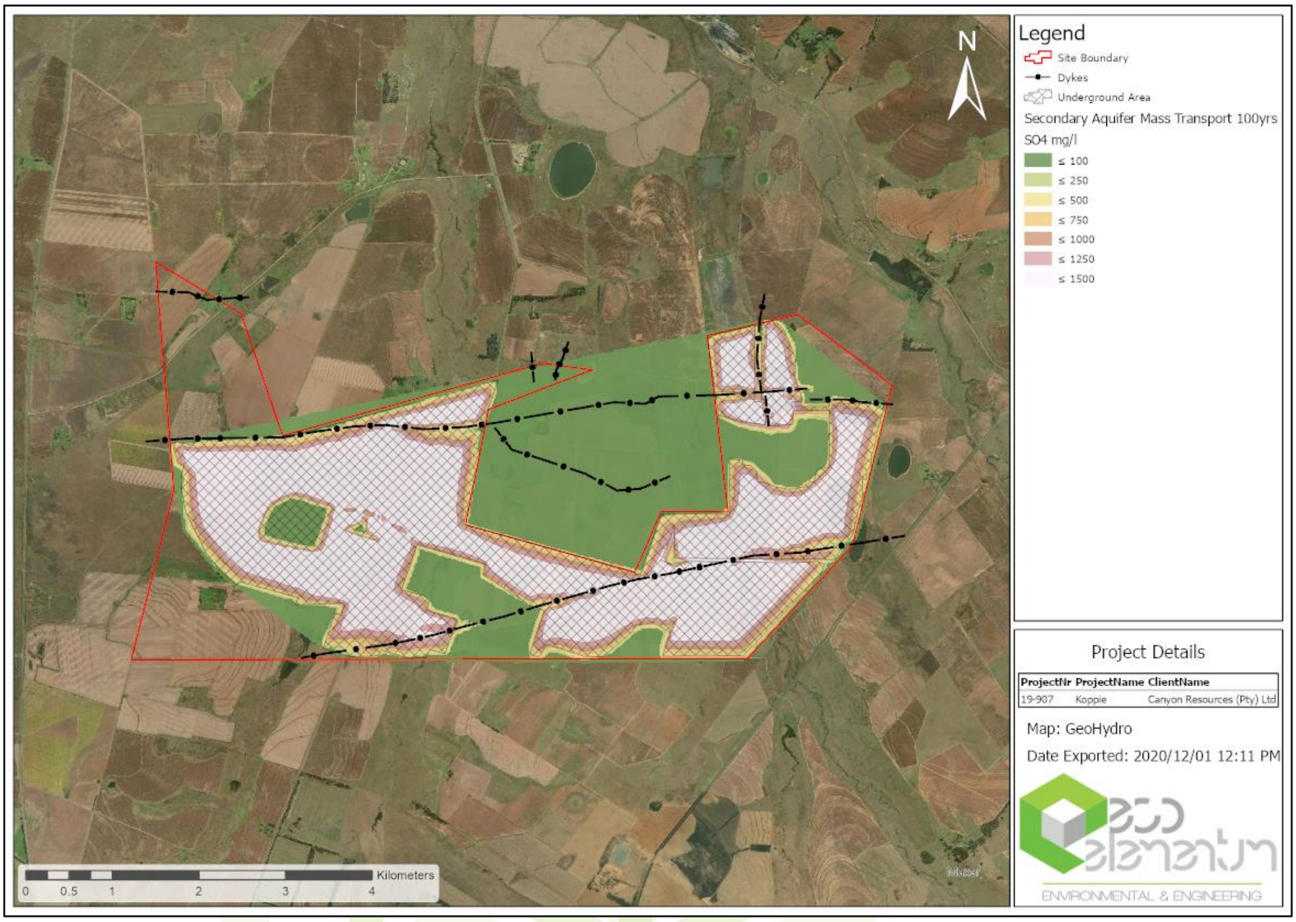


Figure 26 indicates that the plume will start to migrate down gradient from the underground void areas. The sulphate concentrations in the underground void areas are expected to increase as a result of acid generation. The sulphate concentration is expected to increase to almost 1 500 mg/l. The pollution plume extent is expected to be limited at 100 years post-closure since the water level recovery is expected to take more than a century and the voids is some areas still act as groundwater a sink. However, where the water levels have recovered a plume may start to migrate away from the mining area and even further along the dyke areas due to higher transmissivity along these features. The pollution plume is not expected to extent more than 300m from the void areas at 100 years post-closure.

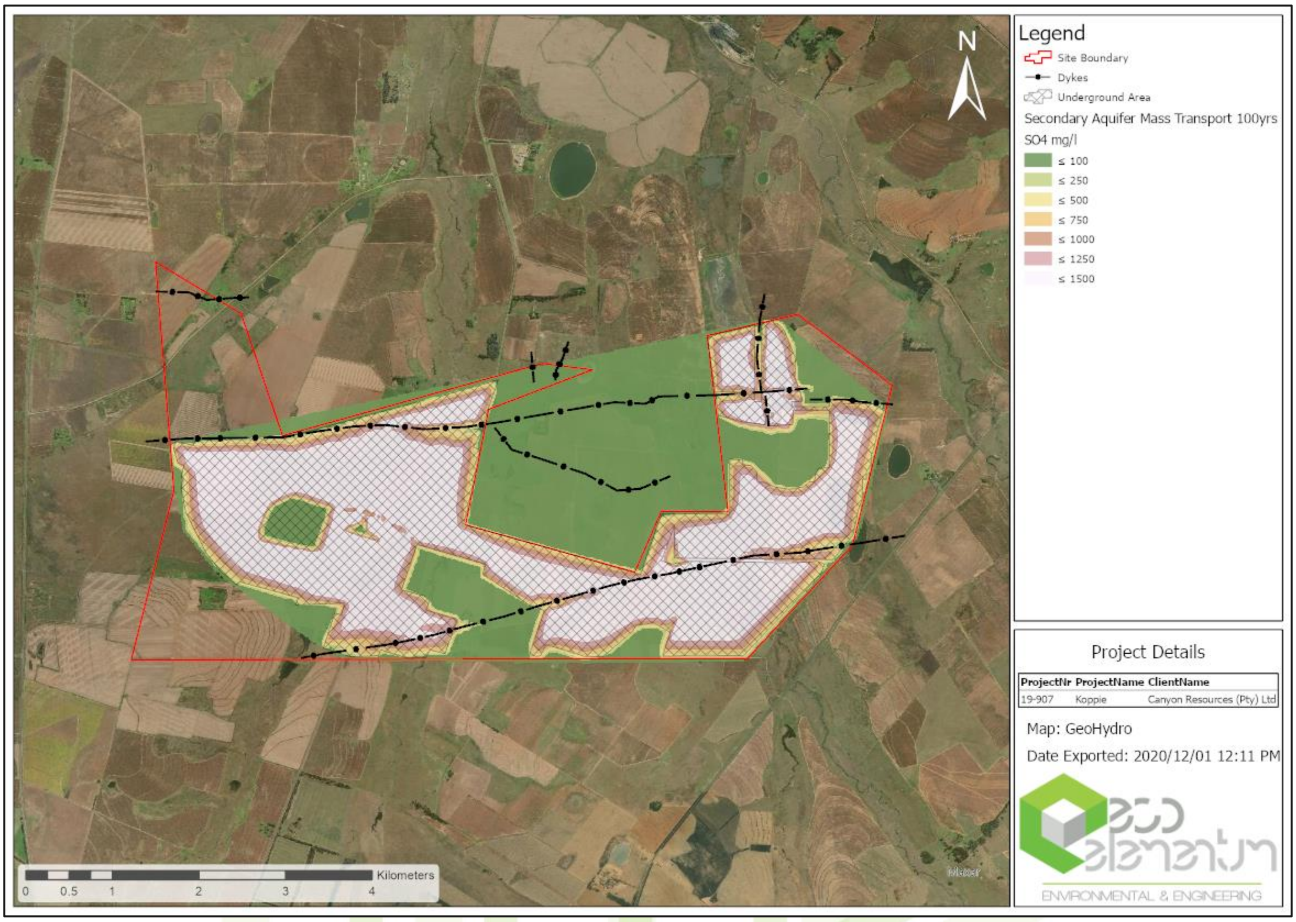


**Figure 26: Model Simulated groundwater contamination plume 100 years post facility for the proposed Koppie underground voids.**

#### *7.8.3.1.1 Preferred Option-Surface Infrastructure*

The mass transport at the 50 years post-mining for Preferred Option is presented in **Error! Reference source not found.**. Once again, t he potential source areas will be removed as part of the decommissioning phase and the groundwater quality at these areas are expected to improve. The maximum sulphate concentration from the surface infrastructure 50 years post-closure is not expected to be less than 600 mg/l. The sulphate concentration in the shaft area may increase over the 50 years period as a result of AMD. The plume is expected to migrate further along the dyke to the north as a result of the fracture zone adjacent to the dyke. The maximum extent of the pollution plume at 50 years post-closure is not expected to exceed 430 m. No users are expected to be impacted on in terms of quality 50 years post-closure.

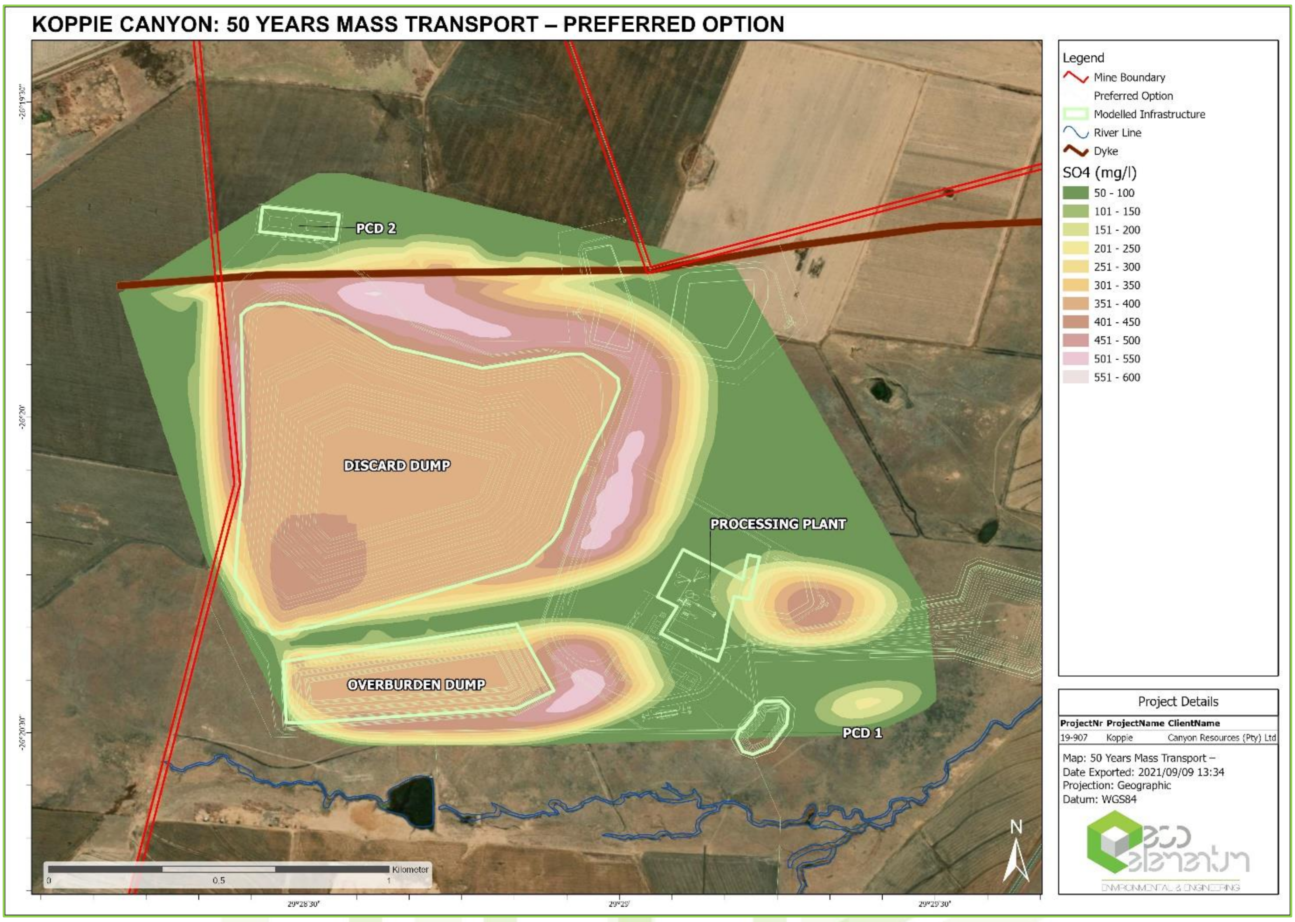


**Figure 27: Preferred Option- The Simulated mass transport at 50 years post-closure in the weathered aquifer.**

#### *7.8.3.1.2 Alternative Option-Surface Infrastructure*

The mass transport at the 50 years post-mining for Alternative Option is presented in **Error! Reference source not found.**. The p otential source areas will be removed as part of the decommissioning phase and the groundwater quality at these areas are expected to improve. The maximum sulphate concentration from the surface infrastructure 50 years post-closure is not expected to be less than 500 mg/l. The sulphate concentration in the shaft area may increase over the 50 years period as a result of AMD. The plume is expected to migrate further along the dykes as a result of the fracture zone adjacent to the dykes. The maximum extent of the pollution plume at 50 years post-closure is not expected to exceed 550 m. Potential users (Figure 6) that may be affected by quality impacts:

- PU7 & PU16.

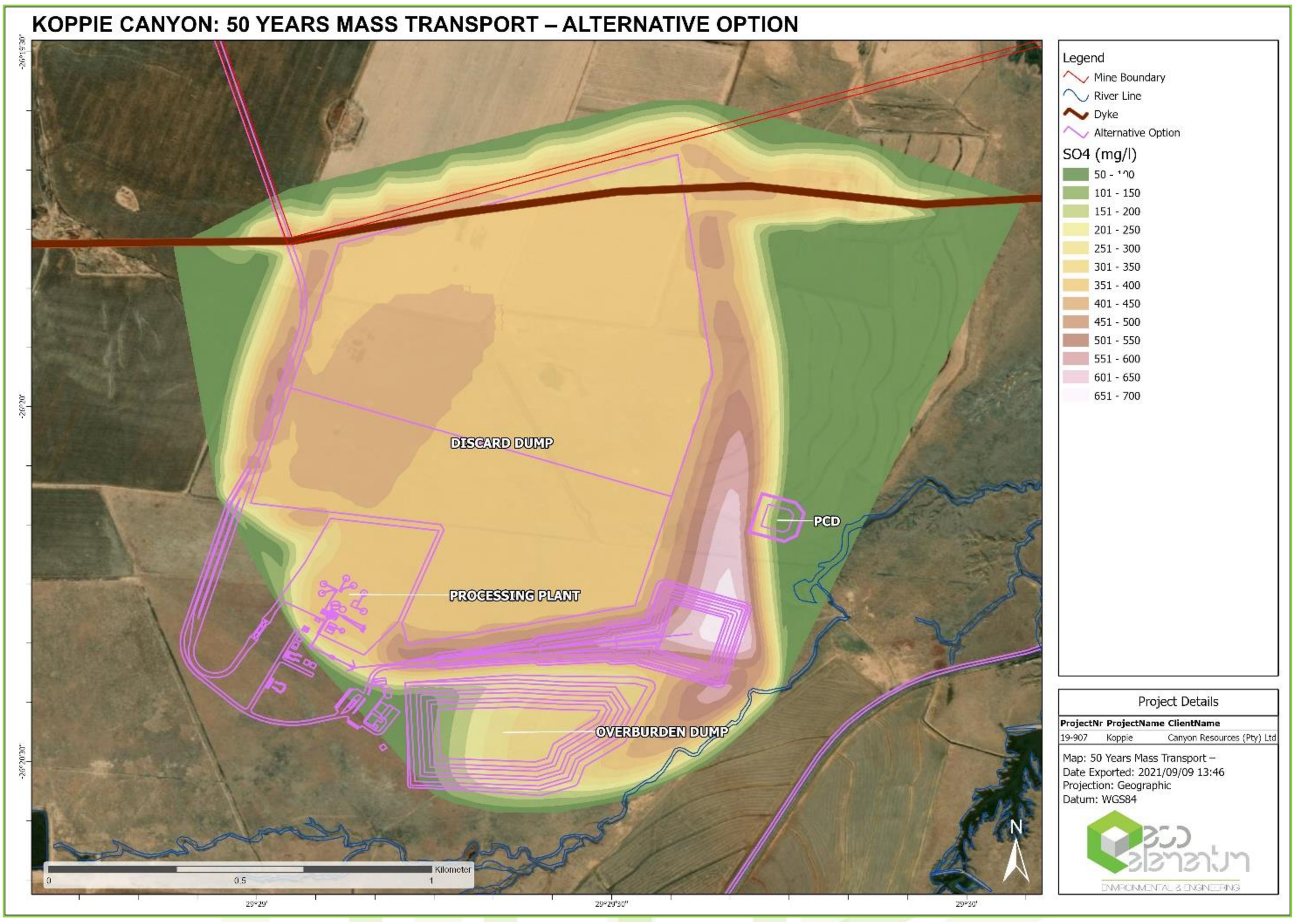


**Figure 28: Alternative Option- The Simulated mass transport at the 50 years post-closure in the weathered aquifer.**

**Table 22: Numerical model results of the potential sulphate pollution plume from the proposed mining underground voids at Koppie.**

| Area | Maximum simulated Sulphate Concentration (mg/l) | Maximum simulated plume extent from boundary (m) | Potential plume migration direction from the source area |
|---|---|---|---|
| Alternative Option – Surface infrastructure | 900 mg/l (at end of mining) | 210m at mine closure,<br>550m 50 years post-closure. | East from discard dump and plant area, south from overburden stockpile. |
| Preferred Option infrastructure | 900 mg/l (at end of mining) | 250 m at mine closure,<br>430m 50 years post-closure. | West and east from discard dump, East from plant, south from Overburden Stockpile. |
| Underground voids | 1 500 mg/l (100 years post-closure) | 300m | Only along the dykes. The plume at 100 years post-closure is not expected to exceed beyond the mine boundary since the water level in the voids has not yet recovered at this time. In the region where the water level has recovered, plume migration will be towards the north-east. |

# 8. POTENTIAL GEOHYDROLOGICAL IMPACTS

The following methodology was used to rank these impacts. Clearly defined rating and rankings scales (**Table 23**) were used to assess the impacts associated with the proposed activities. The impacts identified by each specialist study and through public participation were combined into a single impact rating table for ease of assessment.

Each impact identified was rated according the expected magnitude, duration, scale and probability of the impact.

To ensure uniformity, the assessment of potential impacts will be addressed in a standard manner so that a wide range of impacts is comparable. For this reason, a clearly defined rating scale will be provided to the specialist to assess the impacts associated with their investigation.

Table 23: Potential Impacts rating and rankings scales

| **Intensity (Magnitude)** | | **ASSIGNED QUANTITATIVE SCORE** |
|---|---|---|
| **The intensity of the impact is considered by examining whether the impact is destructive or benign, whether it has a significant, moderate or insignificant** | | |
| **(L)OW** | The impact alters the affected environment in such a way that the natural processes or functions are not affected. | **1** |
| **(M)EDIUM** | The affected environment is altered, but functions and processes continue, albeit in a modified way. | **3** |
| **(H)IGH** | Function or process of the affected environment is disturbed to the extent where it temporarily or permanently ceases. | **5** |
| **Duration** | | |
| **The lifetime of the impact, that is measure in relation to the lifetime of the proposed development.** | | |
| **(S)HORT TERM** | The impact will either disappear with mitigation or will be mitigated through a natural process in a period shorter than that of the construction phase. | **1** |
| **(SM) SHORT - MEDIUM TERM** | The impact will be relevant through to the end of a construction phase. | **2** |
| **(M)MEDIUM** | The impact will last up to the end of the development phases, where after it will be entirely negated. | **3** |
| **(L)ONG TERM** | The impact will continue or last for the entire operational lifetime (i.e. exceed 20years) of the development, but will be mitigated by direct human action or by natural processes thereafter. | **4** |
| **(P)ERMANENT** | This is the only class of impact, which will be non-transitory. Mitigation either by man or natural process will not occur in such a way or in such a time span that the impact is transient. | **2** |
| **Spatial Scale/Extent** | | |
| **Classification of the physical and spatial aspect of the impact** | | |
| **(F)OOTPRINT** | The impacted area extends only as far as the activity, such as footprint occurring within the total site area. | **1** |
| **(S)ITE** | The impact could affect the whole, or a significant portion of the site. | **2** |
| **(R)EGIONAL** | The impact could affect the area including the neighbouring Farms, the transport routes and the adjoining towns. | **3** |
| **(N)ATIONAL** | The impact could have an effect that expands throughout the country (South Africa). | **4** |
| **(I)NTERNATIONAL** | Where the impact has international ramifications that extend beyond the boundaries of South Africa. | **5** |
| **Probability** | | |
| **This describes the likelihood of the impact actually occurring. The impact may occur for any length of time during the life cycle of the activity. The classes are rated as follows:** | | |

| | | |
|---|---|---|
| **(I)MPROBABLE** | The possibility of the Impact occurring is none, due to the circumstances or design. The chance of this Impact occurring is zero (0%) | **1** |
| **(P)OSSIBLE** | The possibility of the Impact occurring is very low, due either to the circumstances or design. The chance of this Impact occurring is defined as 25% or less | **2** |
| **(L)IKELY** | There is a possibility that the impact will occur to the extent that provisions must therefore be made. The chances of Impact occurring is defined as 50% | **3** |
| **(H)IGHLY LIKELY** | It is most likely that the Impacts will occur at some stage of the development. Plans must be drawn up before carrying out the activity. The chances of this impact occurring is defined as 75 %. | **4** |
| **(D)EFINITE** | The impact will take place regardless of any prevention plans, and only mitigation actions or contingency plans to contain the effect can be relied on. The chance of this impact occurring is defined as 100 %. | **5** |
| **Weighting Factor** | | |
| **Subjective score assigned by Impact Assessor to give the relative importance of a particular environmental component based on project knowledge and previous experience. Simply, such a weighting factor is indicative of the importance of the impact in terms of the potential effect that it could have on the surrounding environment. Therefore, the aspects considered to have a relatively high value will score a relatively higher weighting than that which is of lower importance** | | |
| **(L)OW** | | **1** |
| **LOW- MEDIUM** | | **2** |
| **MEDIUM (M)** | | **3** |
| **MEDIUM-HIGH** | | 4 |
| **HIGH (H)** | | 5 |
| **Mitigation Measures and Mitigation Efficiency** | | |
| **Determination of significance refers to the foreseeable significance of the impact after the successful implementation of the necessary mitigation measures** | | |
| Mitigation measures were recommended to enhance benefits and minimise negative impacts and address the following:<br>Mitigation objectives: what level of mitigation must be aimed at: For each identified impact, the specialist must provide mitigation objectives (tolerance limits) which would result in measurable reduction in impact. Where limited knowledge or expertise exists on such tolerance limits, the specialist must make "educated guesses" based on professional experience;<br>Recommended mitigation measures: For each impact the specialist must recommend practicable mitigation actions that can measurably affect the significance rating. The specialist must also identify management actions, which could enhance the condition of the environment. Where no mitigation is considered feasible, this must be stated and reasons provided;<br>Effectiveness of mitigation measures: The specialist must provide quantifiable standards (performance criteria) for reviewing or tracking the effectiveness of the proposed mitigation actions, where possible; and<br>Recommended monitoring and evaluation programme: The specialist is required to recommend an appropriate monitoring and review programme, which can track the efficacy of the mitigation objectives. Each environmental impact is to be assessed before and after mitigation measures have been implemented.<br>The management objectives, design standards, etc., which, if achieved, can eliminate, minimise or enhance potential impacts or benefits. National standards or criteria are examples, which can be stated as mitigation objectives. | | |
| **HIGH** | The impact is of major importance. Mitigation of the impact is not possible on a cost-effective basis. The impact is regarded as high importance and taken within the overall context of the project, is regarded as a fatal flaw. An impact regarded as high significance, after mitigation could render the entire development option or entire project proposal unacceptable. | **1,00** |
| **MEDIUM-HIGH** | The impact is of major importance but through the implementation of the correct mitigation measures, the negative impacts will be reduced to acceptable levels | **0,80** |
| **MEDIUM** | Notwithstanding the successful implementation of the mitigation measures, to reduce the negative impacts to acceptable levels, the negative impact will remain of significance. However, taken within the overall context of the project, the persistent impact does not constitute a fatal flaw | **0,60** |
| **LOW -MEDIUM** | The impact is of importance, however, through the implementation of the correct mitigation measures such potential impacts can be reduced to acceptable levels | **0,40** |
| **LOW** | The impact will be mitigated to the point where it is of limited importance | **0,20** |

| Extent | Duration | Intensity | Probability | Weighting Factor (WF) | Significance Rating (SR) | Mitigation Efficiency (ME) | Significance Following Mitigation (SFM) |
|---|---|---|---|---|---|---|---|
| Footprint 1 | Short term 1 | Low 1 | Probable 1 | Low 1 | Low 0-19 | High 0,2 | Low 0-19 |
| Site 2 | Short to medium 2 | | Possible 2 | Low to medium 2 | Low to medium 20-39 | Medium to high 0,4 | Low to medium 20-39 |
| Regional 3 | Medium term 3 | Medium 3 | Likely 3 | Medium 3 | Medium 40-59 | Medium 0,6 | Medium 40-59 |
| National 4 | Long term 4 | | Highly Likely 4 | Medium to high 4 | Medium to high 60-79 | Low to medium 0,8 | Medium to high 60-79 |
| International 5 | Permanent 5 | High 5 | Definite 5 | High 5 | High 80-100 | Low 1,0 | High 80-100 |

The following activities form part of the proposed Koppie operations:

- Access / haul roads
- Washing plant
- Workshops
- Offices
- Weighbridge
- Pollution Control Dams
- Slurry Dams
- Stormwater management facilities
- Boreholes
- Powerlines
- Substation
- Sewage management systems
- Conveyor belt systems
- Explosive magazine
- Shaft complex
- Lamp room
- Ventilation Shafts
- Discard Dump.

## 8.1 CONSTRUCTION PHASE

### 8.1.1 Impacts on Groundwater Quantity

No significant impacts are expected during the construction phase in terms of groundwater quantity. The removal of vegetation in preparation of the mining area and infrastructure construction may cause an increase in surface runoff and therefore a small decrease in aquifer recharge. The run-off will in turn contribute to the catchment yield.

The development of the decline shaft is expected cause a decrease in the water level due to dewatering as the shaft will be developed to an elevation lower than the steady state water level elevations.

### 8.1.2 Impacts on Groundwater Quality

The proposed Koppie activities is not expected to impact on the groundwater quality during the construction phase. The only possible impacts may be from example fuel spillages from the construction vehicles.

### 8.1.3 Groundwater Management

Should fuel spillages occur during the construction phase immediate action is required to minimise the impact on the groundwater regime. No management can be incorporated to limit the impacts of dewatering in the immediate vicinity of the shaft area. Construction of any infrastructure should not be conducted with the use of carbonaceous material.

## 8.2 OPERATIONAL PHASE

### 8.2.1 Impacts on Groundwater Quantity

The operational phase impacts on the groundwater quantity will mainly be as a result of the dewatering of the surrounding deep aquifer(s) during the underground mining. The groundwater level in close proximity of the underground void is expected to decrease since groundwater seepage to the void will be abstracted. The numerical modelling indicated that the shallow aquifer will largely be unaffected by the dewatering of the deeper aquifer(s). The shallow aquifer is expected to be affected in the case where subsidence of the overlying rock strata occurs and leads to fracturing and cracking of the rock. Therefore, the shallow aquifer will dewater into the underground mining void. It is not expected that subsidence will occur, and priority should be to mine in such a manner to minimise or eliminate surface subsidence.

As simulated with the numerical model the extent of the dewatering cone in the deep aquifer is not expected to exceed 570 m in the aquifer and 900 m along the dykes from the underground mine boundary. Any groundwater users within this dewatering cone extent utilising the secondary aquifer may experience a decrease in water levels.

### 8.2.2 Impacts on Groundwater Quality

During the operational phase and for the period after mining when the groundwater level has not yet recovered, the mine void will act as a groundwater sink area. Groundwater gradients and therefore groundwater flow will be towards the underground void area. For this reason, groundwater contamination will not be able to flow down gradient from the underground void area during the operational phase.

The acid-base accounting for the proposed Koppie mining area indicated an intermediate to mild risk to generate acid. The dewatering of the underground voids will result in any contaminated water in the underground voids to be removed. For this reason, no impacts in terms of contamination are expected to influence the secondary aquifer beyond the mining boundary.

Preferred Option surface infrastructure: The decline shaft area is situated within a buffer zone and within the NFEPA wetland area. The remainder of the infrastructure is situated outside of the 100m buffer zone of the wetland areas. The contamination plume from the infrastructure is not expected to exceed 250 m from the source boundaries. The plume will migrate towards the west, north and east from the discard dump area, towards the east of the plant area and towards the south of the overburden stockpile area. The plume is expected to reach the wetland and stream towards the east of the discard dump and also the wetland towards the south of the overburden stockpile.

Alternative Option surface infrastructure: The majority of the potential contamination sources are situated within the buffer zone and within the NFEPA wetland areas. These features may be influenced by contamination in the event that base-flow to the streams and wetlands occur. The dewatering of the shallow aquifer in the immediate vicinity of the decline shaft area will result in some of the shallow aquifer contamination flowing towards the shaft area. The pollution plume extent at the end of mining is not expected to exceed 210 m along the dyke at the north of the discard dump area. The plume from the overburden stockpile is expected to reach the Joubertsvleispruit south-east of the dump.

### 8.2.3 Impacts on Surface Water

Based on **Figure 29**, several NFEPA wetlands are located within the mining area of the proposed Koppie mining area. The proposed underground bord-&-pillar mining area is located below the Joubertsvleispruit and some of its tributaries as well as a tributary of the Viskuilespruit. It is also underlying several NFEPA wetlands and pans.

Mining depth is planned at 59 to 133 mbs for the proposed Koppie mining area. The bord-&-pillar mining method will be used, and the extraction ratio is estimated at 56%. Fracturing or cracking is not expected to occur at the Koppie mining project. If no fracturing, cracking and subsidence occur, the surface water features and wetlands are not expected to be impacted on in terms of losing water.

In the case where fracturing, cracking or subsidence occur below surface water features such as the wetlands and streams, an increase in inflow of water to the underground mining voids will occur and the surface water feature will be impacted on in terms of losing water. Mining should be conducted in such a manner to minimise or eliminate surface subsidence.

Two alternatives for surface infrastructure locations have been investigated as part of this project:

- Preferred Option:
    - The following features are located within the 100 m buffer zone as well as within the NFEPA wetland areas:
        - Decline Shaft area.
    - The decline shaft will cause a dewatering cone and water from the wetland in which it is located will also flow into the shaft area. The shallow aquifer as well as this wetland area in the vicinity of the shaft area will be dewatered.
    - The pollution plume from the discard dump as well as the overburden stockpile area reaches the nearby streams and wetlands. Contaminated base-flow to these features may impact negatively on the water quality in the wetland and streams.

- Alternative Option:
    - The following features are located within the 100 m buffer zone as well as within the NFEPA wetland areas:
        - PCD,
        - Discard Dump,
        - Overburden Dump and
        - Decline Shaft area.
    - Groundwater baseflow may influence the wetland and river areas in terms of groundwater contamination since the potential source areas are situated within the buffer zones as well as within the NFEPA wetland areas.
    - The decline shaft will cause a dewatering cone and water from the wetland in which it is located will also flow into the shaft area. The shallow aquifer as well as this wetland area in the vicinity of the shaft area will be dewatered.

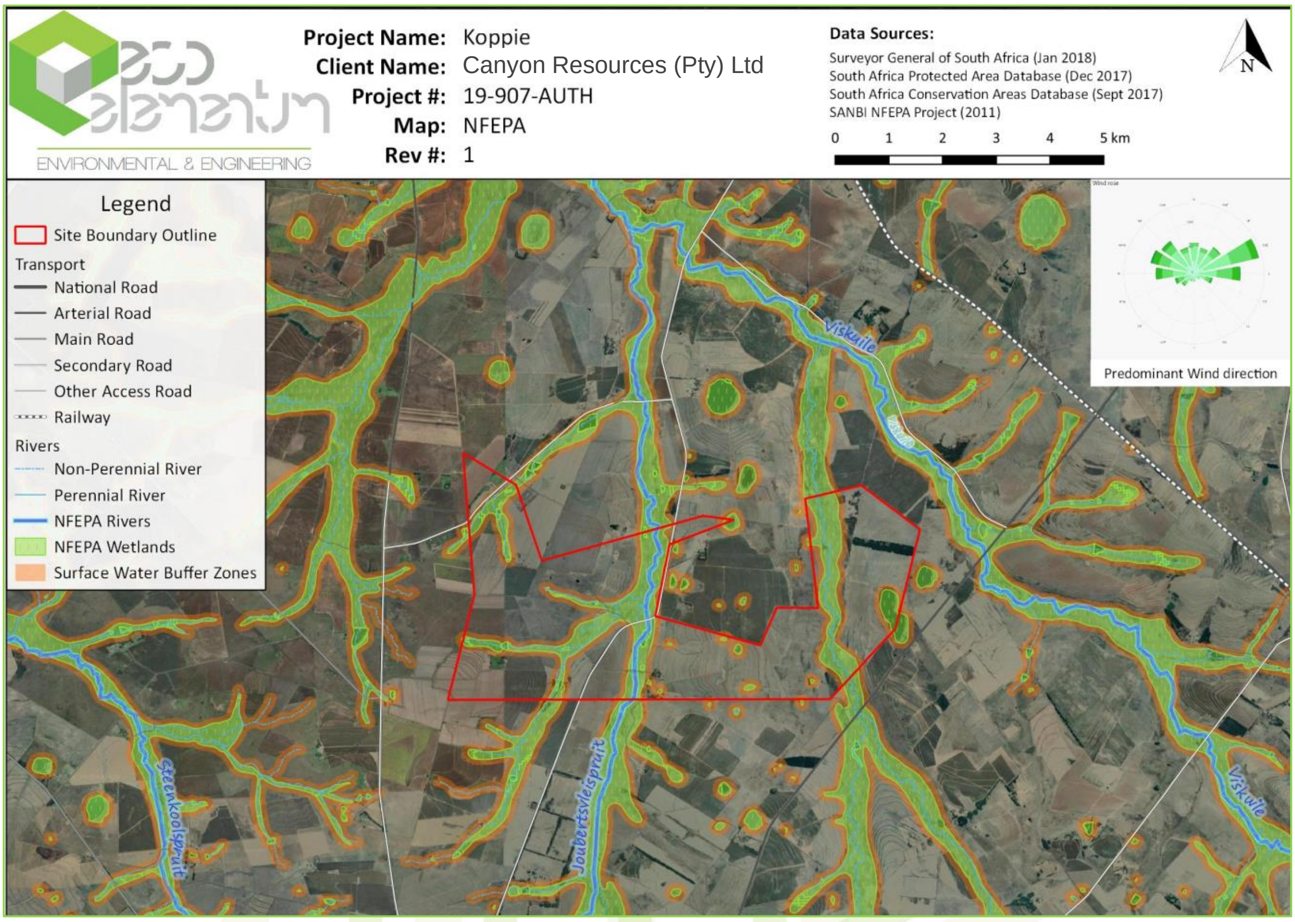


**Figure 29: NFEPA Wetlands in the region of the Koppie.**

### 8.2.4 Groundwater Management

Dewatering of the underground voids are a necessity for safe mining. Dewatering as a result of the mining operations cannot be prevented. Some mitigation measures for the operational phase are indicated in Table 24 below.

**Table 24: Mitigation measures for the Operational Phase**

| Potential Impacts | Mitigation Measures |
|---|---|
| • Impacts in terms of groundwater levels are expected during this phase. The dewatering of the underground voids will cause a drawdown in the water levels within the immediate vicinity of the underground activities in the secondary aquifer.<br>• No adverse impacts on the groundwater qualities surrounding the underground voids in the secondary aquifer are expected during this phase.<br>• A pollution plume may start to migrate downgradient of the potential surface contamination sources such as the discard dump, slurry dam and the PCD. | • Groundwater levels in the monitoring boreholes should be measured on at least a quarterly interval.<br>• Should the water levels of surrounding users be influenced in terms of groundwater level or quality decline, any potential users should be compensated.<br>• Monitor groundwater inflow rates on a monthly basis throughout the mining operation.<br>• The groundwater quality in the monitoring boreholes should be analysed on a quarterly basis.<br>• Annual reporting on the groundwater qualities and levels should be conducted and submitted to the DWA.<br>• The numerical model should be updated once a year when time-series monitoring data (water levels and qualities) are available.<br>• Conduct frequent surface inspection to detect any surface subsidence as soon as possible. |

| Potential Impacts | Mitigation Measures |
|---|---|
| | • Any subsidence areas should be mitigated to obtain free surface run-off. |

## 8.3 Decommissioning Phase

During the decommissioning phase all the potential surface contamination sources such as the PCD's, discard dump, slurry dam, etc. will be removed. This will decrease the surface sources for further groundwater contamination.

Any fractures or cracks and surface subsidence, if any, should be rehabilitated as to decrease water inflow into the underground voids and maintain free surface run-off.

## 8.4 Post Closure

### 8.4.1 Groundwater Quantity

Since dewatering has ceased at the end of the operational phase, the groundwater level will start to recover to a state of equilibrium. Decant from the lowest elevation where the underground and surface are connected may occur once the groundwater levels have recovered. Decant will therefore only occur should the recharge to the underground void be too high to be accommodated by the downgradient aquifers. This will typically be the case wherever subsidence of the roof strata overlying the underground mining area occurs and cracking/fracturing of the overlying rock material occurs. The recharge to the underground void will increase significantly if cracking or fracturing occurs and the shallow aquifer will also start to be dewatered.

Decant elevations and estimated rates were discussed in Section 7.8.3 of this report.

In the case where no subsidence occurs and the water level has recovered close to pre-mining levels, the horizontal groundwater flow is expected to resume through the receiving aquifer very similar as pre-mining.

### 8.4.2 Groundwater Quality

Geochemical analysis conducted for the Koppie area indicated a probability for acid generating. Therefore, the groundwater quality in the underground void regions will decrease as a result of the acidification. The contamination plume is not expected to significantly migrate away from the mining area after 100 years since the underground voids is only expected to be filled after 133 years. The voids will therefore act as groundwater sink areas for the period until the water levels have recovered. Wherever the voids have fill and dykes are connected to the voids, the contamination plume may start to migrate away from the mining void. The plume is not expected to migrate more than 300m from the underground boundaries.

Please refer to Section 7.8.3 of this document for more information in the expected groundwater quality conditions post closure.

### 8.4.3 Cumulative Impact

The Koppie area is situated in an area with several mining activities at or near its boundaries. The mining activities situated in the same quaternary catchment, B11A, as Koppie are:

- Exxaro Forzando South – bordering north of Koppie,
- Overlooked Colliery – 3km north of Koppie,
- Sudor Mine – 5km north of Koppie,
- Bultfontein Colliery – 10km north of Koppie.

Dewatering of the local aquifers are not limited to the Koppie area. The mining operations as mentioned above and especially Exxaro operations will have a cumulative impact on the aquifers in terms of quality and quantity. Acid mine drainage as well as the dewatering of the aquifers as a result of all these mining activities may decrease the groundwater qualities and have a nett loss on the water supply to the groundwater users and the springs in the area.

### 8.4.4 Groundwater Management

The potential impacts and mitigation measures post-closure are summaries in **Table 25** below.

**Table 25: Mitigation measures for Groundwater Management**

| Potential Impacts | Mitigation Measures |
|---|---|
| • The water level post-closure will start to rise as the underground void starts to fill.<br>• Decant may occur once the water level in the underground void has recovered and there is a connection between the underground void and the surface.<br>• Once the water levels have recovered, a groundwater pollution plume may start to migrate down gradient away from the underground void. | • Conduct frequent surface inspection to detect any surface subsidence as soon as possible.<br>• Any subsidence areas should be mitigated to obtain free surface run-off.<br>• The groundwater quality in the monitoring boreholes should continue to be analysed on a quarterly interval basis.<br>• Should any evidence of potential decant emerge, methods of handling potential decant should be investigated and may include treatment of polluted water. |

**Table 26: Potential impacts on groundwater regime rating summary for the proposed Koppie activities.**

| Activity | Aspect | Impact | Phase | Significance without mitigation | | Significance with mitigation | | Mitigation measures | Action Plan |
|---|---|---|---|---|---|---|---|---|---|
| Surface clearing and preparation. | Removal of vegetation. | Increase in surface run-off and therefore decrease in aquifer recharge. | Construction | 9 | Low | 1,8 | Low | Re-vegetate. | Rehabilitation plan. |
| Shaft Complex | Dewatering. | Decrease in water level from the point where development is lower than the water level. | Construction | 68 | Med-High | 68 | Med-High | No management can be incorporated to limit the impacts of dewatering should the box-cut floor be lower than the groundwater level. | Quarterly monitoring of monitoring boreholes. |
| Topsoil and overburden stockpiling. | Leaching from stockpiles. | Acid generation in the case of carbonaceous material placement. | Operation | 24 | Low-Med | 9,6 | Low | Cut-off trenches to intercept the shallow contamination plume. Keep dirty water areas separated from clean surface run-off areas. | Quarterly monitoring of monitoring boreholes. |
| ROM stockpiling. | Leaching from stockpiles. | Acid generation as a result of carbonaceous material. | Operation | 24 | Low-Med | 9,6 | Low | Cut-off trenches to intercept the shallow contamination plume. Keep dirty water areas separated from clean surface run-off areas. | Quarterly monitoring of monitoring boreholes. |
| Pollution Control Dams | Seepage should lining fail or dam overflow | Contaminated water in the dams can seep to the aquifer. | Operation | 24 | Low-Med | 9,6 | Low | Should a contamination plume be detected, investigate the possibility of groundwater abstraction to contain the plume. | Quarterly monitoring of monitoring boreholes. |
| Hydrocarbon spills. | Plume migration. | Spills from mining vehicles can infiltrate to the aquifer and cause a down gradient plume migration. | Construction & Operation | 14 | Low | 2,8 | Low | Clean any hydrocarbon spills in the appropriate manner. | Report any hydrocarbon spillage. |

| Activity | Aspect | Impact | Phase | Significance without mitigation | | Significance with mitigation | | Mitigation measures | Action Plan |
|---|---|---|---|---|---|---|---|---|---|
| Bord-&-pillar underground mining | Dewatering | The water infiltrating the voids will be removed for safe mining, causing a decrease in the water level of the secondary aquifer. Impacts on the shallow aquifer is not expected unless cracking or fracturing causes inflow of shallow aquifer to the underground voids. | Operation | 85 | High | 85 | High | No management can be incorporated to limit the impacts of dewatering. | Quarterly Monitoring. Compensate users for losses, if any. Monitor groundwater inflow rates, Annual Monitoring report, Update Numerical Model. |
| Closure of the mine | Groundwater rebound | Groundwater decant is not expected should the system behave as expected. If any connection between the underground void and the surface exist, decant is a possibility | Closure and Decommissioning | 36 | Low-Med | 14,4 | Low | Treat decant water before release to the environment | Establish a Passive treatment system in the form of a constructed wetland or similar. |
| Closure of the mine | Groundwater rebound | Pollution Plume spread | Closure and Decommissioning | 39 | Low-Med | 26 | Low-Med | Treat decant water before release to the environment | Establish a Passive treatment system in the form of a constructed wetland or similar. |

# 9. GROUNDWATER MONITORING SYSTEM

## 9.1 Groundwater Monitoring Network

### 9.1.1 Source, Plume, Impact and Background Monitoring

Source monitoring is the monitoring of specific and potential sources. These include the monitoring boreholes drilled strategically to detect any impact from sources as soon as possible. Once impacts in these boreholes, especially in terms of quality impacts are detected, additional boreholes down gradient of the source monitoring borehole can be included in the program and is referred to as plume monitoring.

In the Koppie area, only source monitoring boreholes will form part of the monitoring network. The monitoring boreholes to form part of the monitoring network have been indicated **Table 2**. Some boreholes are proposed for the monitoring of water levels and qualities in the deep aquifer in which the underground mining will occur. Other boreholes are proposed for the surface infrastructure monitoring. The surface monitoring boreholes are dependent on Preferred Option or 2, depending on which one is chosen.

### 9.1.2 System Response Monitoring Network

The groundwater regime will mostly be impacted on in terms of dewatering (operational) and contamination (operational and post-closure). A quarterly monitoring programme is critical to determine the response especially of groundwater levels during the operational phase and the qualities post-closure of the mining activities. Changes in the groundwater level will influence the flow directions and pollution migration rates. Frequent monitoring will aid in understanding the response of the system to the mining activities.

### 9.1.3 Monitoring Frequency

It is suggested that monitoring boreholes be monitored on a quarterly basis. Samples and water levels should be collected by an independent groundwater consultant, using best practice guidelines.

## 9.2 Monitoring Parameters

Groundwater samples should be analysed by an SANAS accredited laboratory for parameters normally associated with coal mining activities. The following parameters are proposed for the Koppie monitoring program:

- The pH, EC, Ca, Mg, Na, K, Cl, SO4, NO4 and F, and
- Al, Fe, Mn, Alkalinity and TDS.

## 9.3 Monitoring Boreholes

New monitoring boreholes are proposed to cover the mining activities at Koppie (**Figure 30**). The borehole coordinates and construction to be included in the mine monitoring program is indicated in **Table 2**.

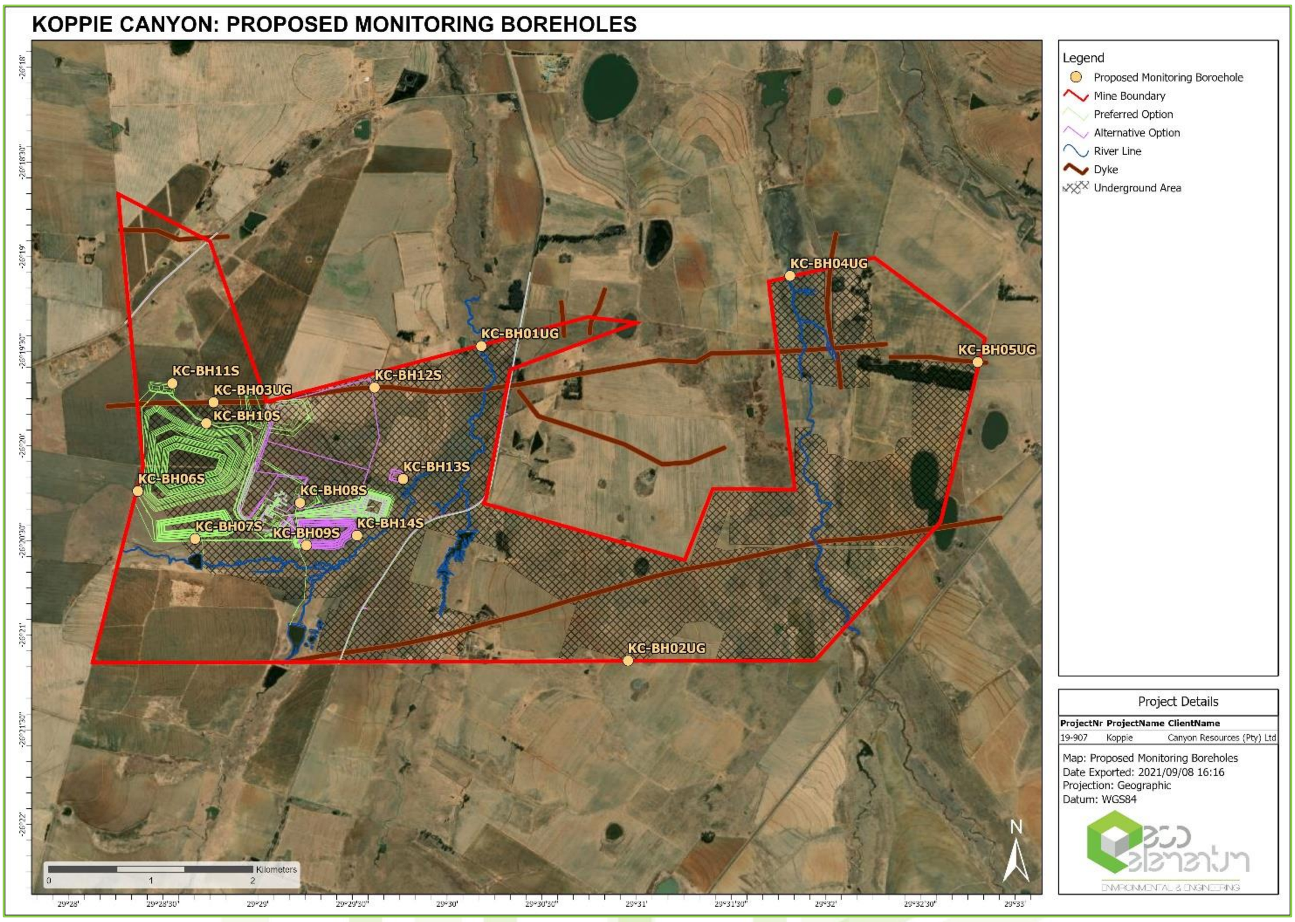


**Figure 30: Positions of the proposed monitoring boreholes to be drilled and form part of the monitoring program at Koppie area.**

# 10. GROUNDWATER ENVIRONMENTAL MONITORING PROGRAMME

## 10.1 Current Groundwater Conditions

The overall quality of the groundwater in the area is good to marginal. The pH in the boreholes were more basic with values varying between 7.1 and 8.5. The most significant impacts on the groundwater are observed in terms of elevated nitrate concentrations. The nitrate concentration in six of the thirteen boreholes exceeded the permissible limits for drinking water. The nitrate concentrations in these six boreholes varied between 20 and 40 mg/l. In the agricultural environment the main source of elevated nitrate concentrations is the use of fertilisers. It is also believed to be the source in the case of these boreholes.

The fluoride concentration in PU11 and the manganese concentration in PU13a also exceeded the permissible limits for drinking water. Drinking of fluoride rich groundwater can cause dental fluorosis or crippling skeletal fluorosis, which is associated with osteosclerosis, calcification of tendons and ligaments, and bone deformities. Exposure to high concentrations of manganese over the course of years has been associated with nervous system diseases with symptoms like Parkinson's disease. The majority of the measured parameters in PU19a seems to be elevated above the baseline concentrations of the area. PU19a is situated at a residence and the causes for the elevated concentrations is unknown. Elevated fluoride concentration may be a result of natural water and rock interactions.

Groundwater level information is available for the model area as they were recorded during the 2020 hydrocensus as well as NGA boreholes (DWS). Only 4 water levels could be measured during the hydrocensus as the majority of the boreholes were equipped with pumps and no access to measure the water levels could be obtained. Groundwater levels varied between 5 and 17mbs in the boreholes recorded.

## 10.2 Predicted Impacts of Facility (Mining)

The expected impacts as a result of the proposed mining operations (Koppie) are summarised as:

- Construction phase:
  - The development of the decline shaft is expected cause a decrease in the water level due to dewatering as the shaft will be developed to an elevation lower than the steady state water level elevations.
  - Fuel spillages from construction vehicles may occur during this phase.
- Operational phase:
  - Impacts in terms of groundwater levels are expected during this phase. The dewatering of the underground voids will cause a drawdown in the water levels within the immediate vicinity of the underground activities in the secondary aquifer.
  - No adverse impacts on the groundwater qualities surrounding the underground voids in the secondary aquifer are expected during this phase.
  - A pollution plume may start to migrate downgradient of the potential surface contamination sources such as the discard dump and the PCDs.
  - The simulated results of the operational phase in term of the water levels are indicated in the table below:

| Area | Drawdown Depth (mbs) | Drawdown Extent (m) |
|---|---|---|
| Shaft Area | 90 | 600 |
| Underground mining voids | 112 | In aquifer = 570m<br>On Dykes = 900m |

- Post Closure:
  - The water level post-closure will start to rise as the underground void starts to fill.

- Decant may occur once the water level in the underground void has recovered and there is a connection between the underground void and the surface.
- Once the water levels have recovered, a groundwater pollution plume may start to migrate down gradient away from the underground void.
- The simulated results of the end of operational and post-closure phase in term of the water quality are indicated in the table below:

| Area | Maximum simulated Sulphate Concentration (mg/l) | Maximum simulated plume extent from boundary (m) | Potential plume migration direction from the source area |
|---|---|---|---|
| Preferred Option – Surface infrastructure | 900 mg/l (at end of mining) | 250 m at mine closure, | Preferred Option – Surface infrastructure |
| Alternative Option – Surface infrastructure | 900 mg/l (at end of mining) | 210m at mine closure,<br>550m at 50 years post-closure. | East from discard dump and plant area, south from overburden stockpile. |
| Underground voids | 1 500 mg/l (100 years post-closure) | 300m at 100 years post closure | Only along the dykes. The plume at 100 years post-closure is not expected to exceed beyond the mine boundary since the water level in the voids has not yet recovered at this time. In the region where the water level has recovered, plume migration will be towards the north-east. |

## 10.3 Mitigation Measures

| Phase | Mitigation Measures |
|---|---|
| **Construction Phase** | • Should fuel spillages occur during the construction phase immediate action is required to minimise the impact on the groundwater regime.<br>• No management can be incorporated to limit the impacts of dewatering in the immediate vicinity of the shaft area. |
| **Operational Phase** | • Groundwater levels in the monitoring boreholes should be measured on at least a quarterly interval.<br>• Should the water levels of surrounding users be influenced in terms of groundwater level or quality decline, any potential users should be compensated.<br>• Monitor groundwater inflow rates on a monthly basis throughout the mining operation.<br>• The groundwater quality in the monitoring boreholes should be analysed on a quarterly basis.<br>• Annual reporting on the groundwater qualities and levels should be conducted and submitted to the DWS.<br>• The numerical model should be updated once more time-series monitoring data (water levels and qualities) are available.<br>• Conduct frequent surface inspection to detect any surface subsidence as soon as possible.<br>• Any subsidence areas should be mitigated to obtain free surface run-off. |
| **Post-Closure Phase** | • Conduct frequent surface inspection to detect any surface subsidence as soon as possible.<br>• Any subsidence areas should be mitigated to obtain free surface run-off.<br>• The groundwater quality in the monitoring boreholes should continue to be analysed on a quarterly interval basis. |

| | |
|---|---|
| | • Should any evidence of potential decant emerge, methods of handling potential decant should be investigated and may include treatment of polluted water. |

## 11. POST-CLOSURE MANAGEMENT PLAN

The following suggestions are made for the post-closure management:

- Conduct frequent surface inspection to detect any surface subsidence as soon as possible.
- Any subsidence areas should be mitigated to obtain free surface run-off.
- The groundwater quality in the monitoring boreholes should continue to be analysed on a quarterly interval basis.
- Should any evidence of potential decant emerge, methods of handling potential decant should be investigated and may include treatment of polluted water.
  - Treatment options in the coal mining environment can either be passive or active.
  - For smaller rates of flow/decant passive treatment options are proposed. These volumes should be less than 500 to 1 000 $m^3$/day.
  - The estimated decant rate, if any, at Koppie underground is not expected to exceed 435 $m^3$/day.
  - Passive treatment options can therefore be investigated for the proposed mining at Koppie.
  - Options include:
    - pH adjustment (anoxic limestone drains (ALD);
    - Bio neutralisation;
    - Successive alkalinity producing systems (SAPS);
    - Metals removal (ALD + oxidation pond; SAPS, sulphate reducing units, wetlands, oxidation cascades); and
    - Sulphate removal (sulphate reducing units + sulphide oxidising bioreactors).
- Down gradient water users should be notified should any impacts may have an effect on their health or availability of groundwater.

# 12. CONCLUSIONS AND RECOMMENDATIONS

The geohydrological environment at Koppie area can be summarised as follows:

- The Koppie is located in the Highveld region of Mpumalanga and in a summer rainfall region.
- The mean annual precipitation is ± 700 mm/annum, while the evaporation is estimated at 1 680 mm/annum.
- Drainage over the regional area and locally is towards the north.
- The Koppie area is underlain by sedimentary rocks from the Karoo Super group's Vryheid Formation.
- Geological structures such as dykes and faults are known to exist in the region of the Koppie. These structures and the weathered zone are possible pathways of elevated groundwater flow and contamination migration.
- On the basis of seam thickness and coal quality the S4L is the prime exploitation target within the No. 4 Seam Group.
- The 2 seam is often split into No. 2 Lower and No. 2 Upper Seam. The No. 2 Lower Seam ("S2L") generally is the thicker seam of the two sub-seams; it has better quality coal, and therefore will be the "theoretical" mining target.
- Two main aquifer systems are found in the Koppie region. Firstly, the shallow weathered aquifer and secondly, the deeper, secondary aquifer.
- Groundwater level information is available for the model area as they were recorded during the 2020 hydrocensus as well as from NGA boreholes (DWS). Only 4 water levels could be measured during the hydrocensus as the majority of the boreholes were equipped with pumps and no access to measure the water levels could be obtained. Groundwater levels varied between 5 and 17mbs in the boreholes recorded.
- The overall quality of the groundwater in the area is good to marginal.
- The nitrate concentration in six of the thirteen boreholes exceeded the permissible limits for drinking water. The nitrate concentrations in these six boreholes varied between 20 and 40 mg/l.
- The fluoride concentration in PU11 and the manganese concentration in PU13a also exceeded the permissible limits for drinking water.
- The ABA from the proposed Koppie mining area concluded that the analysed samples can be classified as intermediate to potentially acid generating.
- The waste classification indicated a Type 3 waste and therefore Class C liners are required in all areas where waste is placed.
- Groundwater Sources:
  - Recharge:
    - Natural recharge: in the region of the proposed project the natural recharge is estimated between 1 and 2% of the MAP. Rivers and drainage systems can also be seen as potential recharge sources. Gaining or losing streams play a role here. Losing streams "lose" their water to the aquifer, making it a natural recharge source. The streams in the immediate vicinity of the proposed project have not been identified as losing or gaining streams or even disconnected streams if they are not connected in any way to the groundwater regime.
    - Artificial recharge: Artificial recharge from the PCD may occur if the lining leaks.
  - Contamination Sources: At the proposed mining operation the potential contamination sources can include:
    - Wet sources: PCD's, Slurry dam and other unlined facilities or where the linings have failed. Water level mounding can be expected at these sources which may influence the groundwater flow gradients.
    - Dry sources: Overburden stockpiles, Discard dumps and ROM stockpiles. Dry sources are only active should water be introduced to the system by means of recharge or some other form where poor quality water seeps into the underlying aquifer. Water level mounding will not occur under dry source areas.
- Groundwater pathways:
  - Fault zones and dykes surrounding the proposed project area may be potential pathways for groundwater contamination migration. Geological structure information is available for the site and these structures are expected to play a role in the impact zone of the proposed mining operation.
- Groundwater receptors:

- River Systems: any contamination from potential sources may be discharged in terms of baseflow into the receiving river systems in the area.
- Potential groundwater users: In the area of the proposed mining operation's impact zone groundwater users exist. The impact zone may increase as pathways such as geological structures are present.
- Underground void: once dewatering of the void commence, water will flow towards the void and therefore act as a groundwater receptor, even though an artificial receptor.

The following impacts may be expected from the proposed Koppie mining operations:

- Construction phase:
  - The development of the decline shaft is expected cause a decrease in the water level due to dewatering as the shaft will be developed to an elevation lower than the steady state water level elevations.
  - Fuel spillages from construction vehicles may occur during this phase.
- Operational phase:
  - Impacts in terms of groundwater levels are expected during this phase. The dewatering of the underground voids will cause a drawdown in the water levels within the immediate vicinity of the underground activities in the secondary aquifer.
  - No adverse impacts on the groundwater qualities surrounding the underground voids in the secondary aquifer are expected during this phase.
  - A pollution plume may start to migrate downgradient of the potential surface contamination sources such as the discard dump and the PCDs.
  - The simulated results of the operational phase in term of the water levels are indicated in the table below:

| Area | Drawdown Depth (mbs) | Drawdown Extent (m) |
|---|---|---|
| Shaft Area | 90 | 600 |
| Underground mining voids | 112 | In aquifer = 570m<br>On Dykes = 900m |

- Post Closure:
  - The water level post-closure will start to rise as the underground void starts to fill.
  - Decant may occur once the water level in the underground void has recovered and there is a connection between the underground void and the surface.
  - Once the water levels have recovered, a groundwater pollution plume may start to migrate down gradient away from the underground void.
  - The simulated results of the end of operational and post-closure phase in term of the water quality are indicated in the table below:

| Area | Maximum simulated Sulphate Concentration (mg/l) | Maximum simulated plume extent from boundary (m) | Potential plume migration direction from the source area |
|---|---|---|---|
| Preferred Option – Surface infrastructure | 900 mg/l (at end of mining) | 250 m at mine closure,<br>430m at50 years post-closure. | West and east from discard dump, East from plant, south from Overburden Stockpile. |
| Alternative Option – Surface infrastructure | 900 mg/l (at end of mining) | 210m at mine closure, | Alternative Option – Surface infrastructure |
| Underground voids | 1 500 mg/l (100 years post-closure) | 300m at 100 years post closure | Only along the dykes. The plume at 100 years post-closure is not expected to exceed beyond the |

| Area | Maximum simulated Sulphate Concentration (mg/l) | Maximum simulated plume extent from boundary (m) | Potential plume migration direction from the source area |
|---|---|---|---|
| | | | mine boundary since the water level in the voids has not yet recovered at this time. In the region where the water level has recovered, plume migration will be towards the north-east. |

The proposed mitigation measures for the proposed mining operation are summarised below:

| Phase | Mitigation Measures |
|---|---|
| **Construction Phase** | • Should fuel spillages occur during the construction phase immediate action is required to minimise the impact on the groundwater regime.<br>• No management can be incorporated to limit the impacts of dewatering in the immediate vicinity of the shaft area. |
| **Operational Phase** | • Groundwater levels in the monitoring boreholes should be measured on at least a quarterly interval.<br>• Should the water levels of surrounding users be influenced in terms of groundwater level or quality decline, any potential users should be compensated.<br>• Monitor groundwater inflow rates on a monthly basis throughout the mining operation.<br>• The groundwater quality in the monitoring boreholes should be analysed on a quarterly basis.<br>• Annual reporting on the groundwater qualities and levels should be conducted and submitted to the DWS.<br>• The numerical model should be updated once a year when time-series monitoring data (water levels and qualities) are available.<br>• Conduct frequent surface inspection to detect any surface subsidence as soon as possible.<br>• Any subsidence areas should be mitigated to obtain free surface run-off. |
| **Post-Closure Phase** | • Conduct frequent surface inspection to detect any surface subsidence as soon as possible.<br>• Any subsidence areas should be mitigated to obtain free surface run-off.<br>• The groundwater quality in the monitoring boreholes should continue to be analysed on a quarterly interval basis.<br>• Should any evidence of potential decant emerge, methods of handling potential decant should be investigated and may include treatment of polluted water. |

## 13. REASONED OPINION

A reasoned opinion-

i. as to whether the proposed activity or portions thereof should be authorized and

ii. if the opinion is that the proposed activity of portion thereof should be authorised, any avoidance, management and mitigation measures that should be included in the EMPR, and where applicable, the closure plan.

It is the opinion of the Geohydrologist that the proposed mining activities should be authorised.

- The environmental impacts associated with the mining activities are limited provided that the proposed mitigation is implemented.
- The impact zone in terms of water levels is not expected to extent more than 900 m from the mining boundaries during the operational phase. This extent is however along dykes which is preferential flow paths. In the aquifer matrix the maximum extent of the cone of depression is not expected to exceed 570m is the deep aquifer.
- The impact zone in terms of groundwater qualities is not expected to extent more than 300 m from the mining boundaries in the secondary aquifer at 100 years post-closure.
- These impact zones represent the impact of the mining activities without mitigation measures in place. Thus, worst-case scenario.
- Groundwater users within the impact zone which utilises the secondary aquifer may be influenced in terms of quantity during the operational phase and quality in the post-closure phase. Users that are impacted on should be compensated for their loss.
- It is highly recommended that Preferred Option should be incorporated as part of the infrastructure plan. The majority of the surface infrastructure is situated outside of the 100m buffer zone of the wetlands and rivers.
- Sufficient financial provision should be provided for the treatment of acid mine drainage (AMD) or decant of polluted water (if decant occurs).

# 14. KNOWLEDGE GAPS, LIMITATIONS, ASSUMPTIONS

The following knowledge gaps, limitations and assumptions apply to the Koppie study area in terms of the groundwater study:

- The layout of Preferred Option surface infrastructure was only available after the geophysical survey was conducted and for this reason the proposed monitoring boreholes for this alternative could only be positioned by means of available topographical and geological information.
- Access to some of the proposed sites for geophysics was not granted at the time of the survey.
- No information on the status of the neighbouring mining activities were available. The impacts and inter-mine interactions can therefore not be determined for future.

# 15. REFERENCES


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