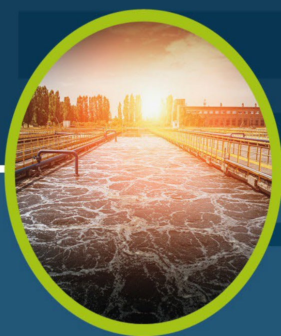
Appendix G5: Geohydrology


Royal HaskoningDHV
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forestry, fisheries
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Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

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SPECIALIST DECLARATION FORM – AUGUST 2023

Specialist Declaration form for assessments undertaken for 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)

REPORT TITLE

Geohydrology Assessment for the Proposed Soufflet Malting Facility

Kindly note the following:

1. This form must always be used for assessment that are in support of applications that must be subjected to Basic Assessment or Scoping & Environmental Impact Reporting, where this Department is the Competent Authority.
2. This form is current as of August 2023. It is the responsibility of the Applicant / Environmental Assessment Practitioner (EAP) to ascertain whether subsequent versions of the form have been published or produced by the Competent Authority. The latest available Departmental templates are available at https://www.dffe.gov.za/documents/forms.
3. An electronic copy of the signed declaration form must be appended to all Draft and Final Reports submitted to the department for consideration.
4. The specialist must be aware of and comply with '*the Procedures for the assessment and minimum criteria for reporting on identified environmental themes in terms of sections 24(5)(a) and (h) and 44 of the act, when applying for environmental authorisation - GN 320/2020)'*, where applicable.

1. SPECIALIST INFORMATION

Title of Specialist Assessment	Geohydrology assessment
Specialist Company Name	GCS Water & Environmental consultants (pty)Ltd
Specialist Name	Hendrik Botha
Specialist Identity Number	[redacted]
Specialist Qualifications:	MSc. Environmental Science (Geohydrology & Geochemistry)
Professional affiliation/registration:	[redacted]
Physical address:	63 Wessel Road Rivonia Gauteng
Postal address:	PO Box 2597, Rivonia, 2128
Postal address	Click or tap here to enter text.
Telephone	[redacted]
Cell phone	[redacted]
E-mail	[redacted]

2. DECLARATION BY THE SPECIALIST

I, Hendrik Botha declare that –

- I act as the independent specialist in this application;
- I am aware of the procedures and requirements for the assessment and minimum criteria for reporting on identified environmental themes in terms of sections 24(5)(a) and (h) and 44 of the National Environmental Management Act (NEMA), 1998, as amended, when applying for environmental authorisation which were promulgated in Government Notice No. 320 of 20 March 2020 (i.e. "the Protocols") and in Government Notice No. 1150 of 30 October 2020.
- I will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant;
- I declare that there are no circumstances that may compromise my objectivity in performing such work;
- I have expertise in conducting the specialist report relevant to this application, including knowledge of the Act, Regulations and any guidelines that have relevance to the proposed activity;
- I will comply with the Act, Regulations and all other applicable legislation;
- I have no, and will not engage in, conflicting interests in the undertaking of the activity;
- I undertake to disclose to the applicant and the competent authority all material information in my possession that reasonably has or may have the potential of influencing –
    - any decision to be taken with respect to the application by the competent authority; and;
    - the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority;
- All the particulars furnished by me in this form are true and correct; and
- I realise that a false declaration is an offence in terms of Regulation 48 and is punishable in terms of section 24F of the NEMA Act.

[redacted]
Pr.Sci.Nat (400139/17)

Signature of the Specialist

GCS (pty)Ltd

Name of Company:

20 Jun 2024

Date

3. UNDERTAKING UNDER OATH/ AFFIRMATION

I, _ Lee-Mari Badenhorst_________, swear under oath / affirm that all the information submitted or to be submitted for the purposes of this application is true and correct.

[redacted]

Signature of the Specialist

GCS Water & Environmental (Pty) Ltd

Name of Company

20.06.2024

Date

[redacted]

Ms. L Badenhorst

Signature of the Commissioner of Oaths

20 Jun 2024

Date

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Geohydrology Assessment for the Proposed Soufflet Malting Facility

Report

Version – Final 1

11 July 2024

RHDHV

GCS Project Number: 24-0032

Client Reference: PO 111909

Report
Version – Final 1

11 July 2024

RHDHV

24-0032

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Author	Hendrik Botha (MSc, Pri. Sci. Nat)	[redacted] Pr.Sci.Nat (400139/17)	11 July 2024
Proof Reader	Lisa Botha (BSc. Hons)	[redacted]	11 July 2024
Director	Hendrik Botha (MSc, Pri. Sci. Nat)	[redacted] 1:52:32 Pr.Sci.Nat (400139/17)	11 July 2024

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 the undertaking of this study. This report presents the findings of the investigations which include the activities set out in the scope of work.

EXECUTIVE SUMMARY

GCS Water and Environment (Pty) Ltd (GCS) was appointed by Royal HaskoningDHV (RHDHV) to undertake this geohydrology assessment to supplement the Environmental Impact Assessment (EIA) and Water Use License (WUL) for the proposed Soufflet Maltings Plant, situated in Graceview Industrial Park, in the Sedibeng District of Gauteng, near Garthdale, Gauteng Province (refer to Figure 1-1 and Figure 2-1). The project falls within Quaternary catchment C22D of the Vaal Water Management Area (WMA) (DWS, 2016).

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 EIA and WULA.

Elevations for the site area range from 1450 to 1500 metres above mean sea level (mamsl) and extend to 1650 mamsl towards the western extents of the project area. The project falls in an area with a MAP in the order of 642 mm/yr and an EMA in the order of 1527 mm/yr.

The surface geology of the study is characterised by alluvium sands (~) along the Klip River floodplain, ferruginous shale and quartzite (Vt) of the Timball Hill Formation and dolomite & chert (Vdm) of the Malmani Formation of the Pretoria and Chuniespoort Supergroups, of the Transvaal Sequence. The presence of dolomite underlying the site has been confirmed by several consultants (refer to Section 5.1).

One (1) groundwater hydrological response unit (GW HRU) describes the drainage of the local area and is bound towards the east by the Klip River. The total area of the GW HRU is in the order of 59.232 km². The sub-catchment can further be viewed as the local sphere of influence in which the activities will take place (i.e., the dewatering of transport movement may impact may only be limited to the sub-catchment in which it falls). Surface water drainage is towards the east of the site, and from the western hilltops via a perennial tributary of the Klip River, which joins the Klip River approximately 3 km north of the site. The site itself is devoid of any recognised drainage lines or rivers/streams. The closest perennial stream is towards the north-west of the site at a distance of ~1.17 km, and the Klip River a major river system is situated approximately 2.5 km downstream east of the site.

According to the Water Allocation Registration Management System (WARMS, 2024), there are 17 WARMS users within a 5 km buffer of the project area, of which 4 groundwater and 1 surface water user falls within the HRU. A review of SADAC GIP groundwater database boreholes further suggests several boreholes within a 5 km radius of the site with groundwater data available. Based on the WARMS data collected it is noted that the existing groundwater use is in the order of 0.9 Mm³/yr and surface water use is in the order of 4.2 Mm³/yr.

Two (2) boreholes exist on the premises, namely Malt BHT3 and Malt BHT4, and were identified during the field hydrocensus. There is substantial evidence of other drilling pads on site, however, these boreholes have been rehabilitated. Other NGA and SADAC GIP boreholes could not be located but are assumed to have existed in the past.

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 (alluvium) of the Klip River flood plain (varies thickness from 0 to 10 m zones)
- A semi-confined/perched aquifer system associated with the weathered very soft rock shale and interbedded zones of WAD and Dolomite bedrock (varied thickness from 9 to 29 m for the site, average in the order of 17.8 m)
- A deeper fractured and Karst aquifer zone associated with the Dolomites (thickness > 100 m)

The aquifer present is classified as a Major Aquifer system (Parsons, 1995). The aquifer underlying the study area is considered high-yielding (median yields > 5 l/sec – Class c5 aquifers). A recharge of 50.5 mm/yr corresponding to 7.9% 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). Based on extrapolated groundwater level data, it is estimated that the groundwater table is in the order of 20 mbgl at the site. Available data suggest that the groundwater table mimics the topography and groundwater flows from high-lying areas (water divides) to low-lying areas. This is despite the very small hydraulic gradient associated with the dolomitic aquifer, as the area is generally flat the water table is also flat.

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 alluvium of the Klip River sediments (as well as river losses) and weathered very soft rock shale and interbedded zones of WAD and Dolomite bedrock that occur in the project area. The primary movement of water in the vadose zone is vertically into the subsequent hard rock and soft rock dolomite formation. Groundwater movement will be towards the east of the site towards the Klip River.

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 propagate towards the Klip River which is the primary surface water receptor in the project area. The groundwater flow velocity is moderate to high due to the karst formation, however, due to the large storage associated with the dolomite the movement may be slow in the system as a result of the shallow hydraulic gradient (i.e. vertical movement as opposed to horizontal movement of water is more favourable). If the Klip River is hydraulically connected to the dolomite aquifer zone, pollution may enter the river system. However, indicates that the Klip River is a losing river rather than a groundwater-gaining river, due to the low baseflow associated with the quaternary.

It will take some time for pollution to migrate in the aquifer and enter the river system and may not be observed during the lifecycle of the project. The proposed project is however considered a “clean” operation, as it will entail the likely abstraction of groundwater, processing of malt and storage of temporary wastewater on site. The only risk would be if there are leakages or spillages associated with the proposed on-site wastewater treatment plant (WWTP).

As there is a likelihood of abstracting groundwater from Malt BHT3 and Malt BHT4, there may be an impact on the groundwater reserve (if overproduction takes place). Indications from the water balance are that there is a surplus groundwater reserve, and a marginal impact is expected. Any poor-quality seepage from facilities at the site could migrate to the boreholes and compromise water quality. Prevention of pollution on the soils at the site should be prioritized to limit the impact on the groundwater regime.

A groundwater flow model was developed to illustrate the zone of impact (ZOIp) and zone of influence (ZOIf) associated with the proposed development and associated groundwater abstraction activities. 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.
- The predicted primary flow path using the particle tracking module in Modflow suggests that preferential groundwater pollution movement will be towards the southeast, from the position of the plant. This is the potential ZOIp flow path.
- The predicted ZOIf associated with groundwater proposed abstraction from Malt BHT3 and Malt BHT4 is available in Section 7.6 The simulation suggests a maximum aquifer drawdown of 0.408 m at pumping for 24hrs per day at a combined volume of 300 m^3/day. The simulation suggests that there may be borehole interference if both boreholes are pumped simultaneously, however, the impact is limited with a predicted higher drawdown at Malt BHT3. The cone of depression and extent thereof is limited to the Graceview Industrial Park and dewatering will likely not affect other groundwater users in the project area.

Several geohydrological risks were identified and are presented in Section 8 as well as several mitigation measures that can be considered. A water monitoring plan is available in Section 9. No alternatives were considered during this assessment; however, it is proposed that the preferred option as discussed above be considered for the discharge of the treated effluent. This will minimise the water liabilities for the applicant associated with direct discharge to the Klip River.

Based on the findings of this assessment GCS believes that the proposed activities pose a low risk to the geohydrological environment. The approval of the activity should be considered to enable the applicant to expand their operations. It is further assumed that mitigation options to offset negative impacts as predicted by this study will be implemented into the EMPr during the operational and closure phases of the project.

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 10.2.
(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.
(l) Conditions for inclusion in the environmental authorisation	Refer to recommendations in Section 10.
(m) Monitoring requirements for inclusion in the EMPr or environmental authorisation	Refer to recommendations in Section 10.
(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 10.5
(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.*

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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
HRU	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 Royal HaskoningDHV (RHDHV) to undertake this geohydrology assessment to supplement the Environmental Impact Assessment (EIA) and Water Use License (WUL) for the proposed Soufflet Maltings Plant, situated in Graceview Industrial Park, in the Sedibeng District of Gauteng, near Garthdale, Gauteng Province (refer to Figure 1-1 and Figure 2-1). The project falls within Quaternary catchment C22D of the Vaal Water Management Area (WMA) (DWS, 2016).

1.1 Background

The Soufflet Malting Facility is to be established at Graceview Industrial Park in Sedibeng which is located in the southern part of Gauteng. The site has been zoned as an industrial development area and the outline scheme reports have been handed over to the council by the original developers of the property. Graceview Industrial Park is selected as the best location for the following reasons:

- Strategically located next to the Heineken Sedibeng facility.
- Availability of ample land for industrial zone development.
- Located near the national highway network.
- Ease of access to raw materials.
- Availability of a variety of types of labour and creation of employment opportunities.

The objective of the project is the establishment of a malt production plant with an annual capacity of 100 kT in Phase 1 and 135 kT in Phase 2 for the local market. The Soufflet Malting Project greatly contributes to import substitution and the enhancement of barley production for the agricultural sector in the country (RHDHV, 2024).

Figure 1-1: Proposed site layout

One of the major environmental aspects of the malt project is its high-water consumption. During the operational phase, the proposed project will require large quantities of water, i.e. for steeping, germination, cleaning, sanitary purposes, laundry, landscaping etc. The quantity of water that will be consumed during phase 1 and phase 2 stages of the project is estimated to be 250,000 m^3/year and 325,000 m^3/year respectively. It is further envisioned that the backup water supply will be from two (2) boreholes, namely Malt BHT3 and Malt BHT4, with a provisional amount of 300 m^3/day reserved for the combined boreholes. The use of groundwater will be supplementary for processing water to the plant (backup purposes only). It should be noted that the usage of the boreholes is still to be determined but included in this investigation to evaluate the potential risks.

While the project is operational, it will likely generate wastewater. It is anticipated that wastewater will be generated from the industrial processing, and sanitation facilities (refer to Table 1-1). The quantity of wastewater that will be discharged during phase 1 and phase 2 stages of the project is estimated to be 200,000 m^3 /year and 260,000 m^3/year respectively. The wastewater is likely to be significant. Table 1-2 depicts the quality concentration of wastewater that will be generated from the proposed project.

There are currently two options for the treatment and discharge of wastewater considered, namely (RHDHV, 2024)

- **Preferred** – treatment at the on-site wastewater treatment plant (WWTP) and then tie-in to the existing ERWAT infrastructure, to the pump station (owned by Midvaal).
- **Alternative** – treatment at the on-site WWTP and then transport of the effluent in a pipeline that runs adjacent to the ERWAT pipeline to a discharge point in the Klip River.

Table 1-1: Effluent quality concentration estimation for the two project phases (RHDHV, 2024)

	Daily Volume m^3	Concentration mg/l				
		COD	BOD	SST	P_t	N total
Scenario 1	548	4000	2160	720	24	120
Scenario 2 (after expansion)	712					

Table 1-2: Effluent estimated constituents' daily loads for the two scenarios (RHDHV, 2024)

	Load kg/d				
	COD	BOD	SST	P_t	N total
Scenario 1	2192	1184	395	13	66
Scenario 2 (after expansion)	2849	1539	513	17	85

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 EIA and WULA.

1.2 Objectives

This hydrogeological investigation assesses the potential impacts associated with the development and operation of the proposed maltings plant on the groundwater environment. 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 were applied to advise on potential 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 groundwater 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 activities:

  - 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 plant.
  - The Australian Groundwater Modelling Guidelines (Barnett, et al., 2012) were considered to ensure that the numerical model adheres to international norms and standards.
- Develop a groundwater monitoring system based on the risks identified to monitor the impact associated with the proposed activity.
- Write a comprehensive report that can be used for decision-making purposes and compliance with an EIA 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)* applicable to geohydrological studies for environmental impacts assessment/water use license applications. The report further considers *Appendix 6 of EIA regulations (as per Table 1 in the executive summary of this report).*

1.5 Limitations

The following limitations are recognised:

- GCS did not undertake any drilling as part of this project no pump testing of the existing boreholes that are designated for proposed groundwater abstraction. All available specialist data from other consultants who undertook geohydrology, geophysical, geotechnical and dolomite assessments for the area were applied to the conceptual model, and the model constructed assumes that the data was accurately captured in these reports. GCS does however propose that dedicated pump tests take place (24 hours) on the boreholes if they are going to be used for water supply. No pump test data is currently available.

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 2.5 km radius of the mining site.
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 development area and the connected upstream and downstream hydrogeological environments.
5. **Groundwater numerical flow and transport update:**
    a. A steady-state model was developed and calibrated with data available for the study area (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 proposed abstraction of groundwater from the existing boreholes at the site (Malt BHT3 and Malt BHT4) was simulated and expressed as the zone of influence (ZOIf).

iii. Source term impacts were presented as the zone of impact (ZOIp) and primary flow paths were simulated using the particle tracking tool in Modflow.

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 system and groundwater management assessment:**
   a. A groundwater monitoring plan was developed based on the predicted groundwater impacts and site-specific activities.
   b. Groundwater management options to further reduce the groundwater risk at the site were assessed and presented.
8. **Reporting:**
   a. This report encompassing all work done was compiled.

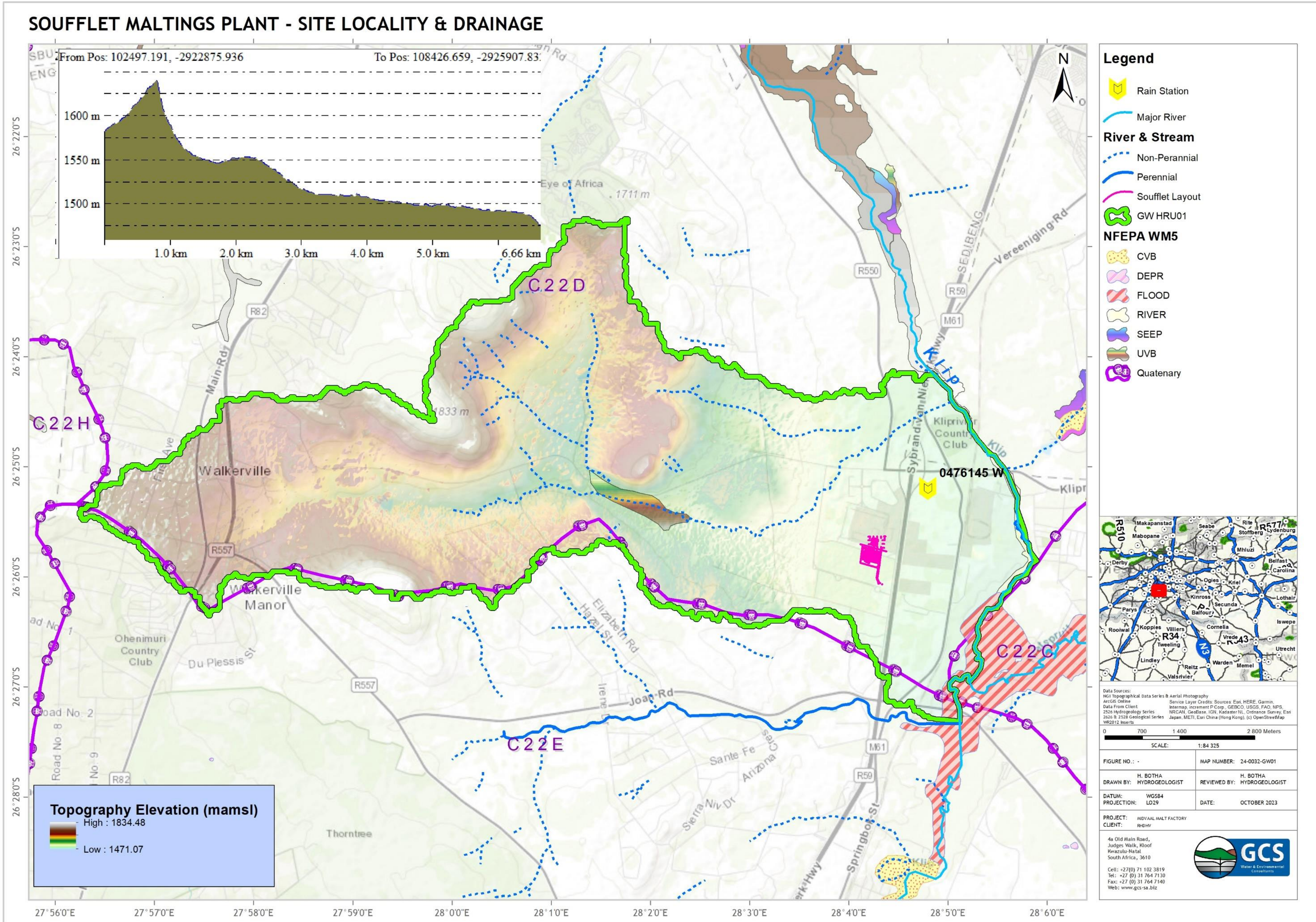


Figure 2-1: Site locality & drainage

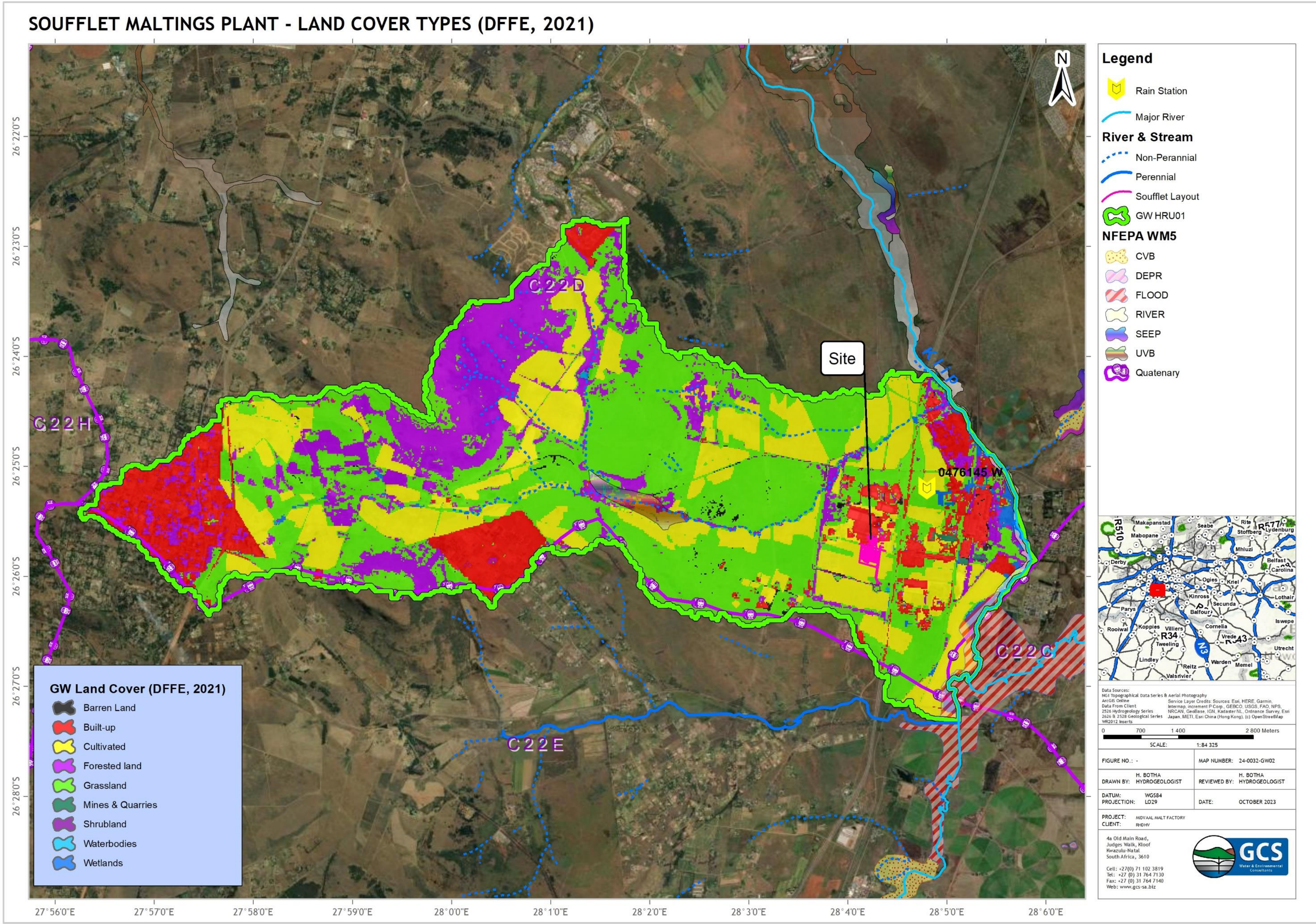


Figure 2-2: Sub-catchments and land cover types (DFFE, 2021)

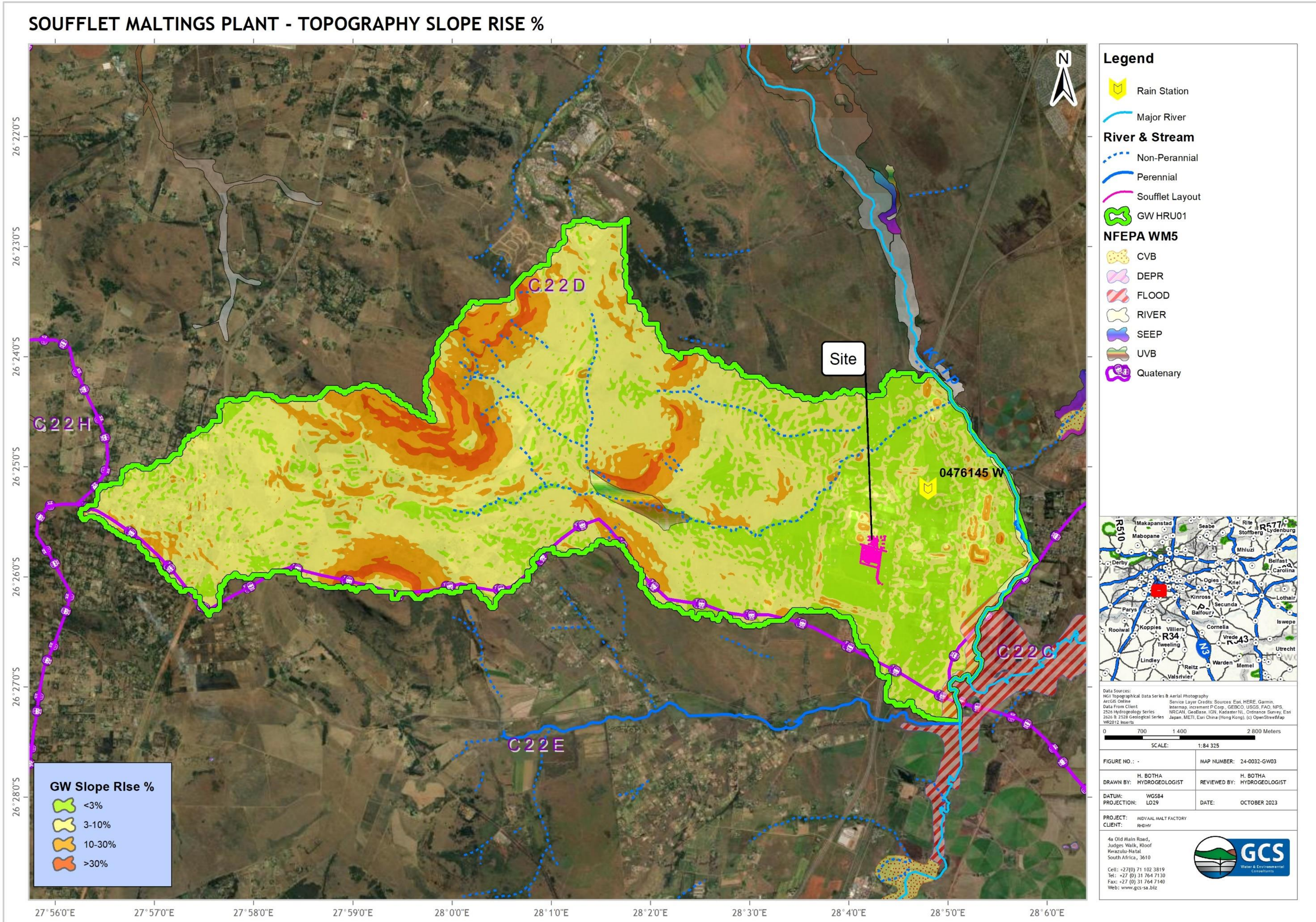


Figure 2-3: **Sub-catchments and topography slope rise %**

3 AREA OF INVESTIGATION

As mentioned previously, the project falls within the quaternary catchment C22D of the Vaal Water Management Area (WMA) (DWS, 2016). Elevations for the site area range from 1450 to 1500 metres above mean sea level (mamsl) and extend to 1650 mamsl towards the western extents of the project area.

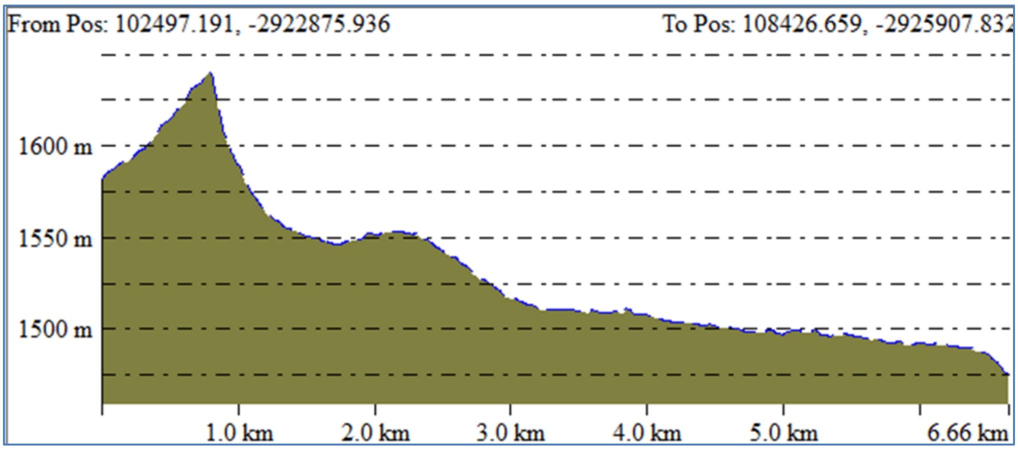


Figure 3-1: Typical cross section from headwaters to the project area

One (1) groundwater hydrological response unit (GW HRU) describes the drainage of the local area and is bound towards the east by the Klip River – refer to Figure 2-1. The total area of the GW HRU is in the order of 59.232 km². The sub-catchment can further be viewed as the local sphere of influence in which the activities will take place (i.e., the dewatering of transport movement may impact may only be limited to the sub-catchment in which it falls). The dominant land types and sub-catchment slope rise for the project area are shown in Figure 2-2 and Figure 2-3.

Surface water drainage is towards the east of the site, and from the western hilltops via a perennial tributary of the Klip River, which joins the Klip River approximately 3 km north of the site. The site itself is devoid of any recognised drainage lines or rivers/streams. The closest perennial stream is towards the north-west of the site at a distance of ~1.17 km, and the Klip River a major river system is situated approximately 2.5 km downstream east of the site.

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 23 to 33°C (high) and -4 to 4°C (Low). As per the Köppen Climate Classification (Kottek, et al., 2006), The study area is situated in a temperate highland tropical climate with dry winters (Köppen: Cwb).

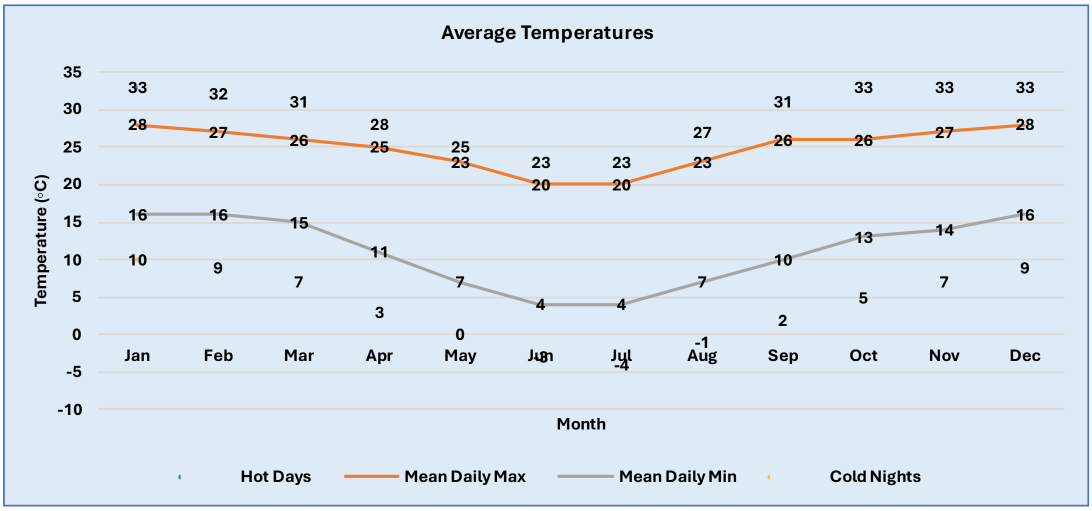


Figure 3-2: Average yearly temperatures (Meteoblue, 2024)

3.1.2 Wind speed and direction

Figure 3-3 shows the modelled wind rose for the project area (site used as reference) and presents the number of hours per year the wind blows from the indicated direction.

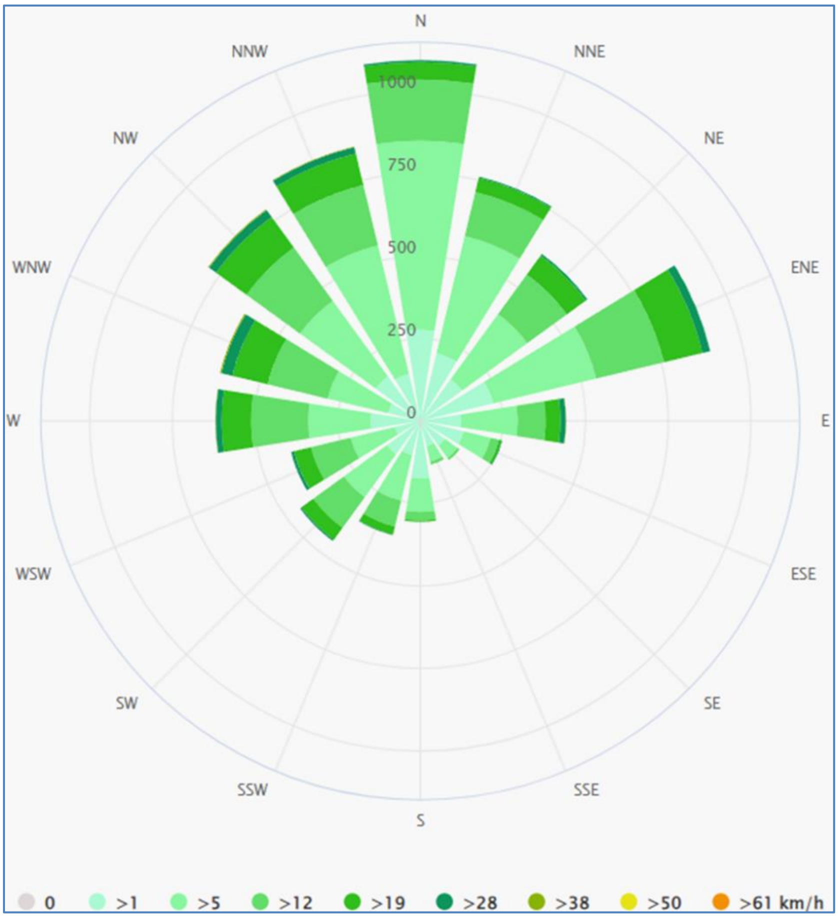


Figure 3-3: Wind rose (Meteoblue, 2024)

3.1.3 Rainfall and evaporation

The project area is situated in rainfall zone C2B. 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

Site	Id	Record	Map
KLIPRIVIER (POL)	0476145_W	64	618
ZWARTKOPJES (RWB)	0476111_W	92	684
NATALSPRUIT	0476228_W	48	693
NEW MARKET	0476227_W	67	696
VARKENSFONTEIN	0475840_W	28	670
Average			**672.2**

The monthly rainfall that represents the site was obtained from WR2012 rainfall station 0476145W (Klipriver Pol). The rainfall record is for the period 1940 to 2003 (64 years). Monthly rainfall for the site is likely to be distributed as shown in Figure 3-4, below. Available rainfall data suggest a MAP ranging from 391 (30th percentile) to 1183 (90th percentile) mm/yr. The average rainfall is in the order of 642 mm/yr.

The project area falls within evaporation zone 11A, 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, below.

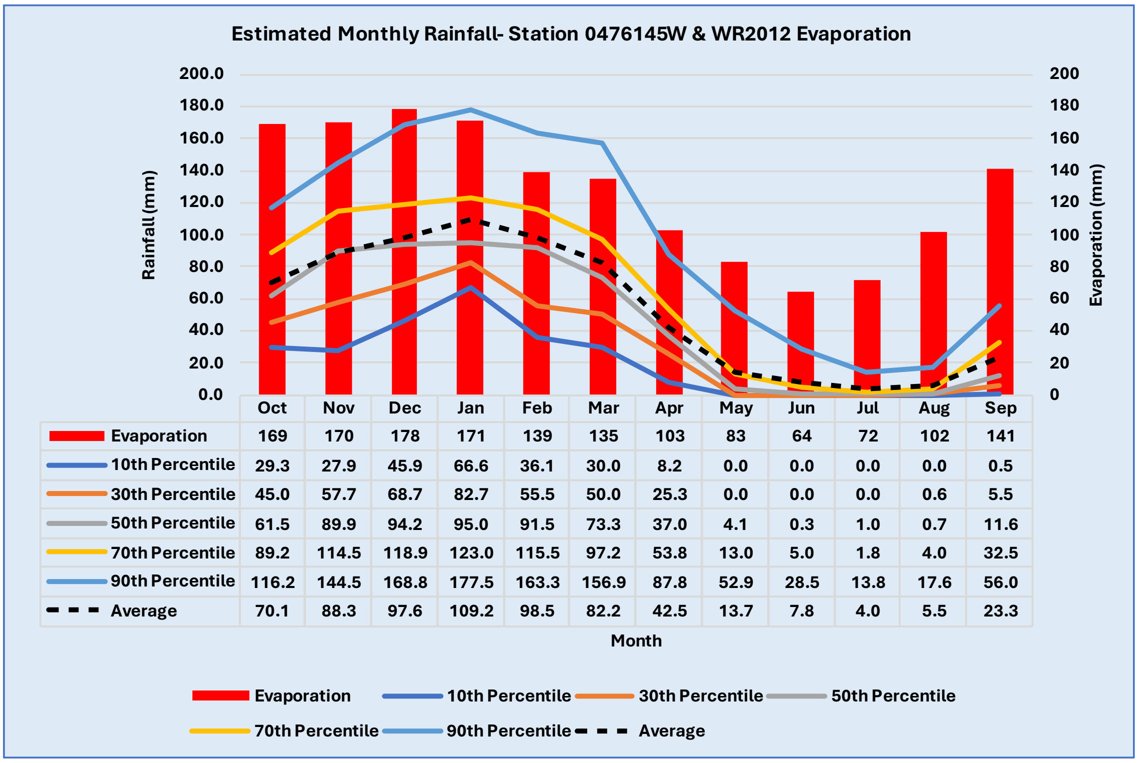
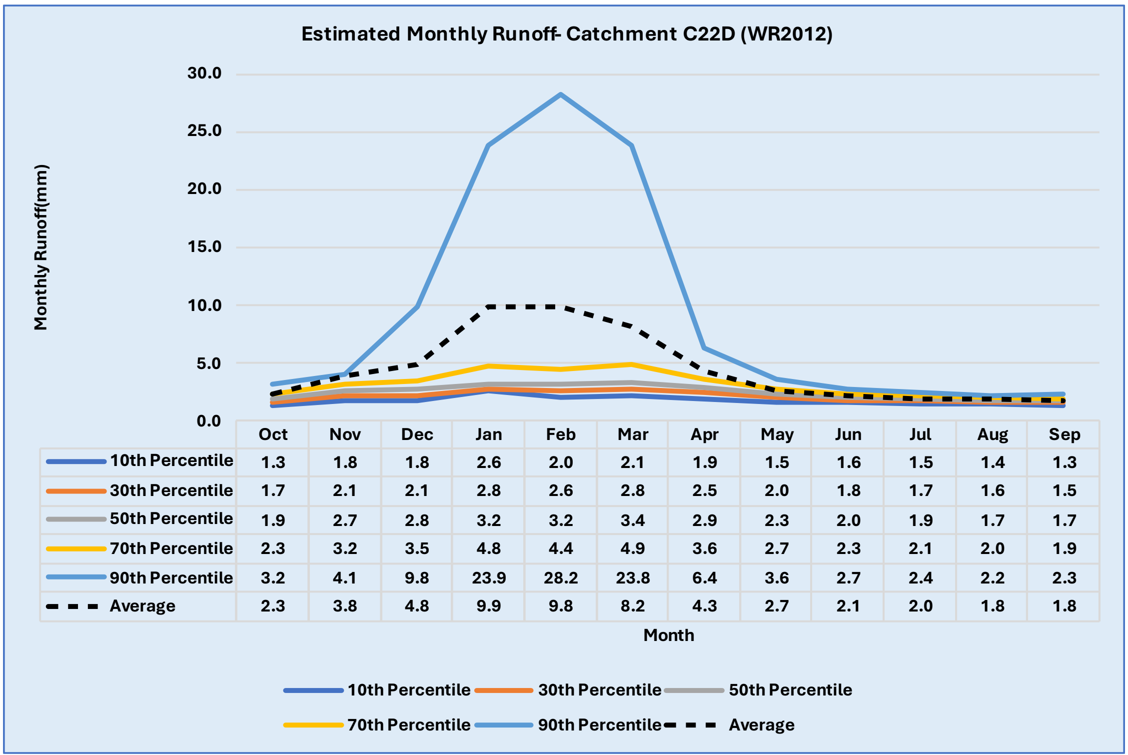


Figure 3-4: Average rainfall for Station 0476145W & WR2012 evaporation

3.1.4 Runoff

Runoff from natural (unmodified) catchments for the quaternary C22D is simulated in WR2012 (WRC, 2015) as being equivalent to 53.6 mm/yr (or 8% of the MAP) - refer to Figure 3-5.



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
10th Percentile	1.3	1.8	1.8	2.6	2.0	2.1	1.9	1.5	1.6	1.5	1.4	1.3
30th Percentile	1.7	2.1	2.1	2.8	2.6	2.8	2.5	2.0	1.8	1.7	1.6	1.5
50th Percentile	1.9	2.7	2.8	3.2	3.2	3.4	2.9	2.3	2.0	1.9	1.7	1.7
70th Percentile	2.3	3.2	3.5	4.8	4.4	4.9	3.6	2.7	2.3	2.1	2.0	1.9
90th Percentile	3.2	4.1	9.8	23.9	28.2	23.8	6.4	3.6	2.7	2.4	2.2	2.3
Average	2.3	3.8	4.8	9.9	9.8	8.2	4.3	2.7	2.1	2.0	1.8	1.8

Figure 3-5: Simulated natural (unmodified) runoff for C22H

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:

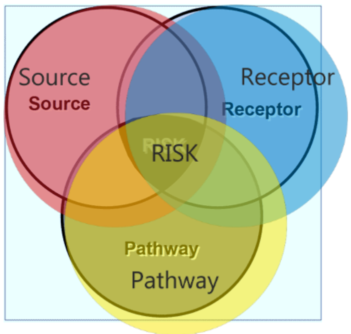
- Temperature:
  - 2021 - 2050: increases by as much as 2.1ºC
  - 2050 - 2100: increases by as much as 2.3ºC
- Annual average hot days:
  - 2021 - 2050: additional 0.16ºC extremely hot days.
  - 2050 - 2100: additional 0.9ºC extremely hot days.
- Annual rainfall totals (MAP):
  - 2021 - 2050: decrease 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 less extreme rainfall days. 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:



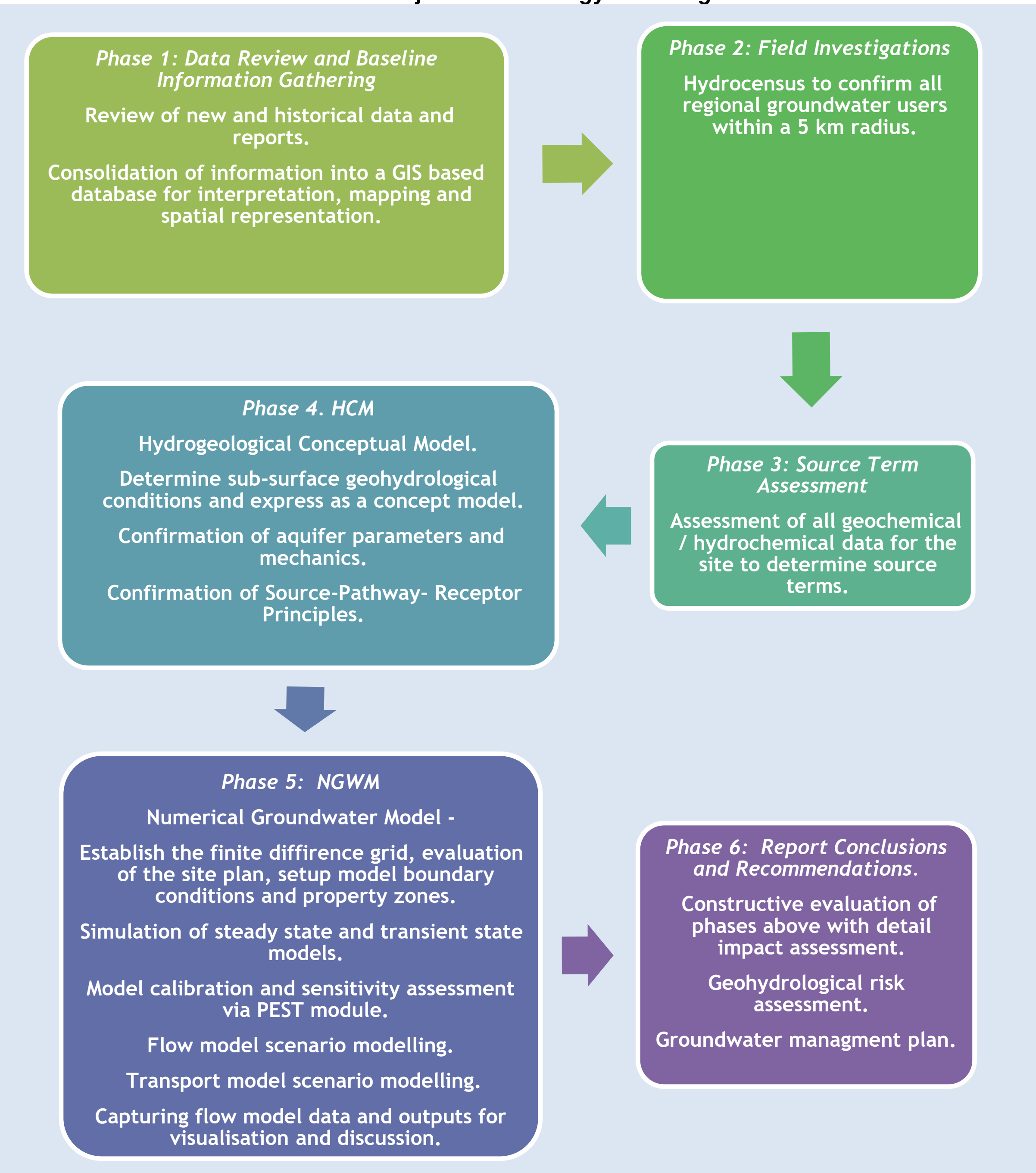
- **Source term** - The source of the risk.
- **Pathway** - The pathway along which the risk propagates; and
- **Receptor** - The target that experiences the risk.

The approach was used to assess:

1. How the existing/proposed site activities could impact groundwater *Quality*; and
2. How the existing/proposed site activities could 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).
- Dolomite compartment maps of South Africa - Gauteng, North West and Ghaap Plateau Dolomite Units Map (DWS, 2024)
- SADC Groundwater Information Portal (SADC GIP) borehole data (SADC GIP, 2023).
- 2526 Johannesburg – 1:500 000 Hydrogeological map series (King, 1998).
- 2628 East Rand - 1:150 000 geology series (DMEA, 1998f).
- Literature on similar geology and hydrogeology:
  - A South African Aquifer System Management Classification (Parsons, 1995);
  - Aquifer Classification of South Africa (DWA, 2012);
  - 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).
- Site-specific data and investigation reports:
  - Malteries Soufflet New Maltings Plant for Heineken Sedibeng Brewery Geotechnical and Dolomite Stability Investigation (ARUP, 2019).
  - Geophysical Survey Report For Soufflet Malt, Midvaal Local Municipality, Sedibeng District, In Gauteng Province (NALEDZI WATERWORKS (PTY) LTD, 2023).
  - Graceview Industrial Park - Services Report for the Construction of Roads, Stormwater Drains, Water and Sewer Reticulation (Willie Coetzee Engineers CC, 2007).
  - Sedibeng Maltings Plant - Project Description/Environmental Impacts (RHDHV, 2024).
  - Geotechnical And Dolomite Stability Investigation For Proposed Malt Plant Sedibeng Graceview Extension 3 (CGEEG, 2016).

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, 2024) 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

According to the Water Allocation Registration Management System (WARMS, 2024), there are 17 WARMS users within a 5 km buffer of the project area, of which 4 groundwater and 1 surface water user falls within the HRU – 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 4-3 and SADAC GIP boreholes within a 5 km radius of the site are presented in Table 4-2. Based on the warms data collected it is noted that the existing groundwater use is in the order of 0.9 Mm^3/yr and surface water use is in the order of 4.2 Mm^3/yr.

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

ID	Latitude (WGS84)	Longitude (WGS84)	Status	Resource Type	WU Sector	Resource	Registered Volume (m³/yr.)
10000946	-26.45550	28.11290	ACTIVE	RIVER/STREAM	AGRICULTURE: IRRIGATION	RIETSPRUIT	175449
10005022	-26.40417	28.08333	ACTIVE	BOREHOLE	INDUSTRY (NON-URBAN)	NO NAME	550000
20011540	-26.47500	28.06111	ACTIVE	BOREHOLE	AGRICULTURE: IRRIGATION	NO NAME	105848
20011568	-26.47500	28.06111	ACTIVE	BOREHOLE	AGRICULTURE: IRRIGATION	NO NAME	135643
20022887	-26.42222	28.10833	ACTIVE	BOREHOLE	AGRICULTURE: IRRIGATION	NO- NAME	12200
20028989	-26.47500	28.06667	ACTIVE	RIVER/STREAM	AGRICULTURE: IRRIGATION	KLIPRIVER	600000
20029050	-26.43056	28.09861	ACTIVE	RIVER/STREAM	AGRICULTURE: IRRIGATION	KLIP RIVER	780000
20029069	-26.42222	28.08333	ACTIVE	BOREHOLE	INDUSTRY (NON-URBAN)	NO NAME	1200
20031644	-26.41062	28.09492	ACTIVE	RIVER/STREAM	AGRICULTURE: IRRIGATION	KLIPRIVER	62220
20037611	-26.46250	28.08472	ACTIVE	RIVER/STREAM	AGRICULTURE: IRRIGATION	KLIP RIVER	1145500
20037620	-26.46111	28.08611	ACTIVE	RIVER/STREAM	AGRICULTURE: IRRIGATION	KLIP RIVER	1460000
20042357	-26.40750	28.03380	ACTIVE	BOREHOLE	AGRICULTURE: IRRIGATION	UNKNOWN BOREHOLE	56301
20053647	-26.46891	28.06771	ACTIVE	BOREHOLE	INDUSTRY (URBAN)	BOREHOLE 1	19.88
20056163	-26.39592	28.01578	ACTIVE	BOREHOLE	AGRICULTURE: IRRIGATION	UNKNOWN BOREHOLE	40000
20056298	-26.42571	27.95522	ACTIVE	BOREHOLE	INDUSTRY (URBAN)	UNNAMED BOREHOLE	300
20059767	-26.43061	28.08252	ACTIVE	BOREHOLE	INDUSTRY (NON-URBAN)	BOREHOLE NO 1	500
20060443	-26.44070	28.12082	ACTIVE	BOREHOLE	INDUSTRY (URBAN)	BOREHOLE	600

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)	Lithology	Aquifer Type	Yield (l/sec)
708265	SADAC GIP	-26.41746	28.09305	1486.26	2.3	Paragneiss, quartzite, schiste, phyllite, amphibolite	Fissured	17
708268	SADAC GIP	-26.48636	28.07136	1467.397	10.7	Paragneiss, quartzite, schiste, phyllite, amphibolite	Fissured	30.3
708270	SADAC GIP	-26.48637	28.07136	1467.44	1.2	Paragneiss, quartzite, schiste, phyllite, amphibolite	Fissured	121.1
708271	SADAC GIP	-26.48636	28.07138	1467.35	6.1	Paragneiss, quartzite, schiste, phyllite, amphibolite	Fissured	0.3
708369	SADAC GIP	-26.43304	28.08413	1491.357	21.3	Paragneiss, quartzite, schiste, phyllite, amphibolite	Fissured	0
708370	SADAC GIP	-26.43304	28.08414	1491.294	10.7	Paragneiss, quartzite, schiste, phyllite, amphibolite	Fissured	0
708389	SADAC GIP	-26.48497	28.03358	1543.743	2.4	Paragneiss, quartzite, schiste, phyllite, amphibolite	Fissured	0
708390	SADAC GIP	-26.48496	28.03358	1543.729	4.3	Paragneiss, quartzite, schiste, phyllite, amphibolite	Fissured	0
708391	SADAC GIP	-26.48497	28.03357	1543.767	7.3	Paragneiss, quartzite, schiste, phyllite, amphibolite	Fissured	0
708392	SADAC GIP	-26.48498	28.03358	1543.757	4	Paragneiss, quartzite, schiste, phyllite, amphibolite	Fissured	0
708393	SADAC GIP	-26.48497	28.03359	1543.719	3.7	Paragneiss, quartzite, schiste, phyllite, amphibolite	Fissured	0
708671	SADAC GIP	-26.3986	28.13997	1553.723	14.2	Paragneiss, quartzite, schiste, phyllite, amphibolite	Fissured	0
708672	SADAC GIP	-26.39887	28.1408	1551	13.5	Paragneiss, quartzite, schiste, phyllite, amphibolite	Fissured	0
708772	SADAC GIP	-26.47831	28.03997	1527.607	14.6	Paragneiss, quartzite, schiste, phyllite, amphibolite	Fissured	0.3
708813	SADAC GIP	-26.47275	28.04969	1505.745	24.1	Paragneiss, quartzite, schiste, phyllite, amphibolite	Fissured	18.9
708814	SADAC GIP	-26.4797	28.06913	1479.17	9.2	Paragneiss, quartzite, schiste, phyllite, amphibolite	Fissured	0
708815	SADAC GIP	-26.47414	28.07386	1471.145	6.3	Paragneiss, quartzite, schiste, phyllite, amphibolite	Fissured	0.4
708818	SADAC GIP	-26.47136	28.07608	1476.612	5.6	Paragneiss, quartzite, schiste, phyllite, amphibolite	Fissured	6.3
708820	SADAC GIP	-26.4672	28.07525	1482.388	11.5	Paragneiss, quartzite, schiste, phyllite, amphibolite	Fissured	12.6
708821	SADAC GIP	-26.46026	28.0733	1483.621	7.7	Paragneiss, quartzite, schiste, phyllite, amphibolite	Fissured	0
708840	SADAC GIP	-26.48053	28.06858	1478.626	17.2	Paragneiss, quartzite, schiste, phyllite, amphibolite	Fissured	0
708908	SADAC GIP	-26.42443	28.09136	1481.606	3.7	Paragneiss, quartzite, schiste, phyllite, amphibolite	Fissured	0
706029	SADAC GIP	-26.41721	28.08858	1488.548	19	Dolomite and limestone	Karst	0
708223	SADAC GIP	-26.40935	28.05016	1533	42.2	Dolomite and limestone	Karst	50
708224	SADAC GIP	-26.42229	28.0528	1531.742	56.2	Dolomite and limestone	Karst	30

ID	Source	Latitude (WGS84) Decimal Degrees	Longitude (WGS84) Decimal Degrees	Elevation (mamsl)	Water Level (mbgl)	Lithology	Aquifer Type	Yield (l/sec)
708225	SADAC GIP	-26.41248	28.05711	1516.363	58.4	Dolomite and limestone	Karst	50
708226	SADAC GIP	-26.42576	28.04991	1522.335	42	Dolomite and limestone	Karst	0
708230	SADAC GIP	-26.40276	28.06525	1502.453	22	Dolomite and limestone	Karst	48
708231	SADAC GIP	-26.39101	28.04663	1549.216	22.3	Dolomite and limestone	Karst	10
708232	SADAC GIP	-26.4341	28.06227	1503.461	29.2	Dolomite and limestone	Karst	50
708234	SADAC GIP	-26.44537	28.05766	1505.983	32.3	Dolomite and limestone	Karst	25
708235	SADAC GIP	-26.45526	28.06025	1492.341	17	Dolomite and limestone	Karst	60
708237	SADAC GIP	-26.3821	28.0423	1580.779	97.3	Dolomite and limestone	Karst	0
708238	SADAC GIP	-26.45848	28.06605	1489.972	15.2	Dolomite and limestone	Karst	45
708239	SADAC GIP	-26.38254	28.05944	1511.733	31.6	Dolomite and limestone	Karst	0
708241	SADAC GIP	-26.3872	28.06302	1503.594	21.8	Dolomite and limestone	Karst	17
708242	SADAC GIP	-26.39348	28.06066	1509.158	31.4	Dolomite and limestone	Karst	30
708243	SADAC GIP	-26.37993	28.05775	1512.599	29.8	Dolomite and limestone	Karst	17
708245	SADAC GIP	-26.41554	28.05555	1525.818	51.3	Dolomite and limestone	Karst	12
708246	SADAC GIP	-26.42168	28.03105	1538.92	1.8	Dolomite and limestone	Karst	0
708267	SADAC GIP	-26.41626	28.06541	1500.027	22	Dolomite and limestone	Karst	1
708281	SADAC GIP	-26.44331	28.03358	1556.412	30	Dolomite and limestone	Karst	3
708337	SADAC GIP	-26.38804	28.03219	1625.83	0.3	Dolomite and limestone	Karst	0
708338	SADAC GIP	-26.38805	28.03219	1625.758	3.1	Dolomite and limestone	Karst	0
708384	SADAC GIP	-26.40887	28.02886	1593.164	3.7	Dolomite and limestone	Karst	0
708663	SADAC GIP	-26.37915	28.0608	1504.762	19	Dolomite and limestone	Karst	0
708664	SADAC GIP	-26.38387	28.05525	1522.38	38.5	Dolomite and limestone	Karst	0
708665	SADAC GIP	-26.38748	28.06163	1505	22	Dolomite and limestone	Karst	0
708666	SADAC GIP	-26.39637	28.06775	1497	12.6	Dolomite and limestone	Karst	0
708722	SADAC GIP	-26.42137	28.03636	1546.605	14	Dolomite and limestone	Karst	17
708725	SADAC GIP	-26.42415	28.05386	1516.624	28.1	Dolomite and limestone	Karst	0
708726	SADAC GIP	-26.4361	28.07469	1496.756	19	Dolomite and limestone	Karst	0
708727	SADAC GIP	-26.41804	28.08302	1489.381	11.2	Dolomite and limestone	Karst	0
708728	SADAC GIP	-26.41165	28.08247	1486.133	9.5	Dolomite and limestone	Karst	2.4
708729	SADAC GIP	-26.41026	28.08247	1490.511	6.5	Dolomite and limestone	Karst	0.6
708734	SADAC GIP	-26.40165	28.0658	1501.238	17.1	Dolomite and limestone	Karst	0
708735	SADAC GIP	-26.40915	28.06997	1491.854	0.5	Dolomite and limestone	Karst	0
708737	SADAC GIP	-26.44304	28.06469	1498.385	22.4	Dolomite and limestone	Karst	0
708738	SADAC GIP	-26.43443	28.0758	1497.617	19.8	Dolomite and limestone	Karst	4.1
708810	SADAC GIP	-26.46859	28.05247	1513.528	16.5	Dolomite and limestone	Karst	31.6
708811	SADAC GIP	-26.46775	28.05108	1524.117	20	Dolomite and limestone	Karst	0
708838	SADAC GIP	-26.46942	28.06775	1488.965	1	Dolomite and limestone	Karst	0.7
708913	SADAC GIP	-26.42693	28.0783	1496.862	17.5	Dolomite and limestone	Karst	2.4
708266	SADAC GIP	-26.41915	28.11302	1510.771	24.8	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708339	SADAC GIP	-26.41999	28.10858	1505.387	25.6	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708345	SADAC GIP	-26.41775	28.13192	1532.826	2.4	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708346	SADAC GIP	-26.41777	28.1319	1532.682	9.1	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708347	SADAC GIP	-26.41779	28.13192	1532.826	11	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708348	SADAC GIP	-26.41777	28.13194	1532.97	7.6	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708349	SADAC GIP	-26.41776	28.13191	1532.754	6.1	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708350	SADAC GIP	-26.41776	28.13193	1532.898	7	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708351	SADAC GIP	-26.41778	28.13191	1532.754	7	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708352	SADAC GIP	-26.41778	28.13193	1532.898	12.2	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0

ID	Source	Latitude (WGS84) Decimal Degrees	Longitude (WGS84) Decimal Degrees	Elevation (mamsl)	Water Level (mbgl)	Lithology	Aquifer Type	Yield (l/sec)
708353	SADAC GIP	-26.41775	28.13191	1532.754	19.2	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708354	SADAC GIP	-26.41775	28.13193	1532.898	19.5	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708355	SADAC GIP	-26.41779	28.13191	1532.754	1.4	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708356	SADAC GIP	-26.41779	28.13193	1532.898	5.2	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708357	SADAC GIP	-26.41776	28.1319	1532.682	1.3	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708358	SADAC GIP	-26.41776	28.13194	1532.97	4.6	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708359	SADAC GIP	-26.41778	28.1319	1532.682	6.1	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708360	SADAC GIP	-26.41778	28.13194	1532.97	12.2	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708361	SADAC GIP	-26.41775	28.1319	1532.682	3.1	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708362	SADAC GIP	-26.41775	28.13194	1532.97	11	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708363	SADAC GIP	-26.41779	28.1319	1532.682	9.1	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708364	SADAC GIP	-26.41779	28.13194	1532.97	5.5	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708365	SADAC GIP	-26.41774	28.13192	1532.826	12.2	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708366	SADAC GIP	-26.41777	28.13189	1532.61	9.1	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708367	SADAC GIP	-26.4178	28.13192	1532.826	0.9	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708368	SADAC GIP	-26.41777	28.13195	1533.042	2.1	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708371	SADAC GIP	-26.48525	28.07747	1471.739	24.4	Shale, mudstone and siltstone	Low potential	0.1
708372	SADAC GIP	-26.48526	28.07747	1471.753	7.3	Shale, mudstone and siltstone	Low potential	0.5
708373	SADAC GIP	-26.48524	28.07747	1471.724	12.2	Shale, mudstone and siltstone	Low potential	0.5
708374	SADAC GIP	-26.48525	28.07746	1471.762	13.7	Shale, mudstone and siltstone	Low potential	0.2
708375	SADAC GIP	-26.48525	28.07748	1471.714	19.2	Shale, mudstone and siltstone	Low potential	0
708376	SADAC GIP	-26.48524	28.07746	1471.75	4.9	Shale, mudstone and siltstone	Low potential	0
708730	SADAC GIP	-26.42415	28.09691	1482.363	5.3	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708731	SADAC GIP	-26.42276	28.09691	1480.993	4.8	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	1.2
708733	SADAC GIP	-26.43248	28.09136	1481.238	8.8	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	1.2
708739	SADAC GIP	-26.40721	28.13441	1541.209	9.9	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708740	SADAC GIP	-26.40693	28.13413	1541.838	19.5	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708741	SADAC GIP	-26.41387	28.13858	1537.61	6.9	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708742	SADAC GIP	-26.41276	28.1408	1535.217	10.1	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708817	SADAC GIP	-26.47553	28.08025	1470.337	5.4	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708828	SADAC GIP	-26.45887	28.11358	1507.631	9	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708829	SADAC GIP	-26.46193	28.11025	1506.162	7	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0.7
708830	SADAC GIP	-26.45887	28.10858	1504.85	7.3	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0.7
708831	SADAC GIP	-26.46581	28.13719	1516.207	7.1	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	7.6
708832	SADAC GIP	-26.46082	28.11997	1512	9.5	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708833	SADAC GIP	-26.48609	28.09969	1507.016	19.3	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708835	SADAC GIP	-26.46192	28.09886	1494.754	13.6	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708836	SADAC GIP	-26.45748	28.09275	1483.399	10.5	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708847	SADAC GIP	-26.43526	28.12025	1502.601	13.5	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708848	SADAC GIP	-26.43582	28.12137	1501.818	11.5	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708849	SADAC GIP	-26.43526	28.12163	1502.444	9.5	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708850	SADAC GIP	-26.43221	28.12441	1508	10.8	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708851	SADAC GIP	-26.43054	28.12469	1512.42	12.3	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708852	SADAC GIP	-26.42998	28.12441	1512.373	12.8	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708853	SADAC GIP	-26.43665	28.11136	1487.046	4.7	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708854	SADAC GIP	-26.43165	28.11969	1508.591	19.8	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708855	SADAC GIP	-26.42748	28.11913	1513.749	19.9	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0.3
708856	SADAC GIP	-26.42693	28.11941	1514.635	21.1	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0.3

ID	Source	Latitude (WGS84) Decimal Degrees	Longitude (WGS84) Decimal Degrees	Elevation (mamsl)	Water Level (mbgl)	Lithology	Aquifer Type	Yield (l/sec)
708861	SADAC GIP	-26.43221	28.11413	1503.948	16.8	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708862	SADAC GIP	-26.42748	28.1158	1510.757	22.6	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708863	SADAC GIP	-26.42248	28.11719	1516	23.6	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708864	SADAC GIP	-26.42276	28.11775	1516.399	20.9	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708865	SADAC GIP	-26.42221	28.11413	1513.153	23.9	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708866	SADAC GIP	-26.4261	28.1383	1525.543	12.3	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708867	SADAC GIP	-26.4411	28.13163	1493.594	4.8	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708868	SADAC GIP	-26.43637	28.12886	1506.877	6.7	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0.1
708869	SADAC GIP	-26.43721	28.12969	1504.785	7.9	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0.3
708870	SADAC GIP	-26.43721	28.12858	1505	10	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0.3
708871	SADAC GIP	-26.43665	28.1283	1505.799	11.3	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0.1
708873	SADAC GIP	-26.43887	28.12691	1500	10.3	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0.1
708875	SADAC GIP	-26.43998	28.12275	1495.319	1.8	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708876	SADAC GIP	-26.43971	28.11886	1489.926	9.3	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708878	SADAC GIP	-26.43804	28.11608	1498.25	17.4	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708879	SADAC GIP	-26.43748	28.11525	1498.936	18	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708880	SADAC GIP	-26.43748	28.11441	1493.123	10.3	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708881	SADAC GIP	-26.43748	28.11219	1482.847	2.4	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708882	SADAC GIP	-26.40776	28.13358	1539.316	9.4	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708883	SADAC GIP	-26.40276	28.12608	1533.551	20.3	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708884	SADAC GIP	-26.40276	28.12886	1535.517	19	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708886	SADAC GIP	-26.4111	28.13247	1537.782	15.6	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708887	SADAC GIP	-26.40693	28.12413	1529.583	10.3	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708888	SADAC GIP	-26.40998	28.12663	1534.744	17.9	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708889	SADAC GIP	-26.41165	28.12469	1530.329	24.6	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708890	SADAC GIP	-26.40915	28.13136	1538	12.5	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708891	SADAC GIP	-26.40971	28.13163	1537.515	22.7	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708893	SADAC GIP	-26.41554	28.13025	1535.256	13.1	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708894	SADAC GIP	-26.41637	28.13247	1535	25.1	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708895	SADAC GIP	-26.43137	28.13247	1515.566	5.3	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708896	SADAC GIP	-26.43248	28.13358	1515.098	5	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708897	SADAC GIP	-26.43082	28.14136	1517.196	11.8	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708899	SADAC GIP	-26.42248	28.10413	1496.973	18.8	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708900	SADAC GIP	-26.42165	28.10497	1498.392	19.4	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708901	SADAC GIP	-26.42193	28.11497	1513.25	26.8	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708902	SADAC GIP	-26.42332	28.11441	1512.375	35.5	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708903	SADAC GIP	-26.42193	28.11219	1511.042	25.4	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	2.2
708904	SADAC GIP	-26.42026	28.10941	1506.147	22.4	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0.1
708905	SADAC GIP	-26.41971	28.11108	1509.266	24	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708907	SADAC GIP	-26.42332	28.12386	1527	19.9	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708909	SADAC GIP	-26.42026	28.09886	1484.537	7	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0.6
708916	SADAC GIP	-26.42165	28.11358	1511.788	26.5	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708917	SADAC GIP	-26.42193	28.10413	1496.893	18.6	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	1.9
708918	SADAC GIP	-26.42276	28.1058	1503.748	22.9	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	1.3
708919	SADAC GIP	-26.42276	28.10525	1500.642	22.9	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708920	SADAC GIP	-26.42026	28.11691	1514.975	22.8	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708921	SADAC GIP	-26.42332	28.11552	1512.632	27.4	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708922	SADAC GIP	-26.42471	28.11275	1512.517	25.1	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	1.9

ID	Source	Latitude (WGS84) Decimal Degrees	Longitude (WGS84) Decimal Degrees	Elevation (mamsl)	Water Level (mbgl)	Lithology	Aquifer Type	Yield (l/sec)
708925	SADAC GIP	-26.42526	28.11497	1513	25.8	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708926	SADAC GIP	-26.42721	28.11136	1508.518	27.7	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708927	SADAC GIP	-26.42693	28.11163	1508.742	23.3	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708928	SADAC GIP	-26.42748	28.11247	1508.627	21.1	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708929	SADAC GIP	-26.42582	28.10969	1509.226	16	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708930	SADAC GIP	-26.4236	28.10747	1503.976	26.5	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	7.5
708933	SADAC GIP	-26.42582	28.10358	1495.789	17.1	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	2.5
708934	SADAC GIP	-26.42304	28.10525	1500.398	22.3	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708946	SADAC GIP	-26.42492	28.11313	1512.021	39	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708948	SADAC GIP	-26.42591	28.11009	1509.87	30	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708949	SADAC GIP	-26.42658	28.11009	1507.881	28	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708953	SADAC GIP	-26.42486	28.11383	1511.988	48	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708954	SADAC GIP	-26.42202	28.11174	1511.621	25	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708959	SADAC GIP	-26.42266	28.12014	1522.948	80	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708976	SADAC GIP	-26.42276	28.09746	1483.108	2.7	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708984	SADAC GIP	-26.4231	28.10024	1489.53	9.5	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708992	SADAC GIP	-26.4147	28.13858	1536.582	90	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708993	SADAC GIP	-26.41692	28.1408	1532.618	140	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708996	SADAC GIP	-26.42026	28.11441	1513	40	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708997	SADAC GIP	-26.42306	28.09746	1482.381	13	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708998	SADAC GIP	-26.41692	28.12913	1535.266	38	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
708999	SADAC GIP	-26.41498	28.13885	1536.053	15	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
709000	SADAC GIP	-26.41609	28.13996	1534.642	68	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
709005	SADAC GIP	-26.43387	28.14552	1508.735	38	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
709006	SADAC GIP	-26.43359	28.14494	1509.136	40	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
709007	SADAC GIP	-26.43248	28.14302	1509.363	55	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
709008	SADAC GIP	-26.43026	28.1438	1515.923	35	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
709009	SADAC GIP	-26.42831	28.13857	1522.939	100	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
709010	SADAC GIP	-26.42276	28.1358	1530.163	57	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
709011	SADAC GIP	-26.42054	28.13386	1533.566	40	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0
709012	SADAC GIP	-26.4222	28.1233	1528.909	42.5	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	0

4.4 Field hydrocensus and walkover assessment

Table 4-4 lists the field boreholes identified in the project area and the localities are shown in Figure 4-1. Two (2) boreholes exist on the premises, namely Malt BHT3 and Malt BHT4. There is substantial evidence of other drilling pads on site, however, these boreholes have been rehabilitated. Other NGA and SADAC GIP boreholes could not be located but are assumed to have existed in the past.

Table 4-4: Summary of field boreholes identified in the project area

BH ID	Latitude (WGS84)	Longitude (WGS84)	Elevation (mamsl)	Status	Collar (m)	Water Level (m)
Malt BHT4	-26.42866111	28.06867778	1530.348	Proposed for GW abstraction. BH is currently sealed. Water Level Taken	0.26	20.5

Malt BHT4

BH ID	Latitude (WGS84)	Longitude (WGS84)	Elevation (mamsl)	Status	Collar (m)	Water Level (m)
Malt BHT3	-26.43099118	28.06877843	1527.554	Prosed for GW Abstraction. Currently, the casing is open. Water sample and water level taken. pH - 6.8 EC - 42 mS/m TDS - 210 mg/l Temp - 18 ºC	0.45	21.45


Malt BHT3

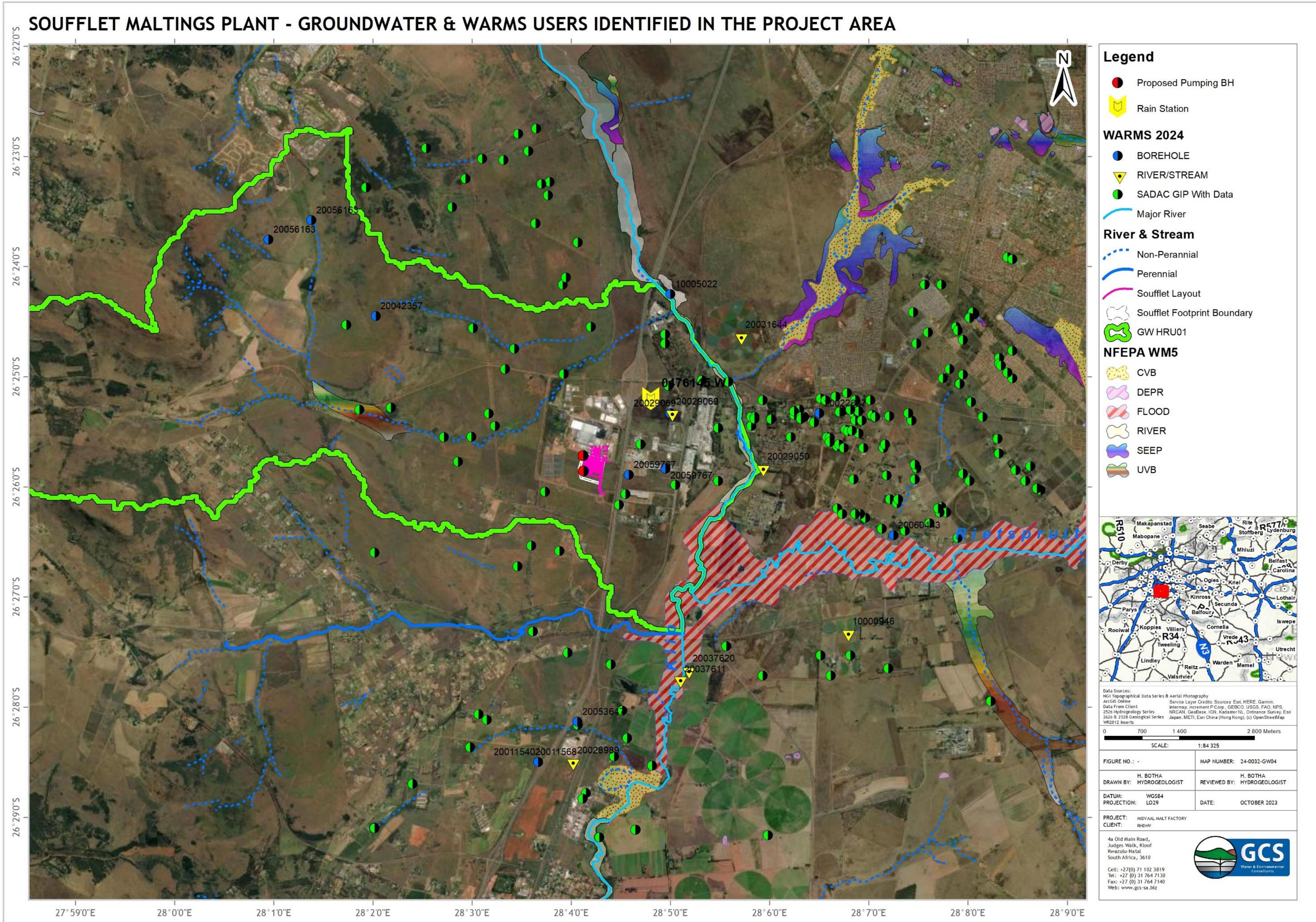


Figure 4-1: **Field boreholes, groundwater and surface water users identified within a 5 km radius of the site**

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. No artificial recharge was considered.

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:

$$R = \frac{Chloride\ concentration\ in\ rainfall}{Chloride\ concentration\ in\ ground\ water}\ x\ 100$$ **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 aquifer dewatering impacts. The groundwater reserve was further supplemented with existing allocations as per the DWS National Integrated Water Information System (NIWIS, 2023).

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

The IGRD considers the following parameters:

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

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

$$GWavailable = (Re) - (EU + BHN + BF + PU)$$ **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; or
- Where water resource quality is under threat.

To provide a quantitative means of defining stress, 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 to modify the stress index by taking the groundwater contribution to baseflow into account.

The modified stress index is as follows:

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

The stress index and classes described in Table 4-5 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 4-5: 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 4-2.

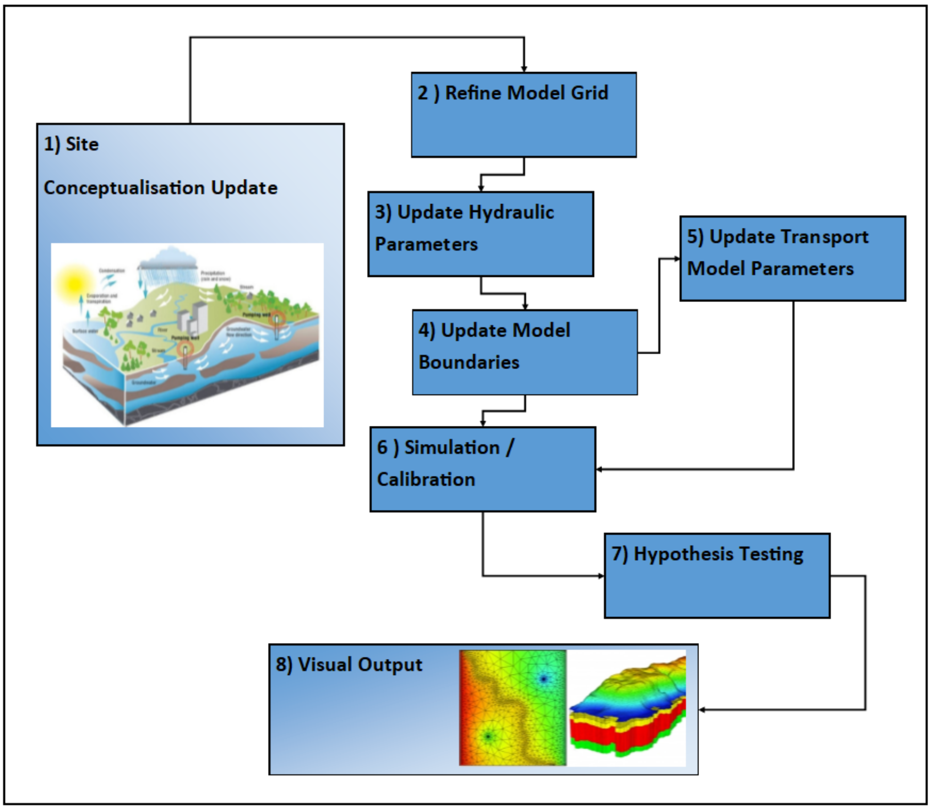


Figure 4-2: Numerical groundwater modelling process

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 how the predictions are 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 1st 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 4-6 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 4-7.

[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 4-6: 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 effect of the impact extends beyond municipal boundaries.
	National (5)	The effect of the impact extends beyond more than 2 regional/provincial boundaries.
	International (6)	The effect of the impact extends beyond country 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 4-7: 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 to be 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) that there is 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 4-3, below.

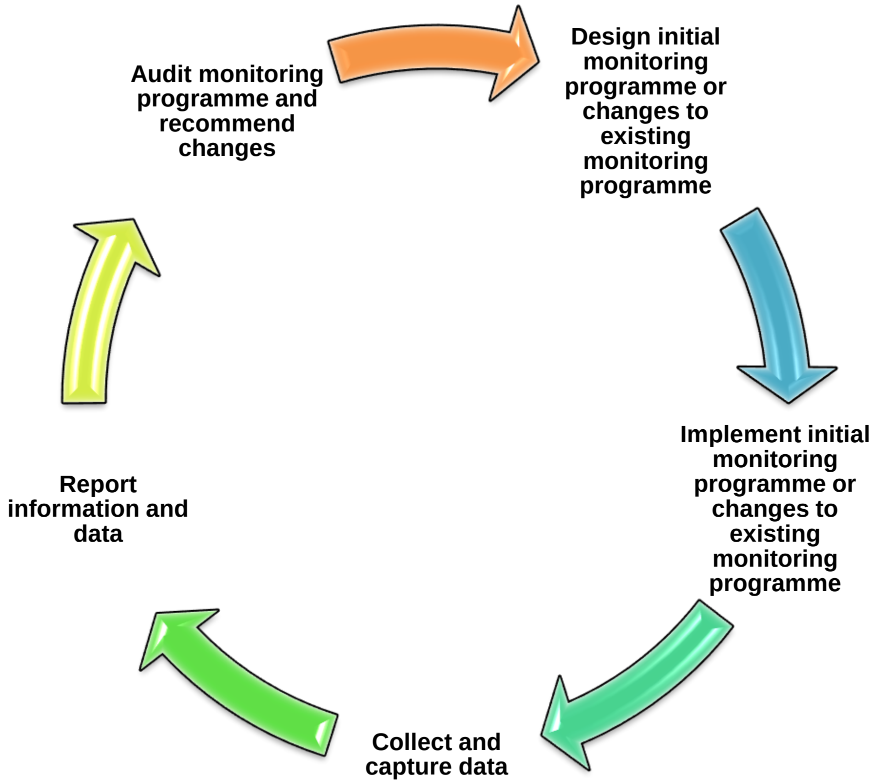


Figure 4-3: Monitoring Process

A groundwater monitoring plan was drafted and is based on 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 completed fieldwork.

5.1 Local geology and soils

According to the 1:150 000 geology series (2628 East Rand) maps for the area (DMEA, 1998f), the surface geology of the study is characterised by alluvium sands (~) along the Klip River flood plain, ferruginous shale and quartzite (Vt) of the Timball Hill Formation and dolomite & chert (Vdm) of the Malmani Formation of the Pretoria and Chuniespoort Supergroups, of the Transvaal Sequence - refer to Figure 5-6.

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

- Ab - Freely drained, red and yellow, dystrophic/mesotrophic, apedal soils comprise > 40% of the land type (yellow soils < 10%).

According to Soil Conservation Service (SCS) data for the project area, the soils are divided into "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

5.1.1 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. D

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. Intrusive dolerite/diabase (Vdi) is generally observed towards the hilly area west of the site – refer to Figure 5-6.

5.1.2 Site-specific geological observations

Several geophysical/gravity, geological investigation and dolomite studies have been completed for the project area (NALEDZI WATERWORKS (PTY) LTD, 2023); (CGEEG, 2016); (ARUP, 2019) in the effort to understand the sub-surface hydrogeology, structural geology and stability. All test pits and core drilling hole positions for the various studies undertaken are shown in Figure 5-7. A total of 41 boreholes have been drilled and the lithology data is available in **Appendix A**. The general lithology as encountered by the studies undertaken for the malt plant area is summarised in the extract below Table 5-2.

A summary of the geotechnical investigation findings for the site is provided below (ARUP, 2019):

- Drilling revealed that the upper soil profile is underlain by a relatively thick horizon of transported and pedogenic material. The transported horizon comprises gravels and fragments of quartzite, dolomite, chert and shale within a reddish-brown silty clay matrix. The transported horizon was encountered to depths ranging between 4 m and 10.5 m below ground level.
- The identification of the transported horizon was better discernible from the core recovered from the rotary drilled boreholes whereas only chips/ fragments of rock are recovered during percussion drilling.
- Evidence of residual dolomite and chert of the Malmani subgroup was encountered at depths ranging between 3 m and 12 m below ground level.
- Weathered altered dolomite (WAD), an insoluble and highly compressible material comprising manganese and iron, developed during the weathering of dolomite, was logged within the dolomite residuum during the percussion drilling.
- Wad was encountered in nine (9) boreholes at depths ranging from 6 m to 31 m except for PPBH04, PBH05 and PPBH09. Cavities were encountered in five (5) of the boreholes (PPBH02, PPBH09 - PPBH12).
- Highly to slightly weathered dolomite was encountered at depths ranging from 9 m to 39 m below existing ground level. Unweathered dolomite was encountered at depths ranging from 19 m and 41 m and is typically based on identification of the chips recovered and where penetration rates are greater than 3 minutes per metre.

- Correlation of the depth of intersection of the dolomite in the percussion and rotary core boreholes show that the highly to slightly weathered dolomite correlates well with the slightly weathered, very hard rock dolomite intersected in the rotary core boreholes at depths of approximately 12 m and 27 m.

Table 5-2: Summary of soil and rock profiles from test drilling (ARUP, 2019)

Geological Origin	Formation	Depth (m)	Description	Water table
Transported material	Alluvium	0-7	Silty sand, with subrounded quartzite gravels.	Out of 18 boreholes drilled, three boreholes had water rest levels (9.8m, 16.1m, 22.1m). The localised occurrence of the rest level measurements suggest that it does not represent a permanent groundwater level.
Residual shale	Residual/very soft shale	9.0-26.0	Layers of silt, carbonaceous shale and coarse sandstone	
Intrusive rocks	Syenite	12-15	Very soft syenite	
Malmani Subgroup, Chuniespoort Group	Residual chert and dolomite	8.1 – 53	Grey silty clay with chert. Dark grey, sandy silt with wad and minor highly weathered dolomite. No Cavities encountered.	
Malmani Subgroup, Chuniespoort Group	Dolomite bedrock	14-60	Grey, slightly weathered, hard rock at least 6m thick	

A gravity survey was conducted on the proposed site in 2014, by Engineering & Exploration Geophysical Services and a follow-up survey by Geofocus Geophysical Services. in 2019. The residual gravity map of the site is characterised by deep and often broad lows edged by highs as shown in Figure 5-1. A comparison of the gravity survey and the percussion drilling results revealed that there exists a good correlation between the gravity high, which reflects shallow bedrock, and gravity low which reflects deep bedrock and/ or potential cavities. The gravity high is denoted by the purple and red tones and the gravity low by blue and green tones. A distinct indication of high density (potential shallow bedrock) and low density (potentially deeply weathered zones/ deep bedrock and/ or potential cavities).

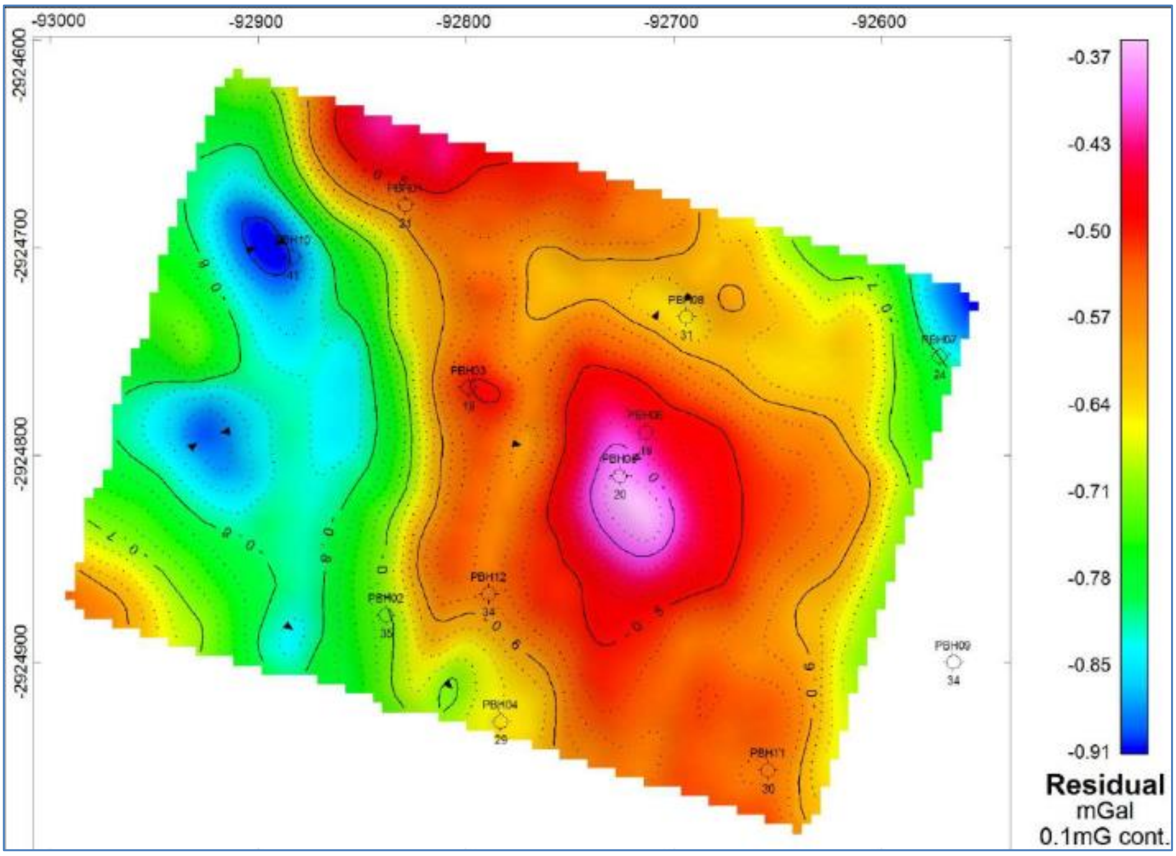


Figure 5-1: Combined 2014 and 2019 gravity survey results (ARUP, 2019)

5.2 Aquifer characteristics and classification

The site falls within National Quaternary catchment C22D, which forms part of the Middle Klip River dolomite compartment. There are no springs recorded within the Upper Vaal Water Management Area (WMA). The general aquifer characteristics and aquifer classification are summarised in Table 5-3.

Table 5-3: Aquifer characteristics and classification

Characteristics	Aquifer Classification
The aquifer host rock comprises carbonate rocks (dolomite) and occurrences of argillaceous rock (shale, mudstone, siltstone, quartzite) towards the west of the project area – refer to Figure 5-8. The aquifers have medium to high hydraulic conductivities (K-value) and porosity (n-value). The aquifer is mainly secondary. The aquifers can be referred to as being Karst (King, et al., 1998). Groundwater is typically encountered in: - Solution channels and fractures occurring in the carbonate rocks of the Chuniespoort Group; and - Faults and associated shear zones.	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 (alluvium) of the Klip River flood plain (varies thickness from 0 to 10m zones) 2. A semi-confined/perched aquifer system associated with the weathered very soft rock shale and interbedded zones of WAD and Dolomite bedrock (varied thickness from 9 to 29 m for the site, average in the order of 17.8 m) 3. A deeper fractured and Karst aquifer zone associated with the Dolomites (thickness > 100 m) The aquifer present is classified as a Major Aquifer system (Parsons, 1995)

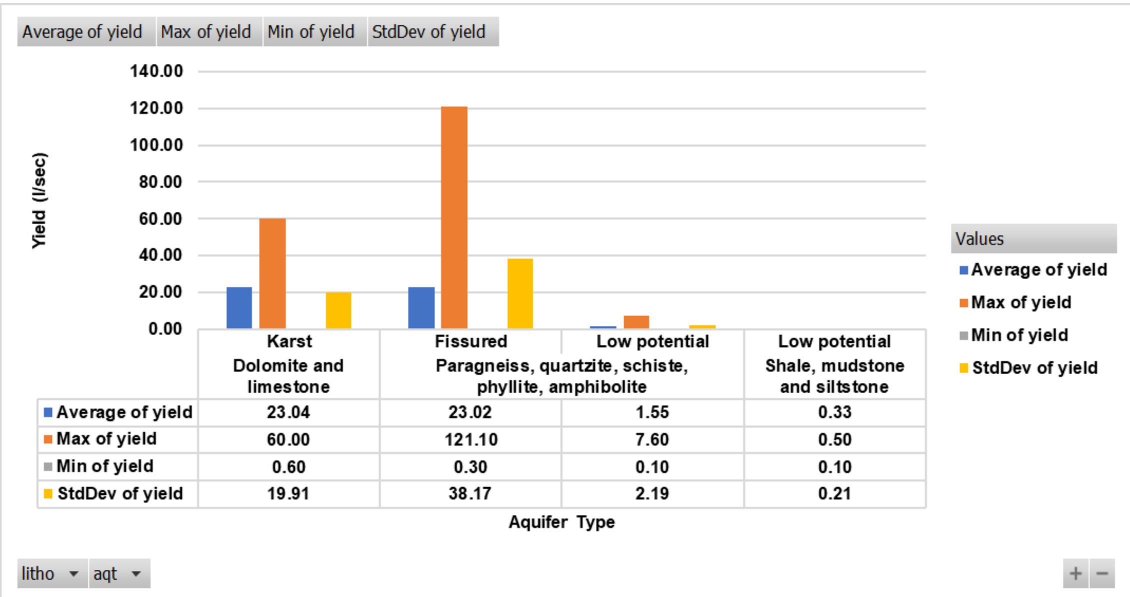
Characteristics	Aquifer Classification
The aquifer's weathered zone is reported to be approx. 20 m to 40 m thick and is highly variable. The fractured/karst aquifer zone is estimated to be approx. 140 m thick (DWAF, 2006). The combined aquifer thickness is estimated to be in the order of 180 m. The aquifer is an important contributor to groundwater baseflow to streams and rivers (King, et al., 1998).	The aquifer underlying the study area is considered high-yielding (median yields > 5 l/sec – Class c5 aquifers).

5.3 Aquifer transmissivity and yield

During geotechnical and dolomite studies conducted by ARUP (2019), it was noted that none of the boreholes had water strikes. However, a review of available SADAC GIP (2024) data suggests variable yields (airlift/blow yields) for successful boreholes drilled with water strikes. Blow yields for different lithologies in the project area are shown in Figure 5-2.

The aquifers occurring at the site have reported yields >5 l/sec. Transmissivity (T) values for the weathered aquifer range between 0.001 - 5 m²/d for boreholes not connected to the Karst system. Test pumping of exploration boreholes in the Klip River and Natalspruit Compartments (Kafri et al 1986) gave highly variable results, with T ranging from 2-10 of m³ /day/m to 1000-2000 m³ /day/m.

The highly transmissive nature of the dolomites results in the water table being very flat, with a very low gradient from one end of a compartment to the other. Solution cavities and fissures are likely to be enlarged with time by the rapid and continuous circulation of water from the surface into mine voids, thus increasing transmissivity and storage. This will induce hydraulic erosion of cavity/fracture infillings and chemical dissolution of the dolomite.



	Karst	Fissured		Low potential
	Dolomite and limestone	Paragneiss, quartzite, schiste, phyllite, amphibolite	Low potential	Shale, mudstone and siltstone
Average of yield	23.04	23.02	1.55	0.33
Max of yield	60.00	121.10	7.60	0.50
Min of yield	0.60	0.30	0.10	0.10
StdDev of yield	19.91	38.17	2.19	0.21

Figure 5-2: Recorded blow yields at successful boreholes drilled in the project area (SADAC, 2024)

5.4 Aquifer storage/storativity

Most groundwater potential occurs in the first 100 m and particularly, the first 30 m below the original water table (DWS, 2006). According to King *et al.* (1998) and DWAF (2006), the aquifer storage/storage coefficient is in the order of magnitude of 0.1 to 1. Table 5-4 provides literature values for various values put forward by other specialist investigations.

The data presented in the above section shows the wide variation in T and S within the dolomite. Because of the nature of karst, these variations cannot be assigned to specific areas or zones and conditions vary greatly over short distances (Hodgson, et al). Transmissivity and S-values obtained from test pumping can be particularly site-specific and also misleading. Water balances offer a better method of obtaining representative S values (Bredenkamp, 1995).

Table 5-4: Summary of specific storage for various material types (DWS, 2006)

Author	Depth Interval	Storage
Foster	0 – 100 m >100 m	6 % 2 %
De Kock	First 30 m Next 30 m >60 m	10 % 2 % <1 %
DWAF	First 30 m 30 to 150 m	15 % 1.5 %
SRK	Average for the Zuurbekom Compartment from a groundwater Balance for the period 1966 to 1983:	1.3 %
Bredenkamp	Dolomites in general	1 – 5 %

5.5 Groundwater recharge

Using comparative, chloride mass balance and water balance methods, Kafri (op cit) derived recharge figures of 20% and 13% of Mean Annual Precipitation (MAP) for chert-rich and chert-poor dolomites, respectively. According to 2012 and DWS (2006) data recharge to the underlying aquifer generally range from 6 to 10% of the MAP on a quaternary level (DWAF, 2006). The recharge to the aquifer on a sub-catchment level (GW HRU) was further refined and determined by running qualified guess analyses using the RECHARGE model developed by IGS, as summarised in Table 5-5. A recharge of 50.5 mm/yr corresponding to 7.9% 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 5-5: RECHARGE Program (Van Tonder & Yongxin Xu, 2000)

Method	mm/a	% of rainfall	Certainty (Very High=5 ; Low=1)	
Soil	80.0	12.5	4	
Geology	54.7	8.5	4	
Vegter	95.0	14.8	4	
Acre	10.0	1.6	3	
Harvest Potential	25.0	3.9	3	
Base Flow (minimum Re)	13.3	2.1		
Recharge =	50.5	7.9	=	2.991115

5.6 Depth to groundwater and flow direction

Groundwater levels are characterized by low gradients bounded by 'steps' along known and inferred dykes. At a regional scale, groundwater levels indicate flow converging onto the main drainage channels and southwards towards the Vaal River. Groundwater in the Kip River area can be divided into numerous small compartments based on groundwater levels. These compartments appear to be in connection with the Klip River. Gradients vary from ~0.1% to ~0.2% (DWS, 2006).

According to WR2012 (Bailey & Pitman, 2015) and DWAF GRAII (DWAF, 2006) data, the groundwater level in the project area average is in the order of 15.7 mbgl (metre below ground level). During geotechnical and dolomite studies conducted by ARUP (2019), it was noted that none of the boreholes had water strikes. The water rest level was also recorded after 24 hours as dry for all boreholes drilled. Available SADAC GIP and field hydrocensus data suggest a local water table in the order of 20 mbgl and that the groundwater table.

It is further noted that the groundwater levels for boreholes drilled into the Karst and fissured/fractured zones have a good relationship with the topography elevations – refer to Figure 5-3 to Figure 5-4. For these aquifer zones, the groundwater levels are expected to mimic the topography to some extent. However, for boreholes drilled into isolated systems i.e. paragneiss, quartzite, schist, phyllite, and amphibolite the water levels vary and a poor correlation is observed– refer to Figure 5-5

Figure 5-9 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.

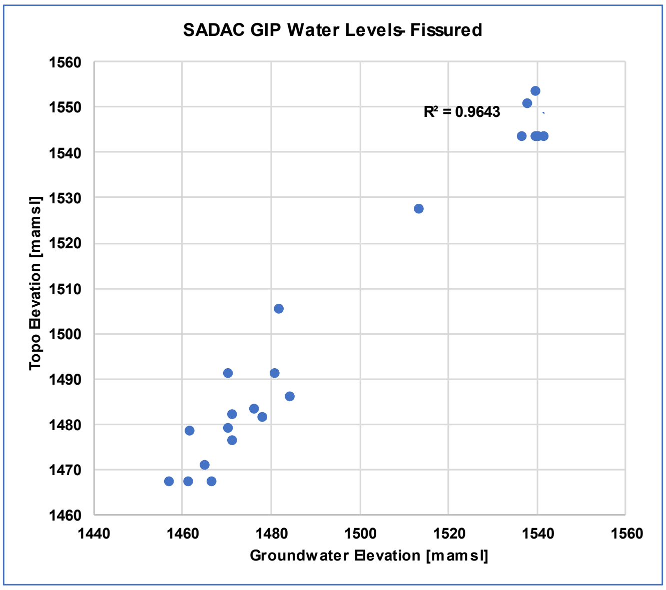


Figure 5-3: Groundwater vs. topography elevations - Fissured

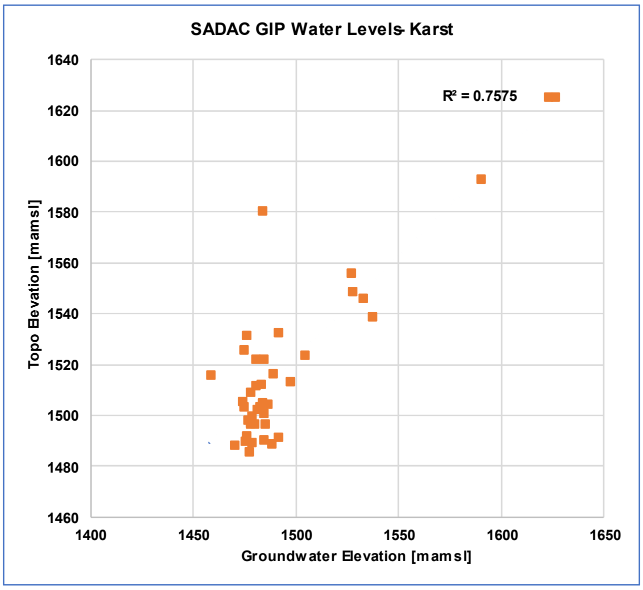


Figure 5-4: Groundwater vs. topography elevations – Karst

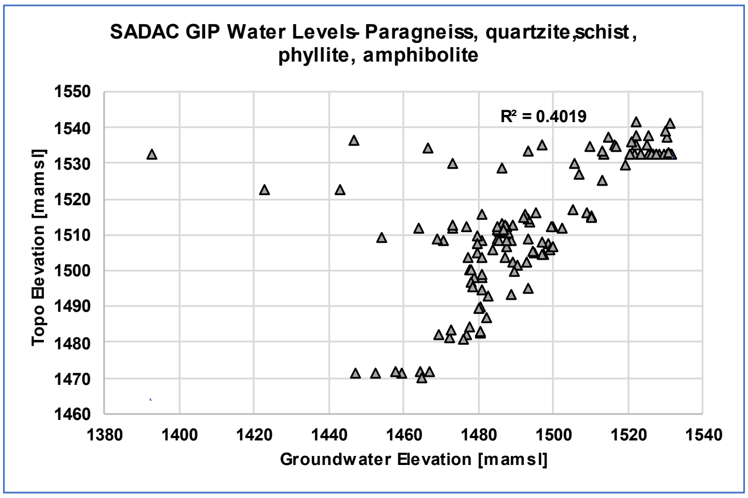


Figure 5-5: Groundwater vs. topography elevations - Paragneiss, quartzite, schist, phyllite, amphibolite

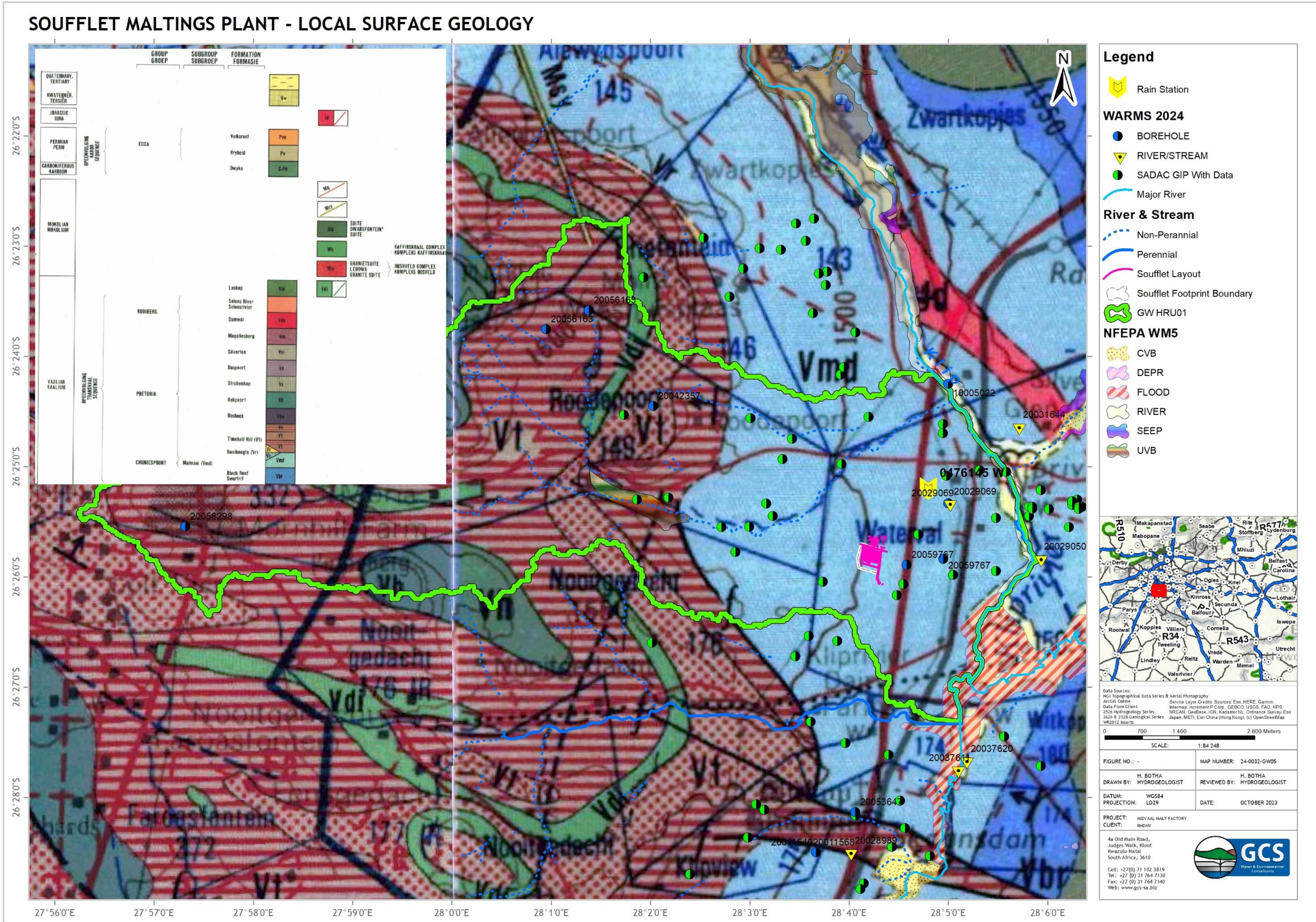


Figure 5-6: Regional surface geology

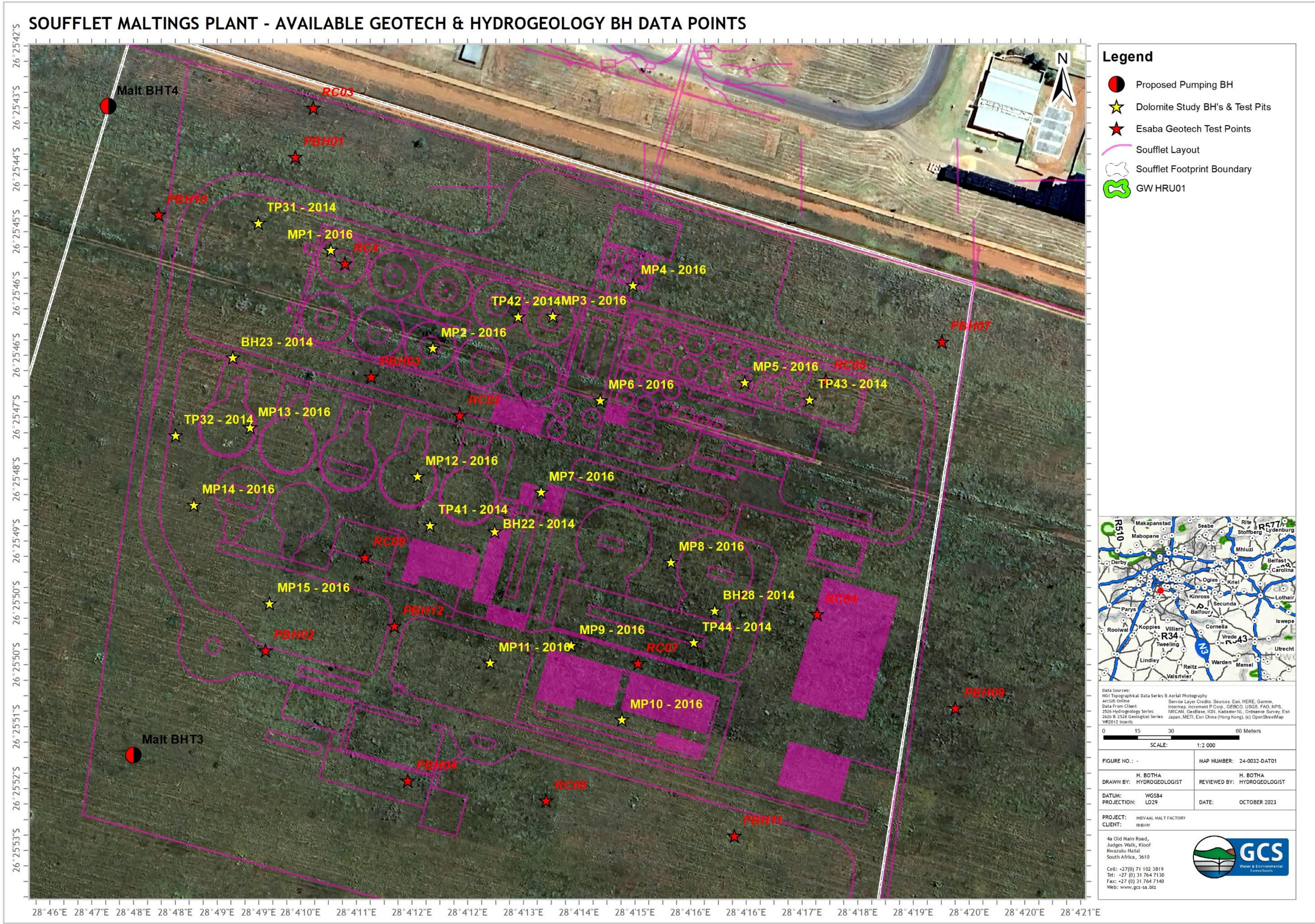


Figure 5-7: **Geotechnical test pits and boreholes used for site conceptualisation**

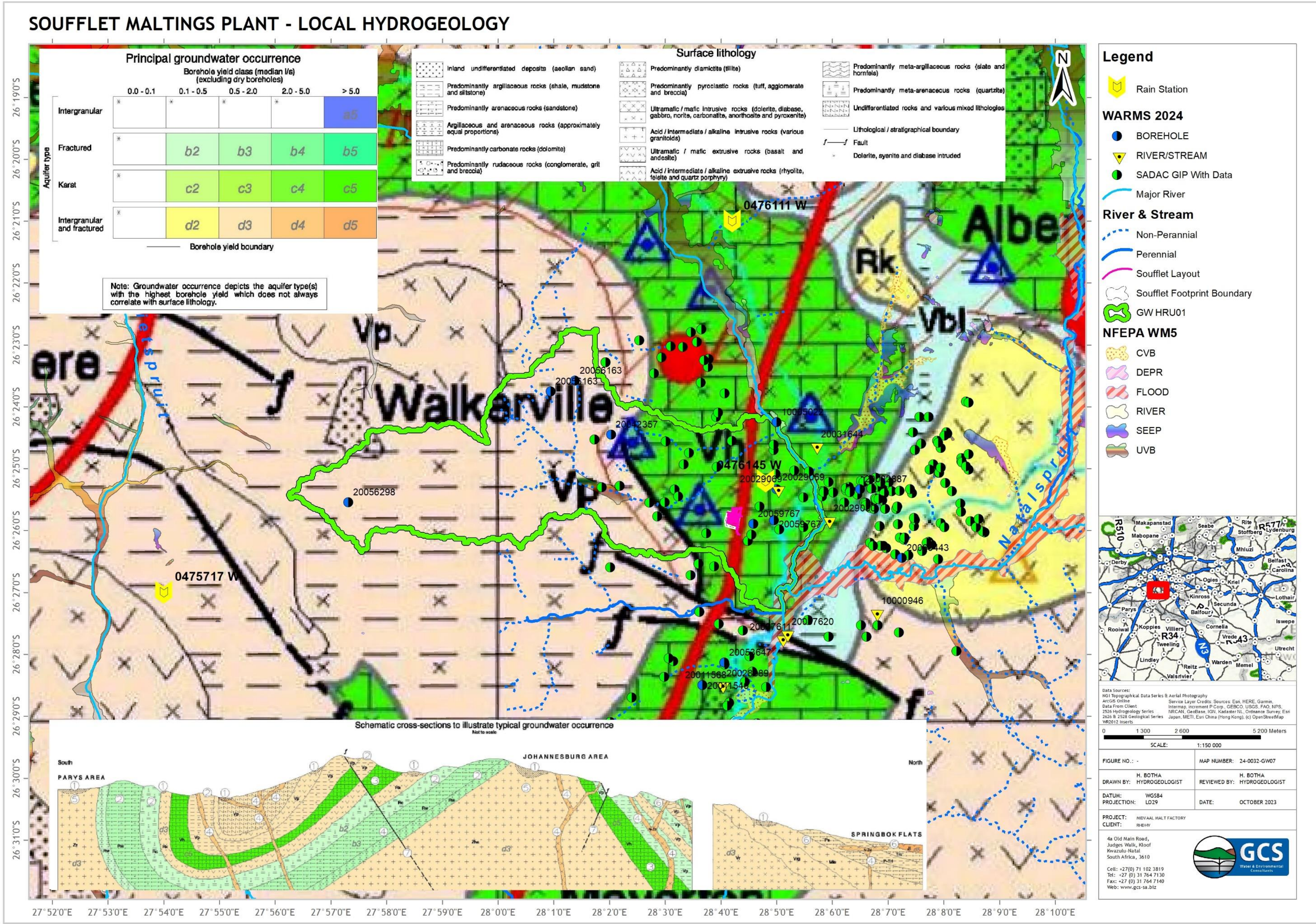


Figure 5-8: **Regional hydrogeological characteristics**

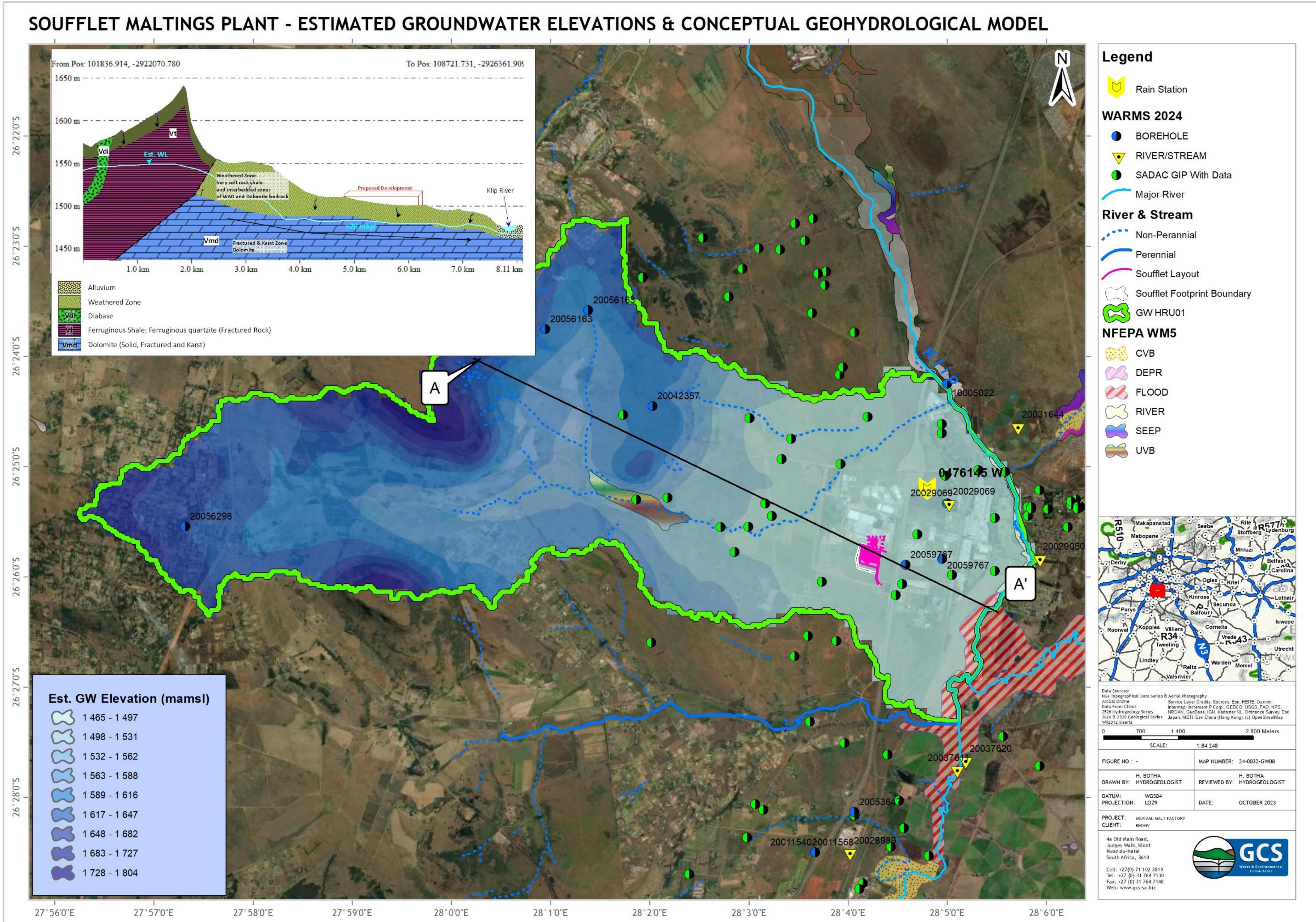


Figure 5-9: **Estimated groundwater elevations, flow direction and site conceptual cross-sections**

5.7 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, the NFEPA WM5 indicates the Klip River flood plain as a riverine system – refer to Figure 5-9.

In terms of river geo-hydrology, baseflow is considered the most important contributor to stream and wetland health. Baseflow (refer to Figure 5-10) is a non-process-related term to signify low amplitude high-frequency flow in a river during dry or fair-weather periods. Baseflow is not a measure of the volume of groundwater discharged into a river or wetland, but it is recognised that groundwater contributes to the baseflow component of a river or wetland flow.

Available literature (WRC, 2015; DWAF, 2006) suggests groundwater contribution to baseflow ranges from 6 mm/yr (PITMAN MODEL) to 13 mm/yr (HUGHES MODEL). This relates to approximately 0.1% to 3% of rainfall.

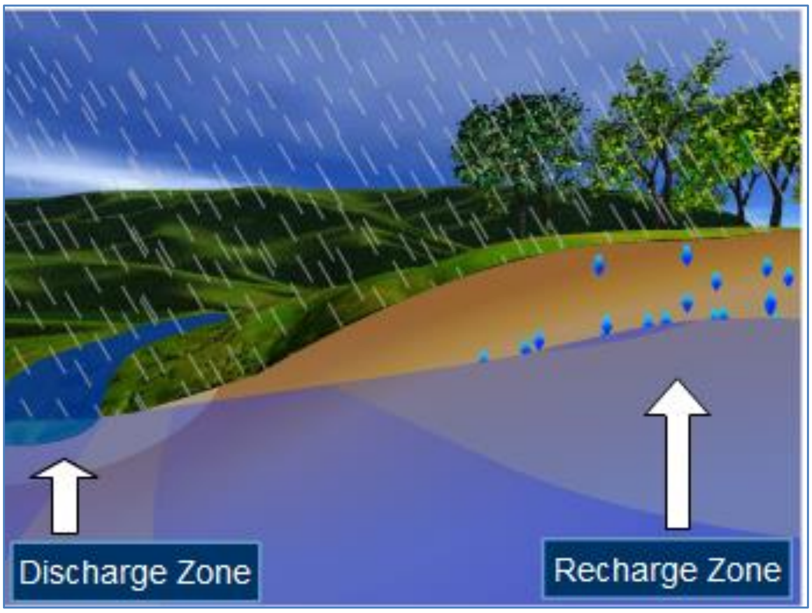


Figure 5-10: Groundwater baseflow concept (DWAF, 2007)

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

Table 5-6 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 5-6: Summary of PES, EIS and EWR

Quat	PES	EIS	Reserve (EWR) % of NMAR	Source
C22H	C Modified	Moderate	20-40%	WR2012

5.9 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 50% for dolomite/limestone will be used)

i =probable average hydraulic gradient (Equation 4)

$$i = \frac{h1-h2}{l}$$ ……………………………………………………………………………… **Equation 8**

The hydraulic gradient is calculated in Table 5-7. Table 5-8 shows the results of the flow velocity equation. A porosity of 50% was applied to the underlying hydrogeology (Freeze and Cherry, 1979).

Table 5-7: Hydraulic gradient calculation

Component	Malt BHT4 to Malt BHT3
h1 (mamsl)	1480.24
h2 (mamsl)	1479.1
h1-h2 (m)	1.14
L (m)	258.35
i	0.004
K (m/day)	2
n	0.5

Table 5-8: Flow velocity calculation

	Malt BHT4 to Malt BHT3
m/day	0.0177
m/year	6.4424

5.10 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 HRU. It should be noted that the site falls on the Middle Klip River dolomite compartment which suggests that there will be transboundary aquifer flow, in context to the delineated GWRU. The study aims at focusing on the local impact and transboundary interflow was not considered in the groundwater modelling. This is due to the type of project and predicted small-scale abstraction proposed (300 m³/day) as a backup supply.

5.11 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.

5.11.1 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 5-11) 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. Natural dolomitic groundwater is essentially a Ca/Mg $(HCO_3)_2$ type - alkaline. In-situ parameters measured on-site correspond to the literature ranges. 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.

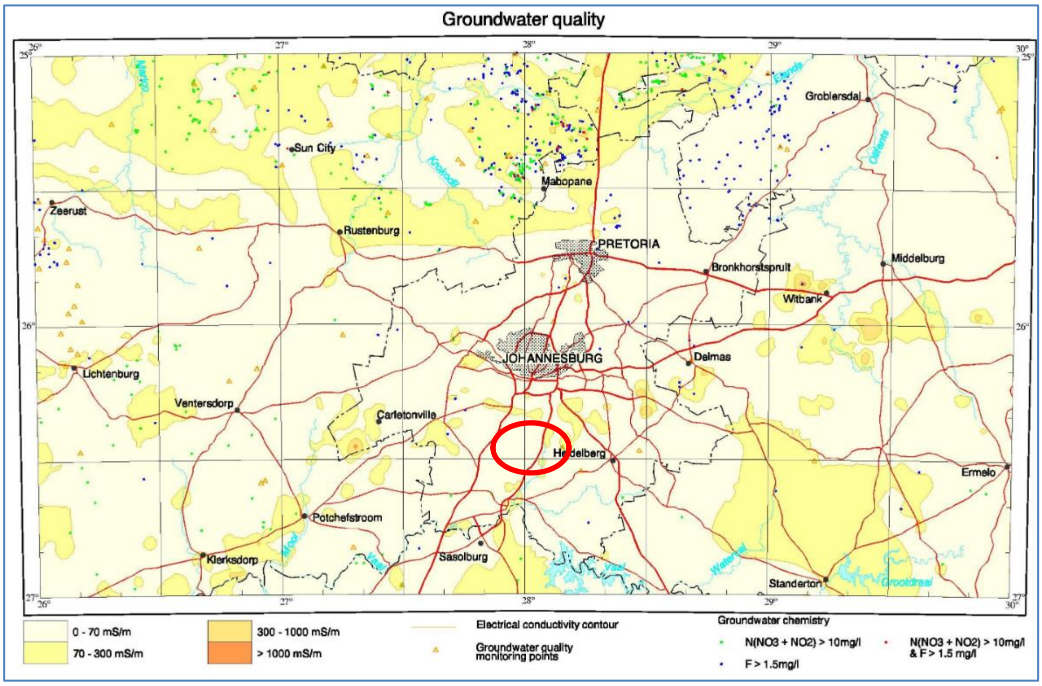


Figure 5-11: Groundwater quality (King, 1998)

5.11.2 Site water quality data

One (1) groundwater sample was collected from Malt BHT3. The sample was submitted to Aquatic Laboratories (SANS T0685) for analytical screening. Table 5-9 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 summarised as follows:

- The groundwater sample is pH-neutral.
- Electrical conductivity (EC) is well withing DWAF TWQV.
- Calcium (Ca) is the only constituent that is high compared to DWAF TWQV. No adverse effects are anticipated if the water is consumed. Scaling of appliances and in-water supply pipes is likely.

A piper diagram for the samples taken is presented in Figure 5-12. The following serves as an interpretation:

- The sample plots towards the upper apex of the left ternary diagram, which indicates that the groundwater is dominated by Ca and Mg cations. Na and K cations are less dominant. This is typical of a dolomitic environment.
- The sample plots towards the left apex of the right ternary diagram, which indicates that the groundwater environment is dominated by HCO_3 anions.
- The sample plots towards the left apex of the centre rhombus, which suggest that the groundwater environment intercepted by BH TBH3 can be classified as Ca-HCO_3 waters. This is typical of shallow fresh groundwater environments.

Table 5-9: Summary of hydrochemistry data

Constituent	Unit	Malt TBH3	DWAF 1996 Domestic Use – TWQR
pH in water at 25ºC	**-**	7.87	4 - 9
Conductivity in mS/m @ 25ºC	**mS/m**	37.7	0 - 70
Bicarbonate Alkalinity as CaCO3	**mg/l**	211	ns
Total Alkalinity as CaCO3	**mg/l**	213	ns
Calcium	**mg/l**	47.3	0 - 32
Magnesium	**mg/l**	28.7	0 - 30
Potassium	**mg/l**	0.831	0 - 50
Sodium	**mg/l**	4.29	0 - 100
Chloride	**mg/l**	1.57	0 - 100
Nitrate	**mg/l**	2.77	0 - 6
Nitrate as N	**mg/l**	2.77	ns
Sulphate	**mg/l**	7.35	0 - 200
Aluminium	**mg/l**	<0.002	0 - 0.15
Iron	**mg/l**	<0.004	<0.1
Manganese	**mg/l**	0.007	<0.05
Orthophosphate (Total Reactive Phosphorous or PO4)	**mg/l**	0.347	ns
Sodium Adsorption Ration (SAR)	**Calculated**	0.12	>8

ns = No Quality Range in Reference Guideline, Orange = Above DWAF (1996) Ideal Water Quality Ranges

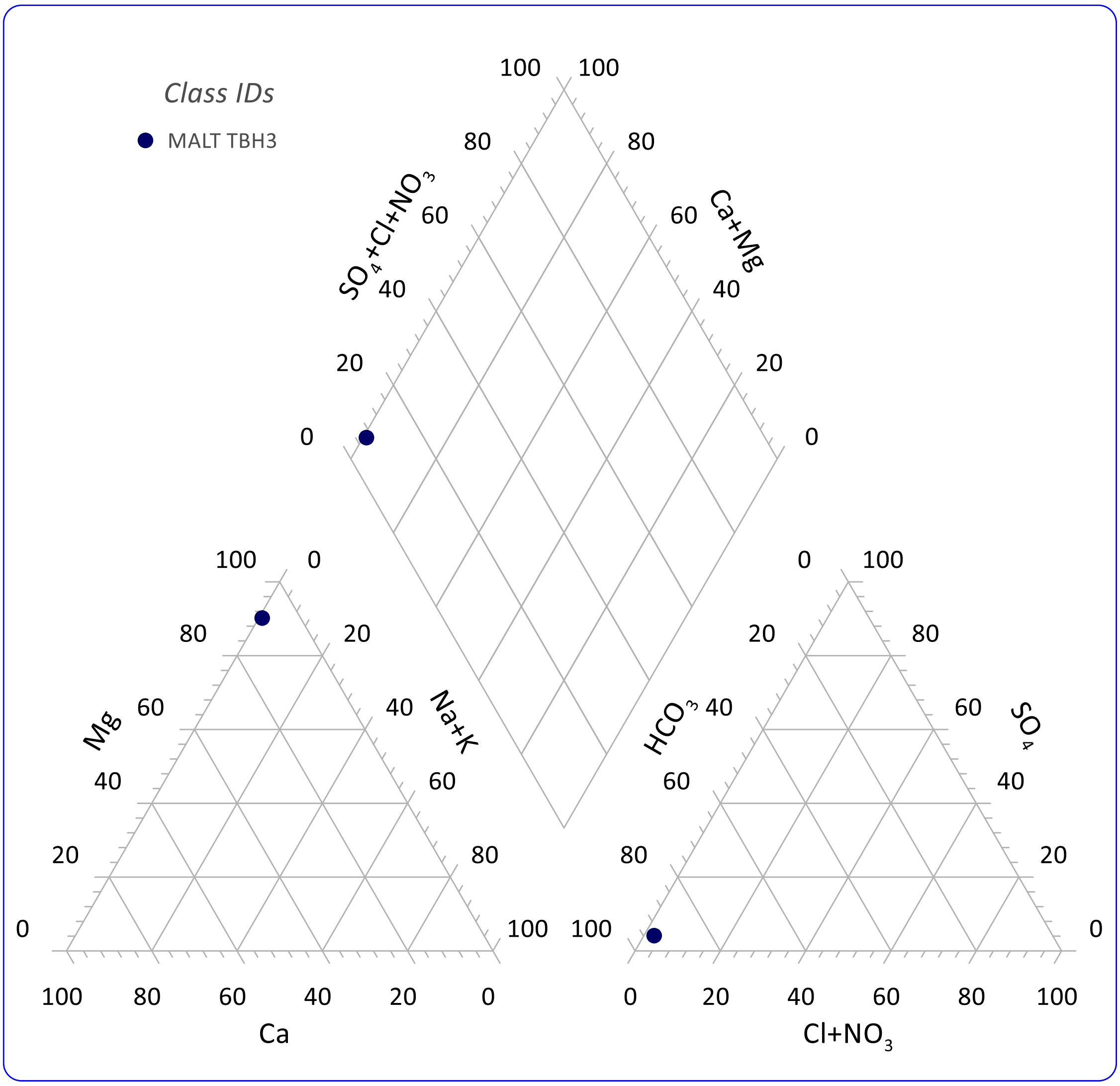


Figure 5-12: Sample piper diagram

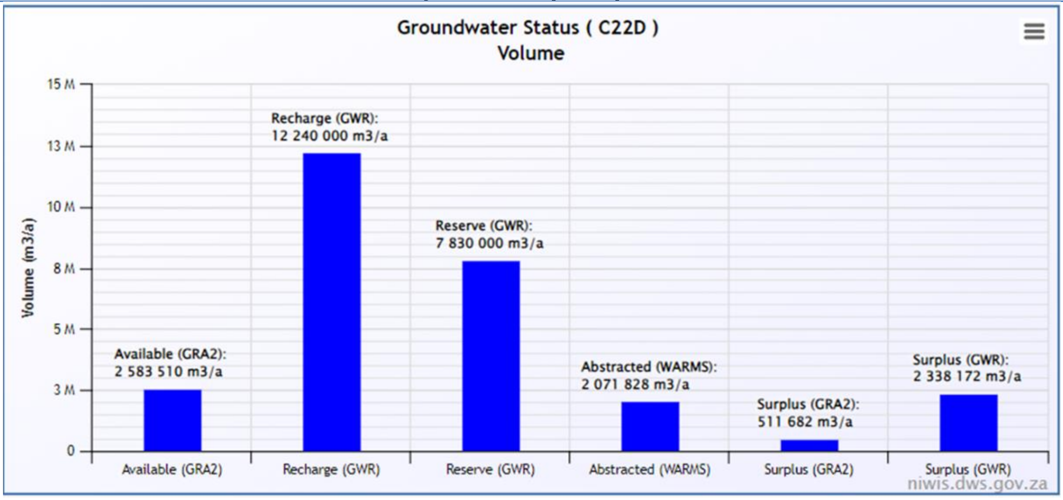
5.12 Groundwater quantity

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 5-10. Reserve allocations retrieved from the DWS (2023) National Integrated Water Information System are presented in Table 5-11. There is a surplus reserve observed for all sub-catchments associated with the project area. Aquifers are therefore considered unstressed.

Table 5-10: Summarised Quaternary Catchment Information (Aquiworx, 2015)

Quaternary Catchment	Total Area (km²)	Recharge (mm/yr)	Rainfall (mm/yr)	Baseflow (mm/yr)
C22D	345.3	58	700.5	13 [Pitman]

Table 5-11: Summary of DWS (2023) GW Reserve Allocations



5.12.1 Existing groundwater usage (EU)

A volume of 2472.91 m³/day is allocated to the water balance. The allocation is based on WARMS data for boreholes (verified or unverified) that fall in the GW HRU.

5.12.2 Basic human needs (BHN)

BHN was calculated from a reduced population from 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.

5.12.3 Proposed groundwater usage (PU)

The PU is based on the likelihood that there will be a combined volume of 300 m³/day pumped from Malt BHT3 and Malt BHT4. It should be noted that the definite usage of the boreholes is yet to be confirmed, and only included to evaluate the potential risks associated with the proposed activity.

5.12.4 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.

5.12.5 Groundwater balance

The reserve determination for the sub-catchment associated with the project is summarized in Table 5-12. A surplus reserve for the GW HRU is noted.

Table 5-12: Groundwater reserve determination for the sub-catchment area

GW HRU01		
Area	59.23	km²
Rainfall	642.60	mm/yr
BF	13.23	mm/yr
Aquifer Recharge		
Re	50.77	mm/yr
Re to Aquifer	3 006 928.97	m³/yr
Re %	7.90	%
Existing Use (EU)		
WARMS 2024	2472.91	m³/day
Total EU Day	2472.91	m³/day
Total EU Year	902611.88	m³/yr
Basic Human Needs		
BHN	0.00	m³/day
BHN	0.00	m³/yr
Base Flow		
BF	783639.36	m³/yr
Available	1320677.73	m³/yr
Proposed Use (PU)		
Malt BHs	300.00	m³/day
		m³/day
Total PU Day	300.00	m³/day
Total PU Year	109500.00	m³/yr
Nett Balance	1211177.73	m³/yr

6 SITE CONCEPTUAL MODEL

The Site Conceptual Model (SCM) developed focused on the Soufflet Maltings Plant area and the receiving groundwater environments. The estimated groundwater flow fields are captured in Figure 5-9 (Section 5) and the conceptual geohydrological cross-section is shown in Figure 6-1.

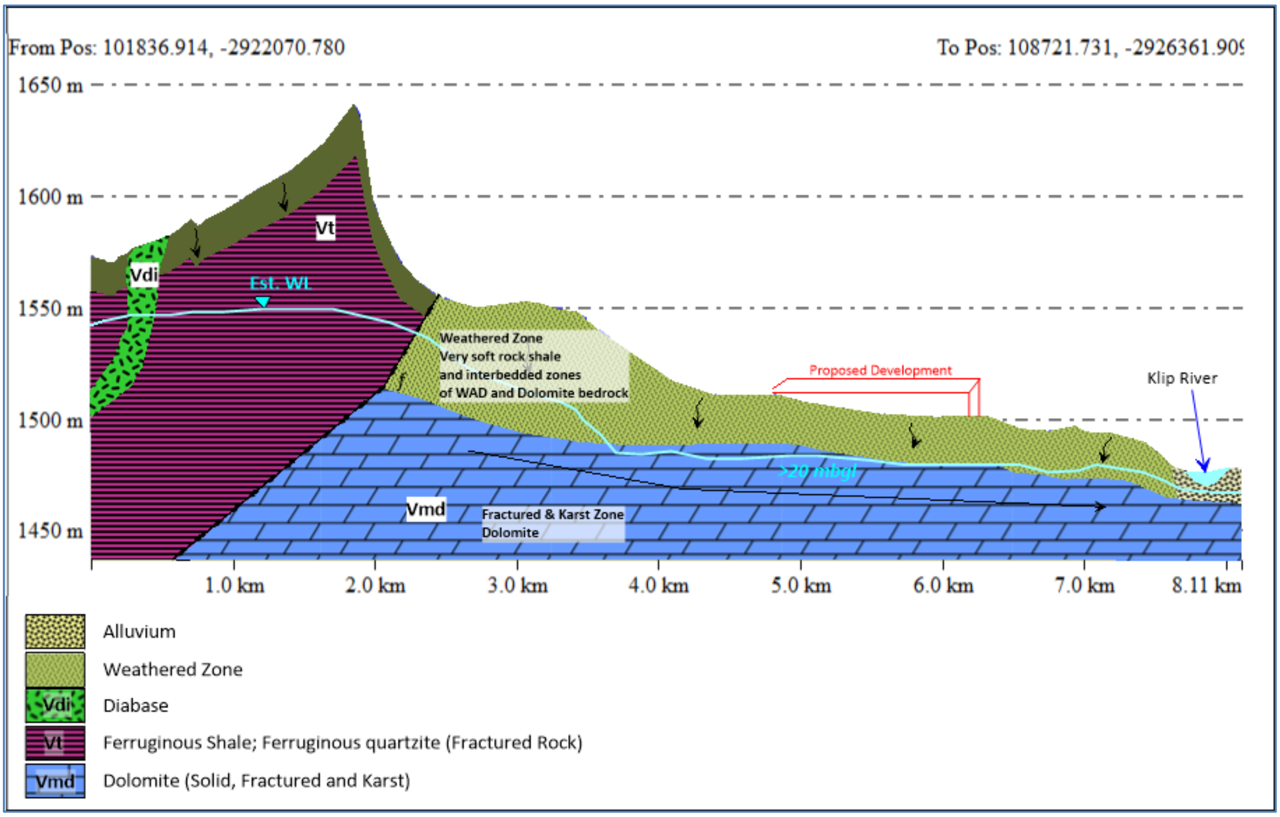


Figure 6-1: SCM - Cross section A-A'

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

- A shallow unconfined aquifer system associated with the quaternary sand deposits (alluvium) of the Klip River flood plain (varies thickness from 0 to 10 m zones).
- A semi-confined/perched aquifer system associated with the weathered very soft rock shale and interbedded zones of WAD and Dolomite bedrock (varied thickness from 9 to 29 m for the site, average in the order of 17.8 m).
- A deeper fractured and Karst aquifer zone associated with the Dolomites (thickness > 100 m).

The aquifer present is classified as a Major Aquifer system (Parsons, 1995). The aquifer underlying the study area is considered high-yielding (median yields > 5 l/sec – Class c5 aquifers). A recharge of 50.5 mm/yr corresponding to 7.9% 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). Based on extrapolated groundwater level data, it is estimated that the groundwater table is in the order of 20 mbgl at the site. Available data suggest that the groundwater table mimics the topography and groundwater flows from high-lying areas (water divides) to low-lying areas. This is despite the very small hydraulic gradient associated with the dolomitic aquifer, as the area is generally flat the water table is also flat.

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 alluvium of the Klip River sediments (as well as river losses) and weathered very soft rock shale and interbedded zones of WAD and Dolomite bedrock that occur in the project area. The primary movement of water in the vadose zone is vertically into the subsequent hard rock and soft rock dolomite formation. Groundwater movement will be towards the east of the site towards the Klip River.

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 propagate towards the Klip River which is the primary surface water receptor in the project area. The groundwater flow velocity is moderate to high due to the karst formation, however, due to the large storage associated with the dolomite the movement may be slow in the system as a result of the shallow hydraulic gradient (i.e. vertical movement as opposed to horizontal movement of water is more favourable). If the Klip River is hydraulically connected to the dolomite aquifer zone, pollution may enter the river system. However, indicates that the Klip River is a losing river rather than a groundwater-gaining river, due to the low baseflow associated with the quaternary.

It will take some time for pollution to migrate in the aquifer and enter the river system and may not be observed during the lifecycle of the project. The proposed project is however considered a “clean” operation, as it will entail the likely abstraction of groundwater, processing of malt and storage of temporary wastewater on site. The only risk would be if there are leakages or spillages associated with the proposed on-site wastewater treatment plant (WWTP).

As there is a likelihood of abstracting groundwater from Malt BHT3 and Malt BHT4, there may be an impact on the groundwater reserve (if overproduction takes place). Indications from the water balance are that there is a surplus groundwater reserve, and a marginal impact is expected. Any poor-quality seepage from facilities at the site could migrate to the boreholes and compromise water quality. 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 particle flow model developed for the Soufflet Maltings Plant. 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 dewatering impacts associated with the proposed groundwater abstraction activities and expressed as the zone of influence (ZOIf).
  - The simulation focuses on the cone of depression around the boreholes and presents the 25-year pumping drawdown areas.
- Determine potential pollution migration spread and travel time from the proposed plant.
  - The particle tracking function in Modflow was applied to show the primary groundwater flow path and man receptor of potential pollution (if pollution does take place). 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 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 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).
- 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.

- 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).
- Transboundary aquifer inflow into the model domain is not considered.
- 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 7-1 **and** Figure 7-2**.** 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. 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	Topographical low/high and river/stream. River drain assigned to the Klip River towards the northeastern extent. River conductance was calculated based on a river depth of 8m, riverbed thickness of 10m, and stage in the order of 6m. River thickness was estimated at 20-30 (on average) depending on reach. 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 low assigned with a river boundary, and several drainage cells. River conductance was calculated based on a river depth of 8 m, riverbed thickness of 10 m, and stage in the order of 6 m. River thickness was estimated at 20-30 (on average) depending on reach. 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 low/high. No drainage lines, for the extension of the Klip River boundary towards the south-western extent of the domain.
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, as well as vertical geometry provided for each of the layers. The flow model was set up as a three (3)-layer, confined/semi-confined aquifer.

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 operations was applied which gradually coarsens away from the site was applied. This is standard practice and does not influence the accuracy of the results obtained.

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 20 m. This layer represents both the alluvium deposits and weathered sediments of the Timball Hill and the Malmani Formations. Diabase intrusions and fault zones were mapped to the cells where required and are based on the regional geology map.
- Layer 2 – Karst, extending to 150 m below surface level (project site), and Ferruginous Shale; Ferruginous quartzite towards the western extent of the site (extending into layer 3).
- Layer 3 – Karst and basement rocs, extending to 300 m below surface level.

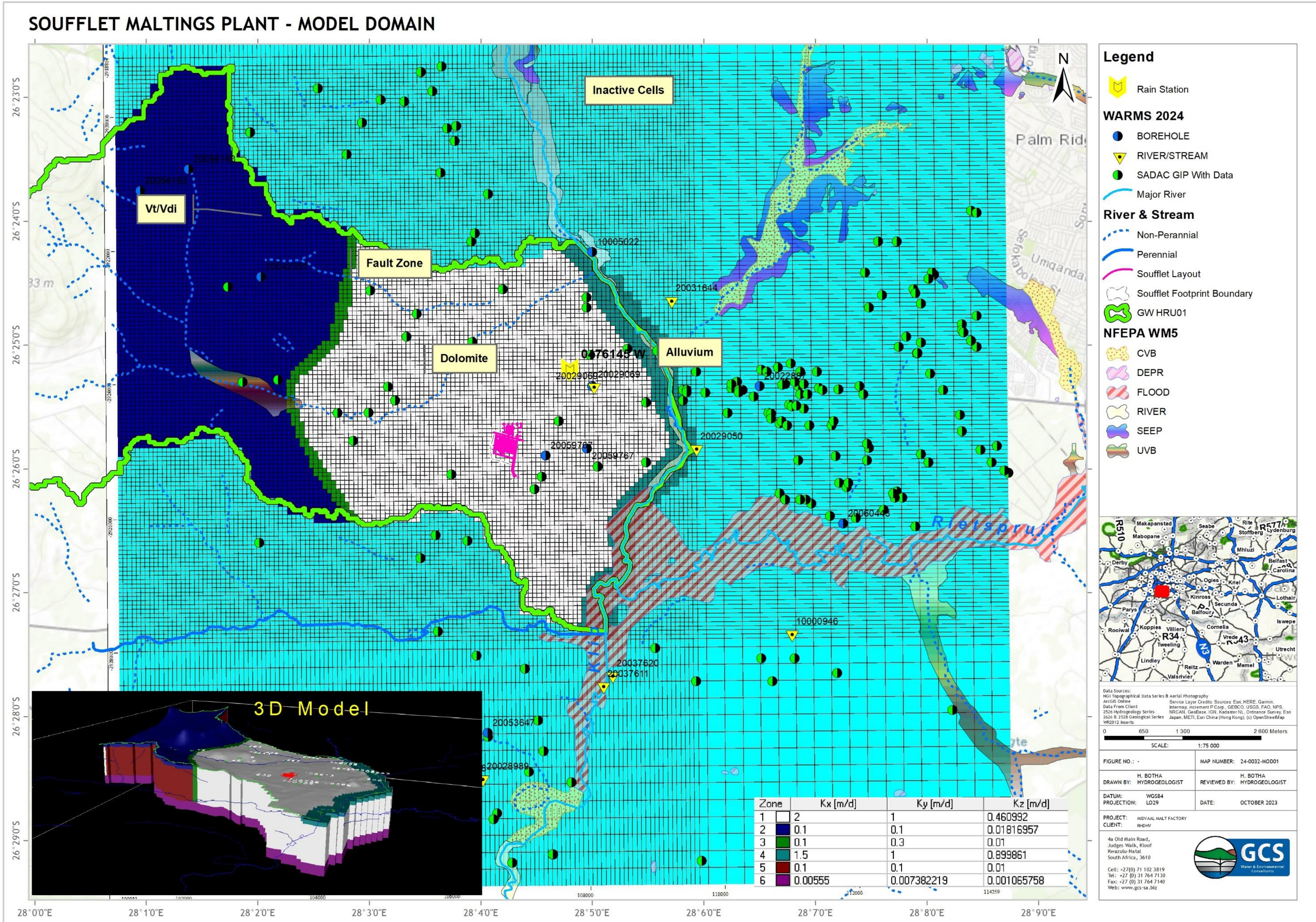
7.3.4 Time Discretization

Time parameters are relevant when modelling transient (time-dependent) conditions. They include time units, the length and number of periods and the number of time 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 dewatering, the transient simulation was discretized into stress periods of 4 months.

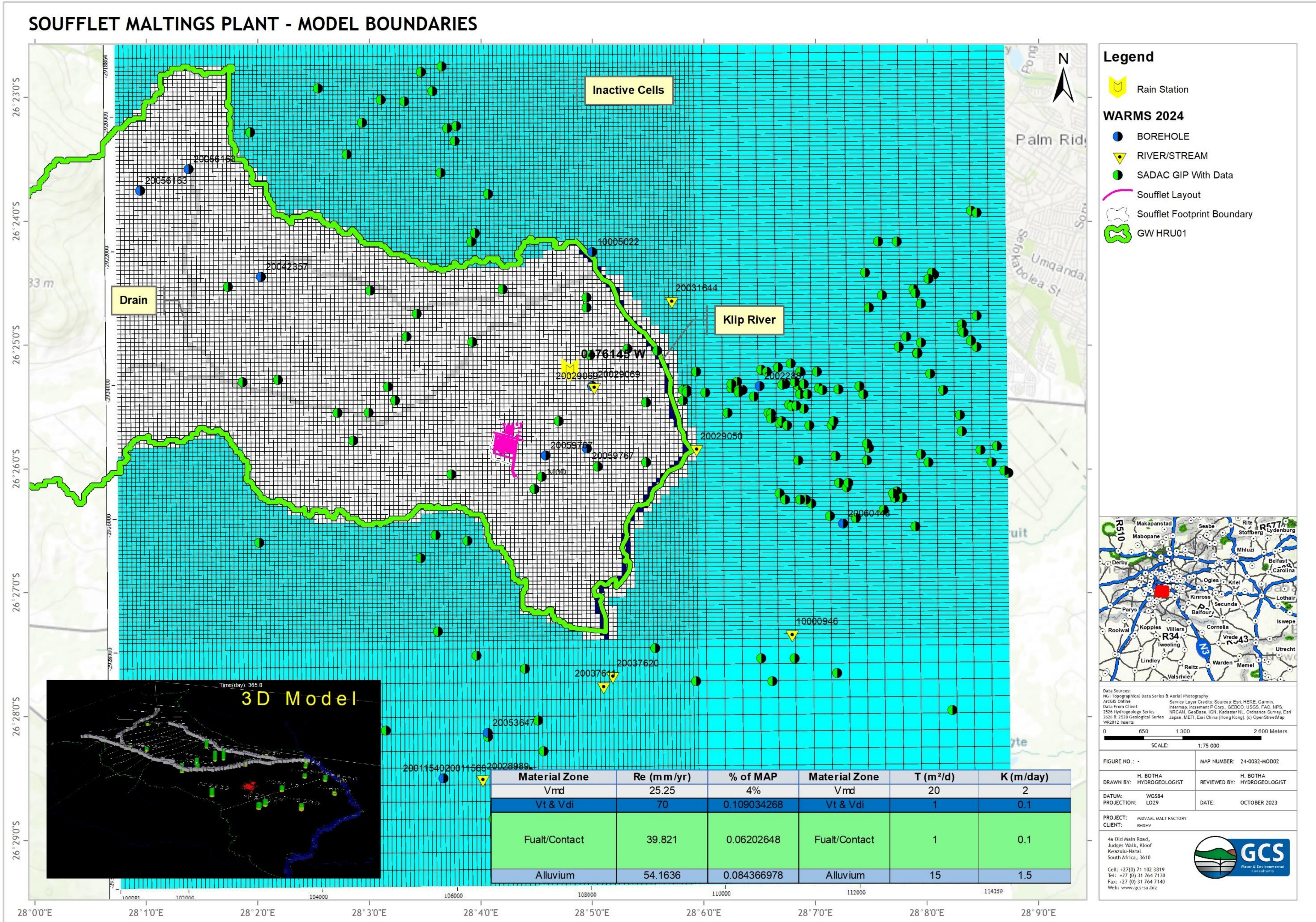
7.3.5 Transient State Model Simulation Time

The model simulation time runs from the year 2024 to the year 2049, and the total simulation time of 9125 days. Selected outputs were taken at 0Y (calibration), 10Y, 20Y and 25Y intervals, with a focus on the 25Y predictions for activities associated with the project.



Zone	Kx [m/d]	Ky [m/d]	Kz [m/d]
1	2	1	0.460992
2	0.1	0.1	0.01816957
3	0.1	0.3	0.01
4	1.5	1	0.899861
5	0.1	0.1	0.01
6	0.00555	0.007382219	0.001065758

Figure 7-1: Model grid, hydraulic conductivity, and storage



Material Zone	Re (mm/yr)	% of MAP	Material Zone	T (m²/d)	K (m/day)
Vmd	25.25	4%	Vmd	20	2
Vt & Vdi	70	0.109034268	Vt & Vdi	1	0.1
Fualt/Contact	39.821	0.06202648	Fualt/Contact	1	0.1
Alluvium	54.1636	0.084366978	Alluvium	15	1.5

Figure 7-2: 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. 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 prediction modelling heads were derived from the steady-state model results. Table 7-2 summarises the input parameters used in the steady state and transient state flow models.

Table 7-2: Input parameters to the flow model

<table>
<tr><th>Parameter</th><th>Value used</th></tr>
<tr><td>Horizontal Hydraulic conductivity (Kx)</td><td>
<table>
<tr><th>Material Zone</th><th>T (m²/d)</th><th>K (m/day)</th></tr>
<tr><td>Vmd</td><td>20</td><td>2</td></tr>
<tr><td>Vt & Vdi</td><td>1</td><td>0.1</td></tr>
<tr><td>Fault/Contact</td><td>1</td><td>0.1</td></tr>
<tr><td>Alluvium</td><td>15</td><td>1.5</td></tr>
</table>
</td></tr>
<tr><td>Vertical Hydraulic conductivity (Kz)</td><td>One order is lower than vertical conductivity.</td></tr>
<tr><td>Specific storage coefficient (Ss)</td><td>
<table>
<tr><th>Material</th><th>S_s (ft^{-1})</th></tr>
<tr><td>Plastic clay</td><td>7.8×10^{-4} to 6.2×10^{-3}</td></tr>
<tr><td>Stiff clay</td><td>3.9×10^{-4} to 7.8×10^{-4}</td></tr>
<tr><td>Medium hard clay</td><td>2.8×10^{-4} to 3.9×10^{-4}</td></tr>
<tr><td>Loose sand</td><td>1.5×10^{-4} to 3.1×10^{-4}</td></tr>
<tr><td>Dense sand</td><td>3.9×10^{-5} to 6.2×10^{-5}</td></tr>
<tr><td>Dense sandy gravel</td><td>1.5×10^{-5} to 3.1×10^{-5}</td></tr>
<tr><td>Rock, fissured</td><td>1×10^{-6} to 2.1×10^{-5}</td></tr>
<tr><td>Rock, sound</td><td>$< 1 \times 10^{-6}$</td></tr>
</table>
</td></tr>
<tr><td>Specific yield (Sy)
Porosity (n) (total)
Specific Retention (%)</td><td>
<table>
<tr><th>Material</th><th>Porosity (%)</th><th>Specific Yield (%)</th><th>Specific Retention (%)</th></tr>
<tr><td>Soil</td><td>55</td><td>40</td><td>15</td></tr>
<tr><td>Clay</td><td>50</td><td>2</td><td>48</td></tr>
<tr><td>Sand</td><td>25</td><td>22</td><td>3</td></tr>
<tr><td>Gravel</td><td>20</td><td>19</td><td>1</td></tr>
<tr><td>Limestone</td><td>20</td><td>18</td><td>2</td></tr>
<tr><td>Sandstone (unconsolidated)</td><td>11</td><td>6</td><td>5</td></tr>
<tr><td>Granite</td><td>0.1</td><td>0.09</td><td>0.01</td></tr>
<tr><td>Basalt (young)</td><td>11</td><td>8</td><td>3</td></tr>
</table>
</td></tr>
<tr><td>Recharge (Re)</td><td>
<table>
<tr><th>Material Zone</th><th>Re (mm/yr)</th><th>% of MAP</th></tr>
<tr><td>Vmd</td><td>25.25</td><td>4%</td></tr>
<tr><td>Vt & Vdi</td><td>70</td><td>0.109034268</td></tr>
<tr><td>Fault/Contact</td><td>39.821</td><td>0.06202648</td></tr>
<tr><td>Alluvium</td><td>54.1636</td><td>0.084366978</td></tr>
</table>
</td></tr>
<tr><td>Top elevation</td><td>Corresponded to surface topography.</td></tr>
</table>

[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, extending to 300 m below surface level.

7.3.7 Model Calibration

Calibration is the process of finding a set of boundary conditions, stresses and hydrogeological parameters that produce results which 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 7-3. A model RMS in the order of 8.835% was achieved.

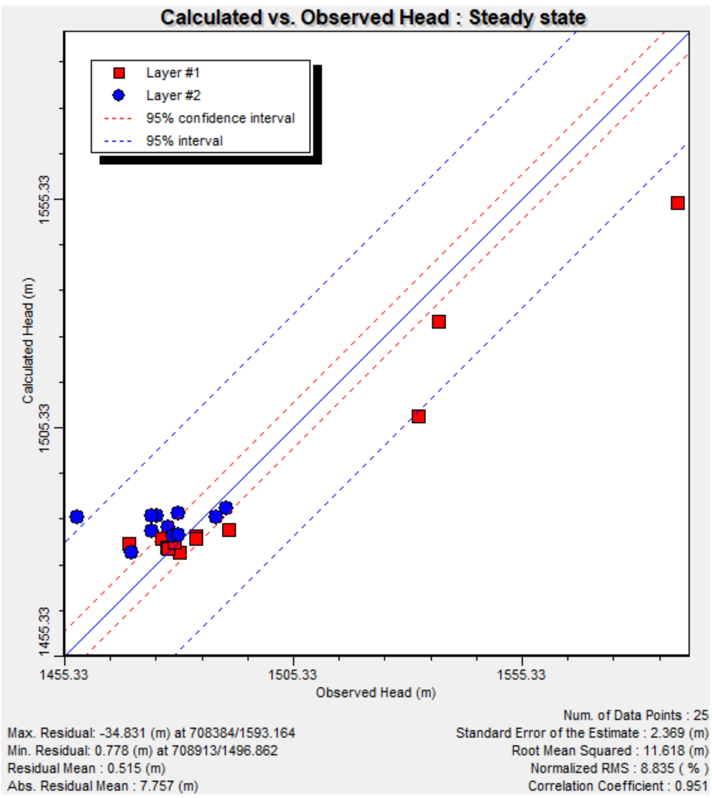


Figure 7-3: Steady-state model calibration achieved

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 7-4 that the calibrated residuals (calculated heads vs observed heads) are slightly skewed towards the left. 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 7-5):

- 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.

The PEST results for aquifer zone conductivity are presented in Table 7-3. The initial conditions were updated with these estimated values, as they fall within reasonable ranges (i.e. in line with the literature and available data for the project area).

Table 7-3: Estimated PEST parameters

Zone	Kx [m/d]	Ky [m/d]	Kz [m/d]
1	2	1	0.460992
2	0.1	0.1	0.01816957
3	0.1	0.3	0.01
4	1.5	1	0.899861
5	0.1	0.1	0.01
6	0.00555	0.007382219	0.001065758

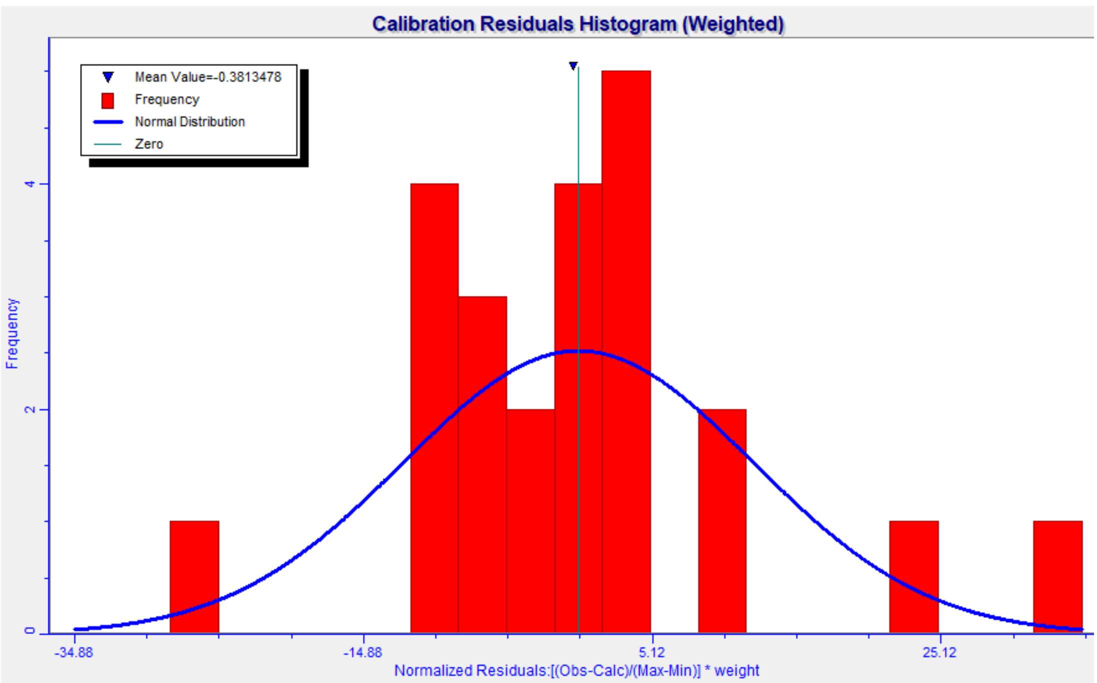


Figure 7-4: PEST Sensitivity Analysis - Histogram

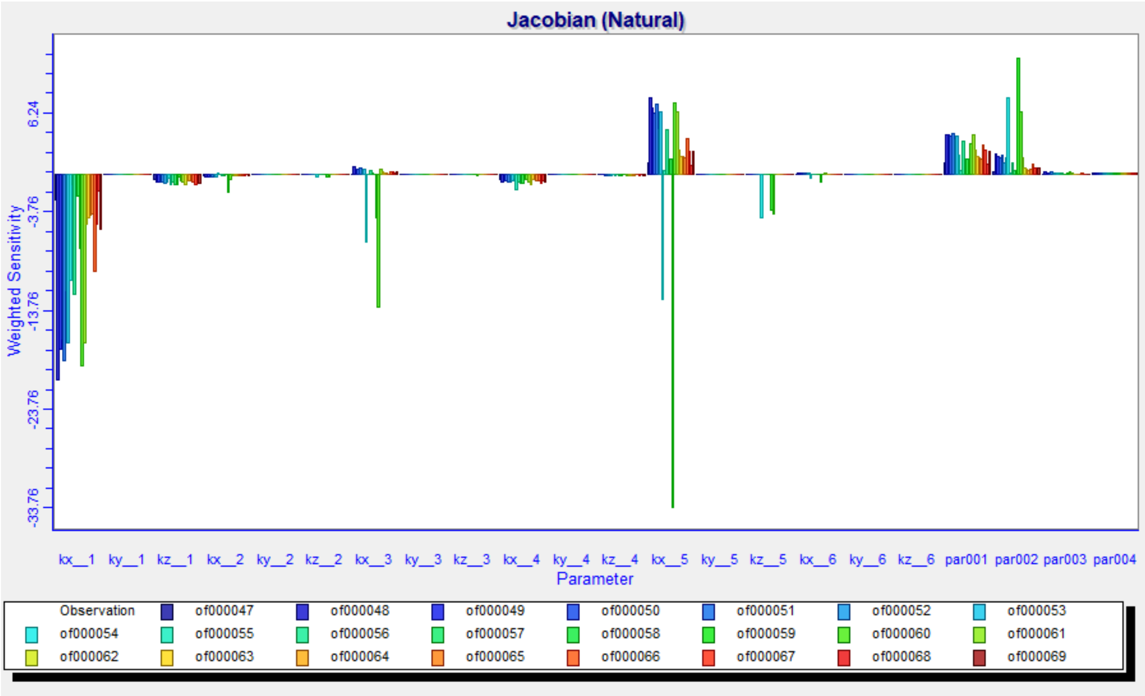


Figure 7-5: PEST Sensitivity Analysis - Weighted Parameter Sensitivity

7.4 Calibrated flow models

The calibrated flow model with simulated groundwater elevations is shown in Figure 7-6. The following is noted when evaluating the flow model:

- The groundwater table mimics the topography.
- Preferential movement is towards the south-east of the project area.
- The flow model indicates groundwater flow velocities ranging from 0.01 (min) > 5 (max) m/day, average flow of 0.055 m/day.

7.5 Predicted transport movement 25Y

The predicted primary flow path using the particle tracking module in Modflow is shown in Figure 7-7. It is noted that preferential groundwater pollution movement will be towards the south-east, from the position of the plant.

7.6 Predicted drawdown after 25Y of dewatering

The predicted ZOIf associated with groundwater **proposed** abstraction from Malt BHT3 and Malt BHT4 is shown in Figure 7-8. The simulation suggests a maximum aquifer drawdown of 0.408m at pumping for 24 hours per day at a combined volume of 300m³/day. The simulation suggests that there may be borehole interference if both boreholes are pumped simultaneously, however, the impact is limited with a predicted higher drawdown at Malt BHT3. The cone of depression and extent thereof is limited to the Graceview Industrial Park and dewatering will likely not affect other groundwater users in the project area.

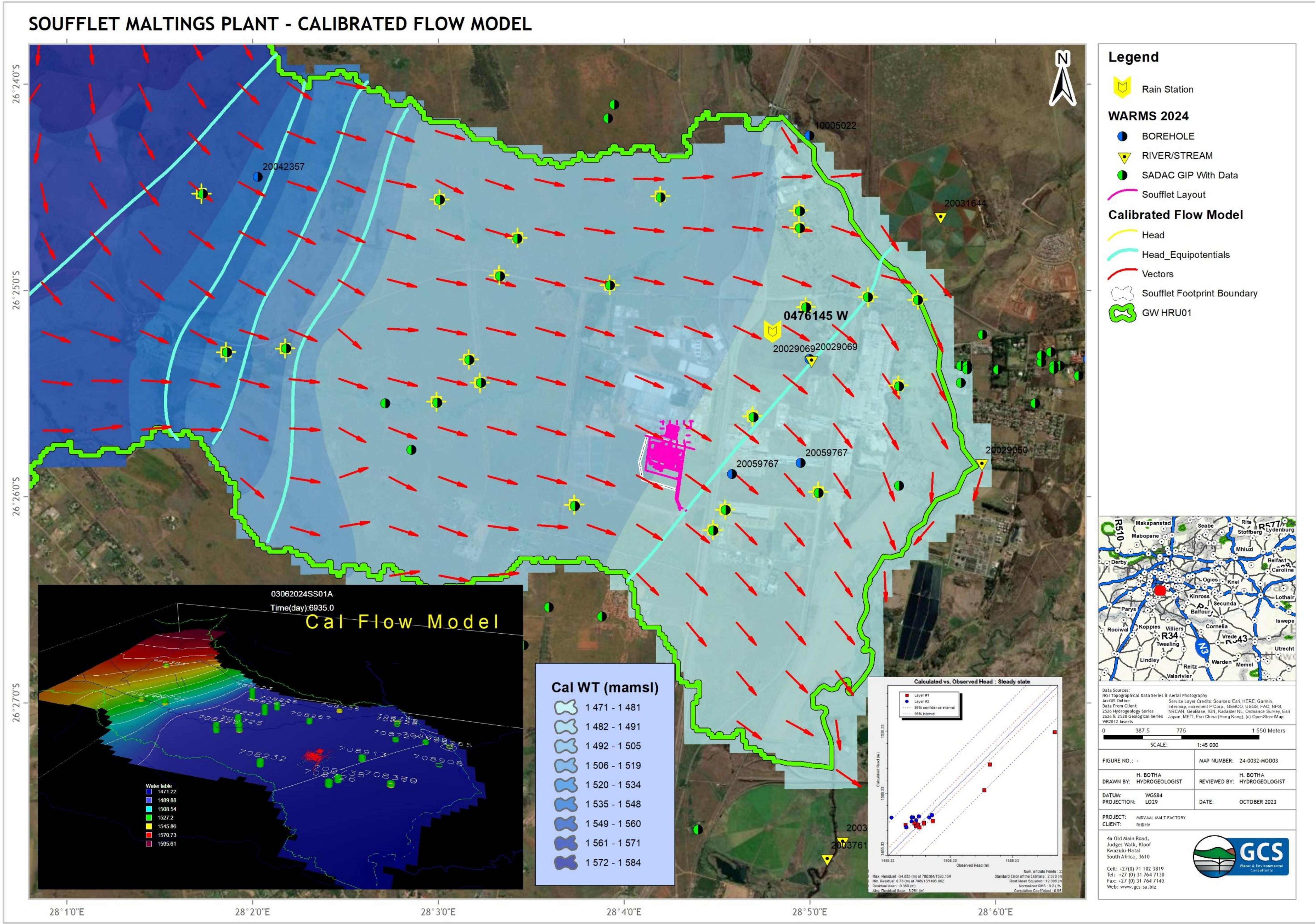


Figure 7-6: Calibrated flow model

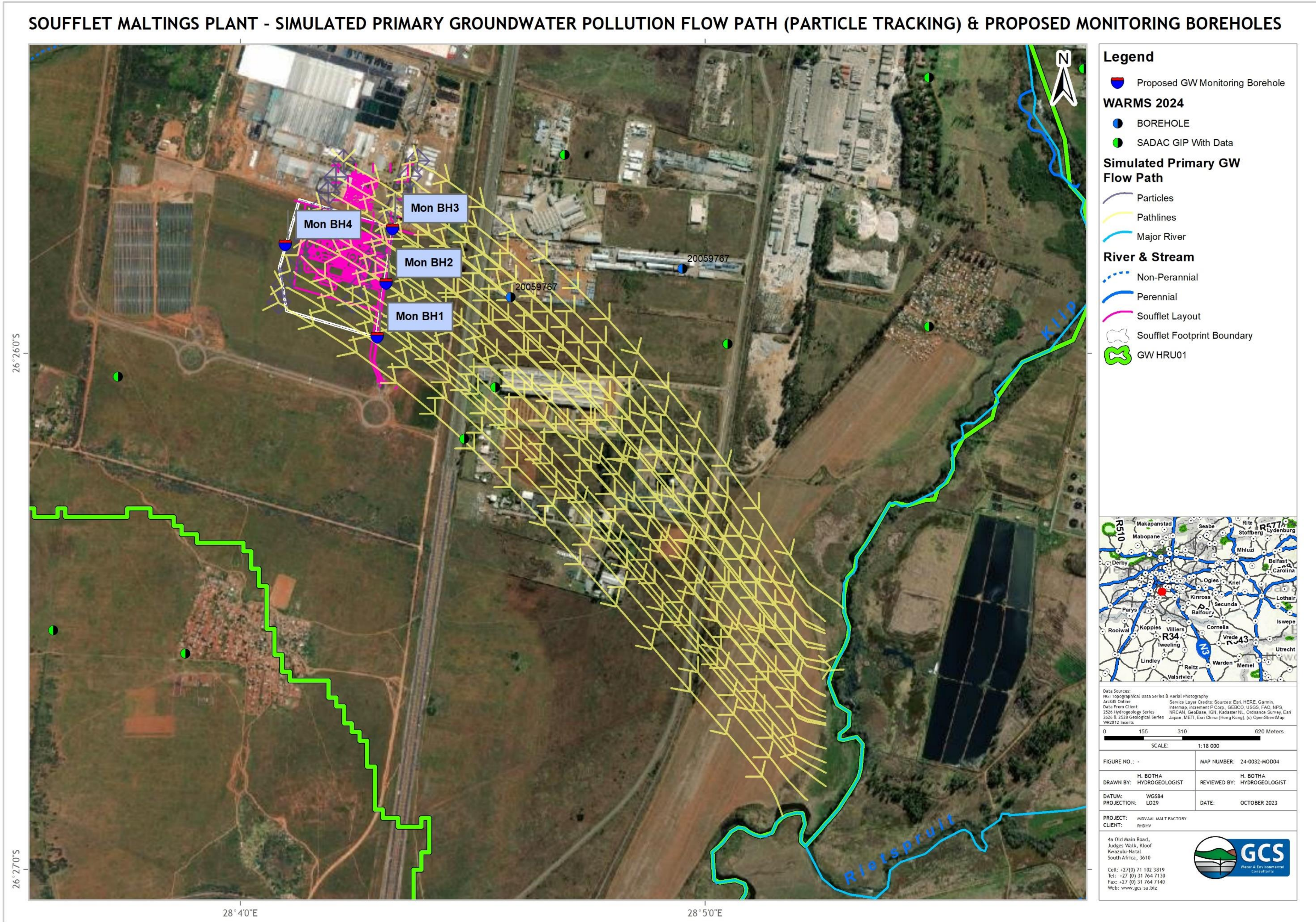
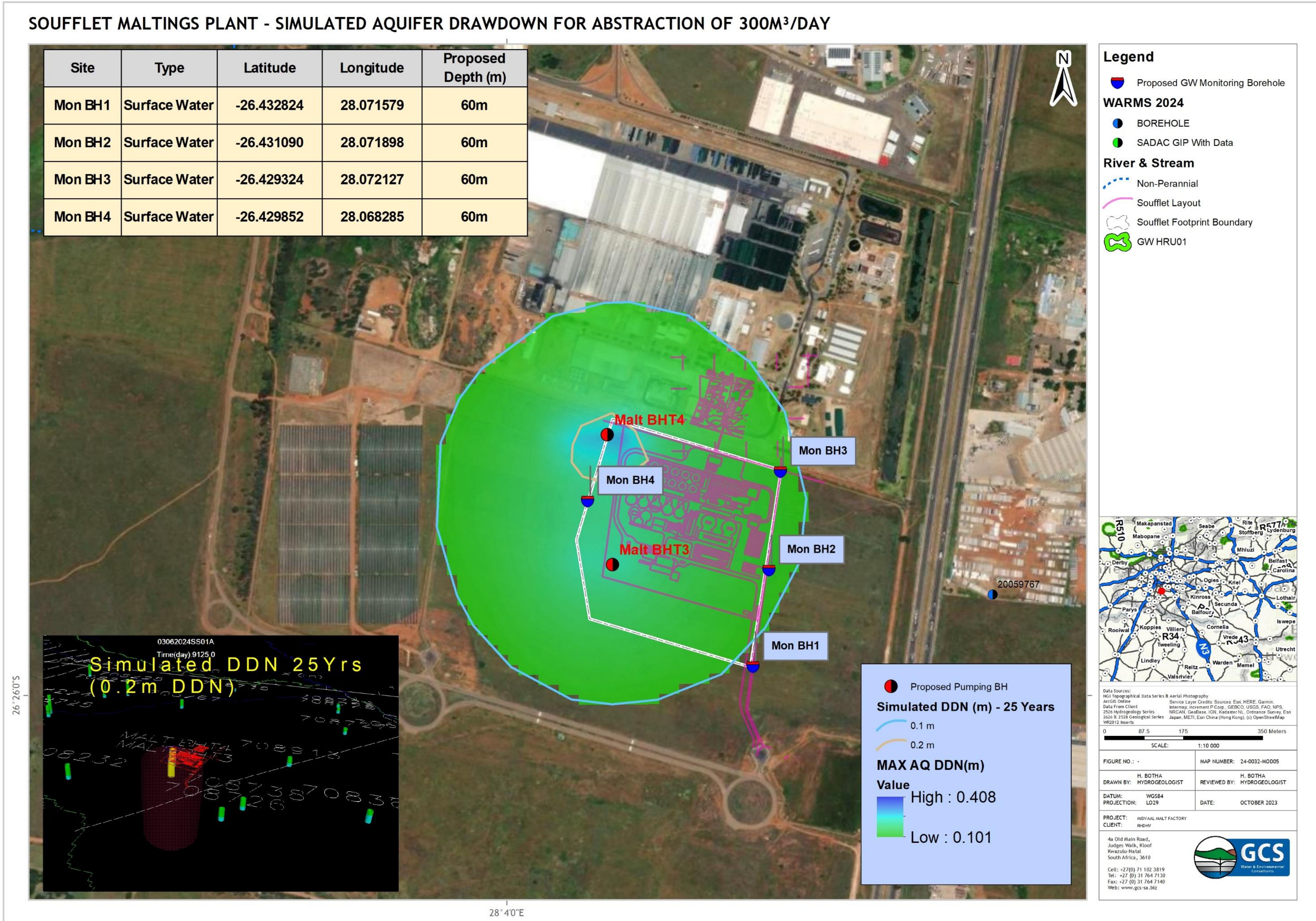


Figure 7-7: **Simulated primary groundwater flow path/potential pollution flow path**



Site	Type	Latitude	Longitude	Proposed Depth (m)
Mon BH1	Surface Water	-26.432824	28.071579	60m
Mon BH2	Surface Water	-26.431090	28.071898	60m
Mon BH3	Surface Water	-26.429324	28.072127	60m
Mon BH4	Surface Water	-26.429852	28.068285	60m

Figure 7-8: Simulated drawdown [ZOIf] after 25 years of pumping Malt BH @ 300 m³/day and proposed monitoring boreholes

8 GEOHYDROLOGICAL RISK ASSESSMENT

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

- Construction phase:
  - Clearing of the vegetation and movement of heavy machinery and equipment at the site that can potentially cause soil pollution (i.e., hydrocarbon spills).
  - Temporary storage and holding facilities and contractors camps during the construction phase, as well as portable toilets and storage of hazardous material (i.e. paints, oils, lubricants etc) during the construction phase.
  - Construction of the plant and associated facilities, including the wastewater treatment works.
- Operational phase:
  - Run of the plan and associated facilities.
  - Vehicles entering and parking on site could cause hydrocarbon spills.
  - Abstraction of groundwater (proposed but not confirmed)
  - Sewage and effluent storage on site. The options are currently:
    - **Preferred** – treatment at the on-site wastewater treatment plant (WWTP) and then tie-in to the existing ERWAT infrastructure, to the pump station (owned by Midvaal).
    - **Alternative** – treatment at the on-site WWTP and then transport of the effluent in a pipeline that runs adjacent to the ERWAT pipeline to a discharge point in the Klip River.
- Closure phase (likely not to occur seeing that the area is an industrial economic zone):
  - Demolition of the plant and associated facilities.
  - Rehabilitation and decommissioning of groundwater boreholes.

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). **There are no surface water-related risks associated with the site, as there are no recognised drainage lines on site or close to the site. The closest perennial stream is towards the north-west of the site at a distance of ~1.17 km, and the Klip River a major river system is situated approximately 2.5 km downstream east of the site.**

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 wastewater storage areas and treatment plant.
- Establishment of 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 geohydrological 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.
- Clearing topsoil from footprint areas will influence the rate of infiltration of water to the shallow groundwater system and/or baseflow components.

- Handling of waste and transport of 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 1st order detection system for any soil and water pollution that may take place. 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 geohydrological impacts for the operational phase of the project are likely to be (refer to Table 8-5):

- Potential poor-quality seepage into the soils and underlying groundwater table from any environmental incidents (i.e. oil spills, fuel spills, spillages from the effluent storage tanks and treatment plant etc.) is the highest risk at the site.
- The direct discharge of treated effluent into the Klip River (if this takes place) could impact surface water quality. The preferred option is to discharge to the municipal sewer main already available in the area (Midvaal).
- Abstraction of groundwater from the proposed boreholes could impact the local groundwater reserve.

In general, the operational phase risk associated with the project is predicted low, and it is foreseen that the impacts can be managed. This is based on the type of project that is proposed.

8.3 Closure and decommissioning phases

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

- Decommission the plant and other supporting infrastructure.
- Cessation of operations and rehabilitation.
- Rehabilitation of the site and abstraction boreholes.
- Immediate aquifer rebound as groundwater abstraction ceases; and

Closure of the site is predicted to be beneficial to the area and will enable long-term stabilisation of the project site. 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; however, it is proposed that the preferred option as discussed above be considered for the discharge of the treated effluent. This will minimise the water liabilities for the applicant associated with direct discharge to the Klip River.

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 phase and if rehabilitation is rolled out. No cumulative impact is anticipated on the dolomite compartment from which water will be drawn, due to the low volumes proposed. The impact on the reserve associated with the groundwater sub-catchment 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. Based on available data the predicted abstraction on a sub-catchment scale will be considered "small scale".

Table 8-2: The estimated scale of abstraction

Scale	
Component	GW HRU01
Re (m³/yr)	3006928.97
Use (m³/yr)	1795751.24
Abs. Scale	0.60
Class	Small Scale

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 "no stress" if groundwater abstraction takes place at the proposed rate of 300 m³/day.

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

Water Stress	
Component	GW HRU01
Proposed Abstraction	109500.00
Re - BF	2223289.61
Stress Index	0.05
Class	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	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	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)
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	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)	Pre- Mitigation: Extent (E)	Pre- Mitigation: Potential for impact on irreplaceable resources (I)	Pre- Mitigation: Severity (S)	Pre- Mitigation: Consequence (C)	Pre- Mitigation: Probability (P)	Pre- Mitigation: Significance	Recommended Mitigation Measures	Post Mitigation: Duration (D)	Post Mitigation: Extent (E)	Post Mitigation: Potential for impact on irreplaceable resources (I)	Post Mitigation: Severity (S)	Post Mitigation: Consequence (C)	Post Mitigation: Probability (P)	Post Mitigation: Significance
Vadose zone soils	Poor quality seepage from the onsite effluent storage facilities and WWTP.	Storage of wastewater and processing thereof	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 on site.	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.	Vehicles and trucks are parked and accessing the site.	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)
Regional groundwater table/groundwater aquifer	Over abstraction of groundwater at the proposed borehole at the site.	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)
	Any poor-quality seepage or runoff accumulation on the site, where it is allowed to percolate into the soils, could potentially impact the dolomitic aquifer water quality.	Poor quality seepage	Medium Term (3)	Site (2)	Yes (1)	Moderate (-2)	Slightly detrimental (-7 to -12) (-12)	Definite (2)	Low – negative (-13 to -24) (-24)	- Park vehicles in dedicated areas. - Have fuel and oil spill cleanup kits on site and clean up these areas immediately. - Pollution prevention and house cleaning should be considered at all times. - Visual soil assessments for signs of contamination on site.	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

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)	Rehabilitation of the plant and associated facilities.	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 dewatering 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

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. 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 7-8.
- **Monthly** water level monitoring of the abstraction borehole should take place.
- **Monthly** abstraction volumes should be taken and kept on record.
- Monitoring for all monitoring boreholes should be **bi-annually (minimum)** 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 $CaCO_3$
  - Biological oxygen demand (BOD)
  - Chemical oxygen demand (COD)
  - Calcium
  - Magnesium
  - Potassium
  - Sodium
  - Chloride
  - Fluoride
  - Nitrate
  - Sulphate
  - Aluminium
  - Iron
  - Manganese
- Monitoring of abstraction holes should be monthly if used for processing, and constituents analysed would need to conform to the food industry or bottling standards.

Table 9-1: Proposed monitoring borehole drilling positions

Site	Type	Latitude	Longitude	Proposed Depth (m)
Mon BH1	Surface Water	-26.432824	28.071579	60m
Mon BH2	Surface Water	-26.431090	28.071898	60m
Mon BH3	Surface Water	-26.429324	28.072127	60m
Mon BH4	Surface Water	-26.429852	28.068285	60m

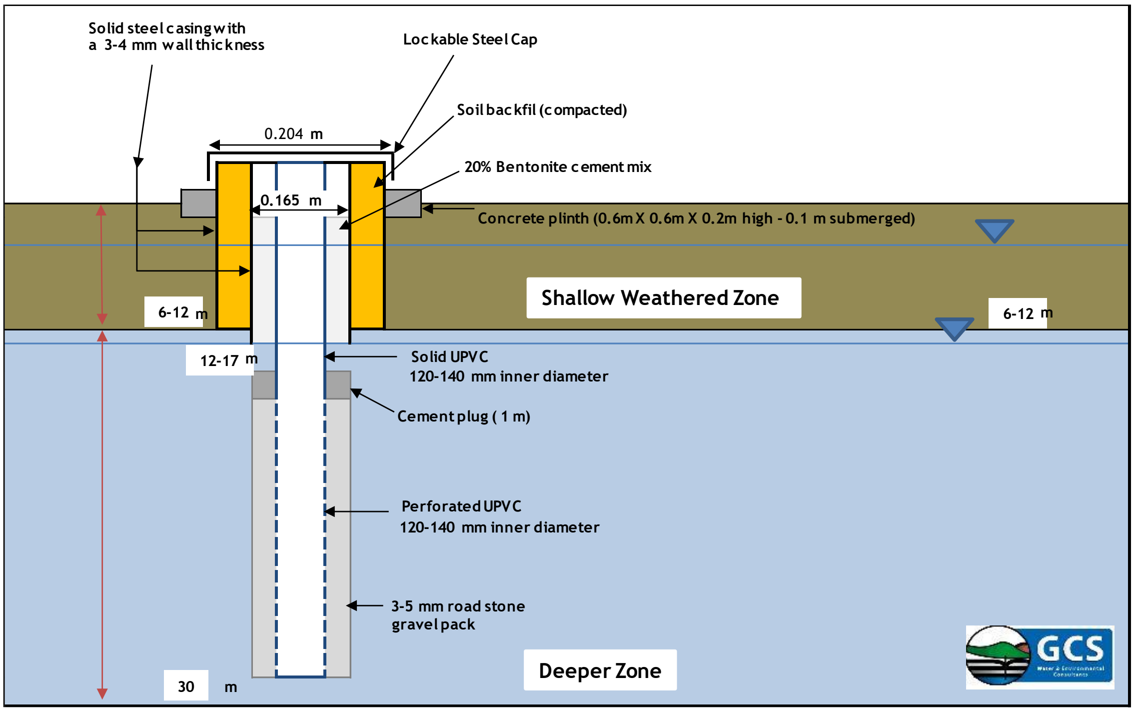


Figure 9-1: Proposed borehole construction (concept – please refer to the table for depths)

10 CONCLUSIONS

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

- The project falls within quaternary catchment C22D of the Vaal Water Management Area (WMA). Elevations for the site area range from 1450 to 1500 metres above mean sea level (mamsl) and extend to 1650 mamsl towards the western extents of the project area. The project falls in an area with a MAP in the order of 642 mm/yr and an EMA in the order of 1527 mm/yr.
- The surface geology of the study is characterised by alluvium sands (~) along the Klip River floodplain, ferruginous shale and quartzite (Vt) of the Timball Hill Formation and dolomite & chert (Vdm) of the Malmani Formation of the Pretoria and Chuniespoort Supergroups, of the Transvaal Sequence. The presence of dolomite underlying the site has been confirmed by several consultants (refer to Section 5.1).

- One (1) groundwater hydrological response unit (GW HRU) describes the drainage of the local area and is bound towards the east by the Klip River. The total area of the GW HRU is in the order of 59.232 km². The sub-catchment can further be viewed as the local sphere of influence in which the activities will take place (i.e., the dewatering of transport movement may impact may only be limited to the sub-catchment in which it falls). Surface water drainage is towards the east of the site, and from the western hilltops via a perennial tributary of the Klip River, which joins the Klip River approximately 3 km north of the site. The site itself is devoid of any recognised drainage lines or rivers/streams. The closest perennial stream is towards the north-west of the site at a distance of ~1.17 km, and the Klip River a major river system is situated approximately 2.5 km downstream east of the site.
- According to the Water Allocation Registration Management System (WARMS, 2024), there are 17 WARMS users within a 5 km buffer of the project area, of which 4 groundwater and 1 surface water user falls within the HRU. A review of SADAC GIP groundwater database boreholes further suggests several boreholes within a 5 km radius of the site with groundwater data available. Based on the WARMS data collected it is noted that the existing groundwater use is in the order of 0.9 Mm³/yr and surface water use is in the order of 4.2 Mm³/yr.
- Two (2) boreholes exist on the premises, namely Malt BHT3 and Malt BHT4, and were identified during the field hydrocensus. There is substantial evidence of other drilling pads on site, however, these boreholes have been rehabilitated. Other NGA and SADAC GIP boreholes could not be located but are assumed to have existed in the past.
- The groundwater environment intercepted by BH TBH3 can be classified as Ca-HCO_3 waters.
- 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 (alluvium) of the Klip River flood plain (varies thickness from 0 to 10 m zones).
  - A semi-confined/perched aquifer system associated with the weathered very soft rock shale and interbedded zones of WAD and Dolomite bedrock (varied thickness from 9 to 29 m for the site, average in the order of 17.8 m).
  - A deeper fractured and Karst aquifer zone associated with the Dolomites (thickness > 100 m).

- The aquifer present is classified as a Major Aquifer system (Parsons, 1995). The aquifer underlying the study area is considered high-yielding (median yields > 5 l/sec – Class c5 aquifers). A recharge of 50.5 mm/yr corresponding to 7.9% 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). Based on extrapolated groundwater level data, it is estimated that the groundwater table is in the order of 20 mbgl at the site. Available data suggest that the groundwater table mimics the topography and groundwater flows from high-lying areas (water divides) to low-lying areas. This is despite the very small hydraulic gradient associated with the dolomitic aquifer, as the area is generally flat the water table is also flat.
- 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 alluvium of the Klip River sediments (as well as river losses) and weathered very soft rock shale and interbedded zones of WAD and Dolomite bedrock that occur in the project area. The primary movement of water in the vadose zone is vertically into the subsequent hard rock and soft rock dolomite formation. Groundwater movement will be towards the east of the site towards the Klip River.
- 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 propagate towards the Klip River which is the primary surface water receptor in the project area. The groundwater flow velocity is moderate to high due to the karst formation, however, due to the large storage associated with the dolomite the movement may be slow in the system as a result of the shallow hydraulic gradient (i.e. vertical movement as opposed to horizontal movement of water is more favourable). If the Klip River is hydraulically connected to the dolomite aquifer zone, pollution may enter the river system. However, indicates that the Klip River is a losing river rather than a groundwater-gaining river, due to the low baseflow associated with the quaternary.
- It will take some time for pollution to migrate in the aquifer and enter the river system and may not be observed during the lifecycle of the project. The proposed project is however considered a “clean” operation, as it will entail the likely abstraction of groundwater, processing of malt and storage of temporary wastewater on site. The only risk would be if there are leakages or spillages associated with the proposed on-site wastewater treatment plant (WWTP). Groundwater movement in both the weathered zones will be slow but severe.

- As there is a likelihood of abstracting groundwater from Malt BHT3 and Malt, there may be an impact on the groundwater reserve (if overproduction takes place). Indications from the water balance are that there is a surplus groundwater reserve, and a marginal impact is expected. Any poor-quality seepage from facilities at the site could migrate to the boreholes and compromise water quality. Prevention of pollution on the soils at the site should be prioritized to limit the impact on the groundwater regime.
- Several geohydrological risks were identified and are presented in Section 8 as well as several mitigation measures that can be considered. A water monitoring plan is available in Section 9.

10.1 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 25 observation points within the study area were successfully applied.
- A groundwater flow model was developed to illustrate the zone of impact (ZOIp) and zone of influence (ZOIf) associated with the proposed development and associated groundwater abstraction activities.
- 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.
    - The predicted primary flow path using the particle tracking module in Modflow suggests that preferential groundwater pollution movement will be towards the southeast, from the position of the plant. This is the potential ZOIp flow path.

- The predicted ZOIf associated with groundwater proposed abstraction from Malt BHT3 and Malt BHT4 is available in Section 7.6 The simulation suggests a maximum aquifer drawdown of 0.408 m at pumping for 24hrs per day at a combined volume of 300 m^3/day. The simulation suggests that there may be borehole interference if both boreholes are pumped simultaneously, however, the impact is limited with a predicted higher drawdown at Malt BHT3. The cone of depression and extent thereof is limited to the Graceview Industrial Park and dewatering will likely not affect other groundwater users in the project area.
- 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 1 confidence level due to the limited groundwater heads available for calibration. Class 1 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 1 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.

10.2 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 dedicated pump tests take place (24 hours) on the boreholes if they are going to be used for water supply. No pump test data is currently available.

- It is recommended that the 4 boreholes as listed in Section 9 be drilled and integrated into the existing groundwater monitoring network. This should be done during the construction phase of the project.

10.3 Identification of any areas that should be avoided

No avoidance areas were identified as part of this assessment. However, it is proposed that the preferred option as discussed above be considered for discharge of the treated effluent. This will minimise the water liabilities for the applicant associated with direct discharge to the Klip River.

10.4 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. The approval of the activity should be considered to enable the applicant to expand their operations. It is further assumed that mitigation options to offset negative impacts as predicted by this study will be implemented into the EMPr during the operational and closure phases of the project.

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APPENDIX A: AVAILABLE DRILLING LOG DATA FOR GEOTECHNICAL BOREHOLES (ARUP DATA)

ID	Deptt (m) >>							
MP1 - 2016	0-5 Silty Clayse Sand	5-14 Very soft rock/shale	14-15.30 claye silt WAD	15.3 - 21 Hard Rock Dolomite	No Water Strikes or rest water level.			
MP2 - 2016	0-5 Silty sand / slightly claye silty sand and gravel	5-17 Very soft rock shale	17-26.2 Claye silt and shale	26.2-32 Hard rock dolomite.	No Water Strikes or rest water level.			
MP3 - 2016	0-5 Silty Sand with gravel.	5-12.5 Very soft rock shale	12.5-19 Hard rock dolomite.	No Water Strikes or rest water level.				
MP4 - 2016	0-4.5 Silty sand with gravel	4.5-7.6 Very soft rock shale	7.6-12 Claye silt WAD	12-14 Claey silt (residual shale)	14-17.1 Very soft rock shale	17.1-23 Hard rock dolomite.	No Water Strikes or rest water level.	
MP5 - 2016	0-4.5 Silty claye silty sand and gravel	4.5-13 Very soft rock shale	13-14.2 Very soft rock shale and interbedded zones of WAD and Dolomite bedrock	14.2-20 Dolomite	No Water Strikes or rest water level.			
MP6 - 2016	0-1 Ferricrete sand	1-6 Claye silty sand with gravel	6-8 Very soft rock shale	8-9.1 Very soft rock Shale and claye silt WAD	9.1-15 Hard rock dolomite	No Water Strikes or rest water level.		
MP7 - 2016	0-3 Silty sand and gravel	3-9.1 Very soft rock shale	9-15 Hard rock dolomite	No Water Strikes or rest water level.				
MP8 - 2016	0-4 Silty sand and gravel	4-11 Very soft rock shale	11-19.3 Dolomite residuum & WAD	19.3-25 Hard rock dolomite	No Water Strikes or rest water level.			
MP9 - 2016	0-4 Silty Sand	4-10.2 Very soft rock shale, with interbedded dolomite from 9 to 10.2	10.2-13 Weathered dolomite	13-14 Soft Dolomite	14-15.3 soft rock syenite	15.3-21 Hard rock dolomite	No Water Strikes or rest water level.	
MP10 - 2016	0-1 Ferricrete soil	1-3 Silty sand and gravel	3-15.3 Soft rock shale	15.3-26 Hard rock dolomite	No Water Strikes or rest water level.			
MP11 - 2016	0-3 Slightly clayey silty sand	3-9 Very soft rock shale	9-12 Very soft rock syenite	12-21 Very soft rock shale	21-24.5 Soft dolomite and WAD.	24.5-30 Dolomite	No Water Strikes or rest water level.	
MP12 - 2016	0-7 Silty Sand and gravel.	7-10 Claye Silt	10-25 Very soft rock shale	25-28.5 Very soft rock dolomite & WAD	28.5-35 Hard rock dolomite	Water strike @32m		
MP13 - 2016	0-1 Ferricrete sand	1-5 Silty sand and gravel	5-21 Claye Silt	21-26 Claye silt WAD	26-27.2 Soft dolomite	27.2-33 Hard rock dolomite	No Water Strikes or rest water level.	
MP14 - 2016	0-1 Silty sand and Ferricrete	1-7 Silty sand and gravel	7-17 Claye Silt	17-26.2 Very soft rock shale	26.-39 Claye silt WAD (dolomite residuum)	39-40.6 Medium weathered dolomite gravel	40.6-53 Claye silt WAD and Hard rock dolomite.	53-54.2 Soft rock dolomite.
MP15 - 2016	0-1 Silty sand and Ferricrete	1-3 Silty sand and gravel	3-13 Claye Silt	13-21.1Very	21.1-27 Hard rock dolomite	No Water Strikes or		

ID	Deptt (m) >>							
				soft rock shale		rest water level.		
BH22 - 2014	0-1 Silty sand and Ferricrete	1-3 Silty sand and gravel	3-7 Claye silt	7-8.1 Claye silty WAD	8.1-14 Hard rock dolomite	No Water Strikes or rest water level.		
BH23 - 2014	0-1 Silty sand and Ferricrete	1-3 Silty sand and gravel	3-15 Very soft rock shale	15-24.3 Clayey silt WAD	24.3-31 Hard rock dolomite	No Water Strikes or rest water level.		
BH28 - 2014	0-3 Silty sand and gravel	3-8 Silty sand and Gravel (with chert)	8-18.7 Claye silt residual shale	18.7-25 Hard rock dolomite	No water strike. Water level @22.1 after drilling.			
TP31 - 2014	0-0.9 Silty Sand.	0.9-1.3 Gravel and cobbles.	1.3-1.7 Moist red-brown mottled black lose to medium dense ferrugised nodular ferrite. Paedogenic.	1.7-1.95 Silty sand and gravel	1.95 Very dense alluvium ~ Refusal			
TP32 - 2014	0-0.2 loose to medium dense intact silty sand	0.2-0.9 Gravel cobbles and boulders	0.9-1.4 As above but dense and medium dense to dense in places ferruginised	1.4 Silty sand and gravel	1.4 Very dense alluvium ~ Refusal			
TP41 - 2014	0-0.4 loose to medium dense intact silty sand	0.4-0.7 Moist red-brown mottled black lose to medium dense ferrugised nodular Ferricrete. Paedogenic.	0.7-1 as above but medium dense to dense with zones of hardpan Ferricrete. paedogenic.	1 Hardpan Ferricrete ~ Refusal				
TP42 - 2014	0-0.5 Moist red-brown mottled black lose to medium dense ferrugised nodular Ferricrete. paedogenic.	0.5-1.6 Moist orange red brown mottled black dense to dense and dense in places ferruginised silty sand with abundant fine to coarse sub-rounded gravel, cobbles, and boulders of mixed origin. Alluvium	1.6 Very dense alluvium ~ Refusal					
TP43 - 2014	0-0.4 Moist red-brown loose intact silty sand. Hillwash	0.4-0.8 Moist red-brown mottled black lose to medium dense ferrugised nodular	0.8-0.9 As above but dense.	0.9 very soft rock consistency hardpan Ferricrete ~ Refusal				

ID	Deptt (m) >>							
		Ferricrete. paedogenic.						
TP44 - 2014	0-0.4 Loose silty sand	0.4-0.8 Moist red-brown mottled black lose to medium dense ferrugised nodular ferrite. paedogenic.	0.8-0.9As above but dense.	0.9 very soft rock consistency hardpan Ferricrete ~ Refusal				

APPENDIX B: LABORATORY CERTIFICATES

aquatico Laboratories (Pty). Ltd.

ilac-MRA sanas Testing Laboratory T0685

Test Report Page 1 of 1

Client:	Groundwater Consulting Services (GCS)	**Date of report:**	01 July 2024
Address:	63 Wessel Road, Woodmead, 2191	**Date accepted:**	20 June 2024
Report no:	188355	**Date completed:**	01 July 2024
Project:	GCS	**Date received:**	20 June 2024

Lab no:					93758
Date sampled:					20-Jun-24
Aquatico sampled:					No
Sample type:					Water
Locality description:					MALT TBH3
		Analyses	**Unit**	**Method**	
A	AQL	pH @ 25°C	pH	ALM 20	7.87
A	AQL	Electrical conductivity (EC) @ 25°C	mS/m	ALM 20	37.7
A	AQL	Total Dissolved solids @ 180°C	mg/l	ALM 24	312
A	AQL	Total Alkalinity	mg $CaCO_3$/l	ALM 01	213
A	AQL	Chloride (Cl)	mg/l	ALM 02	1.57
A	AQL	Sulphate (SO_4)	mg/l	ALM 03	7.35
A	AQL	Nitrate (NO_3) as N	mg/l	ALM 06	2.77
A	AQL	Total oxidised nitrogen as N	mg/l	ALM 06	2.77
A	AQL	Orthophosphate (PO_4) as P	mg/l	ALM 12	0.347
A	AQL	Calcium (Ca)	mg/l	ALM 30	47.3
A	AQL	Magnesium (Mg)	mg/l	ALM 30	28.7
A	AQL	Sodium (Na)	mg/l	ALM 30	4.29
A	AQL	Potassium (K)	mg/l	ALM 30	0.831
A	AQL	Aluminium (Al)	mg/l	ALM 31	<0.002
A	AQL	Iron (Fe)	mg/l	ALM 31	<0.004
A	AQL	Manganese (Mn)	mg/l	ALM 31	0.007
A	AQL	Bicarbonate alkalinity	mg $CaCO_3$/l	ALM 26	211
N	AQL	Acidity pH 8.3	mg $CaCO_3$/l	ALM 60	13.8

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.	0
Geometry of existing mine residue disposal/storage areas	0
Transport model calibration points and confidence of constant sampling data	0
Aquifer dewatering rates / verified estimates	1
Model Data Confidence Rating	*Class 1*
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

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

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

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 Proposed Soufflet Malting Facility

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:	[redacted]			
Physical address:	23 Roggeveld Street, Vaal Park			
Postal address:				
Postal code:	1947		Cell:	
Telephone:	[redacted]		Fax:	
E-mail:	[redacted]			

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.

[redacted]
2:21:52
Pr.Sci.Nat (400139/17)

Signature of the Specialist

GCS SA (Pty) Ltd

Name of Company:

11 July 2024

Date

APPENDIX F: CV OF SPECIALIST

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

SCAN ME
PROJECT RECORD