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# Follow-Up Geohydrological Assessment for the proposed 2-Seam (Pty) Ltd Mine River Diversion

## Report

**Version - Final 1**

**25 October 2022**

**Environmental Sustainability**

**GCS Project Number: 22-0619**

**Client Reference: GCS002**

**GCS (Pty) Ltd.** Reg No: 2004/000765/07 Est. 1987
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**LEGAL NOTICE**

## DECLARATION OF INDEPENDENCE

GCS (Pty) Ltd (GCS) was appointed to conduct this specialist groundwater study and to act as the independent hydrogeological specialist. GCS objectively performed the work, even if this results in views and findings that are not favourable. GCS has the expertise in conducting the specialist investigation and has no conflict of interest in undertaking this study. This report presents the findings of the investigations which include the activities set out in the scope of work.

## EXECUTIVE SUMMARY

GCS Water and Environment (Pty) Ltd (GCS) was appointed by Environmental Sustainability (Pty) Ltd to undertake a geohydrological assessment and numerical model update for the 2-Seam (Pty) Ltd Mine (hereafter referred to as 2 Seam), situated about 12 km north-east of the town of Kriel, in the Mpumalanga Province.

This follow-up geohydrological assessment focuses on the **proposed OC4 and OC4A opencast operations, as well as the proposed stream diversion associated with the Olifants River segment along the northern boundary of the 2-Seams Mine**. The initial geohydrology assessment was undertaken by GCS in 2020 and focussed on the entire mine site.

*The groundwater risk associated with the proposed pollution control dams (PCDs), processing plants, run-of-mine (ROM) stockpile, contractors camp and tailings storage facility (TSF) is recorded in a dedicated geohydrology report, titled "Follow-Up Geohydrology Assessment for the proposed 2 Seam Supporting Mine Infrastructure" (GCS, 2022 – Report No 22-0619_Support).*

Mining of OC4 will target the No. 2 seam and based on the mine plan for OC4, mining will be conducted over twelve (12) months and will commence after mining at OC2A is completed (estimated around November 2022). For the proposed opencast and mine expansion to take place (referred to as OC4A – extension to OC4 and OC4 Box cut – orange polygon), there will need to be a stream diversion of a portion of the Olifants River, flowing in the mining right area. Based on the information made available by the client, the following is proposed:

- Initially, a 40 to 50 m buffer zone will be maintained between OC4 and the Olifants River, and then the expansion of OC4A into the river with a river diversion is proposed.
- A 50m buffer will then be maintained between the opencast and the diverted section of the Olifants River.
- Diversion of the tributary of the Olifants River that flows across the OC4A area, to a position approximately 450 m east of its current position within the central section of the OC4A layout.
- The construction of a berm between OC4A and the Olifants River corresponds to the 1:100-year flood line for the diverted Olifants River section.
- A clean water berm is situated west and south of OC4A, to prevent overland flow into the opencast area.
- A barrier pillar of 30 m will be maintained between the historical underground workings and OC4 & OC4A.

Geohydrological risk associated with the proposed activity, and the implication and the groundwater flow regime, were assessed by adopting the source-pathway-receiver principle and constructing a groundwater flow and transport model.

The 2 Seam Mine is in the Highveld Region of Mpumalanga. Summer rainfall is experienced in the study area, with a MAP rate of approximately 691 mm/year. Evaporation is estimated to be 1385 mm/annum. Three (3) sub-catchments (HRUs) (1:10 000 stream count, 30m DTM fill) were delineated for the project area – refer to Figure 1 2. The sub-catchments describe the drainage from the 2-Seams mine, as well as surrounding mines, which fall in the same drainage area. As such, the combined extent of HRU1 to HRU3 can be considered the sphere of groundwater influence and forms the geohydrological boundaries for the project area. Drainage associated with the Olifants River is from a larger sub-catchment extending over the boundaries of quaternary B11B to B11A. The combined surface area for HRU1 (78.22 $km^2$), HRU2 (19.97 $km^2$) and HRU3 (8.15 $km^2$) associated with the project is in the order of 106.34 $km^2$.

The study area is underlain by stratigraphy of the Vryheid Formation, Ecca Group of the Karoo Supergroup. The coal-bearing Vryheid Formation consists predominantly of fine-grained sandstone, platy shale, and coal (No. 4, No. 2 and No. 1 seams). the No. 2 and No.4 seams are the major mining targets at 2 Seam Mine.

Three (3) aquifers occur within the study area: an alluvium zone (unconfined) along the Olifants River flood plain, an upper weathered Ecca aquifer (shallow aquifer formed in the weathered zone of the Karoo sediments), fractured aquifers within the unweathered but fractured Ecca stratigraphy and fractured aquifer underlying the Ecca sediments consisting of low yielding Dwyka and/or basement rocks. An additional hydrogeological unit is present within the study area, attributed to the disturbance of in-situ hydrogeological conditions by historical mining activities.

The latest groundwater level measurements at 2 Seam Mine range between 1.12 to 30.56 mbgl and indicate subdued groundwater levels in some areas due to historical mining activities. Groundwater contamination within the vicinity of the historical underground mining areas has historically been exhibited by BH2, BH3 and prominently BH5 (EC > 300 mS/m, TDS> 2500 mg/l, SO4 > 2500 mg/l). Total dissolved solids (TDS) concentrations within old rehabilitated pits that have become flooded range between 500 mg/l and 2400 mg/l. Sulphate varies between 200 mg/l and 1400 mg/l. Neutral pH conditions are observed (GCS, 2016).

Acid-base accounting analyses conducted on material sampled for the 2 Seam Mine indicate that 33.3% of the carbonaceous mudstone/shale samples have a high potential to generate acidic drainage; 100% (4 out of 4 samples) of the coal samples collected have a high potential to generate acidic drainage; 50% (2 out of 4) of the shale samples collected has a very high potential to generate acidic drainage, 25% (2 out of 8) of the sandstone/mudstone samples collected has a high potential to generate acidic drainage and 100% (1 out of 1) of the soil and clay samples collected has low potential to generate acidic drainage (and will generate a low to medium salt load.

Based on the conceptual and numerical geohydrological models developed, the following higher-risk activities are noted:

- The mining of OC4 is predicted to affect the Olifants River and subsequent aquifer, by inducing a 0.5 to 1 m drawdown of the subsequent aquifer zone. Therefore, just before the stream diversion takes place, there may be baseflow loss from the Olifants River segment. After the proposed diversion takes place, a drawdown ranging from 32 to 20 mbgl, with a greater drawdown towards the south of OC4, is predicted. A new flow regime is established due to the diversion of the river. The predicted impact on the diverted flow area is < 2 m, and the stream diversion area appears to be safe from the dewatering associated with the OC4A expansion. The groundwater flow system along the Olifants River that will be diverted is predicted to change significantly. Groundwater baseflow and groundwater recharge resulting from the presence of the Olifants River will decrease along OC4 & OC4A, and a long-term dewatering zone is predicted because the natural hydraulic boundary conditions changes if the Olifants River is diverted. It is important to calibrate the numerical model during the opencast expansion, and if the diversion is approved, more boreholes should be drilled in the area to refine and calibrate the groundwater flow fields. Based on the analytical estimates a rebound of the opencast working is expected between 18 to 47 years, however, the numerical model that considers aquifer flow and baseflow suggests a longer rebound due to the stream diversion.

- From the transport model for predicted sulphate ($SO_4$) movement from OC4 and OC4A, it is predicted that the 250 mg/l $SO_4$ contours will remain isolated along the mined-out opencast workings, with greater concentrations (>1000 mg/l) predicted for the access box/cut and initial OC4 mine blocks. If the Olifants River segment is not diverted, the preferential movement towards the Olifants River is observed, with the 1000 mg/l plume reaching the river in < 10 years. At LOM of OC4A, it is observed that the 250 mg/l $SO_4$ contour remains on the fringe of the mine works, with increases in concentrations towards older sections of the workings. The 50 Year (Y) $SO_4$ plume shows preferential movement towards the Olifants River stream diversion, with the 250 mg/l contours infringing the southern portion of the diversion. $SO_4$ loads to the river are estimated in the order of 150 mg/l. It is predicted that If the opencast workings are to be capped to decrease recharge by <3%, the plume movement to the surrounding environment will be reduced by several orders.
- Based on the coal floor elevations, the existing mine plan and the proposed mine plan for OC4 and OC4A, one (1) decant area previously identified for OC4 will fall away, and 2 new potentials decant areas associated with OC4A will likely occur (along the north and east side of the pit). Decant volumes are estimated to be between 26 to 66.5 $m^3$/day for the backfilled OC4 and OC4A areas (refer to section 6.2).

Hydrogeological risks identified are captured in Section 8, and mitigation measures, as well as groundwater management considerations, are captured in Section 10 and Section 11.1. Recommendations to improve the monitoring network, specifically in the OC4 and OC4A areas have been made and can be found in Section 9.

It is fair to conclude that all data made available for this investigation, and data obtained from the site visit, have successfully been incorporated into the site conceptual model and numerical flow & transport model. Considering the proposed activities, the risk has been evaluated in terms of best practice guidelines. The zone of impact (ZOIp) and zone of influence (ZOIf) and impacts of the project area were successfully simulated and presented in this report.

The pros and cons need to be weighed, in line with social-economical impacts and other specialist reports (wetland, hydrology and land capability) to determine if the diversion is feasible, or if OC4A should be considered a “no-go”. If the river diversion is not implemented, there may be a risk of contaminated groundwater migration directly into the Olifants River; and if the river is diverted, the salt ingress is predicted to be lower but it will take some time for the groundwater-surface water flow system to stabilise to a new equilibrium as a result of the diversion. The proposed diversion, from a geohydrological perspective, seems feasible, in context with the limitations and risks identified in this assessment.

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| | |
|---|---|
| **ABA** | **Acid-Base Accounting** |
| **AD** | Acid Drainage |
| **Al** | Aluminium (mg/l) |
| **AMD** | Acid Mine Drainage |
| **ANC** | Acid Neutralising Capacity |
| **ARD** | Acid Rock Drainage |
| **As** | Arsenic |
| **BH** | Borehole |
| **BHN** | Basic Human Needs |
| **Ca** | Calcium (mg/l) |
| **Cd** | Cadmium (mg/l) |
| **Cl** | Chloride (mg/l) |
| **$CO_3$** | Carbonate (mg/l) |
| **DEM** | Digital Elevation Model |
| **DW&S (DWS)** | Department of Water and Sanitation (previously DWA and DWAF) |
| **DWA** | Department of Water Affairs |
| **DWAF** | Department of Water and Forestry |
| **EC** | Electrical Conductivity (mS/m) |
| **EMPR** | Environmental Management Plan Report |
| **EU** | Existing Groundwater Usage |
| **F** | Fluoride (mg/l) |
| **Fe** | Iron (mg/l) |
| **GCS** | GCS Water and Environment (Pty) Ltd |
| **GRIP** | Groundwater Resource Information Project |
| **GW** | Groundwater |
| **h** | Potentiometric head |
| **$HCO_3$** | Bicarbonate (mg/l) |
| **HDPE** | High-Density Polyethylene (Plastic) |
| **HMP** | Hydrogeological Management Plan |
| **INAP** | The International Network for Acid Prevention |
| **IGRD** | Intermediate Groundwater Reserve Determination |
| **IWULA** | Integrated Water Use License Application |
| **IWWMP** | Integrated Water and Waste Management Plan |
| **K** | Potassium (mg/l) |
| **K (k)** | Hydraulic Conductivity (m/day) |
| **Kxx** | Hydraulic Conductivity on x-axis (m/day) |
| **Kyy** | Hydraulic Conductivity on the y-axis (m/day) |
| **Kzz** | Hydraulic Conductivity on the z-axis (m/day) |
| **LFCR** | Linear flow channel reactor |
| **LU** | Existing Land Use |
| **m** | Metres |
| **MALK** | Measured Alkalinity |
| **mamsl** | Meters above mean sea level |
| **MAP** | Mean Annual Precipitation |
| **mbgl** | Meters below ground level |
| **Mg** | Magnesium (mg/l) |
| **Mn** | Manganese (mg/l) |
| **n** | Porosity |

| | |
|---|---|
| **Na** | Sodium (mg/l) |
| **NAG** | Net Acid Generation |
| **ND** | Neutral Drainage |
| **NEMA** | National Environmental Management Act |
| **NGDB** | National Groundwater Database |
| **$NO_3$** | Nitrate (mg/l) |
| **Non-PAG** | Non-Potentially Acid Generation |
| **NWA** | National Water Act |
| **PAG** | Potentially Acid Generating |
| **PAN** | Potentially Acid Neutralising |
| **Pb** | Lead (mg/l) |
| **PCD** | Pollution Control Dam |
| **PEST** | Parameter Estimation Simulation |
| **PU** | Proposed Groundwater Usage |
| **Re** | Recharge (%) |
| **RMS** | Root Mean Squared / Normalised Distribution |
| **RO** | Reverse Osmosis |
| **S** | Storativity |
| **SANS** | South African National Standards |
| **Sb** | Antimony (mg/l) |
| **SD** | Saline Drainage |
| **SD** | Saline Drainage |
| **$SO_4$** | Sulphate (mg/l) |
| **SS** | Specific Storage / Suspended Solids (mg/l) |
| **Ss** | Specific Storage |
| **Sy** | Specific Yield |
| **T** | Transmissivity ($m^2$/d) |
| **t** | Time (days) |
| **Talk** | Total Alkalinity (mg/l) |
| **TDS** | Total Dissolved Solids (mg/l) |
| **W** | Groundwater Flux |
| **WQ** | Water Quality |
| **WUL** | Water Use License |
| **WULA** | Water Use License Application |
| **XRD** | X-Ray Diffraction |
| **XRF** | X-Ray Fluorescence |
| **Y** | Years |
| **Zn** | Zinc (mg/l) |
| **ZOI** | Zone of Influence |
| **θ** | Porosity |

# 1 INTRODUCTION

GCS Water and Environment (Pty) Ltd (GCS) was appointed by Environmental Sustainability (Pty) Ltd to undertake a geohydrological assessment and numerical model update for the 2-Seam (Pty) Ltd Mine (hereafter referred to as 2 Seam), situated about 12 km north-east of the town of Kriel, in the Mpumalanga Province (refer to Figure 1-2).

This follow-up geohydrological assessment focuses on the **proposed OC4 and OC4A opencast operations, as well as the proposed stream diversion associated with the Olifants River segment along the northern boundary of the 2-Seams mine**. The initial geohydrology assessment was undertaken by GCS in 2020 and focussed on the entire mine site.

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## 1.1 Project background

Elemental Sustainability (Pty) Ltd. (the client) was appointed by 2 Seam to submit an environmental authorisation application in terms of the National Environmental Management Act, 1998 (Act No. 107 of 1998), the Waste Management Licence in terms of National Environmental Management Waste Act, 2008 (Act No. 59 of 2008) as amended, and the Environmental Impact Assessment Regulations of 2014, as amended, to Mining Right (MP) 30/5/1/2/3/2/1 (405) EM to include a coal washing plant, tailings facility and pollution control dams on site. In addition, 2 Seam is applying for an additional opencast pit to be located within the approved mining right boundary. As part of the application, the two existing approved EMPRs will be combined into a single EMPR and the new activities will be added to the EMPR. The river diversion of the Olifants River will also be applied. A Section 102 application in terms of the Mineral and Petroleum Resources Development Act, 2002 (MPRDA) (Act 28 of 2002) will be submitted to the Department of Mineral Resources and Energy (DMRE) for amendments to the Environmental Management Programme.

This geohydrological assessment is required to inform the section 102 process and supplement the water use license application (WUL) and Environmental impact assessment (EIA) for the proposed mine area.

## 1.2 Site layout / proposed activity

2 Seam Mine has mined two opencast pits (OC1 and OC3) in recent years and is currently mining the third opencast pit (OC2), using conventional opencast strip-mining techniques (i.e. drilling, blasting, loading and hauling). Mining of an additional four opencast pits (OC4 & OC4A, OC5 and OC6) is planned, while mining in OC2A has started. Based on available information for the site, the following is noted:

- Mining will be conducted in a phased approach, i.e. mining will start and cease in each opencast before the commencement of mining in the next opencast.
- ROM and clean coal will be stockpiled in demarcated areas before being transported off-site.
- Stripped topsoil and subsoil will be stockpiled in demarcated areas.
- Haul roads will be constructed and used during the operational phase of the mining for transporting coal materials to a processing facility. In addition, internal service roads will be constructed as needed.

Mining of OC4 will target the No. 2 seam and based on the mine plan for OC4, mining will be conducted over twelve (12) months and will commence after mining at OC2A is completed (estimated around November 2022). For the proposed opencast and mine expansion to take place (referred to as OC4A – extension to OC4 and OC4 Box cut – orange polygon), there will need to be a stream diversion of a portion of the Olifants River, flowing in the mining right area. Based on the information made available by the client, the following is proposed:

- Initially, a 40 to 50 m buffer zone will be maintained between OC4 and the Olifants River, and then the expansion of OC4A into the river with a river diversion is proposed.
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- A clean water berm is situated west and south of OC4A, to prevent overland flow into the opencast area.
- A barrier pillar of 30 m will be maintained between the historical underground workings and OC4 & OC4A.

The site infrastructure at the 2-Seam (Pty) Ltd Mine is shown in Figure 1-3. The proposed infrastructure and mine works (as highlighted above) include additional opencast mining and subsequent river diversion, development of a tailings facility, run of mine (ROM) stockpile, processing plant area, plant pollution control; dam (PCD) and a second PCD. The mining plan is shown in Figure 1-1.

**Table 1-1: Pit Design and Mining Schedules**

| Opencast (O/C) | Target seam(s) | Pit Design | | | | | |
|---|---|---|---|---|---|---|---|
| | | Pit Floor Elevation (mamsl) | Pit Floor Depth (mbgl) | Surface Area ($m^2$) | Duration | | |
| | | | | | Start | End | Total (months) |
| 1 | No.4 and 2 seams | 1506 - 1522 | 16 - 33 | 75 300 | Mining Completed (Dec-2018 to August 2019) | | |
| 2 | No.4 and 2 seams | 1519- 1534 | 16 - 32 | 42 100 | Jan-20 | Oct-20 | 10 |
| 2A | No.4 and 2 seams | 1509 - 1512 | 37 - 41 | 17 300 | Oct-20 | Mar-21 | 6 |
| 3 | No.4, 2 and 1 seams | 1518 - 1525 | 10 - 21 | 61 700 | Mining Completed (Jun-2018 to Nov-2018) | | |
| 4 & 4A | No. 2 and 1 seams | 1493 - 1503 | 28 to 47 | 107696,7 | Nov-22 | Oct-23 | 12 |
| 5 | No. 4 seam | 1530 - 1535 | 11 - 38 | 222 500 | Jan-24 | Apr-25 | 16 |
| 6 | No. 4 Seam | 1532 - 1542 | 16 - 36 | 697 100 | Jan-22 | Dec-23 | 24 |

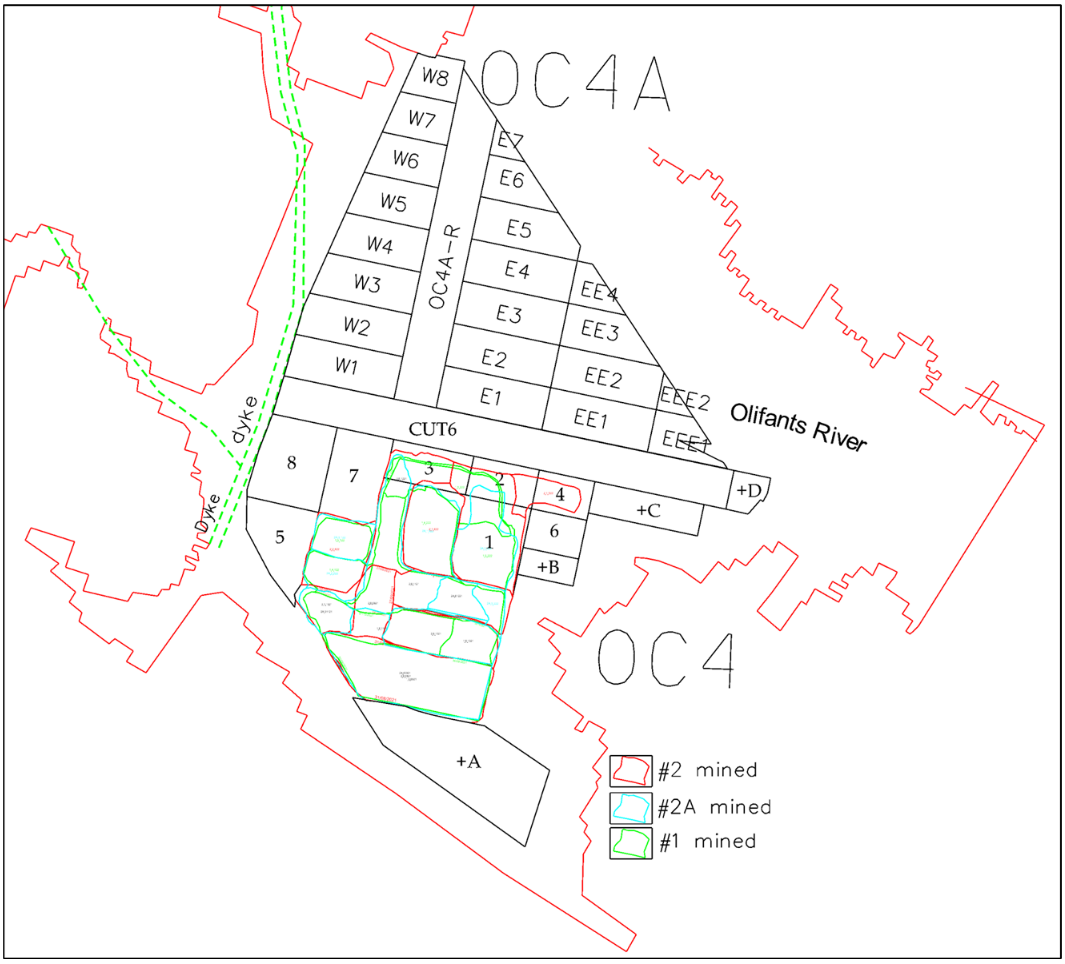



**Figure 1-1: Plan of the remaining reserves on OC4 and OC4A (Elemental Sustainability, 2022)**

## 1.3 The layout of this report

The report has been structured, as far as possible, as per Annexure D of the Government Gazette (GN267 of 24 March 2017) applicable to geohydrological studies for environmental impacts assessment/water use license applications. The specialist Appendix in terms of the NEMA EIA regulation has been taken into account as the report supports both the WULA and the NEMA EA.

## 1.4 Study relevance to the season in which it was undertaken

This study was undertaken as a once-off study, and relies on historical/current water monitoring, hydrological, geohydrological and climate data for the site; as well as recognised hydrological, geohydrological and water resource databases for South Africa. Data generated during the time of this study is not seasonally bound, as average yearly data was applied where required and as scientifically acceptable.

## 1.5 Limitations

The following limitations are recognised:

- No exploration drilling was undertaken for this study. Available borehole log data, specialist reports for the study area and literature data for the lithological occurrences in the area were used to supplement the geohydrological conceptual model for the site. The literature review filled the drilling gap. Moreover, the gaps in lithostratigraphy and geohydrological information would be further addressed during the establishment of the proposed monitoring boreholes at the site (refer to Section 4.4.2).

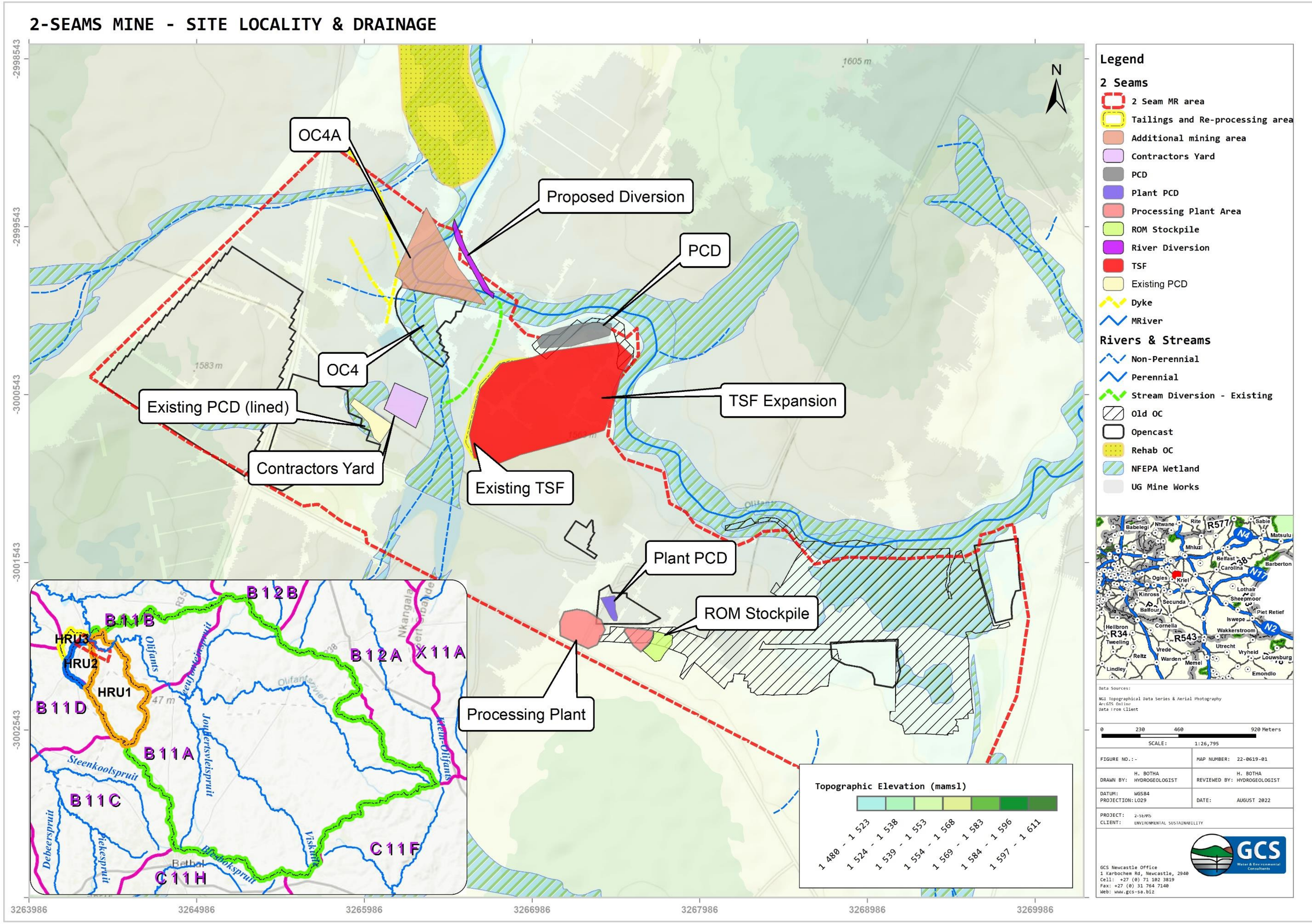



Figure 1-2: Site locality & drainage

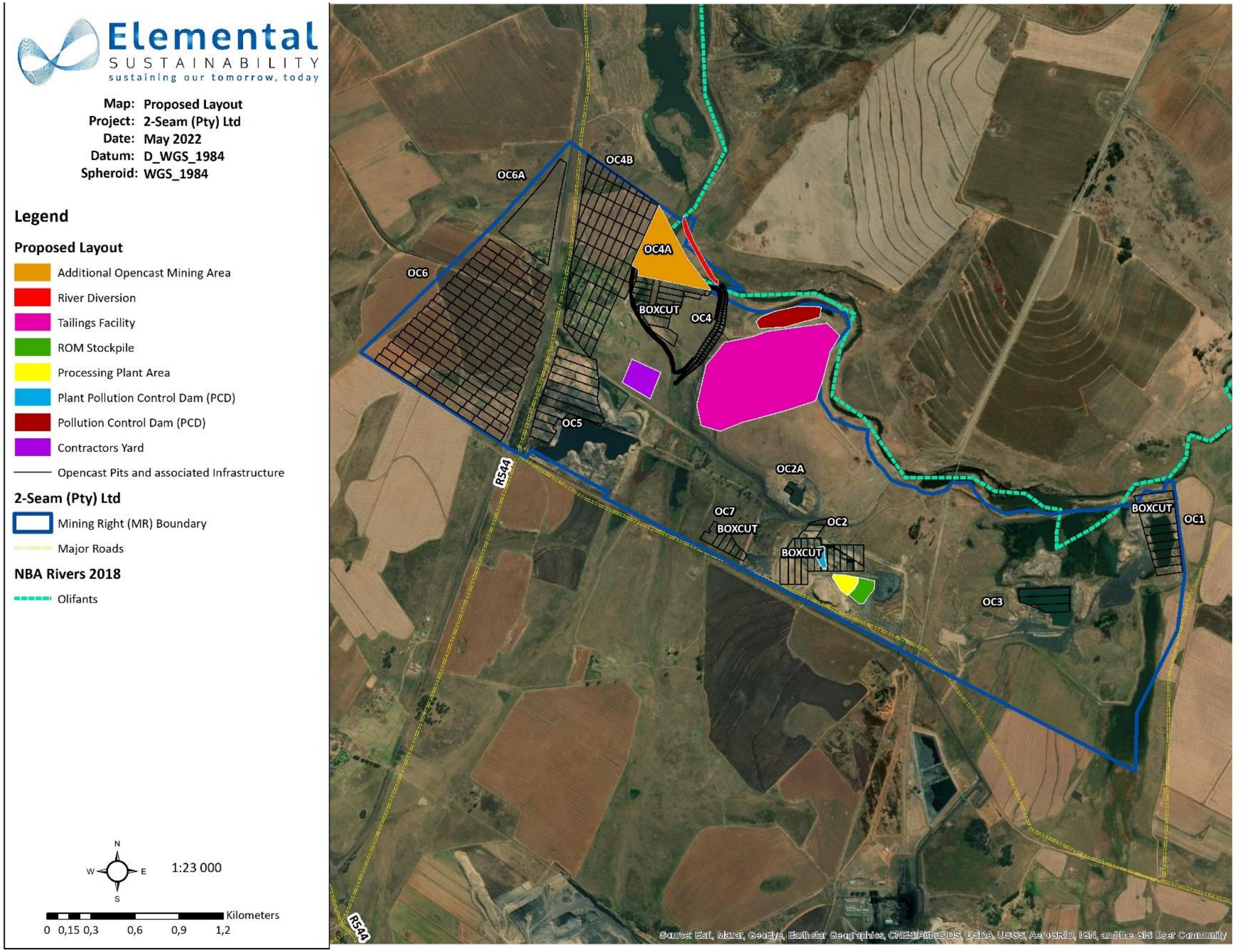



**Figure 1-3: Site layout plan and proposed mine expansion area (Elemental Sustainability, 2022)**

# 2 AREA OF INVESTIGATION

The following section supplies a brief overview of the regional setting, topography, climate, and geological and soil occurrences in the project area. The information in this section was obtained from the public domain, fieldwork and reports for the project.

## 2.1 Sub-catchments / hydrological response units (HRUs)

The site is situated along the western bank of the Olifants River, about 12km northeast of the Town of Kriel, in Mpumalanga Province. The mine falls within quaternary catchment B11B of the Olifants Water Management Area (DWS, 2016) (WMA 2). Based on the topography of the area, natural drainage will be towards the north-east of the mine (entire mining right area), where drainage will confluence with the Olifants River in a north direction. Elevations on the site typically range from 1530 to 1600 metres above mean sea level (mamsl).

Three (3) sub-catchments (HRUs) (1:10 000 stream count, 30m DTM fill) were delineated for the project area – refer to Figure 1-2. The sub-catchments describe the drainage from the 2-Seams mine, as well as surrounding mines, which fall in the same drainage area. As such, the combined extent of HRU1 to HRU3 can be considered the sphere of groundwater influence and forms the geohydrological boundaries for the project area. Drainage associated with the Olifants River is from a larger sub-catchment extending over the boundaries of quaternary B11B to B11A. The combined surface area for HRU1 (78.22 $km^2$), HRU2 (19.97 $km^2$) and HRU3 (8.15 $km^2$) associated with the project is in the order of 106.34 $km^2$.

## 2.2 Historical mining and surrounding land use

Surrounding land use consists mainly of large-scale agricultural and mining activities. Although only limited information is available on surrounding mining activities; the Project area is bordered by the following mining activities to the best of our knowledge and available information:

- Universal Coal Development New Clydesdale Colliery (NCC) VKS underground workings situated to the west and north-west – mining of the No. 2 Seam. The underground workings were active between ~1948 and February 2007 (GCS, 2012).
- Exxaro Coal (Pty) Ltd Dorstfontein West and East Colliery (DCM) to the south – opencast and underground mining of the No. 4 and No. 2 Seams.
- TNC Colliery – a defunct mine historically mined by opencast (No. 2 and 4 Seams) (north-west of the project area) and underground methods including bord and pillar and stooping (No. 2 seam) (underlying the study area).
- Phoenix and Douglas underground mines situated west and north-west, respectively, of the project area – predominantly targeted the No. 2 Seam (GCS, 2012).
- Historical opencast mining immediately south of the proposed 2 Seam Mine OC5 (2014-2016).

## 2.3 Climate

Climate, amongst other factors, influences soil-water processes. The most influential climatic parameter is rainfall. Rainfall intensity, duration, evaporative demand and runoff were considered in this study to indicate rainfall partitioning within the project area.

### *2.3.1 Temperature*

The average yearly temperature (refer to Figure 2-1) for the project area ranges from 18 to 33 C (high) and -4 to 2 °C (Low). The study area is situated in a subtropical highland climate (Cwb) area, as per the Köppen Climate Classification (Kottek, et al., 2006). The project area receives summer rainfall.

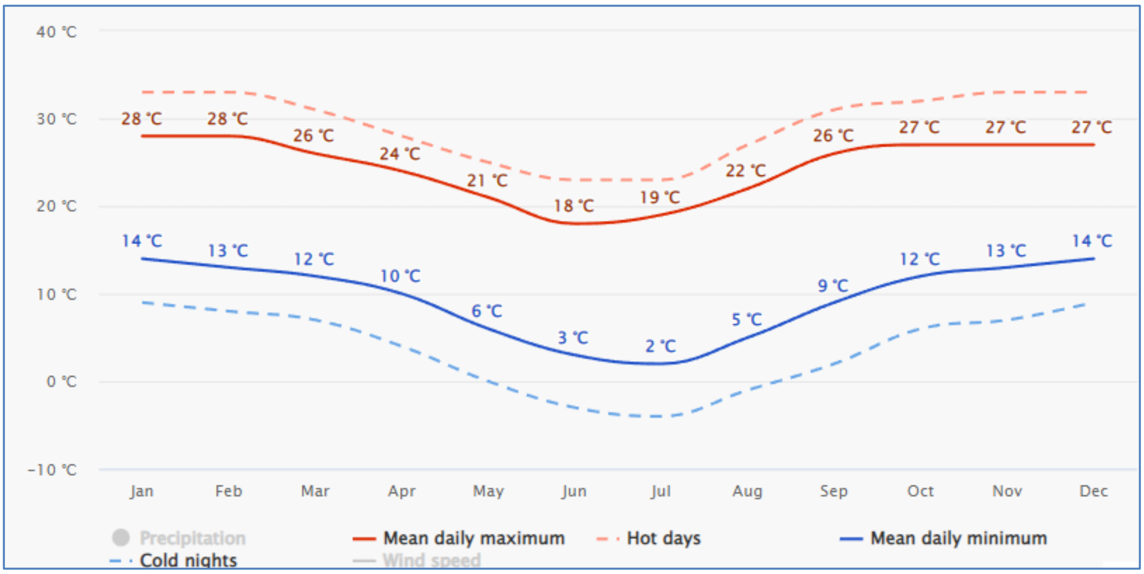



**Figure 2-1: Average yearly temperatures (Meteoblue, 2022)**

### *2.3.2 Wind speed and direction*

Figure 2-2 shows the wind rose for the project area (Kriel used as reference) and presents the number of hours per year the wind blows from the indicated direction. The wind blows from NW, WNE, W, NNW, ENE and E, at velocities ranging > 19- 28 km/hr; and from other directions but less frequently and at lower velocities (<19 km/hr). Precipitation intensity during wind will likely cause precipitation intensity changes on slopes perpendicular to the wind direction, throughout the year.

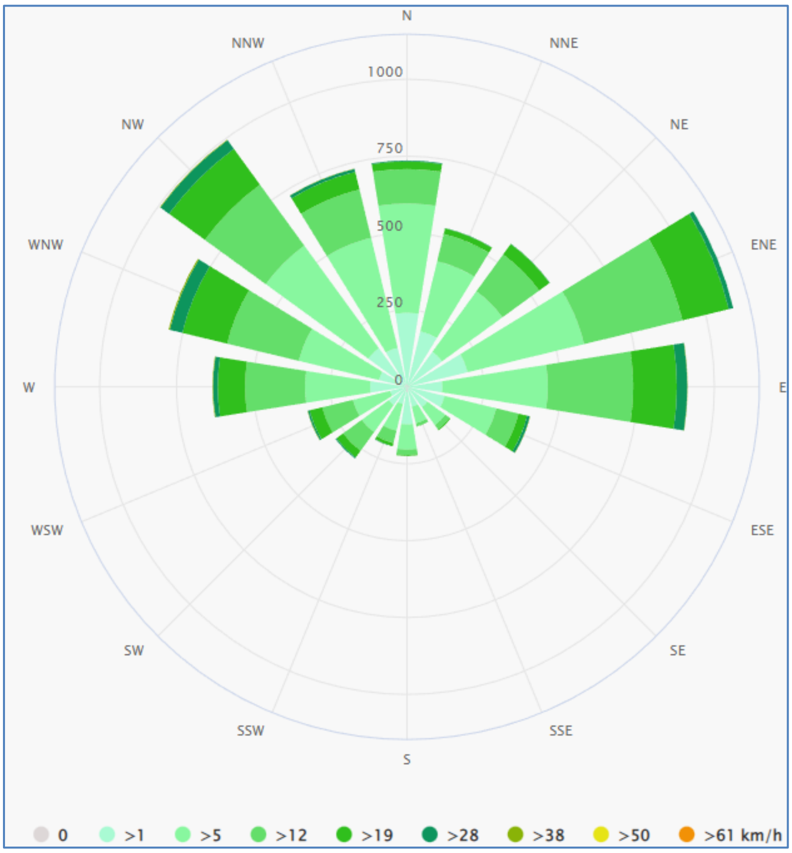
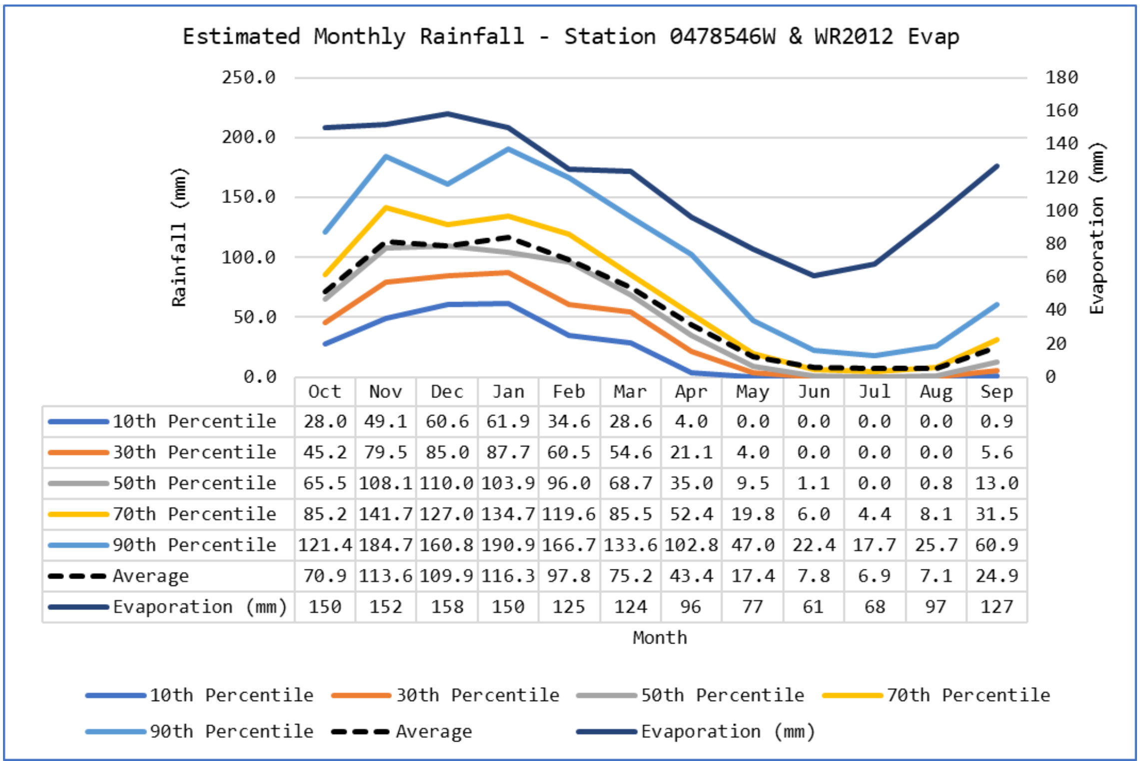



**Figure 2-2: Wind rose (Bailey & Pitman, 2015)**

### *2.3.3 Rainfall and evaporation*

The project area is situated in rainfall zone B1A. The monthly rainfall data used to calculate Mean Annual Precipitation (MAP) was obtained from rainfall station 0478546W. The rainfall record is for the period 1928 to 2003 (75 years). Monthly rainfall for the site is likely to be distributed as shown in Figure 2-3, below.

Available rainfall data suggest a MAP ranging from 443 ($30^{th}$ percentile) to 1234 ($90^{th}$ percentile) mm/yr. The average rainfall is in the order of 691.2 mm/yr. The project area falls within evaporation zone 4A, of which Mean Annual Evaporation (MAE) ranges from 1 300 to 1 400 mm/yr. The MAE far exceeds the MAP for the site, which implies greater evaporative losses when compared to incident rainfall. Monthly evapotranspiration for the site is likely to be distributed as shown in Figure 2-3, below.

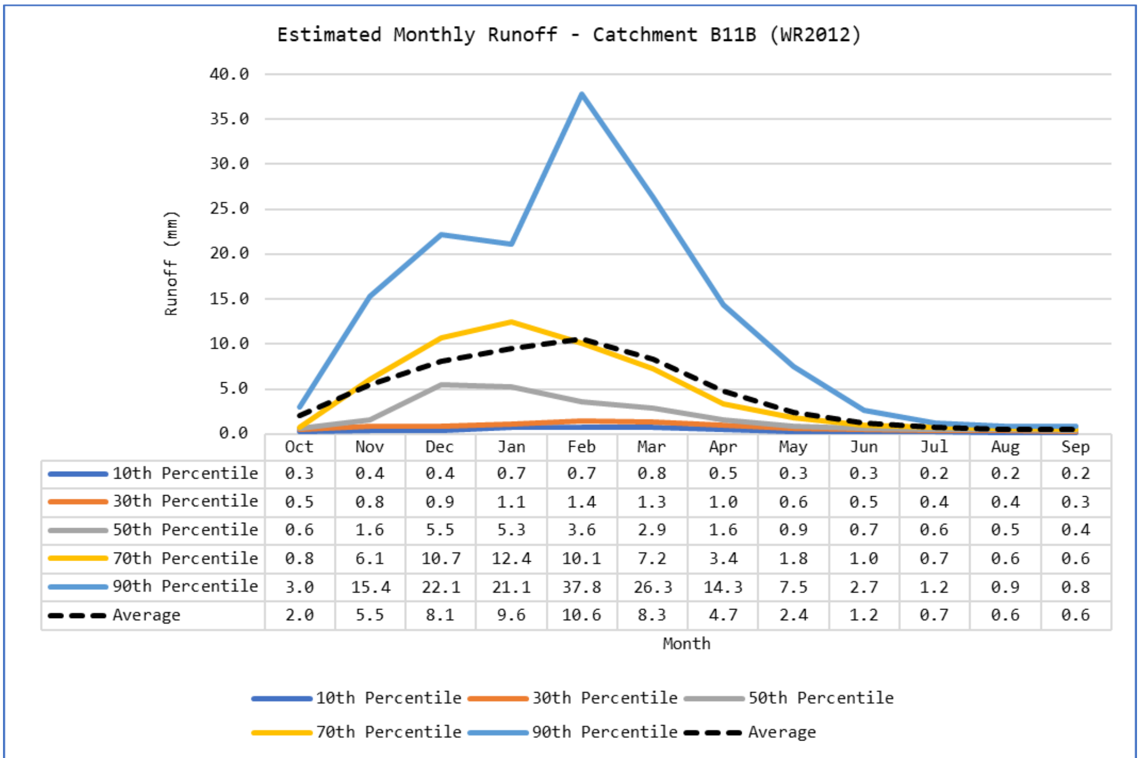



| | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10th Percentile | 28.0 | 49.1 | 60.6 | 61.9 | 34.6 | 28.6 | 4.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.9 |
| 30th Percentile | 45.2 | 79.5 | 85.0 | 87.7 | 60.5 | 54.6 | 21.1 | 4.0 | 0.0 | 0.0 | 0.0 | 5.6 |
| 50th Percentile | 65.5 | 108.1 | 110.0 | 103.9 | 96.0 | 68.7 | 35.0 | 9.5 | 1.1 | 0.0 | 0.8 | 13.0 |
| 70th Percentile | 85.2 | 141.7 | 127.0 | 134.7 | 119.6 | 85.5 | 52.4 | 19.8 | 6.0 | 4.4 | 8.1 | 31.5 |
| 90th Percentile | 121.4 | 184.7 | 160.8 | 190.9 | 166.7 | 133.6 | 102.8 | 47.0 | 22.4 | 17.7 | 25.7 | 60.9 |
| Average | 70.9 | 113.6 | 109.9 | 116.3 | 97.8 | 75.2 | 43.4 | 17.4 | 7.8 | 6.9 | 7.1 | 24.9 |
| Evaporation (mm) | 150 | 152 | 158 | 150 | 125 | 124 | 96 | 77 | 61 | 68 | 97 | 127 |

**Figure 2-3: Average rainfall for Station 0478546W & WR2012 evaporation**

### *2.3.4 Runoff*

Runoff from natural (unmodified) catchments for quaternary catchment W11B is simulated in WR2012 (WRC, 2015) as being equivalent to 54.3 mm/yr (or 8% of the MAP). This is approximately 23.65 $Mm^3$/yr NMAR for the surface area of W11B.




| | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10th Percentile | 0.3 | 0.4 | 0.4 | 0.7 | 0.7 | 0.8 | 0.5 | 0.3 | 0.3 | 0.2 | 0.2 | 0.2 |
| 30th Percentile | 0.5 | 0.8 | 0.9 | 1.1 | 1.4 | 1.3 | 1.0 | 0.6 | 0.5 | 0.4 | 0.4 | 0.3 |
| 50th Percentile | 0.6 | 1.6 | 5.5 | 5.3 | 3.6 | 2.9 | 1.6 | 0.9 | 0.7 | 0.6 | 0.5 | 0.4 |
| 70th Percentile | 0.8 | 6.1 | 10.7 | 12.4 | 10.1 | 7.2 | 3.4 | 1.8 | 1.0 | 0.7 | 0.6 | 0.6 |
| 90th Percentile | 3.0 | 15.4 | 22.1 | 21.1 | 37.8 | 26.3 | 14.3 | 7.5 | 2.7 | 1.2 | 0.9 | 0.8 |
| Average | 2.0 | 5.5 | 8.1 | 9.6 | 10.6 | 8.3 | 4.7 | 2.4 | 1.2 | 0.7 | 0.6 | 0.6 |

**Figure 2-4: Simulated natural (unmodified) runoff for W11B**

# 3 SCOPE OF WORK

The scope of work completed was as follows:

1. Desktop study and Data Review:
    a. All available groundwater monitoring data, previous studies conducted by GCS, and other site-specific reports made available for this study were assessed. Data were extracted from the reports to establish groundwater quality and quantity conditions. Subsequently, data were assimilated for numerical application.
    b. A desktop-level hydrocensus was completed for the study area. The latest National Groundwater Archive (NGA, 2021) and groundwater resource information project (GRIP, 2016) data were assessed.
2. Field investigation:
    a. A site walkover survey was undertaken to identify potential sensitive surface-groundwater areas was completed;
    b. A hydrocensus (within a 2.5 km radius of the proposed underground and opencast areas – and in the sub-catchment associated with the site) was undertaken in the study area to identify groundwater users.
    c. Several geophysical profile lines (magnetic methods) were conducted to confirm the presence and orientation of dolerite dykes at the site. The data was used to determine future monitoring of borehole drilling positions and to supplement the numerical model and risk assessment.
    d. Water sampling of hydrocensus boreholes was conducted to gather groundwater quality data for hydrocensus boreholes identified in the field.
    e. Several slug tests were conducted on selected boreholes, to confirm aquifer parameters.
    f. All field data were evaluated and interpreted per best practice guidelines.
3. Hydrogeological and geological conceptual Model development:
    a. Hydrogeological, geochemical and geological conceptual models were developed for the site – based on the data gathered for the site.
    b. A site conceptual model was developed in support of the numerical groundwater flow and transport model.
4. Groundwater numerical flow and transport modelling:

   a. A numerical model grid was developed and the flow model was calibrated to the existing setting (for the year 2022) with available data for the study (transient state);
   b. Scenario modelling was undertaken to evaluate the flow system and impact on the receiving environment and decant potential if the stream diversion is implemented (50 and 100Y).

5. Hydrogeological risk assessment:
   a. The source-pathway-receptor (SPR) principle was applied to the site, along with the conceptual site model and numerical model outputs to evaluate hydrogeological risk. The aim was to assess:
      i. Preferential groundwater flow paths;
      ii. Decant areas and decant quantities & qualities;
      iii. Impact on groundwater baseflow to the Olifants River; and
      iv. Impact on the water quality of the Olifants River.

6. Monitoring plan:
   a. The existing groundwater monitoring network was reviewed, and a gap assessment was undertaken.
   b. Geophysical data gathered during this investigation was also assessed to site future groundwater monitoring boreholes, that can be used to improve the monitoring system.

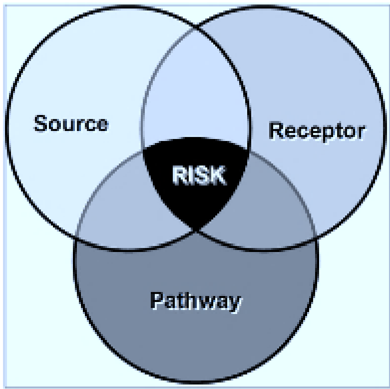
7. Reporting:
   a. A geohydrological report encompassing all work done as well as a preliminary groundwater risk assessment and monitoring plan were compiled.

# 4 METHODOLOGY & APPROACH

The study followed a logical and holistic approach, whereby all existing and new hydrogeological data for the site were assessed (limited to accessible public, GCS internal reports and reports shared with GCS by the client). A systematic phased approach was followed to adhere to the objectives and agreed-upon scope of work for the assessment. The tasks were subdivided into different project phases, as presented in Table 4-1.

A logical and holistic approach was adopted to assess the study area. The Best Practice Guidelines for Impact Prediction (G4) (DWAF, 2008), were considered to define and understand the three basic components of the hydrogeological risk (also referred to as "SPR"):

- S**ource term** - The source of the risk (i.e. operational risk associated with the activities at the site);
- **Pathway** - The pathway along which the risk propagates (i.e. percolation to the groundwater aquifer or overland runoff); and
- **Receptor** - The target that experiences the risk (i.e. water bodies or groundwater users).

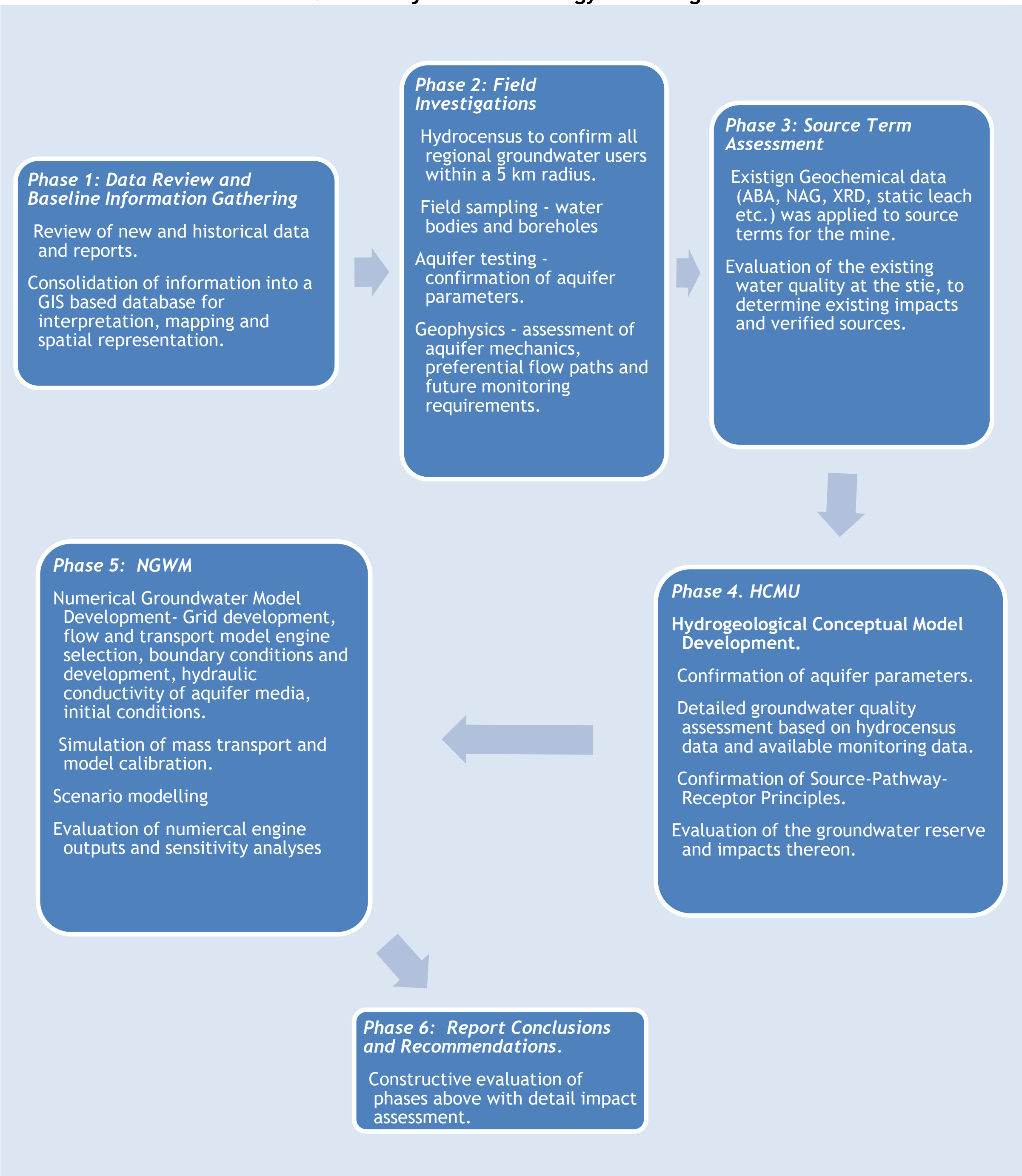



The approach was used to assess:

1. How the existing site activities have impacted groundwater *Quality*; and
2. How the existing site activities have affected the groundwater *Quantity*.

Subsequently, a groundwater model was developed to illustrate the conceptual understanding of the groundwater flow system. Groundwater modelling is an efficient tool for groundwater management and remediation. Models are a simplification of reality to investigate certain phenomena or to predict future behaviour. The challenge is to simplify the reality in a way that does not adversely influence the accuracy and ability of the model output to meet the intended objectives. In terms of quality control, the Australian Groundwater Modelling Guidelines (Barnett, et al., 2012) were considered to ensure that the numerical model adheres to international norms and standards.

**Table 4-1: Project methodology flow diagram**



## 4.1 Literature review and desktop study

The following sources supply an overview of the hydrogeological conditions of the project area, as per the desktop information reviewed for this assessment:

- Site-specific specialist reports:
    - 2 Seam (Pty) Ltd Colliery – Vlaklaagte JS 45 Farm (2019a) Geohydrological Report for the inputs to the WULA. (Eco Elementum).
    - 2 Seam (Pty) Ltd Colliery – Vlaklaagte JS 45 Farm (2019b) Water Balance Update and Pollution Control Dam Status Quo. (Eco Elementum).
    - 2 Seam (Pty) Ltd Vlaklaagte Mine (2016) Hydrogeological Assessment (GCS).
    - 2 Seam (Pty) Ltd Vlaklaagte Mine (2018) Hydrogeological Assessment Update (GCS).
    - Exxaro Coal (Pty) Ltd. (2012) New Clydesdale Colliery Hydrogeological Study (GCS).
    - Exxaro Coal (Pty) Ltd. (2015) Dorstfontein West Hydrogeological Investigation (GCS).
    - Exxaro Coal (Pty) Ltd (2015) Dorstfontein Hydrogeological Investigation (GCS)
    - TNC – defunct mine historically mined by opencast and underground methods.
    - Anglo American 2015. Goedehoop Colliery, Hope No. 4 Seam Project - Environmental Impact Report (EIR) and Environmental Management Programme (EMPr).
    - 2 Seam Pty Ltd Mines (Pty) Ltd., 2012. Vlaklaagte, TNC Village Coal Mine Groundwater Impact Assessment - Amendment to EMP.
    - Seam (Pty) Ltd Vlaklaagte Mine: Opencast OC4 Hydrogeological Assessment (GCS, 2020).
- SADC Groundwater Information Portal (SADC GIP) borehole data (SADC GIP, 2022).
- National groundwater archive borehole data (NGA, 2022).
- 2526 Johannesburg – 1:500 000 Hydrogeological map series (King, 1998)
- 2628 East Rand – 1:250 000 Geological map series (DMEA, 1998f)
- Literature on similar geology and hydrogeology:
    - A South African Aquifer System Management Classification (Parsons, 1995);
    - Aquifer Classification of South Africa (DWA, 2012);
    - The relationship between South African geology and geohydrology (Lourens, 2013).

## 4.2 Hydrological overview

Hydrometeorological data for the study area were obtained from various sources including the South African Water Resources Study WR2012 database (Bailey & Pitman, 2015), South African Atlas of Agrohydrology, and Climatology (Schulze, 1997), and the Daily Rainfall Data Extraction Utility (Lynch, 2004). Moreover, sources such as the Köppen Climate Classification (Kottek, et al., 2006), World Climate Data CMIP6 V2.1 (Eyring, 2016), and Meteoblue (Meteoblue, 2022) were used to refine hydrological data.

These sources provided means of determining the Mean Annual Precipitation (MAP), Mean Annual Runoff (MAR), and Mean Annual Evaporation (MAE) of the study site as well as the design rainfall data. Data was applied to the site water balance calculations, groundwater recharge calculations, runoff peak flow estimates for flood line modelling and stormwater runoff peak flow estimates for stormwater system sizing (where applicable to this study).

## 4.3 Desktop hydrocensus

A review of SADC GIP (2022) data for the study area indicates that there are fifteen (15) boreholes within a 5km radius of the site. The groundwater users identified are listed in Table 4-2 and their positions are shown in Figure 4-5. The boreholes are concentrated towards the north of the site, with a few falling in the existing mining right area and south of the mine. Only water level data is available for the boreholes identified.

**Table 4-2: Boreholes identify within a 10km radius of the site**

| ID | Source | Latitude (WGS84) Decimal Degrees | Longitude (WGS84) Decimal Degrees | Elevation (mamsl) | Water Level (mbgl) |
|---|---|---|---|---|---|
| 712910 | SADAC GIP | -26.14606 | 29.33912 | 1537.744 | 3.5 |
| 712911 | SADAC GIP | -26.14246 | 29.34413 | 1532 | 3.1 |
| 712912 | SADAC GIP | -26.14826 | 29.34413 | 1531.174 | 3.8 |
| 712913 | SADAC GIP | -26.14736 | 29.34673 | 1536.472 | 4 |
| 712914 | SADAC GIP | -26.14246 | 29.34573 | 1534.383 | 0 |
| 712915 | SADAC GIP | -26.14016 | 29.33862 | 1532.008 | 7.9 |
| 712916 | SADAC GIP | -26.17666 | 29.36333 | 1535.612 | 6.5 |
| 712917 | SADAC GIP | -26.17716 | 29.36133 | 1538.272 | 17.3 |
| 712930 | SADAC GIP | -26.24222 | 29.42473 | 1679.941 | 9.1 |
| 712934 | SADAC GIP | -26.21726 | 29.43306 | 1617.111 | 9.1 |
| 712941 | SADAC GIP | -26.15056 | 29.30805 | 1581.983 | 7.6 |
| 712954 | SADAC GIP | -26.17554 | 29.41971 | 1544.143 | 6.1 |
| 712964 | SADAC GIP | -26.12579 | 29.42191 | 1621.955 | 5.2 |
| 713511 | SADAC GIP | -26.26728 | 29.34972 | 1639 | 8.8 |
| 679093 | SADAC GIP | -26.16723 | 29.4714 | 1598.218 | 10.4 |

## 4.4 Hydrocensus and field investigation

The following section summarises the fieldwork completed at 2-Seams, as part of this hydrogeological investigation. A field hydrocensus within a 2.5km radius of the site and a geophysical investigation to identify preferential groundwater flow paths in the area. Moreover, several slug tests were conducted on suitable boreholes to update hydraulic aquifer parameters for the site. Water quality samples were collected to illustrate the ambient water quality.

### *4.4.1 Field hydrocensus*

GCS conducted a field hydrocensus exercise from the 11th and the 12th of July 2022 within 2.5 kilometres of the opencast mine; with the objective of:

- Obtain up-to-date hydrogeological data, i.e. groundwater levels and hydrochemistry data;
- Identify boreholes that had not been previously recorded; and
- Assess the status and adequacy of the existing boreholes and confirm any information gaps in the field.

During the hydrocensus field investigation, the following borehole information was recorded/confirmed:

- Identify/update all water users within the surrounding area;
- Borehole locality (coordinates using a hand-held global positioning system – GPS);
- Borehole status (incl. equipment) and construction details;
- Static water level; and
- Obtain groundwater samples from five (5) boreholes (hydrochemistry data).

The results of the hydrocensus boreholes are in Table 4-5, while their spatial distribution is shown in Figure 4-6. A photographic log of the boreholes identified is available in **Appendix A**. Due to the expansion of the mining activities, previously identified hydrocensus boreholes (BH-EM14, BH-EM16, BHX3, BH-09, BHX-1, BH2, and BH-EM22) have been destroyed. The areas where the boreholes were located are currently being mined.

GCS did however manage to visit a total of fourteen (14) boreholes around and on the site. Ten (10) of the 14 boreholes were accessible for groundwater level measurements, with one of the boreholes (NBH02) fitted with a locked borehole cap, and borehole DFBH was located behind a locked gate therefore, the static water level could not be measured. The measured static water levels ranged between 1.12 to 30.56 mbgl.

### *4.4.2 Geophysical investigation*

Four (4) magnetic traverses were conducted at the site and the profile start, end and target structures are summarised in Table 4-3. The main objective of the geophysical survey was to determine the location of geological structures that could be associated with subsurface fracturing and weathering near the proposed river diversion site. The Geophysical survey was conducted on the 12th of July 2022. The detailed geophysical investigation methodology and data interpretation are available in **Appendix A**.

The contrast in magnetic susceptibility and/or remnant magnetism gives rise to anomalies related to structures like intrusive dykes, faults, lithologic contacts, and weathered/ fractured bedrock. The magnetic survey methods are useful in identifying intrusive dykes such as the diabase dykes that were the main targets for the geophysical survey.

The result from the geophysics indicates a magnetic low on Line 1 at 200m and Line 2 at 320m. This could indicate the presence of a dyke running through the site from northwest to southeast direction. Line 4A and Line 4B were conducted with the start of each line opposite the other line. Line 4A indicates a low magnetic at 395m and Line 4B indicates a low magnetic at 200m, this could indicate a possible dyke.

**Table 4-3: Summary of magnetic traverse conducted**

| Traverse Number | Traverse Direction | Coordinates | | | | Traverse Length [m] | Geological Target |
|---|---|---|---|---|---|---|---|
| | | Traverse Start | | Traverse End | | | |
| | | Latitude [DD] | Longitude [DD] | Latitude [DD] | Longitude [DD] | | |
| Line 1 | SE-NE | -26.157399 | 29.341658 | -26.15542 | 29.345425 | ~430 | Lineament (dyke) and fracturing. |
| Line 2 | SE-NE | -26.157661 | 29.341631 | -26.158034 | 29.346627 | ~510 | Lineament (dyke) and fracturing. |
| Line 4A | SE-NE | -26.158412 | 29.3388 | -26.155142 | 29.342775 | ~510 | Lineament (dyke) and fracturing. |
| Line 4B | SE-NE | -26.155197 | 29.34284 | -26.158289 | 29.339052 | ~520 | Lineament (dyke) and fracturing. |
| ***Note/s:*** | | | | | | | |
| Unit and coordinate system description: | | | | | | | |
| · [DD] - decimal degrees | | | | | | | |
| · [m] - metres | | | | | | | |
| Datum: *WGS84* | | | | | | | |

### *4.4.3 Slug testing/falling head tests*

Slug tests were used to estimate the hydraulic parameters of the existing boreholes in the study area. Four (4) boreholes were subjected to a slug test with a 60min duration. The slug had dimensions of 2m long and a diameter of 90mm. The water level response over time was then recorded manually by taking water level measurements with a dip meter. The results were then analysed using the AQTESOLV software to estimate the hydraulic conductivity (K) and transmissivity (T) of each borehole. The results of the tests can be seen in Table 4-4 and the location of the tested boreholes is shown in Figure 4-6. The Bouwer and Rice mathematical model was applied to the slug test data gathered to derive aquifer hydraulic permeability (refer to Figure 4-1 to Figure 4-4). The hydraulic conductivity is low for boreholes BH-5M and NBH4 indicating that flow in areas where boreholes are located is low.

**Table 4-4: Summary of slug test results**

| Slug Test | K (m/d) | K (m/s) |
|---|---|---|
| BH-5M | 0.0594 | 6.875 x 10-7 |
| BH-2M | 5.025 | 5.816 x 10-5 |
| BH4 | 2.056 | 2.379 x 10-5 |
| NBH4 | 0.06802 | 7.783 x 10-7 |

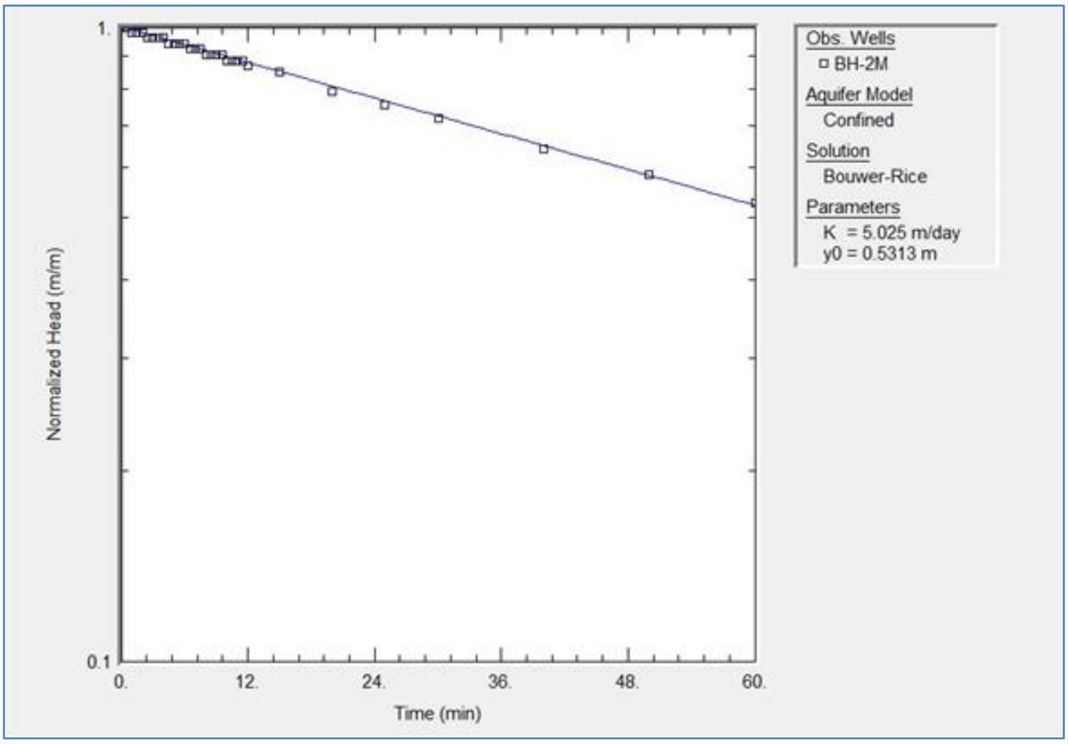



**Figure 4-1: The hydraulic conductivity for BH-2M using Bouwer and Rice Solution**

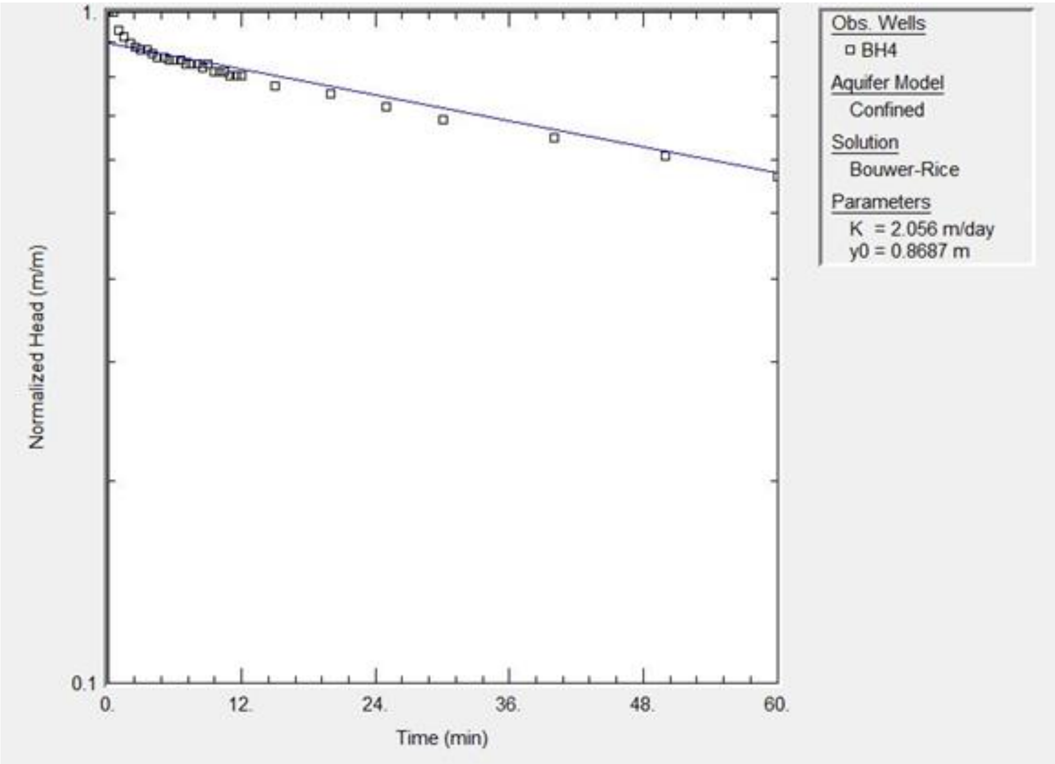



**Figure 4-2: The hydraulic conductivity for BH4 using Bouwer and Rice Solution**

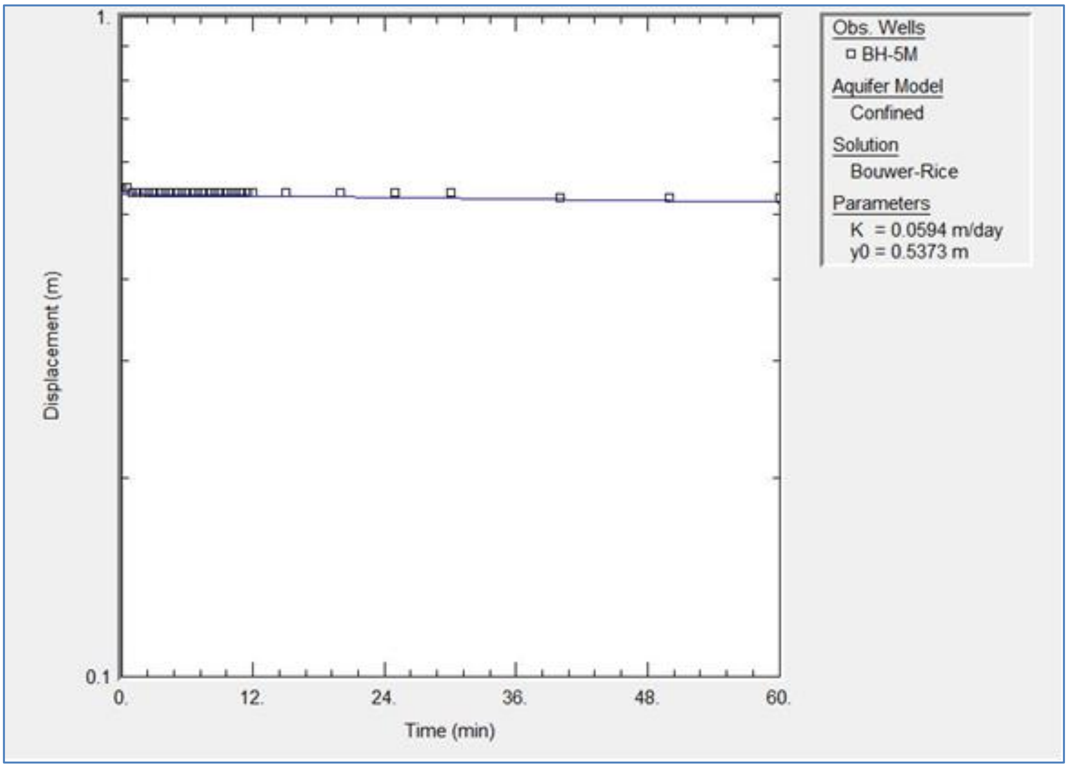



**Figure 4-3: The hydraulic conductivity for BH-5M using Bouwer and Rice Solution**

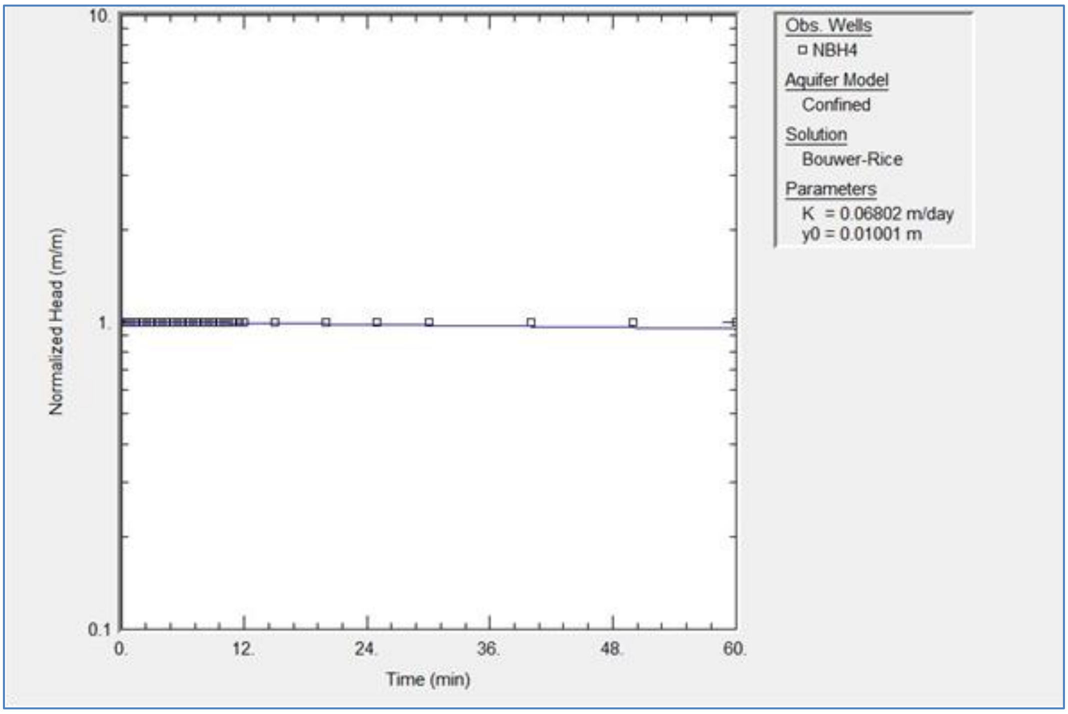



**Figure 4-4: The hydraulic conductivity for NBH4 using Bouwer and Rice Solution**

**Table 4-5: Field hydrocensus boreholes identified**

| BH ID | Coordinates (WGS84 DD) | | Property | Elevation | SWL | Borehole depth | Uses | | Equipment | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| | Latitude | Longitude | | (mamsl) | (mbgl) | (mbgl) | Irrigation | Monitoring | (Pumps) | |
| NBH3 | -29.34359 | 30.13344 | Mine | 1534 | 14.01 | 33.36 | | X | None | Old, abandoned Borehole is fitted with steel casing only and had no borehole cap |
| BH-2M | -26.15645 | 29.34175 | Mine | 1533 | 2.89 | 32.85 | | X | None | Old, abandoned Borehole is fitted with steel casing only and had no borehole cap |
| NBH5 | -26.15807 | 29.34465 | Mine | 1536 | 17.16 | 33.25 | | X | None | Old, abandoned Borehole is fitted with steel casing only and had no borehole cap |
| NBH4 | -26.16935 | 29.33416 | Private | 1564 | 30.56 | 57.40 | | X | None | Old, abandoned Borehole is fitted with steel casing only and had no borehole cap |
| DFBH | -26.17492 | 29.34407 | Private | 1547 | -- | -- | | X | None | The borehole is locked behind a locked gate |
| BH4 | -26.16235 | 29.33874 | Mine | 1543 | 4.51 | 12.91 | | X | None | Monitoring borehole with a borehole cap |
| EUB-1 | -26.15842 | 29.33632 | Mine | 1545 | 1.62 | 35.67 | | X | None | Old, abandoned Borehole is fitted with steel casing only and had no borehole cap |
| NBH5A | -26.17028 | 29.35657 | Mine | 1537 | 4.32 | 19.43 | | X | None | Old, abandoned Borehole is fitted with steel casing only and had no borehole cap |
| NBH1 | -26.15688 | 29.34527 | Private | 1540 | 7.4 | 33.1 | | X | None | Old, abandoned Borehole is fitted with steel casing only and had no borehole cap |
| NBH2 | -26.15685 | 29.34528 | Private | 1541 | 7.69 | 33.22 | | X | None | Old, abandoned Borehole is fitted with steel casing only and had no borehole cap |
| NBH02 | -26.16933 | 29.33361 | Private | 1565 | -- | 64 | | X | None | The borehole cap was locked; therefore, water level measurements could not be obtained |
| BH-5M | -26.15705 | 29.34382 | Mine | 1534 | 14.2 | 29.02 | | X | None | Old, abandoned Borehole is fitted with steel casing only and had a borehole cap |
| BH-1M | -26.1588 | 29.33255 | Mine | 1548 | 1.12 | 11.90 | | X | None | Monitoring the borehole the mine used for water level measurements |
| BH5 | -26.17065 | 29.35382 | Mine | 1543 | 10.15 | 32.74 | | X | None | Monitoring the borehole the mine used for water level measurements |

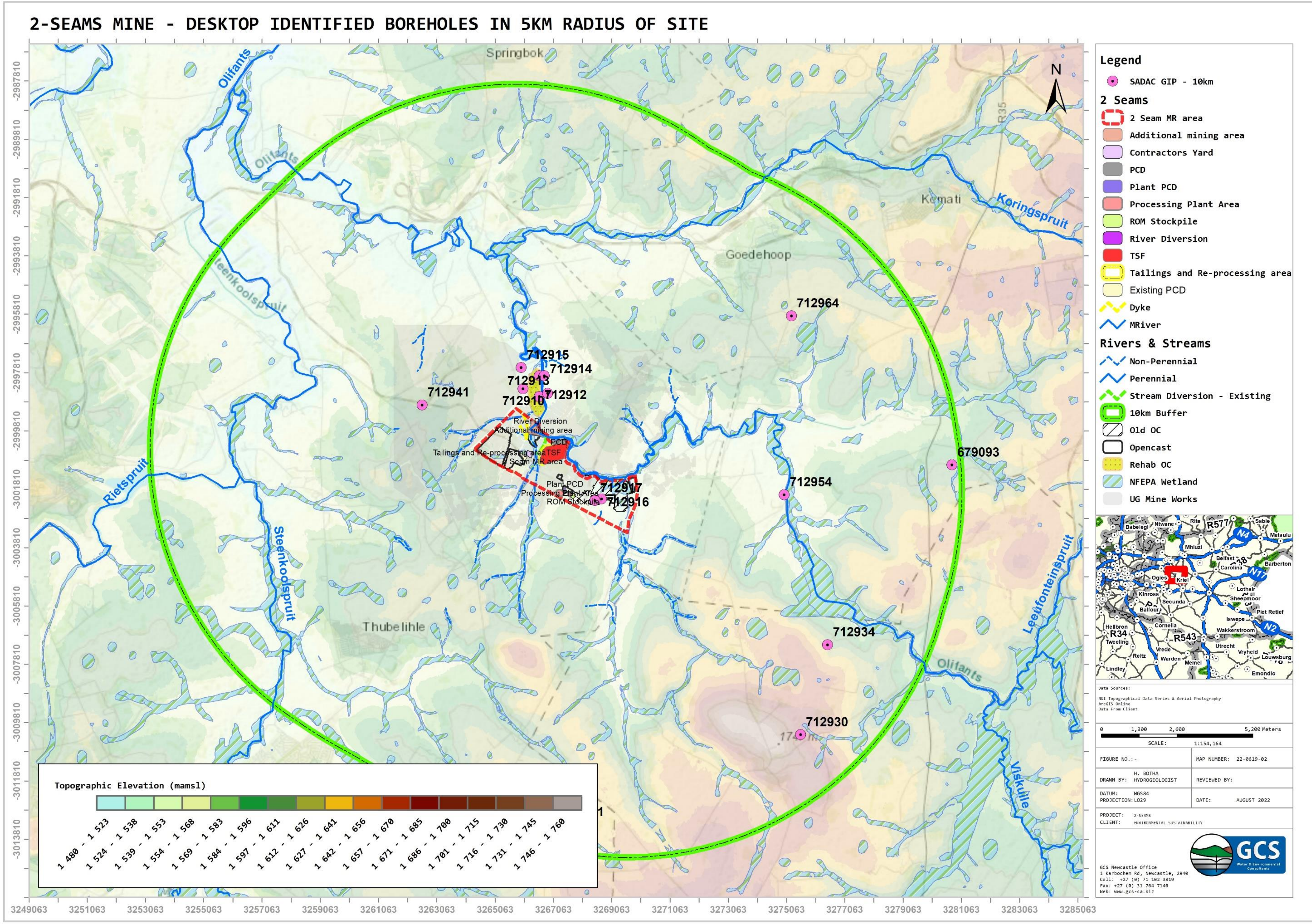



**Figure 4-5:** Spatial distribution of database boreholes within a 5km radius of the site

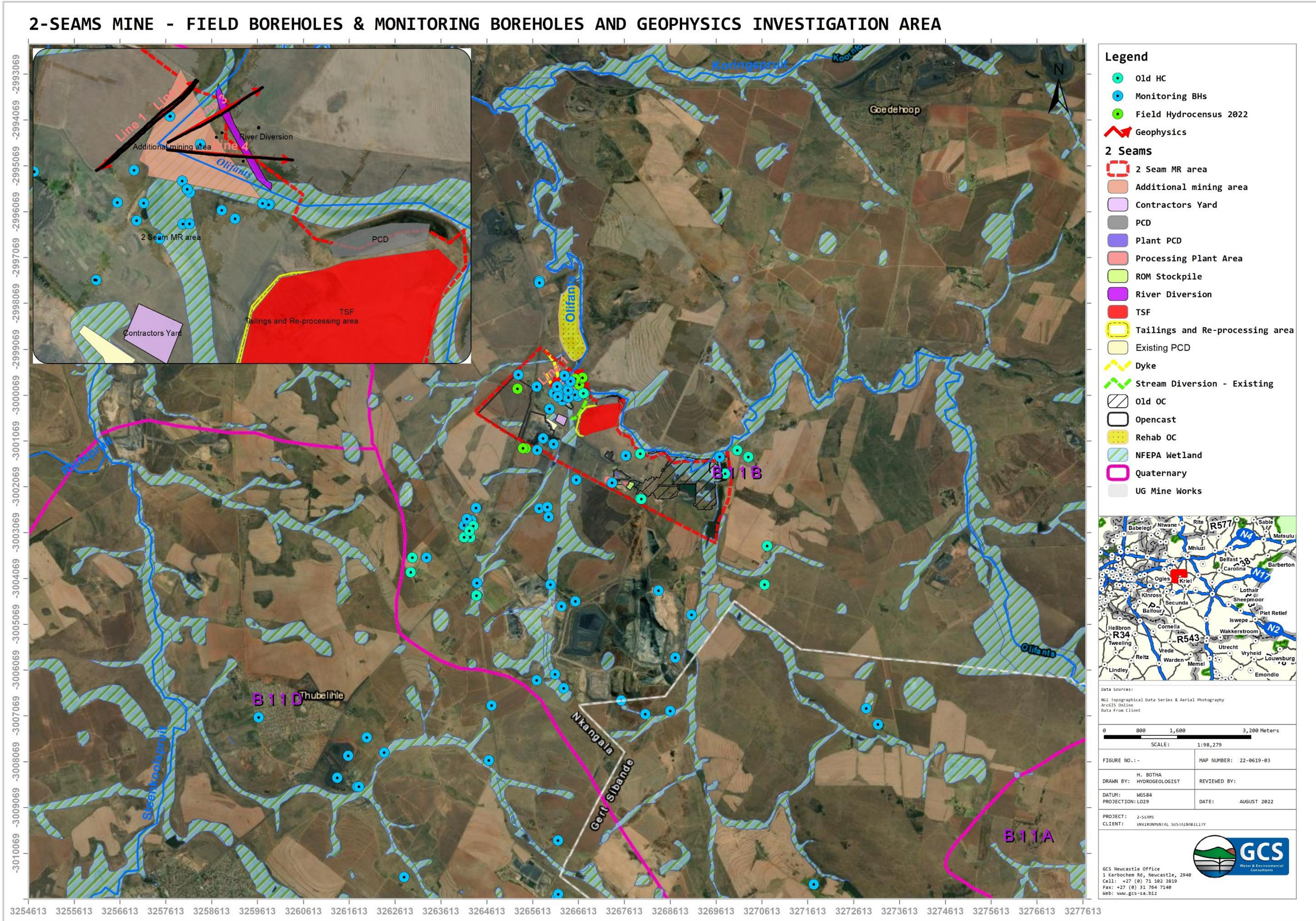



**Figure 4-6:** Spatial distribution of field boreholes identified, monitoring boreholes & geophysical investigation area

## 4.5 Groundwater recharge calculations

Recharge is defined as the process by which water is added from outside to the zone of saturation of an aquifer, either directly into a formation, or indirectly by way of another formation. The effective rainfall recharge is dependent on catchment geology, soils and surface run-off and stream morphology. Seepage from onsite infrastructure such as the return water dams and/or pollution control dams may contribute a small proportion of recharge to the system. Groundwater recharge was estimated from the literature and geohydrology maps for the study area. The groundwater recharge (Re) for the local area was also calculated using the chloride method (Bredenkamp, et al., 1995) and is expressed as a percentage of the MAP. The method is based on the following equation:

$$R = \frac{Chloride\ concentration\ in\ rainfall}{Chloride\ concentration\ in\ ground\ water}\ x\ 100 \qquad \textit{Equation 1}$$

The recharge to the aquifer was further refined and determined by running qualified guess analyses using the RECHARGE model developed by IGS.

## 4.6 Groundwater modelling

The modelling processes followed are indicated in Figure 4-7.

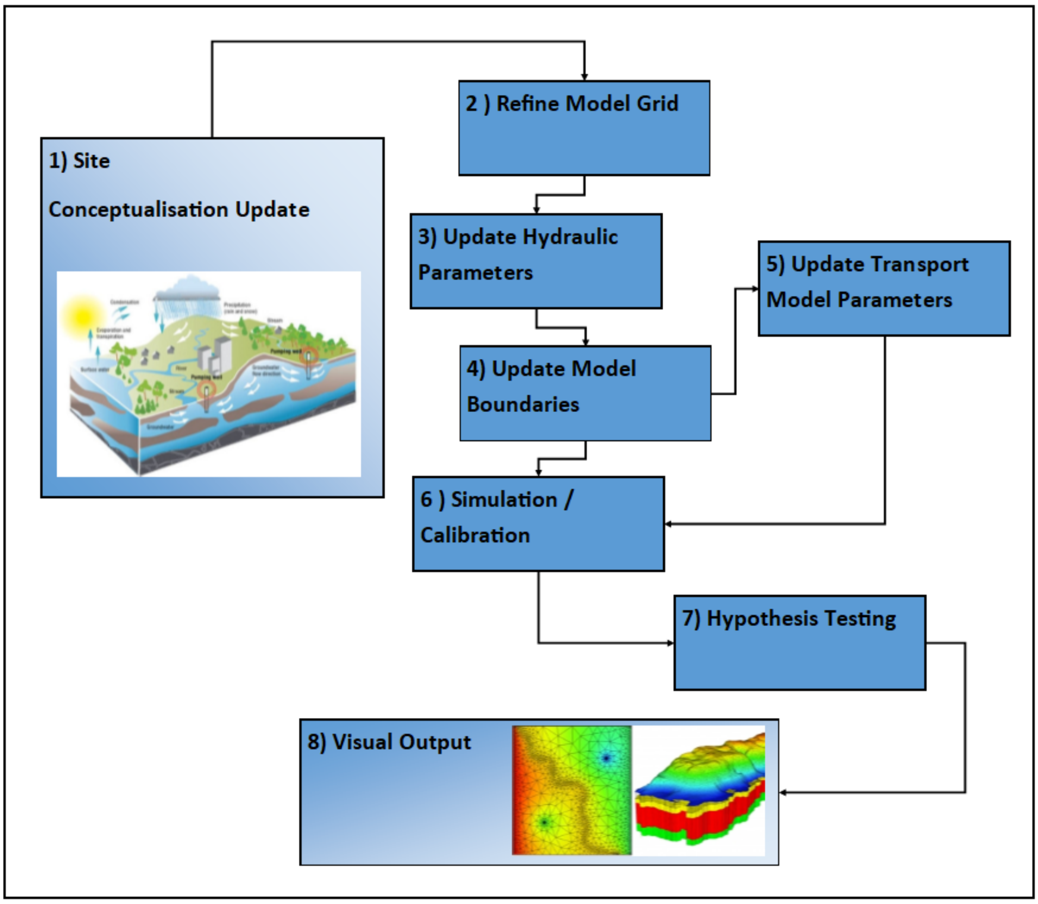



**Figure 4-7: Numerical groundwater modelling process**

### *4.6.1 Model software package*

The numerical model for the project was constructed using Visual Modflow 6.1 Pro, Build 7088.31257, a pre-and post-processing package for the modelling code MODFLOW. MODFLOW is a modular three-dimensional groundwater flow model developed by the United States Geological Survey (Harbaugh, et al., 2000). MODFLOW uses 3D finite-difference discretisation and flow codes to solve the governing equations of groundwater flow.

### *4.6.2 Governing Equations*

The numerical model used in this modelling study was based on the conceptual model developed from the findings of the desktop and the baseline investigations. The simulation model simulates groundwater flow based on a three-dimensional cell-centred grid and may be described by the following partial differential equation:

$$\frac{\partial}{\partial x}(K_{xx}\frac{\partial h}{\partial x})+\frac{\partial}{\partial y}(K_{yy}\frac{\partial h}{\partial y})+\frac{\partial}{\partial z}(K_{zz}\frac{\partial h}{\partial z})\pm W = S_s\frac{\partial h}{\partial t} \qquad \textbf{Equation 2}$$

where:

- Kxx, Kyy, and Kzz are values of hydraulic conductivity along the x, y, and z coordinate axes, which are assumed to be parallel to the major axes of hydraulic conductivity (L/T).
- h is the potentiometric head (L).
- W is a volumetric flux per unit volume representing sources and/or sinks of water,

with:

- W < 0.0 for flow out of the ground-water system, and W>0.0 for flow in (T-1).
- Ss is the specific storage of the porous material (L-1), and
- it is time (T).

Equation 2, when combined with boundary and initial conditions, describes transient three-dimensional groundwater flow in a heterogeneous and anisotropic medium, provided that the principal axes of hydraulic conductivity are aligned with the coordinate directions (Harbaugh, et al., 2000).

#### *4.6.3 Model confidence*

The Australian Groundwater Modelling Guidelines (Barnett *et al.*, 2012) refer to the following two principles that were considered in the numerical calibration process:

- **Guiding Principle 2.3:**
  - A target model confidence level classification should be agreed upon and documented at an early stage of the project to help clarify expectations. The classification can be estimated from a semi-quantitative assessment of the available data on which the model is based (both for conceptualisation and calibration), the way the model is calibrated and how the predictions are formulated.
  - GCS aimed to construct a Class 2 to 3 model. Class 2-3 models are founded on enough hydrogeological data and can be used to predict the future behaviour of a groundwater aquifer system.
- **Guiding Principle 2.4:**
  - The initial assessment of the confidence level classification should be revisited at later stages of the project, as many of the issues that influence the classification will not be known at the model planning stage.

The model confidence rating is assessed in **Appendix F**.

## 4.7 Groundwater quantity/availability assessment

An Intermediate Groundwater Reserve Determination (IGRD) was conducted for the study area to fulfil the requirements of the Water Use License with regards to groundwater use, in terms of Section 21a of the National Water Act (No. 36 of 1998). The IGRD aims to establish the groundwater reserve thereby quantifying the safe aquifer yield, which is required to determine aquifer dewatering impacts.

It is necessary, from a groundwater point of view, to quantify the groundwater quantity and likely future impacts on quantity. Moreover, the groundwater balance gives an estimate of how much groundwater can safely be abstracted on a sub-catchment level (i.e. groundwater dewatering or wellfield dewatering).

The IGRD considers the following parameters:

- Effective recharge from rainfall and specific geological conditions;
- Basic human needs for the sub-catchment;
- Groundwater contribution to surface water (baseflow);
- Existing and proposed abstraction; and
- Surplus reserve.

The groundwater balance and hence the reserve determination on a sub-catchment scale is summarised below:

- $GW_{available}$ = (Re) - (EU + BHN + BF + PU)

Where:

- $Gw_{available}$ = Available groundwater for use.
- Re = Effective recharge to the aquifer.
- BF = Baseflow to surface water streams.
- EU = Existing groundwater abstraction / use (identified on sub-catchment, excluding applicant).
- PU = proposed use / likely dewatering use.
- BHN = Basic Human Needs.

## 4.8 Geohydrological risk assessment

Each impact identified for the operational phase was assessed in terms of probability (likelihood of occurring), scale (spatial scale), magnitude (severity) and duration (temporal scale). To enable a scientific approach to the determination of the environmental significance (importance), a numerical value is linked to each rating scale.

The following criteria were applied:

- **Occurrence:**
    - Probability of occurrence (how likely is it that the impact may occur?); and
    - Duration of occurrence (how long the impact may last?).
- **Severity:**
    - Magnitude (severity) of impact (will the impact be of high, moderate or low severity?); and
    - Scale/extent of impact (will the impact affect the national, regional or local environment or only that of the site?).

The impact assessment rankings used are listed in Table 4-6. The significance of the impact was determined by the formula below and was screened according to Table 4-7.

**SP (significance of impact) = (magnitude + duration + scale) x probability**

**Table 4-6: Impact assessment rankings**

| Status of Impact | |
|---|---|
| +: Positive (A benefit to the receiving environment) | |
| N: Neutral (No cost or benefit to the receiving environment) | |
| -: Negative (A cost to the receiving environment) | |
| **Magnitude: =M** | **Duration: =D** |
| 10: Very high/don't know | 5: Permanent |
| 8: High | 4: Long-term (ceases with the operational life) |
| 6: Moderate | 3: Medium-term (5-15 years) |
| 4: Low | 2: Short-term (0-5 years) |
| 2: Minor | 1: Immediate |
| 0: Not applicable/none/negligible | 0: Not applicable/none/negligible |
| **Scale: =S** | **Probability: =P** |
| 5: International | 5: Definite/don't know |
| 4: National | 4: Highly probable |
| 3: Regional | 3: Medium Probability |
| 2: Local | 2: Low probability |
| 1: Site only | 1: Improbable |
| 0: Not applicable/none/negligible | 0: Not applicable/none/negligible |

**Table 4-7: Impact significance ratings**

| Significance | Environmental Significance Points | Colour Code |
|---|---|---|
| High (positive) | >60 | H |
| Medium (positive) | 30 to 60 | M |
| Low (positive) | 15 to 30 | L |
| Low-Marginal (positive) | 0 to 15 | L-Marginal |
| Neutral | 0 | N |
| Low-Marginal (Negative) | 0 to -15 | L-Marginal |
| Low (negative) | -15 to -30 | L |
| Medium (negative) | -30 to -60 | M |
| High (negative) | <-60 | H |

### 4.9 Water monitoring

The monitoring network is based on the principles of a monitoring network design as described by the DWAF Best Practice Guidelines: G3 Monitoring (DWAF, 2007). The methodological approach that the monitoring plan follows is represented in Figure 4-8, below.

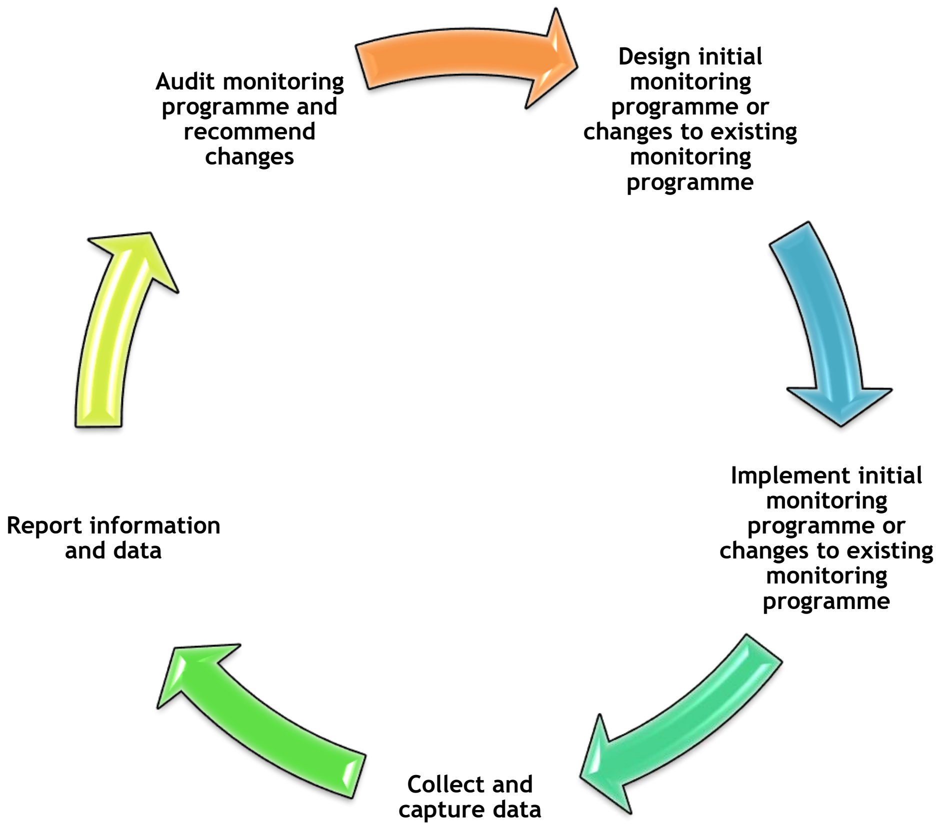



**Figure 4-8: Monitoring Process**

A groundwater monitoring improvement, or full monitoring plan, was developed based on available site information and risks identified.

### 4.10 Groundwater Management Plan

Groundwater management measures were formulated based on the results of the groundwater impact assessment. A groundwater monitoring network was proposed based on existing and predicted groundwater impacts.

# 5 PREVAILING GROUNDWATER CONDITIONS

The following section supplies an overview of the prevailing geohydrological conditions encountered at the 2-Seams Mine. The data were derived from available literature sources and completed fieldwork.

## 5.1 Local geology & soils

According to the 2628 Geological Series – East Rand (DMEA, 1998f), the project area of the known coal deposits in South Africa is hosted in sedimentary rocks of the Karoo Basin, a large foreland basin which developed on the Kaapvaal Craton and filled between the Late Carboniferous and Middle Jurassic periods. The Karoo Supergroup is subdivided into the Dwyka, Ecca and Beaufort groups and succeeded by the Molteno, Elliot, Clarens, and Drakensburg formations. The coal ranges in age from early Permian (Ecca Group) through to Late Triassic (Molteno Formation) and is predominantly bituminous to anthracitic in rank, which is classified in terms of metamorphism under influence of temperature and pressure. Please refer to Figure 5-1 for a regional geology map.

Nineteen coalfields have been defined within the Karoo Basin, based on variations in sedimentation, origin, formation, distribution and coal quality. These variations are in turn related to specific conditions of deposition and the local tectonic history of each area.

Sediments of the Dwyka Group and the coal-bearing Ecca Group developed on an undulating pre-Karoo erosion surface. The undulating nature of this surface has had a large influence on the thickness and depth of the deposited coal seams. Post-Karoo erosion removed large parts of the stratigraphic column including substantial volumes of coal along the northern margin of the coalfield, exposing pre-Karoo rocks along the northern and western boundaries of the coalfield.

The coal seams are usually separated by coarse to fine-grained sandstone, siltstone and/or shale at the top. Glauconitic sandstones, indicative of transgressive marine periods, are present above the No.4 and No.5 Seams. The coal zone is overlain by another deltaic sequence, which consists of sandstone and sandy micaceous shale and siltstone with varying thicknesses (approximately 60 to 100m thick).

The Karoo sediments are practically undisturbed and geological structures (e.g. faults, shears, associated fracturing) are rare. However, fractures are common in rocks such as sandstone and coal. Dolerite intrusions, in the form of sills or dykes cause in some locations various mining problems (i.e. de-volatilised coal, weakened roof strata and/or displaced coal seams), where near vertical dykes have very little displacement associated transgression through the seam.

According to the Land types of South Africa databases (Land Type Survey Staff, 1972 – 2006c (ARC, 2006)), the soils in the study area fall within the land types Bb– Red and yellow, dystrophic/mesotrophic, apedal soils with plinthic subsoils (plinthic soils comprise >10% of land type, red soils comprise <33% of land type).

## 5.2 Structural geology

The Project area is underlain by stratigraphy of the Vryheid Formation, Ecca Group of the Karoo Supergroup. The coal-bearing Vryheid Formation consists predominantly of fine-grained sandstone, platy shale and coal (No. 4, No. 2 and No. 1 seams). Combinations of these rock types are often found in the form of interbedded shale, coal and sandstone. The coal reserves located in the Project area form part of the Springs-Witbank Coalfield. The five monitoring and test boreholes drilled on-site during a previous GCS study in 2016, intersect mainly fine-grained sandstone and/or platy shale with several coal seams.

The Ecca group in the project area is relatively thin and thicknesses range between ~30 mbgl to near the surface. No evidence of large-scale intrusions of dykes or sills has been encountered at the site. The coal seams (and strata) at the site are generally flat-lying to gently undulating with a regional dip to the south-southeast. Drilling conducted at OC4 in 2020, intersected Ecca stratigraphy to depths between 30 and 36 mbgl (Siyaphambili Geoservices, 2020). The No. 2 coal seam is separated from the No.1 coal seam by a thin sandstone parting. The depth of the No.2A seam located below the No.2 Seam, but above the sandstone parting overlying the No.1 seam, varies between 26 and 31 mbgl.

Due to the varied depositional environments (e.g. basement topography) and the present-day erosional surface not all seams are present at any one locality. At the site the No. 4, No. 2 and No. 1 seam is present. The seams targeted at the 2 Seam Mine are mainly the No. 2 and No. 4 seams. No. 1 seam has been targeted only where this is feasible.

The undulating nature of the pre-Karoo formations has resulted in sub- outcropping occurring in the south-south-eastern portion of the study area. Porphyritic rhyolite with embedded mudstone and sandstone, of the Selons River Formation, Rooiberg Group represents the pre-Karoo lithology within the regional study area.

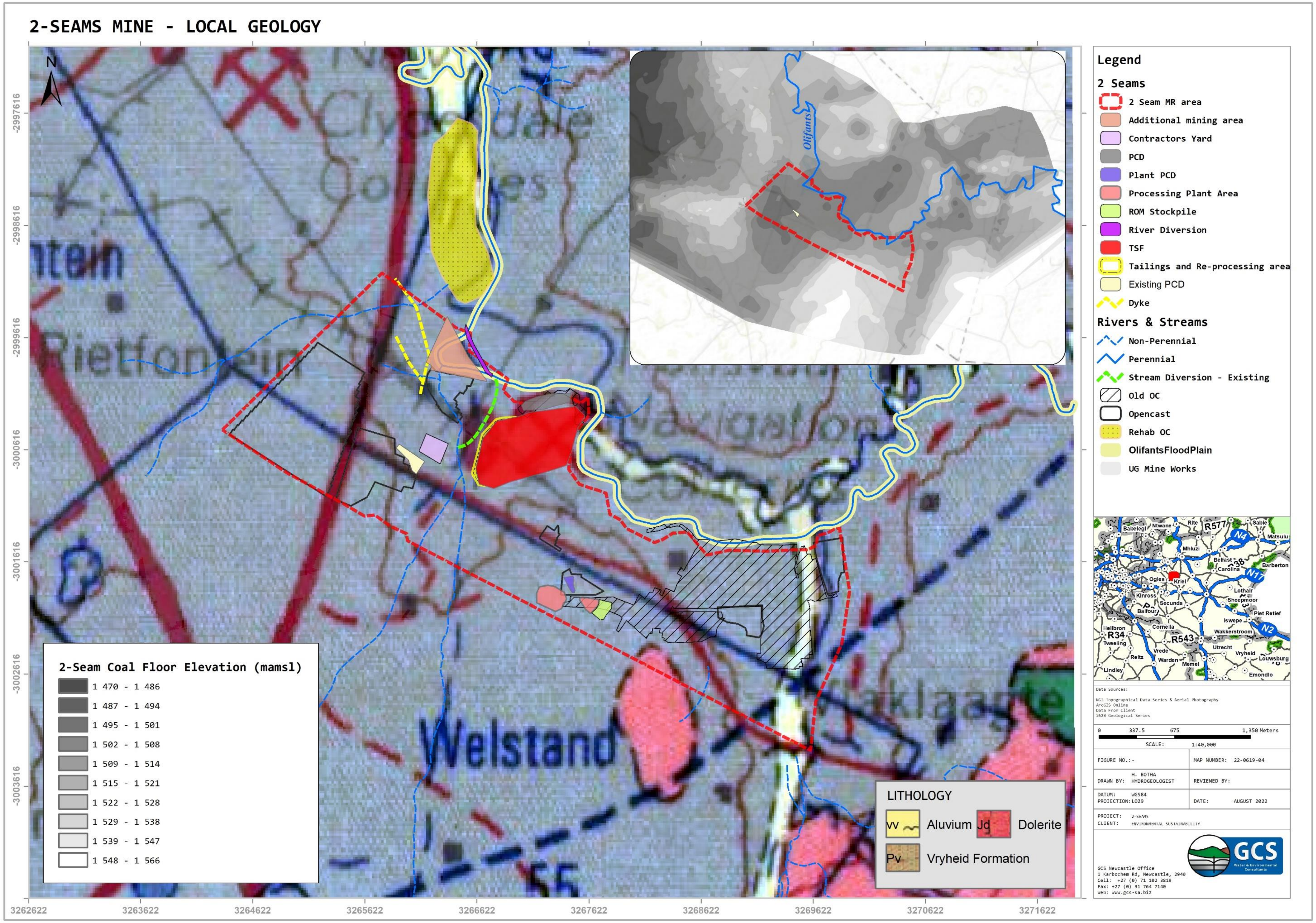



**Figure 5-1:** Local surface geology

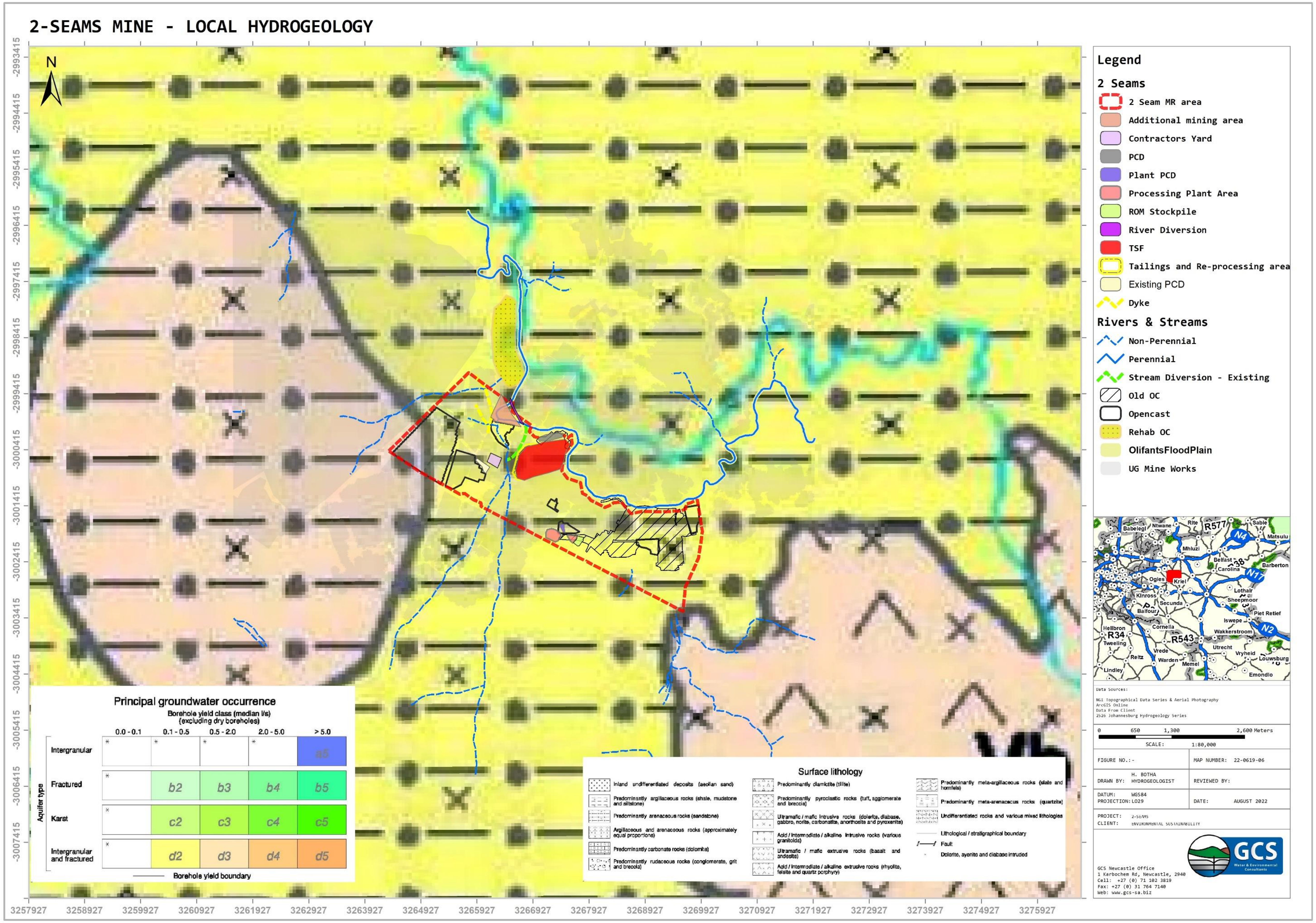



**Figure 5-2:** Local hydrogeology setting

## 5.3 Geochemical overview

A total of 19 rock samples were collected by GC in 2016 as part of a geohydrological assessment, from the 2 Seam Pty Ltd Mine. The following rock samples were collected:

- Carbonaceous mudstones and shales samples;
- 4 Coal samples;
- Sandstone and mudstone samples; and
- 1 Weathered sandstone and clay sample.

The samples were subjected to acid-base accounting (ABA) and net acid generation (NAG) testing, as well as sulphur speciation (S-Spec), distilled water leach and peroxide leach tests and mineralogical testing such as X-ray diffraction and X-ray-florescence (XRD & XRF). The test work data is deemed still valid, as the same resource is being mined and the same wastes are being generated. The test results were used to quantify the source terms associated with the 2-Seams Mine, and are summarized as follows (GCS, 2016):

**Mineralogy (XRD & XRF):**

- The hanging-and-footwall carbonaceous clastic rocks comprised mostly of kaolinite with lesser amounts of coal compared to the coal samples. The sandstone is comprised predominantly of kaolinite with lesser quartz.
- Carbonaceous mudstone - sample comprises mainly kaolinite and coal as dominant and major minerals with lesser muscovite and quartz.
- Carbonaceous shale with subordinate coal - sample comprises mainly kaolinite and coal as dominant and major minerals with lesser muscovite and siderite.
- Coal with subordinate carbonaceous mudstone - samples comprise mainly coal and kaolinite as dominant and major minerals with lesser muscovite and quartz.
- Fine sandstone with subordinate mudstone - sample comprises mainly kaolinite as the dominant mineral with lesser coal, microcline, muscovite, and quartz.
- Coal with subordinate fine sandstone): The sample comprises mainly coal and kaolinite as dominant and major minerals with lesser quartz.

**ABA & NAG:**

- 33.3% (2 out of 6 samples) of the carbonaceous mudstone/shale samples collected have a high potential to generate acidic drainage (and will generate a high salt load), and 17% (1 out of 6) have a low potential to generate acidic drainage (and will generate a low to medium salt load), 17% (1 out of 6) has a very low potential to generate acidic drainage (and will generate a very low to medium salt load), 33.3% (2 out of 6 samples) of the carbonaceous mudstone/shale samples collected has no potential to generate acidic drainage (and will generate no salt load);

- 100% (4 out of 4 samples) of the coal samples collected have a high potential to generate acidic drainage (and will generate a high salt load);
- 50% (2 out of 4) of the shale samples collected have a very high potential to generate acidic drainage (and will generate a very high salt load), and 50% (2 out of 4) have a very low potential to generate acidic drainage (and will generate a very low salt load)
- 25% (2 out of 8) of the sandstone/mudstone samples collected have a high potential to generate acidic drainage (and will generate a high salt load), and 38% (3 out of 8) have a low to medium potential to generate acidic drainage (and will generate a medium to high salt load), 17% (1 out of 8) has a low potential to generate acidic drainage (and will generate a low to medium salt load), 17% (1 out of 8) has a very low potential to generate acidic drainage (and will generate a very low to medium salt load) 13, 13% (13 out of 8 samples) of the sandstone/ mudstone samples collected has no potential to generate acidic drainage (and will generate no salt load); and
- 100% (1 out of 1) of the soil and clay samples collected have low potential to generate acidic drainage (and will generate a low to medium salt load);
- The carbonaceous mudstone samples generally have a variable %S content at an average of 0.274%. There is, however, an average neutralisation potential of 30.3 kg/t CaCO3, thus the initial leachate from these rocks will not be acidic as confirmed by the NAG testing but it is suspected that 66% of the samples have sufficient sulphide content and will acidify over the long-term because of the high sulphide content;
- The coal samples all have a high %S content and a lower neutralisation content thus if subjected to oxidisation then leached acidic drainage will occur as confirmed by NAG testing;
- The sandstone and mudstone samples have variable %S content with a relatively high neutralisation potential, but about 38-76% of the samples have the potential to generate acidic drainage if oxidised and subsequently leached as confirmed by NAG testing;
- The weathered sandstone and clay sample have a relatively low %S content with a low neutralisation potential thus there is a low potential to generate acidic drainage.
- Overall, it could be concluded that about 50% of the hanging wall/waste rock material (sandstone, mudstones, shales) has the potential to generate acidic drainage if the material is oxidised and leaching occurs subsequently. The coal samples have a high potential to generate acidic drainage if subjected to oxidisation. Usually, the coal is mined before significant oxidation occurs and only coal remaining in the mine will potentially be of concern over the long term.

Reagent water leach:

- The static leach test performed at a 1:20 ratio is a relatively diluted extraction and did not leach the chemicals at significant concentrations. It is expected that metals like Fe, Mn, Co, Ni and Pb will only be significantly present in acidic leachate if the rocks are subjected to atmospheric conditions (oxidation).

## 5.4 Hydrogeology and aquifer units

Based on available information for the study area three (3) aquifer zones occur, namely:

- Unconfined aquifer zone, associated with the flood plain and alluvium deposits of the Olifants River;
- Semi-confided to confined weathered zone, associated with the weathered Ecca sediments; and
- Deeper fractured and confined aquifer zone associated with older Karoo rock and basement granites.

The hydrogeological occurrences and aquifer zones are discussed below.

### *5.4.1 Unsaturated Zone*

The unsaturated zone also referred to as the vadose zone, is the zone between the land surface and the top of the phreatic zone (groundwater table). Based on the latest groundwater level data for the Project area, the unsaturated zone varies in thickness between 3 and 30 m (depending largely on hillslope position and weathered soil types, followed by weathered aquifer rock).

### *5.4.2 Saturated Zone*

The saturated zone, also termed the phreatic zone or aquifer, is the zone below the groundwater table, in which all pores and fractures, are saturated with water (refer to Figure 5-2).

Three principal aquifers are identified: the weathered aquifer; the fractured Karoo aquifer; and the fractured pre-Karoo aquifer (Hodgson & Krantz, 1998). The Karoo rocks are not known for the development of high-yielding aquifers, but high-yielding boreholes may be present occasionally. The aquifers that occur in the area can therefore be classified as minor aquifers (low yielding), but of high importance (Parsons, 1995).

According to WRC report 291/1/98, three distinct superimposed groundwater systems are present within the Olifants River Catchment. They can be classified as:

- The upper weathered Ecca aquifer (shallow aquifer formed in the weathered zone of the Karoo sediments). The shallow aquifer is locally perched on fresh bedrock.
- Fractured aquifers within the unweathered but fractured Ecca stratigraphy.

- Fractured aquifer underlying the Ecca sediments consisting of low-yielding Dwyka and/or basement rocks.
- The systems do not necessarily occur in isolation from one another and can form a composite groundwater regime comprised of one, some, or all of the systems.

An additional hydrogeological unit is present within the study area, attributed to the disturbance of in-situ hydrogeological conditions by historical mining activities and the alluvium deposits associated with the Olifants River (though limited at the 2-Seams Mine).

#### *5.4.2.1 Alluvium aquifer zone*

The flood plains of the Olifants River are characterised by consolidated alluvium, and when saturated can be considered an unconfined aquifer zone. The hydraulic permeability of the alluvium zones is several orders higher than the weathered and fractured rock aquifer zones, and the water table in the alluvium sediments is free to fluctuate up and down based on the degree of saturation of the riverbed sediments and atmospheric pressure. It should further be noted that the Olifants River can act as both a losing or gaining stream, depending on the season and the river stage – which will drive groundwater contribution to baseflow.

#### *5.4.2.2 Weathered Aquifer*

The Ecca sediments consist of *in-situ* weathered material and transported material with a thickness that varies between 5 and 20 m below the surface in the Project area. The upper aquifer is associated with this weathered zone and water is often found a few meters below the surface. The lower 5 to 10 m of the shallow aquifer is saturated due to the impervious nature of the competent, horizontally stratified lithologies of the underlying fractured aquifers. The saturated depth of this aquifer is dependent on rainfall recharge thus the influx of water into an opencast mining operation is expected to vary seasonally.

- This aquifer is recharged by rainfall. Highly variable recharge occurs over the area, but generally, values are between 1 and 3% of the Mean Annual precipitation (MAP) based on work by Kirchner et al. (1991) and Bredenkamp (1978) in other parts of the country.
- Rainfall that infiltrates the weathered rock reaches an impermeable layer of shale underlying the weathered zone.
- Groundwater flows laterally along the direction of the surface slope.
- The water reappears on the surface at springs where the flow paths are obstructed by a barrier, such as a dolerite dyke, paleo-topographic highs in the bedrock, or where the surface topography cuts into the groundwater level at streams.

The aquifer within the weathered zone is generally low-yielding (range 100 – 2000 l/h) due to its insignificant thickness. Few farmers, therefore, tap this aquifer by a borehole, however, wells or trenches dug into the upper aquifer are often sufficient to secure a constant water supply of good quality.

#### *5.4.2.3 Fractured Aquifer*

Pores within the Ecca sediments are too well cemented to allow any significant permeation of water. Groundwater movement is therefore along secondary structures, such as fractures, cracks and joints in the sediments.

Of all the unweathered sediments in the Ecca, the coal seams often have the highest hydraulic conductivity. Packer testing of the No. 2 Seam (WRC Report No 291/1/98) has identified a hydraulic conductivity distribution as indicated in Table 5-1.

**Table 5-1: Statistics for Results on Packer Tests (WRC Report No 291/1/98)**

| Statistics | No. 2 Seam – k (m/day) |
|---|---|
| Mean (m/d) | 0.102 |
| Median (m/d) | 0.074 |
| Standard deviation (m/d) | 0.13 |
| Min (m/d) | 0.0007 |
| Max (m/d) | 0.5 |
| Number of tests | 21 |

The data listed in Table 5-1 suggest that seepage of water through the No 2 seam is possible. In terms of water quality, the fractured Karoo aquifer exhibits higher salt loads than the upper weathered aquifer. Higher parameter concentrations are attributed to the longer contact time between water and rock within the fractured aquifer. Occasional high chloride and sodium levels are attributed to boreholes in the vicinity of areas where salts naturally accumulate on the surface, such as pans and springs.

#### *5.4.2.4 Mine Hydrogeological Unit*

Historical underground workings have likely led to the formation of a mine hydrogeological unit, formed within areas that have undergone coal extraction. Significantly higher hydraulic conductivity and storage values are expected for the aquifer due to the presence of mine voids or backfilled material with higher permeability than surrounding sediment/rock.

## 5.5 Preferential flow paths

Dolerite intrusions in the form of dykes and sills are common in the Karoo Supergroup and are often encountered in the study area. These intrusions can serve as both aquifers and aquifuges[1].

Thick un-weathered dykes will inhibit the flow of water, while the baked and cracked contact zones can be highly conductive. These conductive zones effectively interconnect the strata of the Ecca sediments both vertically and horizontally into a single, but highly heterogeneous and anisotropic zone on the scale of typical mining activity. The strike of the dolerite/diabase dykes in this area are both parallel and perpendicular to the direction of groundwater flow and therefore act as no flow and preferential flow boundaries.

## 5.6 Primary groundwater occurrence

Hydrogeology is mainly controlled by weathering and secondary structures such as faulting and dykes. According to available literature for the region (King, 1998) groundwater is typically encountered in/along:

- Unconsolidated sediments associated with flood river flood plains;
- Dolerite dyke and sill contacts with host rock;
- Contact zones between lithologies or unconformities; and
- Faults and associated fracture zones.

## 5.7 Groundwater recharge

Recharge to the underlying aquifer is estimated to range from 5.5 to 7.4 % (average 6.5% = 44.93 mm/yr) of the MAP (691.2 mm) which falls within quaternary catchment B11B (DWAF, 2006). The recharge to the aquifer was further refined and determined by running qualified guess analyses using the RECHARGE model developed by IGS, as summarised in Table 5-2. A recharge of 48.6 mm/yr corresponding to 7% recharge was applied to the groundwater model.

**Table 5-2: RECHARGE Program (Van Tonder & Yongxin Xu, 2000)**

| Method | mm/a | % of rainfall |
|---|---|---|
| Cl | 55.3 | 8.0 |
| Qualified Guesses : | | |
| Soil | | |
| Geology | 15.9 | 2.3 |
| Vegter | 57.0 | 8.2 |
| Acru | 45.0 | 6.5 |
| Harvest Potential | 25.0 | 3.6 |
| Average recharge | 48.6 | 7.0 |
| Recharge = | 48.6 | 7.0 |

[1] Aquifuge: An impermeable body of rock which contains no interconnected openings or interstices and therefore neither absorbs nor transmits water.

## 5.8 Aquifer yield & hydraulic conductivity

The aquifer is considered a low-yielding aquifer and has a reported yield in the order of 0.1 l/s to 0.5 l/s (King, 1998). GCS conducted the aquifer hydraulic testing program between the 20th and 25th September 2016 which consisted of five (5) falling-head tests and three (3) pump and recovery tests. As stated previously (Section 4.4.3).

Table 5-3 provides a summary of aquifer test data (transmissivity and hydraulic conductivity) for existing and new aquifer test data collected for the 2-Seams Mine. Available data indicate that aquifer transmissivity (T) values range from 0.25 to 50.25 m²/day. Assuming a uniform saturated aquifer thickness of ± 10 m, yields an aquifer hydraulic conductivity (K-value) ranging from 0.03 to 5.03 m/day. T values for the alluvium sediments associated with the Olifants River are estimated in the order of 100 m²/d (Botha, 1998).

**Table 5-3: Summary of aquifer test data**

| BH ID | Source | Test Type | K (m/day) | T (m²/day) |
|---|---|---|---|---|
| BH1 | GCS (2016) | Falling Head Test | 0.03 | 0.25 |
| BH2 | GCS (2016) | Falling Head Test | 3.50 | 35.00 |
| BH2 | GCS (2016) | Pump Test | 2.80 | 28.00 |
| BH3 | GCS (2016) | Falling Head Test | 0.03 | 0.31 |
| BH3 | GCS (2016) | Pump Test | 0.70 | 7.00 |
| BH4 | GCS (2016) | Falling Head Test | 0.06 | 0.56 |
| BH5 | GCS (2016) | Falling Head Test | 0.10 | 0.97 |
| BH5 | GCS (2016) | Pump Test | 1.20 | 12.00 |
| BH-5M | GCS (2022) | Falling Head Test | 0.06 | 0.59 |
| BH-2M | GCS (2022) | Falling Head Test | 5.03 | 50.25 |
| BH4 | GCS (2022) | Falling Head Test | 2.06 | 20.56 |
| NBH4 | GCS (2022) | Falling Head Test | 0.07 | 0.68 |

## 5.9 Aquifer storage/storativity

According to King *et al.* (1998) and DWAF (2006), the aquifer storage/storage coefficient is in the order of magnitude of < 3.1 x $10^{-3}$ (unitless) – supported by available pump test data. The porosity of the aquifer is expected to range from 15 to 20 %. Literature data suggest that aquifer storage coefficients range from 5 to 10%.

## 5.10 Groundwater levels

The groundwater levels for boreholes identified in the project area are summarised as follows:

- Groundwater levels for the site range from 1.12 to 30.56 mbgl; and
- Groundwater levels for the catchment range from 3 to 50 mbgl.

Figure 5-3 plots the groundwater elevation vs topographic elevation for groundwater monitoring boreholes situated at the site. It can be seen that there is a good linear relationship (R ≈ 97%) between topographic and groundwater elevations. The data suggest that the groundwater table mimics the topography. Figure 5-4 shows the estimated groundwater elevations for the site area, based on Bayesian interpolation of available monitoring data.

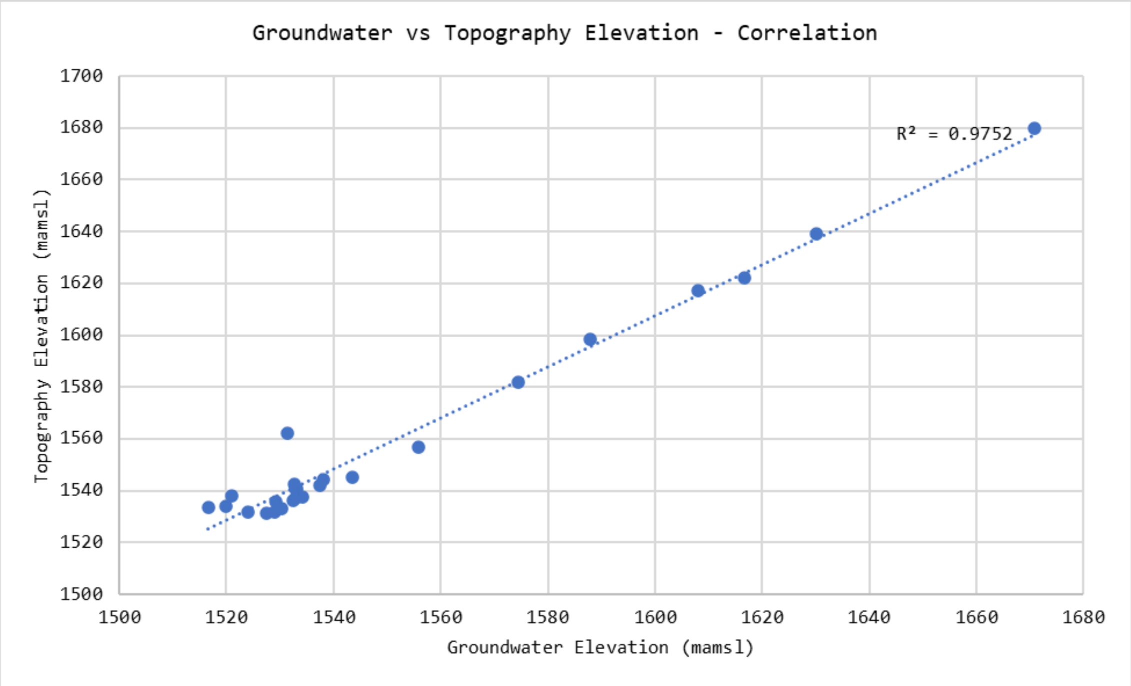



**Figure 5-3: Groundwater elevation vs topographic elevation - correlation**

## 5.11 Groundwater velocities and flow rates

The calculation of the groundwater flow rate is important when determining the rate at which a pollutant will migrate into an aquifer. The average flow velocity can be calculated, using Darcy's Flow Velocity equation, as given below in Equation 3.

$$v = \frac{Ki}{\theta}$$ ……………………………………………………………………………**Equation 3**

Where: *v=flow velocity*

*K=hydraulic conductivity*

*θ=porosity (a standard porosity of 20% for sandstones will be used)*

*i =probable average hydraulic gradient (Equation 4)*

$$i = \frac{h1-h2}{l}$$ ……………………………………………………………………………**Equation 4**

The hydraulic gradient is calculated in Table 5-4. Table 5-5 shows the results of the flow velocity equation, which indicates that groundwater will flow through the weathered aquifer at an approximate average rate of 0.113 m/day or 41.5 m/year. This flow rate is considered slow. However, the flow rate will increase in areas adjacent to dykes, which act as preferential pathways. A porosity of 15-20% was applied, based on the typical porosity for shale and sandstone from the literature (Freeze and Cherry, 1979).

**Table 5-4: Hydraulic gradient calculation**

| | OC4 (NE section of Diversion) - NBH1 to BH-5M | OC6 to OC4 - EUB-1 to BH-1M | OC4 to Olifants River (BH4 to BH-5M) |
|---|---|---|---|
| h1 (mamsl) | 1533.168 | 1543.503 | 1537.526 |
| h2 (mamsl) | 1519.846 | 1519.846 | 1519.846 |
| h1-h2 (m) | 13.322 | 23.657 | 17.68 |
| L (m) | 139 | 379 | 776 |
| i | 0.096 | 0.062 | 0.023 |
| K (m/day) - GeoMean | 0.33 | 0.33 | 0.33 |
| n | 0.2 | 0.15 | 0.15 |

**Table 5-5: Flow velocity calculation**

| | OC4 (NE section of Diversion) - NBH1 to BH-5M | OC6 to OC4 - EUB-1 to BH-1M | OC4 to Olifants River (BH4 to BH-5M) | Average |
|---|---|---|---|---|
| ***m/day*** | 0.1563 | 0.1357 | 0.0495 | 0.1138 |
| ***m/year*** | 57.0401 | 49.5318 | 18.0794 | 41.5504 |

Groundwater flow generally follows the topographical characteristics of the area and local streams, and rivers act as groundwater boundaries for the shallow weathered aquifer.

The site is bound to the northeast by the Olifants which can be regarded as the local weathered aquifer's boundary. Considering the stream diversion of the Olifants river would mean that the boundary will be shifted. It is, therefore, important to consider the existing groundwater flow field and post-stream diversion groundwater flow field. The local sphere of groundwater influence is indicated in Figure 5-4. The focus of the groundwater impact assessment is within this area.

## 5.12 Aquifer contextualization and extent

As groundwater flow behaviour is aligned to surface water flow conditions, it was assumed that the aquifer extent for the work conducted by GCS coincides with the surface water catchment boundaries.

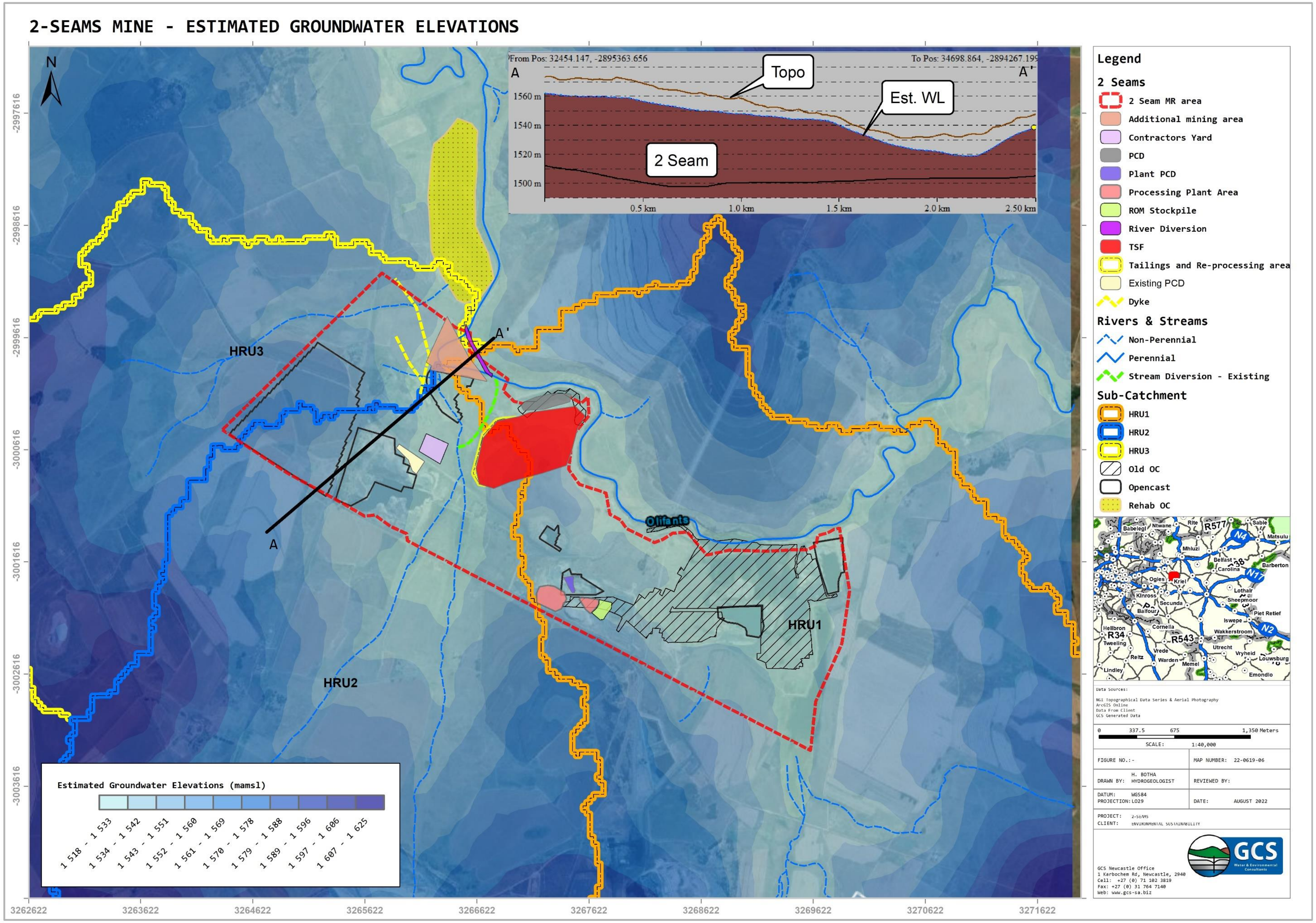



**Figure 5-4: Bayesian estimation of groundwater table at the site and sphere of groundwater influence**

## 5.13 Aquifer classification & vulnerability

The weathered/fractured aquifer that underlies the site may be classified as a minor aquifer (Parsons, 1995) due to the general yields of less than 2.0 l/s. The Minor Aquifer System is defined as "fractured or potentially fractured rocks which do not have high primary permeability or other formations of variable permeability. Aquifer extent may be limited and water quality variables. Although these aquifers seldom produce large quantities of water, they are important both for local supplies and in supplying base flow to rivers."

Eco Elementum (2019a) evaluated the groundwater vulnerability of the 2 Seam Area by assessing the Aquifer Vulnerability Map of South Africa (DWA, 2013) and conducting a Groundwater Vulnerability Assessment. Based on the Aquifer Vulnerability map the Mine is located in the least to moderate vulnerability rating area. A vulnerability rating of 7 was determined for the area, indicative of medium vulnerability.

Eco Elementum (2019a) combined the Aquifer System Management Classification and the Vulnerability Classification Rating to determine the Groundwater Quality Management (GQM) Classification, which provides the level of aquifer protection. The GQM Index for the Mining area is 4, which indicates a medium level of protection. Based on the Aquifer Susceptibility Map of South Africa (DWA, 2013), the mining area is classified as having a low to moderate susceptibility to contamination. It is, therefore, essential that a monitoring protocol is in place and followed at the mine.

## 5.14 Wetland areas

Based on available National Wetland Freshwater Ecosystem Priority Areas (NFEPA) (Van Deventer, 2018) the portion of the Olifants River bordering the 2-Seams Mine (the very portion that will be diverted), as well as the existing stream diversion area, is classified as flood plain areas associated with the Mesic Highveld Grassland Bioregion (Floodplain) – refer to Figure 1-2 and Figure 5-1.

In terms of wetland geohydrology, baseflow is considered the most important contributor to wetland health. Baseflow (refer to Figure 5-5) is a non-process-related term to signify low amplitude high-frequency flow in a river during dry or fair-weather periods. Baseflow is not a measure of the volume of groundwater discharged into a river or wetland, but it is recognised that groundwater contributes to the baseflow component of river or wetland flow.

Available literature (WRC, 2015; DWAF, 2006) suggests groundwater contribution to baseflow ranging from 3.58mm/yr (PITMAN MODEL) to 13.63 mm/yr (HUGHES MODEL). This relates to approximately 0.52% to 2% of rainfall.

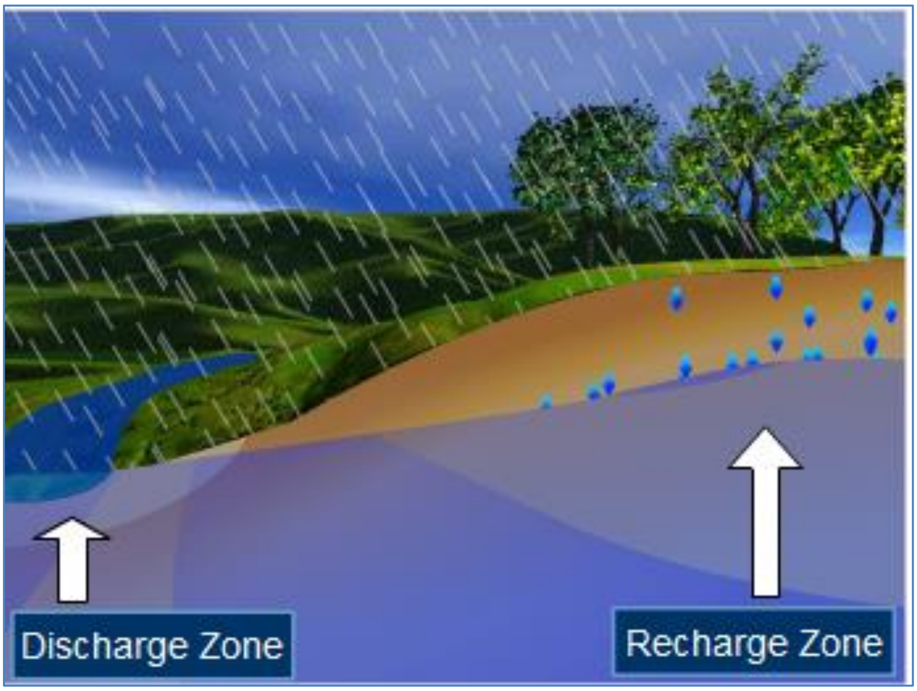



**Figure 5-5: Groundwater baseflow concept (DWS, 2011)**

## 5.15 Present ecological state (PES) and ecological importance and sensitivity (EIS)

According to WR2012 data (WRC, 2015) & (DWAF, 2003) quaternary catchment, B11B PES is classified as a Category D (largely modified) and EIS is classified as moderately sensitive.

## 5.16 Hydrochemistry

The following section supplies a brief overview of the hydrochemical conditions at the site, as well as hydrocensus boreholes situated in the project area.

### *5.16.1 Hydrocensus water quality data*

GCS collected five (5) hydrochemistry samples as part of the hydrocensus for this project. The samples were submitted to X-lab earth (Accreditation No. T0775) for sample analysis. Refer to **Appendix C** for the analysis certificate.

Table 5-6 summarises the catchment scale groundwater quality for the study area. The results are compared with DWAF (1996) Ideal Target Water Quality Ranges (TWQR) for Domestic Water Use to contextualise the water quality data.

From the hydrochemistry data obtained, the following can be said:

- All samples exhibit neutral pH conditions;
- Electrical conductivity (EC) for the samples is well within DWAF target values for potable use, except for borehole BH-2M with an above-average EC > 120 mS/m.
    - Borehole BH-2M shows high Na, F, and $SO_4$ concentrations, compared to DWAF's ideal target water quality ranges.

- Borehole NBH1 exhibits a high $NO_3$ concentration, above DWAF ideal water quality ranges, and is possibly related to the use of nitrate-rich explosives at 2-Seams. Nitrate leachate from the opencast workings and overburden is likely the cause of the high $NO_3$ concentration.
- Fe and Mn are high in borehole BH4, compared to DWAF's ideal water quality limits for potable water use.
- Figure 5-6 shows a piper plot of the hydrocensus borehole samples. From the piper-plot, the following is noted:
  - All samples, except NBH5A, plot towards the middle of the left ternary diagram. The sample spread suggests that Ca, Mg, and Na ions are present in molar equivalent concentrations, but that in sample NBH5A Na ions are more dominant.
  - The samples plot towards the left-middle of the right ternary diagram, except NBH1 which plots towards the right corner of the right ternary diagram. The majority of the samples appear to be dominated by bicarbonate ($HCO_3^-$). NBH1 is affected by $NO_3$ as a result of the mining.
  - The sample spread in the centre rhombus varies and suggests that water from borehole BH-5M and NBH5A can be classified as Ca-$HCO_3$ type groundwater (typical of shallow or fresh groundwater), water from borehole BH4 and BH-2M exists in a mixed state (i.e. undergoing chemical weathering or active ion exchange) and water from NBH1 can be classified as Ca-$SO_4$ type groundwater (typical of mine drainage affected water).

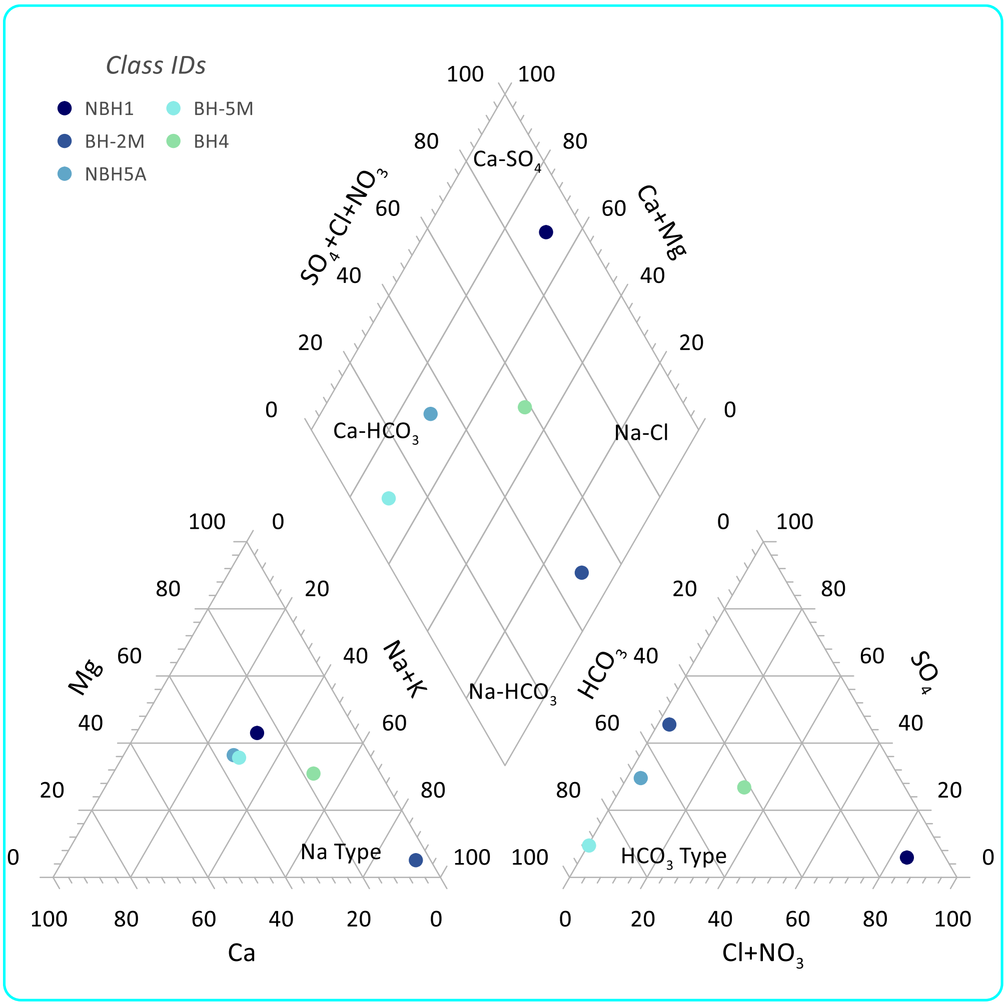



**Figure 5-6: Field hydrocensus hydrochemistry - Piper plot**

**Table 5-6: Summary of field hydrocensus water quality data**

| Determinant | Unit | NBH1 | BH-2M | NBH5A | BH-5M | BH4 | DWAF 1996 Domestic Use - TWQR |
|---|---|---|---|---|---|---|---|
| pH at 25°C | pH units | 5.3 | 8.8 | 7.3 | 8.6 | 6.3 | 4 - 9 |
| Electrical Conductivity at 25°C | mS/m | 22 | 124 | 56 | 17 | 25 | 0 - 70 |
| Bicarbonate Alkalinity* | mg $HCO_3^-$/ℓ | 12 | 415 | 244 | 104 | 61 | ns |
| Total Alkalinity | mg $CaCO_3$/ℓ | <12 | 340 | 200 | 85 | 50 | ns |
| Dissolved Calcium | mg Ca/ℓ | 9.9 | 9.9 | 43 | 12 | 7.2 | 0 - 32 |
| Dissolved Magnesium | mg Mg/ℓ | 10 | 8.1 | 27 | 7.6 | 7.8 | 0 - 30 |
| Sodium | mg Na/ℓ | 10 | 271 | 37 | 10 | 23 | 0 - 100 |
| Potassium | mg K/ℓ | 6.3 | 3.3 | 4.9 | 3.7 | 2.9 | 0 - 50 |
| Chloride | mg Cl/ℓ | 28 | 14 | 7.2 | 0.08 | 27 | 0 - 100 |
| Fluoride | mg F/ℓ | <0.05 | 1.7 | 0.23 | 0.2 | 0.17 | 0 - 1 |
| Nitrate | mg N/ℓ | 54 | <0.1 | 0.7 | 0.2 | <0.1 | 0 - 6 |
| Sulphate | mg $SO_4$/ℓ | 5.6 | 289 | 85 | 8.6 | 31 | 0 - 200 |
| Aluminium | mg Al/ℓ | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 | 0.15 |
| Iron | mg Fe/ℓ | <0.05 | <0.05 | <0.05 | <0.05 | 5.2 | 0.1 |
| Manganese | mg Mn/ℓ | 0.03 | 0.01 | <0.01 | <0.01 | 0.74 | 0.05 |
| ns = No Quality Range in Reference Guideline, Orange = Above DWAF (1996) Ideal Water Quality Ranges | | | | | | | |

### *5.16.2 Monitoring network water quality*

Groundwater quality monitoring data was provided by the client from January 2022 to July 2022 (Zyntha Consulting, 2022). The data is captured here to provide an overview of the existing hydrochemistry of the site with a focus on pH, EC, TDS, Fe, $SO_4$ and Mn, which are typically associated with pollution from Coal Mines (INAP, 2018). The criteria used in the latest water monitoring report provided are as follows:

***Surface water contextualisation***

No guidelines were published in the WUL for surface water analysis and no RQO were set for the biophysical node in which the site is located. Based on this, the water quality standards that will be used to measure compliance at 2 Seams are the Water Quality Planning Limits (WQPL) for the Upper Olifants. The WQPL for the Upper Olifants Catchment was published by the Department of Water and Sanitation (DWS, 2016) and Quaternary Catchment B11B, in which the 2-Seams Mine is located, falls under Management Unit 8 – refer to Table 5-7.

**Table 5-7: Surface water compliance screening criteria**

| pH | EC (mS/m) | TDS (mg/l) | Alk (mg/l) | N (mg/l) | Cl (mg/l) | $SO_4$ (mg/l) | F (mg/l) | Na (mg/l) | K (mg/l) | Ca (mg/l) | Mg (mg/l) | Al (mg/l) | Fe (mg/l) | Mn (mg/l) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| <6,5<br>>8,4 | >90 | >350 | >120 | >0,5 | >40 | >150 | >0,75 | >50 | >25 | >50 | >30 | >0,02 | >0,3 | >0,05 |

***Groundwater chemistry contextualisation***

No guidelines were published in the WUL for groundwater analysis and no RQO were set for the biophysical node in which the 2 Seams Mine is located. Based on this, the water quality standard that will be used to measure compliance at 2 Seams Mine is SANS 241:2015 – refer to Table 5-8.

**Table 5-8: Groundwater compliance screening criteria**

| pH | EC (mS/m) | TDS (mg/l) | Alk (mg/l) | N (mg/l) | Cl (mg/l) | $SO_4$ (mg/l) | F (mg/l) | Na (mg/l) | K (mg/l) | Ca (mg/l) | Mg (mg/l) | Al (mg/l) | Fe (mg/l) | Mn (mg/l) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| <5<br>>9,7 | >170 | >1 200 | >300 | >11 | >300 | >250 | >1,5 | >200 | >50 | >32 | >30 | >0,3 | >0,3 | >0,1 |

**Please refer to the water monitoring report compiled by Zyntha Consulting (2022) for time chemistry trends. Hydrochemistry laboratory certificates for this section are available in Appendix C.**

*5.16.2.1 Groundwater*

There are seven (7) groundwater monitoring boreholes at 2-Seams (refer to Table 5-9), and their spatial positions are shown in Figure 5-7 (Zyntha Consulting, 2022). It is noted that BH2, BH4 and ODW are no longer operational. Hence, only four (4) boreholes are being monitored. Sampling is undertaken monthly and quarterly. Based on a review of the hydrochemistry data provided, the following is noted:

- BH1 exhibits neutral pH conditions, and TDS, $SO_4$, Fe and Al are well within the target water quality ranges. No mining impact is noted.
- BH4 exhibits neutral pH conditions, and TDS, $SO_4$, Fe and Al are well within the target water quality ranges. Only Mn occasionally exceeds the No mining impact is noted.
- BH5 generally exceeds five of the tested parameters namely; EC, TDS, $SO_4$, Na, and Mg, and the concentrations are still high as of July 2022 (EC > 300 mS/m, TDS> 2500 mg/l, $SO_4$ > 2500 mg/l) compared to the target water quality limit. This borehole shows a definite mining impact.
- BH-1 generally exhibit neutral pH conditions, with only $NO_3$ (> 12 mg/l in March 2022, and >14 mg/l in July 2022) observed. The borehole was also sampled by GCS, and high nitrate is confirmed. Nitrate leachate from the opencast workings and overburden is likely the cause of the high $NO_3$ concentration.

**Table 5-9: Summary of groundwater sampling points (Zyntha Consulting, 2022)**

| Site Label | Description | Latitude | Longitude |
|---|---|---|---|
| BH1 | Monitoring borehole located West of Block 5, just below 4 seam floor | 26°09’21.2” S | 29°19’57.1” E |
| BH2 | Monitoring borehole located Block 2 / Block 3A, Just below 2 seam floors. | 26°10'31.50"S | 29°21'3.79"E |
| BH3 | Monitoring borehole below 2 seam floor | 26°10'15.17"S | 29°22'19.77"E |
| BH4 | Monitoring borehole located Block 5, Just below 4 seam floor | 26° 9'44.45"S | 29°20'19.69"E |
| BH5 | Monitoring borehole located Mined Out Block 1, Just below 2 seam floor / historical mining depth | 26°10'14.16"S | 29°21'13.54"E |
| NEW | Monitoring point for purpose of portable water uses - office drinking water *(not included in this section as water is pristine)* | 26°10’42.2” S | 29°21’34.0” E |
| BH-1 | Mining monitoring borehole located close to the OC void | 26°10'10.37"S | 29°20'10.49"E |

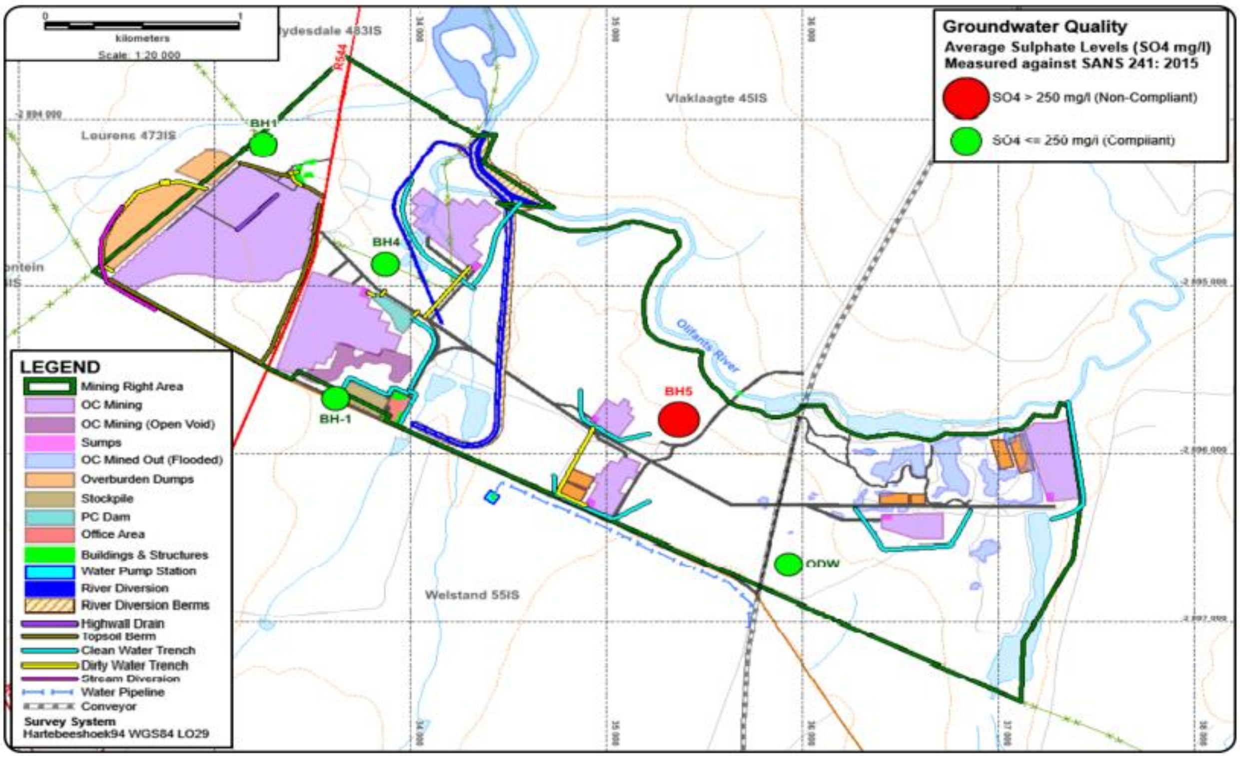



**Figure 5-7: Groundwater monitoring points (Zyntha Consulting, 2022) - $SO_4$compliante March 2022**

#### *5.16.2.2 Surface water*

There are twenty-two (22) dedicated surface water sample sites at 2-Seams (refer to Table 5-10), and the positions are shown in Figure 5-8 (Zyntha Consulting, 2022). Sampling is undertaken monthly, and the data provided suggest that 11 points have been removed, and monitoring of only 11 sites is taking place. *The focus of this overview is on the Olifants River water quality and the existing stream diversion associated with OC4*. Based on a review of the hydrochemistry data provided, the following is noted:

- 2S_SW1 (Olifants River – middle stream)
  - The point has been exhibiting neutral pH conditions in 2022, with a definite increase in TDS, $SO_4$, F, Ca, Mg and Al observed in March 2022, which has decreased in the latest sample run in July 2022 (TDS < 500 mg/l, $SO_4$ < 100 mg/l, Fe < 0.5 mg/l).
- 2S_SW2 (Olifants River – Upstream)
  - The point has been exhibiting neutral pH conditions in 2022, with a definite increase in TDS (>4000 mg/l), F (>0.7 mg/l) and Al (>0.1 mg/l) observed in March 2022, which has decreased in the latest sample run in July 2022 (TDS < 360 mg/l, $SO_4$ < 100 mg/l, Fe < 0.5 mg/l). It is noted that Al and Fe concentrations are often above the target water quality limits. It is noted that Al and Fe concentrations are often above the target water quality limits.
- 2S_SW3 (Olifants River – Downstream)
  - The point has been exhibiting neutral pH conditions in 2022, with a definite increase in TDS (>600 mg/l), $SO_4$ (>200 mg/l), F (0.7 > mg/l), Ca (>60 mg/l), Mg (>30 mg/l), Al (>0.06 mg/l) and Mn (>0.15 mg/l) observed in March 2022, which has decreased in the latest sample run in July 2022 (TDS < 450 mg/l, $SO_4$ < 150 mg/l, Fe < 0.6 mg/l). It is noted that Al and Fe concentrations are often above the target water quality limits.
- 2S_SW4 (existing stream diversion)
  - The point exhibits neutral pH conditions but has been exhibiting high EC, TDS, Alk, $SO_4$, Ca, Mg, Al and Mn concentrations, above the target water quality limits. It is noted that in July 2022 pH has remained stable, with consistently high TDS (>1600 mg/l), $SO_4$ (> 900 mg/l), and Fe (>0.15 mg/l).

Available water quality data for the Olifants River does suggest that there has been a mining impact on the river. The change in TDS from upstream to downstream is estimated in the order of 66 mg/l, and pH remains stable in the order of 7.7. Inflow from the existing stream diversion draining the 2-Seams area is contributing to the total dissolved salt load in the river.

**Table 5-10: Summary of surface water sampling points**

| Site Label | Sampling Frequency | Sampled (Y/N) | The reason, if not sampled | Latitude | Longitude |
|---|---|---|---|---|---|
| 2S_SW1 | Monthly | Y | | 26°10'5.85"S | 29°21'20.98"E |
| 2S_SW2 | Monthly | Y | | 26°10'10.03"S | 29°22'26.91"E |
| 2S_SW3 | Monthly | Y | | 26° 9'9.71"S | 29°20'44.10"E |
| 2S_SW4 | Monthly | Y | | 26° 9'52.2" S | 29°20'36.7" E |
| 2S_SW5 | Monthly | N | Removed | 26° 9'24.93"S | 29°19'35.13"E |
| 2S_SW6 | Monthly | N | Removed | 26° 9'11.31"S | 29°20'28.73"E |
| 2S_SW7 | Monthly | Y | | 26°10'8.78"S | 29°20'29.03"E |
| 2S_SW8 | Monthly | Y | | 26°10'13.28"S | 29°20'35.96"E |
| 2S_SW9 | Monthly | Y | | 26°10'16.46"S | 29°22'23.45"E |
| 2S_SW10 | Monthly | N | Removed | 26°11'31.48"S | 29°22'12.37"E |
| 2S_SW11 | Monthly | N | Removed | 26°11'13.94"S | 29°20'26.14"E |
| 2S_SW12 | Monthly | N | Removed | 26°10'54.48"S | 29°19'57.30"E |
| 2S_SW13 | Monthly | N | Removed | 26°11'23.83"S | 29°22'21.70"E |
| 2S_SW14 | Monthly | Y | | 26°10'34.49"S | 29°22'20.12"E |
| 2S_SW15 | Monthly | N | Removed | 26°10'30.44"S | 29°22'19.30"E |
| 2S_SW16 | Monthly | Y | | 26°10'28.84"S | 29°22'5.67"E |
| 2S_SW17 | Monthly | N | Removed | 26°10'25.11"S | 29°21'57.91"E |
| 2S_SW18 | Monthly | Y | | 26° 9'55.58"S | 29°20'23.83"E |
| SWL01 | Monthly | N | Removed | 26° 9' 40.49" S | 29° 19' 20.6" E |
| SWL02 | Monthly | N | Removed | 26° 9' 15.19" S | 29° 20' 9.3" E |
| SWL03 | Monthly | N | Removed | 26° 9' 7.4" S | 29° 20' 32.81" E |
| VLK-SW7 | Monthly | Y | | 26°10'5.38"S | 29°20'22.77"E |

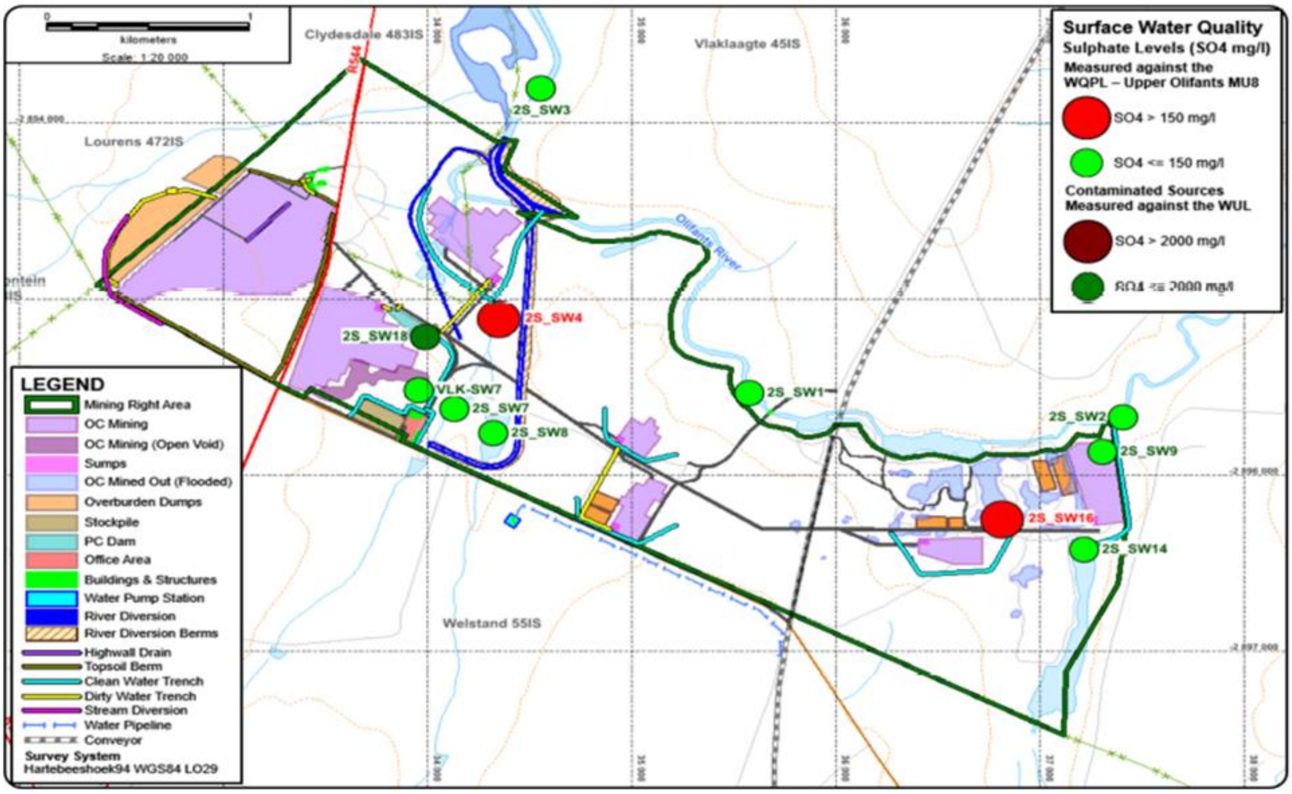



**Figure 5-8: Surface water monitoring points (Zyntha Consulting, 2022) - $SO_4$ compliance March 2022**

## 5.17 Groundwater quantity assessment

Data from relevant hydrogeological databases was obtained from the Water Resources of South Africa Report 2012 (WR2012, 2015) and Groundwater Resource Assessment Ver. 2 datasets (DWAF, GRAII, 2006). As stated previously, the site falls within quaternary catchment B11B as tabulated in Table 5-11.

**Table 5-11: Summarised Quaternary Catchment Information**

| Quaternary Catchment | Total Area (km²) | Recharge (mm/a) | Rainfall (mm/a) | Baseflow (mm/a) | Population |
|---|---|---|---|---|---|
| B11B | 435.3628 | 7% | 691.2 | 3.58 [PITMAN Model] | >8255 |

### *5.17.1 Sub-catchment Delineation*

The delineated sub-catchment is indicated in Figure 1-3. The combined extent of the sub-catchment areas is approximately 106.35 km².

### *5.17.2 Existing groundwater usage (EU)*

No existing groundwater users were identified via the desktop and field hydrocensus. Hence, no EU is reserved for the water balance.

### *5.17.3 Basic human needs (BHN)*

The population in B11B is > 8255 people. As a result of the population not being known, and the limited water supply boreholes in the area, no BHN is reserved (i.e. available data suggest that the aquifer units in the area are poorly exploited for groundwater use).

### *5.17.4 Proposed groundwater usage (PU)*

No PU is reserved for the 2-Seams mine. The only groundwater that will be removed is groundwater ingress into opencast operations. Hence, no fixed PU is reserved. The

### *5.17.5 Existing land use (LU)*

Based on 2018 South African National Land Cover data for the sub-catchment the sub-catchment consists predominantly of mine dumps, mine operations, thickets, bushels and natural grassland (DEA, 2019). The project area is also extensively mined, and hence, there may be both decreases/increases in groundwater recharge. To be conservative, these anthropogenic activities are not accounted for, to present a base case groundwater reserve.

### *5.17.6 Groundwater balance*

Table 5-12 presents the groundwater reserve calculations for the delineated sub-catchments. Based on available information and the water balance undertaken, there is a surplus amount of groundwater available for all sub-catchments delineated. All groundwater dewatering as a result of opencast and underground expansions should be evaluated in context to the surplus reserve calculated.

**Table 5-12: Estimated groundwater reserves for delineated sub-catchments**

| HRU1 | | | HRU2 | | | HRU3 | | |
|---|---|---|---|---|---|---|---|---|
| Area | 78.22 | $km^2$ | Area | 19.97 | $km^2$ | Area | 8.15 | $km^2$ |
| Rainfall | 691.23 | mm/yr | Rainfall | 691.23 | mm/yr | Rainfall | 691.23 | mm/yr |
| BF | 13.63 | mm/yr | BF | 13.63 | mm/yr | BF | 13.63 | mm/yr |
| Aquifer Recharge | | | Aquifer Recharge | | | Aquifer Recharge | | |
| Re | 48.39 | mm/yr | Re | 48.39 | mm/yr | Re | 48.39 | mm/yr |
| Re to Aquifer | 3784868.85 | $m^3$/yr | Re to Aquifer | 966461.33 | $m^3$/yr | Re to Aquifer | 394566.44 | $m^3$/yr |
| Existing Use (EU) | | | Existing Use (EU) | | | Existing Use (EU) | | |
| | None | $m^3$/day | | None | $m^3$/day | None | | $m^3$/day |
| Total EU Day | 0.00 | $m^3$/day | Total EU Day | 0.00 | $m^3$/day | Total EU Day | 0.00 | $m^3$/day |
| Total EU Year | 0.00 | $m^3$/yr | Total EU Year | 0.00 | $m^3$/yr | Total EU Year | 0.00 | $m^3$/yr |
| Basic Human Needs | | | Basic Human Needs | | | Basic Human Needs | | |
| BHN | 0.00 | $m^3$/day | BHN | 0.00 | $m^3$/day | BHN | 0.00 | $m^3$/day |
| BHN | 0.00 | $m^3$/yr | BHN | 0.00 | $m^3$/yr | | 0.00 | $m^3$/yr |
| Base Flow | | | Base Flow | | | Base Flow | | |
| BF | 1066176.76 | $m^3$/yr | BF | 272246.85 | $m^3$/yr | BF | 111147.20 | $m^3$/yr |
| Available | 2718692.08 | $m^3$/yr | Available | 694214.48 | $m^3$/yr | Available | 283419.24 | $m^3$/yr |
| Proposed Use (PU) | | | Proposed Use (PU) | | | Proposed Use (PU) | | |
| | None | $m^3$/day | | None | | | None | |
| | | $m^3$/day | | 147.17 | | | | |
| Total PU Day | 0.00 | $m^3$/day | Total PU Day | 147.17 | $m^3$/day | Total PU Day | 0.00 | $m^3$/day |
| Total PU Year | 0.00 | $m^3$/yr | Total PU Year | 53716.32 | $m^3$/yr | Total PU Year | 0.00 | $m^3$/yr |
| Nett Balance | 2718692.08 | $m^3$/yr | Nett Balance | 640498.16 | $m^3$/yr | Nett Balance | 283419.24 | $m^3$/yr |

# 6 CONCEPTUAL GEOHYDROLOGICAL MODEL

Based on the information for the site a conceptual model was developed. The conceptual model illustrates the existing flow system and aims to evaluate potential groundwater pollution sources (i.e. opencast workings, PCDs, TSF etc.), potential activities that could impact the groundwater flow regime (i.e. opencast mine dewatering, underground mine dewatering, river diversion), as well as the end-receivers that will be exposed to the risk (Olifants river, vadose zone and aquifer units).

Figure 6-1 shows the current site layout, planned mining pits (OC4 and OC4A) and the proposed Olifants river diversion portion. Based on the conceptual model developed, the following is noted:

- The 2 Seam Mine is located in the Highveld Region of Mpumalanga. Summer rainfall is experienced in the study area, with a MAP rate of approximately 691 mm/year. Evaporation is estimated to be 1385 mm/annum.
- Regional drainage features flow towards the North, but locally the Olifants River flows towards the northwest. The topography across the study area is slightly undulating with a general gradient of 3° to 10° towards the north-northeast where the Olifants River borders the site.
- The study area is underlain by stratigraphy of the Vryheid Formation, Ecca Group of the Karoo Supergroup. The coal-bearing Vryheid Formation consists predominantly of fine-grained sandstone, platy shale and coal (No. 4, No. 2 and No. 1 seams). the No. 2 and No.4 seams are the major mining targets at 2 Seam Mine.
- Three (3) aquifers occur within the study area: an alluvium zone (unconfined) along the Olifants River flood plain, an upper weathered Ecca aquifer (shallow aquifer formed in the weathered zone of the Karoo sediments), fractured aquifers within the unweathered but fractured Ecca stratigraphy and fractured aquifer underlying the Ecca sediments consisting of low yielding Dwyka and/or basement rocks. An additional hydrogeological unit is present within the study area, attributed to the disturbance of in-situ hydrogeological conditions by historical mining activities.
- The latest groundwater level measurements at 2 Seam Mine range between 1.12 to 30.56 mbgl and indicate subdued groundwater levels in some areas due to historical mining activities.
- Groundwater contamination within the vicinity of the historical underground mining areas has historically been exhibited by BH2, BH3 and prominently BH5 (EC > 300 mS/m, TDS> 2500 mg/l, $SO_4$ > 2500 mg/l).
- TDS concentrations within old rehabilitated pits that have become flooded range between 500 mg/l and 2400 mg/l. Sulphate varies between 200 mg/l and 1400 mg/l. Neutral pH conditions are observed (GCS, 2016).

- Acid-base accounting analyses conducted on material sampled for the 2 Seam Mine indicate that 33.3% of the carbonaceous mudstone/shale samples have a high potential to generate acidic drainage; 100% (4 out of 4 samples) of the coal samples collected have a high potential to generate acidic drainage; 50% (2 out of 4) of the shale samples collected has a very high potential to generate acidic drainage, 25% (2 out of 8) of the sandstone/mudstone samples collected has a high potential to generate acidic drainage and 100% (1 out of 1) of the soil and clay samples collected has low potential to generate acidic drainage (and will generate a low to medium salt load.

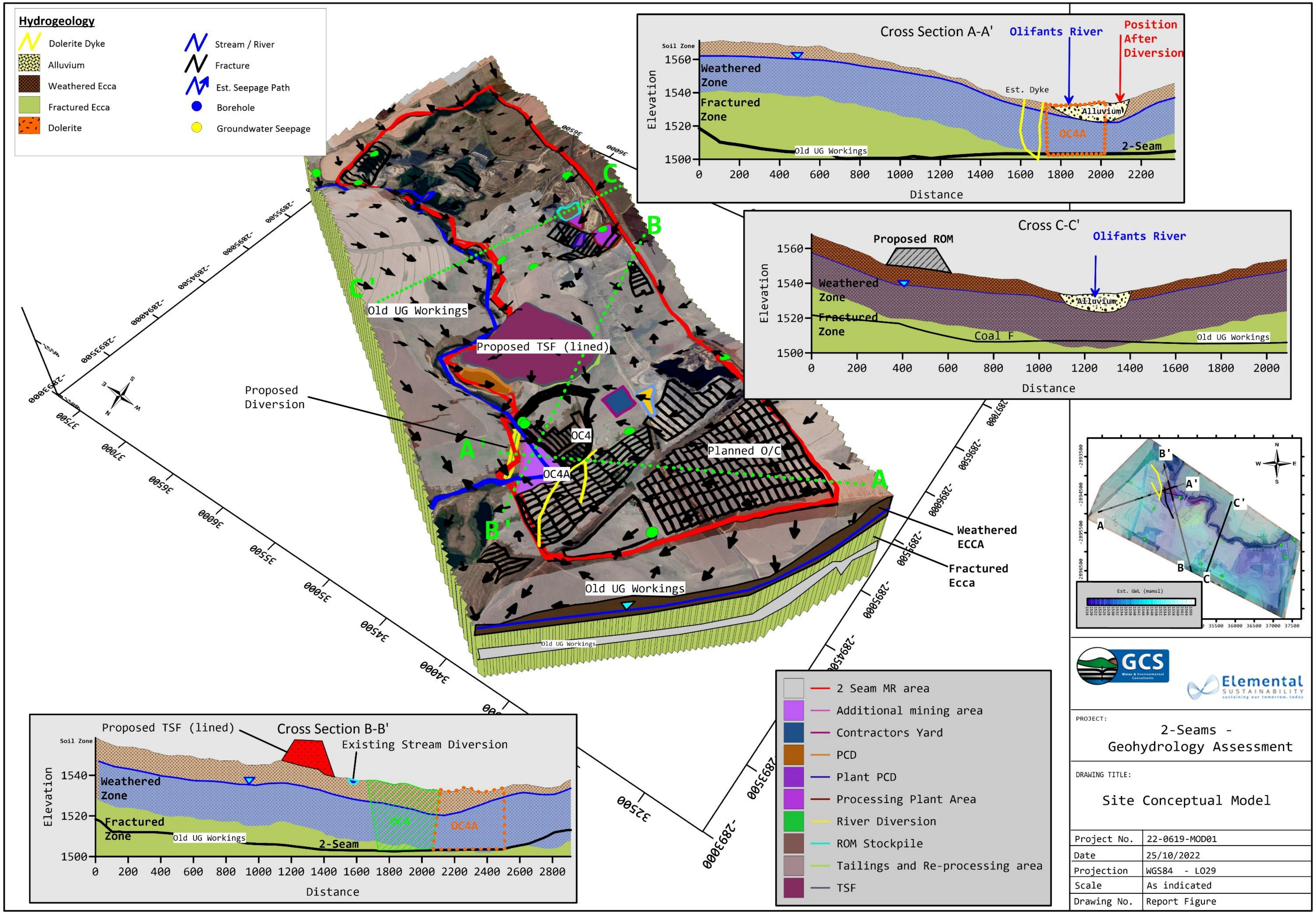



**Figure 6-1: Conceptual geohydrological model**

## 6.1 Potential contaminants, sources-pathways and receptors

The source-pathway-receptor principle should be addressed by the conceptual hydrogeological model, and is presented as follows:

- Groundwater Sources:
    - Recharge: Natural recharge to the weathered aquifer is estimated to be within 1 and 3% of MAP (Grobbelaar et al, 2004). Recharge could also potentially occur from surface water bodies Artificial sources of recharge include leakage from pollution control dams (PCD) if the structural integrity of their foundations is compromised, waste rock dumps, ROM stockpiles and backfilled opencast workings. Recharge to dumps, stockpiles and old rehabilitated opencast could range between 8 and 80% of MAP, depending on the degree to which the dumps/backfill have been levelled and rehabilitated (Hodgson and Krantz, 1998), but a general recharge value of 20% can be expected for these features within the study area.
    - Contamination: The potential sources of contamination associated with the opencast mining and the river diversion induce seepage and runoff from the opencast workings, old, backfilled opencast workings, overburden and waste rock dumps. The underground mine workings could pose a risk of groundwater contamination, as is likely evident at BH5.

Any poor quality seepage from the above-mentioned sources will likely show contaminant signatures relating to High EC, low pH (or neutral depending on drainage type), high $SO_4$, and a variety of metals of which Fe, Mn and Al will be dominant – refer to static and peroxide geochemical leach test data (Section 5.3).

- Groundwater Pathways:
    - Contaminants may migrate from potential sources of contamination to sensitive receptors through the weathered aquifer. Groundwater flow towards rivers and streams could lead to the contamination of surface water bodies if baseflow contribution occurs.
    - Contaminated recharge may permeate through the vadose zone to the shallow weathered aquifer, and depending on aquifer interconnectivity, migrate to the fractured aquifer.
    - Decant and consequent overland flow towards depressions can contaminate downstream receptors. Infiltration of contaminated decant may also occur.

- o Fault zones and dykes represent preferential pathways of groundwater movement and contaminant migration. Although no site-specific data is available to detect these structures, the Karoo Supergroup does exhibit brittle deformation and has been intruded by dolerite dykes.

- Groundwater Receptors:
  - o Dewatering of the opencast pits will result in groundwater flow towards the mines, thereby, creating artificial groundwater receptors.
  - o Drainage systems: contaminated baseflow contribution may occur to surface water bodies and ecosystems such as wetlands if a groundwater contaminant plume has migrated to the drainage systems. Decant and overland flow may lead to the contamination of surface water bodies. The reduced baseflow contribution due to the development of a dewatering cone of depression during mining may also occur.
  - o Potential groundwater users within the dewatering cone of depression and contaminant plume impact area. The impact area may become larger if geological structures are intercepted.
  - o The groundwater flow system along the Olifants River that will be diverted is predicted to change significantly. Groundwater baseflow and groundwater recharge resulting from the presence of the Olifants River will decrease along OC4 & OC4A, and a long-term dewatering zone is predicted as a result of the natural hydraulic boundary conditions changes if the Olifants River is diverted. The zone of influence (ZOIp) was further assessed by numerical groundwater modelling.

## 6.2 Decant elevations, water accumulation in the final void and decanting areas

Decant may occur if (refer to Figure 6-2 and Figure 6-3):

1. Excess rainwater ingress or rainfall runoff is allowed to accumulate in unrehabilitated and rehabilitated opencast and access adits (box cuts), as well as hydraulically connected boreholes. The aim should be to reduce runoff into the mine workings, and compact and slope rehabilitated workings to reduce infiltration.
2. Areas that are topographically lower than the highest flooded underground working sections, may be at risk of decanting. The likely decant will be driven by the following factors:
   - o The water in the flooded / partially flooded workings will form a positive piezometric head. Hence, water under pressure will tend to reach this piezometric level either through the underground workings or escaping through fractures, fissures, adits, contact zones, fault zones or higher conductive areas.

- Exploration boreholes, opencast box cuts, and ventilation shafts into underground workings with an elevation below the piezometric pressure level are at risk of becoming decant points (flow conduits).

Decant may not be a point source discharge (i.e. seen on the surface as a running stream of water such as a spring) but can also occur via the weathered aquifer or vadose zone (i.e. as baseflow seepage).

Based on existing information for the site, and factoring in the drivers of decant mentioned above, decant at 2-Seams is given a probability in the probability range of moderate to high. It is important to update the decant risk and management strategies as mining progresses and as more geohydrological data becomes available. The interconnectivity of the underground workings with that of the opencast workings needs to also be carefully monitored, as mine interflow can subject connected mine works areas in lower laying areas to decant.

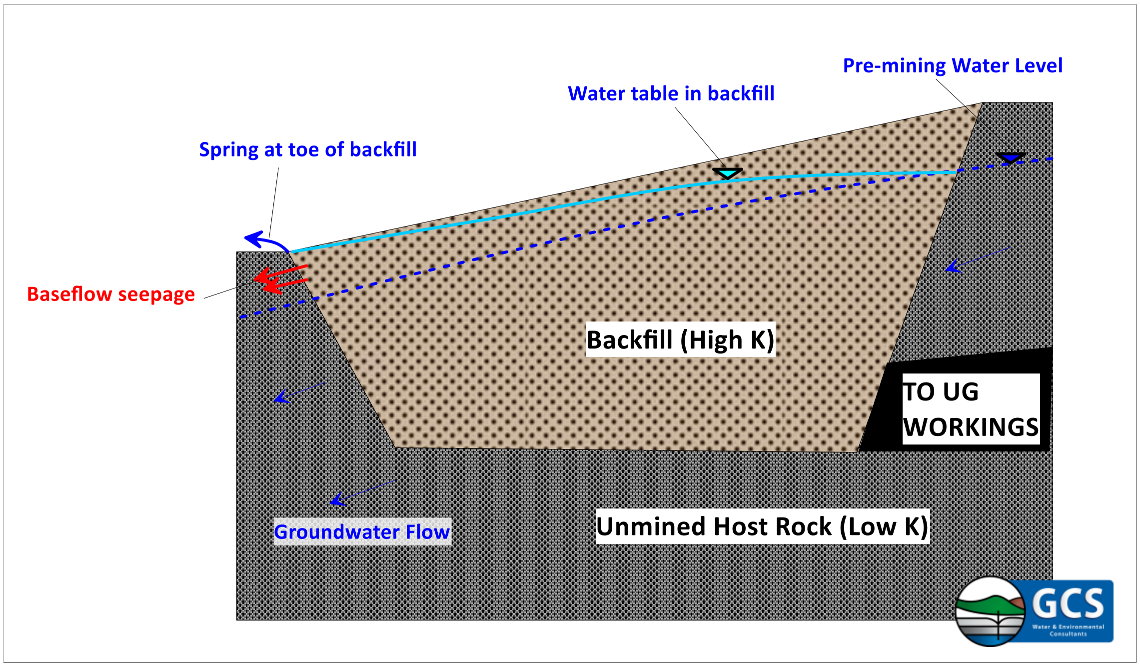



**Figure 6-2: Concept of decanting from backfilled adits**

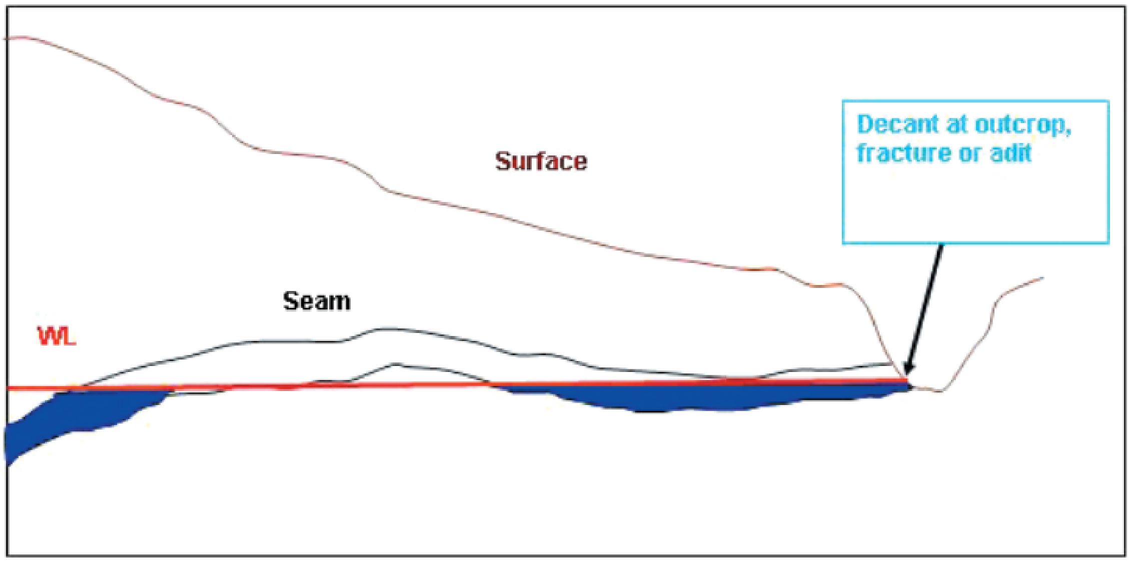



**Figure 6-3: Decant illustration of an unflooded mine, with one seam mined (after Vermeulen and Usher, 2017)**

The decant location, elevation and decant probability are captured in Table 6-1 and shown in Figure 6-4 and Figure 6-5. Based on the coal floor elevations, the existing mine plan and proposed mine plan for OC4 and OC4A, one (1) decant area previously identified for OC4 will fall away, and 2 new potentials decant areas associated with OC4A will likely occur (along the north and east side of the pit). Decant volumes are estimated to be between 26 to 66.5 $m^3$/day for the backfilled OC4 and OC4A areas.

**Table 6-1: Potential decant locations and probability**

| Block | OC1 | OC2 | OC2A | OC3 | OC4A -1 | OC4A -2 | OC5 | OC6 |
|---|---|---|---|---|---|---|---|---|
| X | 37148.823 | 35444.883 | 35081.537 | 36377.502 | 34235.2 | 34458.6 | 33899.743 | 33529.017 |
| Y | -2895873.6 | -2896215.9 | -2895713 | -2896357.6 | -2894151 | -2894151 | -2895234.8 | -2894458 |
| Lowest Topography or Decant Elevation (mamsl) | 1534 | 1549 | 1549 | 1534 | 1532.804 | 1532.059 | 1547 | 1551 |
| Average WL Depth (mbgl) | 5 | 16 | 14 | 12.5 | 5 | 5 | 13 | 9 |
| Duration of Mining (months) | 9 | 10 | 6 | 6 | 12 | 12 | 16 | 24 |
| Approximate Average Depth Below Decant Point ($m^3$/day) | 27 | 24 | 38 | 15 | 31 | 31 | 22 | 29 |
| Pit Surface Area ($m^2$) | 75300 | 42100 | 17300 | 61700 | 175859 | 175859 | 222500 | 697100 |
| Minimum Time to Decant (years) (15% void ratio, 20% recharge) | 7 | 18 | 16 | 14 | 18 | 18 | 17 | 18 |
| Maximum Time to Decant | 26 | 75 | 66 | 59 | 47 | 47 | 65 | 58 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **(years) (25% void ratio, 8% recharge)** | | | | | | | | |
| **Minimum Decant Volume ($m^3$/day)** | 11 | 6 | 3 | 9 | 26 | 26 | 33 | 102 |
| **Maximum Decant Volume ($m^3$/day)** | 28 | 15 | 6 | 23 | 66.5 | 66.5 | 81 | 255 |
| **Comment** | Likely to decant. Need to verify historical inflows. | Unlikely to decant. | Unlikely to decant. | Uncertainty regarding decant potential. Need to verify historical inflows. | Likely to decant. | Likely to decant. | Unlikely to decant. | Unlikely to decant. |

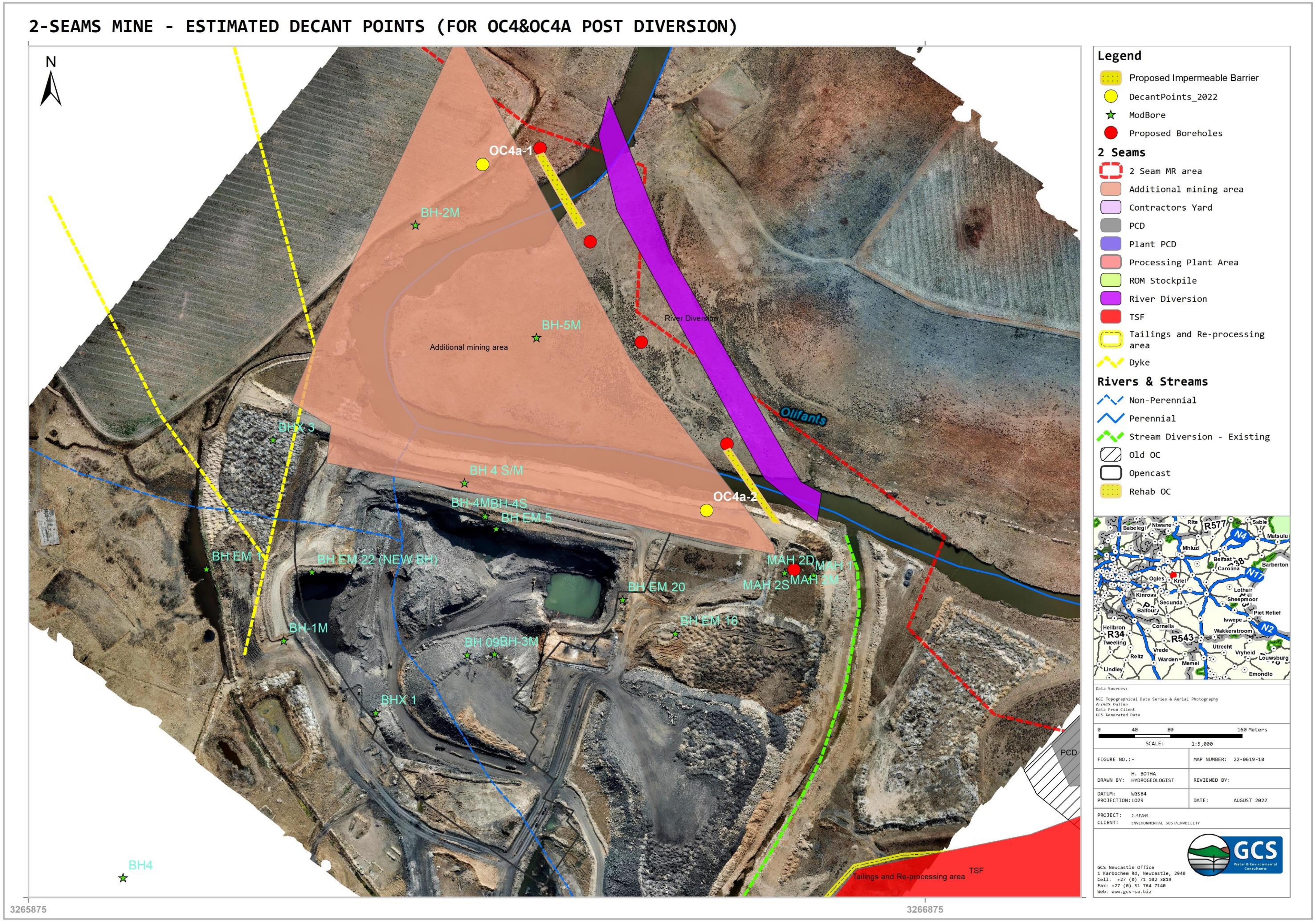



**Figure 6-4: Identified decant points**

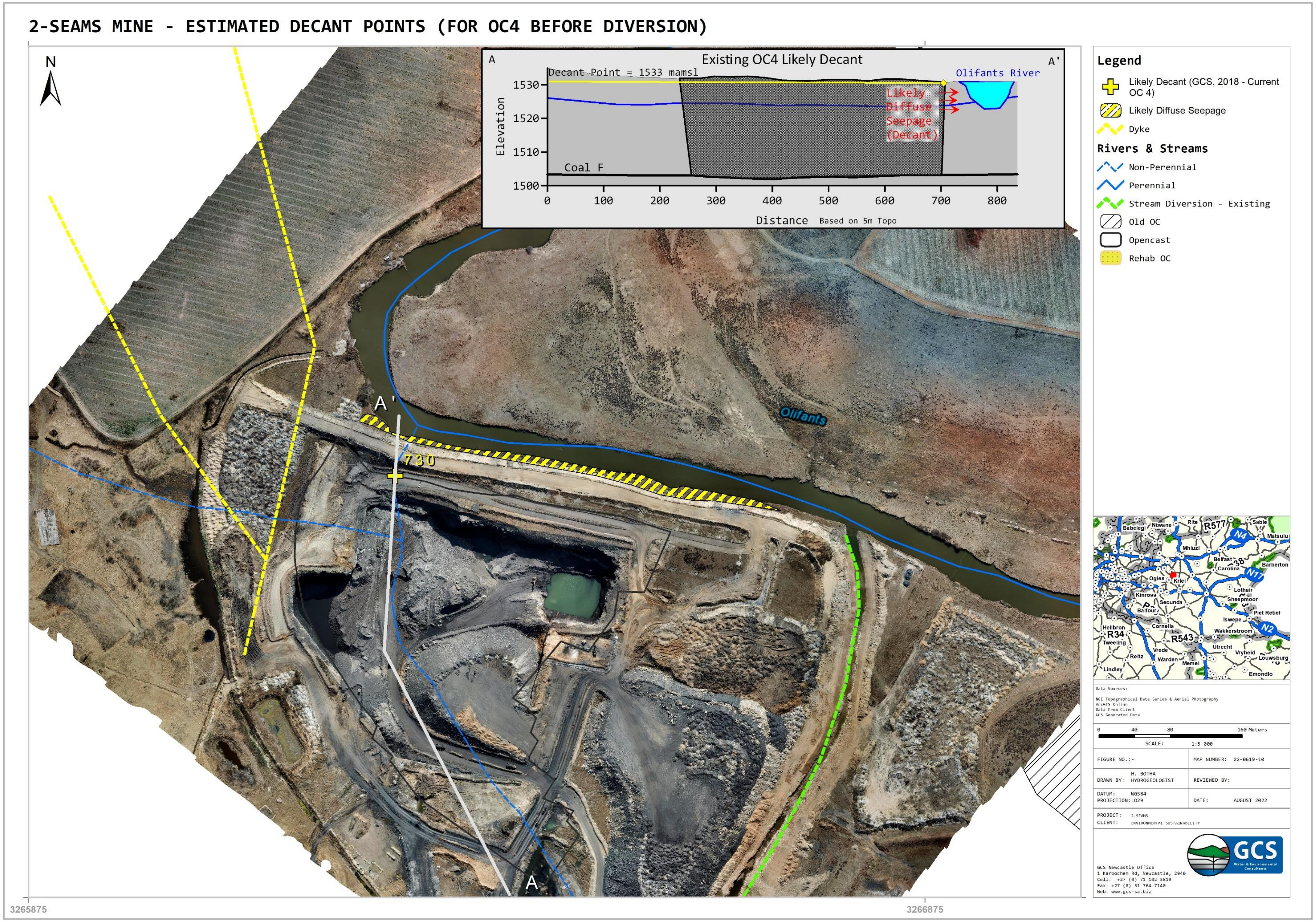



**Figure 6-5:** **Estimated diffuse decant area**

# 7 NUMERICAL GROUNDWATER MODEL AND TRANSPORT MODEL

The numerical groundwater model developed describes the predicted Zone of Influence (ZOIf) and Zone of Impact (ZOIp) of the activities associated with the proposed OC4, OC4a and Olifants River diversion activities.

## 7.1 The objective of the model

As stated previously, the groundwater flow and transport models were developed to:

- Simulate the operational and assumed post-closure groundwater flow system (particularly for OC4 and OC4a); and
- Evaluate the flow system and impact on the receiving environment and decant potential if the stream diversion is implemented (50 and 100Y).

## 7.2 Model assumptions and limitations

The following model assumptions and limitations are recognised:

- Groundwater-specific yield and specific storage values were derived from literature ranges for the rock encountered in the study area. It is assumed that specific yield and specific storage values in the model domain are like literature values.
- $SO_4$ was used to illustrate the predicated zone of impact due to the physical and chemical attributes of $SO_4$. $SO_4$ is typically associated with mine drainage from coal mines and is, therefore, a good tracer to predict impacts (INAP, 2018).
- Conductance for river and stream drainage cells was derived from the literature and built-in stream conductance models in Visual Modflow. It is assumed that conductance in the model domain is like literature values.
- The model does not consider kinetic mineral reactions (i.e. oxidation of minerals within the waste storage facilities or seepage thereof).
- Source terms were defined based on available data for the site and were traced based on available borehole $SO_4$ data and google imagery of the site.
- No capping of the opencast workings (OC4 and OC4A) is simulated. It is therefore assumed that the workings will be backfilled and seeded. In the numerical simulation, a recharge range of 10 to 15% is applied to the backfilled pit areas.

## 7.3 Model time

The model runs from 2010 to 2210 and has a total simulation time of 73 000 days. The mining of OC4 and OC4a will take place from November 2022 to October 2023, with the river diversion planned for Feb 2023. The model simulation time was derived from available mine sequences and mine plans. The model time is available in Table 7-1.

**Table 7-1: Numerical model time**

| Year | Simulation Time (days) | Comment | Sub-Model Time |
|---|---|---|---|
| 2010 | 0 | Model Start | |
| 2011 | 365 | | |
| 2012 | 730 | | |
| 2013 | 1095 | | |
| 2014 | 1460 | | |
| 2015 | 1825 | | |
| 2016 | 2190 | | |
| 2017 | 2555 | | |
| 2018 | 2920 | | |
| 2019 | 3285 | | |
| 2020 | 3650 | | |
| 2021 | 4015 | | |
| 2022 | 4380 | OC4 & OC4A Start in Nov | see sub-model table below |
| 2023 | 4745 | OC4 & OC4A End Ct | |
| 2024 | 5110 | 2 Months after OC4a End | |
| 2025 | 5475 | | |
| 2026 | 5840 | | |
| 2027 | 6205 | | |
| 2028 | 6570 | | |
| 2029 | 6935 | | |
| 2030 | 7300 | | |
| 2033 | 8395 | 10Y after OC4A | |
| 2073 | 22995 | 50Y | |
| 2123 | 41245 | 100Y | |
| 2210 | 73000 | End | |

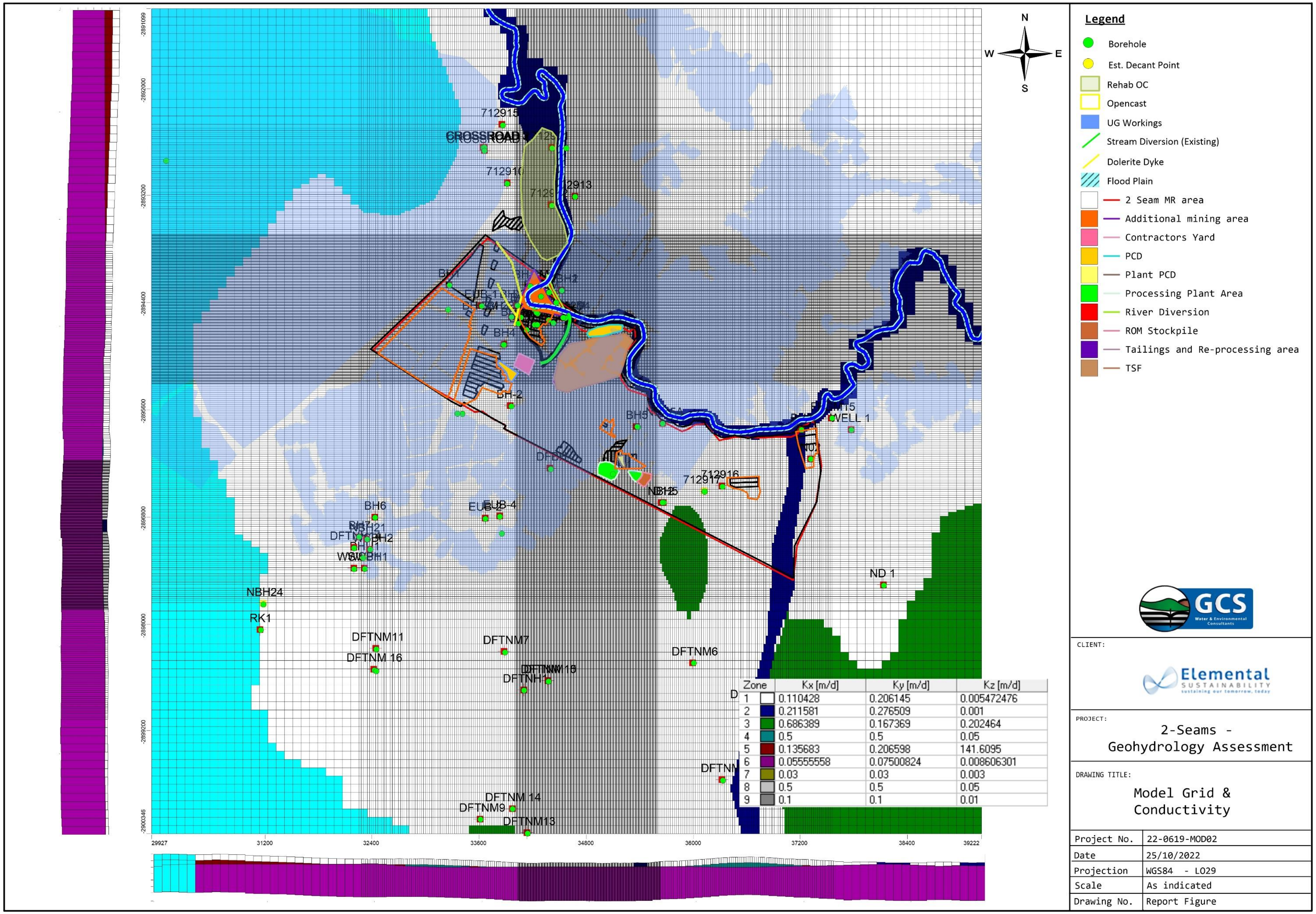
| Month | Month No in Yr | Simulation Time (end of the month) | Comment |
|---|---|---|---|
| Nov | 11 | 4714.583333 | OC4 Start |
| Dec | 12 | 4745 | |
| Jan | 13 | 4775.416667 | |
| Feb | 14 | 4805.833333 | River Diversion |
| Mar | 15 | 4836.25 | |
| Apr | 16 | 4866.666667 | OC4a Extension |
| May | 17 | 4897.083333 | |
| Jun | 18 | 4927.5 | |
| Jul | 19 | 4957.916667 | |
| Aug | 20 | 4988.333333 | |
| Sep | 21 | 5018.75 | |
| Oct | 22 | 5049.166667 | LOM |
| Nov | 23 | 5079.583333 | Backfill |
| Dec | 24 | 5110 | Backfill |

## 7.4 Model conceptualisation

The groundwater model grid and boundary condition visualisation are shown in Figure 7-1 and Figure 7-2. The model describes the groundwater flow field within the sphere of influence mentioned earlier in the report. Both hydrocensus, monitoring and SADAC GIP data for the model domain were applied to calibrate and illustrate the groundwater flow system for the project area. Table 7-2 summarises the model constructs.

**Table 7-2: Numerical modal constructs and conditions**

<table>
<tr><th>Component</th><th>Model Conditions</th></tr>
<tr><td>Model Flow Engine</td><td>USGS 2005 Flow Engine<br>Rewetting Enabled</td></tr>
<tr><td>Transport Model Engine</td><td>MT3DMS</td></tr>
<tr><td>Model Grid and Layers</td><td>Grid of 2.5 to 5 m, and >30m moving further away from the site.<br>3 Layers represent the alluvium, weathered and fractured aquifer systems.</td></tr>
<tr><td>Boundary Conditions</td><td>Stream drains and rivers are assigned to all identified streams and rivers.<br>Drains are assigned to non-perennial streams and the Olifants River. The drains for the river diversion were made inactive per the mine plan, to change the Olifants River flow path. The conductance was estimated at 5mbgl x surface area of the drainage zone.<br>7% = 48.3 mm/yr of the MAP (691 mm).</td></tr>
<tr><td>Initial Heads</td><td>The depth to water level ranged between 0.1 to 23 mbgl.</td></tr>
<tr><td>Conductivity</td><td><table>
<tr><th>Zone</th><th>Kx [m/d]</th><th>Ky [m/d]</th><th>Kz [m/d]</th></tr>
<tr><td>1</td><td>0.110428</td><td>0.206145</td><td>0.005472476</td></tr>
<tr><td>2</td><td>0.211581</td><td>0.276509</td><td>0.001</td></tr>
<tr><td>3</td><td>0.686389</td><td>0.167369</td><td>0.202464</td></tr>
<tr><td>4</td><td>0.5</td><td>0.5</td><td>0.05</td></tr>
<tr><td>5</td><td>0.135683</td><td>0.206598</td><td>141.6095</td></tr>
<tr><td>6</td><td>0.05555558</td><td>0.07500824</td><td>0.008606301</td></tr>
<tr><td>7</td><td>0.03</td><td>0.03</td><td>0.003</td></tr>
<tr><td>8</td><td>0.5</td><td>0.5</td><td>0.05</td></tr>
<tr><td>9</td><td>0.1</td><td>0.1</td><td>0.01</td></tr>
</table></td></tr>
<tr><td>Storage</td><td><table>
<tr><th>Zone</th><th>Ss [1/m]</th><th>Sy []</th><th>Eff. Por. []</th><th>Tot. Por. []</th></tr>
<tr><td>1</td><td>0.0001</td><td>0.2</td><td>0.2</td><td>0.4</td></tr>
<tr><td>2</td><td>0.001</td><td>0.25</td><td>0.3</td><td>0.4</td></tr>
<tr><td>3</td><td>5E-5</td><td>0.15</td><td>0.2</td><td>0.3</td></tr>
<tr><td>4</td><td>0.01</td><td>0.3</td><td>0.3</td><td>0.35</td></tr>
<tr><td>5</td><td>1E-5</td><td>0.15</td><td>0.15</td><td>0.3</td></tr>
<tr><td>6</td><td>1E-5</td><td>0.15</td><td>0.15</td><td>0.3</td></tr>
<tr><td>7</td><td>0.0001</td><td>0.2</td><td>0.2</td><td>0.4</td></tr>
<tr><td>8</td><td>0.0001</td><td>0.2</td><td>0.2</td><td>0.4</td></tr>
<tr><td>9</td><td>0.0001</td><td>0.2</td><td>0.2</td><td>0.4</td></tr>
</table></td></tr>
<tr><td>Dispersity</td><td><table>
<tr><th>Zone</th><th>Dl [m]</th></tr>
<tr><td>1</td><td>30</td></tr>
<tr><td>2</td><td>60</td></tr>
<tr><td>3</td><td>20</td></tr>
<tr><td>4</td><td>50</td></tr>
<tr><td>5</td><td>10</td></tr>
<tr><td>6</td><td>10</td></tr>
<tr><td>7</td><td>10</td></tr>
<tr><td>8</td><td>60</td></tr>
<tr><td>9</td><td>40</td></tr>
</table></td></tr>
<tr><td>Model Calibration Points</td><td>68 Head Boreholes<br>8 concentration boreholes</td></tr>
</table>




| Zone | Kx [m/d] | Ky [m/d] | Kz [m/d] |
|---|---|---|---|
| 1 | 0.110428 | 0.206145 | 0.005472476 |
| 2 | 0.211581 | 0.276509 | 0.001 |
| 3 | 0.686389 | 0.167369 | 0.202464 |
| 4 | 0.5 | 0.5 | 0.05 |
| 5 | 0.135683 | 0.206598 | 141.6095 |
| 6 | 0.05555558 | 0.07500824 | 0.008606301 |
| 7 | 0.03 | 0.03 | 0.003 |
| 8 | 0.5 | 0.5 | 0.05 |
| 9 | 0.1 | 0.1 | 0.01 |

**Figure 7-1: Model grid**

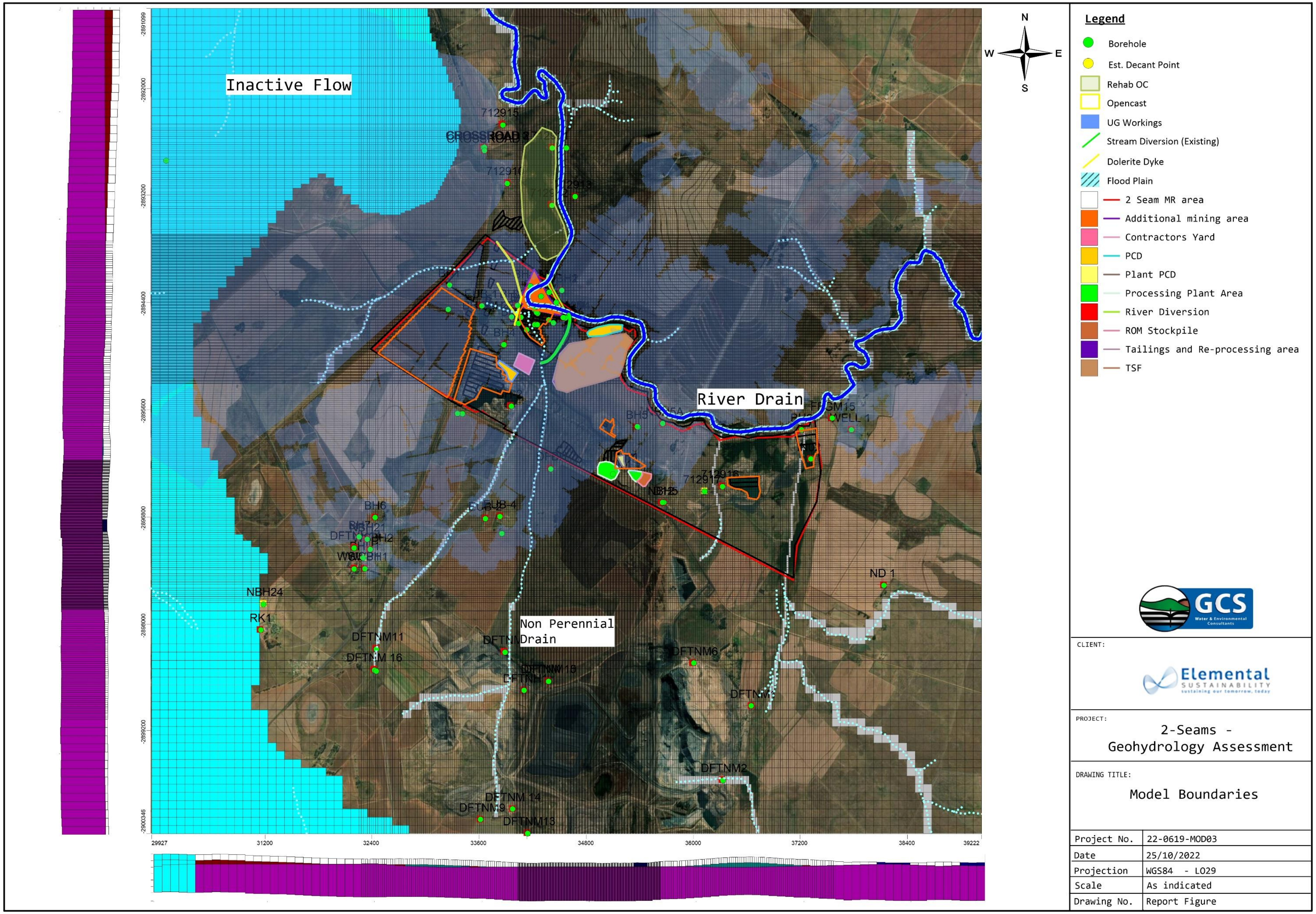



**Figure 7-2: Model boundary conditions**

## 7.5 Model calibration and output visualization process

The ZOI presentations from the model calibration process are as follows:

- Based on the monitoring data for the site, $SO_4$ was used to calibrate the transport model. It was observed that $SO_4$ is generally high in boreholes surrounding known diffuse and point sources at the site and that $SO_4$ is typically associated with poor-quality leachate from these facilities. Geochemical testing has also confirmed that $SO_4$ is typically associated with mine drainage at the site.
- The plume presentation indicates 250 mg/l and 500 mg/l sulphate plume contour lines. The above-mentioned was applied to demarcate potentially contaminated groundwater zones, based on model calibration. The 250 mg/l and 500 mg/l zones represent the SANS 241-1:2015 water quality ranges.
    - These guidelines are not intended to be used for environmental compliance and are used only as a benchmark value, to contextualise the results.
    - Table 7-3 *s*upplies the target water quality range for sulphate as per the DWAF 1996 and SANS 241-1 guideline documents.
- Conductance for river and stream drainage cells was derived from the literature and T values of weathered zone rock.
- The dewatering presentation indicates 0.5 m drawdown contours. The contours aim to illustrate and demarcate the maximum radius of influence and rebound time due to the likely aquifer dewatering activity.

**Table 7-3: Summary of the target water quality range as per the DWAF 1996 and SANS 241-1: 2015 guideline documents for $SO_4$ (mg/l)**

<table>
<tr><th>System</th><th>Aquatic Ecosystems</th><th colspan="2">Domestic / Potable Use</th><th colspan="2">Recreation</th><th colspan="2">Industry</th><th colspan="2">Agriculture</th></tr>
<tr><td rowspan="4">DWAF 1996</td><td rowspan="4">N/A</td><td rowspan="4">Human Consumption</td><td rowspan="4">0-200 mg/l</td><td rowspan="2">Full Contact</td><td rowspan="2">NA</td><td>Category 1</td><td>0-30 mg/l</td><td rowspan="2">Livestock Watering</td><td rowspan="2">0-1000 mg/l</td></tr>
<tr><td>Category 2</td><td>0-80 mg/l</td></tr>
<tr><td rowspan="2">Intermediate Contact</td><td rowspan="2">NA</td><td>Category 3</td><td>0-200 mg/l</td><td>Irrigation</td><td>N/A</td></tr>
<tr><td>Category 4</td><td>0-500 mg/l</td><td>Agriculture</td><td>N/A</td></tr>
<tr><td rowspan="2">SANS 241-1: 2015</td><td rowspan="2">N/A</td><td>Aesthetic</td><td>>250 mg/l</td><td rowspan="2" colspan="2">N/A</td><td rowspan="2" colspan="2">N/A</td><td rowspan="2" colspan="2">N/A</td></tr>
<tr><td>Acute Health</td><td>>500 mg/l</td></tr>
</table>

## 7.6 Model calibration

Aquifer parameters used in the model were obtained from field measurements and model calibration, using measured groundwater levels. Figure 7-3 illustrates the calibration graph for the calculated versus observed heads for the steady-state model. A scaled absolute mean value of below 10-15 % (RMS < 15 %) is generally regarded as acceptable for a local/regional model (Hill & Tiedeman, 2005).

The initial calibration was done under steady-state conditions. An RMS in the order of 12 % was achieved for the steady-state flow model (refer to Figure 7-3). When calibrated, the model can be used as an input to a transient state model, to predict future scenarios.

Adopting this approach, the flow model was calibrated with data for the year 2022, and an RMS in the order of 12.2% was achieved (refer to Figure 7-4).

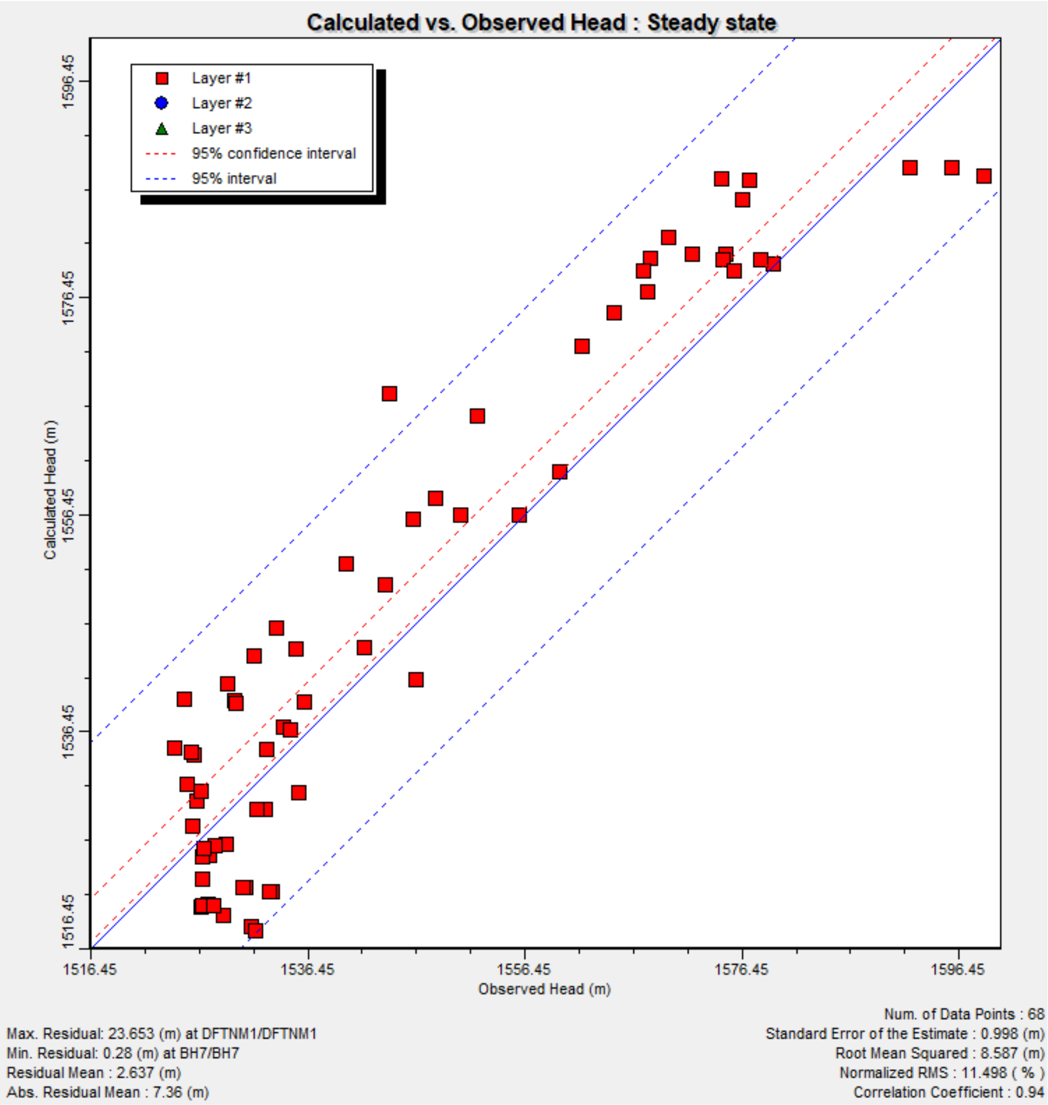



**Figure 7-3: Calibrated steady-state model**

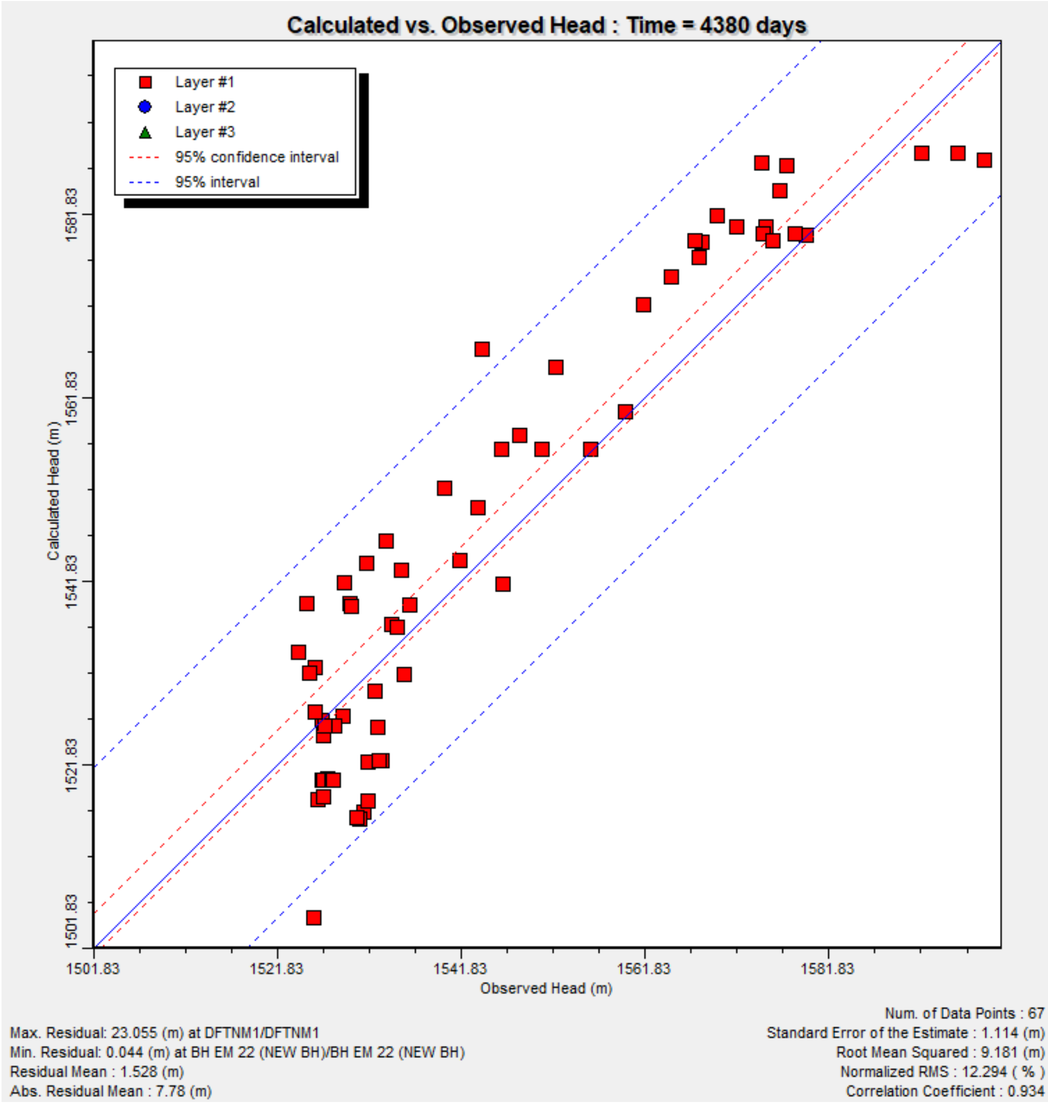



**Figure 7-4: Calibrated transient-state model (the year 2022)**

## 7.7 Model sensitivity

A sensitivity analysis was carried out on the calibrated steady-state model using zones to assess the influence on groundwater level and flow dimensions by running the model in the PEST and sensitivity mode.

It can be seen from Figure 7-5 and Figure 7-6 that the calibrated residuals (calculated heads vs observed heads) are slightly skewed towards the left. However, most of the data plots are within 5-10% of the normalised distribution of the dataset used for calibration.

The following summarises the sensitivity analyses:

- The flow model is very sensitive to changes in aquifer recharge (Par001);
- The flow model is sensitive to changes in horizontal hydraulic conductivity (Kx and Ky) in the 1st layer (top weathered aquifer) and 2nd layer (transition to fractured zone); and
- The flow model is less sensitive to changes in storage and vertical hydraulic conductivity (Ss, Sy and Kz).

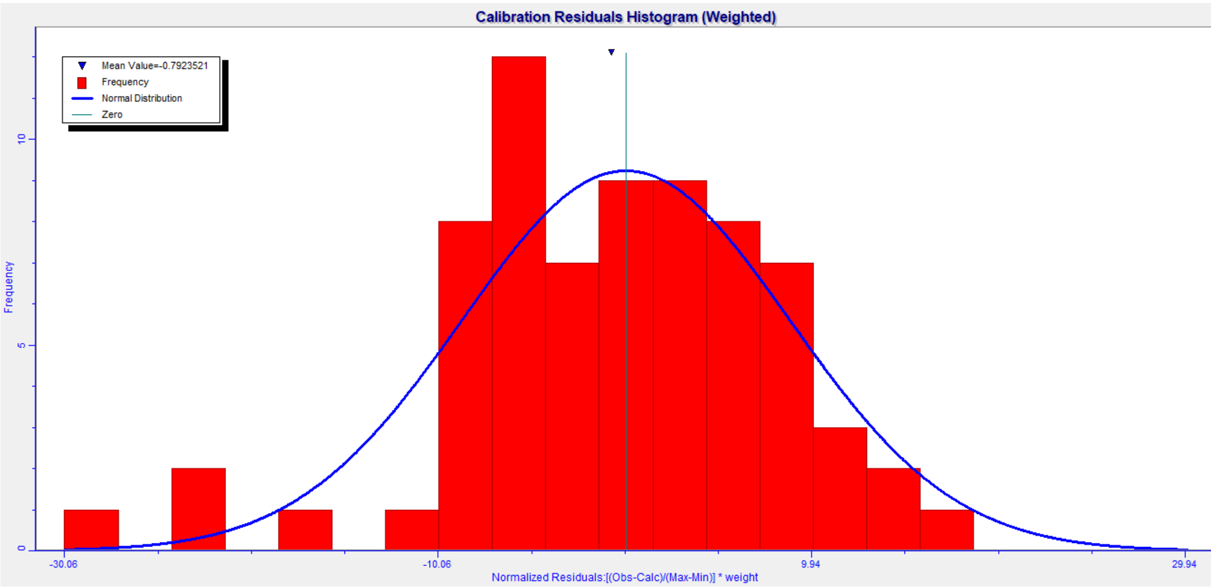



**Figure 7-5: PEST run simulation histogram**

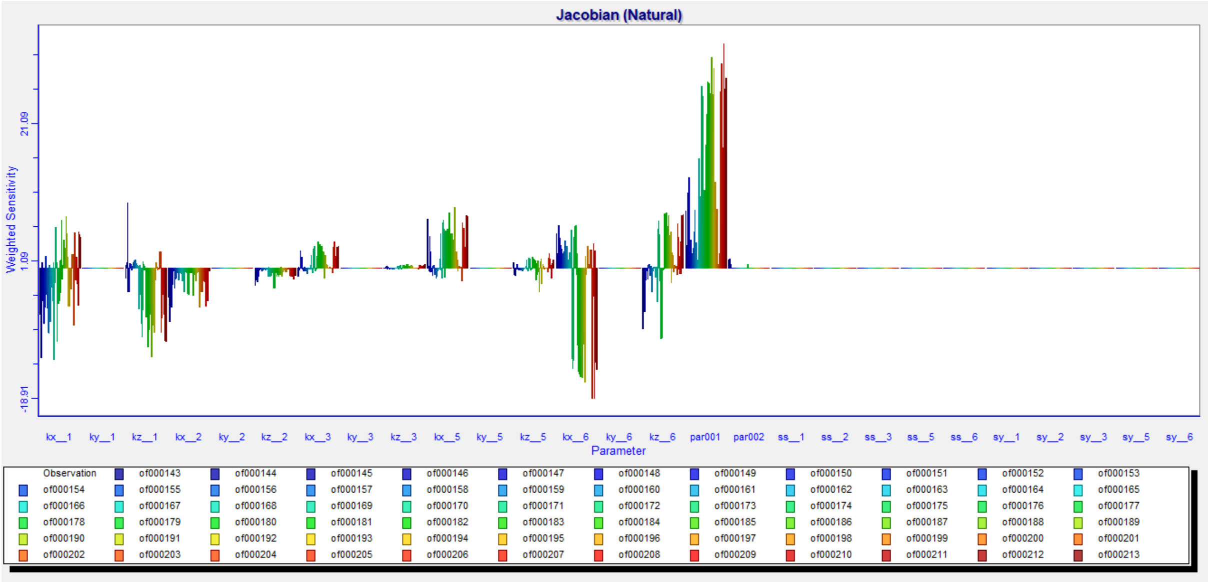



**Figure 7-6: Model sensitivity**

## 7.8 Model results

The numerical modelling outcome is discussed in the sub-sections below.

### *7.8.1 Calibrated flow model (2022)*

The calibrated flow model is shown in Figure 7-7. The following observations are made from the calibrated flow model:

- Groundwater flow is towards the various rivers in the area and follows the topography (further supported by measured correlation data for groundwater elevations and topography elevations for the study area).
- Preferential flow from the OC4 and proposed OC4A areas is towards the Olifants River.
- The flow model indicates flow velocities ranging from 0.001 to 0.2 m/day, with greater velocities achieved for the alluvium aquifer zones. Hence, groundwater flow through the aquifer is slow. The flow model velocities are in the same order of magnitude as the Darcy flow estimates presented in Section 5.11).

### *7.8.2 Simulated drawdown as a result of pit expansion and river diversion*

The simulated aquifer drawdown for the development of OC4 and subsequently OC4A is shown in Figure 7-8. From the simulation, the following is noted:

- At the end of OC4 pit development, before the diversion of the Olifants River, it is noted that greater drawdown occurs in the southern portions of the opencast workings and gradually extends towards the fringe of the proposed OC4A that will mine out the existing portion of the Olifants River.

- The mining of OC4 is predicted to affect the Olifants River and subsequent aquifer, by inducing a 0.5 to 1m drawdown of the subsequent aquifer zone. Therefore, just before the stream diversion takes place, there may be baseflow loss from the Olifants River segment.
- After the diversion takes place, a drawdown ranging from 32 to 20 mbgl, with a greater drawdown towards the south of OC4, is predicted. Because the Olifants River is diverted, a new flow regime is established. The predicted impact on the diverted flow area is < 2 m, and the stream diversion area appears to be safe from the majority of the dewatering associated with the OC4A expansion.
- 50Y after LOM of the OC4 and OC4A pits, it is observed that groundwater levels have not yet recovered to pre-mining levels (with regards to OC4 & OC4A) and that a lingering cone of depression occurs in the area. The lingering cone of depression in the simulation is caused by the new flow system that has been established, and the groundwater system will take several years to establish a new equilibrium (about 100 years based on the current simulation data and model assumptions made in the simulation).

It is important to calibrate the numerical model during the opencast expansion, and if the diversion is approved, more boreholes should be drilled in the area to refine and calibrate the groundwater flow fields. Based on the analytical estimates a rebound of the opencast working is expected between 18 to 47 years, however, the numerical model that considers aquifer flow and baseflow suggests a longer rebound due to the stream diversion.

### *7.8.3 Simulated solute transport / $SO_4$ plume from OC4 & OC4A*

The simulated sulphate transport from OC4 and OC4A, operational and after LOM for the workings, is shown in Figure 7-9. From the simulation, the following is noted:

- The 250 mg/l $SO_4$ contour remains isolated along the mined-out opencast workings, with greater concentrations (>1000 mg/l) predicted for the access box/cut and initial OC4 mine blocks.
    - If the Olifants River segment is not diverted, the preferential movement towards the Olifants River is observed, with the 1000 mg/l plume reaching the river in < 10 years.
- At LOM of OC4A, it is observed that the 250 mg/l $SO_4$ contour remains on the fringe of the mine works, with increases in concentrations towards older sections of the workings.
- The 50Y $SO_4$ plume shows preferential movement towards the Olifants River stream diversion, with the 250 mg/l contours infringing the southern portion of the diversion. $SO_4$ loads to the river are estimated in the order of 150 mg/l.
- The 100Y $SO_4$ plume presents a similar picture to that of the 50Y plume migration. Preferential movement is towards the Olifants River stream diversion, and the $SO_4$ load is estimated to increase to approximately 200 mg/l.

It is predicted that If the opencast workings are to be capped to decrease recharge by <3%, the plume movement to the surrounding environment will be reduced by several orders.

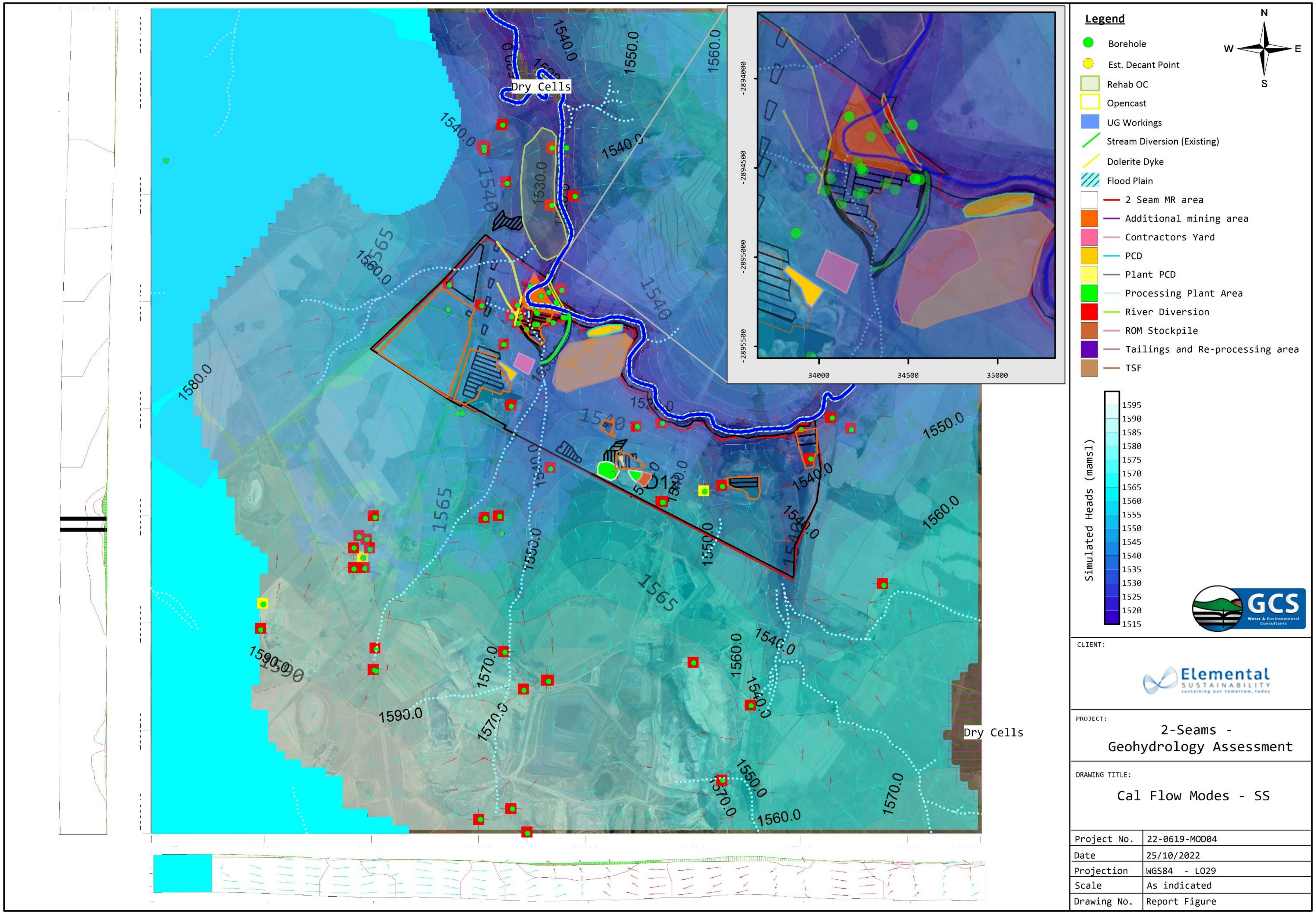



**Figure 7-7: Calibrated flow model (2022)**

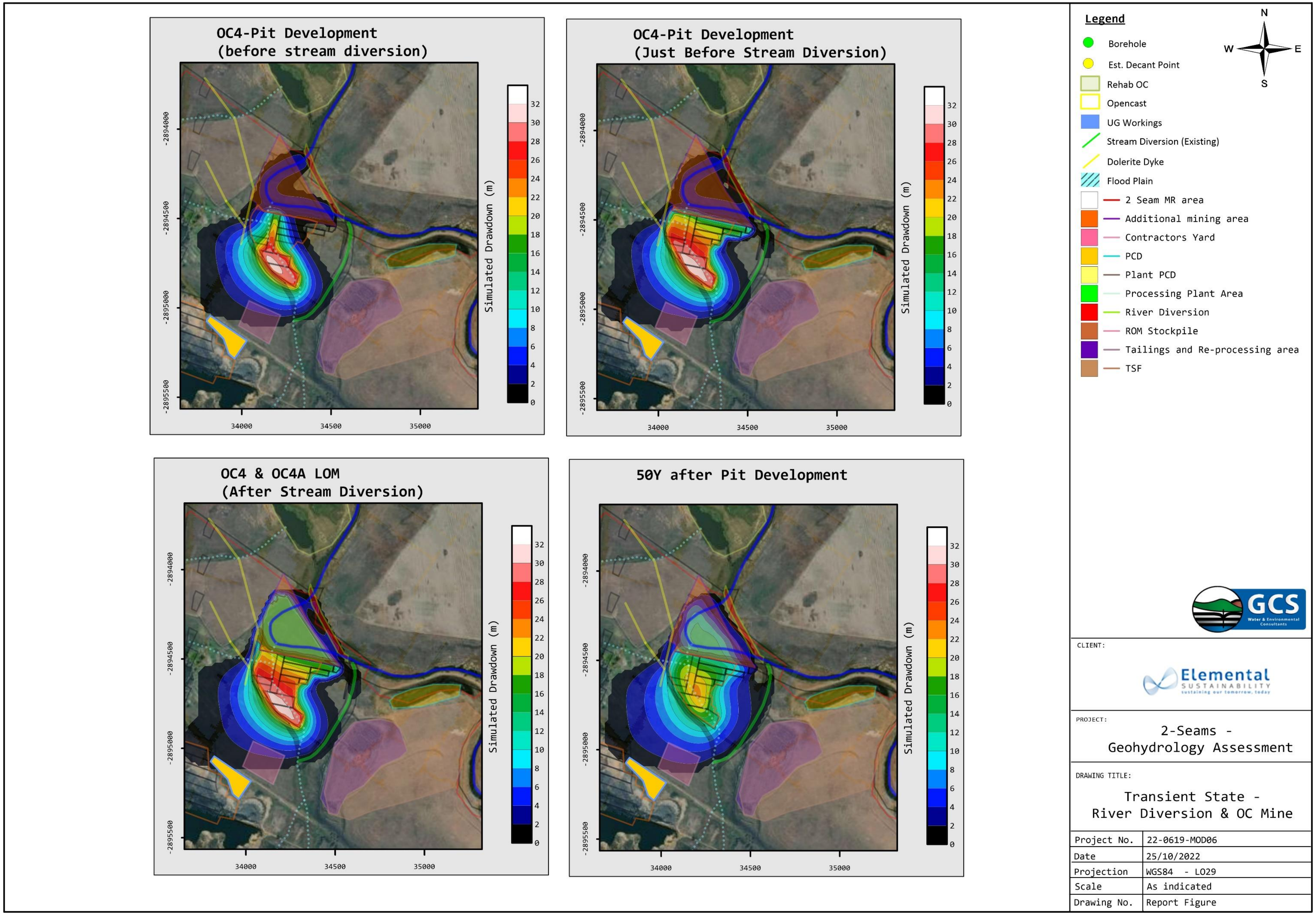



**Figure 7-8: Simulated drawdown - OC4 & OC4A**

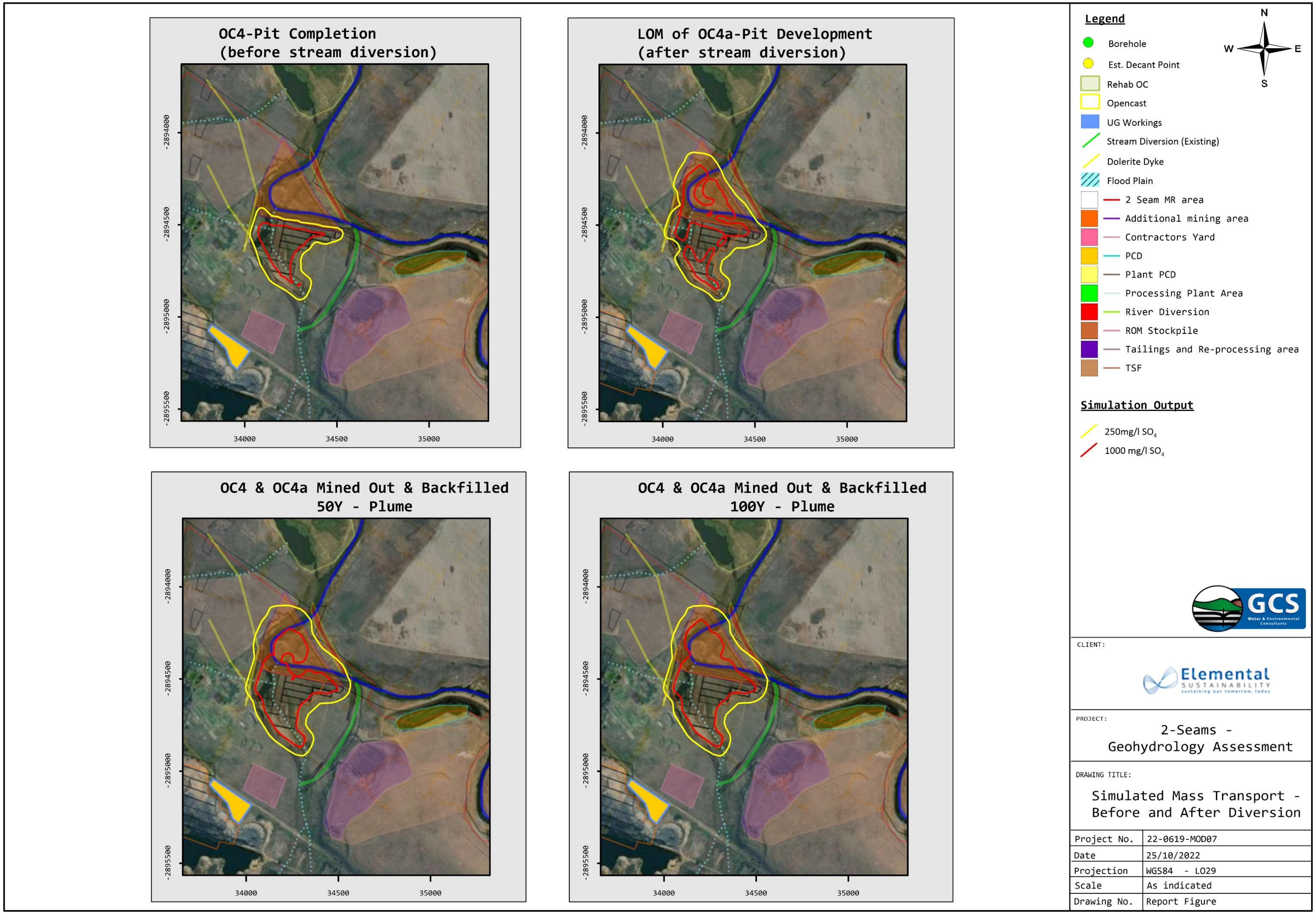



**Figure 7-9:** Simulated solute transport - OC4 & OC4A

# 8 GEOHYDROLOGICAL IMPACTS AND MITIGATION MEASURES

Risk assessment entails understanding the generation of a hazard, the probability that the hazard will occur, and the consequences if it should occur. The net consequence is established by the following equation:

**SP (significance of impact) = (magnitude + duration + scale) x probability**

The anticipated geohydrological impacts for the construction / pre-mining, operational and closure phases of the OC4 and OC4A workings are summarised in Table 8-1 to Table 8-3. Mitigation measures are captured in the table, and the net result of the applied mitigation is evaluated in the last column of the tables. This risk assessment focuses on the proposed OC4 and OC4A operations, and stream diversion associated with the Olifants River.

## 8.1 Pre-mining / development phase

The activities during the pre-mining / development phase of the proposed OC4, OC4A and river diversion will include:

- Typical earthworks are required to start mining of OC4 and OC4A, as well as to divert the Olifants River segment;
- Excavation for the establishment of water management dams and systems;
- Establishment of access roads and other logistics infrastructure;
- Establishment of service platforms, material handling areas and other temporary infrastructure;
- Blasting at the proposed opencast; and
- Placing of topsoil, softs and hard rock on the designated dumps.

The identified risks for the pre-mining phase include (refer to Table 8-1):

- The destruction of the localised geological units at the opencast development. This impact is permanent and is therefore not included in the impact table as no mitigation measures can be recommended.
- Clearing topsoil from footprint areas will influence the rate of infiltration of water to the shallow groundwater system and/or baseflow component to shallow streams.
- Diversion of the Olifants river to a new flow path will void the existing river segment and subsequent alluvium aquifer sone of groundwater baseflow.
- Handling of waste and transport of material can cause various types of spills (domestic waste, sewage water, hydrocarbons) which can infiltrate and contaminate the groundwater system.

- Poor quality mine drainage from material removed during the opencast development (i.e. from overburdened rock piles) may cause local soil and groundwater contamination.
- Oil and fuel spills and leakages at hard park areas, and in the mining pits, may cause poor-quality seepage and soil contamination.
- Stripping of the topsoil during the channel creation for the Olifants River diversion may cause temporary sedimentation as the river takes to the new flow path. There may be some bank erosion which could also lead to sedimentation and suspended solid transport.
- If vehicles and machines leak hydrocarbons during the diversion trenching, there may be local soil contamination that could impact the surface and groundwater quality.

The establishment and continuation of the groundwater monitoring plan during construction is critical. This will ensure that water quality and water levels are continuously monitored. The collected information should be used as part of an active water management system and act as an early warning system for the application of mitigation measures. Except for the destruction of the geology, the other identified impacts during the construction phase are rated low after mitigation and management measures are applied. The identified impacts are therefore not likely to negatively affect the commencement of the proposed project.

## 8.2 Operational phase

The activities during the operational phase will include all mining operations until the end of LOM:

- Opencast mining;
- Opencast dewatering; and
- Pollution control dam for dewatered pit water, tailings facility (TSF), and dirty runoff from surface water infrastructure.

The identified risks for the operational phase include (refer to Table 8-2):

- The destruction of the localised geological units as the opencast workings are developed. This impact is permanent and is therefore not included in the impact table as no mitigation measures can be recommended.
- Opencast mining will result in groundwater inflows into the pits which need to be pumped out for mine safety and will lead to a lowering of groundwater levels in the surrounding aquifers.
- Dewatering activity may impact the shallow baseflow of the Olifants River and its tributaries.

- Diversion of the Olifants river to a new flow path will void the existing river segment and subsequent alluvium aquifer sone of groundwater baseflow.
- Analyses showed that acid mine drainage (AMD) formation is expected and poor-quality leachate can occur based on the leaching potential of the material. This can influence the water quality in the surrounding aquifers. However, groundwater flow directions will be directed towards the opencast and contaminant migration away from the mining areas will be limited during active mining.
- Potentially contaminated groundwater ingress if fracture networks from underground workings are intercepted during opencast mining.
- Poor quality seepage associated with coal transport via haulage roads, concurrent backfilling of opencast pits, overburdened rock, coal and ROM stockpiles, and the plant could lead to spillages, and workshop areas (hydrocarbons, sewage, domestic waste) and pollution Control Dams (existing and proposed).

With exception of the destruction of the geology and the lowering of the water table, which is an expected impact from any mining project, the other identified impacts during the operational phase are rated moderate to low after mitigation and management measures are applied and it is not likely to negatively affect any decisions on the proceeding of the project.

One of the most effective mitigation measures is the use of the existing groundwater and numerical model as a management and predictive tool. Long-term monitoring data and an optimised groundwater monitoring network will provide valuable information to update and re-run the model annually. Monitoring groundwater levels is also critical to ascertain how affected groundwater users may be compensated for losses of groundwater related to the mining operations and to distinguish such from seasonal groundwater level drops. Updates to the model will have to include rainfall, geological, a mining plan and infrastructure data updates. Regular updates will increase the prediction accuracy as well as provide long-term trends and allow for intervention and timely prevention measures. It is further advised that fuel spill and oil clean-up kits are kept on-site to mitigate any hydrocarbon contamination if it occurs.

## 8.3 Closure and decommissioning phases

The closure and decommissioning phases will be per an agreed and approved closure plan for the proposed OC4 and OC4A workings. This will include:

- Cessation of mining operations and rehabilitation;
- Backfill and closure of the opencast with waste rock dump material; and
- Flooding of mining works and resultant altering of the groundwater flow regime for the flooding period.

The identified risks for these phases include (refer to Table 8-3):

- Rebounding water levels.
- Migration of groundwater contaminant plume and contaminated groundwater seepage to streams and Olifants river (salt load).
- Depending on the pit water balance, the pit can decant at the lowest topographical area and negatively impact groundwater and stream quality. This is particularly probable for OC4A.
- Potentially contaminated groundwater ingress if fracture networks from underground workings were intercepted during mining.

## 8.4 Concluding remarks on the risks identified

The identified impacts during closure and post-closure phases are rated moderate-low after mitigation and management measures are applied and are therefore not likely to negatively affect any decisions on the proceeding of the project. The majority of the geohydrological risk relates well to previously identified risks for the 2-Seams Mine.

The largest geohydrological risk is the proposed Olifant River diversion to mine OC4A. The diversion of the river will mean that the existing groundwater flow system will change significantly. The numerical flow model predicts that it will take several years after mining has ceased for the flow system to stabilise after the river is diverted. This will be the result of the diversion as well as projected dewatering cones of depression.

Based on the numerical groundwater model outputs for a diversion vs non-diversion option, if the Olifants River segment is not diverted, there will be significant plume ingress into the river system as baseflow, as well as probable, decant directly into the river from OC4 workings. Mining OC4A reduces direct decant risk associated with the OC4 workings, but does not eliminate the probability of decanting. An only alternative is a no-mining option, where source mitigation would need to be applied to ensure that no plume migration from OC4 takes place (i.e. point source control methods such as capping of the opencast to reduce infiltration to <3%, phytoremediation application to maintain low water levels etc.)>

The proposed OC4 and OC4A areas fall within the existing 2-seams mining right area. As such, there is already an existing mining impact noted - based on available groundwater monitoring data. The proposed mining of OC4 and OC4A will add to the cumulative impact on the local groundwater aquifer and the Olifants River.

**Table 8-1: Geohydrological impacts during the pre-mining phase/ pit development phase/diversion (OC4 & OC4A and Olifants River diversion)**

| POTENTIAL ENVIRONMENTAL IMPACT | ACTIVITY | ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION | | | | | | | RECOMMENDED MITIGATION MEASURES | ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | M | D | S | P | TOTAL | STATUS | SP | | M | D | S | P | TOTAL | STATUS | SP |
| Water Quantity<br>> Groundwater<br>> Olifants River | Clearing topsoil from footprint areas will influence the rate of infiltration of water to the shallow groundwater system and/or baseflow component to shallow streams. | 3 | 2 | 1 | 3 | 18 | - | L | Groundwater level monitoring should be conducted down the gradient of these facilities, in terms of the groundwater flow direction.<br><br>Footprint areas should be minimised and compacted to reduce infiltration. | 3 | 2 | 1 | 3 | 18 | - | L |
| | Diversion of the Olifants river to a new flow path will void the existing river segment and subsequent alluvium aquifer sone of groundwater baseflow. | 8 | 5 | 1 | 5 | 70 | - | H | No mitigation is possible, as the river will be mined. A new flow equilibrium will take place along the diversion path. Peak flows in the river are not anticipated to change, only recharge and baseflow characteristics are associated with the riverbed sediments. | | | | | | | |
| Water Quality<br>> Groundwater<br>> Olifants River | Handling of waste and transport of material can cause various types of spills (domestic waste, sewage water, hydrocarbons) which can infiltrate and contaminate the groundwater system.<br><br>Poor quality mine drainage from material removed during the opencast development (i.e. from overburdened rock piles) may cause local soil and groundwater contamination.<br><br>Oil and fuel spills and leakages at hard park areas, and in the mining pits, may cause poor-quality seepage and soil contamination. | 4 | 3 | 1 | 4 | 32 | - | M | Waste should be discarded in the allocated waste area. The waste area should be bunded. Spills should be cleaned up immediately according to the WULA conditions. DWS should be notified in the event of a significant spill.<br><br>Solid waste must similarly either be stored at the site in an approved waste disposal area or removed by credible contractors.<br><br>Groundwater quality monitoring (quarterly) to identify problem areas.<br><br>Have fuel & oil spill clean-up kits on site.<br><br>Park vehicles in designated areas.<br><br>Ensure route geochemical monitoring (quarterly ABA, NAG, static leach test) of material excavated and placed during mining to confirm AMD potential. | 3 | 2 | 1 | 3 | 18 | - | L |
| | Stripping of the topsoil during the channel creation for the Olifants River diversion may cause temporary sedimentation as the river takes to the new flow path. There may be some bank erosion which could also lead to sedimentation and suspended solid transport.<br><br>If vehicles and machines leak hydrocarbons during the diversion trenching, there may be local soil contamination that could impact the surface and groundwater quality. | 4 | 3 | 1 | 4 | 32 | - | M | Mitigation will likely have a minimum effect, as stream diversion will be required to mine OC4A. The only mitigation measures that can be considered are:<br>• Have fuel and oil spill clean-up kits on-site during stream division trenching.<br>• Park vehicles in designated areas.<br>• Ensure re-vegetation of eroded areas. | 4 | 3 | 1 | 3 | 24 | - | L |

**Table 8-2: Geohydrological impacts during the operational phase (OC4 & OC4A and Olifants River diversion)**

| POTENTIAL ENVIRONMENTAL IMPACT | ACTIVITY | ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION | | | | | | | RECOMMENDED MITIGATION MEASURES | ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | M | D | S | P | TOTAL | STATUS | SP | | M | D | S | P | TOTAL | STATUS | SP |
| Water Quantity<br>> Groundwater Level | Opencast mining will result in groundwater inflows into the pits which need to be pumped out for mine safety and will lead to a lowering of groundwater levels in the surrounding aquifers. | 5 | 2 | 2 | 5 | 45 | - | M | Dewatering should be conducted over as short a period as possible.<br><br>Groundwater ingress rates should be monitored.<br>Water supply should be compensated if any community supply boreholes are influenced.<br><br>Groundwater level and quality monitoring should be conducted. | 4 | 2 | 2 | 5 | 40 | - | M |
| Water Quantity<br>> Baseflow | Dewatering activity may impact shallow baseflow to the Olifants River and tributaries. | 4 | 2 | 1 | 5 | 35 | - | M | Dewatering should be conducted over as short a period as possible.<br><br>Impacts on the surface water bodies should be monitored.<br><br>Groundwater level monitoring should be conducted close to the Olifants River, and additional boreholes should be drilled to monitor the water table and fluctuations. | 3 | 2 | 1 | 3 | 18 | - | L |
| Water Quantity<br>> Olifants River | Diversion of the Olifants river to a new flow path will void the existing river segment and subsequent alluvium aquifer sone of groundwater baseflow. | 8 | 5 | 1 | 5 | 70 | - | H | No mitigation is possible, as the river will be mined. A new flow equilibrium will take place along the diversion path. Peak flows in the river are not anticipated to change, only recharge and baseflow characteristics are associated with the riverbed sediments. | | | | | | | |
| Water Quality<br>> Soil water<br>> Aquifer zones (water table) | Analyses showed that acid mine drainage (AMD) formation is expected and poor-quality leachate can occur based on the leaching potential of the material. This can influence the water quality in the surrounding aquifers. However, groundwater flow directions will be directed towards the opencast workings and contaminant migration away from the mining areas will be limited during active mining. | 5 | 4 | 1 | 4 | 40 | - | M | Loose coal should be removed continuously within pits to reduce the exposure period.<br><br>The operational term of the opencast pit should be kept to a minimum.<br><br>Groundwater quality monitoring should be conducted in the surrounding area.<br><br>Ensure route geochemical monitoring (quarterly ABA, NAG, static leach test) of material excavated and placed during mining to confirm AMD potential. | 5 | 4 | 1 | 4 | 40 | - | M |
| Water Quality<br>> Aquifer zones (water table) | Potentially contaminated groundwater ingress if fracture networks from underground workings are intercepted during opencast mining. | 7 | 4 | 1 | 3 | 36 | - | M | Fracture networks and flow paths should be sealed to prevent the ingress of fresh or contaminated groundwater during mining.<br><br>Blasting should be conducted in such a manner as to reduce impacts on the stability of barrier pillars between opencast workings and old underground workings. | 7 | 4 | 1 | 2 | 24 | - | L |
| Water Quality<br>> Soil water<br>> Aquifer zones (water table)<br>> Dust fallout along the rivers and streams in the project area | Coal transport via haulage roads. | 4 | 4 | 1 | 3 | 27 | - | L | Spillages should be cleaned regularly. | 3 | 3 | 1 | 3 | 21 | - | L |
| Water Quality<br>> Aquifer zones (water table) | Concurrent backfilling of opencast pits - poor quality seepages. | 6 | 5 | 1 | 4 | 48 | - | M | Backfill of the opencast pits with overburden should be conducted correctly - geology with the highest acid leach potential must be backfilled at the base of the pit and compacted.<br>Waste rock should be backfilled to at least 5 m below the static groundwater level, well compacted and lime added.<br><br>Ensure that pollution control dams are lined and their structural integrity maintained.<br><br>Groundwater level and quality monitoring are necessary. | 4 | 5 | 1 | 3 | 30 | - | L |
| Water Quality<br>> Aquifer zones (water table) | Waste disposal on surface - poor quality seepages. | 9 | 4 | 1 | 4 | 56 | - | M | The footprint areas of waste rock dumps should be kept to a minimum.<br><br>The footprint areas should be compacted before disposal and prepared per the results of the waste classification. | 6 | 4 | 1 | 3 | 33 | - | M |

| POTENTIAL ENVIRONMENTAL IMPACT | ACTIVITY | ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION | | | | | | | RECOMMENDED MITIGATION MEASURES | ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | M | D | S | P | TOTAL | STATUS | SP | | M | D | S | P | TOTAL | STATUS | SP |
| | | | | | | | | | Dumps should be constructed to facilitate runoff into trenches.<br><br>Dumps should be separated from any surface water bodies by a berm.<br><br>Groundwater level and quality monitoring are necessary. | | | | | | | |
| Water Quality<br>> Soil water<br>> Aquifer zones (water table) | Coal and ROM Stockpiles. | 9 | 4 | 1 | 4 | 56 | - | M | The footprint areas of stockpiles should be kept to a minimum.<br><br>The footprint areas should be compacted before disposal.<br><br>Stockpiles should be constructed to facilitate runoff into trenches.<br><br>Stockpiles should be separated from any surface water bodies by a berm.<br><br>Groundwater level and quality monitoring are necessary. | 6 | 4 | 1 | 4 | 44 | - | M |
| Water Quality<br>> Soil water<br>> Aquifer zones (water table) | Operation of the plant could lead to spillages. | 7 | 4 | 1 | 4 | 48 | - | M | Spillages should be cleaned regularly and prevented.<br><br>Trenches should be constructed around the plant area to divert contaminated runoff/interflow to the PCD. | 6 | 4 | 1 | 3 | 33 | - | M |
| Water Quality<br>> Soil water<br>> Aquifer zones (water table) | Workshops and spillages (hydrocarbons, sewage, domestic waste). | 4 | 3 | 1 | 4 | 32 | - | M | Waste should be discarded in the allocated waste area, The waste area should be bunded. Spills should be cleaned up immediately according to the WULA conditions. DWS should be notified in the event of a significant spill.<br><br>Solid waste must similarly either be stored at the site in an approved waste disposal area or removed by credible contractors.<br><br>Have fuel & oil spill clean-up kits on site. | 3 | 2 | 1 | 3 | 18 | - | L |
| Water Quality<br>> > Soil water<br>> Aquifer zones (water table) | Pollution Control Dams (existing and proposed)- poor quality seepages. | 8 | 4 | 1 | 5 | 65 | - | H | The liner of the existing PCD is not adequate to contain dirty water and may result in groundwater contamination. The liner needs to be maintained or replaced to ensure functionality.<br><br>Groundwater level and quality monitoring are necessary.<br><br>Ensure that the new PCD is lined with an impermeable barrier. | 8 | 4 | 1 | 2 | 26 | - | L |

**Table 8-3: Geohydrological impacts during the closure phase (OC4 & OC4A and Olifants River diversion)**

| POTENTIAL ENVIRONMENTAL IMPACT | ACTIVITY | ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION | | | | | | | RECOMMENDED MITIGATION MEASURES | ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | M | D | S | P | TOTAL | STATUS | SP | | M | D | S | P | TOTAL | STATUS | SP |
| Groundwater Quantity<br>> Groundwater Levels | **Rehabilitated mining areas** - rebounding water levels. | 5 | 2 | 2 | 5 | 45 | - | M | Water supply should be compensated if any community supply boreholes are influenced.<br><br>Groundwater level and quality monitoring should be conducted. | 3 | 2 | 2 | 4 | 28 | - | L |

| POTENTIAL ENVIRONMENTAL IMPACT | ACTIVITY | ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION | | | | | | | RECOMMENDED MITIGATION MEASURES | ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | M | D | S | P | TOTAL | STATUS | SP | | M | D | S | P | TOTAL | STATUS | SP |
| Water Quality<br>> Olifants River<br>> Groundwater table | **Rehabilitated mining areas** - Migration of groundwater contaminant plume and contaminated groundwater seepage to streams and Olifants river (salt load). | 10 | 5 | 2 | 4 | 68 | - | H | Groundwater levels in the backfilled pits will recover. Pollution plumes may migrate to surface water bodies such as the Olifants River, its tributaries and wetlands.<br><br>The final backfilled opencast topography should be engineered such that runoff is directed away from the opencast areas to reduce recharge.<br><br>The final layer (just below the topsoil cover) should be as clayey as possible and compacted if feasible, to reduce recharge into the opencast workings.<br><br>Material with the highest acid leach potential must be backfilled at the base of the pit, below the regional groundwater level and compacted.<br><br>Surface water monitoring of the streams will be essential.<br><br>Quarterly groundwater sampling should be done to establish a database of plume movement trends, to aid eventual mine closure.<br><br>If it is established that contaminated baseflow seepage occurs to surface water bodies, suitable remediation measures should be evaluated and implemented as soon as possible.<br><br>It should also be considered only backfilling OC4 and OC4A with non-acid generating material (if possible). This will reduce long-term liability.<br><br>If it is determined that private groundwater users are affected by the potential contaminant plumes, their water supply can be compensated.<br><br>Groundwater level and quality monitoring post-closure is crucial, particularly between the opencast pits and surface water bodies. | 8 | 5 | 2 | 3 | 45 | - | M |
| Water Quality<br>> Olifants River<br>> Groundwater table | **Rehabilitated mining areas** - depending on the pit water balance, the pit can decant at the lowest topographical area and negatively impact groundwater and stream quality. This is particularly probable for OC4A. | 10 | 4 | 2 | 4 | 64 | - | H | To manage AMD, a detailed water balance should be calculated for the mine.<br><br>Pit groundwater inflows should be recorded and used to update the decant calculations.<br>Decant calculations should be updated for the final pit topography.<br><br>Water influx into the mining areas should be kept to the absolute minimum possible. In this regard, the fracturing of the overlying strata due to blasting or surface subsidence should be avoided at all costs, to prevent increased infiltration of surface water into the mine workings.<br><br>Berms should be constructed and maintained between pit and downstream surface water bodies and depressions to reduce the flow of decanting to surface water bodies.<br><br>Backfilling should be conducted to limit recharge to the opencast pits and free drainage to trenches should be facilitated. Diverted water should be managed. | 8 | 4 | 2 | 3 | 42 | - | M |

| POTENTIAL ENVIRONMENTAL IMPACT | ACTIVITY | ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION | | | | | | | RECOMMENDED MITIGATION MEASURES | ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | M | D | S | P | TOTAL | STATUS | SP | | M | D | S | P | TOTAL | STATUS | SP |
| | | | | | | | | | Treating decanting mine water to acceptable water quality levels can be achieved by the installation of a treatment plant. The level to which the water is treated depends on the use of the water after treatment.<br><br>As a minimum, treated water should meet the standards for use for livestock watering and irrigation.<br><br>Groundwater level and quality monitoring post-closure is crucial, particularly between the opencast pits and surface water bodies. | | | | | | | |
| Water Quality<br>> Olifants River<br>> Groundwater table | Potentially contaminated groundwater ingress if fracture networks from underground workings were intercepted during mining. | 7 | 5 | 1 | 3 | 39 | - | M | Fracture networks and flow paths should be sealed to prevent the ingress of fresh or contaminated groundwater during mining.<br><br>Blasting should be conducted in such a manner as to reduce impacts on the stability of barrier pillars between opencast workings and old underground workings. | 7 | 4 | 1 | 2 | 24 | - | L |

# 9 GROUNDWATER MONITORING

The 2-Seams mine has an existing groundwater and surface water monitoring programme. After consideration of the proposed activities and geohydrological risks identified, the following improvements are proposed:

- Undertake quarterly geochemical monitoring of overburdened rock (footwall and high wall rock - this is the rock in contact with the coal seam). The rock samples should be subjected to ABA, NAG, Sulphur-speciation, XRD and static leach testing, to determine the acid/naturalisation potential of the overburden mixture. Understanding the AMD potential will help to plan for closure, understand the poor-quality seepage potential, and help determine what the long-term water liability could be.
- Drill six (6) additional monitoring boreholes downstream of the OC4 and OC4A area, and consider the proposed stream diversion, within the 50m buffer area that will be maintained. It is proposed that the boreholes be drilled before any stream diversion activities take place to verify the baseline groundwater conditions and verify the potential risks identified in this geohydrological assessment. The proposed borehole construction is shown in Figure 9-1. It is further proposed that the boreholes be integrated into the existing groundwater monitoring program after drilling and pump testing.

**Table 9-1: Proposed drilling positions to improve groundwater detection system**

| Site | Type | Latitude | Longitude |
|---|---|---|---|
| 2S-BH1 | Groundwater | -26.155750 | 29.342977 |
| 2S-BH2 | Groundwater | -26.156597 | 29.343480 |
| 2S-BH3 | Groundwater | -26.157506 | 29.343991 |
| 2S-BH4 | Groundwater | -26.158427 | 29.344850 |
| 2S-BH5 | Groundwater | -26.159565 | 29.345520 |
| 2S-BH6 | Groundwater | -26.160456 | 29.348999 |

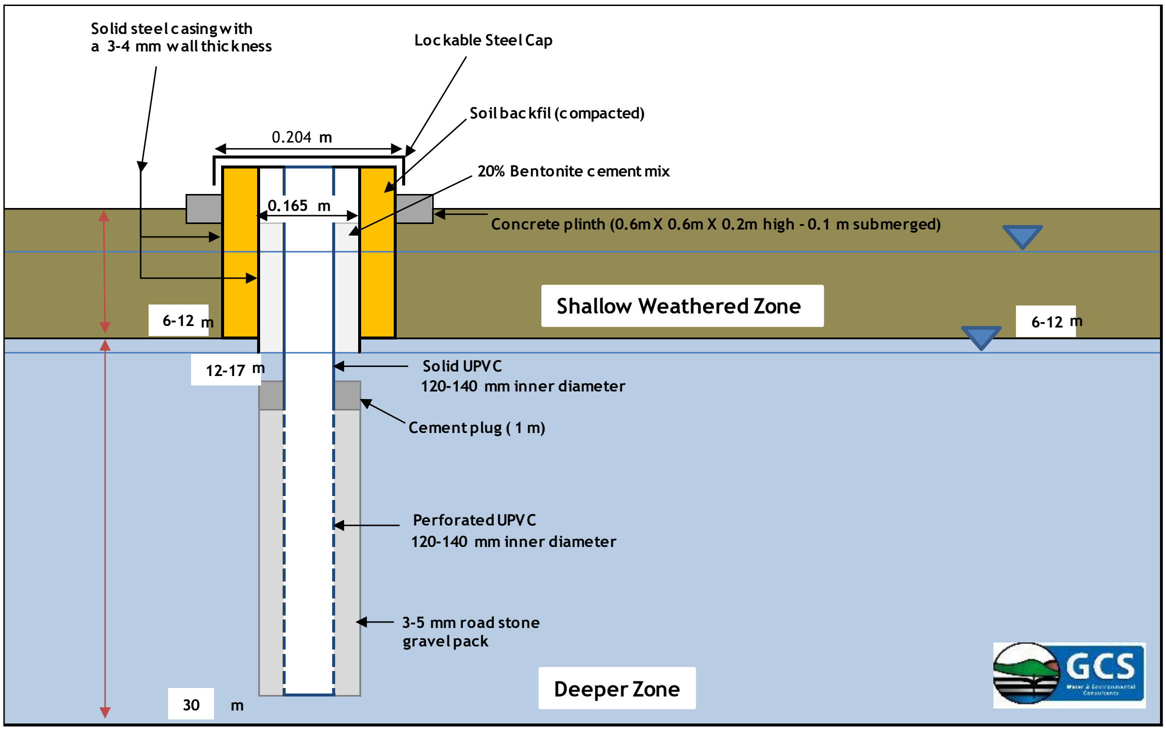
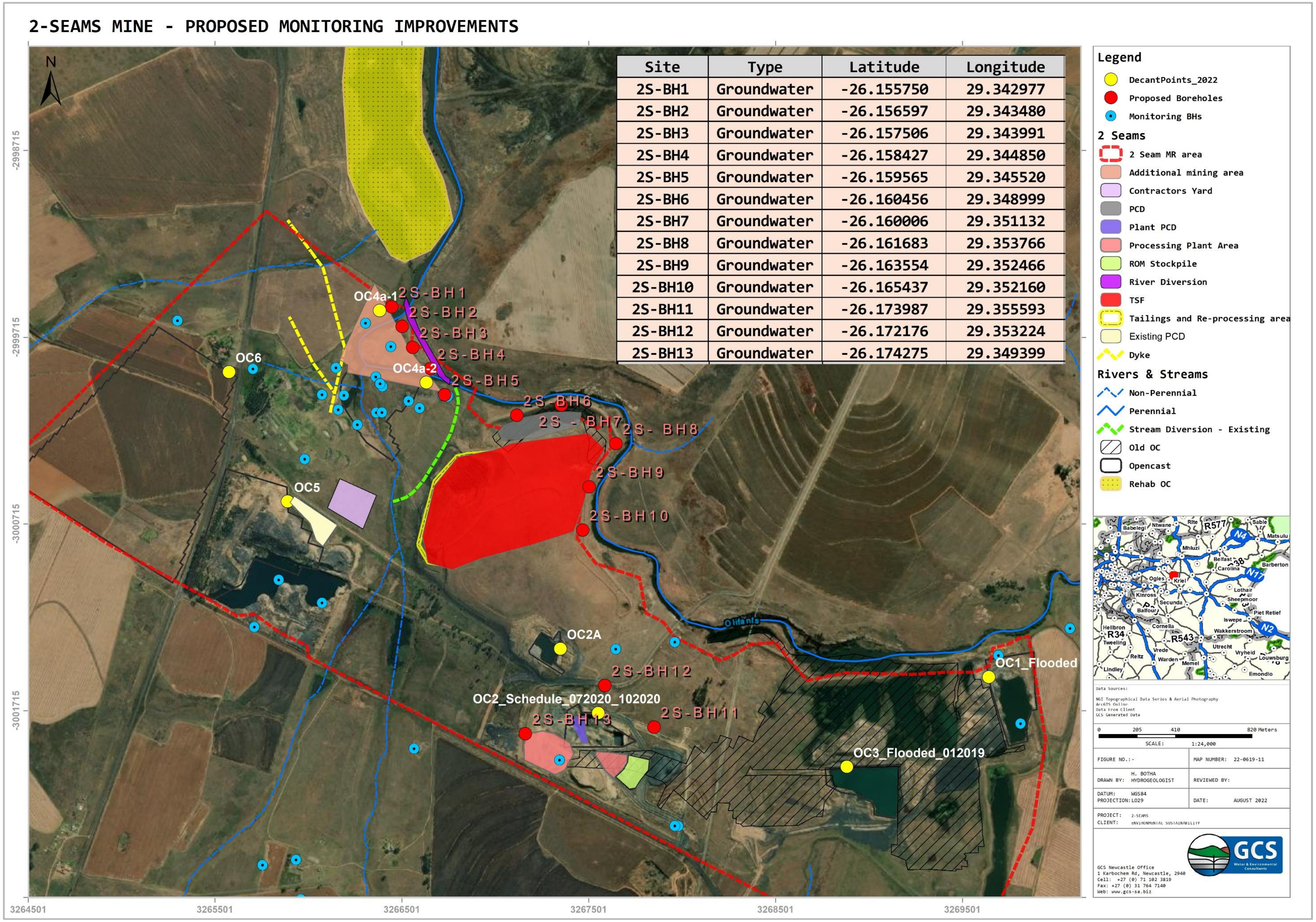



**Figure 9-1: Proposed borehole construction**




| Site | Type | Latitude | Longitude |
|---|---|---|---|
| 2S-BH1 | Groundwater | -26.155750 | 29.342977 |
| 2S-BH2 | Groundwater | -26.156597 | 29.343480 |
| 2S-BH3 | Groundwater | -26.157506 | 29.343991 |
| 2S-BH4 | Groundwater | -26.158427 | 29.344850 |
| 2S-BH5 | Groundwater | -26.159565 | 29.345520 |
| 2S-BH6 | Groundwater | -26.160456 | 29.348999 |
| 2S-BH7 | Groundwater | -26.160006 | 29.351132 |
| 2S-BH8 | Groundwater | -26.161683 | 29.353766 |
| 2S-BH9 | Groundwater | -26.163554 | 29.352466 |
| 2S-BH10 | Groundwater | -26.165437 | 29.352160 |
| 2S-BH11 | Groundwater | -26.173987 | 29.355593 |
| 2S-BH12 | Groundwater | -26.172176 | 29.353224 |
| 2S-BH13 | Groundwater | -26.174275 | 29.349399 |

**Figure 9-2: Proposed additional monitoring boreholes**

# 10 GROUNDWATER MANAGEMENT

The following section supplies a brief groundwater management plan which could help to improve the groundwater conditions during the operational and decommissioning phases of the OC4 and OC4A operations (and other opencast operations at 2-Seam).

## 10.1 Operational and decommissioning phase

To restrict the local groundwater and surface water impact, the following actions are proposed:

- Reduce the recharge potential through stockpiles, rock dumps and coal waste dumps using capping or covering the material with a geomembrane. Ongoing rehabilitation through implementation and maintenance of the above-mentioned will reduce the impact on the groundwater.
- Re-use of groundwater seepage collected in soak ways, stormwater trenches, cut-off trenches, underground and opencast workings and adequately sized pollution control facilities.
- Keep dirty areas like workshops and oil and diesel storage areas as small as possible.
- Contain poor quality runoff from dirty areas and divert this water to PCDs for re-use.
- Have oil/diesel spill kits on site.
- Do not stoop coal pillars which are situated at depths shallower than 30 mbgl in underground workings and leave a 30m to 50m barrier between opencast and underground workings which are mining the same coal seam (if no access adit is established).
- Confirm groundwater and surface water monitoring protocol and plans during the operational and pre-closure phase, as well as the groundwater risk and potential water liabilities.

## 10.2 Groundwater closure objectives

To restrict the local groundwater and surface water impact, the following actions are proposed:

- Cap or line overburden dumps with a geomembrane or clay liner, to reduce infiltration into the dumps. Hence, this will reduce poor-quality seepage percolation into the groundwater aquifer.
- Multiple-level monitoring wells must be constructed to monitor base-flow quality within the identified sensitive zones and to monitor groundwater level behaviour in the open cast pits. Use the results of the monitoring programme to confirm/validate the predicted impacts on groundwater availability and quality after closure.

- Update existing predictive tools to verify long-term impacts on groundwater, if required.
- Present the results to the competent authority on an annual basis to determine compliance with the closure objectives set during the Decommissioning Phase.
- Negotiate and get groundwater closure objectives approved by the competent authority during the decommissioning phase of the project, based on the results of the monitoring information obtained during the construction and operational phases of the project, and through verification of the numerical model constructed for the project.
- Continue with groundwater quality and groundwater level monitoring for a period of at least two to four years after the pits and waste facilities are decommissioned to establish post-closure groundwater level and quality trends. The monitoring information must be used to update, verify and recalibrate the predictive tools used during the study to increase confidence in the closure objectives and management plans.
- Present results of the monitoring programme to the competent authority on an annual basis. The post-closure monitoring programme will be re-evaluated on an annual basis in consultation with the competent authority.
- Negotiate closure with competent authority based on the results of the groundwater monitoring undertaken, after the two to four-year post-closure monitoring periods.

# 11 CONCLUSIONS

This specialist study focused on evaluating the existing groundwater and surface water setting of the 2-Seams Mine and specifically focused on the proposed mining of OC4 and OC4A with subsequent diversion of the Olifants River to enable mining of OC4A.

Concluding remarks concerning the investigation and the groundwater model outputs are summarised as follows:

- The study area is underlain by stratigraphy of the Vryheid Formation, Ecca Group of the Karoo Supergroup. The coal-bearing Vryheid Formation consists predominantly of fine-grained sandstone, platy shale and coal (No. 4, No. 2 and No. 1 seams). the No. 2 and No.4 seams are the major mining targets at 2 Seam Mine.
- Three (3) aquifers occur within the study area: an alluvium zone (unconfined) along the Olifants River flood plain, an upper weathered Ecca aquifer (shallow aquifer formed in the weathered zone of the Karoo sediments), fractured aquifers within the unweathered but fractured Ecca stratigraphy and fractured aquifer underlying the Ecca sediments consisting of low yielding Dwyka and/or basement rocks. An additional hydrogeological unit is present within the study area, attributed to the disturbance of in-situ hydrogeological conditions by historical mining activities.
- The OC4 and OC4A will be situated in an area associated with alluvium sediments (nearing the Olifants River), and the Ecca rock of the Karoo Sequence. To mine the 2-seam that underlies the Olifants River, the Olifants River would need to be diverted to an area that appears to have been a historic diversion (refer to google imagery of the area).
- The latest groundwater level measurements at 2 Seam Mine range between 1.12 to 30.56 mbgl and indicate subdued groundwater levels in some areas due to historical mining activities.
- Groundwater contamination within the vicinity of the historical underground mining areas has historically been exhibited by BH2, BH3 and prominently BH5 (EC > 300 mS/m, TDS> 2500 mg/l, $SO_4$ > 2500 mg/l).
- TDS concentrations within old rehabilitated pits that have become flooded range between 500 mg/l and 2400 mg/l. Sulphate varies between 200 mg/l and 1400 mg/l. Neutral pH conditions are observed (GCS, 2016).

- The mining of OC4 is predicted to affect the Olifants River and subsequent aquifer, by inducing a 0.5 to 1 m drawdown of the subsequent aquifer zone. Therefore, just before the stream diversion takes place, there may be baseflow loss from the Olifants River segment. After the diversion takes place, a drawdown ranging from 32 to 20 mbgl, with a greater drawdown towards the south of OC4, is predicted. A new flow regime is established, as a result of the stream diversion. The predicted impact on the diverted flow area is < 2 m, and the stream diversion area appears to be safe from the dewatering associated with the OC4A expansion. The groundwater flow system along the Olifants River that will be diverted is predicted to change significantly. Groundwater baseflow and groundwater recharge resulting from the presence of the Olifants River will decrease along OC4 & OC4A, and a long-term dewatering zone is predicted as a result of the natural hydraulic boundary conditions changes if the Olifants River is diverted. It is important to calibrate the numerical model during the opencast expansion, and if the diversion is approved, more boreholes should be drilled in the area to fine-tune and calibrate the groundwater flow fields. Based on the analytical estimates a rebound of the opencast working is expected between 18 to 47 years, however, the numerical model that considers aquifer flow and baseflow suggests a longer rebound due to the stream diversion.
- The 250 mg/l SO4 contour remains isolated along the mined-out opencast workings, with greater concentrations (>1000 mg/l) predicted for the access box/cut and initial OC4 mine blocks. If the Olifants River segment is not diverted, the preferential movement towards the Olifants River is observed, with the 1000 mg/l plume reaching the river in < 10 years. At LOM of OC4A, it is observed that the 250 mg/l $SO_4$ contour remains on the fringe of the mine works, with increases in concentrations towards older sections of the workings. The 50Y $SO_4$ plume shows preferential movement towards the Olifants River stream diversion, with the 250 mg/l contours infringing the southern portion of the diversion. $SO_4$ loads to the river are estimated in the order of 150 mg/l. It is predicted that If the opencast workings are to be capped to decrease recharge by <3%, the plume movement to the surrounding environment will be reduced by several orders.
- Based on the coal floor elevations, the existing mine plan and the proposed mine plan for OC4 and OC4A, one (1) decant area previously identified for OC4 will fall away, and 2 new potentials decant areas associated with OC4A will likely occur (along the north and east side of the pit). Decant volumes are estimated to be between 26 to 66.5 $m^3$/day for the backfilled OC4 and OC4A areas (refer to section 6.2).
- According to Guiding Principles 2.3 and 2.4 in the Australian groundwater modelling guidelines (Barnett *et al.*, 2012) the degree of confidence in the groundwater flow and transport model was evaluated:

- The flow model is assigned a Class 2 confidence level due to the numerous groundwater heads available for calibration. Class 2 models are suitable for assessing higher-risk developments in higher-value aquifers (i.e. major aquifers for groundwater supply or an aquifer highly susceptible to pollution).
- The transport model is assigned a Class 2 confidence as a sufficient amount of groundwater concentration calibration points are available.

- It is fair to conclude that all data made available for this investigation, and data obtained from the site visit, have successfully been incorporated into the site conceptual model and numerical flow & transport model. Considering the proposed activities, the risk has been evaluated in terms of best practice guidelines. The zone of impact (ZOIp) and zone of influence (ZOIf) and impacts of the project area were successfully simulated and presented in this report.
- The pros and cons need to be weighed, in line with social-economical impacts and other specialist reports (wetland, hydrology and land capability) to determine if the diversion is feasible, or if OC4A should be considered a “no-go”. If the river diversion is not implemented, there may be a risk of contaminated groundwater migration directly into the Olifants River; and if the river is diverted, the salt ingress is predicted to be lower but it will take some time for the groundwater-surface water flow system to stabilise to a new equilibrium as a result of the diversion. The proposed diversion, from a geohydrological perspective, seems feasible, in context with the limitations and risks identified in this assessment.

## 11.1 Recommendations

The following recommendations are made:

- It is recommended that the monitoring network improvements as per Section 9 be implemented.
- The following can be done to improve the assumptions and understanding of the groundwater aquifer and hence improve the numerical groundwater model confidence:
    - Based on available aquifer data, it is recommended that 24-hour pump tests be performed on three (3) different boreholes situated within each proposed groundwater management area (so 9 in total). Aquifer pump test data will help to determine and confirm invaluable aquifer parameter data (aquifer storage, aquifer specific yield and aquifer transmissivity) which cannot be determined by slug testing.

  - All monitoring boreholes drilled in the area should note groundwater occurrences as well as strike depths. The data can be used to update the conceptual hydrogeological model which is incorporated into the numerical flow model.
  - Water levels of dedicated monitoring boreholes that will be drilled, as well as any new boreholes which are discovered in the area during routine hydrocensus updates, should be monitored (quarterly dedicated holes, bi-annual hydrocensus).

- It is recommended that the numerical groundwater model and transport model be updated annually, to:
  - Recalibrate the flow system based on the dedicated monitoring boreholes drilled and routine water level monitoring data gathered for the site.
  - Confirm preferential flow paths and groundwater migration velocities as new geological data is attained via mining.
  - Evaluate the spatial impact (i.e. $SO_4$ plume) calibrated with the proposed monitoring borehole data.
  - Confirm long-term liabilities associated with the workings (i.e. predict likely changes in flow fields etc.); and
  - Ensure no monitoring network gaps exist (i.e. check if the monitoring network is representative of the site).
- The numerical groundwater model should be updated when changes to the site plan occur, and at least 5 years before decommissioning and site closure. It is important to verify groundwater quality objectives for the closure phase, and predict what the groundwater liabilities will be post closure.
- Ensure that all dams and PCDs are operated to capacities to prevent overflow during 1:50 and 1:100yr storm events.

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## APPENDIX A: PHOTOGRAPHIC LOG

**Name: BH-1M**
**Coordinates: -26.155883 29.332548**

**Name: BH-2M**
**Coordinates: -26.156453°29.341746°**

**Name: BH4**
**Coordinates: -26.162351° 29.338736°**

**Name: BH5**
**Coordinates: -26.170654°29.353816°**

**Name: BH-5M**
**Coordinates: -26.157053° 29.343819°**

**Name: DFBH**
**Coordinates: -26.174920 29.344070**

**Name: EUB-1**
**Coordinates: -26.158448˚ 29.336318˚**

**Name: NBH1**
**Coordinates: -26.156875˚ 29.345273˚**

**Name: NBH02**
**Coordinates: -26.169332° 29.333613°**

**Name: NBH2**
**Coordinates: -26.156853° 29.345276°**

**Name: NBH3**
**Coordinates: -26.157211° 29.343592°**

**Name: NBH4**
**Coordinates: -26.169349° 29.334159°**

**Name: NBH5**
**Coordinates: -26.158073° 29.344654°**

**Name: NBH5A**
**Coordinates: -26.170279 29.356566°**

# APPENDIX B: GEOPHYSICAL INVESTIGATION METHODOLOGY AND DATA INTERPRETATION

**MAGNETIC INVESTIGATION METHODOLOGY**

The geophysical system used in this investigation was a Geonics G5-proton precession magnetometer (Mag). The aim was to identify if there are dolerite intrusive rock or contact areas in the area, extrapolate the likely spatial spread of these structures, and site future monitoring boreholes.

The presence of magnetic minerals in rocks causes deviations in the earth's magnetic field. The proton precision magnetometer measures the remnant magnetic field strength of these rocks. The instrument measures the magnetic field strength in Nano Tesla (nT). Rock associated with magmatic intrusions, such as dolerite sills and dykes, have more magnetic minerals than the surrounding sedimentary rocks or metamorphic rocks. The zone between the intruding rocks is known as the baked zone (a zone that is weathered and cracked due to intruding magmatic rock heat and pressure) and is known to be associated with preferential flow paths of groundwater. It is these structures that are primarily targeted in Karoo aquifer systems for groundwater development and as potential pollution transmitters/boundaries. Hence, the purpose of the survey was to identify structures that may/may not promote groundwater flow.

1. **Survey orientation and spacing length**

Four (4) Mag profiles were completed. The Mag traverse varied from approximately 270 to 900 m in length. Mag readings were taken at 5 m intervals in lines 1 and 2 and at 10 m intervals in lines 3 and 4. Moreover, each spacing was recorded with a handheld GPS.

2. **Potential inference**

Electricity power lines exist near the waste facilities. The Mag lines were shifted and oriented to best avoid and compensate for the interference sources.

3. **Data analyses**

The data obtained from the magnetic survey was analysed as follows:

- All magnetic data was captured in Microsoft Excel ®, and profile trend graphs for the profile lines walked were constructed. A 3-point average algorithm was applied to smooth the data. The magnetic anomalies observed were then interpreted based on the magnetic field strength observed along the profile lines.

## 4. Results

The magnetic field strength for the traverses conducted is shown in Figure A to Figure D. The result from the geophysics indicates a magnetic low on Line 1 at 200m and Line 2 at 320m. This could possibly indicate the presence of a dyke running through the site from northwest to southeast direction.

Line 4A and Line 4B were conducted with the start of each line opposite the other line. Line 4A indicates a low magnetic at 395m and Line 4B indicates low magnetic at 200m, this could indicate a possible dyke.

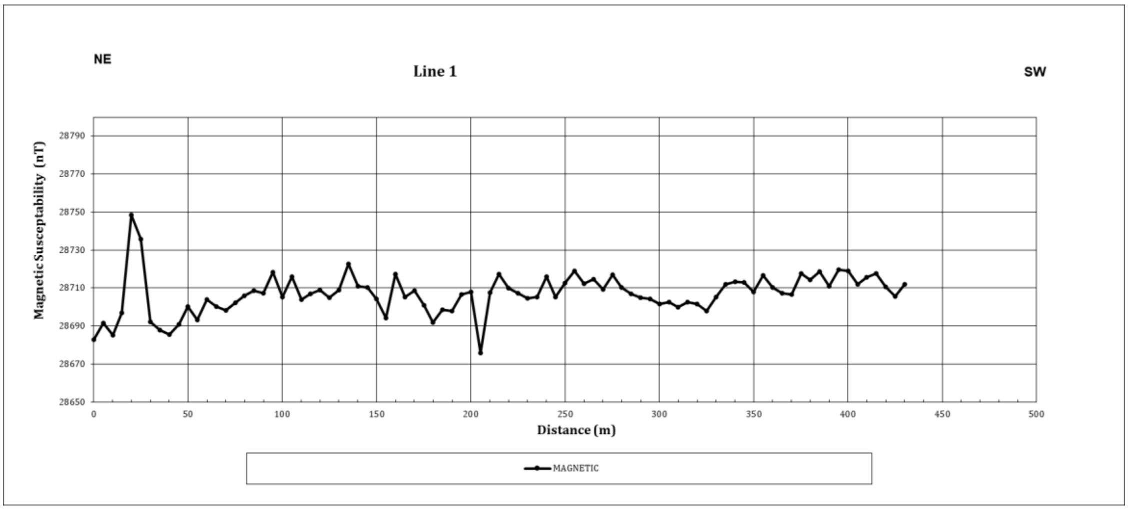


***Figure A - Line 1 – magnetic traverse***

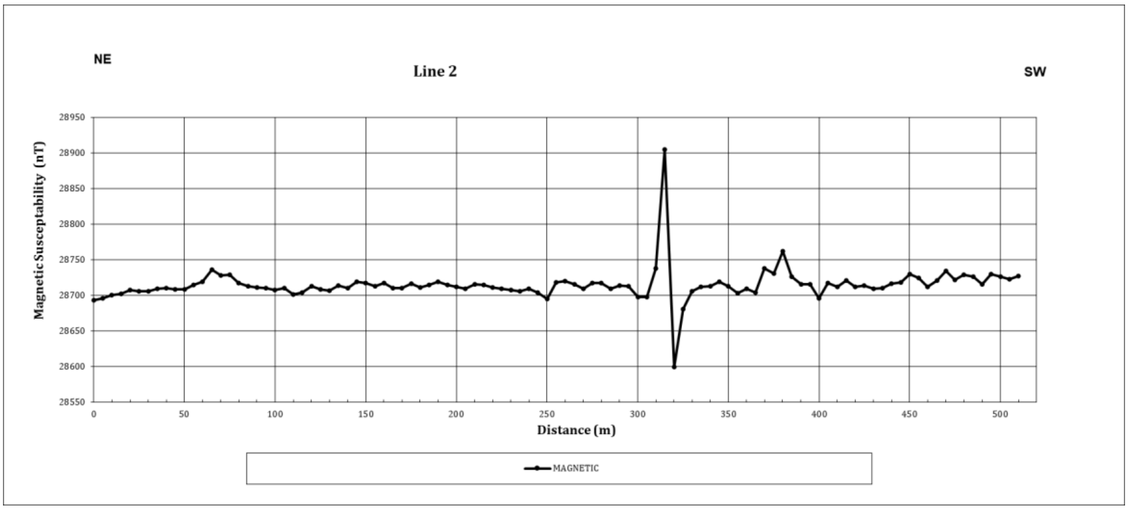


***Figure B - Line 2 – magnetic traverse***

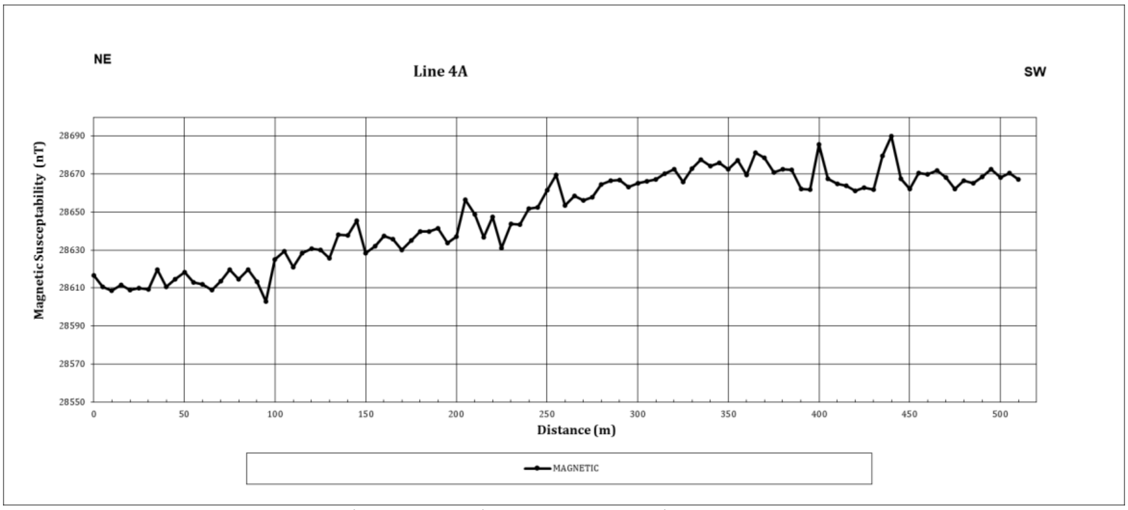


*Figure C - Line 3 – magnetic traverse*

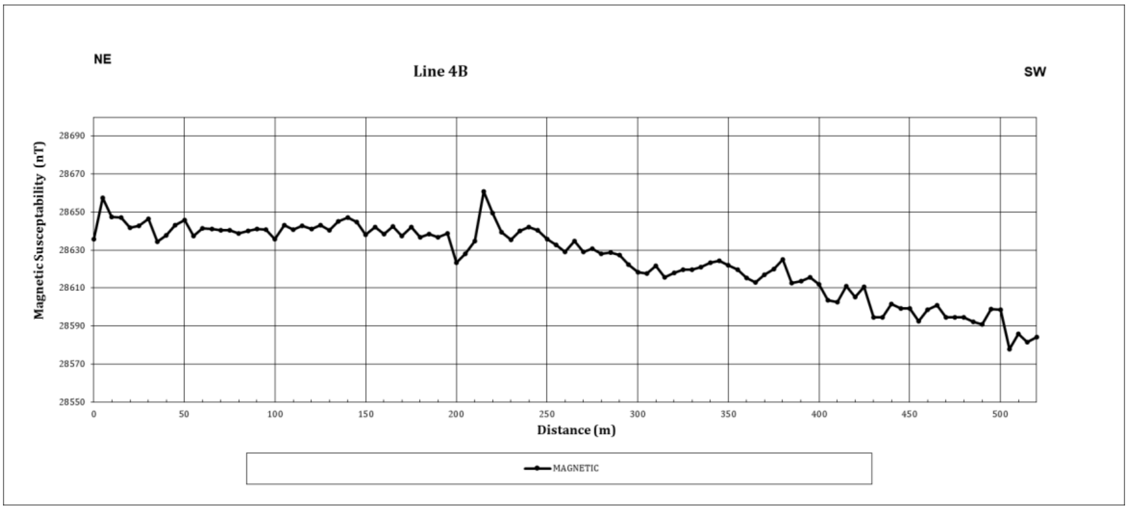


*Figure D - Line 4 – magnetic traverse*

## APPENDIX C: LABORATORY CERTIFICATES & DATA USED IN THIS ASSESSMENT

X-LAB EARTH

JBX22-12339

Report number 0000045374

Client reference:

22-0619-2seams Opencast Mining

### METHOD SUMMARY

| METHOD | METHOD SUMMARY |
|---|---|
| ME-AN-016 | The pH of an aliquot of aqueous sample is measured electrometrically using an electrode connected to a calibrated meter with automated temperature correction. This method is based on APHA 4500-H B. |
| ME-AN-011 | Total dissolved solids (TDS) is determined gravimetrically on a filtered aliquot of aqueous sample by evaporating the sample to dryness in a pre-weighed container at 105 deg C. The method is based on APHA 2540 C. |
| ME-AN-001 | An aliquot of aqueous sample is titrated first to pH 8.3 and then to 4.3 using standardised acid. The volumes of acid titrated are used to calculate total alkalinity and/or alkaline species. The method is based on EPA 310.2 and APHA 2320 B. |
| ME-AN-007 | The conductivity of an aliquot of aqueous sample is measured electrometrically using a standard cell connected to a calibrated meter with automated temperature correction. This method is based on APHA 2510. |
| ME-AN-027 | Dissolved metals are determined on a filtered and acidified (to 1% $HNO_3$) portion of aqueous sample by inductively coupled plasma optical emission spectrometry (ICP-OES). The method is based on EPA 200.7 and APHA 3120. |
| ME-AN-014 | Inorganic anions (Br, Cl, F, $NO_3$, $NO_2$, $SO_4$) are determined on aqueous samples by ion chromatography. The method is based on EPA 300.1 and APHA 4110 B. |
| Calculation of Anion-Cation Bal... | Calculation of the cation/anion balance |

FOOTNOTES

| | | | |
|---|---|---|---|
| IS | Insufficient sample for analysis. | - | The sample was not analysed for this analyte |
| LNR | Sample listed, but not received. | * | *Results marked "Not SANAS Accredited" in this report are not included in the SANAS Schedule of Accreditation for this laboratory / certification body / inspection body".* |
| ^ | Performed by outside laboratory. | | |
| LOR | Limit of Reporting | | |

Samples analysed as received.
Solid samples expressed on a dry weight basis.

Unless otherwise indicated, samples were received in containers fit for purpose.



LAB-QLT-REP-001

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JBX22-12339

Report number 0000045374

Client reference:

22-0619-2seams Opencast Mining

TEST REPORT

| Parameter | Units | LOR | Sample Number JBX22-12339.005<br>Sample Name BH4 |
|---|---|---|---|
| **ICP-OES Metals on waters (Dissolved) Method: ME-AN-027 (continued)** | | | |
| Aluminium * | mg/l | 0.02 | <0.02 |
| Calcium * | mg/l | 0.5 | 7.2 |
| Iron * | mg/l | 0.05 | 5.2 |
| Magnesium * | mg/l | 0.01 | 7.8 |
| Manganese * | mg/l | 0.01 | 0.74 |
| Potassium * | mg/l | 0.2 | 2.9 |
| Sodium * | mg/l | 0.5 | 23 |
| **Anions on Waters by Ion Chromatography Method: ME-AN-014** | | | |
| Chloride * | mg/l | 0.05 | 27 |
| Fluoride * | mg/l | 0.05 | 0.17 |
| Nitrate * | mg/l | 0.1 | <0.1 |
| Sulphate * | mg/l | 0.05 | 31 |
| **pH in water Method: ME-AN-016** | | | |
| pH in water at 25ºC * | - | 1 | 6.3 |

JBX22-12339

Report number 0000045374

Client reference:

22-0619-2seams Opencast Mining

TEST REPORT

| Parameter | Units | LOR | Sample Number JBX22-12339.005<br>Sample Name BH4 |
|---|---|---|---|
| **Calculation of Anion-Cation Balance** | | | |
| Anion-Cation Balance * | % | -100 | -2.96 |
| Sum of Anion Milliequivalents * | meq/l | - | 2.39 |
| Sum of Cation Milliequivalents * | meq/l | - | 2.25 |
| **Alkalinity on waters by titration    Method: ME-AN-001** | | | |
| Total Alkalinity as CaCO3 * | mg/l | 12 | 50 |
| Bicarbonate Alkalinity as CaCO3 * | mg/l | 12 | 50 |
| Bicarbonate Alkalinity as HCO3 * | mg/l | 12 | 61 |
| Bicarbonate as CaCO3 * | mg/l | 12 | 50 |
| Carbonate Alkalinity as CaCO3 * | mg/l | 12 | <12 |
| Carbonate Alkalinity as CO3 * | mg/l | 12 | <12 |
| **Conductivity on waters    Method: ME-AN-007** | | | |
| Conductivity in mS/m @ 25ºC * | mS/m | 2 | 25 |
| **Total Dissolved Solids (TDS) in water at 105 deg    Method: ME-AN-011** | | | |
| TDS (0.7µm) @ 105ºC * | mg/l | 21 | 130 |

**ICP-OES Metals on waters (Dissolved)    Method: ME-AN-027**

7/15/22

Page 4 of 6

JBX22-12339

Report number 0000045374

Client reference:

22-0619-2seams Opencast Mining

TEST REPORT

| Parameter | Units | LOR | Sample Number: JBX22-12339.001<br>Sample Name: NBH1 | JBX22-12339.002<br>BH-2M | JBX22-12339.003<br>NBH5A | JBX22-12339.004<br>BH-5M |
|---|---|---|---|---|---|---|
| **ICP-OES Metals on waters (Dissolved) Method: ME-AN-027 (continued)** | | | | | | |
| Aluminium * | mg/l | 0.02 | <0.02 | <0.02 | <0.02 | <0.02 |
| Calcium * | mg/l | 0.5 | 9.9 | 9.9 | 43 | 12 |
| Iron * | mg/l | 0.05 | <0.05 | <0.05 | <0.05 | <0.05 |
| Magnesium * | mg/l | 0.01 | 10 | 8.1 | 27 | 7.6 |
| Manganese * | mg/l | 0.01 | 0.03 | 0.01 | <0.01 | <0.01 |
| Potassium * | mg/l | 0.2 | 6.3 | 3.3 | 4.9 | 3.7 |
| Sodium * | mg/l | 0.5 | 10 | 271 | 37 | 10 |
| **Anions on Waters by Ion Chromatography Method: ME-AN-014** | | | | | | |
| Chloride * | mg/l | 0.05 | 28 | 14 | 7.2 | 2.1 |
| Fluoride * | mg/l | 0.05 | <0.05 | 1.7 | 0.23 | 0.08 |
| Nitrate * | mg/l | 0.1 | 54 | <0.1 | 0.7 | 0.2 |
| Sulphate * | mg/l | 0.05 | 5.6 | 289 | 85 | 8.6 |
| **pH in water Method: ME-AN-016** | | | | | | |
| pH in water at 25ºC * | - | 1 | 5.3 | 8.8 | 7.3 | 8.6 |

7/15/22 Page 3 of 6

**JBX22-12339**

Report number 0000045374
Client reference:
22-0619-2seams Opencast Mining

## TEST REPORT

| Parameter | Units | LOR | JBX22-12339.001 NBH1 | JBX22-12339.002 BH-2M | JBX22-12339.003 NBH5A | JBX22-12339.004 BH-5M |
|---|---|---|---|---|---|---|
| **Calculation of Anion-Cation Balance** | | | | | | |
| Anion-Cation Balance * | % | -100 | -1.67 | -0.70 | 1.03 | -5.38 |
| Sum of Anion Milliequivalents * | meq/l | - | 1.99 | 13.2 | 5.97 | 1.94 |
| Sum of Cation Milliequivalents * | meq/l | - | 1.92 | 13.0 | 6.09 | 1.74 |
| **Alkalinity on waters by titration — Method: ME-AN-001** | | | | | | |
| Total Alkalinity as CaCO3 * | mg/l | 12 | <12 | 340 | 200 | 85 |
| Bicarbonate Alkalinity as CaCO3 * | mg/l | 12 | <12 | 340 | 200 | 85 |
| Bicarbonate Alkalinity as HCO3 * | mg/l | 12 | 12 | 415 | 244 | 104 |
| Bicarbonate as CaCO3 * | mg/l | 12 | <12 | 340 | 200 | 85 |
| Carbonate Alkalinity as CaCO3 * | mg/l | 12 | <12 | <12 | <12 | <12 |
| Carbonate Alkalinity as CO3 * | mg/l | 12 | <12 | <12 | <12 | <12 |
| **Conductivity on waters — Method: ME-AN-007** | | | | | | |
| Conductivity in mS/m @ 25ºC * | mS/m | 2 | 22 | 124 | 56 | 17 |
| **Total Dissolved Solids (TDS) in water at 105 deg — Method: ME-AN-011** | | | | | | |
| TDS (0.7µm) @ 105ºC * | mg/l | 21 | 140 | 730 | 330 | 110 |

ICP-OES Metals on waters (Dissolved) Method: ME-AN-027

7/15/22 Page 2 of 6

X-LAB EARTH

## TEST REPORT

| CLIENT DETAILS | | LABORATORY DETAILS | |
|---|---|---|---|
| Contact | Keolebogile | Laboratory | X-Lab Earth Science |
| Client | GCS - GROUNDWATER CONSULTING SERVICES (PTY) LTD | Address | 2 Samantha Street, Strydompark, Randburg, 2169 |
| Address | 63 Wessel Road<br>Rivonia<br>Sandton | Telephone | +27 (0)11 590 3000 |
| Telephone | | Laboratory Manager | Mrs Tasneem Tagari |
| Facsimile | | Lab Reference | JBX22-12339 |
| Email | Keolebogileh@gcs-sa.biz | Report Number | 0000045374 |
| Order Number | 22-0619-2seams Opencast Mining | Date Received | 13/07/2022 16:03 |
| Samples | 5 | Date Started | 14/07/2022 15:25 |
| Sample matrix | WATER | Date Reported | 15/07/2022 14:05 |

The document is issued in accordance with SANAS's accreditation requirements.
Accredited for compliance with ISO/IEC 17025. SANAS accredited laboratory T0775.

Samples recieved at ambient temp good condition.

SIGNATORIES

Tasneem Tagari

General Manager/Technical Signatory

X-Lab Earth Science (Pty) Ltd www.xlab.earth LAB-QLT-REP-001

sanas Testing Laboratory T0156

(PTY) LTD 2018/379064/07
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## ZYNTHA CONSULTING
## VLAKLAAGTE 2 SEAM ( PTY) Ltd

Suite 445 MW , Private Bag X 1838, MIDDEKBURG , 1050

### CERTIFICATE OF ANALYSIS

ATT : Mr. Jaco Kleynhans
'e-mail : jaco@zyntha.co.za

| | |
|---|---|
| Date Received: | 08-Jul-2022 |
| Date Reported | 18-Jul-2022 |
| Dates Analysed: | 08-Jul-2022 to 18-Jul-2022 |
| Quantity Analyzed : | 16 |
| Our Ref : | ZYN / 555 - 570 / A / 07/22 |
| Lab No: | A570 |

| SAMPLE DESCRIPTION | | OFFICE DRINKING WATER |
|---|---|---|
| Co - Ordinates South | | 26°10'42.2"S |
| Co - Ordinates East | | 29°21'34.0"E |
| TIME : | | 13:44 |
| | Water Level (m) | |
| ANALYSIS RESULTS in mg/l | Test Method | |
| Total Dissolved Solids | LPM 2 | 19 |
| Suspended Solids | LPM 1 | <2.0 |
| Nitrate & Nitrite as N | LPM 76A | <0.1 |
| Chloride as Cl | LPM 76A | 1.41 |
| Total Alkalinity as $CaCO_3$ | LPM 11 | 13 |
| Fluoride as F | LPM 76A | <0.20 |
| Sulphate as $SO_4$ | LPM 76A | 4.63 |
| Total Hardness as $CaCO_3$ | LPM 85 | 5 |
| Calcium Hardness as $CaCO_3$ | LPM 85 | 3 |
| Magnesium Hardness as $CaCO_3$ | LPM 85 | 2 |
| Calcium as Ca | LPM 15 | 1.06 |
| Magnesium as Mg | LPM 15 | 0.51 |
| Sodium as Na | LPM 15 | 3.30 |
| Potassium as K | LPM 15 | 0.16 |
| Iron as Fe | LPM 15 | <0.01 |
| Manganese as Mn | LPM 15 | <0.01 |
| Conductivity at 25° C (mS/m) | LPM 51 | 2.50 |
| pH Value at 25 ° C (pH units) | LPM 51 | 6.13 |
| pHs 21° Celsius | LPM 85 | 10.12 |
| Langelier Saturation Index | LPM 85 | -3.99 |
| Turbidity (NTU) | LPM 23 | 0.35 |
| Dissolved Oxygen * | LPM 86 | 4.77 |
| Ortho Phosphate $PO_4$ as P | LPM 76A | <0.1 |
| Free and Saline Ammonia as N | LPM 76A | <0.20 |
| Chromium as Cr | LPM 15 | [redacted] |
| Aluminium as Al | LPM 15 | <0.01 |
| Total Petroleum Hydrocarons ( TPH) * | LPM 73 | [redacted] |

All heavy metal analyses have been performed on filtered samples.Tests marked with an asterisk * are not SANAS accredited.These results are related only to the items tested. These results must be read in conjunction with the Uncertainty of Measurement list as provided by Regen Waters Laboratory

| QUALITY CONTROL CHECKS | |
|---|---|
| Cation Balance | 0.24 |
| Anion Balance | 0.25 |
| % Difference | 1.3 |
| Measured TDS | - |
| Calculated TDS | - |
| Limits | - |
| Calc TDS / E.C. | - |

(Calculated TDS)

P.L.G. UYS / A.KOHRS
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Page 1 of 4

sanas Testing Laboratory T0156

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CERTIFICATE OF ANALYSIS

ATT : Mr. Jaco Kleynhans
'e-mail : jaco@zyntha.co.za

| | |
|---|---|
| Date Received: | 08-Jul-2022 |
| Date Reported | 18-Jul-2022 |
| Dates Analysed: | 08-Jul-2022 to 18-Jul-2022 |
| Quantity Analyzed : | 16 |
| Our Ref : | ZYN / 555 - 570 / A / 07/22 |

| Lab No: | | A567 | A568 |
|---|---|---|---|
| SAMPLE DESCRIPTION | | BH1 | BH4 |
| Co - Ordinates South | | 26°9'22.81"S | 26°9'44.45"S |
| Co - Ordinates East | | 29°19'57.68"E | 29°20'19.69"E |
| TIME : | | 12:21 | 13:25 |
| | Water Level (m) | 1.05 | 4.12 |
| ANALYSIS RESULTS in mg/l | Test Method | | |
| Total Dissolved Solids | LPM 2 | 166 | 152 |
| Suspended Solids | LPM 1 | 22.8 | 86.4 |
| Nitrate & Nitrite as N | LPM 76A | 0.12 | <0.1 |
| Chloride as Cl | LPM 76A | 31.1 | 24.3 |
| Total Alkalinity as $CaCO_3$ | LPM 11 | 70 | 42 |
| Fluoride as F | LPM 76A | 0.57 | 0.32 |
| Sulphate as $SO_4$ | LPM 76A | 35.5 | 30.1 |
| Total Hardness as $CaCO_3$ | LPM 85 | 63 | 43 |
| Calcium Hardness as $CaCO_3$ | LPM 85 | 30 | 17 |
| Magnesium Hardness as $CaCO_3$ | LPM 85 | 33 | 26 |
| Calcium as Ca | LPM 15 | 11.9 | 6.74 |
| Magnesium as Mg | LPM 15 | 8.03 | 6.31 |
| Sodium as Na | LPM 15 | 30.3 | 24.1 |
| Potassium as K | LPM 15 | 6.22 | 2.73 |
| Iron as Fe | LPM 15 | 0.03 | 0.05 |
| Manganese as Mn | LPM 15 | <0.01 | 0.57 |
| Conductivity at 25° C (mS/m) | LPM 51 | 29.9 | 22.1 |
| pH Value at 25 ° C (pH units) | LPM 51 | 7.72 | 6.42 |
| pHs 21° Celsius | LPM 85 | 8.44 | 8.90 |
| Langelier Saturation Index | LPM 85 | -0.72 | -2.48 |
| Turbidity (NTU) | LPM 23 | 11.1 | 380 |
| Dissolved Oxygen * | LPM 86 | 4.74 | 4.68 |
| Ortho Phosphate $PO_4$ as P | LPM 76A | <0.1 | <0.1 |
| Free and Saline Ammonia as N | LPM 76A | <0.20 | <0.20 |
| Chromium as Cr | LPM 15 | 4.74 | 4.68 |
| Aluminium as Al | LPM 15 | 0.02 | <0.01 |
| Total Petroleum Hydrocarons ( TPH) * | LPM 73 | Attached | Attached |

All heavy metal analyses have been performed on filtered samples.Tests marked with an asterisk * are not SANAS accredited.These results are related only to the items tested. These results must be read in conjunction with the Uncertainty of Measurement list as provided by Regen Waters Laboratory

| QUALITY CONTROL CHECKS | | |
|---|---|---|
| Cation Balance | 3.01 | 2.27 |
| Anion Balance | 3.05 | 2.17 |
| % Difference | -0.6 | 2.2 |
| Measured TDS | 166 | 152 |
| Calculated TDS | 167 | 120 |
| Limits | 1.0 | 1.3 |
| Calc TDS / E.C. | 0.6 | 0.5 |

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Electronic Signature

Page 2 of 4

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## ZYNTHA CONSULTING

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### CERTIFICATE OF ANALYSIS

ATT : Mr. Jaco Kleynhans
'e-mail : jaco@zyntha.co.za

| | |
|---|---|
| Date Received: | 08-Jul-2022 |
| Date Reported | 18-Jul-2022 |
| Dates Analysed: | 08-Jul-2022 to 18-Jul-2022 |
| Quantity Analyzed : | 16 |
| Our Ref : | ZYN / 555 - 570 / A / 07/22 |

| Lab No: | | A569 |
|---|---|---|
| SAMPLE DESCRIPTION | | BH5 |
| Co - Ordinates South | | 26°10'14.16"S |
| Co - Ordinates East | | 29°21'13.54"E |
| TIME : | | 11:36 |
| | Water Level (m) | 10.12 |
| ANALYSIS RESULTS in mg/l | Test Method | |
| Total Dissolved Solids | LPM 2 | 2570 |
| Suspended Solids | LPM 1 | 71.6 |
| Nitrate & Nitrite as N | LPM 76A | 42.5 |
| Chloride as Cl | LPM 76A | 94.9 |
| Total Alkalinity as $CaCO_3$ | LPM 11 | 255 |
| Fluoride as F | LPM 76A | <0.20 |
| Sulphate as $SO_4$ | LPM 76A | 1472 |
| Total Hardness as $CaCO_3$ | LPM 85 | 1428 |
| Calcium Hardness as $CaCO_3$ | LPM 85 | 477 |
| Magnesium Hardness as $CaCO_3$ | LPM 85 | 951 |
| Calcium as Ca | LPM 15 | 191 |
| Magnesium as Mg | LPM 15 | 231 |
| Sodium as Na | LPM 15 | 285 |
| Potassium as K | LPM 15 | 15.6 |
| Iron as Fe | LPM 15 | <0.01 |
| Manganese as Mn | LPM 15 | 0.10 |
| Conductivity at 25° C (mS/m) | LPM 51 | 308 |
| pH Value at 25 ° C (pH units) | LPM 51 | 6.35 |
| pHs 21° Celsius | LPM 85 | 6.99 |
| Langelier Saturation Index | LPM 85 | -0.64 |
| Turbidity (NTU) | LPM 23 | 33.6 |
| Dissolved Oxygen * | LPM 86 | 4.86 |
| Ortho Phosphate $PO_4$ as P | LPM 76A | <0.1 |
| Free and Saline Ammonia as N | LPM 76A | <0.20 |
| Chromium as Cr | LPM 15 | 1 |
| Aluminium as Al | LPM 15 | 0.04 |
| Total Petroleum Hydrocarons ( TPH) * | LPM 73 | Attached |

All heavy metal analyses have been performed on filtered samples.Tests marked with an asterisk * are not SANAS accredited.These results are related only to the items tested. These results must be read in conjunction with the Uncertainty of Measurement list as provided by Regen Waters Laboratory

| QUALITY CONTROL CHECKS | |
|---|---|
| Cation Balance | 41.34 |
| Anion Balance | 38.42 |
| % Difference | 3.7 |
| Measured TDS | 2570 |
| Calculated TDS | 2636 |
| Limits | 1.0 |
| Calc TDS / E.C. | 0.9 |

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CERTIFICATE OF ANALYSIS

| | |
|---|---|
| ATT : Mr. Jco Kleynhans | |
| 'e-mail : jaco@zyntha.co.za | |
| Date Received: | 08-Jul-2022 |
| Date Reported | 18-Jul-2022 |
| Dates Analysed: | 08-Jul-2022 to 18-Jul-2022 |
| Quantity Analyzed : | 16 |
| Our Ref : | ZYN / 555 - 570 / A / 07/22 |

| Lab No: | | A566 |
|---|---|---|
| SAMPLE DESCRIPTION | | BH-1 |
| Co - Ordinates South | | 26°10'10.37"S |
| Co - Ordinates East | | 29°20'10.49"E |
| TIME : | | 12:16 |
| | Water Level (m) | 22.17 |
| ANALYSIS RESULTS in mg/l | Test Method | |
| Total Dissolved Solids | LPM 2 | 322 |
| Suspended Solids | LPM 1 | 20.4 |
| Nitrate & Nitrite as N | LPM 76A | 15.2 |
| Chloride as Cl | LPM 76A | 34.2 |
| Total Alkalinity as $CaCO_3$ | LPM 11 | 47 |
| Fluoride as F | LPM 76A | <0.20 |
| Sulphate as $SO_4$ | LPM 76A | 37.7 |
| Total Hardness as $CaCO_3$ | LPM 85 | 123 |
| Calcium Hardness as $CaCO_3$ | LPM 85 | 66 |
| Magnesium Hardness as $CaCO_3$ | LPM 85 | 57 |
| Calcium as Ca | LPM 15 | 26.5 |
| Magnesium as Mg | LPM 15 | 13.9 |
| Sodium as Na | LPM 15 | 17.9 |
| Potassium as K | LPM 15 | 5.08 |
| Iron as Fe | LPM 15 | 0.01 |
| Manganese as Mn | LPM 15 | <0.01 |
| Conductivity at 25° C (mS/m) | LPM 51 | 39.5 |
| pH Value at 25 ° C (pH units) | LPM 51 | 6.95 |
| pHs 21° Celsius | LPM 85 | 8.32 |
| Langelier Saturation Index | LPM 85 | -1.37 |
| Turbidity (NTU) | LPM 23 | 13.3 |
| Dissolved Oxygen * | LPM 86 | 4.77 |
| Ortho Phosphate $PO_4$ as P | LPM 76A | <0.1 |
| Free and Saline Ammonia as N | LPM 76A | <0.20 |
| Chromium as Cr | LPM 15 | 0.01 |
| Aluminium as Al | LPM 15 | 0.01 |
| Total Petroleum Hydrocarons ( TPH) * | LPM 73 | Attached |

All heavy metal analyses have been performed on filtered samples.Tests marked with an asterisk * are not SANAS accredited.These results are related only to the items tested. These results must be read in conjunction with the Uncertainty of Measurement list as provided by Regen Waters Laboratory

| QUALITY CONTROL CHECKS | |
|---|---|
| Cation Balance | 3.38 |
| Anion Balance | 3.09 |
| % Difference | 4.5 |
| Measured TDS | 322 |
| Calculated TDS | 240 |
| Limits | 1.3 |
| Calc TDS / E.C. | 0.6 |

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Page 4 of 4

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## ZYNTHA CONSULTING

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Suite 445 MW , Private Bag X 1838, MIDDEKBURG , 1050

### CERTIFICATE OF ANALYSIS

| | |
|---|---|
| Attention: | Jaco Kleynhans |
| e-mail: | jaco@zyntha.co.za |
| Date Received: | 08-Jul-2022 |
| Date Reported | 18-Jul-2022 |
| Dates Analysed: | 08-Jul-2022 to 18-Jul-2022 |
| Quantity Analyzed : | 16 |
| Our Ref : | ZYN / 555 - 570 / A / 07/22 |

| Lab No: | | A555 | A556 |
|---|---|---|---|
| SAMPLE DESCRIPTION | | 2S_SW1 | 2S_SW2 |
| Co - Ordinates South | | 26°10'5.85"S | 26°10'10.03"S |
| Co - Ordinates East | | 29°21'20.98"E | 29°22'26.91"E |
| TIME : | | 11:15 | 9:42 |
| ANALYSIS RESULTS in mg/l | Test Method | | |
| Total Dissolved Solids | LPM 2 | 504 | 360 |
| Suspended Solids | LPM 1 | 7.6 | 5.2 |
| Nitrate & Nitrite as N | LPM 76A | <0.1 | <0.1 |
| Chloride as Cl | LPM 76A | 40.8 | 43.4 |
| Total Alkalinity as $CaCO_3$ | LPM 11 | 134 | 134 |
| Fluoride as F | LPM 76A | 0.49 | 0.47 |
| Sulphate as $SO_4$ | LPM 76A | 150 | 105 |
| Total Hardness as $CaCO_3$ | LPM 85 | 227 | 181 |
| Calcium Hardness as $CaCO_3$ | LPM 85 | 112 | 92 |
| Magnesium Hardness as $CaCO_3$ | LPM 85 | 115 | 89 |
| Calcium as Ca | LPM 15E | 45.0 | 36.9 |
| Magnesium as Mg | LPM 15E | 27.9 | 21.5 |
| Sodium as Na | LPM 15E | 43.0 | 42.1 |
| Potassium as K | LPM 15E | 7.84 | 7.64 |
| Iron as Fe | LPM 15E | 0.13 | 0.11 |
| Manganese as Mn | LPM 15E | 0.03 | <0.01 |
| Conductivity at 25° C (mS/m) | LPM 51 | 64.4 | 56.7 |
| pH Value at 25 ° C (pH units) | LPM 51 | 7.43 | 7.54 |
| pHs 21° Celsius | LPM 85 | 7.68 | 7.73 |
| Langelier Saturation Index | LPM 85 | -0.25 | -0.19 |
| Turbidity (NTU) | LPM 23 | 8.70 | 7.48 |
| Dissolved Oxygen * | LPM 86 | 4.49 | 4.62 |
| Ortho Phosphate $PO_4$ as P | LPM 76A | <0.1 | <0.1 |
| Free and Saline Ammonia as N | LPM 76A | <0.20 | <0.20 |
| Aluminium as Al | LPM 15E | 0.08 | 0.11 |

All heavy metal analyses have been performed on filtered samples.Tests marked with an asterisk * are not SANAS accredited.These results are related only to the items tested. These results must be read in conjunction with the Uncertainty of Measurement list as provided by Regen Waters Laboratory

| QUALITY CONTROL CHECKS | | |
|---|---|---|
| Cation Balance | 6.63 | 5.65 |
| Anion Balance | 6.98 | 6.11 |
| % Difference | -2.6 | -3.9 |
| Measured TDS | 504 | 360 |
| Calculated TDS | 397 | 339 |
| Limits | 1.3 | 1.1 |
| Calc TDS / E.C. | 0.6 | 0.6 |

P.L.G. UYS / A.KOHRS
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Page 1 of 6

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Suite 445 MW , Private Bag X 1838, MIDDEKBURG , 1050

CERTIFICATE OF ANALYSIS

| | | | |
|---|---|---|---|
| Attention: | Jaco Kleynhans | | |
| e-mail: | jaco@zyntha.co.za | | |
| Date Received: | 08-Jul-2022 | | |
| Date Reported | 18-Jul-2022 | | |
| Dates Analysed: | 08-Jul-2022 to 18-Jul-2022 | | |
| Quantity Analyzed : | 16 | | |
| Our Ref : | ZYN / 555 - 570 / A / 07/22 | | |
| Lab No: | | A557 | A558 |
| SAMPLE DESCRIPTION | | 2S_SW3 | 2S_SW4 |
| Co - Ordinates South | | 26°9'9.71"S | 26°9'36.14"S |
| Co - Ordinates East | | 29°20'44.10"E | 29°20'29.09"E |
| TIME : | | 10:59 | 13:10 |
| ANALYSIS RESULTS in mg/l | Test Method | | |
| Total Dissolved Solids | LPM 2 | 426 | 1644 |
| Suspended Solids | LPM 1 | 14.0 | 19.6 |
| Nitrate & Nitrite as N | LPM 76A | <0.1 | <0.1 |
| Chloride as Cl | LPM 76A | 42.1 | 27.2 |
| Total Alkalinity as $CaCO_3$ | LPM 11 | 127 | 108 |
| Fluoride as F | LPM 76A | 0.46 | 0.47 |
| Sulphate as $SO_4$ | LPM 76A | 144 | 981 |
| Total Hardness as $CaCO_3$ | LPM 85 | 215 | 1072 |
| Calcium Hardness as $CaCO_3$ | LPM 85 | 107 | 524 |
| Magnesium Hardness as $CaCO_3$ | LPM 85 | 108 | 548 |
| Calcium as Ca | LPM 15 | 42.8 | 210 |
| Magnesium as Mg | LPM 15 | 26.2 | 133 |
| Sodium as Na | LPM 15 | 42.6 | 74.4 |
| Potassium as K | LPM 15 | 7.85 | 16.7 |
| Iron as Fe | LPM 15 | 0.08 | 0.18 |
| Manganese as Mn | LPM 15 | <0.01 | 0.02 |
| Conductivity at 25° C (mS/m) | LPM 51 | 63.4 | 190 |
| pH Value at 25 ° C (pH units) | LPM 51 | 7.49 | 7.33 |
| pHs 21° Celsius | LPM 85 | 7.71 | 7.25 |
| Langelier Saturation Index | LPM 85 | -0.22 | 0.08 |
| Turbidity (NTU) | LPM 23 | 12.5 | 6.70 |
| Dissolved Oxygen * | LPM 86 | 6.08 | 4.56 |
| Ortho Phosphate $PO_4$ as P | LPM 76A | <0.1 | <0.1 |
| Free and Saline Ammonia as N | LPM 76A | <0.20 | <0.20 |
| Aluminium as Al | LPM 15 | 0.08 | 0.10 |

All heavy metal analyses have been performed on filtered samples.Tests marked with an asterisk * are not SANAS accredited.These results are related only to the items tested. These results must be read in conjunction with the Uncertainty of Measurement list as provided by Regen Waters Laboratory

| QUALITY CONTROL CHECKS | | |
|---|---|---|
| Cation Balance | 6.36 | 25.11 |
| Anion Balance | 6.75 | 23.37 |
| % Difference | -3.0 | 3.6 |
| Measured TDS | 426 | 1644 |
| Calculated TDS | 383 | 1509 |
| Limits | 1.1 | 1.1 |
| Calc TDS / E.C. | 0.6 | 0.8 |

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Electronic Signature

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sanas Testing Laboratory T0156

(PTY) LTD 2018/379064/07
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**ZYNTHA CONSULTING**
**VLAKLAAGTE 2 SEAM ( PTY) Ltd**
Suite 445 MW , Private Bag X 1838, MIDDEKBURG , 1050

CERTIFICATE OF ANALYSIS

| | | | |
|---|---|---|---|
| Attention: | Jaco Kleynhans | | |
| e-mail: | jaco@zyntha.co.za | | |
| Date Received: | 08-Jul-2022 | | |
| Date Reported | 18-Jul-2022 | | |
| Dates Analysed: | 08-Jul-2022 to 18-Jul-2022 | | |
| Quantity Analyzed : | 16 | | |
| Our Ref : | ZYN / 555 - 570 / A / 07/22 | | |
| Lab No: | | A559 | A560 |
| SAMPLE DESCRIPTION | | 2S_SW7 | 2S_SW8 |
| Co - Ordinates South | | 26°10'8.78"S | 26°10'13.28"S |
| Co - Ordinates East | | 29°20'29.03"E | 29°20'35.96"E |
| TIME : | | 12:55 | 12:50 |
| ANALYSIS RESULTS in mg/l | Test Method | | |
| Total Dissolved Solids | LPM 2 | 294 | 672 |
| Suspended Solids | LPM 1 | 45.2 | 2.8 |
| Nitrate & Nitrite as N | LPM 76A | <0.1 | <0.1 |
| Chloride as Cl | LPM 76A | 20.7 | 19.8 |
| Total Alkalinity as $CaCO_3$ | LPM 11 | 42 | 189 |
| Fluoride as F | LPM 76A | 0.37 | 0.48 |
| Sulphate as $SO_4$ | LPM 76A | 128 | 294 |
| Total Hardness as $CaCO_3$ | LPM 85 | 128 | 407 |
| Calcium Hardness as $CaCO_3$ | LPM 85 | 64 | 212 |
| Magnesium Hardness as $CaCO_3$ | LPM 85 | 64 | 195 |
| Calcium as Ca | LPM 15 | 25.6 | 85.0 |
| Magnesium as Mg | LPM 15 | 15.6 | 47.3 |
| Sodium as Na | LPM 15 | 19.0 | 33.9 |
| Potassium as K | LPM 15 | 11.6 | 16.5 |
| Iron as Fe | LPM 15 | 0.25 | 0.18 |
| Manganese as Mn | LPM 15 | <0.01 | 0.05 |
| Conductivity at 25° C (mS/m) | LPM 51 | 40.3 | 91.4 |
| pH Value at 25 ° C (pH units) | LPM 51 | 6.69 | 7.70 |
| pHs 21° Celsius | LPM 85 | 8.37 | 7.28 |
| Langelier Saturation Index | LPM 85 | -1.68 | 0.42 |
| Turbidity (NTU) | LPM 23 | 9.87 | 6.18 |
| Dissolved Oxygen * | LPM 86 | 3.83 | 5.06 |
| Ortho Phosphate $PO_4$ as P | LPM 76A | <0.1 | <0.1 |
| Free and Saline Ammonia as N | LPM 76A | 0.30 | <0.20 |
| Aluminium as Al | LPM 15 | 0.01 | 0.17 |

All heavy metal analyses have been performed on filtered samples.Tests marked with an asterisk * are not SANAS accredited.These results are related only to the items tested. These results must be read in conjunction with the Uncertainty of Measurement list as provided by Regen Waters Laboratory

| QUALITY CONTROL CHECKS | | |
|---|---|---|
| Cation Balance | 3.72 | 10.06 |
| Anion Balance | 3.91 | 10.48 |
| % Difference | -2.5 | -2.1 |
| Measured TDS | 294 | 672 |
| Calculated TDS | 247 | 612 |
| Limits | 1.2 | 1.1 |
| Calc TDS / E.C. | 0.6 | 0.7 |

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## ZYNTHA CONSULTING
## VLAKLAAGTE 2 SEAM ( PTY) Ltd

Suite 445 MW , Private Bag X 1838, MIDDEKBURG , 1050

CERTIFICATE OF ANALYSIS

| | | | |
|---|---|---|---|
| Attention: | Jaco Kleynhans | | |
| e-mail: | jaco@zyntha.co.za | | |
| Date Received: | 08-Jul-2022 | | |
| Date Reported | 18-Jul-2022 | | |
| Dates Analysed: | 08-Jul-2022 to 18-Jul-2022 | | |
| Quantity Analyzed : | 16 | | |
| Our Ref : | ZYN / 555 - 570 / A / 07/22 | | |
| Lab No: | | A561 | A562 |
| SAMPLE DESCRIPTION | | 2S_SW9 | 2S_SW14 |
| Co - Ordinates South | | 26°10'16.46"S | 26°10'34.49"S |
| Co - Ordinates East | | 29°22'23.45"E | 29°22'20.12"E |
| TIME : | | 9:50 | 10:00 |
| ANALYSIS RESULTS in mg/l | Test Method | | |
| Total Dissolved Solids | LPM 2 | 932 | 812 |
| Suspended Solids | LPM 1 | 27.6 | 5.2 |
| Nitrate & Nitrite as N | LPM 76A | 0.10 | <0.1 |
| Chloride as Cl | LPM 76A | 26.4 | 26.7 |
| Total Alkalinity as $CaCO_3$ | LPM 11 | 140 | 144 |
| Fluoride as F | LPM 76A | 0.52 | 0.51 |
| Sulphate as $SO_4$ | LPM 76A | 467 | 436 |
| Total Hardness as $CaCO_3$ | LPM 85 | 517 | 478 |
| Calcium Hardness as $CaCO_3$ | LPM 85 | 236 | 218 |
| Magnesium Hardness as $CaCO_3$ | LPM 85 | 281 | 260 |
| Calcium as Ca | LPM 15 | 94.5 | 87.4 |
| Magnesium as Mg | LPM 15 | 68.3 | 63.1 |
| Sodium as Na | LPM 15 | 60.8 | 57.6 |
| Potassium as K | LPM 15 | 8.80 | 8.39 |
| Iron as Fe | LPM 15 | 0.07 | 0.06 |
| Manganese as Mn | LPM 15 | 0.05 | 0.01 |
| Conductivity at 25° C (mS/m) | LPM 51 | 116 | 111 |
| pH Value at 25 ° C (pH units) | LPM 51 | 7.75 | 7.83 |
| pHs 21° Celsius | LPM 85 | 7.41 | 7.41 |
| Langelier Saturation Index | LPM 85 | 0.34 | 0.42 |
| Turbidity (NTU) | LPM 23 | 28.6 | 3.25 |
| Dissolved Oxygen * | LPM 86 | 4.59 | 4.69 |
| Ortho Phosphate $PO_4$ as P | LPM 76A | <0.1 | <0.1 |
| Free and Saline Ammonia as N | LPM 76A | <0.20 | <0.20 |
| Aluminium as Al | LPM 15 | 0.11 | 0.05 |

All heavy metal analyses have been performed on filtered samples.Tests marked with an asterisk * are not SANAS accredited.These results are related only to the items tested. These results must be read in conjunction with the Uncertainty of Measurement list as provided by Regen Waters Laboratory

| QUALITY CONTROL CHECKS | | |
|---|---|---|
| Cation Balance | 13.22 | 12.28 |
| Anion Balance | 13.29 | 12.73 |
| % Difference | -0.3 | -1.8 |
| Measured TDS | 932 | 812 |
| Calculated TDS | 812 | 767 |
| Limits | 1.1 | 1.1 |
| Calc TDS / E.C. | 0.7 | 0.7 |

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Suite 445 MW , Private Bag X 1838, MIDDEKBURG , 1050

### CERTIFICATE OF ANALYSIS

| | |
|---|---|
| Attention: | Jaco Kleynhans |
| e-mail: | jaco@zyntha.co.za |
| Date Received: | 08-Jul-2022 |
| Date Reported | 18-Jul-2022 |
| Dates Analysed: | 08-Jul-2022 to 18-Jul-2022 |
| Quantity Analyzed : | 16 |
| Our Ref : | ZYN / 555 - 570 / A / 07/22 |

| Lab No: | | A563 |
|---|---|---|
| SAMPLE DESCRIPTION | | 2S_SW16 |
| Co - Ordinates South | | 26°10'28.8"S |
| Co - Ordinates East | | 29°22'5.6"E |
| TIME : | | 10:31 |
| ANALYSIS RESULTS in mg/l | Test Method | |
| Total Dissolved Solids | LPM 2 | 874 |
| Suspended Solids | LPM 1 | <2.0 |
| Nitrate & Nitrite as N | LPM 76A | <0.1 |
| Chloride as Cl | LPM 76A | 16.7 |
| Total Alkalinity as $CaCO_3$ | LPM 11 | 174 |
| Fluoride as F | LPM 76A | 0.72 |
| Sulphate as $SO_4$ | LPM 76A | 459 |
| Total Hardness as $CaCO_3$ | LPM 85 | 559 |
| Calcium Hardness as $CaCO_3$ | LPM 85 | 245 |
| Magnesium Hardness as $CaCO_3$ | LPM 85 | 313 |
| Calcium as Ca | LPM 15 | 98.3 |
| Magnesium as Mg | LPM 15 | 76.1 |
| Sodium as Na | LPM 15 | 47.4 |
| Potassium as K | LPM 15 | 7.99 |
| Iron as Fe | LPM 15 | 0.05 |
| Manganese as Mn | LPM 15 | 0.01 |
| Conductivity at 25° C (mS/m) | LPM 51 | 116 |
| pH Value at 25 ° C (pH units) | LPM 51 | 7.89 |
| pHs 21° Celsius | LPM 85 | 7.29 |
| Langelier Saturation Index | LPM 85 | 0.60 |
| Turbidity (NTU) | LPM 23 | 0.67 |
| Dissolved Oxygen * | LPM 86 | 4.86 |
| Ortho Phosphate $PO_4$ as P | LPM 76A | <0.1 |
| Free and Saline Ammonia as N | LPM 76A | <0.20 |
| Aluminium as Al | LPM 15 | 0.03 |

All heavy metal analyses have been performed on filtered samples.Tests marked with an asterisk * are not SANAS accredited.These results are related only to the items tested. These results must be read in conjunction with the Uncertainty of Measurement list as provided by Regen Waters Laboratory

| QUALITY CONTROL CHECKS | |
|---|---|
| Cation Balance | 13.44 |
| Anion Balance | 13.54 |
| % Difference | -0.4 |
| Measured TDS | 874 |
| Calculated TDS | 812 |
| Limits | 1.1 |
| Calc TDS / E.C. | 0.7 |

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Suite 445 MW , Private Bag X 1838, MIDDEKBURG , 1050

### CERTIFICATE OF ANALYSIS

| | |
|---|---|
| Attention: | Jaco Kleynhans |
| e-mail: | jaco@zyntha.co.za |
| Date Received: | 08-Jul-2022 |
| Date Reported | 18-Jul-2022 |
| Dates Analysed: | 08-Jul-2022 to 18-Jul-2022 |
| Quantity Analyzed : | 16 |
| Our Ref : | ZYN / 555 - 570 / A / 07/22 |

| Lab No: | | A564 | A565 |
|---|---|---|---|
| SAMPLE DESCRIPTION | | 2S_SW18 | VLK SW7 |
| Co - Ordinates South | | 26°9'55.58"S | 26°10'5.38"S |
| Co - Ordinates East | | 29°20'23.83"E | 29°20'22.77"E |
| TIME : | | 13:40 | 12:35 |
| ANALYSIS RESULTS In mg/l | Test Method | | |
| Total Dissolved Solids | LPM 2 | 2546 | 280 |
| Suspended Solids | LPM 1 | <2.0 | 332 |
| Nitrate & Nitrite as N | LPM 76A | 3.58 | <0.1 |
| Chloride as Cl | LPM 76A | 22.8 | 42.1 |
| Total Alkalinity as $CaCO_3$ | LPM 11 | 200 | 47 |
| Fluoride as F | LPM 76A | 1.05 | 0.44 |
| Sulphate as $SO_4$ | LPM 76 | 1556 | 63.7 |
| Total Hardness as $CaCO_3$ | LPM 85 | 1638 | 85 |
| Calcium Hardness as $CaCO_3$ | LPM 85 | 662 | 45 |
| Magnesium Hardness as $CaCO_3$ | LPM 85 | 976 | 40 |
| Calcium as Ca | LPM 15 | 265 | 18.2 |
| Magnesium as Mg | LPM 15 | 237 | 9.66 |
| Sodium as Na | LPM 15 | 142 | 35.1 |
| Potassium as K | LPM 15 | 11.4 | 9.01 |
| Iron as Fe | LPM 15 | 0.02 | 0.63 |
| Manganese as Mn | LPM 15 | 0.31 | 0.06 |
| Conductivity at 25° C (mS/m) | LPM 51 | 281 | 35.3 |
| pH Value at 25 ° C (pH units) | LPM 51 | 7.75 | 6.71 |
| pHs 21° Celsius | LPM 85 | 6.95 | 8.80 |
| Langelier Saturation Index | LPM 85 | 0.80 | -2.02 |
| Turbidity (NTU) | LPM 23 | 0.53 | 109 |
| Dissolved Oxygen * | LPM 86 | 4.90 | 3.53 |
| Ortho Phosphate $PO_4$ as P | LPM 76A | <0.1 | <0.1 |
| Free and Saline Ammonia as N | LPM 76A | 0.26 | <0.20 |
| Aluminium as Al | LPM 15 | 0.04 | 0.19 |

All heavy metal analyses have been performed on filtered samples.Tests marked with an asterisk * are not SANAS accredited.These results are related only to the items tested. These results must be read in conjunction with the Uncertainty of Measurement list as provided by Regen Waters Laboratory

| QUALITY CONTROL CHECKS | | |
|---|---|---|
| Cation Balance | 39.23 | 3.51 |
| Anion Balance | 37.09 | 3.48 |
| % Difference | 2.8 | 0.4 |
| Measured TDS | 2546 | 280 |
| Calculated TDS | 2375 | 207 |
| Limits | 1.1 | 1.4 |
| Calc TDS / E.C. | 0.8 | 0.6 |

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## APPENDIX D: NUMERICAL FLOW AND TRANSPORT MODEL CONFIDENCE

In the development of the numerical model, a detailed data review was conducted. Data confidence and data availability dictate model confidence. A summary of the required data versus the data available is outlined below; 3: indicates sufficient data availability, 2: indicates moderate availability, and 1: indicates limited or no availability.

As indicated in the table below, critical data required for the development of a medium-high confidence model is available. Based on the model, key data gaps will be identified. These data gaps will be required to be filled before updating the model and producing a higher confidence model suitable for defendable predictive modelling.

**Model Data Confidence (1: low, 2: moderate, 3: high)**

| Data types | Confidence |
|---|---|
| Spatial and temporal distribution of groundwater head observations is required to adequately define groundwater behaviour, especially in areas of greatest interest and where outcomes are to be reported. | 3 |
| The spatial distribution of bore logs and associated stratigraphic interpretations clearly define aquifer geometry. | 2 |
| Reliable metered groundwater extraction and injection data are available. | 1 |
| Rainfall and evaporation data is available. | 3 |
| Aquifer-testing data to define key parameters. | 2 |
| Streamflow and stage measurements are available with reliable base flow estimates at several points. | 1 |
| Reliable land-use and soil mapping data available. | 2 |
| Good quality and adequate spatial coverage of digital elevation model to define ground surface elevation. | 3 |
| The geometry of the existing opencast workings. | 3 |
| Geometry and temporal plan of future mine workings. | 2 |
| The geometry of existing mine residue disposal/storage areas | 2 |
| Transport model calibration points and confidence of constant sampling data | 2 |
| Aquifer dewatering rates / verified estimates | 1 |
| *Model Data Confidence Rating* | *Class 2* |

| | |
|---|---|
| ***Class 1: Low Confidence Model*** | ***Score <16 (40%)*** |
| ***Class 2: Intermediate Confidence Model*** | ***Score 16 - 31 (41-80%)*** |
| ***Class 3: High Confidence Model*** | ***Score <31 (80 - 100%)*** |

## DISCLAIMER

The opinions expressed in this Report have been based on site /project information supplied to GCS (Pty) Ltd (GCS) by Environmental Sustainability (Pty) Ltd and are based on public domain data, field data and data supplied to GCS by the client. GCS has acted and undertaken this assessment objectively and independently.

GCS has exercised all due care in reviewing the supplied information. Whilst GCS has compared key supplied data with expected values, the accuracy of the results and conclusions are entirely reliant on the accuracy and completeness of the supplied data. GCS does not accept responsibility for any errors or omissions in the supplied information and does not accept any consequential liability arising from commercial decisions or actions resulting from them.

The boreholes that were sited in this investigation are sited according to scientific principles which relate to sub-surface hydrogeological signatures/structures which may act as preferential groundwater flow paths. It should be noted that in some cases (3 out of 10 boreholes) the hydrogeological signatures may indicate high water potential, however, during drilling low yields are observed. For this reason, GCS recommends that a hydrogeological specialist supervises the drilling to ensure that drilling is stopped, or the method is adapted if hydrogeology differs from desktop and sitting data. Even with such oversight and scientific recommendations, a high-yielding borehole is not guaranteed, and GCS cannot be held responsible or liable for dry or low-yielding boreholes or for any hydrogeological or any other condition which may affect the yield volume or yield water quality.

Opinions presented in this report, apply to the site conditions, and features as they existed at the time of GCS's investigations, and those reasonably foreseeable. These opinions do not necessarily apply to conditions and features that may arise after the date of this report, about which GCS had no prior knowledge nor had the opportunity to evaluate.

**DETAILS OF THE SPECIALIST, DECLARATION OF INTEREST AND UNDERTAKING UNDER OATH**

Application for authorisation in terms of the National Environmental Management Act, Act No. 107 of 1998, as amended and the Environmental Impact Assessment (EIA) Regulations, 2014, as amended (the Regulations)

**PROJECT TITLE**

| |
|---|
| Geohydrological Assessment for the proposed 2-Seam (Pty) Ltd Mine River Diversion |

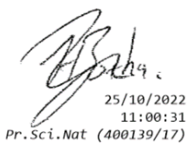
SPECIALIST INFORMATION

| | | | | |
|---|---|---|---|---|
| Specialist Company Name: | GCS Water and Environment Pty Ltd | | | |
| B-BBEE | Contribution level (indicate 1 to 8 or non-compliant) | 4 | Percentage Procurement Recognition | |
| Specialist name: | Hendrik Botha | | | |
| Specialist Qualifications: | MSc Environmental Sciences (Geohydrology & Geochemistry)<br>BSc Hons. Environmental Sciences (Hydrology) | | | |
| Professional affiliation/registration: | PR SCI NAT 400139/17 | | | |
| Physical address: | 1 Karbochem Road, Newcastle, KZN | | | |
| Postal address: | | | | |
| Postal code: | 2940 | Cell: | | |
| Telephone: | 071 102 3819 | Fax: | | |
| E-mail: | hendrikb@gcs-sa.biz | | | |

DECLARATION BY THE SPECIALIST

I, _Hendrik Botha, declare that –

- I act as the independent specialist in this application.
- I will perform the work relating to the application objectively, 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 concerning the application by the competent authority; and - the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority.
- all the particulars furnished by me in this form are true and correct; and
- I realise that a false declaration is an offence in terms of regulation 48 and is punishable in terms of section 24F of the Act.




Signature of the Specialist

GCS

Name of Company:

25 October 2022

Date

## CV OF SPECIALIST

Hendrik Botha

**Technical Director**

### CORE SKILLS

- Project management
- Analytical and numerical groundwater modelling
- Geochemical assessments and geochemical modelling
- Hydropedology and hydrological assessments
- Hydrology, floodline modelling & storm water management
- Groundwater vulnerability, impact, and risk assessments
- Technical report writing
- GIS and mapping

### DETAILS

**Qualifications**

- BSc Chemistry and Geology (Environmental Sciences) (2012)
- BSc Hons Hydrology (Environmental Sciences) (2013)
- MSc Geohydrology and Hydrology (Environmental Sciences) (2014-2016)

**Membership**

- Groundwater Division of GSSA
- Groundwater Association of KwaZulu Natal Member
- International Mine Water Association (IMWA)

**Languages**

- Afrikaans - Speak, read, write.
- English - Speak, read, write.

**Projects undertaken in**

- South Africa
- Nigeria
- Namibia
- Liberia

### PROFILE

Hendrik (Henri) Botha is currently the manager of the GCS Newcastle Office and occupies the role of principal hydrogeologist. Groundwater, geochemistry and surface hydrology, as well as knowledge of water chemistry together with GIS, analytical and numerical modelling skills, is some of his sought-after expertise. General and applied logical knowledge are his key elements in problem-solving.

**Professional Affiliations:**

SACNASP Professional Natural Scientist (400139/17)

**Areas of Expertise:**

- Waste classification and Impact Assessments
- Aquifer vulnerability assessments
- Geochemical sampling, data interpretation and modelling
- Geophysical surveys and data interpretation
- GIS
- Water quality sampling and data interpretation
- Groundwater impact and risk assessments
- Numerical and Conceptual Visual Modelling (Visual Modflow, ModflowFLEX, Voxler, RockWorks, Surfer and Excel)
- Hydropedology (Hydrological Soil Types) & Soils Assessments
- Floodline Modelling (HEC-RAS)
- Stormwater Management Systems and Modelling
- Surface Water Yield Assessments
- Water and Salt Balances