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Geohydrology Assessment for the Bundu Mining (Rietvalei) Mining Permit

Report

Version – Final 2

28 October 2024

Umhlaba Environmental Consulting CC

GCS Project Number: 23-0738

Client Reference: Bundu Mining (Rietvalei) Geohydro

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DECLARATION OF INDEPENDENCE

GCS (Pty) Ltd was appointed to conduct this specialist groundwater study and to act as the independent groundwater specialist. GCS objectively performed the work, even if this resulted in views and findings that were not favourable. GCS has the expertise to conduct the specialist investigation and does not have a 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.

APPENDIX 6 OF THE EIA REGULATION – CHECKLIST AND REFERENCE FOR THIS REPORT

Table 1 - Requirements from Appendix 6 of GN 326 EIA Regulation 2017

Requirements from Appendix 6 of GN 326 EIA Regulation 2017	**Chapter**
(a) Details of: (i) The specialist who prepares the reports; and (ii) the expertise of that specialist to compile a specialist report, including a curriculum vitae	Appendix E and F.
(b) Declaration that the specialist is independent in a form as may be specialities by the competent authority	Appendix E and F.
(c) Indication of the scope of, and purpose for which, the report was prepared	Section 2
(cA) Indication of the quality and age of base data used for the specialist report	Sections 1, 2, 4 and 5.
(cB) A description of existing impacts on the site, cumulative impacts of the proposed development and levels of acceptable change	Sections 6, 7 and 8
(d) Duration, Date and seasons of the site investigation and the relevance of the season to the outcome of the assessment	Section 1.2
(e) Description of the methodology adopted in preparing the report or carrying out the specialised process, including equipment and modelling used	Section 4
(f) Details of an assessment of the specifically identified sensitivity of the site related to the proposed activity or activities and its associate's structures and infrastructure, inclusive of a site plan identifying alternative	Sections 1, 2, 4 and 5
(g) Identification of any areas to be avoided, including buffers	Section 11.2.
(h) Map superimposing the activity and associated structures and infrastructure on environmental sensitivities of the site, including areas to be avoided, including buffers	Section 1, 3, 5, 6, 7 and 8.
(i) Description of any assumptions made and uncertainties or gaps in knowledge	Sections 1, 7, and 8.
(j) A description of the findings and potential implications of such findings on the impact of the proposed activity, including identified alternatives on the environment or activities	Sections 7, 8 and 10.
(k) Mitigation measures for inclusion in the EMPr	Sections 9, 10 and 11.
(l) Conditions for inclusion in the environmental authorisation	Refer to recommendations in Section 11.
(m) Monitoring requirements for inclusion in the EMPr or environmental authorisation	Refer to recommendations in Section 11.
(n) Reasoned opinion – (i) as to whether the proposed activity, activities or portions thereof should be authorised. (a) regarding the acceptability of the proposed activity or activities and (ii) if the opinion is that the proposed activity, activities, or portions thereof should be authorised, and avoidance, management, and mitigation measures should be included in the EMPr, and where applicable, the closure plan	Section 11.5
(o) Description of any consultation process that was undertaken during preparing the specialist report	*None required.*
(p) A summary and copies of any comments received during any consultation process and, where applicable, all responses thereto	*None required.*
(q) Any other information requested by the competent authority	*None required.*

EXECUTIVE SUMMARY

GCS Water and Environment (Pty) Ltd (GCS) was appointed by Umhlaba Environmental Consulting CC (Umhlaba) to undertake a geohydrology assessment to supplement the Water Use License (WUL) for the proposed Bundu Mining (Rietvalei) Mining Right (MR) Application, situated in the Kameeldrif West area, in Gauteng Province. The project falls within Quaternary catchment A211 of the Limpopo Water Management Area (WMA) (DWS, 2016).

The end client (Bundu Mining) wants to apply for a mining right at Bundu Mining Rietvalei, situated in the Kameeldrif West area in Gauteng Province. There are two drainage lines on either side of the application area that had to be evaluated, as these were pre-identified as potential watercourses.

Existing infrastructure entails a non-operational plant, one small-scale shovel (TLB and excavator) mining excavation, a stormwater dam and several settlement ponds which have been silted up due to historic mining activities. Rehabilitated sand mining operations that pre-date Bundu mining are evident all over the project area.

Activities associated with the proposed MR include the addition of a proposed washing and settlement dam, which would be a shallow and deep opencast quarry, into the ridge. The client is currently developing a resource statement and mine plan based on the proposed area. Therefore, no formal mine plan is available for the proposed Project. The Client [Bundu Mining] indicated that the maximum mining depths would be 10m and 50m for the shallow and deep blasting operations. The estimated time to reach the 50m mark, which forms the LOM, is between 25 and 30 years. Groundwater and surface water will be used for dust suppression and to provide water to the sand-washing plant.

This geohydrological assessment is required to evaluate the geohydrological risk associated with the proposed mining activity and groundwater abstraction activities, and the geohydrology report will supplement the Mining Permit Application (MPA) and Water Use License Application (WULA).

This study found that:

- The project falls within quaternary catchment A21H of the Limpopo Water Management Area (WMA). Elevations for the site area range from 1200 to 1550 metres above mean sea level (mamsl).
- The site is bound to the south by a steep hilltop, and two (2) dominant drainage lines exist, one towards the east and one towards the west of the hilltop, where valleys have been carved by erosion. One (1) groundwater sub-catchment/hydrological response unit (GHRU) describes the natural drainage of the site.

  - For the majority of the site, there are no recognised drainage lines or streams/rivers. The proposed MR area falls between the two drainage lines, and based on the delineated topography and GHRUs, the activity will likely not impact the western drainage line and will further have a limited impact on the eastern drainage stream. From the site investigation, it is clear that free drainage takes place for the entire site, with occasional depressions where surface water collects shortly after rainfall events.
  - It is clear from the site walkover assessment that historic mining has changed the surface water flow paths, and micro-catchment style free drainage from higher to lower elevations takes place. The overall drainage direction is towards the north of the Swartspruit River. The Swartspruit River is situated about 1.04 km downstream of the site and flows towards the west to the Hartbeespoort Dam.

- The project falls in an area with a Mean Annual Precipitation (MAP) in the order of 690 mm/yr and a Mean Annual Evaporation (MAE) in the order of 1600 mm/yr.

- Available desktop hydrocensus and Department of Water and Sanitation Water Allocation Registry Management System (DWS WARMS) data suggest that there are about twenty-eight (28) WARMS users within a 5 km buffer of the project area, of which none of them fall within the GHRUs. A review of SADAC GIP groundwater database boreholes further suggests several boreholes within a 5 km radius of the site with groundwater data available. 98% of the WARMS users are boreholes, amounting to a total allocation in the order of 0.7 Mm^3/yr, followed by 1 registered spring user and 1 surface water stream user. 1 groundwater user (WARMS ID: 26075176) is associated with the GHRU of the site.

- 42 groundwater boreholes were identified within a 5km radius of the site in the field. Abstraction volumes for boreholes identified vary from 2500 to 15 000 l/hr, and water usage ranges from small-scale irrigation to domestic to livestock watering. The average pH of the groundwater resource ranges from slightly acid (pH ~5.5) to neutral (pH ~ 7.6). Groundwater conductivity ranges from 170 µS/cm to >1200 µS/cm (slightly salty). Identified groundwater users generally fall outside the GHRU, with only several of them falling inside, namely 96-5 and 96-7, Jura BH1 to Jura BH3, Bundu BH-BH4. It is highly likely that boreholes falling outside the GHRU will not be impacted; however, they still fall in the potential sphere of influence. Refer to the groundwater model section of this report for the risks identified.

- A site conceptual geohydrological model (SCM) was developed for the site, and based thereon, the following three (3) aquifer systems were identified in the project area:

  - A shallow, unconfined aquifer system associated with the quaternary sand deposits;
  - A semi-confined/perched aquifer system associated with both fractured and intergranular weathered rock of the Pretoria Group.
  - A deeper, confined, fractured aquifer network is associated with older basement rocks.

- The aquifers underlying the study area are considered low-yielding aquifers (median yields of 0.5 to 2 l/sec – Class d3 aquifer and b2 aquifers). Based on extrapolated groundwater level data, it is estimated that the groundwater table is in the order of 13 mbgl at the site, which indicates that mining will take place above the regional groundwater table (expected maximum mining depth is about 10 m). Available data suggest that the groundwater table mimics the topography and groundwater flows from high-lying areas (water divides) to low-lying areas.

- In the SCM, the main source of groundwater recharge is rainfall. The rainfall infiltrates into the ground to become groundwater through the Vadose Zone. The water then moves both vertically and horizontally in the quaternary sand deposits and weathered zone of the Pretoria Group sediments, with greater interflow in a horizontal direction within the weathered zone matrix. Where shallow hard rock outcrops or intrusive dolerite outcrops occur, there may be the formation of springs, and subsequently, where shallow quaternary sand depots accumulate on shallow hard rock, there may be water logging. Shallow and deep groundwater movement will likely be towards the north, towards the valley where the Swartspruit River is situated.

- Any pollution that does occur on the surface and is allowed to percolate into the vadose zone could potentially impact the groundwater table. The contaminants would then slowly propagate towards the Swartspruit River, which is the primary surface water receptor in the project area. The groundwater flow velocity is slow, and it will take some time for pollution to enter the river system, which may not be observed during the lifecycle of the project. The mining activity is, however, considered a “clean” operation, as it involves the excavation and washing of sand and hard rock, which appears to be inert. The sands are relatively inert based on available hydrochemical and waste classification data (refer to GCS Waste Classification and Hydrology Reports, 2023).

- A numerical groundwater flow model was developed (refer to Section 7), and based on the flow and transport model constructed and selected scenarios, the following is observed:

- The flow model indicates groundwater flow velocities ranging from 0.01 (min) to 5 (max) m/day. Groundwater movement in the weathered zone is greater than that of the deeper aquifer zones, and several orders are greater in the alluvium zones when compared to the host rock.
- The predicted maximum aquifer drawdown for the workings and abstraction activities at LOM is in the order of 32m for the deeper workings (extending to 50m below surface level) and gradually decreases to 1m towards the east and west of the operations. It is observed that drawdown is limited to the meta-argillaceous rocs towards the north of the hilltop (where the workings are) and that the hilltop with the meta-arenaceous rocks (quartzite) acts as an aquiclude. This is due to the low recharge and low permeability associated with the quarzitic rock. The predicted aquifer drawdown does nit reach any of the identified groundwater users in the GHRU or SOIF.
- The predicted initial dewatering volume for the proposed mining works (up to an assumed maximum depth of 10m for the shallow operations and 50m for the deeper operations) is 496.53 m^3/day. The dewatering rate is estimated to increase to 820.76 m^3/day, approaching the maximum depth of blasting pit after 30 years of mining. Water level rebound is expected within 1-2 years after mining ceases.

- Several hydrological risks were identified and presented in Section 8, and several mitigation measures can be considered. A water monitoring and groundwater management plan is available in Sections 8 and 9. The following provides a summary of the predicted impacts:
  - The predicted dewatering that will take place will have an impact on the groundwater reserve on a sub-catchment scale. On a quaternary scale, the impact is projected to be marginal. Any poor-quality seepage from facilities at the site could also migrate to the borehole and compromise water quality, as the borehole is situated downstream of the mining and settlement dam areas.
  - In terms of the preparation and operational phase, there are expected cumulative impacts on the soils associated with the site. The impact is predicted to improve at the closure of the mine and if rehabilitation is rolled out. The sub-catchments in which the mining will take place are isolated from other mines and activities in the area, and hence, cumulative impacts on a larger scale will be limited. Dewatering impacts are predicted to be the largest risk associated with the proposed Project but will be limited to the GHRU.

Based on the findings of this assessment, GCS believes that the proposed activities pose a low risk to the geohydrological environment and existing groundwater users in the project area. The approval of the activity should be considered to enable Bundu to excavate and process the sands that occur in the project area. It is further assumed that mitigation options to offset negative impacts, as predicted by this study for Bundu Mining, will be implemented into the EMPr during the operational and closure phases of the project.

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GENERAL LIST OF ACRONYMS

Acronym	Description
DEM	Digital Elevation Model
DWA	Department of Water Affairs
DWAF	Department of Water and Forestry
DWS	Department of Water and Sanitation (previously DWA and DWAF)
DWS	Department of Water and Sanitation
EMPR	Environmental Management Plan Report
FD	Finite Difference
GCS	GCS Water and Environment Consultants (Pty) Ltd
GRIP	Groundwater Information Project
GW	Groundwater
h	Potentiometric head
ha	Hectare
HDPE	High-Density Polyethylene (Plastic)
HMP	Hydrogeological Management Plan
GHRU	Groundwater Hydrological Response Unit
IWULA	Integrated Water Use License Application
IWWMP	Integrated Waste and Water Management Plan
K (k)	Hydraulic Conductivity (m/day)
Kxx	Hydraulic Conductivity on the x-axis (m/day)
Kyy	Hydraulic Conductivity on the y-axis (m/day)
Kzz	Hydraulic Conductivity on the z-axis (m/day)
m	Metres
m^3	Cubic Metres
MAE	Mean annual evaporation
mamsl	Meters above mean sea level
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
mbgl	Meters below ground level
n	Porosity
NEMA	National Environmental Management Agency
NGDB	National Groundwater Database
n-Value	Manning's Roughness Coefficients
NWA	National Water Act, 1998 (Act No. 36 of 1998)
PCD	Pollution Control Dam
PCD	Pollution Control Dam
PEST	Parameter Estimation Simulation
PFD	Process flow diagram
Re	Recharge (%)
S	Storativity
SANS	South African National Standards
Ss	Specific Storage
SW	Surface Water
Sy	Specific Yield
T	Transmissivity (m^2/d)
t	Time (days)
TDS	Total dissolved solids
USG	Unstructured Grid
W	Groundwater Flux
WMA	Water Management Area
WQ	Water Quality
WR2012	Water Resources of South Africa 2012
Y (Yr.)	Years
ZOI	Zone of Influence
θ	Porosity

1 INTRODUCTION

GCS Water and Environment (Pty) Ltd (GCS) was appointed by Umhlaba Environmental Consulting CC (Umhlaba) to undertake a geohydrology assessment to supplement the Water Use License (WUL) for the proposed Bundu Mining (Rietvalei) Mining Right (MR) Application, situated in the Kameeldrif West area, in Gauteng Province (refer to Figure 2-1). The project falls within Quaternary catchment A211 of the Limpopo Water Management Area (WMA) (DWS, 2016).

1.1 Background

The end client (Bundu Mining) wants to apply for a mining right at Bundu Mining Rietvalei, situated in the Kameeldrif West area in Gauteng Province. There are two drainage lines on either side of the application area that had to be evaluated, as these were pre-identified as potential watercourses.

The proposed mining right, as well as existing infrastructure at the site, is shown in Figure 2-1. Existing infrastructure entails a non-operational plant, one small-scale shovel (TLB and excavator) mining excavation, a stormwater dam and several settlement ponds which have been silted up due to historic mining activities. Rehabilitated sand mining operations that pre-date Bundu mining are evident all over the project area.

Activities associated with the proposed MR include the addition of a proposed washing and settlement dam, which would be a shallow and deep opencast quarry, into the ridge. The client is currently developing a resource statement and mine plan based on the proposed area. Therefore, no formal mine plan is available for the proposed Project. The Client [Bundu Mining] indicated that the maximum mining depths would be 10m and 50m for the shallow and deep blasting operations. The estimated time to reach the 50m mark, which forms the LOM, is between 25 and 30 years. Groundwater and surface water will be used for dust suppression and to provide water to the sand-washing plant.

This geohydrological assessment is required to evaluate the geohydrological risk associated with the proposed mining activity and groundwater abstraction activities, and the geohydrology report will supplement the Mining Permit Application (MPA) and Water Use License Application (WULA).

1.2 Objectives

This hydrogeological investigation is required to assess the impact that the mining activities may have on the local and regional groundwater regimes, considering the current and future predicted dewatering associated with the current operations. The results from the numerical groundwater flow and transport model were used to conclude the current and predicted groundwater yield and groundwater quality-related impacts and should be used to advise on mitigation measures.

The objectives of this study were as follows:

- Evaluate the site's hydrological setting (i.e., climate, rainfall, drainage, etc.).
- Understand and characterize the geohydrological setting to set a basis for evaluating potential impacts relating to the existing and proposed mining activities.
- Evaluate existing round water users, water quality and characteristics associated with potential groundwater abstraction for existing boreholes at the site.
- Develop a site conceptual model (CSM) to illustrate the geohydrological setting, underlying aquifers and groundwater flow paths.
- Understand all groundwater risks associated with the proposed Project:
    - A sub-catchment scale groundwater model was developed to characterize the groundwater flow systems more fully (i.e., particle flow analyses, groundwater flow, head changes, etc.).
    - The Zone of Influence (i.e., pumping borehole or dewatering zones of influence [ZOIf] and potential pollution migration zone of impact [ZOIp]) were determined for the proposed mining activities.
    - The Australian Groundwater Modelling Guidelines (Barnett, et al., 2012) were considered to ensure that the numerical model adheres to international norms and standards.
- The existing monitoring system was evaluated, and improvements were proposed to monitor the impact associated with the proposed activity.
- Produce a comprehensive report which can be used for decision-making purposes and compliance with an MPA and WULA.

1.3 Study relevance to the season in which it was undertaken

This study was undertaken as a once-off study and relies on field-generated data backed by historical geohydrological, water monitoring and climate data for the site, as well as recognised geo-hydrological 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.

1.4 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), and is applicable to geohydrological studies for environmental impacts assessment/water use license applications. The report further considers *Appendix 6 of EIA regulations.*

1.5 Limitations

- No formal mine plan is available for the proposed Project. Only the site layout plan was provided. The Client [Bundu Mining] indicated that the maximum mining depths would be 10m and 50m for the shallow and deep blasting operations. The estimated time to reach the 50m mark, which forms the LOM, is between 25 and 30 years. The numerical simulations are based on the foreseen LOM of 30 years up to the maximum mining depth of 50m and assume closure thereafter. This limitation can only be overcome once a formal mine plan and mine block model is made available, indicating the sequence of mining, mining duration and depths associated with the Project.

2 SCOPE OF WORK

The scope of work completed is as follows:

1. **Desktop data review:**
   a. All available reports relating to the site were assessed, including a review of all geohydrology, hydrology, hydrochemistry, and geology literature data.
   b. A desktop-level hydrocensus was conducted. The National Groundwater Archive (NGA, 2023), Groundwater Resource Information Project (GRIP, 2016) and the Southern African Development Community Groundwater Information Portal (SADAC GIP) databases were assessed to identify existing groundwater users in the area.
2. **Baseline hydrology review:**
   a. Hydro-meteorological data collection and analysis.
   b. Catchment delineation and drainage characteristics.
   c. Determination of catchment hydraulic and geometric parameters.
3. **Field investigation:**
   a. A site walk-over assessment was undertaken to map sensitive groundwater-surface water interaction zones identified on a desktop level.
   b. A groundwater hydrocensus was conducted within a 5 km radius of the mining site.
   c. A geophysical investigation was carried out near the existing plant and proposed settlement dams' area to identify potential geological contacts or features which act as preferential flow paths or flow barriers.
   d. A 12-hour pump test was conducted on an existing borehole at the Bundu Mining plant to determine the sustainable abstraction yield.

4. **Hydrogeological and geological conceptual model:**
    a. A hydrogeological and geological site conceptual model was developed with data obtained for the study area – focusing on the proposed activities.
5. **Groundwater numerical flow and transport update:**
    a. A steady-state model was developed and calibrated with data available for the study area (2023-2024 field and desktop data). The steady-state model was converted to a transient-state model to enable scenario modelling. The following were evaluated:
        i. Groundwater flow velocities and directions.
        ii. The dewatering impact associated with the abstraction and dewatering of groundwater was simulated and expressed as the zone of influence (ZOIf).
        iii. Source term impacts presented as the zone of impact (ZOIp) for the proposed new plant and settlement dam area was simulated.
6. **Geohydrological risk and impact assessment:**
    a. A risk assessment was conducted based on the source-pathway-receptor principle.
    b. The existing and potential future impacts associated with the proposed operations on the groundwater and subsequent surface water environments were evaluated.
7. **Monitoring audit:**
    a. A groundwater and surface water monitoring plan, with mitigation measures, was developed for the site based on the baseline assessment of the site conditions.
8. **Reporting:**
    a. This report, which encompasses all the work done, was compiled.

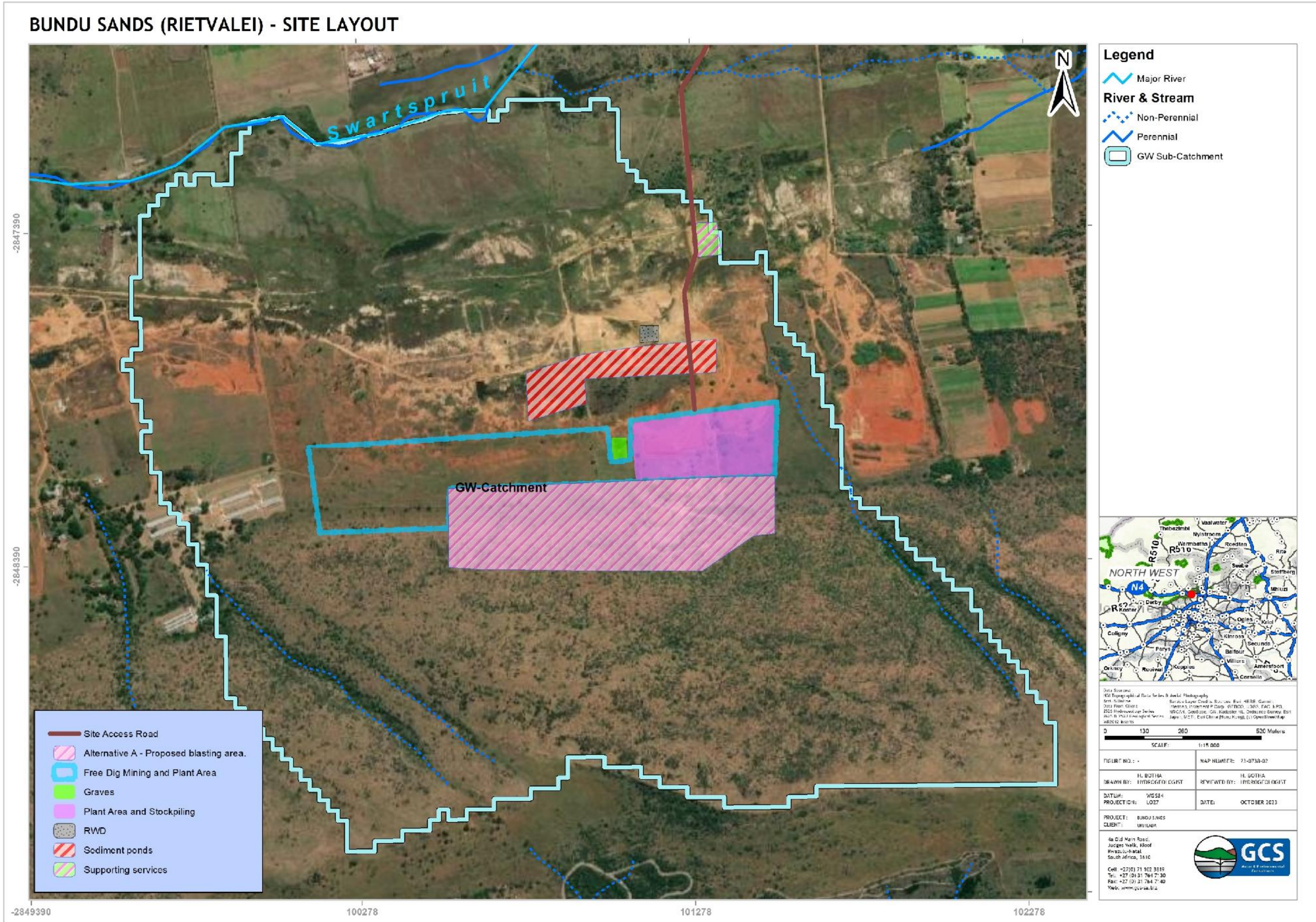


Figure 2-1: Site layout

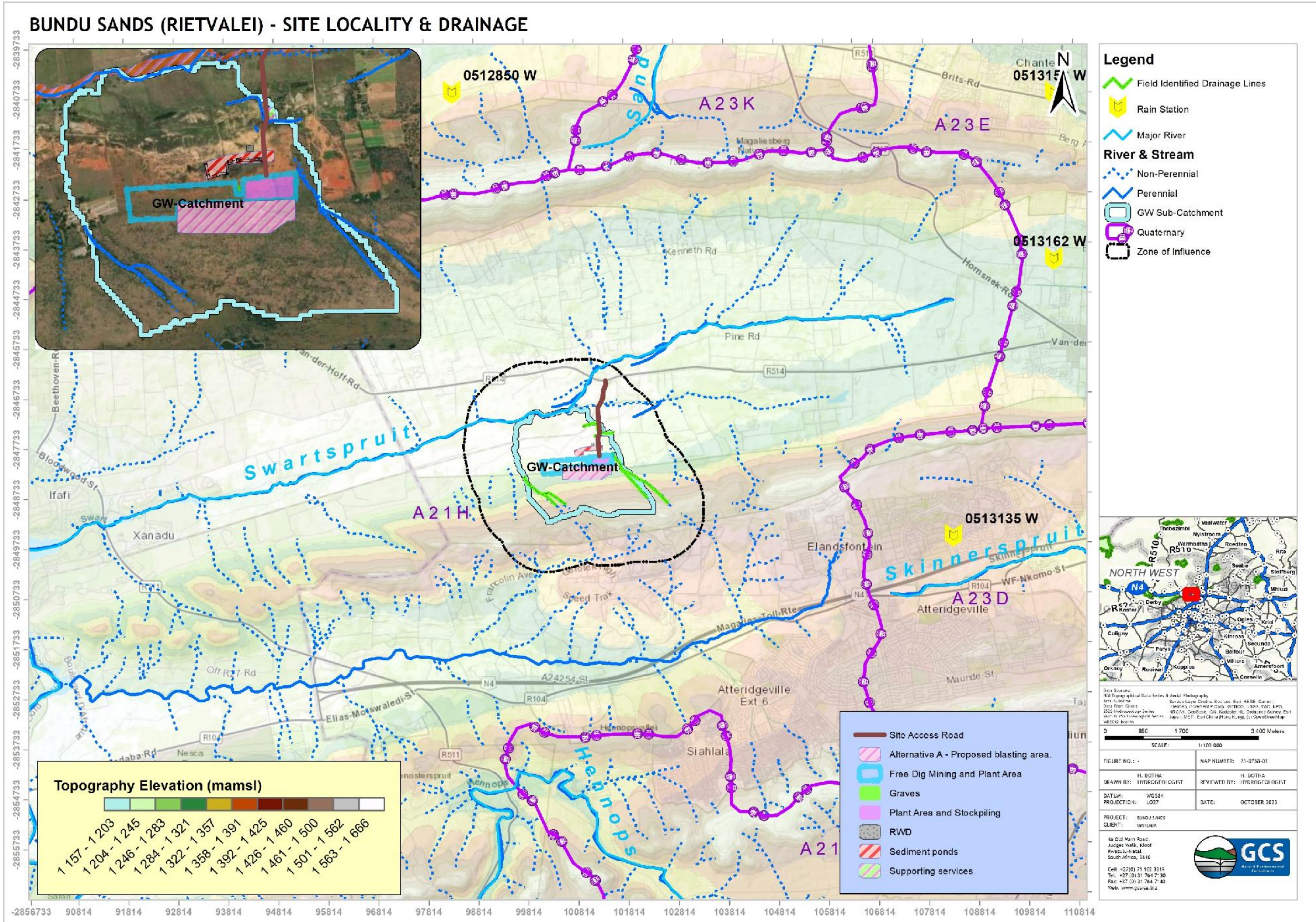


Figure 2-2: Site locality and drainage

3 AREA OF INVESTIGATION

As mentioned previously, the project falls within the quaternary catchment A21H of the Limpopo Water Management Area (WMA) (DWS, 2016). Elevations for the site area range from 1200 to 1550 metres above mean sea level (mamsl).

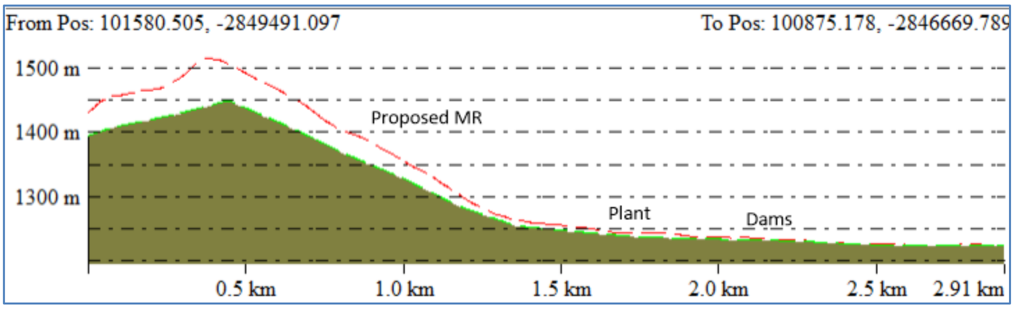


Figure 3-1: Typical cross section from headwaters to the project area

One (1) groundwater hydrological response unit (GHRU) describes the drainage of the local area and is bound towards the south by the hilltop sequence and towards the north by the Swartspruit River – refer to Figure 2-2. The total area of the sub-catchment is in the order of 4.09 km². The sub-catchment can further be viewed as the local sphere of influence associated with the proposed mining activities (i.e., the dewatering of transport movement may impact may only be limited to the sub-catchment in which it falls). For this study, the sphere of influence was further extended by 500 m of the sub-catchment boundary to ensure the maximum potential impact area is assessed.

The site is bound to the south by a steep hilltop, and two (2) dominant drainage lines exist, one towards the east and one towards the west of the hilltop, where valleys have been carved by erosion. For the majority of the site, there are no recognised drainage lines or streams/rivers. The proposed MR area falls between the two drainage lines, and based on the delineated topography and GHRUs, the activity will likely not impact the western drainage line and will have a limited impact on the eastern drainage stream. From the site investigation, it is clear that free drainage takes place for the entire site, with occasional depressions where surface water collects shortly after rainfall events.

It is clear from the site walkover assessment that historic mining has changed the surface water flow paths, and micro-catchment style free drainage from higher to lower elevations takes place. The overall drainage direction is towards the north of the Swartspruit River. The Swartspruit River is situated about 1.04 km downstream of the site and flows towards the west to the Hartbeespoort Dam.

3.1 Climate

Climate, amongst other factors, influences soil-water processes, runoff, and peak flows. 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.

3.1.1 Temperature

The average yearly temperature (refer to Figure 3-2) for the project area ranges from 20 to 35°C (high) and -5 to 3°C (Low). The study area is situated in a subtropical monsoon climate (Köppen: Cwa) with long, hot, rainy summers and short, dry and mild winters, as per the Köppen Climate Classification (Kottek, et al., 2006). The area is subjected to summer rainfall.

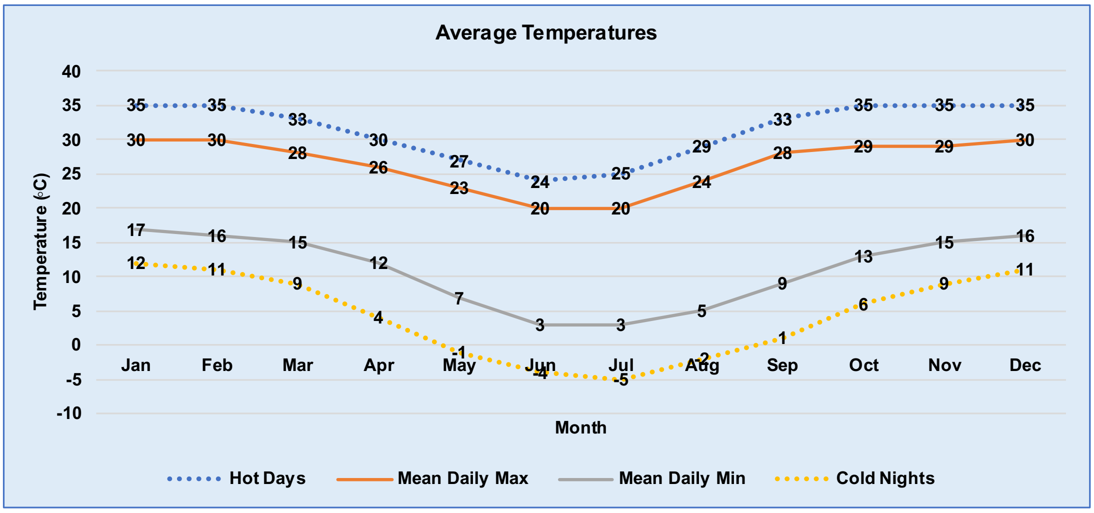


Figure 3-2: Average yearly temperatures (Meteoblue, 2023)

3.1.2 Wind speed and direction

Figure 3-3 shows the modelled wind rose for the project area (Hilton used as reference) and presents the number of hours per year the wind blows from the indicated direction. Wind generally blows from W, N and E and more often from the direction between N and ENE at velocities > 19 km/h.

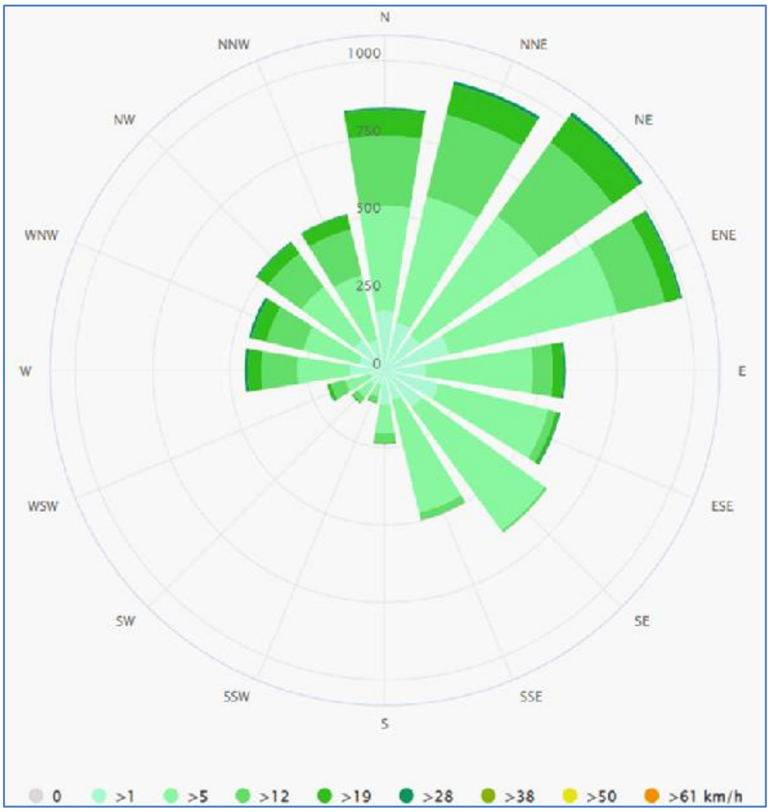


Figure 3-3: Wind rose (Meteoblue, 2023)

3.1.3 Rainfall and evaporation

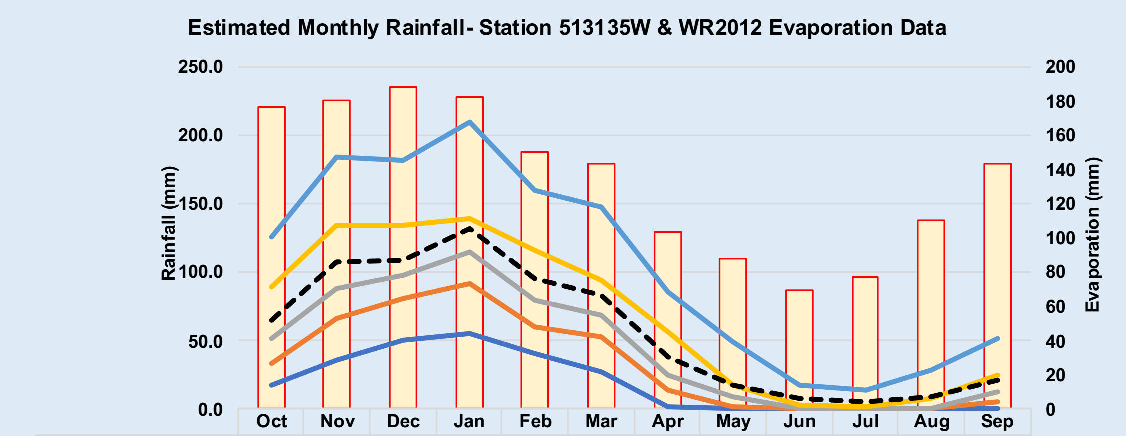
The project area is situated in rainfall zone A2C. The Mean Annual Precipitation (MAP) recorded at the nearest rainfall stations is summarised in Table 3-1 (WRC, 2015). The MAP for several sites is in the same order of magnitude.

Table 3-1: Summary of MAP recorded at nearest rainfall stations

Station Name	ID	Record (Yr)	MAP (mm/yr)
WYLIE'S FARM	0513135_W	83	681
PRETORIA-(POW)	0513255_W	75	687
PRETORIA-VOORTREKERHOOG	0513227_W	71	709
ZANDFONTEIN	0513162_W	38	691
PRETORIA-WEST END PLTN	0513254AW	31	713
PRETORIA-SKINNERSCOURT	0513254_W	58	713
Average			**699**

The monthly rainfall that represents the site was obtained from WR2012 rainfall station 0513135W (Wylies Farm). The rainfall record is for the period 1905 to 1988 (83 years). Monthly rainfall for the site is likely to be distributed, as shown in Figure 3-4. Available rainfall data suggest a MAP ranging from 405 (30^{th} percentile) to 1258 (90^{th} percentile) mm/yr. The average rainfall is in the order of 690 mm/yr.

The project area falls within evaporation zone 3A, of which Mean Annual Evaporation (MAE) ranges from 1 500 to 1 600 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 3-4.



Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Evaporation	176	180	188	182	150	143	104	88	69	77	110	143
10th Percentile	17.3	36.1	50.1	54.8	41.1	27.3	2.2	0.0	0.0	0.0	0.0	0.0
30th Percentile	33.6	65.8	80.6	92.2	60.4	52.5	13.3	1.4	0.0	0.0	0.0	5.4
50th Percentile	51.4	88.6	97.8	114.8	79.5	68.6	24.7	8.6	0.0	0.0	0.9	12.8
70th Percentile	89.0	133.9	133.8	139.1	116.5	94.0	56.9	17.8	2.4	1.8	7.3	25.4
90th Percentile	125.7	184.4	181.6	210.0	160.2	147.3	86.2	49.3	17.3	13.8	28.8	52.1
Average	64.8	107.0	109.1	132.3	95.0	83.0	38.5	17.8	7.3	5.9	8.5	21.8

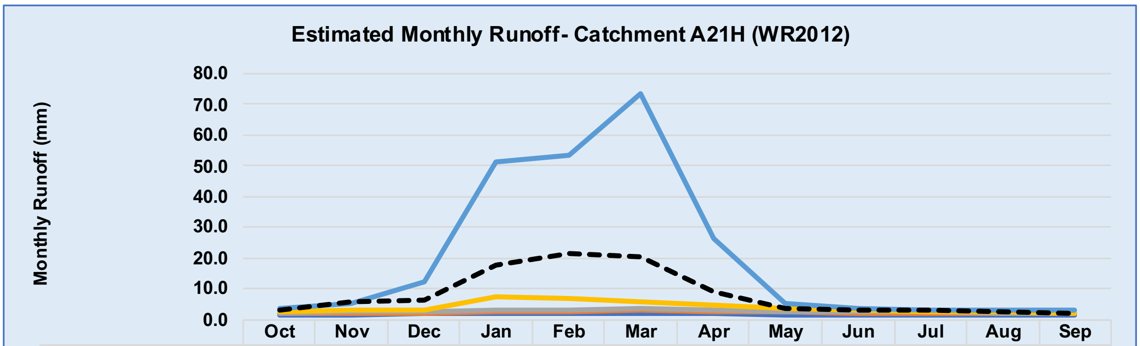
Month

Evaporation 10th Percentile 30th Percentile 50th Percentile 70th Percentile 90th Percentile Average

Figure 3-4: Average rainfall for Station 0513135W & WR2012 evaporation

3.1.4 Runoff

Runoff from natural (unmodified) catchments for the quaternary A21A is simulated in WR2012 (WRC, 2015) as being equivalent to 96.5 mm/yr (or 14% of the MAP) - refer to Figure 3-5.



Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
10th Percentile	1.6	1.6	1.7	2.0	1.9	1.9	1.8	1.6	1.6	1.6	1.5	1.3
30th Percentile	1.8	2.0	2.2	2.5	2.7	2.8	2.6	2.2	2.1	2.0	1.9	1.8
50th Percentile	2.1	2.4	2.6	3.0	3.2	3.6	3.2	2.6	2.4	2.3	2.2	1.9
70th Percentile	2.5	2.9	3.2	7.3	6.9	5.5	4.7	3.4	3.0	2.7	2.3	2.2
90th Percentile	3.3	5.2	12.1	51.1	53.5	73.7	26.4	5.2	3.6	3.0	2.8	2.7
Average	2.8	5.6	6.1	17.5	21.3	20.3	9.1	3.8	2.8	2.8	2.3	2.0

Month

10th Percentile 30th Percentile 50th Percentile 70th Percentile 90th Percentile Average

Figure 3-5: Simulated natural (unmodified) runoff for A21H

3.1.5 Considerations on climate change

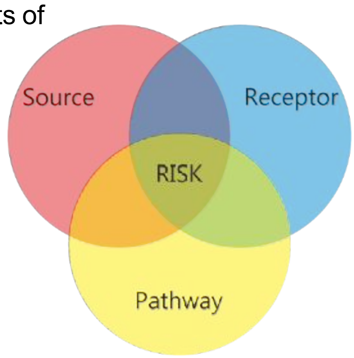
Based on available climate change models for the project area, derived from World Climate Data CMIP6 V2.1 (Eyring, 2016), RCP 4.5 and 8.5 scenarios were chosen, and the following is predicted for the project area:

- Temperature:
  - 2021 - 2050: increases by as much as 2.1ºC
  - 2050 - 2100: increases by as much as 2.3ºC
- Annual average hot days:
  - 2021 - 2050: additional 0.16ºC extremely hot days.
  - 2050 - 2100: additional 0.9ºC extremely hot days.
- Annual rainfall totals (MAP):
  - 2021 - 2050: decrease in rainfall by as much as 89 mm/yr.
  - 2050 - 2100: decrease in rainfall by as much as 133 mm/yr.
- The annual average number of extreme rainfall days:
  - 2021 - 2050: decrease by as much as 2.1 days.
  - 2050 - 2100: decrease by as much as 3.1 days.

Based on the above, it is predicted that there will be future temperature increases with more frequent extreme temperatures, which will result in fewer days of rainfall. Based on the rainfall decrease projections, it is concluded that there will be less frequent storm events (though not extreme) to facilitate the projected decreases in annual rainfall.

4 METHODOLOGY

A logical and holistic approach was adopted to assess the study area. The Best Practice Guidelines for Impact Prediction (G4) (Department of Water Affairs and Forestry [DWAF], 2008) were considered to define and understand the three basic components of the geohydrological risk associated with the site activities:



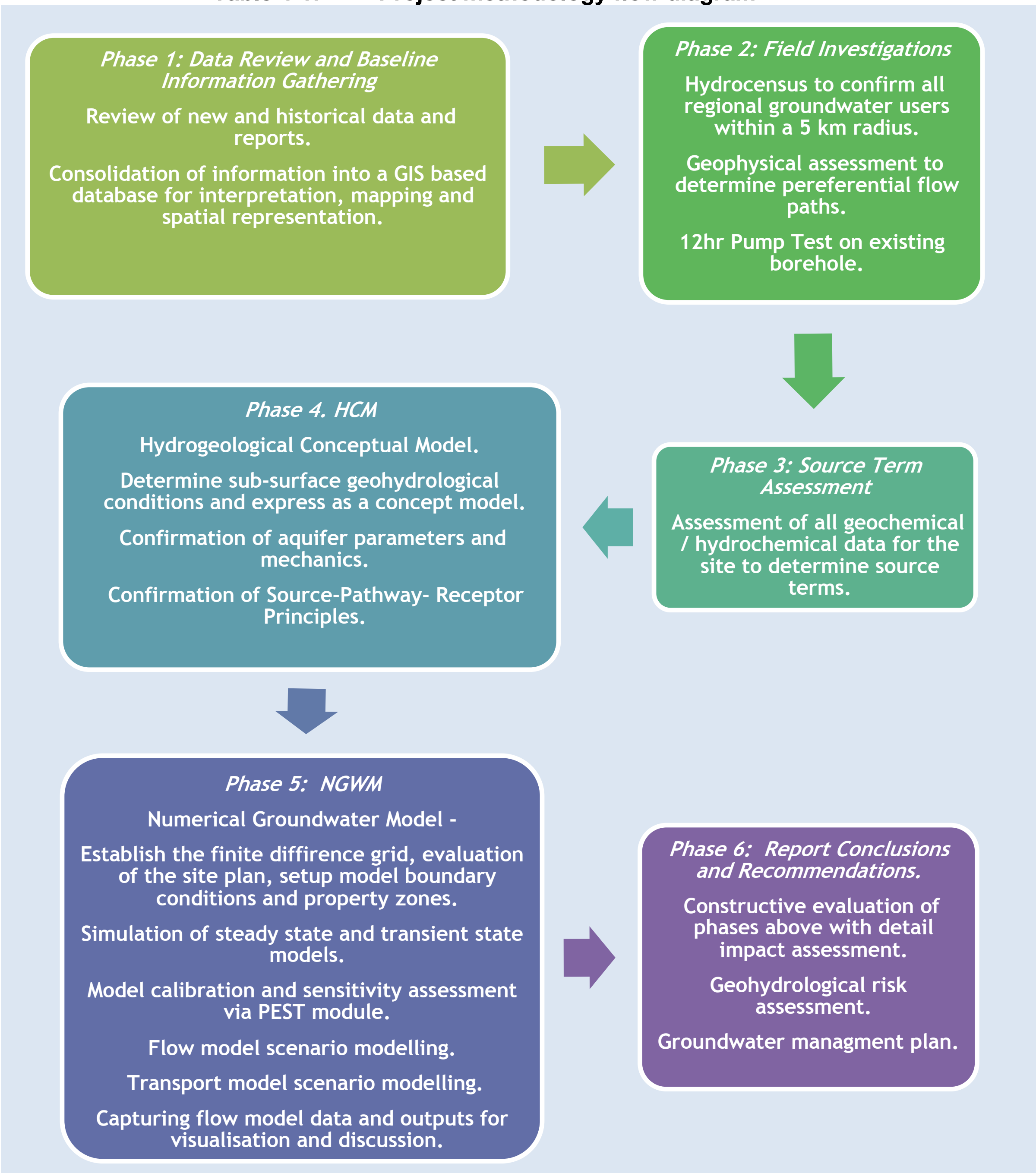
- **Source term** - The source of the risk.
- **Pathway** - The pathway along which the risk propagates.
- **Receptor** - The target that experiences the risk.

The approach was used to assess:

1. How could the existing/proposed site activities impact groundwater *Quality*?
2. How could the existing/proposed site activities affect 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 presents an overview of the project methodological approach followed.

Table 4-1: Project methodology flow diagram



4.1 Literature review and desktop study

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

- Groundwater Resource Information Project (GRIP, 2016)), National Groundwater Database Archives (Parsons, 1995).
- SADC Groundwater Information Portal (SADC GIP) borehole data (SADC GIP, 2023).
- 2526 Johannesburg – 1:500 000 Hydrogeological map series (King, 1998).
- 2526 Rustenburg - 1:150 000 geology series (DMEA, 1981).
- 2528 Pretoria - 1:150 000 geology series (DMEA, 1998).
- Literature on similar geology and hydrogeology:
    - A South African Aquifer System Management Classification (Parsons, 1995);
    - Aquifer Classification of South Africa (DWA, 2012);
    - Karoo Aquifers: Their Geology, Geometry and Physical Properties. Water Research Council (WRC) Report No: 457/1/98 (Botha, et al., 1998);
    - Karoo Groundwater Atlas Volume 2 (Woodford, 2013); and
    - The relationship between South African geology and geohydrology (Lourens, 2013).
- GCS internal database and reports for Kangra (refer to reference list).

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, 2023) 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, 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 Groundwater users in the study area (DWS and Public Data)

According to the Water Allocation Registration Management System (WARMS, 2019), there are only twenty-eight (28) WARMS users within a 5 km buffer of the project area, of which none of them fall within the GHRUs – refer to Figure 4-1. A review of SADAC GIP groundwater database boreholes further suggests several boreholes within a 5 km radius of the site with groundwater data available. The registry entry into WARMS for water use is summarised in Table 4-2, and SADAC GIP boreholes within a 5 km radius of the site are presented in Table 4-3.

98% of the WARMS users are boreholes, amounting to a total allocation in the order of 0.7 Mm^3/yr, followed by 1 registered spring user and 1 surface water stream user. 1 groundwater user (WARMS ID: 26075176) is associated with the GHRU of the site.

Table 4-2: Summary of WARMS users within a 5 km radius of the site

ID	Latitude (WGS84)	Longitude (WGS84)	User	Resource Type	Resource	Register Status	Lawfulness Finding	Registered Volume (m^3/yr.)
26008800	-25.71880	27.99010	FOURCHAPS BOERDERY	BOREHOLE	NO NAME	ACTIVE	LAWFULNESS STILL TO BE DETERMINED	17234
26010566	-25.72010	27.98870	FOURCHAPS BOERDERY	BOREHOLE	NO NAME	ACTIVE	LAWFULNESS STILL TO BE DETERMINED	12720
26011672	-25.77190	27.97950	FOURCHAPS BOERDERY	RIVER/STREAM	SAARTJIESPRUIT	ACTIVE	LAWFULNESS STILL TO BE DETERMINED	35520
26014394	-25.72390	27.98690	FOURCHAPS BOERDERY	BOREHOLE	NO NAME	ACTIVE	LAWFULNESS STILL TO BE DETERMINED	21380
26014401	-25.71550	27.96070	FOURCHAPS BOERDERY	BOREHOLE	NO NAME	ACTIVE	LAWFUL	40722
26015339	-25.71000	28.02960	FOURCHAPS BOERDERY	BOREHOLE	NO NAME	ACTIVE	LAWFULNESS STILL TO BE DETERMINED	8000
26019399	-25.71730	27.99110	FOURCHAPS BOERDERY	BOREHOLE	NO NAME	ACTIVE	LAWFULNESS STILL TO BE DETERMINED	18670
26020092	-25.76000	27.98120	FOURCHAPS BOERDERY	BOREHOLE	NO NAME	ACTIVE	LAWFULNESS STILL TO BE DETERMINED	14700
26020163	-25.70900	28.02450	FOURCHAPS BOERDERY	BOREHOLE	NO NAME	ACTIVE	LAWFULNESS STILL TO BE DETERMINED	24100
26021448	-25.73290	28.02200	FOURCHAPS BOERDERY	BOREHOLE	NO NAME	ACTIVE	LAWFULNESS STILL TO BE DETERMINED	16980
26022214	-25.72370	28.01670	FOURCHAPS BOERDERY	BOREHOLE	NO NAME	ACTIVE	LAWFULNESS STILL TO BE DETERMINED	69600
26023605	-25.76694	27.98444	FOURCHAPS BOERDERY	BOREHOLE	NO NAME	ACTIVE	LAWFULNESS STILL TO BE DETERMINED	50000
26026540	-25.70770	28.02970	FOURCHAPS BOERDERY	BOREHOLE	NO NAME	ACTIVE	LAWFULNESS STILL TO BE DETERMINED	12050
26026586	-25.70990	28.03820	FOURCHAPS BOERDERY	BOREHOLE	NO NAME	ACTIVE	LAWFULNESS STILL TO BE DETERMINED	1800
26028334	-25.77170	27.96190	FOURCHAPS BOERDERY	BOREHOLE	NO NAME	ACTIVE	LAWFULNESS STILL TO BE DETERMINED	11155
26041809	-25.75000	28.05000	FOURCHAPS BOERDERY	BOREHOLE	NO NAME	ACTIVE	LAWFUL	15000
26046699	-25.73806	27.96528	FOURCHAPS BOERDERY	BOREHOLE	NO NAME	ACTIVE	LAWFULNESS STILL TO BE DETERMINED	1543
26046797	-25.71020	28.04120	FOURCHAPS BOERDERY	BOREHOLE	NO NAME	ACTIVE	LAWFUL	32486
26046804	-25.71190	28.04200	FOURCHAPS BOERDERY	BOREHOLE	NO NAME	ACTIVE	LAWFUL	15399
26048054	-25.74200	27.97090	FOURCHAPS BOERDERY	BOREHOLE	NO NAME	ACTIVE	LAWFULNESS STILL TO BE DETERMINED	100
26059675	-25.77140	27.96560	FOURCHAPS BOERDERY	SPRING/EYE	MONGWANE	ACTIVE	LAWFULNESS STILL TO BE DETERMINED	27300
26060976	-25.71330	27.97390	FOURCHAPS BOERDERY	BOREHOLE	NO NAME	ACTIVE	LAWFULNESS STILL TO BE DETERMINED	106560
26067247	-25.72436	28.06094	FOURCHAPS BOERDERY	BOREHOLE	NO NAME	ACTIVE	LAWFULNESS STILL TO BE DETERMINED	96000
26068022	-25.72710	28.05648	FOURCHAPS BOERDERY	BOREHOLE	BOREHOLE	ACTIVE	LAWFULNESS STILL TO BE DETERMINED	45720
26069254	-25.71150	28.02520	FOURCHAPS BOERDERY	BOREHOLE	NO NAME	ACTIVE	LAWFULNESS STILL TO BE DETERMINED	12000
26072473	-25.70725	28.04361	FOURCHAPS BOERDERY	BOREHOLE	SWART SPRUIT RIVER	ACTIVE	LAWFULNESS STILL TO BE DETERMINED	36933

ID	Latitude (WGS84)	Longitude (WGS84)	User	Resource Type	Resource	Register Status	Lawfulness Finding	Registered Volume (m³/yr.)
26075176	-25.73758	27.99456	FOURCHAPS BOERDERY	BOREHOLE	GROUNDWATER	ACTIVE	LAWFULNESS STILL TO BE DETERMINED	9600
26075381	-25.72569	28.03489	FOURCHAPS BOERDERY	BOREHOLE	LONGSIDE BH1	ACTIVE	LAWFUL	14198

Table 4-3: Summary of SADAG GIP / NGA boreholes within a 5 km radius of the site

ID	Source	Latitude (WGS84) Decimal Degrees	Longitude (WGS84) Decimal Degrees	Elevation (mamsl)	Water Level (mbgl)
673059	SADAC GIP / NGA 2023	-25.70133000	27.97500000	1318.5	5.5
673065		-25.70127000	27.97594000	1318.9	16.2
675536		-25.70250000	28.00922000	1269.2	22.9
675560		-25.70183000	28.01219000	1271.6	14.9
675584		-25.70153000	28.00925000	1272.0	27.4
675594		-25.72919000	28.04441000	1282.4	21.9
675894		-25.73846000	28.02369000	1310.9	30.5
677359		-25.77144000	28.01525000	1304.5	4
677360		-25.77377000	28.01953000	1309.9	8
677361		-25.77227000	28.01695000	1305.1	7
677362		-25.77169000	28.01023000	1305.9	11
677363		-25.77439000	28.00061000	1284.0	7
677364		-25.77004000	28.01804000	1310.6	9
121	DWS RQS 2023	-25.706111	27.983056	1310	no data

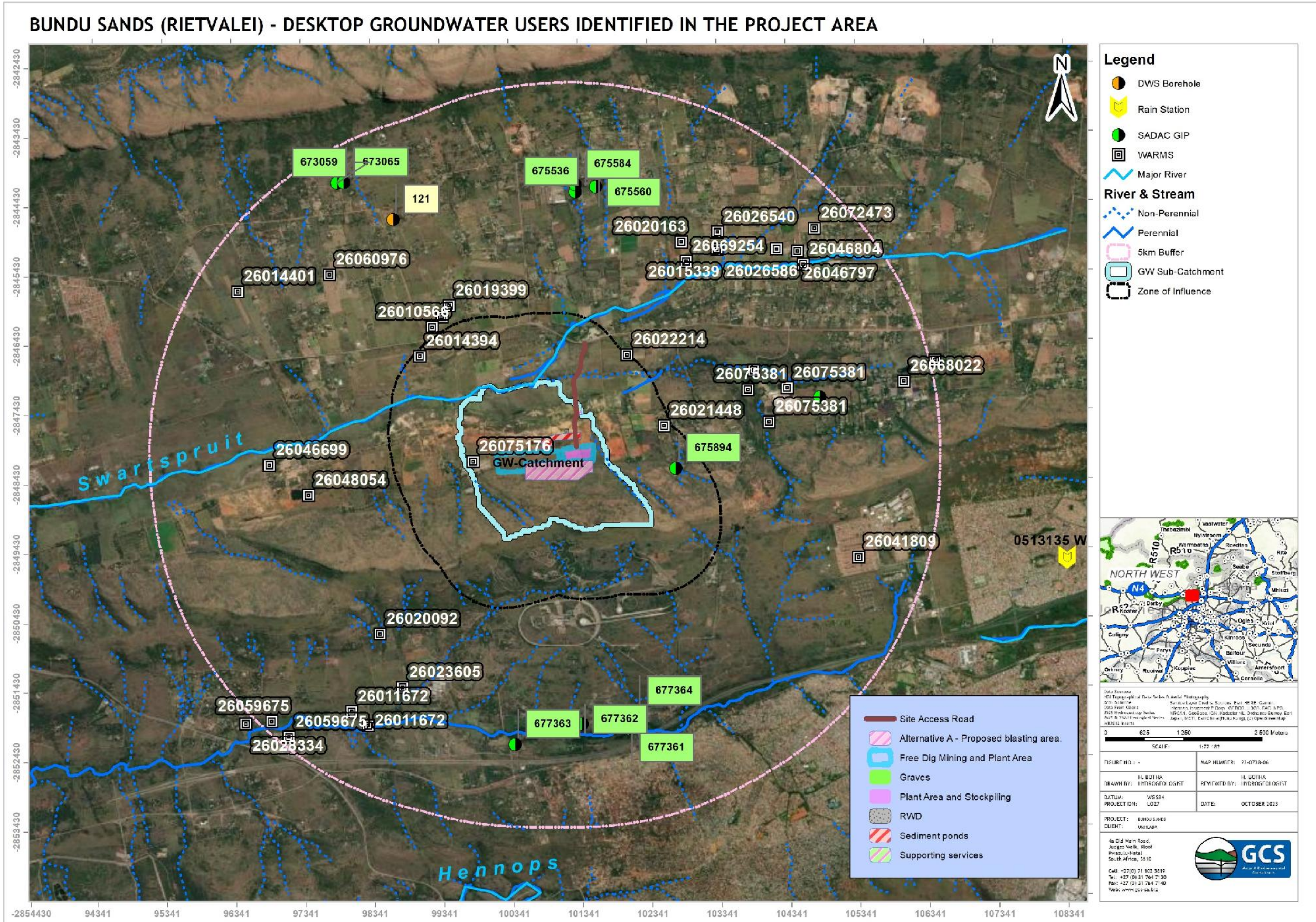


Figure 4-1: Desktop-level groundwater and surface water users identified within a 5 km radius of the site

4.4 Field investigation

The fieldwork integrated into this assessment is as follows:

- A field hydrocensus was undertaken on the 23rd of October 2023, with follow hydrocensus in November and September 2024.
    - 4 boreholes were identified, one of which is a borehole near the existing plant that will be used for water supply (sand washing and dust suppression).
    - An additional 31 groundwater boreholes were identified within a 5km radius of the site.
    - A surface water sample was taken from the stormwater dam at the site to evaluate site water quality.
- A geophysical assessment was undertaken using magnetic methods.
    - The aim was to determine the presence of intrusive dolerite dykes/sills or contacts in the vicinity of the site and specifically structures that may intersect the MR area, proposed washing plant and settlement dams' area.
    - The contact between the intrusive rock and the sedimentary rock is known as preferential groundwater flow paths.
    - Several potential dolerite intrusion areas were observed.
- A 12-hour pump test was conducted on a borehole situated near the existing washing plant to determine the sustainable abstraction yield.
    - The borehole will be used for about 8-12 hours per day to supplement water drawn from the stormwater dam for dust suppression (via truck) and washing water for the plant. Small-scale use is expected.
    - SANS-10299-4-2003 for borehole pump testing suggested that a 12-hour pump test should be sufficient to determine the sustainable yield for 12-hour usage per day.

4.4.1 Field hydrocensus

Table 4-4 lists the field boreholes identified at the Project Site, and Table 4-5 summarises groundwater users identified within a 5km radius of the proposed project. The spatial distribution of the users identified is shown in Figure 4-2. 35 groundwater boreholes were identified within a 5km radius of the site.

Abstraction volumes for boreholes identified vary from 2500 to 15 000 l/hr, and water usage ranges from small-scale irrigation to domestic to livestock watering. The average pH of the groundwater resource ranges from slightly acid (pH ~5.5) to neutral (pH ~ 7.6). Groundwater conductivity ranges from 170 µS/cm to >1200 µS/cm (slightly salty).

Identified groundwater users generally fall outside the GHRU, with only several of them falling inside, namely 96-5, 96-, Bundu BH-BH4. It is highly likely that boreholes falling outside the GHRU will not be impacted; however, they still fall in the potential sphere of influence. Refer to the groundwater model section of this report for the risks identified.

Table 4-4: Summary of field boreholes identified on-site and in the GHRU

ID	Source	Latitude (WGS84) Decimal Degrees	Longitude (WGS84) Decimal Degrees	Elevation (mamsl)	Water Level (mbgl)	Type	Collar	Usage	Owner
Bundu BH	GCS Field 2023	-25.733259	28.008528	1243.586	6.63	Borehole	0.1	Domestic	Bundu Mining
Bundu BH2		-25.73000833	28.00865	1235.64	0.1	Borehole	0.25	Washing and Domestic	Bundu Mining
Bundu BH3		-25.73818363	28.01388927	1282.902	Dry	Hand-dug well	N/A	Livestock	None. Old hand dug well.
Bundu BH4		-25.73783696	28.00435679	1256.403	Dry	Borehole	N/A	Livestock	None. An old borehole existed before mining took place in the area.

Table 4-5: Summary of boreholes identified within a 5km radius of the proposed Project and outside the GHRU

Borehole ID	Owner Name	Contact Details	Coordinates		Water Level (m)	Casing Height (m)	Borehole Depth (m)	Volume Abstracted (l/hr)	pH	Electrical Conductivity [µS/cm]	TDS (mg/l)	Temperature	Comment
			Latitude	Longitude									
313/6	Elize Pieterse		-25.71519	28.012041	NA	NA	64	unknown	6.4	880	440	19.5	Sample taken from jojo tank linked to borehole. The primary use is domestic use and gardening.
249/6	MJ Bredenkamp		-25.715298	28.012948	14.86		80	unknown	6.9	800	400	27.7	Sample taken from jojo tank linked to borehole. The primary use is domestic use and gardening.
311/6	BM Chatburn		-25.71683	28.012961	NA	NA	23	unknown	6.9	770	390	23.1	Sample taken from jojo tank linked to borehole. The primary use is domestic use and gardening.
314/18-1	WS Bredenkamp		-25.73674	28.01684	NA	NA	90	unknown	5.6	160	80	22.3	Primarily used for domestic use, stock watering and gardening
314/18-2	WS Bredenkamp		-25.73761	28.0166008	NA	NA	NA	unknown	NA	NA	NA	NA	Borehole is dry at 5.5m
314/18-3	WS Bredenkamp		-25.737565	28.0154216	NA	NA	90	unknown	NA	NA	NA	NA	The borehole is covered with sand and is under the ground
Gillia 103-1	Niel Van Zyl		-25.73413	28.01933	NA	1.27	225	2500	NA	NA	NA	NA	Primarily used for irrigation and is shut close after each season
Gillia 103-2	Niel Van Zyl		-25.73641	28.018225	NA	0.26	65	6000	NA	NA	NA	NA	Used primarily for irrigation
Gillia 103-3	Niel Van Zyl		-25.730825	28.01761	NA	NA	105	15000	NA	NA	NA	NA	Used primarily for irrigation, the borehole is covered underground.
Gillia 103-4	Niel Van Zyl		-25.737258	28.019037	NA	NA	115	10000	NA	NA	NA	NA	Used primarily for irrigation, the borehole is covered underground.
Gillia 103-5	Niel Van Zyl		-25.72946	28.015908	NA		50	4000	NA	NA	NA	NA	Used primarily for irrigation. The borehole is equipped, no SWL was recorded.
Gillia 103-6	Niel Van Zyl		-25.729123	28.016012	NA		70	12000	NA	NA	NA	NA	Used primarily for irrigation, the borehole is covered underground.
Gillia 103-7	Niel Van Zyl		-25.728515	28.016392	NA	NA	70	7500	NA	NA	NA	NA	The borehole is not currently in use, and is buried underground
Van Schalkwyk 22	Tanya Kotze	826591656	-25.736982	28.027967	28.19	NA	80	unknown	5.5	200	100	19.7	A sample was taken from a tap connected to the borehole, the borehole is used for the household/domestic use.
Plot 72	Marlet Botha	marletbotha73@gmail.com	-25.721808	28.020035	18.35	NA	37	unknown	6.5	1110	550	22	The borehole is primarily used for irrigation and to supply the household with water. There is foam coming out of the borehole, pollution is suspected.
161/352	Defense force		-25.75073	28.029041	NA	0.1	30	Dry	NA	NA	NA	NA	The borehole is equipped with a solar panel pump, the borehole itself is dry and was used for the fishing pond nearby.
119/314	Oom Willie	828962041	-25.738382	27.9914667	NA	0.6	30	4500	5.3	170	80	21.7	Sampled directly from borehole, the water is used for the household
112/314	Oom Willie	828962041	-25.735113	27.9839067	NA	0.6	35	5000	5.6	280	140	20.7	Primarily used for domestic use, stock watering and gardening. The borehole is equipped, the swl could not be taken
96-1	Japie du Plessis		-25.72184	28.005628	NA	NA	30	10000	6.6	1220	610	22.6	Sample taken from jojo tank linked to borehole. The primary use is domestic use and gardening.
96-2	Japie du Plessis		-25.72513	28.005595	26.76	0.4	30	unknown	6.2	1250	630	21.7	Sample taken directly from borehole. It is used for irrigation and stock watering.
96-3	Japie du Plessis		-25.722438	28.005505	6.7	0	30	unknown	NA	NA	NA	NA	Could not take a sample due to the pump cables being stolen. It is used for irrigation
96-4	Japie du Plessis		-25.726748	28.005933	1.1	0.2	92	unknown	7.6	710	350	20.9	Not in use currently
96-5	Japie du Plessis		-25.727285	28.005058	2.89	0		unknown	NA	NA	NA	NA	The borehole is blocked at 2.89m

Borehole ID	Owner Name	Contact Details	Coordinates		Water Level (m)	Casing Height (m)	Borehole Depth (m)	Volume Abstracted (l/hr)	pH	Electrical Conductivity [µS/cm]	TDS (mg/l)	Temperature	Comment
			Latitude	Longitude									
96-6	Japie du Plessis		-25.727765	28.00821	4.23	0	45	unknown	6.8	320	160	23	Used primarily for irrigation. The borehole is equipped.
96-7	Japie du Plessis		-25.729273	28.007347	NA	0.55	NA	unknown	NA	NA	NA	NA	The borehole is dry at 5m.
Van Schalkwyk 19	Danie		-25.736196	28.0250065	36.86	NA	42	unknown	NA	NA	NA	NA	The borehole ran dry after pumping for 1 minute. A sample could not be taken.
Laerskool Kameeldrift	Marlet Botha	marletbotha73@gmail.com	-25.71198	28.006935	NA	NA	NA	unknown	7	990	500	20.7	The borehole is equipped, and no swl could be taken. The water is used for domestic use and for watering the sports field.
HBH4	Rita Oosthuizen. Plot 133 Vld Hoff Rd	663976271	-25.722297	27.987986	NA	NA	NA	unknown	7.66	788	395	23.9	Unable to measure SWL, it was cemented
HBH3	Van der Schyf. 371 Kameldrift ,313 JR	vdschyfi@gmail.com	-25.720108	27.987439	NA	NA	NA	4000	7.54	775	388	23.32	Unable to measure SWL, BH was covered with steel due to theft around the area. The primary uses of water are for household and gardening.
HBH2	JS Viljoel. Plot 60, Roux Str	824731552	-25.704611	28.026778	NA	NA	NA	unknown	7.02	558	282	21.11	The BH was unable to measure SWL because it was equipped. Domestic Use.
HBH1	Basil Gorlt. Kameldrift West	825339674	-25.711792	28.026647	NA	NA	NA	5000	6.92	597	292	21.68	Stockwater Use. The SWL, collar height, and casing diameter were unable to be measured because the BH was sealed.
Smit BH3	Jacob Smit. Kameldrift West	0828879742	-25.69328	27.99368	NA	NA	NA	NA	NA	NA	NA	NA	The BH is not in use and is the pump is damaged. The is no casing in BH
Smit BH2	Jacob Smit. Kameldrift West	0828879742	-25.69359	27.99394	NA	NA	NA	unknown	NA	NA	NA	NA	The BH is not in use and is equipped with pump
Smit BH1	Jacob Smit. Kameldrift West	0828879742	-25.6936	27.99389	32.53	N/A_flashed on the ground	220	2500	6.70	130	60	14.30	Domestic water supply.
Jura BH4	Jura Poultry. Uitzicht		-25.738373	27.9925	NA			unknown	6.30	230	120	20.40	Unable to measure SWL, because it was equipped. The BH is also used for drinking.
Jura BH3	Jura Poultry. Uitzicht		-25.73776	27.99462	22.39	22.39		unknown	5.30	30	60	20.1	The BH is used for plants and grass
Jura BH2	Jura Poultry. Uitzicht		-25.738126	27.994288	25.17	0.095	20	unknown	4.9	50	90	13.6	BH used to supply man-made dam.
Jura BH1	Jura Poultry. Uitzicht		-25.73845	27.99428				unknown	5.2	30	60	18.40	Unable to measure SWL, collar height and the casing diameter because the BH was equipped.BH used to supply man-made dam with water.

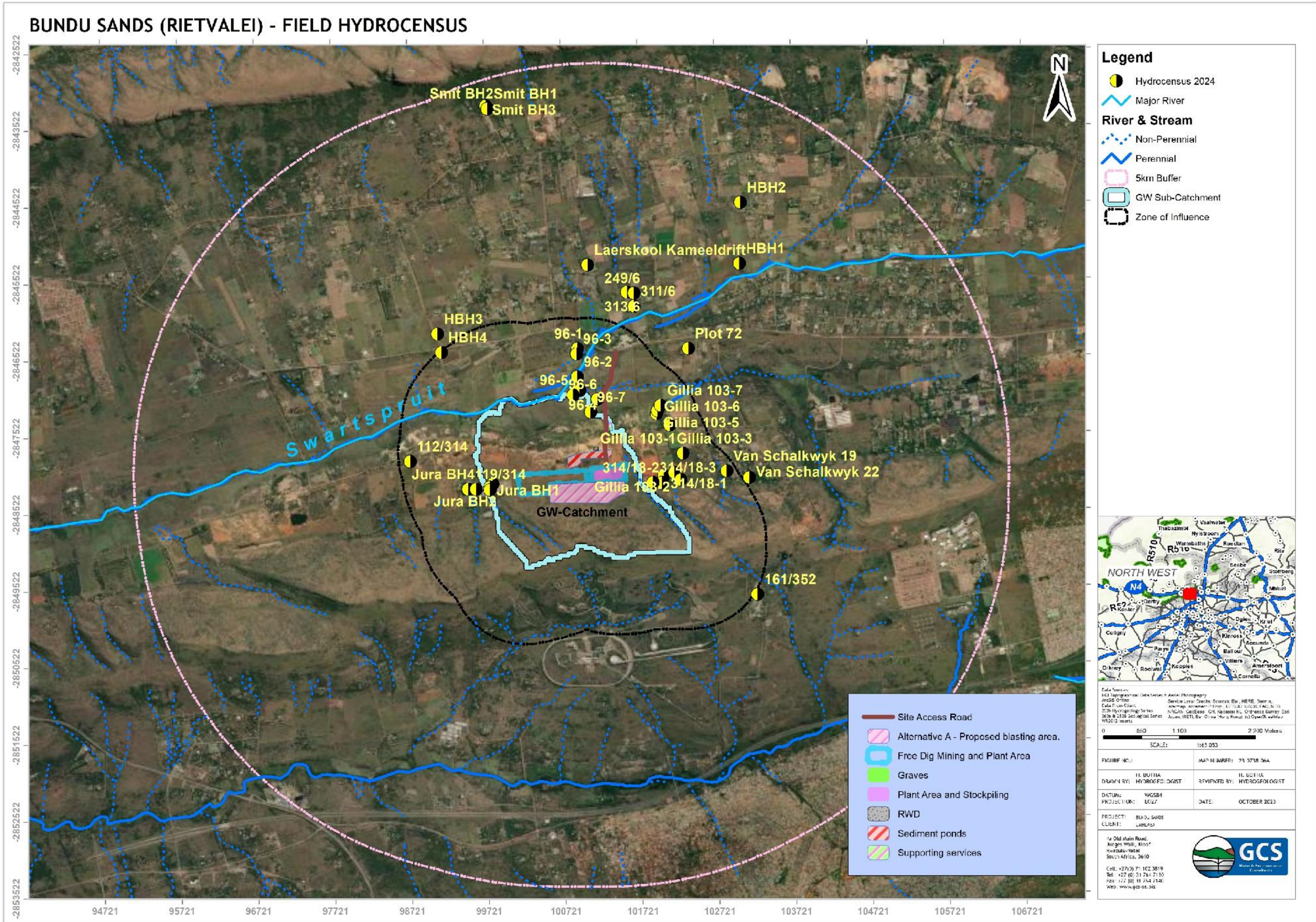


Figure 4-2: **Field hydrocensus boreholes identified in the project area**

4.4.2 Geophysical investigation

The detailed geophysical investigation methodology and data interpretation are available in **Appendix A**. The findings are briefly summarised as follows:

- Two (2) magnetic traverses were completed and focused on the proposed settlement and plant areas. The spatial orientation of the investigation lines is presented in Figure 4-4.
- Several magnetic anomalies were observed on both of the magnetic survey lines. Based on the parabola-shaped anomalies observed, several thin dolerite dykes likely exist in these areas and possibly underly the existing and proposed settlement dams' area. Depending on the degree of fracturing, these structures may promote or limit groundwater movement.

4.4.3 Drilling targets

Three (3) boreholes were sited based on the geophysical data obtained and are presented in Table 4-6 and shown in Figure 4-4. It is advised that all 3 boreholes be drilled to:

- Calibrate geophysical data obtained.
- Confirm lithological occurrences and geohydrological data.
- Establish permanent groundwater monitoring positions.
- Undertake aquifer testing and update hydraulic parameters; and
- Include in any future groundwater modelling updates.

Table 4-6: Proposed monitoring borehole drilling positions

Target ID	Latitude (WGS84)	Longitude (WGS84)	rec Depth (m)
T1-100	-25.73368459	28.00976666	30m
T1-340	-25.73396426	28.00732038	30m
T2-60	-25.73454261	28.0066131	30m

4.4.4 Aquifer testing

A constant discharge (CRD) and recovery test were performed on Bundu BH for 12 hours. The pumping rate was set at 2 l/sec, and the pump inlet was at 55 m. The pump test drawdown and recovery curve are shown in Figure 4-3. Over the pumping period, about 3.6% of the available drawdown (AD) was used, and the borehole recovered to 83% after 60 minutes.

The flow characterisation (FC) method developed by the Institute of Groundwater Studies (IGS) was applied to the pump test data to evaluate the sustainable yield. The FC analyses of the data generated during the pump testing are summarised in Table 4-8.

The calculated sustainable yield for the borehole is as follows (and summarised in Table 4-7):

- Pumping 12 hours = in the order of 183.32 m³/day can likely be achieved.

Table 4-7: Summary of estimated sustainable yields

Q Sustain	**l/sec**	4.24
Rec Pump Time	**Hours**	12.00
Q Sustain Total	**m³/day**	183.32
Q Sustain Total	**m³/month**	5499.50

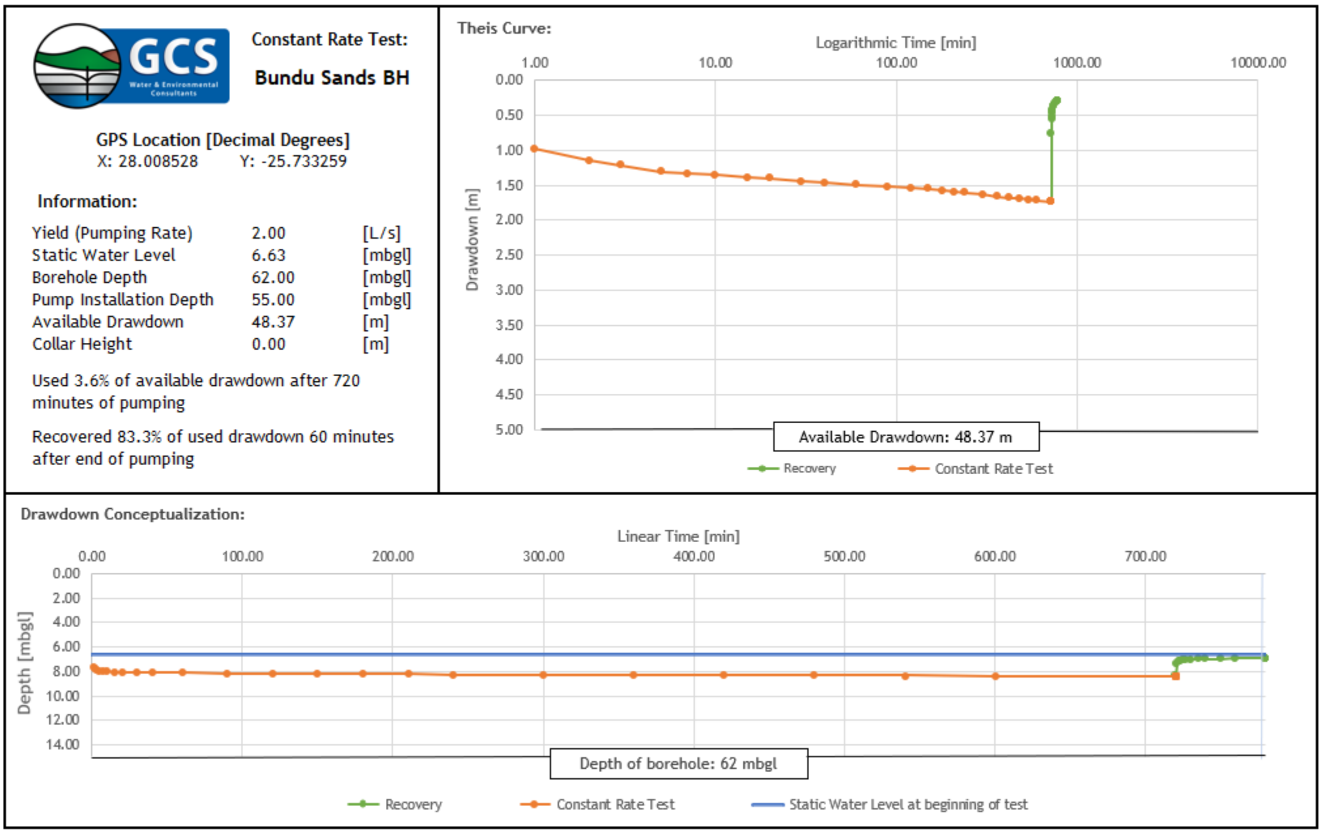


Figure 4-3: Bundu BH - Pump test drawdown and recovery curve

Table 4-8: FC Analyses – Bundu BH

Method	Sustainable yield (l/s)	Std. Dev	Early T (m^2/d)		Late T (m^2/d)		S	AD used
Basic FC	2.77	2.23	8		7.5		2.64E-03	48.4
Advanced FC	5.29		8		7.5		1.00E-03	48.4
Cooper-Jacob	8.55	5.53			40.1		4.66E-05	48.4
FC Non-Linear	2.49	2.20			34.0		5.06E-03	48.4
Barker	4.31	4.48	K_f =	2303		S_s =	1.60E-04	48.4
Average Q_sust (l/s)	**3.71**	**1.32**	b =	0.22	Fractal dimension n =		1.73	

Recommended abstraction rate (L/s)	**2.00**	for 24 hours per day		
Hours per day of pumping / **12**	**2.83**	L/s for	12	hours per day
Amount of water allowed to be abstracted per month	**5184**	m^3		
A borehole could satisfy the basic human need of	**6912**	persons		
Is the water suitable for domestic use (Yes/No)	**Y**			
Recommended pump depth below surface (m)	**50**			

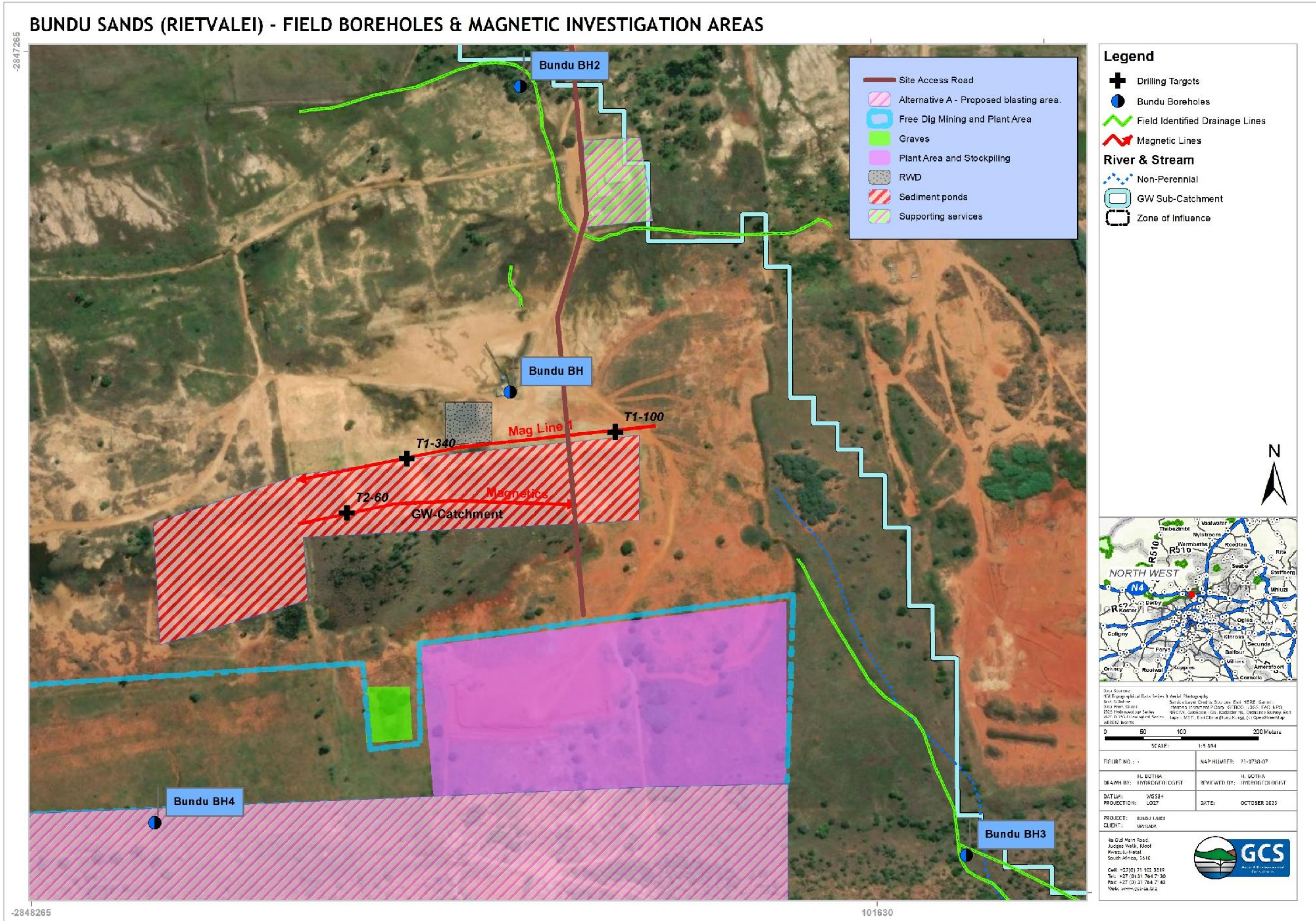


Figure 4-4: Geophysical investigation areas

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, soil 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:

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

The recharge to the aquifer was further refined and determined by running qualified guess analyses using the RECHARGE model developed by IGS (Van Tonder & Xu, 2000); (Vegter, 1995).

4.6 Groundwater quantity/availability assessment

An Intermediate Groundwater Reserve Determination (IGRD) (Parsons & Wentzel, 2007) was conducted for the study area to fulfil the requirements of the Water Use License concerning groundwater use in terms of Section 21a of the NWA. The IGRD aims to establish the groundwater reserve, thereby quantifying the safe aquifer yield, which is required to determine the impact of aquifer dewatering. The groundwater reserve was further supplemented with existing allocations as per the DWS National Integrated Water Information System (NIWIS, 2023).

From a groundwater point of view, it is necessary to determine the groundwater quantity and the 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 the reserve determination on a sub-catchment scale are summarised below:

$$\boldsymbol{GWavailable} = (\boldsymbol{Re}) - (\boldsymbol{EU} + \boldsymbol{BHN} + \boldsymbol{BF} + \boldsymbol{PU})$$ **Equation 2**

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.

4.6.1 Scale of abstraction

Based on the DWS Requirements for Water Use License Application: Groundwater Abstraction [S21(a)], the license application must be evaluated in terms of three possible categories. Categories A, B, and C each have an applicable list of information requirements for the license application. The categories are as follows:

- **Small-scale abstractions (< 60% recharge) Category A**
- **Medium-scale abstractions (60 - 100% recharge) Category B**
- **Large-scale abstractions (> 100% of recharge) Category C**

The scale of abstraction was determined based on available site information.

4.6.2 Water quantity stress index

The status of a groundwater resource unit can be assessed in terms of sustainable use, observed ecological impacts, or water stress. As no ecological reserve is available for the affected catchment, the impact of the proposed abstraction on the ecological reserve cannot be determined.

The concept of stressed water resources is addressed by the National Water Act, 1998 (Act No. 36 of 1998) (NWA) but is not defined. Part 8 of the Act gives some guidance by providing the following qualitative examples of water stress:

- Where water demands are approaching or exceed the available supply.
- Where water quality problems are imminent or already exist.

- Where water resource quality is under threat.

A groundwater stress index was developed by dividing the volume of groundwater abstracted from a groundwater unit by the estimated recharge to that unit (Parsons and Wentzel, 2007). However, this concept does not take cognisance of the impact of other land-use practices on groundwater and surface water resources. It is therefore proposed that the stress index be modified by taking the groundwater contribution to baseflow into account.

The modified stress index is as follows:

$$\textit{Stress Index} = \textit{Proposed Abstraction} / (\textit{Recharge} - \textit{Baseflow}) \qquad \textbf{Equation 3}$$

The stress index and classes described in Table 4-9 are a guide for determining the level of stress of a groundwater resource unit based on abstraction, baseflow, and recharge (modified after (Parsons & Wentzel, 2007).

Table 4-9: Guide for determining the level of stress of a groundwater resource unit

Present Status Category	Description	Stress Index
A	Unstressed or low level of stress	< 0.05
B		0.05 - 0.2
C	Moderate levels of stress	0.2 – 0.5
D		0.5 – 0.75
E	Stressed	0.75 – 0.95
F	Critically stressed	> 0.95

The estimated stress on the groundwater resource unit was determined based on available and proposed abstraction data for the site.

4.7 Numerical model development

The modelling processes followed are indicated in Figure 4-5.

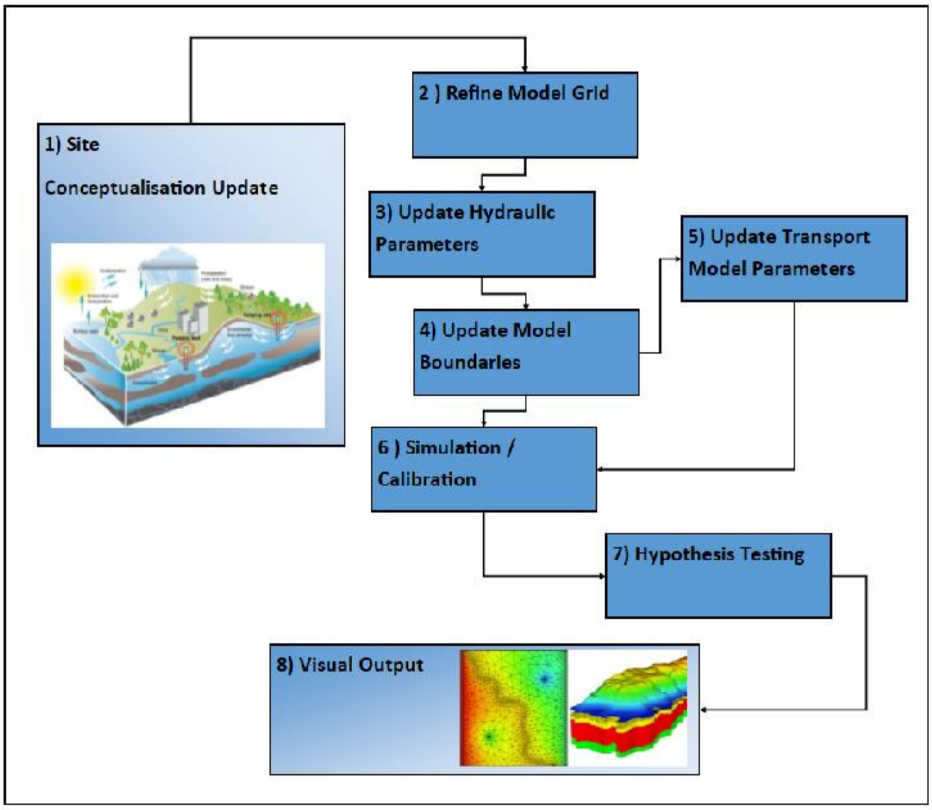


Figure 4-5: Numerical groundwater modelling process

4.7.1 Model software package

The numerical model for the project was constructed using Visual Modflow 9 Pro, 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.

4.7.2 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:

$$\frac{\partial}{\partial x}(K_{xx}\frac{\partial h}{\partial x})+\frac{\partial}{\partial y}(K_{yy}\frac{\partial h}{\partial y})+\frac{\partial}{\partial z}(K_{zz}\frac{\partial h}{\partial z})\pm W=S_s\frac{\partial h}{\partial t}$$ **Equation 4**

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
- t is time (T).

Equation 4, 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).

4.7.3 Model confidence level classification

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

- **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 the predictions formulated.
    - GCS aimed to construct a Class 1 flow and transport model. This is due to the limited data identified for the project area. Class 1 models are founded on limited hydrogeology data supplemented by literature data (i.e., water level data and aquifer hydraulic parameters) and can be used for 1^{st} order predictions and simulations.
- **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 may not be known at the model planning stage.

4.8 Geohydrology risk and impact assessment

Due to the assessment forming part of a larger risk assessment for the study area, the potential impacts and the determination of impact significance were assessed. The process of assessing the potential impacts of the project encompasses the following four activities:

1. Identification and assessment of potential impacts.
2. Prediction of the nature, magnitude, extent, and duration of potentially significant impacts.
3. Identification of mitigation measures that could be implemented to reduce the severity or significance of the impacts of the activity and
4. Evaluation of the significance of the impact after the mitigation measures have been implemented, i.e., the significance of the residual impact.

Per GNR 982 of the EIA Regulations (2014), the significance of potential impacts was assessed in terms of the following criteria:

I. Cumulative impacts.
II. Nature of the impact.
III. The extent of the impact.
IV. Probability of the impact occurring.
V. The degree to which the impact can be reversed.
VI. The degree to which the impact may cause irreplaceable loss of resources and
VII. The degree to which the impact can be mitigated.

Table 4-10 provides a summary of the criteria used to assess the significance of the potential impacts identified. An explanation of these impact criteria is provided in Table 4-11.

[Consequence = (Duration + Extent + Irreplaceability of resource) x Severity]
Equation 5

The environmental significance of an impact was determined by multiplying the consequence by probability.

[Environmental Significance = (Consequence x (Probability)] **Equation 6**

Table 4-10: Proposed Criteria and Rating Scales to be used in the Assessment of the Potential Impacts

Criteria	Rating Scales	Notes
Nature	Positive (+)	An evaluation of the effect of the impact related to the proposed development.
	Negative (-)	
Extent	Footprint (1)	The impact only affects the area in which the proposed activity will occur.
	Site (2)	The impact will affect only the development area.
	Local (3)	The impact affects the development area and adjacent properties.
	Regional (4)	The impact extends beyond municipal boundaries.
	National (5)	The impact extends beyond more than 2 regional/provincial boundaries.
	International (6)	The impact extends beyond the country's borders.
Duration	Temporary (1)	The duration of the activity associated with the impact will last 0-6 months.
	Short-term (2)	The duration of the activity associated with the impact will last 6-18 months.
	Medium-term (3)	The duration of the activity associated with the impact will last 18 months-5 years.
	Long-term (4)	The duration of the activity associated with the impact will last more than 5 years.
Severity	Low (1)	Where the impact affects the environment in such a way that natural, cultural, and social functions and processes are minimally affected.
	Moderate (2)	Where the affected environment is altered, but natural, cultural, and social functions and processes continue, albeit in a modified way, and valued, important, sensitive, or vulnerable systems or communities are negatively affected.
	High (3)	Where natural, cultural, or social functions and processes are altered to the extent that the natural process will temporarily or permanently cease, and valued, important, sensitive, or vulnerable systems or communities are substantially affected.
Potential for impact on irreplaceable resources	No (0)	No irreplaceable resources will be impacted.
	Yes (1)	Irreplaceable resources will be impacted.
Consequence	Extremely detrimental (-25 to -33)	A combination of extent, duration, intensity, and the potential for impact on irreplaceable resources.
	Highly detrimental (-19 to -24)	
	Moderately detrimental (-13 to -18)	
	Slightly detrimental (-7 to -12)	
	Negligible (-6 to 0)	
	Slightly beneficial (0 to 6)	
	Moderately beneficial (7 to 18)	
	Highly beneficial (19 to 24)	
	Extremely beneficial (25 to 33)	
Probability (the likelihood of the impact occurring)	Improbable (0)	It is highly unlikely or less than 50% likely that an impact will occur.
	Probable (1)	It is between 50 and 70% certain that the impact will occur.
	Definite (2)	It is more than 75% certain that the impact will occur, or the impact will occur.
Significance	Very high – negative (-49 to -66)	A function of Consequence and Probability.
	High – negative (-37 to -48)	
	Moderate – negative (-25 to -36)	
	Low – negative (-13 to -24)	
	Neutral - Very low (0 to -12)	
	Low–positive (0 to 12)	
	Moderate–positive (13 to 24)	
	High–positive (24 to 48)	
	Very high – positive (49 to 66)	

Table 4-11: Explanation of Assessment Criteria

Criteria	Explanation
Nature	This is an evaluation of the type of effect the construction, operation, and management of the proposed development would have on the affected environment. Will the impact of change on the environment be positive, negative, or neutral?
Extent or Scale	This refers to the spatial scale at which the impact will occur. The extent of the impact is described as footprint (affecting only the footprint of the development), site (limited to the site), and regional (limited to the immediate surroundings and closest towns to the site). The extent of scale refers to the actual physical footprint of the impact, not to the spatial significance. It is acknowledged that some impacts, even though they may be of a small extent, are of very high importance, e.g., impacts on species of very restricted range. To avoid “double counting, specialists have been requested to indicate spatial significance under “intensity” or “impact on irreplaceable resources” but not under “extent” as well.
Duration	The lifespan of the impact is indicated as temporary, short, medium, and long-term.
Severity	This is a relative evaluation within the context of all the activities and the other impacts within the framework of the project. Does the activity destroy the impacted environment, alter its functioning, or render it slightly altered?
Impact on irreplaceable resources	This refers to the potential for an environmental resource to be replaced should it be impacted. A resource could be replaced by natural processes (e.g., by natural colonization from surrounding areas), through artificial means (e.g., by reseeding disturbed areas or replanting rescued species) or by providing a substitute resource, in certain cases. In natural systems, providing substitute resources is usually not possible, but in social systems, substitutes are often possible (e.g., by constructing new social facilities for those who are lost). Should it not be possible to replace a resource, the resource is essentially irreplaceable, e.g., red data species that are restricted to a particular site or habitat to a very limited extent.
Consequence	The consequence of the potential impacts is a summation of the above criteria, namely the extent, duration, intensity, and impact on irreplaceable resources.
Probability of occurrence	The probability of the impact occurring is based on the professional experience of the specialist with environments of a similar nature to the site and/or with similar projects. It is important to distinguish between the probability of the impact occurring and the probability that the activity causing a potential impact will occur. Probability is defined as the probability of the impact occurring, not as the probability of the activities that may result in the impact.
Significance	Impact significance is defined as a combination of the consequence (as described below) and the probability of the impact occurring. The relationship between consequence and probability highlights that the risk (or impact significance) must be evaluated in terms of the seriousness (consequence) of the impact, weighted by the probability of the impact occurring. In simple terms, if the consequence and probability of an impact are high, then the impact will have a high significance. The significance defines the level to which the impact will influence the proposed development and/or environment. It determines whether mitigation measures need to be identified and implemented and whether the impact is important for decision-making.
Degree of confidence in predictions	Specialists and the EIR team were required to indicate the degree of confidence (low, medium, or high) in the predictions made for each impact based on the available information and their level of knowledge and expertise. The degree of confidence is not considered in the determination of consequence or probability.
Mitigation measures	Mitigation measures are designed to reduce the consequence or probability of an impact or to reduce both consequence and probability. The significance of impacts has been assessed both with mitigation and without mitigation.

4.9 Water monitoring plan

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 4-6.

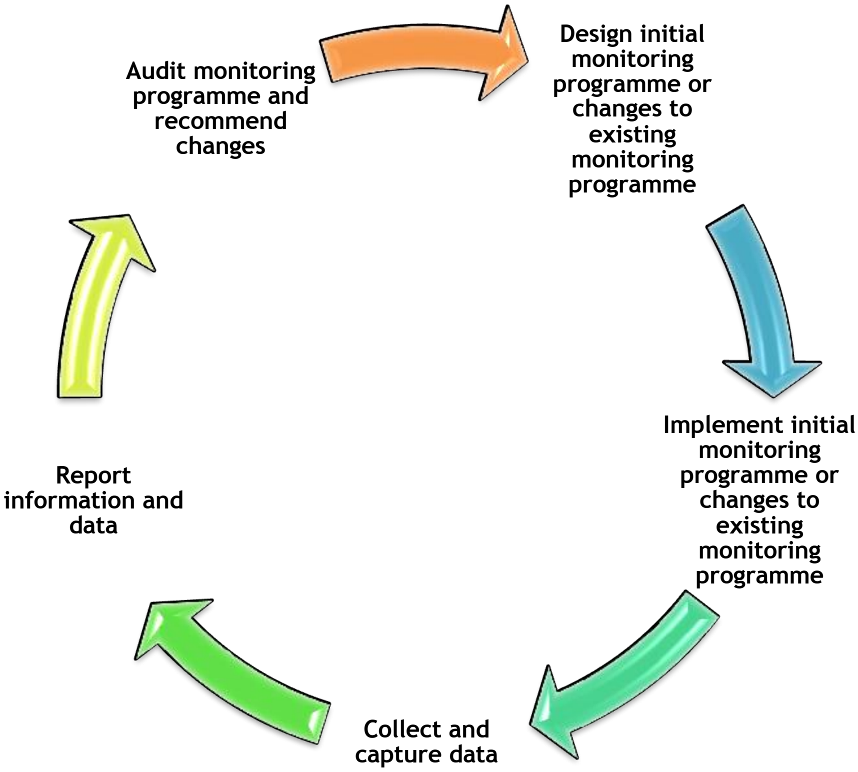


Figure 4-6: Monitoring Process

A groundwater monitoring plan was drafted based on the existing monitoring points, the site's conceptual model, and risk assessment.

5 PREVAILING GROUNDWATER CONDITIONS

The following section supplies an overview of the prevailing geohydrological conditions encountered in the area for the proposed development. The data was derived from available literature sources, and fieldwork was completed.

5.1 Local geology and soils

According to the 1:150 000 geology series (2526 Rustenburg & 2528 Pretoria) maps for the area (DMEA, 1981); (DMEA, 1998), the surface geology of the study is characterised by quaternary sands (Qb), intrusive diabase (di), quartzite (Vdq), and sediments of the Silverton and Hekpoort formations (shale, slate, hornfels, weathered andalusite, quartzite, basalt, tuff, shale and chert) of the Pretoria Supergroup, of the Transvaal Sequence - refer to Figure 5-2.

According to the Land Types of South Africa databases (ARC, 2006), the soils in the area fall within the Ib and Ba types. Soils associated with these groups typically entail:

- Ba (towards the plant and settlement dams area) - Freely drained, red and yellow, dystrophic/mesotrophic, apedal soils comprise > 40% of the land type (yellow soils <10%)
- Ib (towards the mining right area)- Rock outcrops comprise > 60% of land type.

According to Soil Conservation Service (SCS) data for the project area, the soils are divided into B/C and type C soils. SCS curve number is a function of the ability of soils to allow infiltration of water, land use and the antecedent soil moisture condition. Table 5-1 provides a summary of the hydrological characteristics of the different SCS soil types.

Table 5-1: Summary of SCS soil type hydrological characteristics (Muthu, 2015)

Hydrological Soil	Type of soil	Runoff Potential	Final Infiltration Rate (mm/hr)	Remarks
Group A	Deep, well-drained sands and gravels	Low	>7.5	High rate of water transmission
Group B	Moderately deep, well-drained with moderately fine to coarse textures	Moderate	3.8-7.5	Moderate rate of water transmission
Group C	Clay loams, shallow sandy loam, soils with moderately fine to fine textures	Moderately high	1.3-3.8	Moderate rate of water transmission
Group D	Clay soils that swell significantly when wet, heavy plastic and soils with a permanent high water table	High	<1.3	Low rate of water transmission

5.2 Structural geology

During the formation of the Pretoria Group, the tension in the crust due to continuing loading leads to failure and, subsequently, intrusion of diabase sills and dykes along weak zones such as fractures, fissures and faults. Consequently, dykes and sills varying between a few centimetres to 300 metres in thickness intruded the study area. Most dolerite dykes have a vertical or near-vertical dip.

The rocks immediately adjoining dolerite intrusions, of both dyke and sill form, are frequently disturbed, fractured and thermally metamorphosed as a result of the injection of the diabase/dolerite. These geological structures can, therefore, act as preferential flow paths or flow barriers, depending on the strike and dip of the host material and intrusive rock.

5.3 Aquifer characteristics and classification

The general aquifer characteristics and aquifer classification are summarised in Table 5-2.

Table 5-2: Aquifer characteristics and classification

Characteristics	Aquifer Classification
The aquifer host rock comprises meta-argillaceous rocs (shale and hornfels) and meta-arenaceous rocks (quartzite). Intrusive ultramafic rock (Diabase) is also known to occur in the project area- refer to Figure 5-3. The aquifers have low to medium hydraulic conductivities (K-value) and porosity (n-value). The aquifer is mainly secondary. The aquifers can be referred to as being primarily intergranular and fractured (King et al., 1998). Groundwater is typically encountered in: - Joints and fractures in competent arenaceous rocks relating to tensional or compressional stress and offloading. - Fault zones. - Along sedimentary or igneous rock contacts (either open, weathered or fractured). The aquifer's weathered zone is reported to be approx. 25 m thick, with the fractured zone approx. 110 m thick (DWAF, 2006). The combined aquifer thickness is estimated to be in the order of 135 m. The aquifer is an important contributor to groundwater baseflow to streams and rivers (King et al., 1998).	Available literature and site observation data suggest that Three (3) aquifer zones exist in the area: 1. A shallow, unconfined aquifer system associated with the quaternary sand deposits; 2. A semi-confined/perched aquifer system associated with both fractured and intergranular weathered rock of the Pretoria Group. 3. A deeper, confined, fractured aquifer network is associated with older basement rocks. The aquifer present is classified as a Minor Aquifer system (Parsons, 1995) The aquifers underlying the study area are considered low-yielding aquifers (median yields of 0.5 to 2 l/sec – Class d3 aquifer and b2 aquifers). Yields may increase to a range of > 5 l/sec for successful boreholes drilled into geological contacts, faults, or weathered sedimentary basins (King et al., 1998).

5.4 Aquifer transmissivity

The aquifers occurring at the site have reported yields ranging from 0.1 to 0.5 l/sec. Transmissivity (T) values for the weathered aquifer range between 0.001 - 5 m^2/d with S-values in the order of 0.001 - 0.0001 (Botha, et al., 1998)

The transmissivity of the deeper fractured bedrock aquifer, in the absence of open fracture systems, is characteristically low and estimated to be in the order of 0.0003 - 0.004 m^2/d (K-values of 0.00003 - 0.0004 m/d). The storativity for this aquifer varies between 0.001 to 0.0001. The T value of the borehole tested (Bundu BH) is that of the quaternary sands and is observed to be several orders higher than the perched/weathered aquifer system.

Slightly higher transmissivity values up to 4.32×10^{-4} m^2/d are associated with dolerite dyke contacts.

5.5 Aquifer storage/storativity

According to King *et al.* (1998) and DWAF (2006), the aquifer storage/storage coefficient is in the order of magnitude of < 9.4×10^{-5} (unit less). Table 5-3 provides literature values for various material types.

Table 5-3: Summary of specific storage for various material types

Material	S_s (ft^{-1})
Plastic clay	7.8×10^{-4} to 6.2×10^{-3}
Stiff clay	3.9×10^{-4} to 7.8×10^{-4}
Medium hard clay	2.8×10^{-4} to 3.9×10^{-4}
Loose sand	1.5×10^{-4} to 3.1×10^{-4}
Dense sand	3.9×10^{-5} to 6.2×10^{-5}
Dense sandy gravel	1.5×10^{-5} to 3.1×10^{-5}
Rock, fissured	1×10^{-6} to 2.1×10^{-5}
Rock, sound	< 1×10^{-6}

5.6 Groundwater recharge

Recharge to the underlying aquifer is estimated to range from 3 to 8% of the MAP (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 5-4. A recharge of 59.8 mm/yr corresponding to 8.7% was determined for the overall combined aquifer, and as further estimated per surface geology unit in the project area (i.e., alluvium recharge is > sedimentary rock > intrusive solid rock). Recharge applied to the numerical model is discussed in Section 7.

Table 5-4: RECHARGE Program (Van Tonder & Yongxin Xu, 2000)

Method	mm/a	% of rainfall	Certainty (Very High=5; Low=1)	
Cl	**206.6**	**29.9**	**3**	
Qualified Guesses:				
Soil	**29.6**	**4.3**	**4**	
Geology	**48.4**	**7.0**	**4**	
Vegter	**32.0**	**4.6**	**4**	
Acru	**40.0**	**5.8**	**3**	
Harvest Potential	**25.0**	**3.6**	**3**	
Average recharge	**59.8**	**8.7**		
Recharge =	**59.8**	**8.7**	**=**	**0.2444624**

5.7 Depth to groundwater and flow direction

According to WR2012 (Bailey & Pitman, 2015) and DWAF GRAII (DWAF, 2006) data, the groundwater level in the study area, on average, is in the order of 16 mbgl (metre below ground level). Available SADAC GIP and field hydrocensus data suggest a local water table in the order of 14 mbgl and that the groundwater table (weathered zone aquifer) generally follows the topography (a good correlation is observed ~ 88% - refer to Figure 5-1).

Figure 5-4 indicates the generated Bayesian interpolated groundwater elevations for the area. The data suggest that the general groundwater movement follows the topography. Conceptual geohydrological cross-sections are also indicated in the figure, showing the estimated groundwater flow paths based on the geohydrological setting.

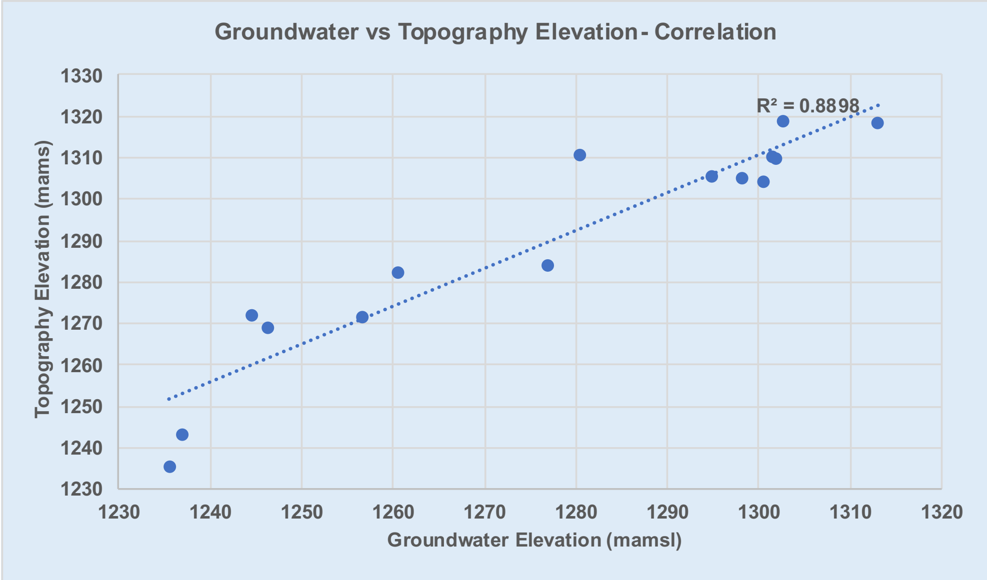


Figure 5-1: Groundwater vs. topography elevations - correlation

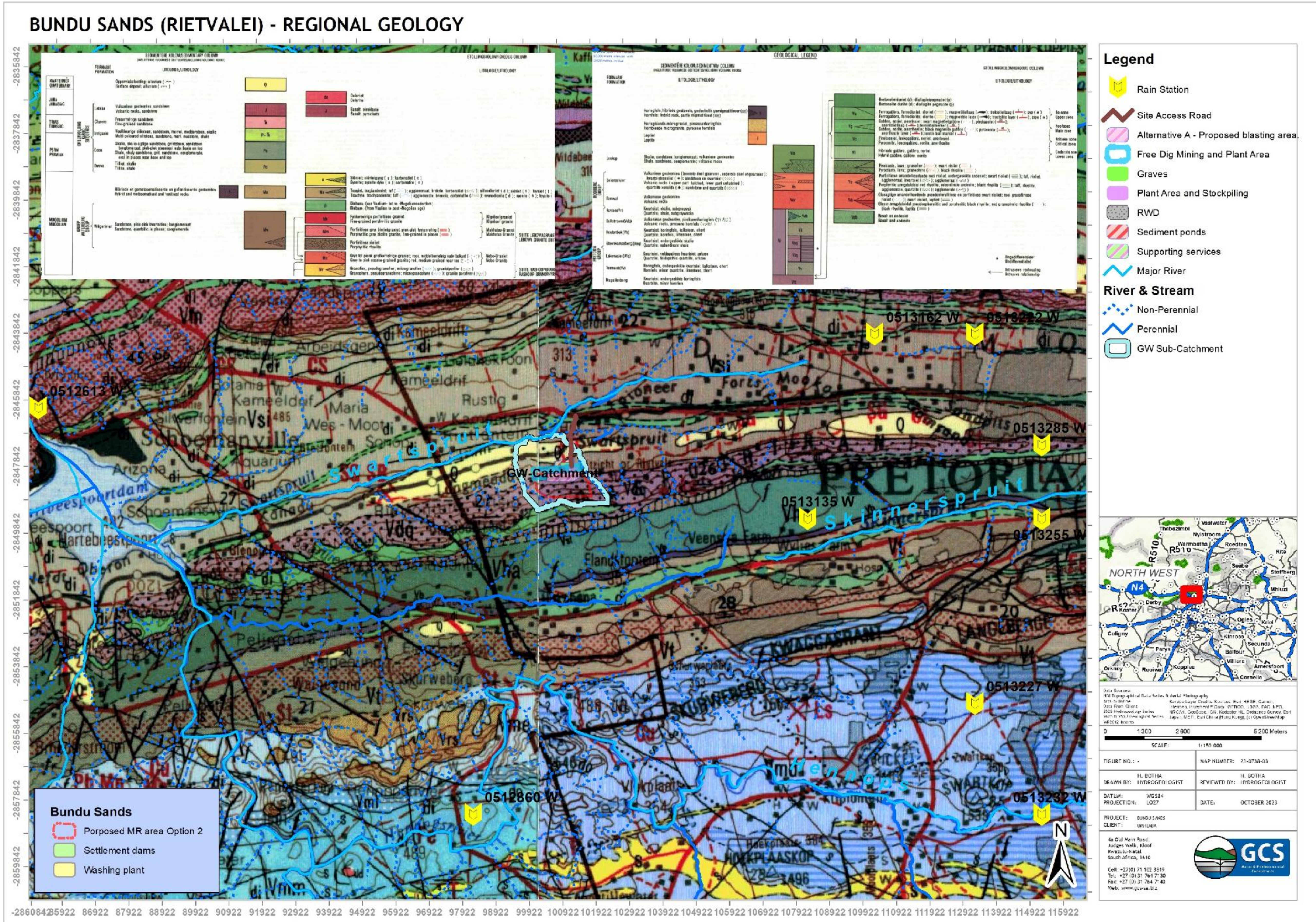


Figure 5-2: **Regional surface geology**

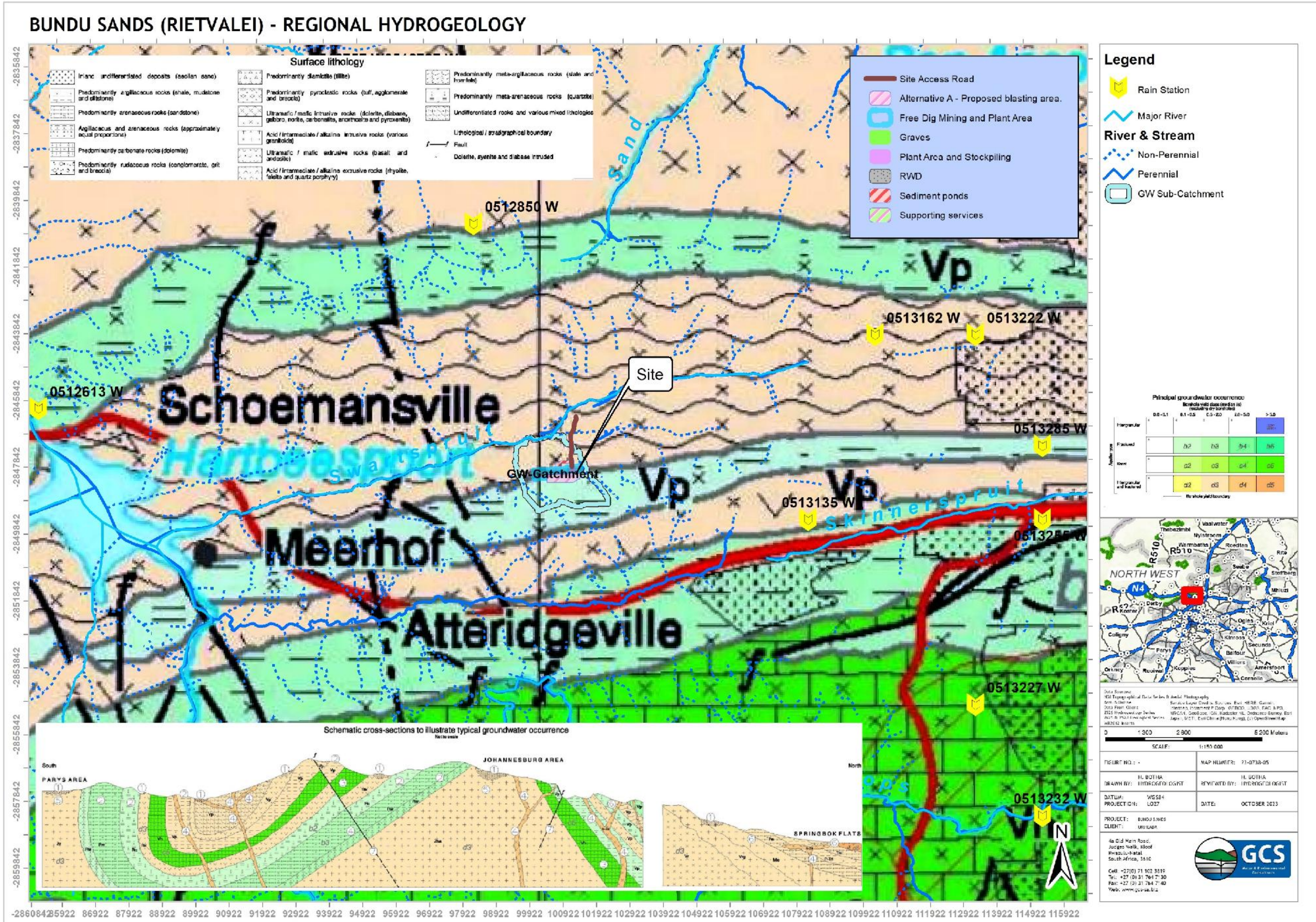


Figure 5-3: **Regional hydrogeological characteristics**

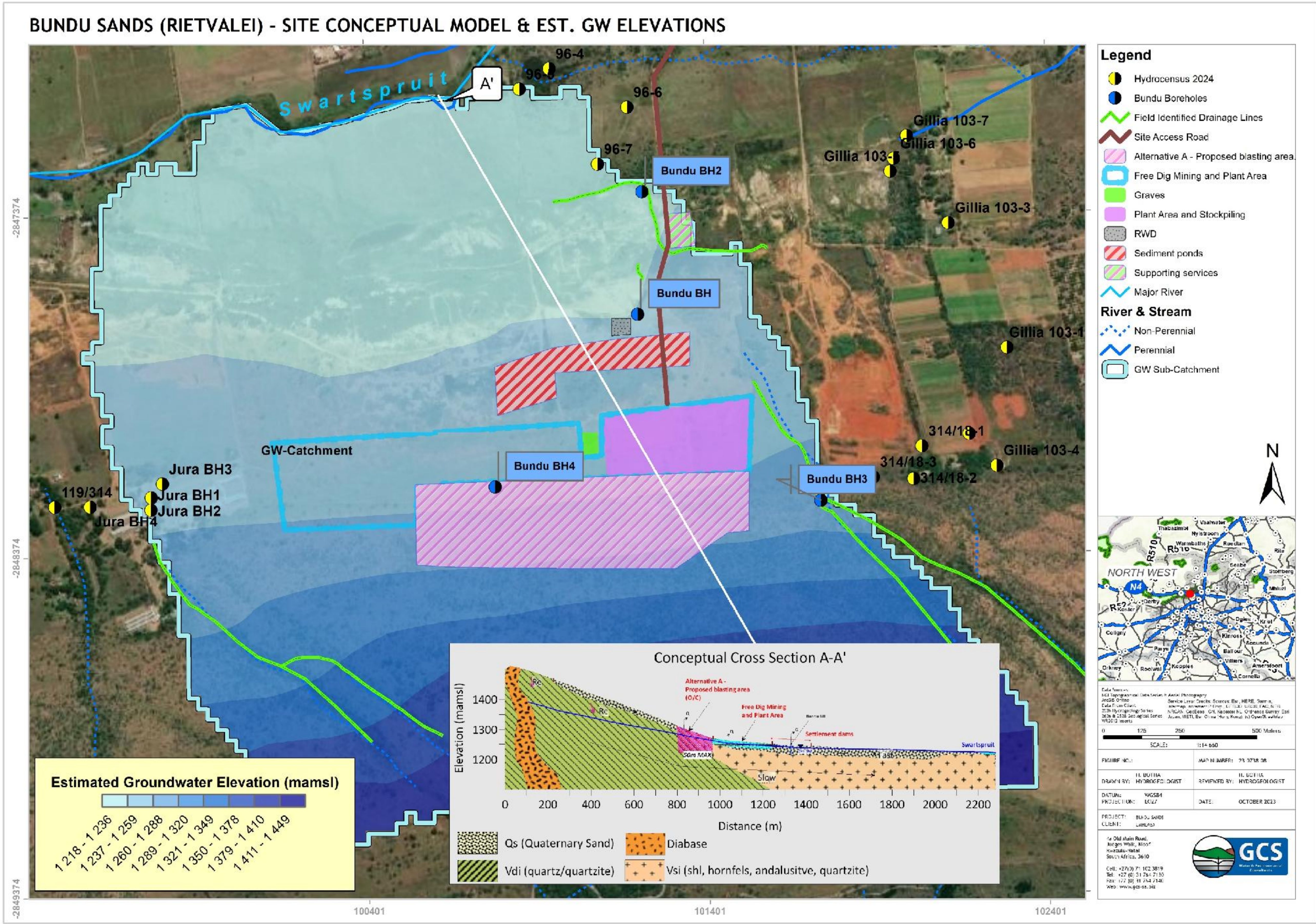


Figure 5-4: Estimated groundwater elevations, flow direction and site conceptual cross-sections

5.8 Desktop wetland and ecological areas

Based on available National Wetland Freshwater Ecosystem Priority Areas (NFEPA) (Van Deventer, 2018) evaluated on a desktop level, there are no wetland areas associated with the project area. However, based on the site investigation undertaken, several waterlogged areas were noted (specifically nearing the Swartspruit River).

In terms of river geo-hydrology, baseflow is considered the most important contributor to stream and wetland health. Baseflow (refer to Figure 5-5) is a non-process-related term that signifies 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 a river or wetland flow.

Available literature (WRC, 2015; DWAF, 2006) suggests groundwater contribution to baseflow ranges from 4.2 mm/yr (PITMAN MODEL) to 13 mm/yr (HUGHES MODEL). This relates to approximately 2% to 3% of rainfall.

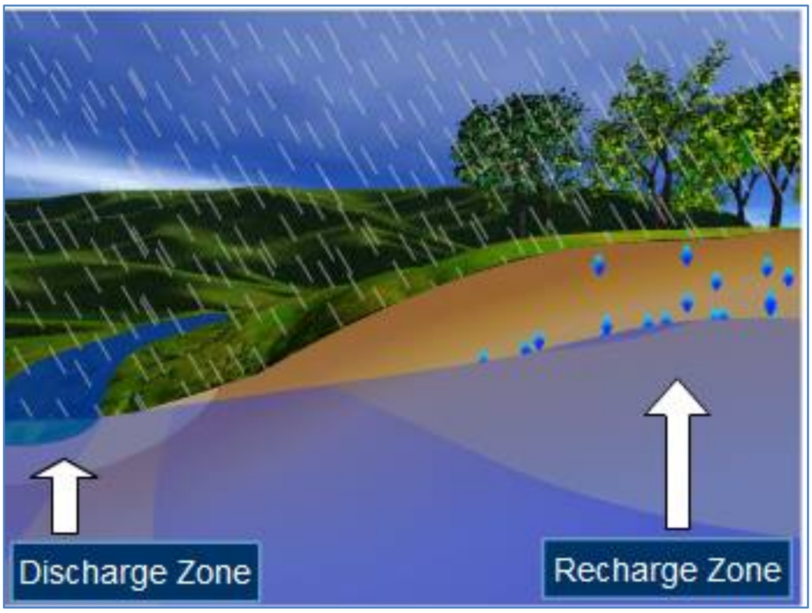


Figure 5-5: Groundwater baseflow concept (DWAF, 2007)

5.9 Present ecological state (PES) and environmental sensitivity and ecological importance (EIS)

Table 5-5 provides a summary of the PES, EIS and EWR (as a percentage of the MAR) for the quaternary catchments associated with the project area. The same conditions are inferred to apply to delineated sub-catchments.

Table 5-5: Summary of PES, EIS and EWR

Quat	PES	EIS	Reserve (EWR) % of NMAR	Source
A21H	C	Moderate	28%	WR2012

5.10 Groundwater velocities

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 7**

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 8**

The hydraulic gradient is calculated in Table 5-6. Table 5-7 shows the results of the flow velocity equation. A porosity of 30% was applied to the underlying hydrogeology (Freeze and Cherry, 1979).

Table 5-6: Hydraulic gradient calculation

Parameter	Bundu BH to Bundu BH2
h1 (mamsl)	1236.956
h2 (mamsl)	1235.54
h1-h2 (m)	1.416
L (m)	360
i	0.004
K (m/day)	0.75
n	0.3

Table 5-7: Flow velocity calculation

Flow rate	Bundu BH to Bundu BH2
m/day	0.0098
m/year	3.5892

5.11 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. The potential sphere of groundwater influence (i.e., the total area that can likely be subjected to groundwater impacts or the so-called domain) associated with the proposed activities relates to the boundary of the groundwater GHRU. For this study, the sphere of influence (SOIF) was further extended by 500 m of the sub-catchment boundary to ensure the maximum potential impact area is assessed – refer to Figure 5-4.

5.12 Groundwater quality

The groundwater quality for the project area was derived from available literature and site-specific data and is discussed in the sub-sections below.

5.12.1 Literature overview

The groundwater quality for the region will be variable and will depend on the underlying geology and hydrogeology characteristics associated with groundwater recharge (i.e., older rock and aquifers with ion exchange will have higher EC, and recently recharged more permeable younger rocks will have lower EC). Literature and available hydrogeology maps for the area (refer to Figure 5-6) suggest that the electrical conductivity (EC) for the underlying aquifers generally ranges from 0 to 70 mS/m (milli Siemens/metre). The pH for the region ranges from 6 to 8. This means that groundwater abstracted from the aquifer can generally be used for domestic and recreational use (DWAF, 1996b). Where groundwater contributes to baseflow, similar water quality is expected.

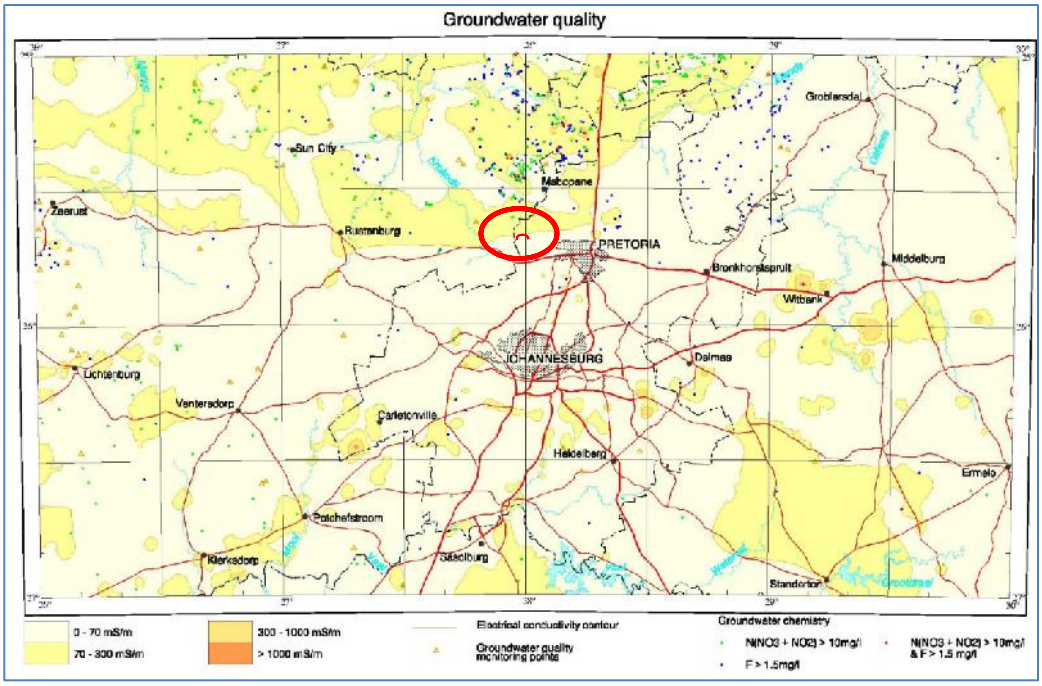


Figure 5-6: Groundwater quality (King, 1998)

5.12.2 Site water quality data

A surface water sample was collected from the stormwater dam near the existing Bundu Mining plant to characterise the site's surface water quality. The sample was submitted to Aquatic Laboratories (SANS T0685) for analytical screening. Table 5-8 summarises the water quality results, and laboratory certificates are available in **Appendix B**. The analytical data is compared to DWAF 1996 target water quality values (TWQV) for domestic water use to contextualise the results (DWAF, 1996b). The results are summarized as follows:

- The surface water sample exhibits neutral pH conditions;
- Electrical conductance (EC) is low, as are dissolved salts and metals. It is observed that the water quality falls well within the DWAF 1996 TWQR for potable use.
- The sodium absorption ratio (SAR) of the water sample suggests that stormwater used for dust suppression/irrigation will have no impact on the soils.

Table 5-8: Summary of surface hydrochemistry data

Constituent	Unit	SW-Dam	DWAF 1996 Domestic Use – TWQR
pH in water at 25ºC	-	7.84	4 - 9
Conductivity in mS/m @ 25ºC	mS/m	12	0 - 70
TDS	mg/l	90	450
Total Alkalinity as CaCO3	mg/l	71.3	ns
Calcium	mg/l	15.3	0 - 32
Magnesium	mg/l	7.74	0 - 30
Potassium	mg/l	2.53	0 - 50
Sodium	mg/l	4.21	0 - 100
Chloride	mg/l	1.01	0 - 100
Fluoride	mg/l	0.351	0 - 1
Nitrate	mg/l	0.303	0 - 6
Sulphate	mg/l	<0.1	0 - 200
Aluminium	mg/l	0.035	0 - 0.15
Copper	mg/l	<0.002	<1
Iron	mg/l	<0.002	<0.1
Manganese	mg/l	<0.002	<0.05
Sodium Adsorption Ratio (SAR)	Calculated	0.22	>8
ns = No Quality Range in Reference Guideline, Orange = Above DWAF (1996) Ideal Water Quality Ranges			

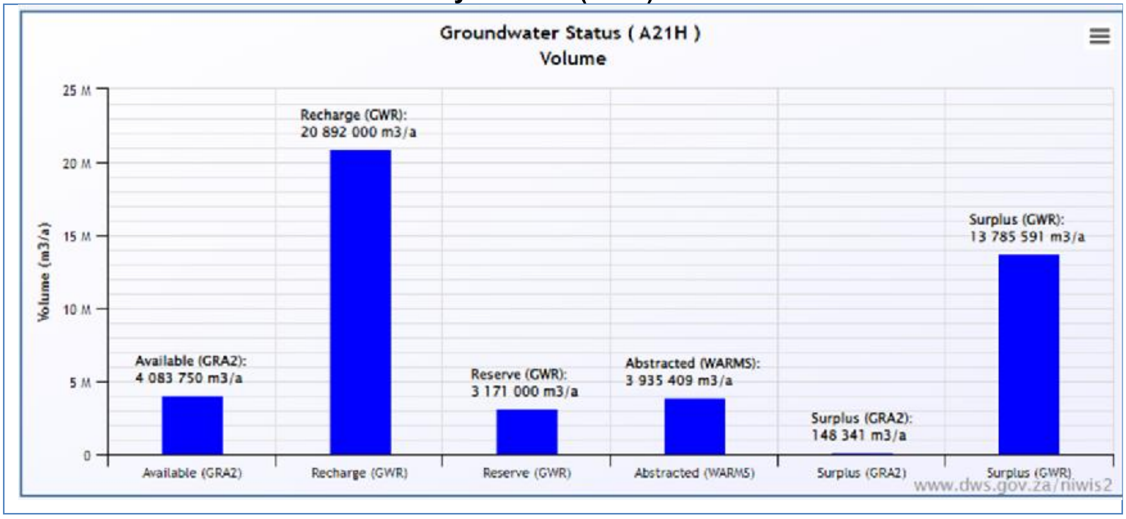
5.13 Groundwater quantity

Data from relevant geohydrological databases, including the Groundwater Resource Directed Measures (GRDM), was obtained from the Department of Water and Sanitation and associated Aquiworx software (Aquiworx, 2015). The site falls within quaternary catchments indicated in Table 5-9. Reserve allocations retrieved from the DWS (2023) National Integrated Water Information System are presented in Table 5-10. A surplus reserve was observed for all sub-catchments associated with the project area. Aquifers are, therefore, considered unstressed.

Table 5-9: Summarised Quaternary Catchment Information (Aquiworx, 2015)

Quaternary Catchment	Total Area (km²)	Recharge (mm/yr)	Rainfall (mm/yr)	Baseflow (mm/yr)
A21H	513.7	56	668.2	4.29

Table 5-10: Summary of DWS (2023) GW Reserve Allocations



5.13.1 Existing groundwater usage (EU)

A volume of 26.3 m³/day is allocated to the water balance. The allocation is based on WARMS data for boreholes (verified or unverified) that fall in the GHRU.

5.13.2 Basic human needs (BHN)

BHN was calculated based on a reduced population on the quaternary to sub-catchment scale. BHN is assumed to also be further supplemented by the EU for boreholes that fall in the sub-catchment.

5.13.3 Proposed groundwater usage (PU)

The PU is based on the recommended 12-hour pumping period per day and amounts to about 183.32 m³/day.

The predicted initial dewatering volume for the proposed mining works (up to an assumed maximum depth of 10m for the shallow operations and 50m for the deeper operations) is 496.53 m³/day. The dewatering rate is estimated to increase to 820.76 m³/day, approaching the maximum depth of blasting pit after 30 years of mining. The maximum potential dewatering volume was applied to the water balance for the GHRU.

5.13.4 Land use (LU)

Based on 2021 South African (SA) National Land Cover data for the sub-catchment, sub-limited urbanisation occurs in the sub-catchments (largely natural) (DFFE, 2021). Hence, the impact of land use on net groundwater recharge will be low.

5.13.5 Groundwater balance

The reserve determination for the sub-catchment associated with the project is summarized in Table 5-11. Considering future groundwater abstraction on a GRU scale, it is observed that there is a deficit. The groundwater system on a GRU scale will be stressed during the mining period. It is predicted to recover within 1-2 years after mining ceases.

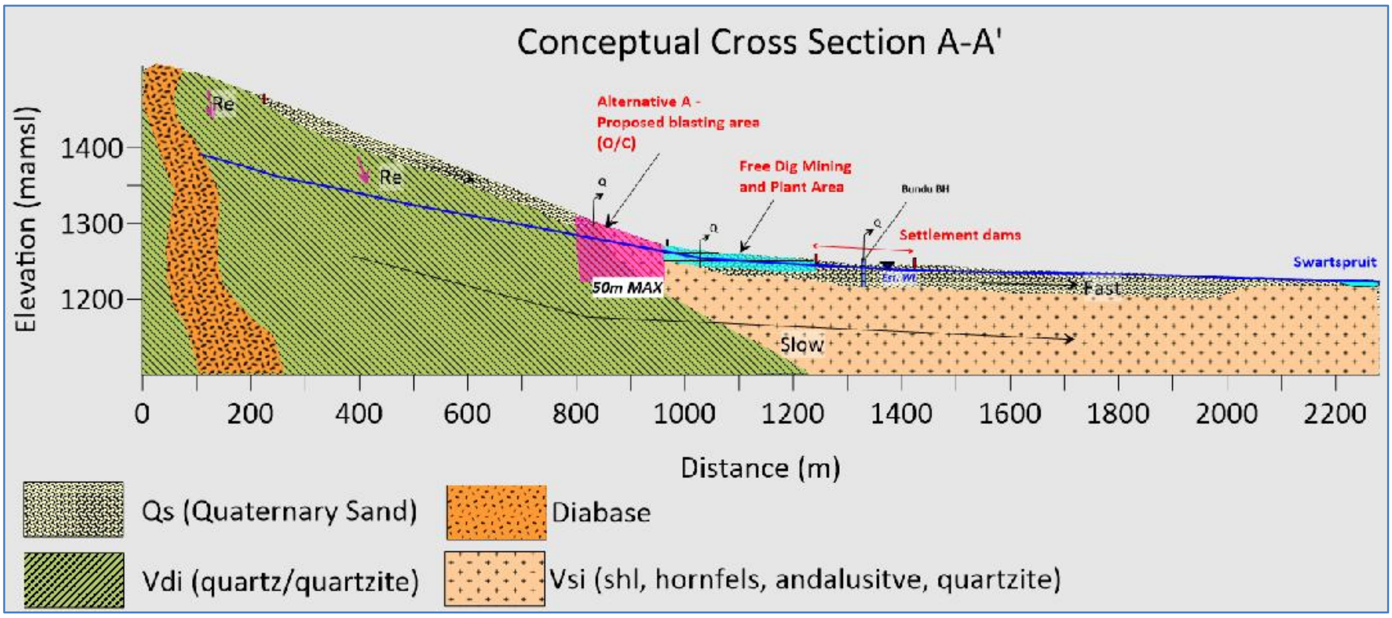
Table 5-11: Groundwater reserve determination for the sub-catchment area

GHRU		
Area	4.09	km²
Rainfall	690.92	mm/yr
BF	4.29	mm/yr
Aquifer Recharge		
Re	60.11	mm/yr
Re to Aquifer	245730.32	m³/yr
Re	8.70	%
Existing Use (EU)		
26075176	26.30	m³/day
Total EU Day	26.30	m³/day
Total EU Year	9600.00	m³/yr
Basic Human Needs		
BHN	0.00	m³/day
BHN	0.00	m³/yr
Base Flow		
BF	17537.52	m³/yr
Available	218592.80	m³/yr
Proposed Use (PU)		
Bundu BH1	183.32	m³/day
Workings	820.76	m³/day
Total PU Day	1004.08	m³/day
Total PU Year	366487.95	m³/yr
Nett Balance	-147895.15	m³/yr

6 SITE CONCEPTUAL MODEL

The Site Conceptual Model (SCM) developed focused on the Bundu Mining (Rietvalei) area and the receiving groundwater environments. The estimated groundwater flow fields are captured in Figure 5-4 (Section 5), and the conceptual geohydrological cross-section is shown in Figure 6-1.

Figure 6-1: SCM - Cross section A-A'



The SCM shows that three (3) aquifers exist in the area:

- A shallow, unconfined aquifer system associated with the quaternary sand deposits;
- A semi-confined/perched aquifer system associated with both fractured and intergranular weathered rock of the Pretoria Group.
- A deeper, confined, fractured aquifer network is associated with older basement rocks.

The aquifers underlying the study area are considered low-yielding aquifers (median yields of 0.5 to 2 l/sec – Class d3 aquifer and b2 aquifers). Based on extrapolated groundwater level data, it is estimated that the groundwater table is in the order of 13 mbgl at the site, which indicates that mining will take place above the regional groundwater table (expected maximum mining depth is about 10 m). Available data suggest that the groundwater table mimics the topography and groundwater flows from high-lying areas (water divides) to low-lying areas.

In the SCM, the main source of groundwater recharge is rainfall. The rainfall infiltrates into the ground to become groundwater through the Vadose Zone. The water then moves both vertically and horizontally in the quaternary sand deposits and weathered zone of the Pretoria Group sediments, with greater interflow in a horizontal direction within the weathered zone matrix. Where shallow hard rock outcrops or intrusive dolerite outcrops occur, there may be the formation of springs, and subsequently, where shallow quaternary sand depots accumulate on shallow hard rock, there may be water logging. Shallow and deep groundwater movement will likely be towards the north, towards the valley where the Swartspruit River is situated.

Any pollution that does occur on the surface and is allowed to percolate into the vadose zone could potentially impact the groundwater table. The contaminants would then slowly propagate towards the Swartspruit River, which is the primary surface water receptor in the project area. The groundwater flow velocity is slow, and it will take some time for pollution to enter the river system, which may not be observed during the lifecycle of the project. The mining activity is, however, considered a “clean” operation, as it involves the excavation and washing of sand. The sands are relatively inert based on available hydrochemical and waste classification data (refer to GCS Waste Classification and Hydrology Reports, 2023).

Dewatering impacts are predicted to be the largest risk associated with the proposed Project but will be limited to the GHRU. Any poor-quality seepage from facilities at the site could also migrate to the borehole and compromise water quality, as the borehole is situated downstream of the mining and settlement dam areas.

Groundwater movement in both the weathered and fractured aquifers will be subjected to a low flow velocity (refer to Sections 5.10 and 7.4). Prevention of pollution on the soils at the site should be prioritized to limit the impact on the groundwater regime.

7 NUMERICAL GROUNDWATER MODEL

The following section supplies an overview of the numerical flow and transport model developed for Bundu Mining. The numerical groundwater model is based on the site conceptual model.

7.1 Model objective

The groundwater flow and transport models were developed to:

- Simulate the current and operational flow systems and predict the future behaviour of the flow system as a result of the proposed activities.
- Determine the dewatering impacts associated with the proposed groundwater abstraction activities and express them as the zone of influence (ZOIf).
    - The mining activity will take place to a maximum estimated depth of 10m for the shallow sand mining area and 50m for the deeper blasting workings. This is above the water table, and dewatering impacts are highly unlikely to occur.
    - The simulation focuses on the cone of depression /ZOIf at the life of mine (LOM) predicted to be between 25-30 years [personal correspondence].
- Determine potential pollution migration spread and travel time from the proposed plant area and settlement dams (higher-risk infrastructure with regards to the project).
    - The aim was to introduce a source term (i.e., processed sand that has oxides with a high TDS) and demonstrate the LOM, 10-year and 50-year potential groundwater contamination plume movement. This is termed the zone of impact (ZOIp).

7.2 Assumptions and limitations

There are uncertainties in the groundwater flow simulated by a numerical model. These uncertainties are due to:

- Simplifications and assumptions in the design of the model.
- Uncertainty in the boundary conditions and input parameters; and
- Limited data is available to calibrate the model to the observed groundwater flow systems.

The model uncertainties and assumptions are as follows:

- Recharge for known rehabilitated opencast areas is estimated at 15% of the MAP (Hughes, 2004). Recharge for other geological types and the overall aquifer is based on the recharge calculation in Section 5.5.

- Available water levels were averaged and assumed to have been constant for one (1) hydrological year. This is a best-case scenario that was applied due to limited data.
- Transmissivity, storage, and porosity values for similar rock types in the area are assumed to be in the same order as available data (refer to Sections 5.3 and 5.4).
- For the plume presentation, a 1000 mg/l TDS was introduced. The diffuse concentration in the aquifer was simulated for 10 years and 50 years.
    - It is noted that the TDS of the source terms, the sand mined and stockpiled, is very low (GCS Waste Classification, 2023).
    - The introduction of the 1000 mg/l TDS was incorporated to simulate a "worst case" scenario where site pollution takes place and to simulate how far such pollution would migrate within 50 years.
- The numerical model is based on the conceptual model as developed for this investigation, as well as the generated field and desktop data as input.
- No formal mine plan is available for the proposed Project. Only the site layout plan was provided. The Client [Bundu Mining] indicated that the maximum mining depths would be 10m and 50m for the shallow and deep blasting operations. The estimated time to reach the 50m mark, which forms the LOM, is between 25 and 30 years.
- The regional geology map was used to create material property zones and is assumed to be sufficient for this numerical model. No exploration drilling or geological block models are available for the operations, which could be applied to refine the property zones.
- Transient state drawdown and transport could not be calibrated, as the project is still in the planning phase, and for the existing operations, no calibration data is available (i.e., no groundwater chemistry or water level data).
- No closure trade-off simulations were undertaken (not part of the scope).

7.3 Conceptualisation and Model Grid

Based on the available data, a conceptual model of the study area was formulated. The conceptual model explains the aquifers that occur in the area, the spatial relationship between the aquifers, aquifer thickness, general geology, groundwater levels and flow directions.

7.3.1 Boundary Conditions

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

- Specified head or Dirichlet or
- Specified flux or Neumann; or
- Mixed or Cauchy boundary conditions.

From the conceptual point of view, it was essential to meet two criteria to the maximum extent possible:

- The modelled area should be defined by natural geological and hydrogeological boundary conditions, i.e., the model domain should preferably encompass entire hydrogeological structures and
- The mesh size of the model grid has to correspond to the nature of the problem being addressed with the model.

Local hydraulic boundaries were identified for model boundaries. They are represented by:

- Local watershed boundaries.
- Topographical highs.
- Constant head and general head boundaries and
- The delineated area of the entire model domain.

These hydraulic boundaries were selected far enough from the area of investigation to not influence the numerical model behaviour artificially.

The model boundaries and model grid are shown in Figure 7-2 and Figure 7-3**.** Table 7-1 provides a summary of the boundaries, boundary descriptions and boundary conditions specified in the hydrogeological model.

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

Boundary	Boundary Description	Boundary Condition
Top	The top surface of the water table	Mixed type: Drain cells for main rivers and non-perennial drainage streams.

Boundary	Boundary Description	Boundary Condition
		No constant or general head boundaries are incorporated into the model Recharge is constant for the model area and calculated based on surface geology type. Recharge flux is applied to the highest active cell. Artificial recharge is not considered for unknown values.
North	No-flow boundary and stream/river	The topographical low is assigned to a river boundary and several drainage cells. River conductance was calculated based on a river depth of 8m, riverbed thickness of 15m, and stage in the order of 6m. Several drainage cells were assigned. Cell conductance was calculated from the hydraulic permeability of the aquifer zones.
East	No-flow boundary and stream/river	Topographical high. Several drainage cells were assigned. Cell conductance was calculated from the hydraulic permeability of the aquifer zones.
South	No-flow boundary and stream/river	Topographical high. No drainage lines, except the two identified in the field, exist. Drainage cells were assigned to these areas. Cell conductance was calculated from the hydraulic permeability of the aquifer zones.
West	No-flow boundary and river	Topographical low and high. Several drainage cells were assigned. Cell conductance was calculated from the hydraulic permeability of the aquifer zones.

7.3.2 Construction of the Finite Difference Grid

Compilation of the finite difference grid using the Visual MODFLOW graphic user interface facilitated the construction of a rectangular horizontal grid, and vertical geometry was provided for each of the layers. The flow model was set up as a two (2)-layer, confined/semi-confined aquifer (refer to Figure 7-1).

The positions of the different geological boundaries are incorporated into the modelling grid. A grid refinement of 5 - 40 m x 5 - 40 m cells for the Bundu Operations was applied, and the cells gradually coarsened away from the site. This is standard practice and does not influence the accuracy of the results obtained.

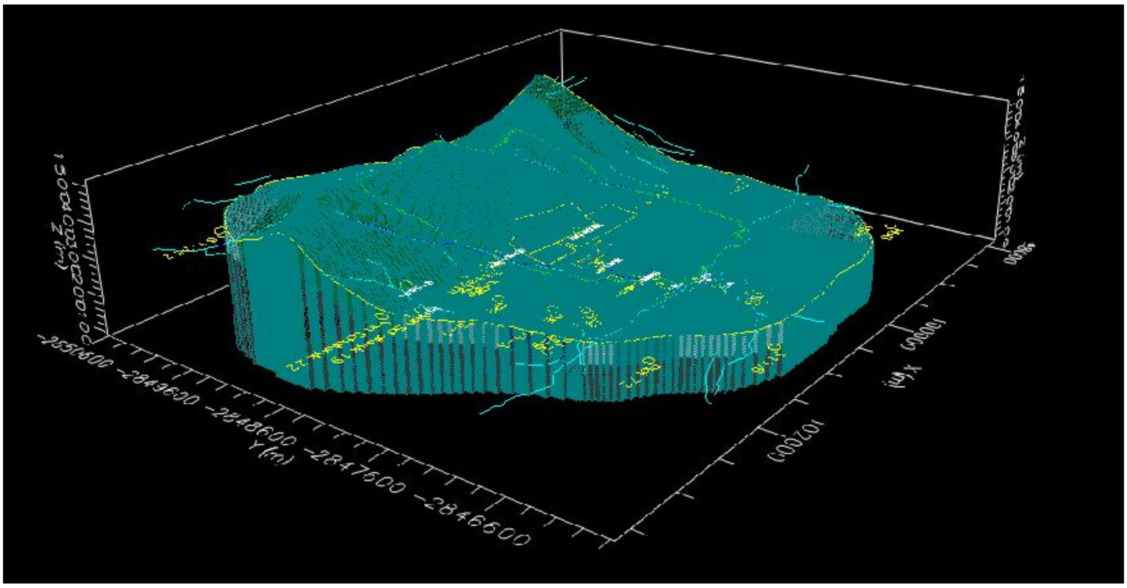


Figure 7-1: Model Grid on 3D setting

7.3.3 Vertical Discretization

Along the vertical direction, the steady-state hydrogeological model is structured in 5 model layers. The layer positions were selected to best incorporate the conceptual model and to allow for accurate horizontal and vertical groundwater flow in the model. The following layers were defined:

- Layer 1 - Topographic elevation and combination of weathered zone sediments up to a maximum depth of 80 m. This layer represents both the quaternary deposits and sediments of the Pretoria Group. Diabase intrusions were mapped to the cells where required and are based on the regional geology map.
- Layer 2 – Fractured and basement rocks extending to 300 m below surface level.

7.3.4 Time Discretization

Time parameters are relevant when modelling transient (time-dependent) conditions. They include time units, the length and number of periods, and the number of steps within each period. All model parameters associated with boundary conditions and various stresses remain constant during one time period. Having more periods allows these parameters to change in time more often (Kresic, 2007).

The steady-state groundwater flow model was used for sensitivity analysis. For the simulation of pollution plume migration and dewatering, the transient simulation was discretized into stress periods of 4 months.

7.3.5 Transient State Model Simulation Time

The model simulation time runs from the year 2008 to the year 2143. The model simulation time takes into consideration the chronological order of events (i.e., when the bundu operations started, what will take place, and when). The Client [Bundu Mining] indicated that the maximum mining depths would be 10m and 50m for the shallow and deep blasting operations. The estimated time to reach the 50m mark, which forms the LOM, is between 25 and 30 years.

Table 7-2 lists the model simulation time. The timeline for constructing the groundwater model was simplified. The simulation time was compiled from available reports and satellite imagery for the mining area (i.e., the BAR and information shared by Bundu Mining).

Table 7-2: Model Simulation Time

Year	Simulation Time (days)	Comment
2008	0	Bundu Existing Operations Start
2023	5475	Calibration Initial
2024	5840	Calibration HC 2024
2025	6205	Assume Mining Starts
2055	17155	30 Years Into Mining. The quarry is estimated to reach 50m of the proposed mining depth. Assume closure at this depth unless an application for deeper mining is initiated.
2033	20805	10Y after mining ceases
2073	35405	50 Years
2143	49275	88 Years
2123	53655	100 Years

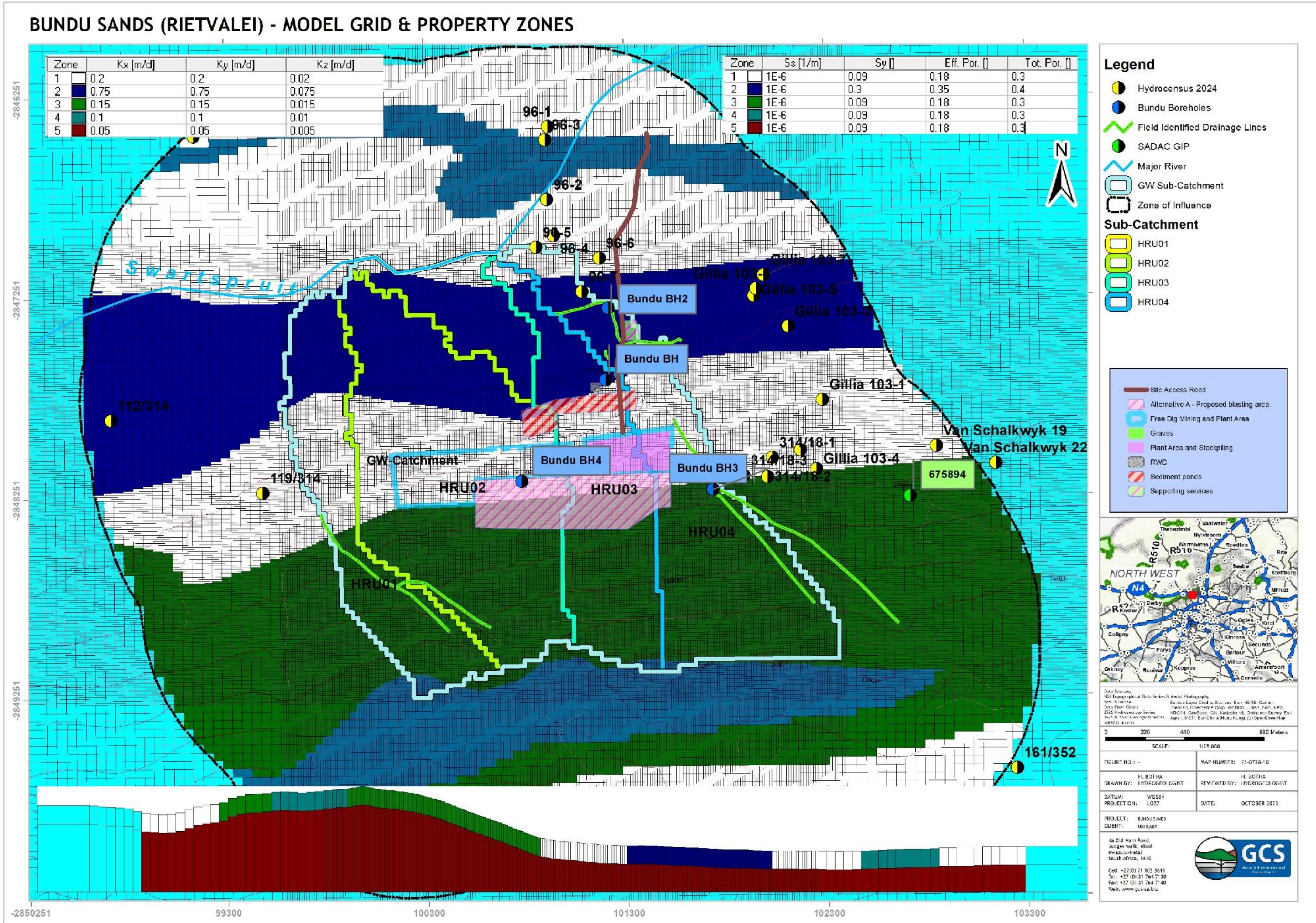


Figure 7-2: Model grid, hydraulic conductivity, and storage

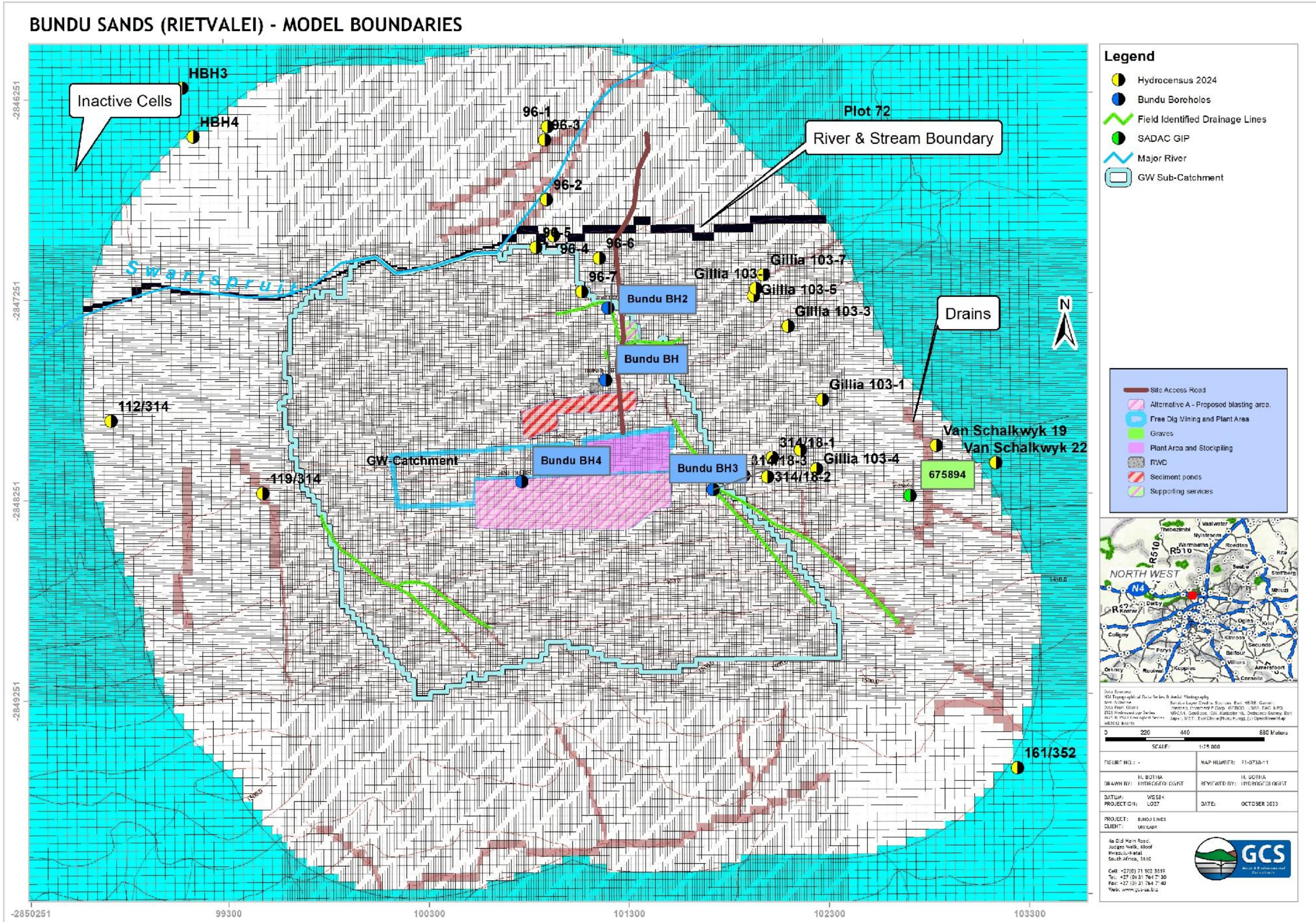


Figure 7-3: **Model boundary conditions**

7.3.6 *Input Parameters/Initial Model Conditions*

Model input parameters for this flow model are divided into two groups:

1. Hydrogeological parameters (hydraulic conductivity, recharge, and aquifer storage); and
2. Initial conditions.

The initial estimates for the hydraulic properties were assigned based on aquifer test data as well as literature data for rock associated with the project area. Property zones and boundaries on a 3D setting for the model are shown in Figure 7-4 and Figure 7-5. These hydraulic conductivity values were assigned to geological layers in the model area. The initial estimates were used for a combination of Parameter Estimation Simulation (PEST)[1] and manual calibration. The initial head conditions specified in the steady-state model were estimated from topography. Initial transient model heads were derived from the steady-state model results. Table 7-3 summarises the input parameters used in the steady state and transient state flow models. Initial estimates were updated with PEST estimated in the final model.

Table 7-3: Input parameters to the flow model

Parameter	Value used
Horizontal Hydraulic conductivity (Kx)	see below

Material Zone	T (m^2/d)	K (m/day)
Q/Al	7.5	0.75
Vdi (quartz)	1.5	0.15
Vsi (shl, hornfels, andalusitve, quartzite)	2	0.2
Di (diabase)	1.5	0.15
Vha (andasite)	0.1	0.01

Parameter	Value used
Vertical Hydraulic conductivity (Kz)	One order is lower than vertical conductivity.

Specific storage coefficient (Ss):

Material	S_s (ft^{-1})
Plastic clay	7.8×10^{-4} to 6.2×10^{-3}
Stiff clay	3.9×10^{-4} to 7.8×10^{-4}
Medium hard clay	2.8×10^{-4} to 3.9×10^{-4}
Loose sand	1.5×10^{-4} to 3.1×10^{-4}
Dense sand	3.9×10^{-5} to 6.2×10^{-5}
Dense sandy gravel	1.5×10^{-5} to 3.1×10^{-5}
Rock, fissured	1×10^{-6} to 2.1×10^{-5}
Rock, sound	$< 1\times10^{-6}$

Specific yield (Sy)
Porosity (n) (total)
Specific Retention (%)

Material	Porosity (%)	Specific Yield (%)	Specific Retention (%)
Soil	55	40	15
Clay	50	2	48
Sand	25	22	3
Gravel	20	19	1
Limestone	20	18	2
Sandstone (unconsolidated)	11	6	5
Granite	0.1	0.09	0.01
Basalt (young)	11	8	3

Recharge (Re)

Material Zone	Re (mm/yr)
Q/Al	71.76
Vdi (quartz)	59.8
Vsi (shl, hornfels, andalusite, quartzite)	59.8
Di (diabase)	47.84
Vha (andesite)	47.84

Parameter	Value used
Top elevation	Corresponded to surface topography.

[1] PEST (Parameter Estimation Simulation): automated parameter estimation tool, which provides a sensitivity and uncertainty analysis of the model, and much more.

Parameter	Value used
Bottom elevation of the 1st layer – extrapolated for rest of model grid	Layer 1 - Topographic elevation and combination of weathered zone sediments up to a maximum depth of 80 m. This layer represents both the quaternary deposits and sediments of the Pretoria Group. Diabase intrusions were mapped to the cells where required and are based on the regional geology map.
The bottom fixed elevation of the 2nd layer	Fractured and basement rocks extend to 300 m below surface level.

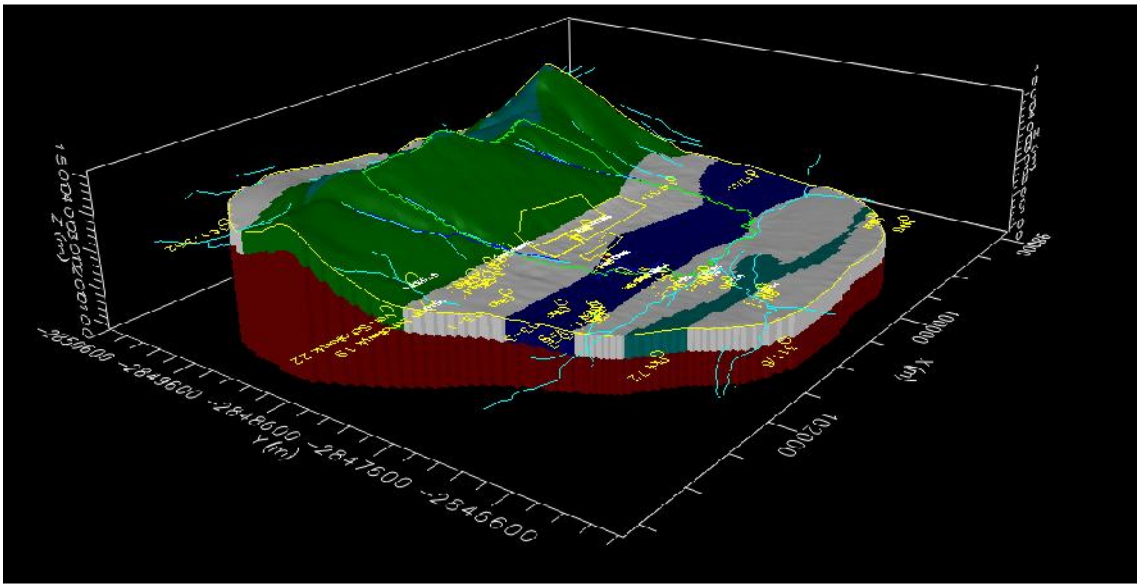


Figure 7-4: Property and aquifer zones on 3D setting

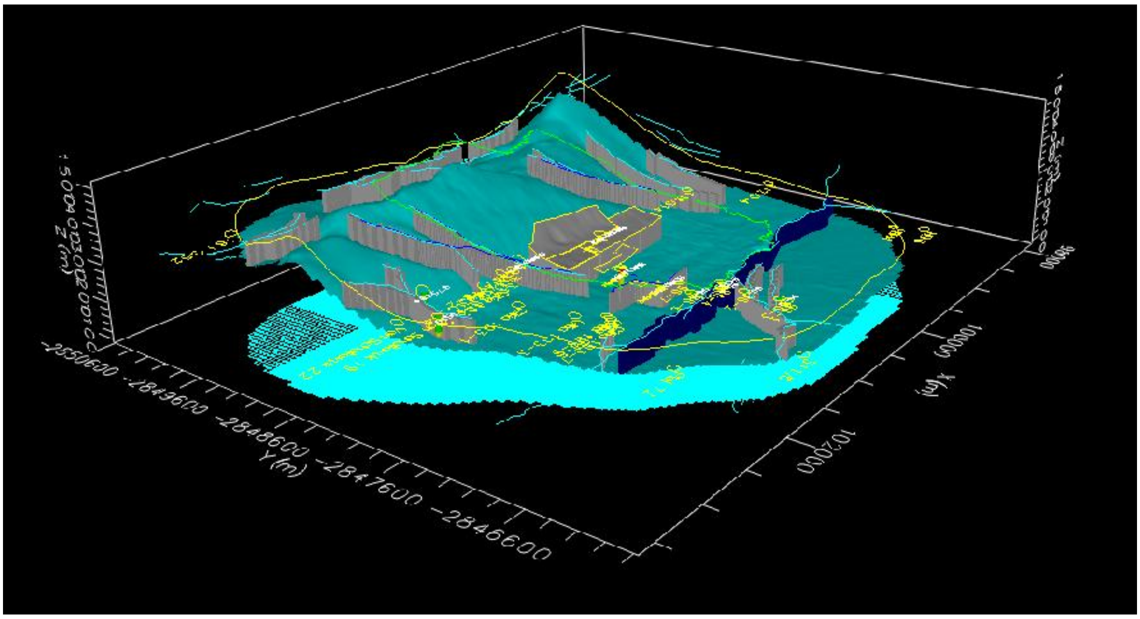


Figure 7-5: Flow boundary conditions on 3D setting

7.3.7 Model Calibration

Calibration is the process of finding a set of boundary conditions, stresses, and hydrogeological parameters that produce results that most closely match field measurements of hydraulic heads and flows.

In a catchment scale groundwater flow model, a difference between calculated and measured heads of up to several meters can be tolerated and is usually expressed as a function of the total range of observations. A scaled absolute mean value of below 10% is generally regarded as acceptable for a regional model (Tiedeman and Hills, 2005).

This calibration was done under steady state and transient state conditions. When calibrated, the model can be used to predict the influence of various management scenarios.

7.3.7.1 Calibration Targets

The steady-state calibration achieved is shown in Figure 7-6. A model RMS in the order of 7.7% was achieved.

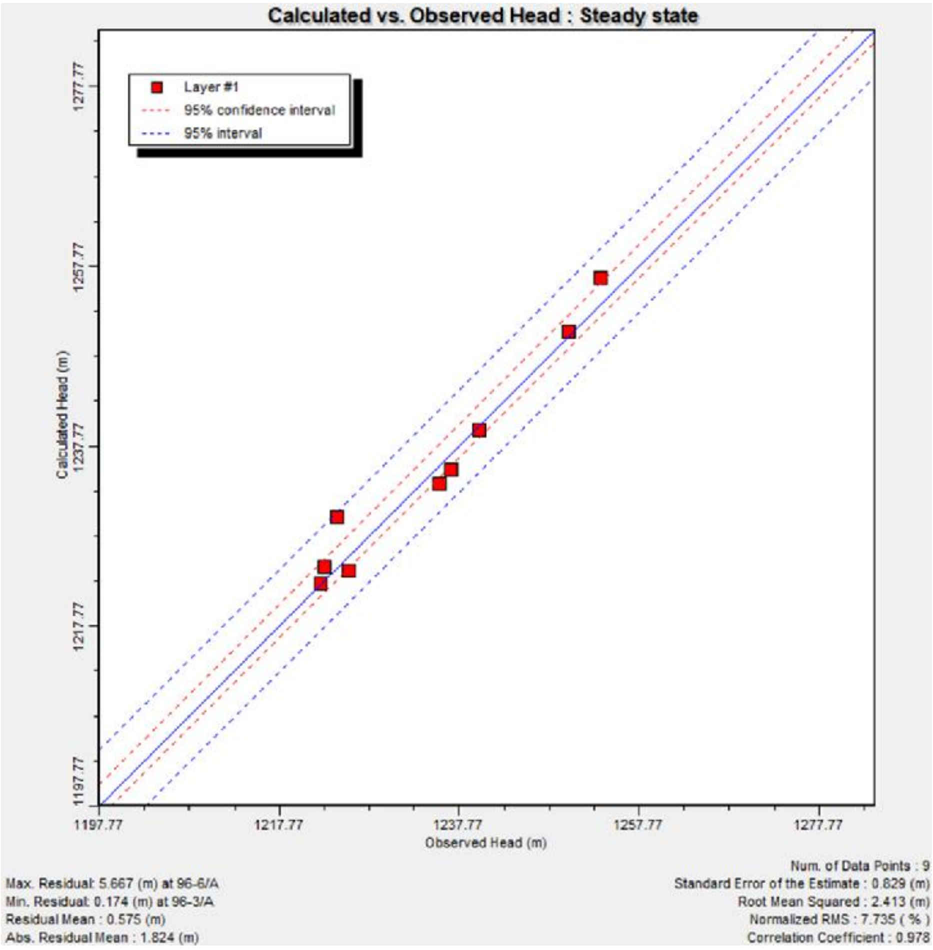


Figure 7-6: Steady-state model calibration achieved

7.3.7.2 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 7-7 that the calibrated residuals (calculated heads vs observed heads) are slightly skewed towards the right. However, most of the data plots within the normalised distribution of the dataset are used for calibration.

The following parameters were observed to be sensitive (refer to Figure 7-8):

- Changes in horizontal hydraulic conductivity values (Kx and Ky) in all layers.
- Recharge (indicated as par001 to par004).

Specific yield and storage were observed to be less sensitive in initial PEST runs and excluded from the final PEST simulation to improve simulation speed. Optimum parameters for the different aquifer zones, as estimated by PEST, are summarised as follows:

- kx__1 0.100000
- ky__1 0.398276
- kz__1 1.000000E-02
- kx__2 0.500000
- ky__2 0.750000
- kz__2 0.100000
- kx__3 1.849696E-02
- ky__3 0.150000
- kz__3 0.500000
- par001 0.100000 [Factor change from initial]
- par002 1.22001 [Factor change from initial]
- par003 1.07857 [Factor change from initial]
- ar004 0.100000 {Factor change from initial]

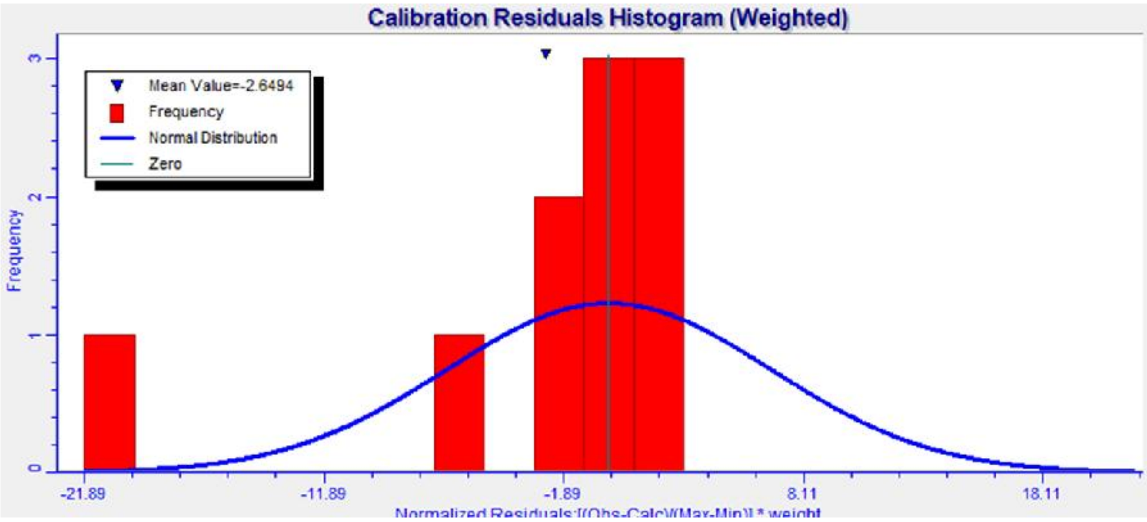


Figure 7-7: PEST Sensitivity Analysis - Histogram

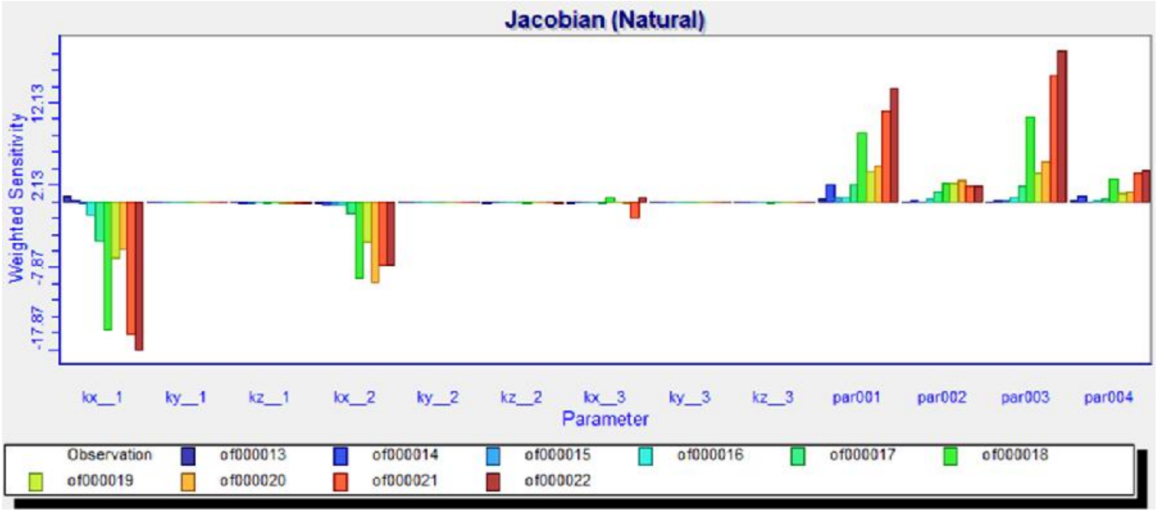


Figure 7-8: PEST Sensitivity Analysis - Weighted Parameter Sensitivity

7.4 Calibrated flow models

The calibrated flow model with simulated groundwater elevations is shown in Figure 7-11. The following is noted when evaluating the flow model:

- The groundwater table mimics the topography.
- Preferential movement is towards the north for the mining area.
- The flow model indicates groundwater flow velocities ranging from 0.01 (min) to 5 (max) m/day.
  - Groundwater movement in the weathered zone is greater than that of the deeper aquifer zones, and several orders are greater in the alluvium zones when compared to the host rock.
  - The numerical velocities are in the same order of magnitude as the analytically estimated flow velocities as presented in Section 5.9.

7.5 Predicted transport movement LOM, 10Y and 50Y (ZOIp)

The predicted transport movement [ZOIp] from the proposed plant and settlement dams' area is shown in Figure 7-12. The simulation suggests that if a source with a TDS in the order of 1000 mg/l percolates into the aquifer, the concentration gradient will be very low. Diffuse concentration gradients are < 50 mg/l, and the 50Y plume is predicted to not intercept the major surface water receptor in the project area (the Swartspruit River). Mining will likely cease long before any significant salt buildup or transport to the river system.

It is noted that the TDS of the source terms, the sand mined and stockpiled, is very low (GCS Waste Classification, 2023). The introduction of the 1000 mg/l TDS was incorporated to simulate a "worst case" scenario where site pollution takes place and to simulate how far such pollution would migrate within 50 years.

7.6 Predicted dewatering impact (ZOIf)

The predicted ZOIf associated with projected groundwater abstraction and dewatering activities is shown in Figure 7-13. The predicted maximum aquifer drawdown for the workings and abstraction activities at LOM is in the order of 32m for the deeper workings (extending to 50m below surface level) and gradually decreases to 1m towards the east and west of the operations. It is observed that drawdown is limited to the meta-argillaceous rocs towards the north of the hilltop (where the workings are) and that the hilltop with the meta-arenaceous rocks (quartzite) acts as an aquiclude. This is due to the low recharge and low permeability associated with the quarzitic rock. The predicted aquifer drawdown does nit reach any of the identified groundwater users in the GHRU or SOIF.

The predicted initial dewatering volume for the proposed mining works (up to an assumed maximum depth of 10m for the shallow operations and 50m for the deeper operations) is 496.53 m³/day. The dewatering rate is estimated to increase to 820.76 m³/day, approaching the maximum depth of blasting pit after 30 years of mining. Water level rebound is expected within 1-2 years after mining ceases.

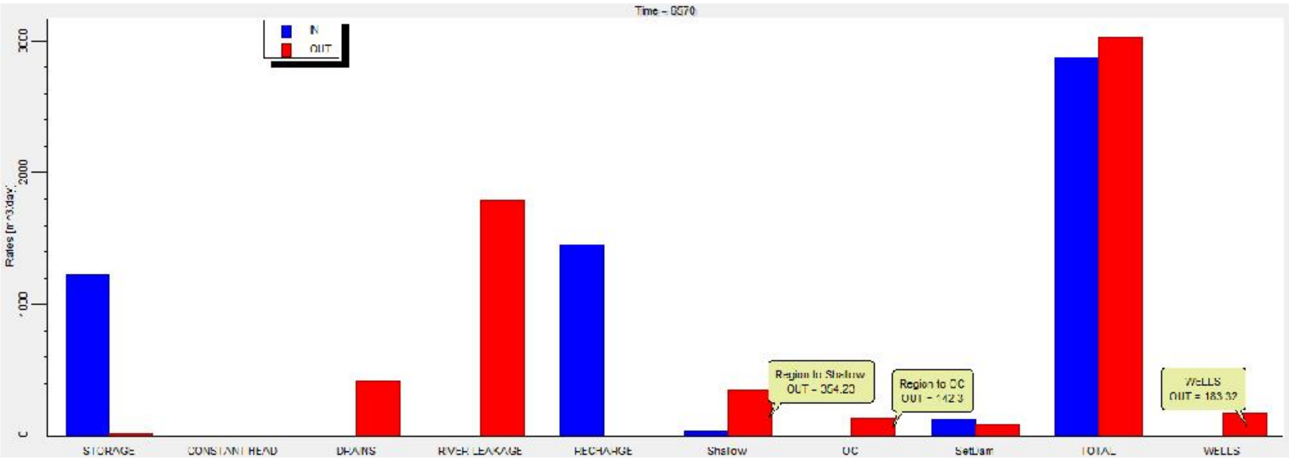


Figure 7-9: Simulated initial water balance for mining works

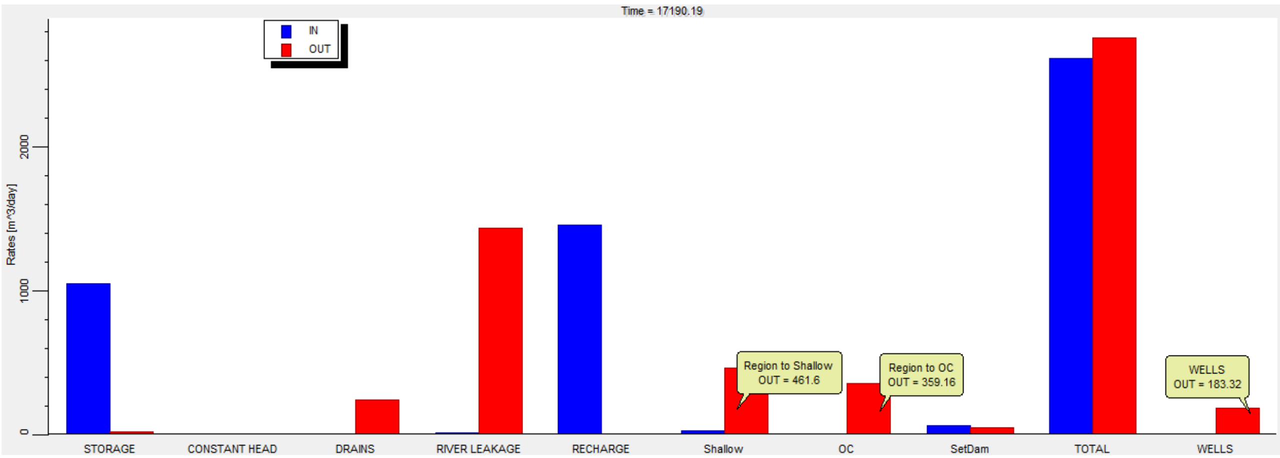


Figure 7-10: Simulated water budgets at LOM (30 years)

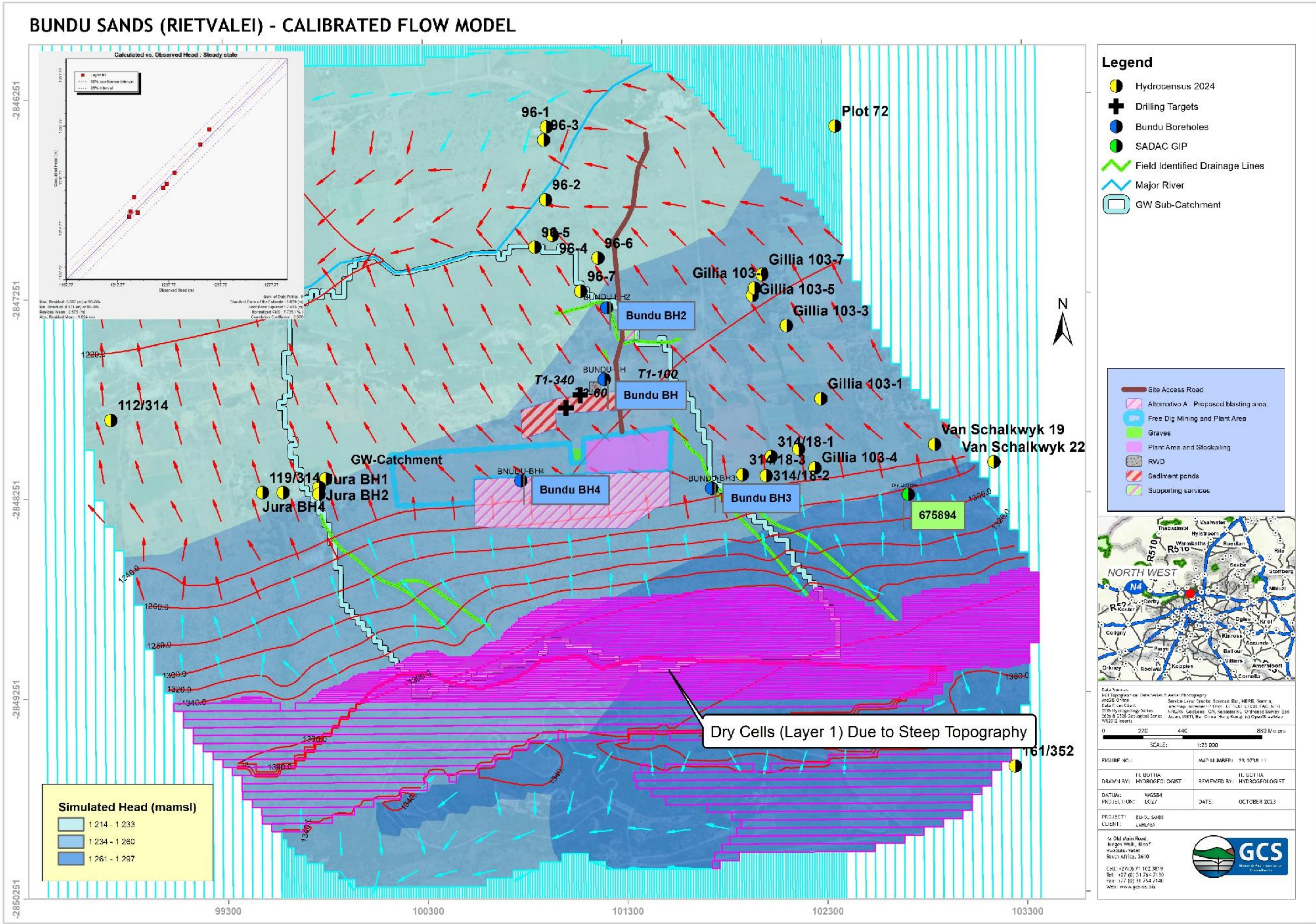


Figure 7-11: Calibrated regional flow model

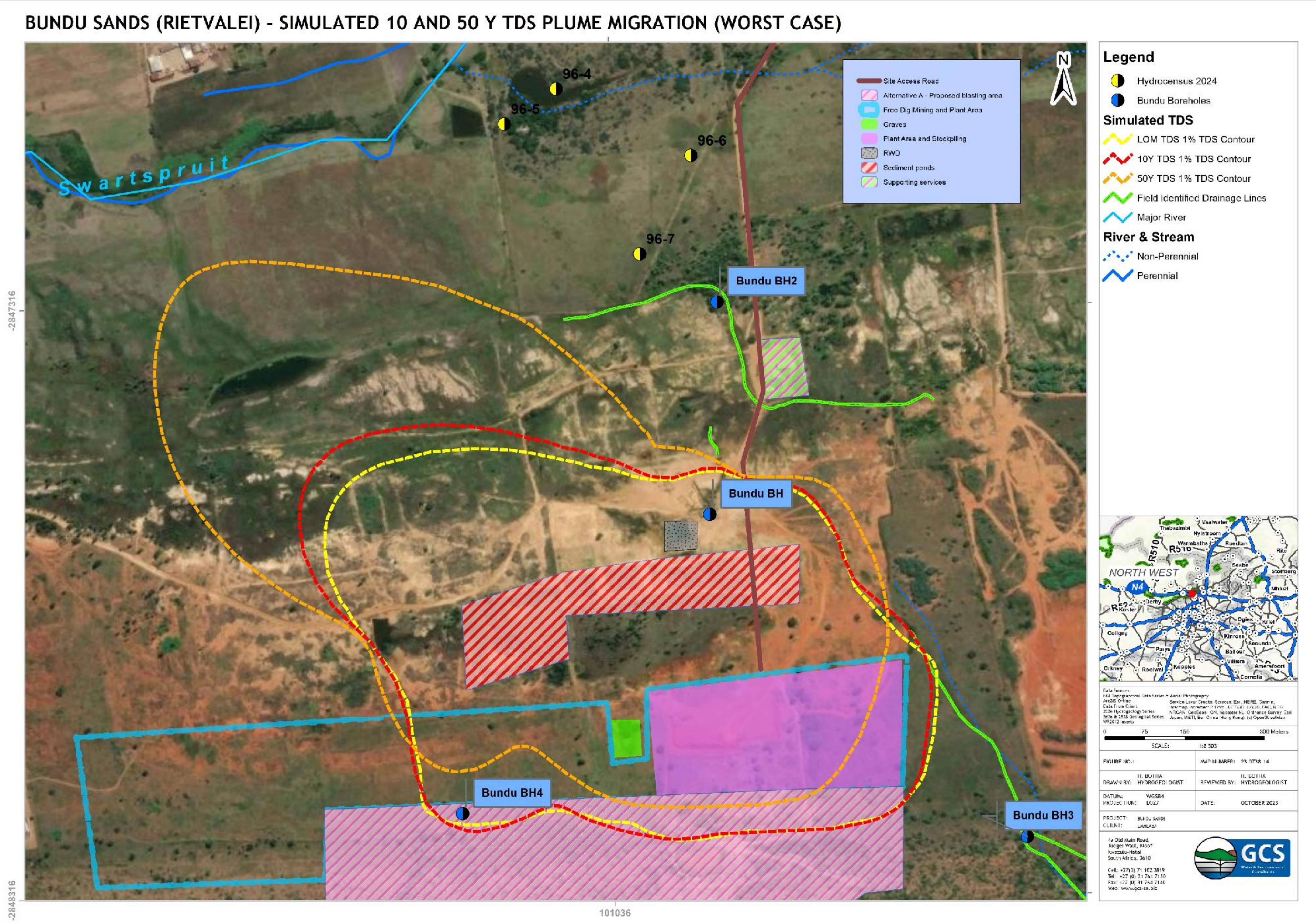


Figure 7-12: Simulated dominant pollution migration direction for plant and settlement dams and plant area

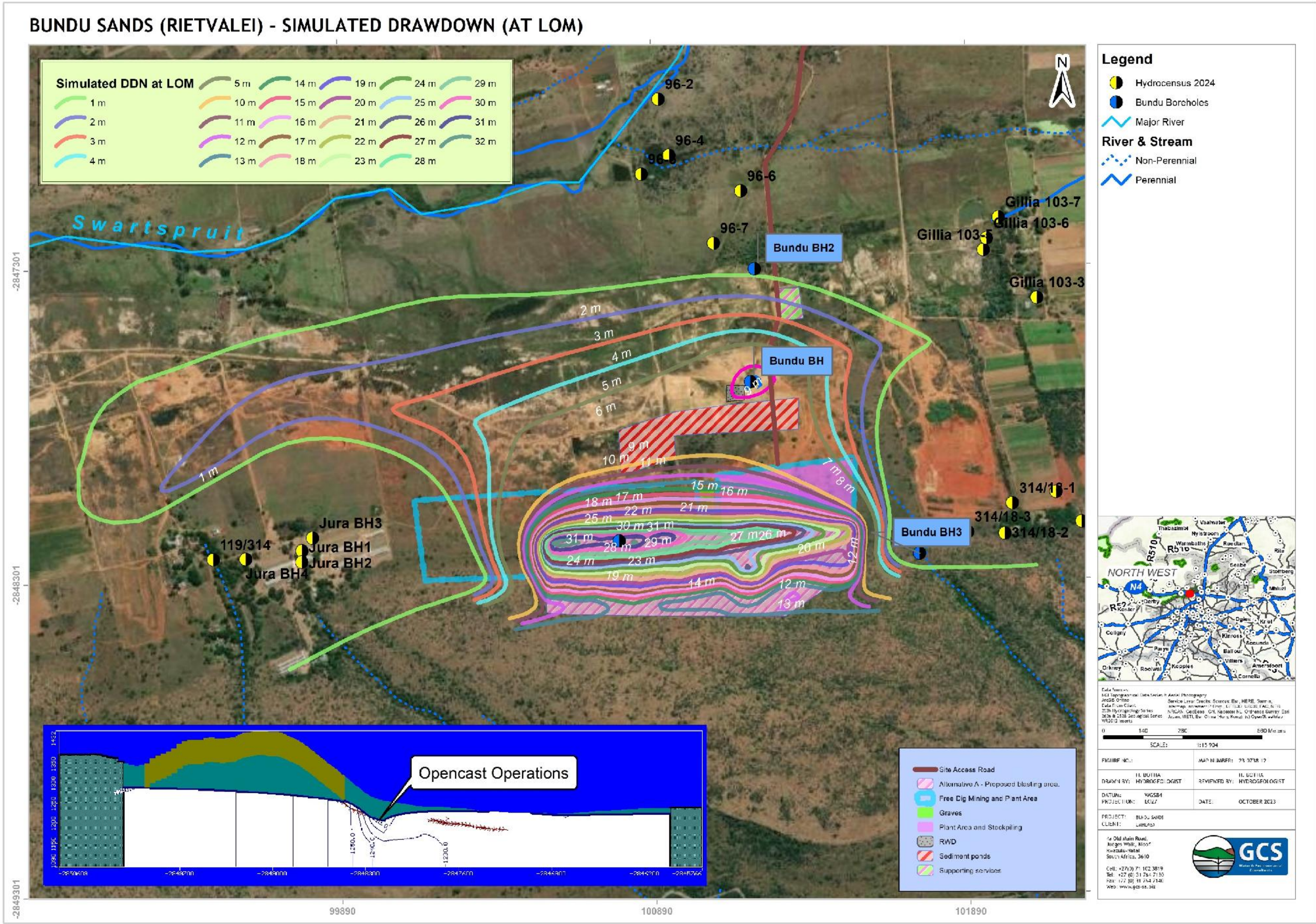


Figure 7-13: Predicted aquifer drawdown for proposed opencast operations

8 GEOHYDROLOGICAL RISK ASSESSMENT

The anticipated geohydrological risk concerning the preparation, operational and closure phase of the proposed project was evaluated. The activities entail:

- Movement of heavy machinery and equipment at the site can potentially cause soil pollution (i.e., hydrocarbon spills) and promote erosion/compaction associated with haul roads.
- Opencast excavations using excavators within the MR area (impact on vadose zone soils).
- Stockpiling of sand at the washing plant for transportation (could lead to sedimentation during stormwater events).
- Solid sand settlement in the proposed settlement dams.
- Groundwater and surface water abstraction (from the stormwater dam) is used to wash the sand and suppress dust. *The volumes required have not yet been determined.*

The source-pathway-receptor (SPR) model (DWAF, 2008) was used to evaluate potential pollution sources and primary receptors within the study area. 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:

Consequence = (Duration + Extent + Irreplaceability of resource) x Severity

The environmental significance of an impact was determined by multiplying the consequence by probability. The risk significance rating is summarised in Table 8-1.

Table 8-1: Risk rating scale

Criteria	Rating Scales
Significance	Very high – negative (-48 to -66)
	High – negative (-36 to -48)
	Moderate – negative (-24 to -36)
	Low – negative (-12 to -24)
	Neutral - Very low (0 to -12)
	Low–positive (0 to 12)
	Moderate–positive (12 to 24)
	High–positive (24 to 48)
	Very high – positive (48 to 66)

Several geohydrological risks were identified and are listed in Table 8-4 (preparation phase), Table 8-5 (operational phase) and Table 8-6 (closure phase).

8.1 Preparation phase

The following activities are anticipated during the construction phase of the project:

- Typical earthworks are required to clear the areas.
- Construction of access roads, housing foundations and buildings.
- Excavation for the proposed settlement dams.
- Establish service platforms, material handling areas, and other temporary infrastructure.
- Dust suppression of access roads.
- Placing of topsoil in designated areas; and
- Constructing laydown areas and temporary stormwater systems and berms.

The identified possible hydrology impacts for the preparation phase include (refer to Table 8-4):

- The destruction of the vadose zone sediments by clearing activities. This impact is permanent and is therefore not included in the impact table, as no mitigation measures can be recommended. This could lead to sediment runoff and surface water contamination.
- 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.
- Handling waste and transporting material can cause various types of spills (domestic waste, sewage water, hydrocarbons), which can infiltrate and contaminate the soils and groundwater system.
- Oil and fuel spills and leakages at vehicle park areas and in the project areas may cause poor-quality seepage and soil contamination.

Visual monitoring of the site on an ongoing (monthly) basis will serve as a 1rst order detection system for any soil and water pollution that may take place. If required, a surface water monitoring plan should be established to monitor the impact on the nearby surface water receptors. 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. The identified impacts are not likely to negatively affect the commencement of the proposed projects.

8.2 Operational phase

The possible hydrological impacts for the operational phase of the project are likely to be (refer to Table 8-5):

- The destruction of the vadose zone sediments by mining activities.
- Stockpiling of washed sands that could lead to sediment runoff during storm events.
- Oil and fuel spillages associated with service and mining vehicles accessing and undertaking maintenance work at the site.
- Sediment stormwater discharges during flooding events.
- Groundwater abstraction/dewatering.
- Reduction of baseflow due to groundwater abstraction activities.

In general, the operational phase risk associated with the project is predicted to be low, and it is foreseen that the impacts can be managed. Dewatering impacts are predicted to be the largest risk associated with the proposed Project but will be limited to the GHRU.

8.3 Closure and decommissioning phases

The closure and decommissioning phases will be per an agreed and approved closure plan for the Bundu Mining operations. The potential risks are captured in Table 8-6 and summarised as follows:

- Cessation of mining operations and rehabilitation.
- Backfill and rehabilitate mining excavations.
- Rehabilitation of the settlement dams.
- Aquifer rebound as groundwater abstraction ceases.
- Decommission the plant and other supporting infrastructure.

Closure of the site is predicted to be beneficial to the area and will enable long-term stabilisation of the mined areas. The area would need to be sloped as per pre-mining conditions and rehabilitated with vegetation grown on site. Stabilisation of the area is required due to the high sediment and erosion potential of the soils in the project area. The boreholes used for groundwater abstraction should be decommissioned as per best practice guidelines to prevent any potential pollution post-closure.

8.4 Alternatives considerations

No alternatives were considered during this assessment, and the mine layout as provided was considered final and targeted the minable resources within the MRA.

8.5 Cumulative impacts and impacts on the groundwater reserve

In terms of the preparation and operational phase, there are expected cumulative impacts on the soils associated with the site. The impact is predicted to improve at the closure of the mine and if rehabilitation is rolled out. The sub-catchments in which the mining will take place are isolated from other mines and activities in the area, and hence, cumulative impacts on a larger scale will be limited.

The impact on the reserve associated with the groundwater sub-catchment and quaternary scale was determined by the evaluation of the scale of abstraction and the stress on water quantity.

8.5.1 Scale of abstraction

The scale of abstraction is summarised in Table 8-2. Both a GRU level and quaternary scale index are provided. Based on the proposed groundwater use and the predicted dewatering volumes, the GHRU will be under “large-scale abstraction”. However, when considered on a quaternary scale, the abstraction scale reduces to a “small scale”. The large abstraction scale predicted for the GHRU is due to the small surface area of the groundwater resource unit.

Table 8-2: The estimated scale of abstraction

Scale		
Component	**GHRU**	**Quat**
Re (m^3/yr)	245730.32	30878587.14
Use (m^3/yr)	393625.47	701004.08
Abs. Scale	1.60	0.02
Class	Large Scale	Small Scale
Water Stress		
Component	**GHRU**	**Quat**
Proposed Abstraction	366487.95	701004.08
Re - BF	228192.80	28674814.14
Stress Index	1.61	0.02
Class	F	A

8.5.2 Water quantity stress index

The predicted abstraction stress on a sub-catchment level is summarised in Table 8-3. The index suggests that the sub-catchment will be under “Large Scale” stress. This is largely due to the small surface area of the groundwater resource unit. Similarly to the scale of abstraction index, the stress on a quaternary scale is considered “small scale”.

Table 8-3: Level of the stress of proposed abstraction

Scale		
Component	**GHRU**	**Quat**
Re (m^3/yr)	245730.32	30878587.14
Use (m^3/yr)	393625.47	701004.08
Abs. Scale	1.60	0.02
Class	Large Scale	Small Scale
Water Stress		
Component	**GHRU**	**Quat**
Proposed Abstraction	366487.95	701004.08
Re - BF	228192.80	28674814.14
Stress Index	1.61	0.02
Class	F	A

Table 8-4: Impacts during the preparation phase

Component Being Impacted On	Activity Which May Cause the Impact	Activity	Pre- Mitigation							Recommended Mitigation Measures	Post Mitigation						
			Duration (D)	Extent (E)	Potential for impact on irreplaceable resources (I)	Severity (S)	Consequence (C)	Probability (P)	Significance		Duration (D)	Extent (E)	Potential for impact on irreplaceable resources (I)	Severity (S)	Consequence (C)	Probability (P)	Significance
Vadose zone soils and subsequent aquifer (groundwater table)	Disturbing vadose zone during soil excavations/construction activities.	Net Result of Earthworks and Mining	Medium Term (3)	Site (2)	Yes (1)	Moderate (-2)	Slightly detrimental (-7 to -12) (-12)	Definite (2)	Low – negative (-13 to -24) (-24)	Only excavated areas apply to the project area. Backfill the material in the same order it was excavated to reduce contamination of deeper soils with shallow, oxidised soils. Cover excavated soils with a temporary liner to prevent contamination. Retain as much indigenous vegetation as possible. Exposed soils are to be protected using a suitable covering or revegetating.	Medium Term (3)	Site (2)	Yes (1)	Low (-1)	Negligible (-6 to 0) (-6)	Probable (1)	Neutral/ Negligible (0 to -12) (-6)
	Poor quality seepage from machinery used to excavate soils. Oil, grease, and fuel leaks could lead to hydrocarbon contamination of the vadose zone - which could percolate into the shallow aquifer.	Net Result of Earthworks and Mining	Medium Term (3)	Site (2)	Yes (1)	Moderate (-2)	Slightly detrimental (-7 to -12) (-12)	Definite (2)	Low – negative (-13 to -24) (-24)	Park heavy machinery in lined areas and place drip trays under vehicles at the site. Visual soil assessments for signs of contamination during construction (monthly)	Medium Term (3)	Site (2)	Yes (1)	Low (-1)	Negligible (-6 to 0) (-6)	Probable (1)	Neutral/ Negligible (0 to -12) (-6)
Primary Surface Water Receivers Swartspruit River is about 1km downstream of the site. No other recognised rivers/streams are associated with the site.	Erosion and sedimentation runoff may enter the river (worst case); however, due to the distance from the site, it is very unlikely.	Net Result of Earthworks and Mining	Medium Term (3)	Site (2)	Yes (1)	Low (-1)	Negligible (-6 to 0) (-6)	Probable (1)	Neutral/ Negligible (0 to -12) (-6)	Use temporary or permanent stormwater systems (as per this report) to prevent erosion and manage sediment runoff. Visual inspections of all vehicles entering and operating at the site.	Medium Term (3)	Site (2)	Yes (1)	Low (-1)	Negligible (-6 to 0) (-6)	Probable (1)	Neutral/ Negligible (0 to -12) (-6)
Groundwater aquifer	Poor quality seepage from machinery used to excavate soils. Oil, grease, and fuel leaks could lead to hydrocarbon contamination of the vadose zone - which could percolate into the shallow aquifer.	Net Result of Earthworks and Mining	Medium Term (3)	Site (2)	Yes (1)	Moderate (-2)	Slightly detrimental (-7 to -12) (-12)	Definite (2)	Low – negative (-13 to -24) (-24)	Park heavy machinery in lined areas and place drip trays under vehicles at the site. Have fuel and oil spill cleanup kits on site and clean up these areas immediately. Ensure that building material stockpiles are covered with a suitable temporary cover or placed in bunded areas to reduce poor-quality seepage probability. Visual soil assessments for signs of contamination during construction (monthly)	Medium Term (3)	Site (2)	Yes (1)	Low (-1)	Negligible (-6 to 0) (-6)	Probable (1)	Neutral/ Negligible (0 to -12) (-6)

Table 8-5: Impacts during the operational phase

Component Being Impacted On	Activity Which May Cause the Impact	Activity	Pre- Mitigation Duration (D)	Extent (E)	Potential for impact on irreplaceable resources (I)	Severity (S)	Consequence (C)	Probability (P)	Significance	Recommended Mitigation Measures	Post Mitigation Duration (D)	Extent (E)	Potential for impact on irreplaceable resources (I)	Severity (S)	Consequence (C)	Probability (P)	Significance
Vadose zone soils	Disturbing vadose zone during soil mining	Net Result of Earthworks and Mining	Medium Term (3)	Site (2)	Yes (1)	Moderate (-2)	Slightly detrimental (-7 to -12) (-12)	Definite (2)	Low – negative (-13 to -24) (-24)	- Keep excavations as small as possible. - Ensure that sediment barriers are in place at mining sites to prevent sediment runoff and erosion.	Medium Term (3)	Site (2)	Yes (1)	Low (-1)	Negligible (-6 to 0) (-6)	Probable (1)	Neutral/ Negligible (0 to -12) (-6)
	Poor quality seepage from machinery used to excavate soils. Oil, grease, and fuel leaks could lead to hydrocarbon contamination of the vadose zone - which could percolate into the shallow aquifer and enter the stormwater system.	Net Result of Earthworks and Mining	Medium Term (3)	Site (2)	Yes (1)	Moderate (-2)	Slightly detrimental (-7 to -12) (-12)	Definite (2)	Low – negative (-13 to -24) (-24)	- Park heavy machinery in lined areas and place drip trays under vehicles at the site. - Visual soil assessments for signs of contamination during construction (monthly)	Medium Term (3)	Site (2)	Yes (1)	Low (-1)	Negligible (-6 to 0) (-6)	Probable (1)	Neutral/ Negligible (0 to -12) (-6)
	Sediment runoff because of dust suppression and movement of vehicles at the site	Net Result of Earthworks and Mining	Medium Term (3)	Site (2)	Yes (1)	Moderate (-2)	Slightly detrimental (-7 to -12) (-12)	Definite (2)	Low – negative (-13 to -24) (-24)	- Park heavy machinery in lined areas and place drip trays under vehicles at the site. - Visual soil assessments for signs of contamination during construction (monthly)	Medium Term (3)	Site (2)	Yes (1)	Low (-1)	Negligible (-6 to 0) (-6)	Probable (1)	Neutral/ Negligible (0 to -12) (-6)
	Poor quality runoff into the environment (if hydrocarbon contamination takes place at the site). The impact will be on local soils as there are no watercourses associated with the site.	Net Result of Earthworks and Mining	Medium Term (3)	Site (2)	Yes (1)	Moderate (-2)	Slightly detrimental (-7 to -12) (-12)	Definite (2)	Low – negative (-13 to -24) (-24)	- Have fuel cleanup kits available on site. - Ensure that stormwater is monitored annually for contaminants.	Medium Term (3)	Site (2)	Yes (1)	Low (-1)	Negligible (-6 to 0) (-6)	Probable (1)	Neutral/ Negligible (0 to -12) (-6)
Primary Surface Water Receivers - Swartspruit River is about 1km downstream of the site. - No other recognised rivers/streams are associated with the site.	Erosion and sedimentation runoff may enter the river (worst case); however, due to the distance from the site, it is very unlikely.	Net Result of Earthworks and Mining	Medium Term (3)	Site (2)	Yes (1)	Low (-1)	Negligible (-6 to 0) (-6)	Probable (1)	Neutral/ Negligible (0 to -12) (-6)	- Use temporary or permanent stormwater systems (as per this report) to prevent erosion and manage sediment runoff. - Visual inspections of all vehicles entering and operating at the site.	Medium Term (3)	Site (2)	Yes (1)	Low (-1)	Negligible (-6 to 0) (-6)	Probable (1)	Neutral/ Negligible (0 to -12) (-6)
Regional groundwater table/groundwater aquifer	Dewatering required at excavations could impact baseflow to the nearby river system.	Net Result of Earthworks and Mining	Medium Term (3)	Site (2)	Yes (1)	Moderate (-2)	Slightly detrimental (-7 to -12) (-12)	Definite (2)	Low – negative (-13 to -24) (-24)	- Ensure that groundwater captured in the excavations is released to the downstream environment.	Medium Term (3)	Site (2)	Yes (1)	Low (-1)	Negligible (-6 to 0) (-6)	Probable (1)	Neutral/ Negligible (0 to -12) (-6)
	Over-abstraction of groundwater	Dewatering	Medium Term (3)	Site (2)	Yes (1)	Moderate (-2)	Slightly detrimental (-7 to -12) (-12)	Definite (2)	Low – negative (-13 to -24) (-24)	- Do not abstract more than what is required or as determined by the borehole sustainable yield testing. - Ensure that the borehole collar is protected to prevent any environmental runoff into the borehole.	Medium Term (3)	Site (2)	Yes (1)	Low (-1)	Negligible (-6 to 0) (-6)	Probable (1)	Neutral/ Negligible (0 to -12) (-6)

Component Being Impacted On	Activity Which May Cause the Impact	Activity	Pre- Mitigation							Recommended Mitigation Measures	Post Mitigation						
			Duration (D)	Extent (E)	Potential for impact on irreplaceable resources (I)	Severity (S)	Consequence (C)	Probability (P)	Significance		Duration (D)	Extent (E)	Potential for impact on irreplaceable resources (I)	Severity (S)	Consequence (C)	Probability (P)	Significance
	Dewatering impacting the reserve on a GHRU scale	Dewatering	Medium Term (3)	Site (2)	Yes (1)	High (-3)	Slightly detrimental (-7 to -12) (-18)	Definite (2)	Moderate – negative (-25 to -36)	No mitigation is possible. The net result of mine dewatering.							
	Dewatering impacting the reserve on a GHRU scale	Dewatering	Medium Term (3)	Site (2)	Yes (1)	Low (-1)	Negligible (-6 to 0) (-6)	Definite (2)	Neutral/ Negligible (0 to -12) (-6)	No mitigation is possible. The net result of mine dewatering.							
	Poor quality seepage from machinery used to excavate soils. Oil, grease, and fuel leaks could lead to hydrocarbon contamination of the vadose zone - which could percolate into the shallow aquifer.	Net Result of Earthworks and Mining	Medium Term (3)	Site (2)	Yes (1)	Moderate (-2)	Slightly detrimental (-7 to -12) (-12)	Definite (2)	Low – negative (-13 to -24) (-24)	Park heavy machinery in lined areas and place drip trays under vehicles at the site. Have fuel and oil spill cleanup kits on site and clean up these areas immediately. Ensure that building material stockpiles are covered with a suitable temporary cover or placed in bunded areas to reduce poor-quality seepage probability. Visual soil assessments for signs of contamination during construction (monthly)	Medium Term (3)	Site (2)	Yes (1)	Low (-1)	Negligible (-6 to 0) (-6)	Probable (1)	Neutral/ Negligible (0 to -12) (-6)

Table 8-6: Impacts during the closure phase/decommissioning phase

			Pre- Mitigation								Post Mitigation						
Component Being Impacted On	**Activity Which May Cause the Impact**	**Activity**	**Duration (D)**	**Extent (E)**	**Potential for impact on irreplaceable resources (I)**	**Severity (S)**	**Consequence (C)**	**Probability (P)**	**Significance**	**Recommended Mitigation Measures**	**Duration (D)**	**Extent (E)**	**Potential for impact on irreplaceable resources (I)**	**Severity (S)**	**Consequence (C)**	**Probability (P)**	**Significance**
Vadose zone soils and subsequent aquifer (groundwater table)	Rehabilitation of mining operations.	Rehabilitation	Medium Term (3)	Site (2)	Yes (1)	High (3)	Moderately beneficial (7 to 18) (18)	Definite (2)	High–positive (24 to 48) (36)								
	Poor quality seepage from machinery used to decommission and rehabilitate the mine operations.	Rehabilitation	Medium Term (3)	Site (2)	Yes (1)	Moderate (-2)	Slightly detrimental (-7 to -12) (-12)	Definite (2)	Low – negative (-13 to -24) (-24)	- Park heavy machinery in lined areas and place drip trays under vehicles at the site. - Visual soil assessments for signs of contamination during rehabilitation (monthly)	Medium Term (3)	Site (2)	Yes (1)	Low (-1)	Negligible (-6 to 0) (-6)	Probable (1)	Neutral/ Negligible (0 to -12) (-6)
	Rehabilitation of settlement dams will stabilise the soils in the project area.	Rehabilitation	Medium Term (3)	Site (2)	Yes (1)	High (3)	Moderately beneficial (7 to 18) (18)	Definite (2)	High–positive (24 to 48) (36)								
Regional groundwater table/groundwater aquifer	Cession of mining activity and rebound of the groundwater table.	Decommissioning	Medium Term (3)	Site (2)	Yes (1)	High (3)	Moderately beneficial (7 to 18) (18)	Definite (2)	High–positive (24 to 48) (36)								
	Decommissioning of the borehole used for groundwater supply.	Decommissioning	Medium Term (3)	Site (2)	Yes (1)	High (3)	Moderately beneficial (7 to 18) (18)	Definite (2)	High–positive (24 to 48) (36)								

9 GROUNDWATER MONITORING

Currently, there is no formal groundwater monitoring network at the site. The activity is also considered a low hazard (i.e., sand and shallow rock mining with low potential source term impacts and shallow mining which will not extend deeper than the regional water table). However, it is proposed that a formal groundwater monitoring plan be considered to monitor any potential impacts on the downstream environment and to maintain a record of the environmental impact that will take place.

Based on the findings of this investigation and numerical simulations, the following improvements are proposed:

- A total of 4 monitoring boreholes are proposed, of which Bundu BH is an existing borehole.
- Drill an additional 3 boreholes as determined by the geophysical investigation to improve the sensitivity of the groundwater monitoring system. Proposed drilling coordinates are presented in Table 9-1, and typical construction considerations are presented in Figure 9-1. Monitoring locations are shown in Figure 9-2.
- **Monthly** water level monitoring of the abstraction borehole should take place.
- **Monthly** abstraction volumes should be taken and kept on record.
- Monitoring for all new groundwater points should be **bi-annually,** and constituents on minimum for laboratory screening should be:
  - pH in water at 25ºC
  - Conductivity in mS/m @ 25ºC
  - TDS
  - Bicarbonate Alkalinity as $CaCO_3$
  - Bicarbonate as $CaCO_3$
  - Total Alkalinity as $CaCO_3$
  - Calcium
  - Magnesium
  - Potassium
  - Sodium
  - Chloride
  - Fluoride
  - Nitrate
  - Sulphate
  - Aluminium
  - Iron
  - Manganese

Table 9-1: Proposed monitoring borehole drilling positions

Target ID	Latitude (WGS84)	Longitude (WGS84)	rec Depth (m)
T1-100	-25.73368459	28.00976666	30m
T1-340	-25.73396426	28.00732038	30m
T2-60	-25.73454261	28.0066131	30m

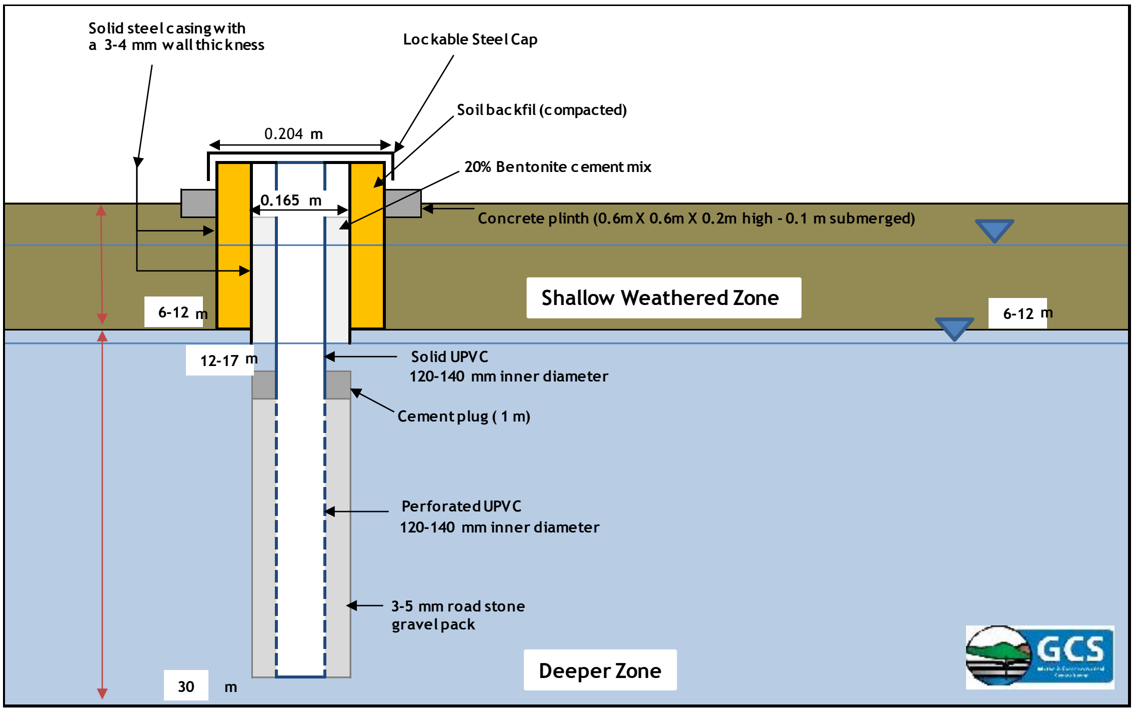


Figure 9-1: Proposed borehole construction

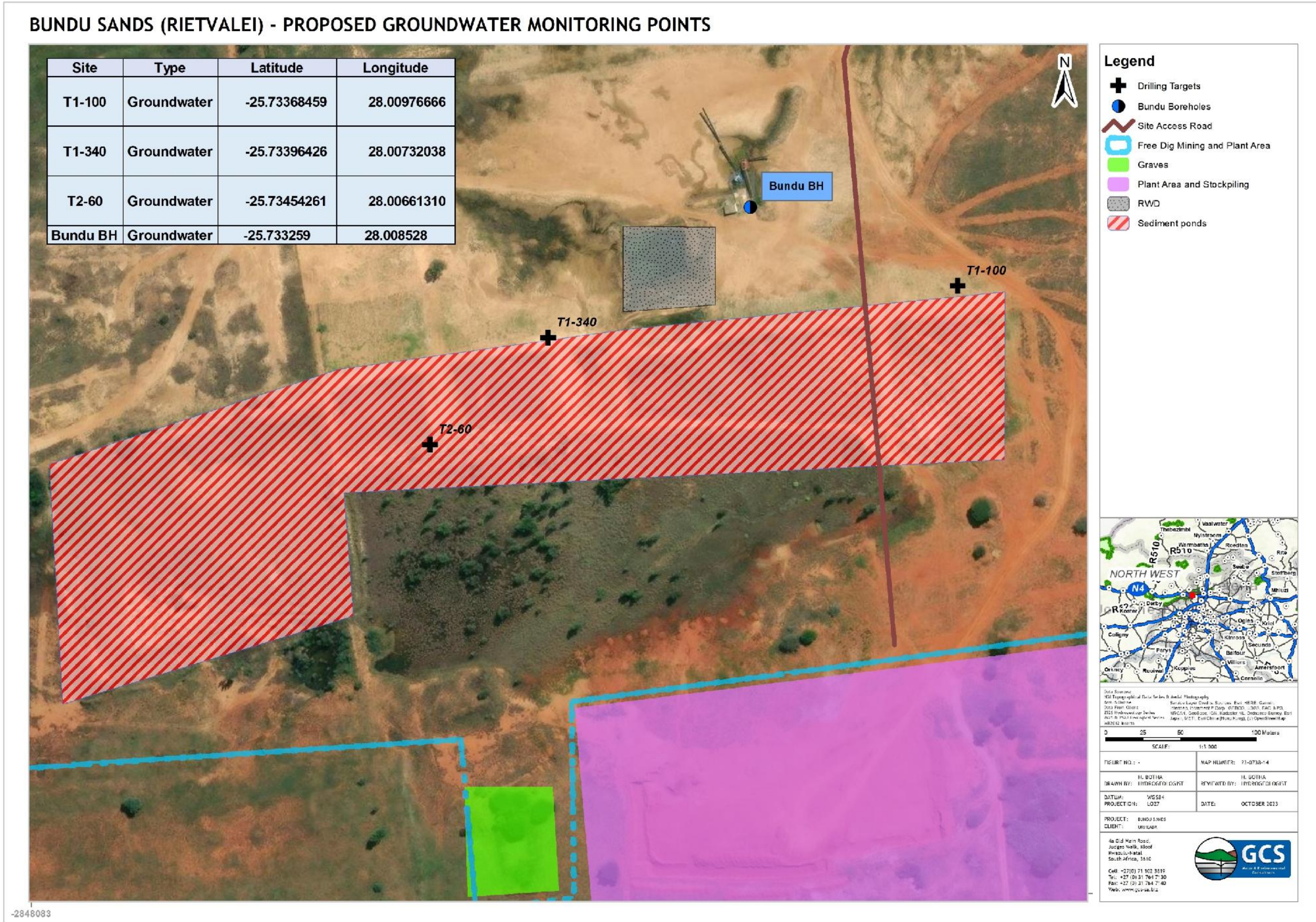


Figure 9-2: **Proposed groundwater monitoring network**

10 GROUNDWATER MANAGEMENT CONSIDERATIONS

The following section supplies a brief groundwater management plan that could help to improve or maintain a low impact on the groundwater system during the project's lifetime.

10.1 Operational and decommissioning phase

The following actions are proposed:

- Mined out excavations:
    - Backfilled and compacted to reduce infiltration to < 1% of the MAP.
    - Sloping should be undertaken, and post-closure stormwater management should be considered to divert water around and away from the backfilled material. Ponding should be prevented.
    - Phytoremediation can be considered if water logging takes place in rehabilitated areas.
- Soft material and topsoil dumps:
    - Place stockpiles in budded areas, where possible.
    - Cover stockpiles temporarily during wet months to reduce percolation into the subsoils.
- Monitoring:
    - Water quality and water level monitoring should continue at least 2years after closure to confirm closure objectives.
- Other consideration:
    - Ensure fuel cleanup kits are kept on-site during the project's lifecycle. Cleanup should take place immediately if hydrocarbon contamination takes place.
    - Ensure that the stormwater system (temporary stormwater and permanent) is maintained and kept operational.
    - Ensure that all surface water and settlement dams are operated to withstand 1-100-year flooding events.

10.2 Groundwater closure objectives

The following actions are proposed:

- Place overburden on a prepared compacted soil area to reduce seepage potential.
- Collect all toe seepage from stockpiles in dedicated collection drains to the settlement dams. If water quality is in line with DWAF general discharge limits or per the WUL requirements, then controlled release to the nearest drainage line is recommended.
- Update existing predictive tools to verify long-term impacts on groundwater, if required (i.e., when the groundwater monitoring network suggests that pollution is taking place).
- 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

Based on the investigation undertaken, the following conclusions are made:

- The project falls within quaternary catchment A21H of the Limpopo Water Management Area (WMA). Elevations for the site area range from 1200 to 1550 metres above mean sea level (mamsl).
- The site is bound to the south by a steep hilltop, and two (2) dominant drainage lines exist, one towards the east and one towards the west of the hilltop, where valleys have been carved by erosion.
    - For the majority of the site, there are no recognised drainage lines or streams/rivers. The proposed MR area falls between the two drainage lines, and based on the delineated topography and GHRUs, the activity will likely not impact the western drainage line and will further have a limited impact on the eastern drainage stream. From the site investigation, it is clear that free drainage takes place for the entire site, with occasional depressions where surface water collects shortly after rainfall events.
    - It is clear from the site walkover assessment that historic mining has changed the surface water flow paths, and micro-catchment style free drainage from higher to lower elevations takes place. The overall drainage direction is towards the north of the Swartspruit River. The Swartspruit River is situated about 1.04km downstream of the site and flows towards the west to the Hartbeespoort Dam.
- The project falls in an area with a MAP in the order of 690 mm/yr and an MAE in the order of 1600 mm/yr.
- Available desktop hydrocensus and DWS WARMS data suggest that there are about twenty-eight (28) WARMS users within a 5 km buffer of the project area, of which none of them fall within the GHRUs. A review of SADAC GIP groundwater database boreholes further suggests several boreholes within a 5 km radius of the site with groundwater data available. 98% of the WARMS users are boreholes, amounting to a total allocation in the order of 0.7 Mm^3/yr, followed by 1 registered spring user and 1 surface water stream user. 1 groundwater user (WARMS ID: 26075176) is associated with the GHRU of the site.

- 42 groundwater boreholes were identified within a 5km radius of the site in the field. Abstraction volumes for boreholes identified vary from 2500 to 15 000 l/hr, and water usage ranges from small-scale irrigation to domestic to livestock watering. The average pH of the groundwater resource ranges from slightly acid (pH ~5.5) to neutral (pH ~ 7.6). Groundwater conductivity ranges from 170 µS/cm to >1200 µS/cm (slightly salty). Identified groundwater users generally fall outside the GHRU, with only several of them falling inside, namely 96-5 and 96-7, Jura BH1 to Jura BH3, Bundu BH-BH4. It is highly likely that boreholes falling outside the GHRU will not be impacted; however, they still fall in the potential sphere of influence. Refer to the groundwater model section of this report for the risks identified.

- A site conceptual geohydrological model (SCM) was developed for the site, and based thereon, the following three (3) aquifer systems were identified in the project area:

    - A shallow, unconfined aquifer system associated with the quaternary sand deposits.

    - A semi-confined / perched aquifer system associated with both fractured and intergranular weathered rock of the Pretoria Group.

    - A deeper, confined, fractured aquifer network is associated with older basement rocks.

- The aquifers underlying the study area are considered low-yielding aquifers (median yields of 0.5 to 2 l/sec – Class d3 aquifer and b2 aquifers). Based on extrapolated groundwater level data, it is estimated that the groundwater table is in the order of 13 mbgl at the site, which indicates that mining will take place above the regional groundwater table (expected maximum mining depth is about 10 m). Available data suggest that the groundwater table mimics the topography and groundwater flows from high-lying areas (water divides) to low-lying areas.

- In the SCM, the main source of groundwater recharge is rainfall. The rainfall infiltrates into the ground to become groundwater through the Vadose Zone. The water then moves both vertically and horizontally in the quaternary sand deposits and weathered zone of the Pretoria Group sediments, with greater interflow in a horizontal direction within the weathered zone matrix. Where shallow hard rock outcrops or intrusive dolerite outcrops occur, there may be the formation of springs, and subsequently, where shallow quaternary sand depots accumulate on shallow hard rock, there may be water logging. Shallow and deep groundwater movement will likely be towards the north, towards the valley where the Swartspruit River is situated.

- Any pollution that does occur on the surface and is allowed to percolate into the vadose zone could potentially impact the groundwater table. The contaminants would then slowly propagate towards the Swartspruit River, which is the primary surface water receptor in the project area. The groundwater flow velocity is slow, and it will take some time for pollution to enter the river system, which may not be observed during the lifecycle of the project. The mining activity is, however, considered a “clean” operation, as it involves the excavation and washing of sand and hard rock (aggregate). The sands are relatively inert based on available hydrochemical and waste classification data (refer to GCS Waste Classification and Hydrology Reports, 2023).
- Several hydrological risks were identified and presented in Section 8, and several mitigation measures can be considered. A water monitoring and groundwater management plan is available in Sections 8 and 9. The following provides a summary of the predicted impacts:
  - The predicted dewatering that will take place will have an impact on the groundwater reserve on a sub-catchment scale. On a quaternary scale, the impact is projected to be marginal. Any poor-quality seepage from facilities at the site could also migrate to the borehole and compromise water quality, as the borehole is situated downstream of the mining and settlement dam areas.
  - In terms of the preparation and operational phase, there are expected cumulative impacts on the soils associated with the site. The impact is predicted to improve at the closure of the mine and if rehabilitation is rolled out. The sub-catchments in which the mining will take place are isolated from other mines and activities in the area, and hence, cumulative impacts on a larger scale will be limited. Dewatering impacts are predicted to be the largest risk associated with the proposed Project but will be limited to the GHRU.

11.1 Numerical flow and transport modelling conclusions

A numerical groundwater flow and transport model was successfully constructed for the site to understand the groundwater flow system and to inform the geohydrological impact assessment. The steady-state model was successfully converted into the transient state, and the model was successfully calibrated with hydrocensus groundwater level data.

- A numerical groundwater flow and transport model was successfully constructed for the site and used to run several prediction scenarios. The steady-state model was successfully converted into the transient state, and the model was successfully calibrated against monitoring and hydrocensus groundwater level data.
- Groundwater level data for more than 6 observation points within the study area were successfully applied. The conceptual groundwater model and understanding of the aquifer, based on available data, were successfully illustrated in this report.

- A groundwater flow and associated transport model was developed to illustrate the potential TDS pollution plume movement (or zone of impact – ZOIp) from the operations, and dewatering impacts were simulated (so-called zone of impact [ZOIp] and zone of influence – [ZOIf]).
- The following is observed from the numerical simulations:
    - The flow model indicates groundwater flow velocities ranging from 0.01 (min) to 5 (max) m/day. Groundwater movement in the weathered zone is greater than that of the deeper aquifer zones, and several orders are greater in the alluvium zones when compared to the host rock.
    - The predicted transport movement [ZOIp] from the proposed plant and settlement dams' area suggests that if a source with a TDS in the order of 1000 mg/l percolates into the aquifer, the concentration gradient will be very low. Diffuse concentration gradients are < 50 mg/l, and the 50Y plume is predicted to not intercept the major surface water receptor in the project area (the Swartspruit River). Mining will likely cease long before any significant salt buildup or transport to the river system. It is noted that the TDS of the source terms, the sand mined and stockpiled, is very low (GCS Waste Classification, 2023). The introduction of the 1000 mg/l TDS was incorporated to simulate a "worst case" scenario where site pollution takes place and to simulate how far such pollution would migrate within 50 years.
    - The predicted maximum aquifer drawdown for the workings and abstraction activities at LOM is in the order of 32m for the deeper workings (extending to 50m below surface level) and gradually decreases to 1m towards the east and west of the operations. It is observed that drawdown is limited to the meta-argillaceous rocs towards the north of the hilltop (where the workings are) and that the hilltop with the meta-arenaceous rocks (quartzite) acts as an aquiclude. This is due to the low recharge and low permeability associated with the quarzitic rock. The predicted aquifer drawdown does not reach any of the identified groundwater users in the GHRU or SOIF.
    - The predicted initial dewatering volume for the proposed mining works (up to an assumed maximum depth of 10m for the shallow operations and 50m for the deeper operations) is 496.53 m^3/day. The dewatering rate is estimated to increase to 820.76 m^3/day, approaching the maximum depth of blasting pit after 30 years of mining. Water level rebound is expected within 1-2 years after mining ceases.
- 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 limited groundwater heads available for calibration. Class 2 models are suitable for undertaking 1st order flow calculations and to illustrate potential impacts on the flow system due to a given activity.
- The transport model is assigned a Class 2 confidence level due to the limited observation boreholes available. The transport model was only used to predict potential pollution movement in the groundwater environment towards the receptors in the project area.

11.2 Avoidance areas

No avoidance areas were identified as part of this assessment.

11.3 Recommendations

The following recommendations are made:

- The following can be done to improve the assumptions and understanding of the groundwater aquifer and hence improve the numerical groundwater model confidence:
  - All new exploration 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).
  - Dewatering volumes (during mining) should be recorded daily and reported bi-monthly (if any, as this assessment predicts that mining will take place above the water table).
- It is recommended that the 3 boreholes, as listed in Section 9, be drilled and integrated into the existing groundwater monitoring network.

11.4 Identification of any areas that should be avoided

Based on available information, no avoidance areas were identified. No alternatives are possible as the MR area targets an economically mineable sand deposit.

11.5 Reasoned opinion on whether EA/WULA should be considered

Based on the findings of this assessment, GCS believes that the proposed activities pose a low risk to the geohydrological environment and existing groundwater users in the project area. The approval of the activity should be considered to enable Bundu to excavate and process the sands that occur in the project area. It is further assumed that mitigation options to offset negative impacts, as predicted by this study for Bundu Mining, will be implemented into the EMPr during the operational and closure phases of the project.

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APPENDIX A: GEOPHYSICAL INVESTIGATION METHODOLOGY & FIELD DATA

1. 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.

Magnetic Investigation Methodology

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.

2. Survey orientation and spacing length

Two (2) Mag profiles were completed in the study area. Mag traverses varied from approximately 300 m in length. Mag readings were taken at 10 m intervals. Moreover, each spacing was recorded with a handheld GPS.

3. Potential inference

Some magnetic interference sources were noted in the survey area (steel structures). The profile lines were shifted to best avoid these magnetic interference sources.

4. Data analyses

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

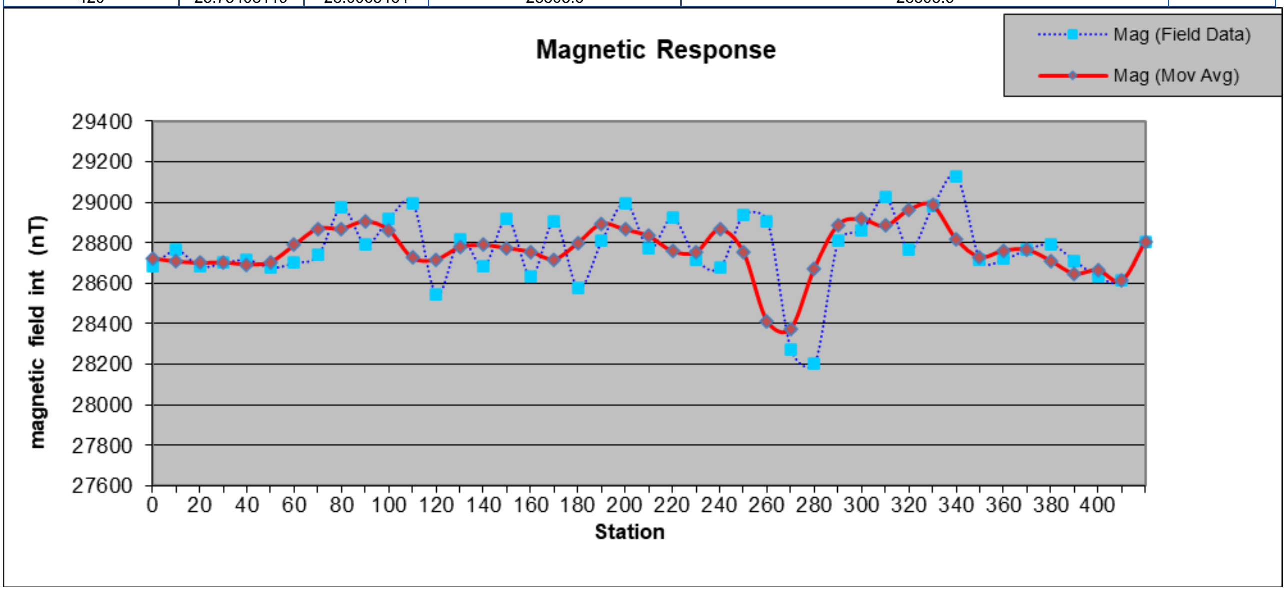
- All magnetic data was captured in Microsoft Excel ®, and profile trend graphs for the profile lines walked were constructed. A 3-point average algorithm was applied to smooth the data. The magnetic anomalies observed were then interpreted based on the magnetic field strength observed along the profile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

5. Magnetic Profiles

MAG LINE 1

Project:	Bundu Mining	Traverse Number:	T1
Project Number:	23-0858	Traverse Direction:	250° W, I 11°
Survey Area:	Test Area	Station Spacing:	10 meters
Date of Survey:	23 October 2013	Operator:	Hendrik

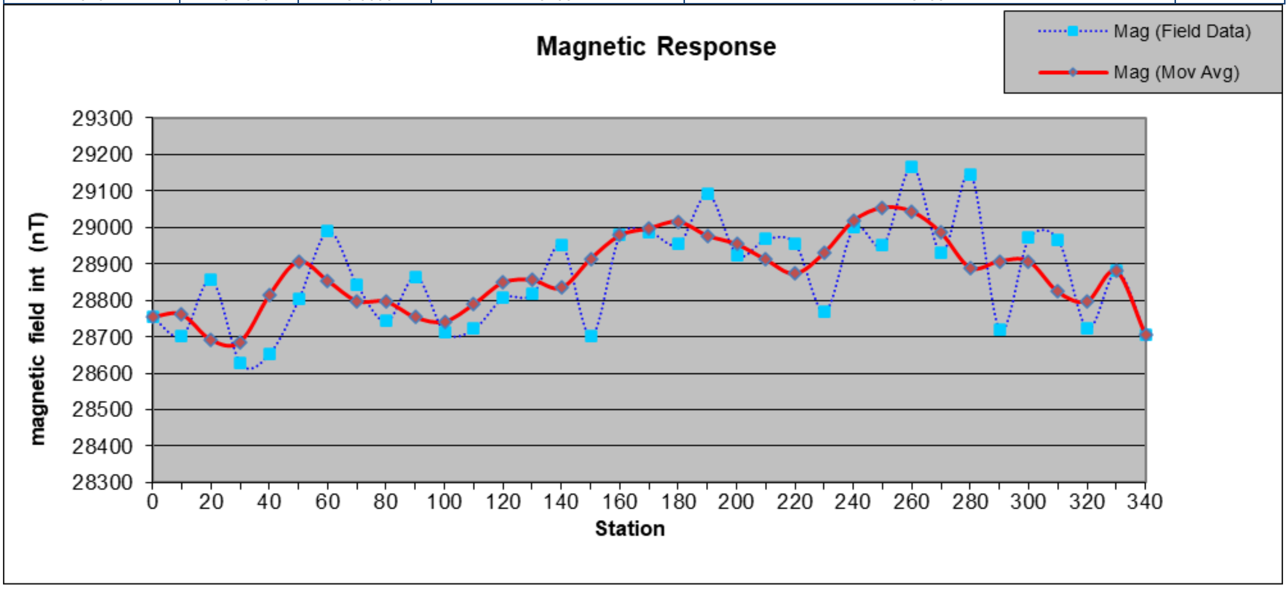
Station	Station Coordinates		Mag		Comments
Station	Latitude (y)	Longitude (x)	Mag	Mag (Mov Average)	
0	-25.7326	28.0088	28685.9	28724.4	
10	-25.7380	28.0102	28764.4	28707.95	
20	-25.7379	28.0102	28682.9	28700.775	
30	-25.7336	28.0102	28701.6	28703.4	
40	-25.7336	28.0102	28717	28693.7	
50	-25.7336	28.0102	28678	28705.15	
60	-25.7336	28.0102	28701.8	28789	
70	-25.7336	28.0101	28739	28871.2	
80	-25.7337	28.0100	28976.2	28870.875	
90	-25.7337	28.0099	28793.4	28907.6	
100	-25.7337	28.0098	28920.5	28864.825	
110	-25.7337	28.0097	28996	28727.4	
120	-25.7337	28.0096	28546.8	28717.9	
130	-25.7337	28.0095	28820	28777.75	
140	-25.7337	28.0094	28684.8	28790.375	
150	-25.7337	28.0093	28921.4	28774.35	
160	-25.7338	28.0092	28633.9	28757.025	
170	-25.7338	28.0091	28908.2	28718.825	
180	-25.7338	28.0090	28577.8	28799.625	
190	-25.7338	28.0089	28811.5	28894.7	
200	-25.7338	28.0088	28997.7	28866.325	
210	-25.7338	28.0087	28771.9	28834.4	
220	-25.7338	28.0086	28923.8	28759.95	
230	-25.7338	28.0085	28718.1	28754.45	
240	-25.7338	28.0084	28679.8	28867.05	
250	-25.7338	28.0082	28940.1	28757.175	
260	-25.7338	28.0081	28908.2	28414.025	
270	-25.7338	28.0080	28272.2	28372.1	
280	-25.7338	28.0079	28203.5	28670.65	
290	-25.7339	28.0078	28809.2	28888.7	
300	-25.7339	28.0077	28860.7	28919.05	
310	-25.7339	28.0076	29024.2	28884.925	
320	-25.7339	28.0075	28767.1	28964.5	
330	-25.7340	28.0074	28981.3	28988.475	
340	-25.7340	28.0073	29128.3	28819.9	
350	-25.7340	28.0072	28716	28730.675	
360	-25.7340	28.0071	28719.3	28762.225	
370	-25.7340	28.0070	28768.1	28766.6	
380	-25.7340	28.0069	28793.4	28712.35	
390	-25.7340	28.0068	28711.5	28647.425	
400	-25.7340	28.0067	28633	28665.75	
410	- 25.73406442	28.0066354	28612.2	28612.2	
420	- 25.73408119	28.0065464	28805.6	28805.6	



MAG LINE 2

Project:	Bundu Mining	Traverse Number:	T2
Project Number:	23-0858	Traverse Direction:	100° W, I 7°
Survey Area:	Test Area	Station Spacing:	10 meters
Date of Survey:	23 October 2013	Operator:	Hendrik

Station	Station Coordinates		Mag		Comments
Station	Latitude (y)	Longitude (x)	Mag	Mag (Mov Average)	
0	-25.7346	28.0060	28753.3	28754.325	
10	-25.7346	28.0061	28703.4	28761.25	
20	-25.7346	28.0062	28857.2	28691.5	
30	-25.7346	28.0063	28627.2	28685.05	
40	-25.7346	28.0064	28654.4	28813.1	
50	-25.7346	28.0065	28804.2	28906.2	
60	-25.7345	28.0066	28989.6	28853.75	
70	-25.7345	28.0067	28841.4	28798.025	
80	-25.7345	28.0068	28742.6	28796.45	
90	-25.7345	28.0069	28865.5	28753.2	
100	-25.7345	28.0070	28712.2	28741.3	
110	-25.7345	28.0071	28722.9	28788.625	
120	-25.7344	28.0072	28807.2	28848.275	
130	-25.7344	28.0073	28817.2	28855.475	
140	-25.7344	28.0074	28951.5	28833.975	
150	-25.7344	28.0075	28701.7	28913.025	
160	-25.7344	28.0076	28981	28978.1	
170	-25.7344	28.0076	28988.4	28997.325	
180	-25.7344	28.0077	28954.6	29015.775	
190	-25.7344	28.0078	29091.7	28977.55	
200	-25.7344	28.0079	28925.1	28954.15	
210	-25.7344	28.0080	28968.3	28911.825	
220	-25.7344	28.0081	28954.9	28873.15	
230	-25.7344	28.0082	28769.2	28930.025	
240	-25.7344	28.0083	28999.3	29017.85	
250	-25.7344	28.0084	28952.3	29054.55	
260	-25.7344	28.0085	29167.5	29043.8	
270	-25.7344	28.0086	28930.9	28985.625	
280	-25.7344	28.0087	29145.9	28889.325	
290	-25.7344	28.0088	28719.8	28907.375	
300	-25.7344	28.0089	28971.8	28907.025	
310	-25.7344	28.0090	28966.1	28823.55	
320	-25.7344	28.0091	28724.1	28797.4	
330	-25.7345	28.0092	28879.9	28879.9	
340	-25.7345	28.0093	28705.7	28705.7	



APPENDIX B: LABORATORY CERTIFICATE

aquatico Laboratories (Pty). Ltd.

ilac-MRA sanas Testing Laboratory T0685

Test Report Page 1 of 1

Client:	Groundwater Consulting Services (GCS)	**Date of report:**	19 October 2023
Address:	63 Wessel Road, Woodmead, 2191	**Date accepted:**	06 October 2023
Report no:	166152	**Date completed:**	19 October 2023
Project:	GCS	**Date received:**	06 October 2023

Lab no:					330046
Date sampled:					06-Oct-23
Aquatico sampled:					No
Sample type:					Water
Locality description:					SW-Dam
		Analyses	**Unit**	**Method**	
A	AQL	pH @ 25°C	pH	ALM 20	7.84
A	AQL	Electrical conductivity (EC) @ 25°C	mS/m	ALM 20	12.0
A	AQL	Total Dissolved solids @ 180°C	mg/l	ALM 24	90
A	AQL	Total Alkalinity	mg $CaCO_3$/l	ALM 01	71.3
A	AQL	Chloride (Cl)	mg/l	ALM 02	1.01
A	AQL	Sulphate (SO_4)	mg/l	ALM 03	<0.141
A	AQL	Nitrate (NO_3) as N	mg/l	ALM 06	0.303
A	AQL	Total oxidised nitrogen as N	mg/l	ALM 06	0.303
A	AQL	Fluoride (F)	mg/l	ALM 08	0.351
A	AQL	Calcium (Ca)	mg/l	ALM 30	15.3
A	AQL	Magnesium (Mg)	mg/l	ALM 30	7.74
A	AQL	Acid Soluble Sodium (Na)	mg/l	ALM 30	9.87
A	AQL	Sodium (Na)	mg/l	ALM 30	4.21
A	AQL	Acid Soluble Potassium (K)	mg/l	ALM 30	2.53
A	AQL	Aluminium (Al)	mg/l	ALM 31	0.035
A	AQL	Manganese (Mn)	mg/l	ALM 31	<0.001
A	AQL	Copper (Cu)	mg/l	ALM 31	<0.002
A	AQL	Turbidity	NTU	ALM 21	1.67
A	AQL	Sodium Adsorption Ratio	SAR	ALM 26	0.22
A	AQL	Total suspended solids (TSS)	mg/l	ALM 25	<4.5
A	AQL	Iron (Fe)	mg/l	ALM 92	<0.000001

A = Accredited N = Non accredited Sub = Sub-contracted NR = Not requested RTF = Results to follow NATD = Not able to determine ATR = Alternative test report ; Results relate only to the items received and tested ; Results reported against the limit of detection; Results marked 'Non SANAS Accredited' in this report are not included in the SANAS Schedule of Accreditation for this laboratory; Uncertainty of measurement available on request for all methods included in the SANAS Schedule of Accreditation; The report shall not be reproduced except in full without approval of the laboratory

M. Swanepoel
Technical Signatory

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APPENDIX C: MODEL CONFIDENCE MATRIX

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, limited data required for the development of a medium-high confidence model is available. These data gaps will be required to be filled before updating the model and producing a higher confidence model suitable for defendable predictive modelling.

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

Data types	Confidence
Spatial and temporal distribution of groundwater head observations are required to adequately define groundwater behaviour, especially in areas of greatest interest and where outcomes are to be reported.	2
The spatial distribution of bore logs and associated stratigraphic interpretations clearly define aquifer geometry.	2
Reliable metered groundwater extraction and injection data are available.	0
Rainfall and evaporation data is available.	2
Aquifer-testing data to define key parameters.	1
Streamflow and stage measurements are available with reliable base flow estimates at a number of points.	1
Reliable land-use and soil mapping data available.	1
Good quality and adequate spatial coverage of digital elevation model to define ground surface elevation.	2
Geometry of the existing mine workings.	1
Geometry and temporal plan of future mine workings.	1
Geometry of existing mine residue disposal/storage areas	1
Transport model calibration points and confidence of constant sampling data	1
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%)***

APPENDIX D: DISCLAIMER AND DECELERATION OF INDEPENDENCE

The opinions expressed in this Report have been based on site /project information supplied to GCS (Pty) Ltd by Umhlaba Environmental Consulting cc (Umhlaba) and are based on public domain 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 that relate to sub-surface hydrogeological signatures/structures that 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, low yields are observed during drilling. For this reason, GCS recommends that a hydrogeological specialist supervise the drilling to ensure that drilling is stopped or that 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, as well as 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.

APPENDIX E: 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

Geohydrology Assessment for the Bundu Mining (Rietvalei) Mining Permit

SPECIALIST INFORMATION

Specialist Company Name:	GCS SA (Pty) Ltd			
B-BBEE	Contribution level (indicate 1 to 8 or non-compliant)	2	Percentage Procurement Recognition	
Specialist name:	Hendrik Botha			
Specialist Qualifications:	MSc Environmental Sciences (Geohydrology & Geochemistry) BSc Hons. Environmental Sciences (Hydrology) BSc. Geology and Chemistry			
Professional affiliation/registration:	PR SCI NAT 400139/17			
Physical address:	20 Jack Hindon Road, Sasolburg, Free-State			
Postal address:				
Postal code:	1947		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.

03/11/2023
2:21:52
Pr.Sci.Nat (400139/17)

Signature of the Specialist

GCS SA (Pty) Ltd

Name of Company:

28 October 2024

Date

APPENDIX F: CV OF SPECIALIST

GCS Water & Environmental Consultants

Hendrik Botha

Technical Director

LinkedIn:

CORE SKILLS

- Project management
- Analytical and numerical groundwater modelling
- Geochemical assessments and geochemical modelling
- Hydropedology, hydrological assessments & yield 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
- Malawi

PROFILE

Hendrik (Henri) Botha is currently the Technical Director at GCS Water and Environment. He holds an MSc in Environmental Science in Geohydrology & Geochemistry, and a BSc Hons. Degree in Hydrology. He is registered as a SACNASP Professional Natural Scientist in the Earth Science Field. Groundwater, geochemistry and surface hydrology, as well as knowledge of water chemistry together with GIS, and analytical and numerical modelling skills, are 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:

- Project Management of water and environmental projects for mining, industrial and agriculture sectors.
- Integrated Water Investigations
- Waste classification and Impact Assessments
- Aquifer vulnerability assessments
- Geochemical sampling, data interpretation and modelling
- 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)
- Conceptual Stormwater Management Assessments
- Surface Water Yield Assessments
- Water and Salt Balances

Page 1 of 8 SCAN ME PROJECT RECORD